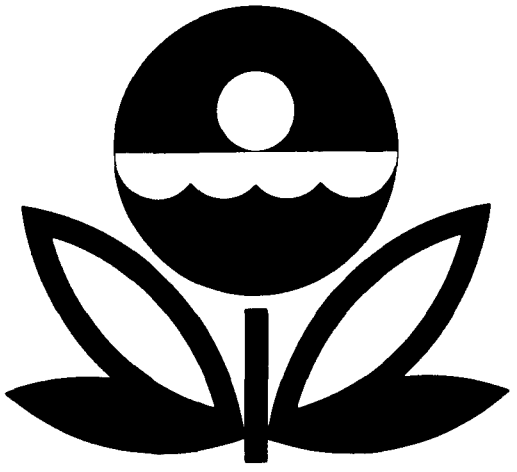
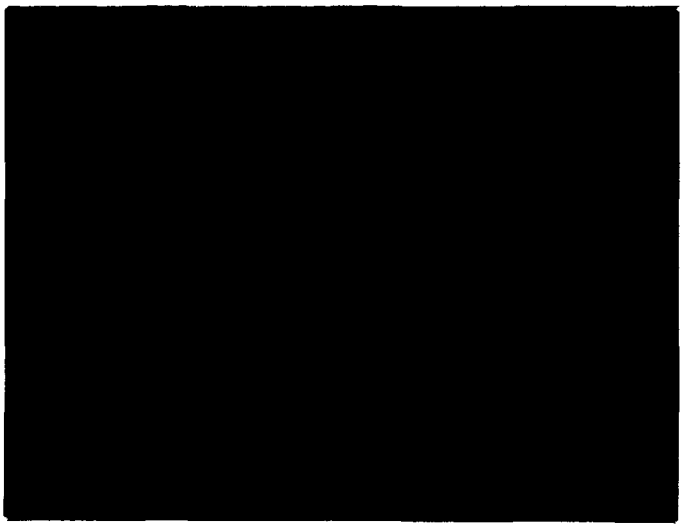
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES





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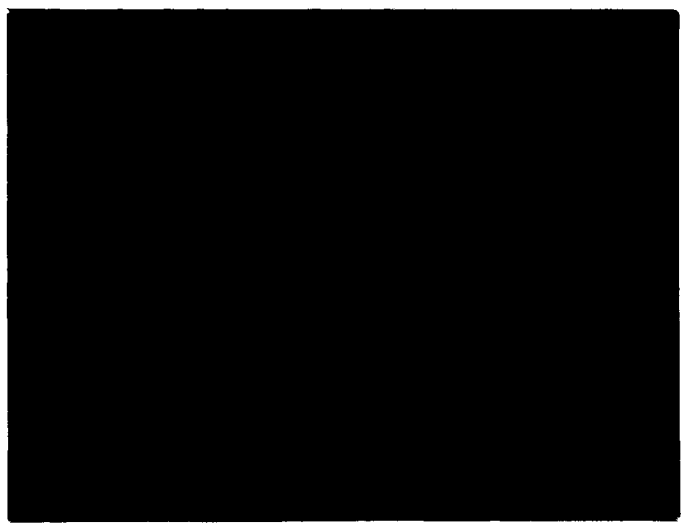

REPORT
ON
CARO RESERVOIR
TUSCOLA COUNTY
MICHIGAN

EPA REGION V

WORKING PAPER No. 190

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

FEBRUARY, 1975

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CONTENTS

F O R E W O R D

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

OBJECTIVES

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

ANALYTIC APPROACH

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

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

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

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

LAKE ANALYSIS

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

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

ACKNOWLEDGMENT

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

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

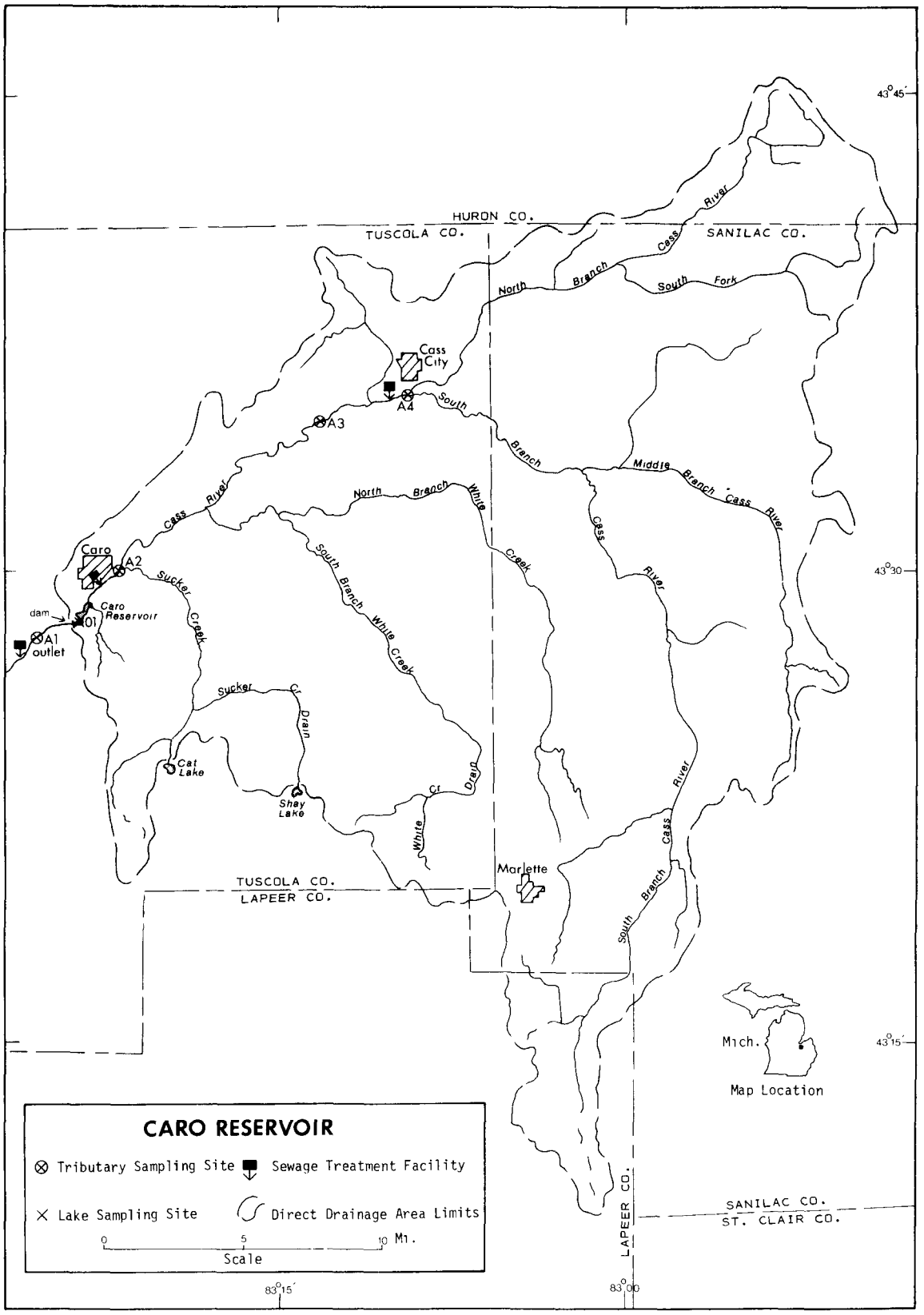
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

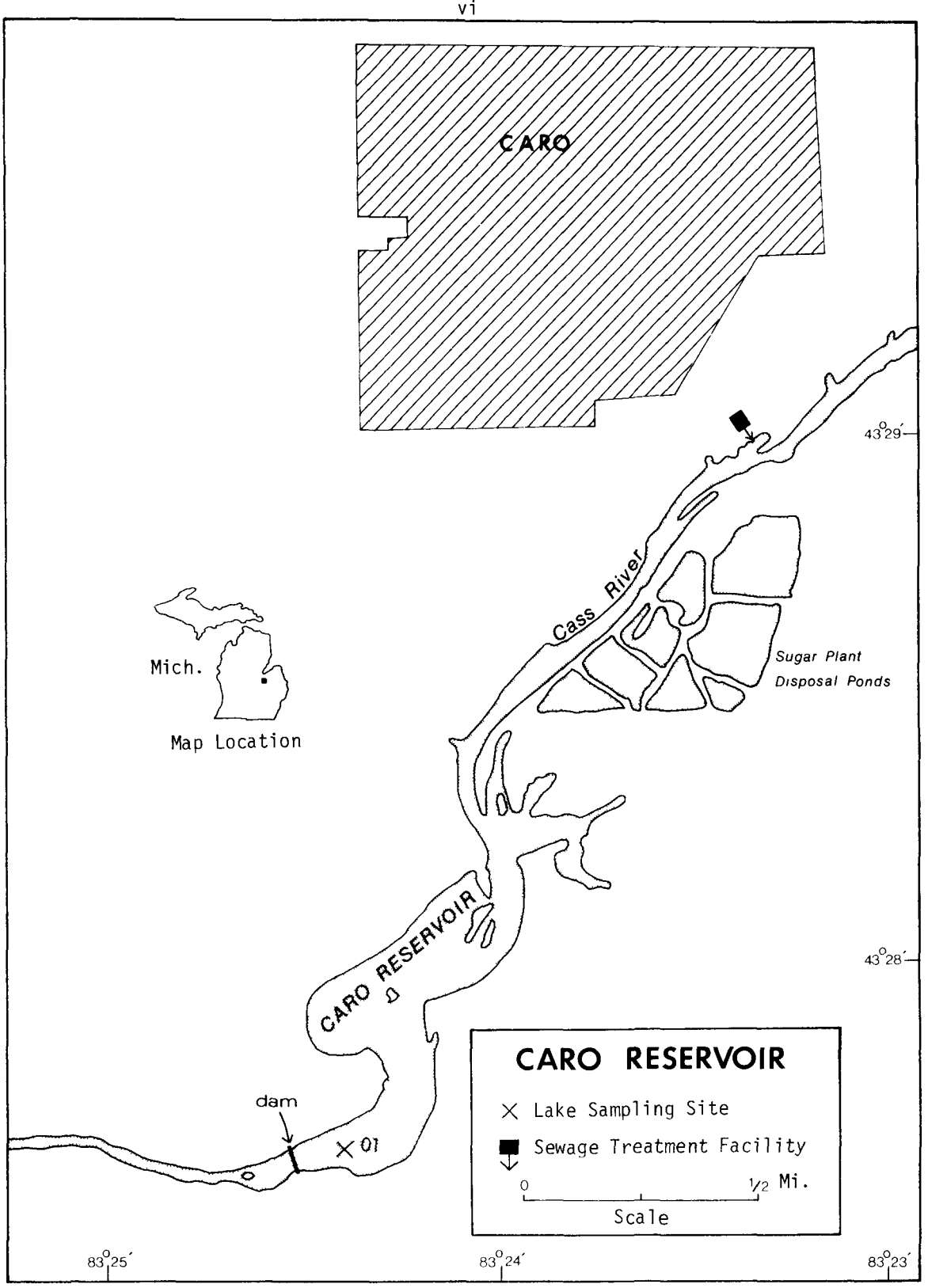
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

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


43°45'
HURON CO.
TUSCOLA CO.
SANILAC CO.
Cass River
North Branch Cass River
South Fork
Cass City
A4
A3
South Branch
Middle Branch Cass River
North Branch White Creek
Cass River
Caro
A2
Sucker Creek
dam
Caro Reservoir
101
A1
outlet
South Branch White Creek
43°30'
Sucker Cr. Drain
Cat Lake
Shay Lake
White Cr. Drain
Cass River
Marlette
TUSCOLA CO.
LAPEER CO.
South Branch Cass River
Mich.
Map Location
43°15'
CARO RESERVOIR
Tributary Sampling Site
Sewage Treatment Facility
Lake Sampling Site
Direct Drainage Area Limits
0
5
10 Mi.
Scale
LAPEER CO.
SANILAC CO.
ST. CLAIR CO.
83°15'
83°00'


CARO
43°29′
Cass River
Sugar Plant
Disposal Ponds
Mich.
Map Location
CARO RESERVOIR
43°28′
dam
01
CARO RESERVOIR
Lake Sampling Site
Sewage Treatment Facility
0
½ Mi.
Scale
83°25′
83°24′
83°23′

CARO RESERVOIR

STORET NO. 26A1

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Caro Reservoir is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, 24 had less mean total phosphorus, 15 had less mean dissolved phosphorus, and none had a higher mean inorganic nitrogen; of all 41 lakes sampled, 21 had less mean chlorophyll a, but only one had less mean Secchi disc transparency*.

Survey limnologists observed abundant rooted aquatic vegetation in the shallower areas of the reservoir.

B. Rate-Limiting Nutrient:

A significant change in nutrients occurred in the algal assay sample between the time of collection and the beginning of the assay, and the results are not representative of conditions in the reservoir at the time the sample was collected (09/19/72).

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

C. Nutrient Controllability:

1. Point sources--During the sampling year, Caro Reservoir received a total phosphorus load at a rate nearly ten times the

* See Appendix A.

rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate. However, it is probable that Vollenweider's model does not apply to water bodies with short hydraulic retention times, and the hydraulic retention time of Caro Reservoir is certain to be very short. For example, the maximum depth sounded by Survey limnologists was six feet; and, even if it is assumed that the mean depth of the reservoir is also six feet, the mean hydraulic retention time would be less than two days.

Now, it is calculated that the communities of Caro and Cass City contributed nearly 30% of the total phosphorus load to Caro Reservoir during the sampling year. In view of the flow-through characteristic of the reservoir, it is likely that a high degree of phosphorus control at these two sources, including the possible industrial source (see page 10), would result in persistent phosphorus limitation (see page 8) and improvement in the trophic condition of Caro Reservoir, as well as provide additional protection for downstream Lake Huron.

2. Non-point sources (see page 12)--During the sampling year, the phosphorus export of the Cass River was somewhat high as compared to other Michigan streams sampled. However, the export N/P ratio of 47/1 indicates point sources probably were not

involved, and it appears that the geological characteristics of the drainage, agricultural practices, or both are the cause of the somewhat higher export rate.

In all, it is estimated that non-point sources, including precipitation, contributed about 70% of the total phosphorus load to Caro Reservoir during the sampling year.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 200 acres.
2. Mean depth: unknown.
3. Maximum depth: unknown.
4. Volume: unknown.

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

1. Tributaries -

Name	Drainage area*	Mean flow*
Cass River	612.0 mi^2	302.2 cfs
Minor tributaries & immediate drainage -	24.7 mi^2	12.4 cfs
Totals	636.7 mi^2	314.6 cfs

2. Outlet -

Cass River	637.0 mi^2**	314.6 cfs

C. Precipitation***:

1. Year of sampling: 32.8 inches.
2. Mean annual: 27.8 inches.

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† Fetterolf, 1973.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Caro Reservoir 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 a single station on the lake and usually from two depths (see map, page v). During each visit, a single depth-integrated (near bottom to surface) sample was collected for phytoplankton identification and enumeration; and a similar sample was collected for chlorophyll *a* analysis. During the second visit, a single five-gallon depth-integrated sample was collected for algal assays. The maximum depth sampled was 4 feet.

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

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

A. Physical and chemical characteristics:

		FALL VALUES (11/15/72)		
Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	3.6	3.6	3.6	3.6
Dissolved oxygen (mg/l)	9.6	9.6	9.6	9.6
Conductivity (μmhos)	850	850	850	850
pH (units)	7.9	7.9	7.9	7.9
Alkalinity (mg/l)	240	251	251	262
Total P (mg/l)	0.116	0.117	0.117	0.119
Dissolved P (mg/l)	0.021	0.022	0.022	0.024
NO_2 + NO_3 (mg/l)	3.410	3.485	3.485	3.560
Ammonia (mg/l)	0.340	0.350	0.350	0.360
		ALL VALUES		
Secchi disc (inches)	14	27	30	37

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
06/17/72	1. Stephanodiscus	679
	2. Navicula	622
	3. Dinobryon	283
	4. Synedra	181
	5. Nitzschia	113
	Other genera	577
	Total	2,455
09/19/72	1. Flagellates	2,620
	2. Cyclotella	2,440
	3. Lagarheimia	723
	4. Cryptomonas	602
	5. Macrinactum	331
	Other genera	874
	Total	7,590
11/15/72	1. Rhaphidiopsis	1,386
	2. Lyngbya	301
	3. Navicula	36
	4. Oscillatoria	24
	5. Achnanthes	6
	Other genera	31
	Total	1,784

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

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/17/72	01	3.6
09/19/72	01	28.9
11/15/72	01	3.4

C. Limiting Nutrient Study:

There was a loss of 29% of the dissolved phosphorus and a 70% gain in inorganic nitrogen in the assay sample from the time of collection to the beginning of the assay. As a result, the N/P ratio was shifted from 10/1 in the reservoir (nitrogen limited) to 29/1 in the assay sample (phosphorus limited). Consequently, the assay results are not representative of conditions in the reservoir at the time the sample was collected (09/19/72).

The reservoir data indicate nitrogen limitation in September (N/P ratio = 10/1) but phosphorus limitation in June and November (N/P = 23/1 and greater).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff month of May when three samples were collected. 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 loading for "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the mean concentrations in the Cass River at station A-4 and the mean ZZ flow.

The operators of the Caro, Caro State Home, and Cass City wastewater treatment plants provided monthly effluent samples and corresponding flow data. In this report, the loads attributed to the Cass River are those measured at station A-2 minus the Cass City loads.

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* See Working Paper No. 1.

The Caro State Home wastewater plant actually discharges to the Cass River downstream from Caro Reservoir. The analytical data are included in Appendix D for informational purposes only.

A beet-sugar processing plant at Caro operates seasonally. Wastes are treated in two groups of ponds on either side of the Cass River downstream from the Survey inlet sampling station (A-2). Discharges from the ponds (if any) were not sampled and may account for the phosphorus and nitrogen loading imbalance observed during the sampling year (see page 13).

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served*	Treatment	Mean Flow (mgd)	Receiving Water
Caro	1,315	trickling filter	0.395	Cass River
Cass City	1,065	trickling filter	0.383	Cass River
Caro State Home	856	act. sludge	0.176	Cass River below reservoir

2. Known industrial -

Name	Treatment	Mean Flow (mgd)	Receiving Water
Sugar plant at Caro (seasonal)	ponds	?	Cass River

* Estimated on the basis of the effluent total nitrogen load of 7.5 lbs per capita per year.
† Lehner, 1972.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Cass River	40,320	67.2
b. Minor tributaries & immediate drainage (non-point load) -	1,810	3.0
c. Known municipal STP's -		
Caro	9,860	16.4
Cass City	7,990	13.3
d. Septic tanks* -	?	-
e. Known industrial -		
Sugar plant, Caro	?	-
f. Direct precipitation** -	30	<0.1
Total	60,010	100.0

2. Outputs -

Lake outlet - Cass River	73,050

3. Net annual P loss - 13,040 pounds

* Probably insignificant.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/yr	% of total
a. Tributaries (non-point load) -		
Cass River	1,904,140	93.2
b. Minor tributaries & immediate drainage (non-point load) -	91,710	4.5
c. Known municipal STP's -		
Caro	26,950	1.3
Cass City	18,610	0.9
d. Septic tanks* -	?	-
e. Known industrial -		
Sugar plant, Caro	?	-
f. Direct precipitation** -	1,930	0.1
Total	2,043,340	100.0

2. Outputs -

Lake outlet - Cass River 2,167,920

3. Net annual N loss - 124,580 pounds

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

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr	N/P Ratio
Cass River (A-2)	66	3,111	47/1

* Probably insignificant.
** See Working Paper No. 1.

E. Yearly Loading Rates:

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

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

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	300.0	loss*	10,216.7	loss*
grams/m^2/yr	33.63	-	1,145.1	-

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

"Dangerous" (eutrophic rate)	3.50
"Permissible" (oligotrophic rate)	1.75

* An apparent loss of some 13,000 lbs of total phosphorus and 125,000 lbs of total nitrogen occurred during the sampling year. While nitrogen loss can occur with certain conditions, losses of both nutrients at this magnitude makes it almost certain that a point source not accounted for was involved. In this case, the wastes from the beet-sugar processing plant are believed to be the unmeasured point source.

Any discharges or seepage from the waste disposal ponds would enter the Cass River downstream from the Survey "inlet" station A-2 and would not be measured there. However, the nutrient impact of such discharges would, in part at least, be measured at the outlet sampling station A-1 and thus result in the observed nutrient imbalance.

V. LITERATURE REVIEWED

Lehner, Richard A., 1972. Treatment plant questionnaires (Caro, Caro State Home, and Cass City STP's). 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 CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500- MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15- MIN DO
26A0	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.678	9.200
26A1	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
26A2	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2606	BARTON LAKE	0.121	0.086	1.489	456.167	27.800	14.850
2609	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	404.333	13.483	14.800
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.800
2640	JORDAN LAKE	0.180	0.144	1.998	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2649	MANISTEE LAKE	0.018	0.010	0.304	451.333	6.317	11.380
2659	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.800
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.246	0.183	0.818	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.600
2673	ROSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

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

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

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

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

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

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 26A1 CARO RESERVOIR

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 637.00

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
26A1A1	637.00	246.00	375.00	1046.00	890.00	380.00	156.00	117.00	71.00	46.00	62.00	145.00	218.00	314.59
26A1A2	612.00	236.00	360.00	1040.00	855.00	365.00	144.00	112.00	68.00	44.00	59.00	139.00	209.00	302.19
26A1Z1	25.00	10.00	15.00	40.00	35.00	15.00	6.00	5.00	3.00	2.00	3.00	6.00	9.00	12.40

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 637.00 TOTAL FLOW IN = 3780.00
SUM OF SUB-DRAINAGE AREAS = 637.00 TOTAL FLOW OUT = 3780.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
26A1A1	10	72	103.00	28	196.00				
	11	72	174.00	28	190.00				
	12	72	437.00						
	1	73	1496.00	4	3100.00	5	2600.00	26	860.00
	2	73	342.00	28	170.00				
	3	73	2353.00	27	3486.00				
	4	73	1169.00	16	611.00				
	5	73	600.00	3	364.00	17	446.00	31	1400.00
	6	73	716.00	28	698.00				
	7	73	184.00	24	62.00				
	8	73	76.00	30	34.00				
	9	73	34.00	28	39.00				
26A1A2	10	72	98.00	28	186.00				
	11	72	167.00	28	182.00				
	12	72	420.00						
	1	73	1420.00	4	2940.00	5	2500.00	26	768.00
	2	73	328.00	28	163.00				
	3	73	2260.00	27	3340.00				
	4	73	1120.00	16	587.00				
	5	73	754.00	3	772.00	17	428.00	31	1340.00
	6	73	687.00	28	670.00				
	7	73	177.00	24	60.00				
	8	73	73.00	30	33.00				
	9	73	33.00	28	37.00				
26A1Z1	10	72	5.00						
	11	72	7.00						
	12	72	17.00						
	1	73	58.00						
	2	73	14.00						
	3	73	93.00						
	4	73	50.00						
	5	73	32.00						
	6	73	29.00						
	7	73	7.00						
	8	73	3.00						
	9	73	1.00						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 73/02/04

26A101
43 27 30.0 083 24 30.0
CARO RESERVOIR
26 MICHIGAN

11EPALES 2111202
4 0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/17	11 30	0000	18.5	5.3	14	560	7.18	187	1.400	0.200	0.108	0.070
72/09/19	04 15	0000			36	550	8.50	238	0.420	0.070	0.071	0.041
	04 15	0004	21.5	11.2		540	8.50	208	0.070	0.110	0.068	0.029
72/11/15	09 50	0000			37	550	7.90	240	3.410	0.360	0.116	0.024
	09 50	0004	3.5	9.6		550	7.90	262	3.560	0.340	0.119	0.021

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/17	11 30	0000	3.0J
72/09/19	04 15	0000	24.0J
72/11/15	09 50	0000	3.4J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/04

26A1A1 LS26A1A1
43 27 00.0 083 26 30.0
CASS RIVER
26 7.5 CARO
O/CARO RESERVOIR
WELLS RD BRDG NE EDGE CARO ST HOSP GROUN
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/28	14 05		1.100	1.844	0.147	0.030	0.120
72/11/28	13 55		2.000	1.470	0.336	0.050	0.140
73/01/05	13 34		4.200	2.450	0.235	0.052	0.110
73/01/26	13 02		2.500	1.300	0.138	0.042	0.085
73/02/28	14 00		1.900	1.700	0.290	0.048	0.090
73/03/27	14 40		1.600	0.920	0.093	0.029	0.085
73/04/18	13 40		1.540	0.890	0.063	0.026	0.080
73/05/03	14 00		0.830	1.150	0.040	0.023	0.095
73/05/17	14 35		1.060	2.100	0.096	0.032	0.090
73/05/31	14 10		1.560	2.100	0.250	0.063	0.130
73/06/28	14 00		1.100	1.890	0.530	0.056	0.195
73/07/24	14 45		0.580	7.700	0.410	0.066	0.170
73/08/30	12 11		0.510	1.600	0.200	0.048	0.155
73/09/28	14 20		0.530	1.000	0.084	0.023	0.115

STORET RETRIEVAL DATE 75/02/04

25A1A2 L526A1A2
43 29 30.0 083 22 30.0
CASS RIVER
25 7.5 CARO
T/CARO RESERVOIR
E DAYTON RD BRDG .5 MI E JFCITY OF CARO
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/26	14 35		1.700	2.000	0.100	0.040	0.130
72/11/28	14 25		1.720	1.800	0.076	0.037	0.053
73/01/04	13 50		4.300	2.350	0.595	0.055	0.110
73/01/26	13 20		2.400	1.150	0.100	0.032	0.070
73/02/28	14 25		1.900	1.760	0.290	0.050	0.085
73/03/27	14 55		1.600	0.840	0.033	0.031	0.085
73/04/18	14 05		1.520	4.700	0.260	0.022	0.055
73/05/03	14 20		0.920	1.200	0.023	0.019	0.065
73/05/17	14 50		1.100	1.050	0.018	0.019	0.050
73/05/31	14 30		1.460	2.450	0.350	0.052	0.100
73/06/28	14 20		0.920	1.260	0.123	0.033	0.100
73/07/24	15 05		0.500	0.780	0.089	0.010	0.050
73/08/30	12 25		0.330	1.470	0.154	0.037	
73/09/28	14 35		0.490	1.650	0.082	0.021	0.075

STORET RETRIEVAL DATE 75/02/04

[illegible] 520413
43 34 00.0 083 14 00.0
CASS RIVER
26 7.5 CASS CITY
17/GRJ RESERVOIR
DODGE RD BRDG BELO CASS CITY STP
ILEPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/28	15 07		3.000	3.800	0.565	0.047	0.200
72/11/28	14 45		2.600	0.910	0.046	0.053	0.088
73/01/04	14 13		4.750	1.850	0.189	0.053	0.100
73/01/26	14 02		2.900	1.150	0.126	0.038	0.080
73/02/28	14 50		2.040	1.200	0.220	0.048	0.075
73/03/27	15 15		1.700	0.840	0.040	0.034	0.085
73/04/18	14 40		1.660	2.400	0.120	0.024	0.065
73/05/03	14 45		1.000	1.540	0.115	0.044	0.095
73/05/17	15 15		1.120	1.100	0.028	0.033	0.070
73/05/31	14 50		1.520	2.300	0.330	0.063	0.150
73/06/28	14 45		1.900	2.500	0.200	0.072	0.320
73/07/24	15 25		0.760	3.300	0.450	0.126	0.150
73/08/30	12 55		1.320	2.200	0.160	0.220	0.280
73/09/28	14 55		1.300	0.600	0.042	0.240	0.290

STORET RETRIEVAL DATE 75/02/04

26A144 L5264A4
43 35 00.0 083 10 30.0
CASS RIVER
26 7.5 CASS CITY
T/CARO RESERVOIR
CEMETERY RD BRDG ABOV CASS CITY STP
11SPALES 21112U4
- 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/28	15 20		3.100	2.000	0.147	0.065	0.150
72/11/28	15 10		2.600	1.400	0.056	0.020	0.050
73/01/05	14 25		5.800	2.000	0.180	0.059	0.105
73/01/26	14 15		2.700	2.720	0.210	0.032	0.070
73/02/28	15 20		1.800	1.200	0.294	0.019	0.040
73/03/27	15 30		1.640	4.500	0.240	0.032	0.085
73/04/18	15 00		1.200	2.400	0.066	0.013	0.045
73/05/03	14 57		0.750	1.700	0.069	0.040	0.095
73/05/17	15 25		0.720	1.000	0.035	0.022	0.055
73/05/31	15 05		1.220	1.540	0.140	0.055	0.105
73/06/28	15 05		1.620	3.500	0.290	0.056	
73/07/24	15 45		0.046	3.600	0.170	0.027	0.055
73/08/30	13 05		0.033	1.200	0.084	0.034	0.060
73/09/28	15 10		0.063	0.480	0.028	0.017	0.042

41 29 00.0 093 23 30.0
CASS
ID 1 CASS
17 ARD RESERVOIR
CASS RIVER
41ADAIR
4 21412O4
0060 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00665 PHOS-TOT MG/L P	00671 PHOS-DIS ORTHO MG/L P	00666 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/17 08 00									
CP(T)-			1.000	25.000	4.300	4.950	7.400	0.453	0.508
73/01/17 16 00									
73/02/19 08 00			1.100	19.900	7.100	7.800	9.500	0.258	0.450
73/03/27 08 00									
CP(T)-			3.100	13.800	3.440	2.600	4.400	0.824	0.550
73/03/27 16 00									
73/04/24 08 00									
CP(T)-			2.600	20.000	5.400	6.000	8.200	0.362	0.550
73/04/24 16 00									
73/05/17 08 00									
CP(T)-			2.700	17.300	3.400	5.200	7.350	0.390	0.450
73/05/17 16 00									
73/06/19 09 00									
CP(T)-			9.900	13.300	1.200	5.600	9.200	0.353	0.549
73/06/19 16 00									
73/07/26 09 00									
CP(T)-			4.400	12.000	0.660	7.900	10.000	0.436	0.314
73/07/26 16 00									
73/08/22 09 00									
CP(T)-			4.920	13.200	1.760	7.300		0.240	0.310
73/08/22 16 00									
73/09/25 09 00									
CP(T)-			4.400	15.700	3.050	6.850	13.000	0.266	0.235
73/09/25 16 00									
73/10/25 09 00									
CP(T)-			3.800	20.000	5.300	7.200	10.000	0.241	0.241
73/10/25 16 00									
73/12/20 09 00									
CP(T)-			4.000	25.000	7.800	6.600	11.500	0.313	0.279
73/12/20 16 00									
74/01/22 09 00									
CP(T)-			2.000	29.000	3.600	4.100	5.900	0.633	0.363
74/01/22 16 00									
74/02/14 09 00									
CP(T)-			1.440	21.000	4.100	4.500	6.500	0.304	0.341
74/02/14 16 00									

STORET RETRIEVAL DATE 75/02/04

26A151 AS26A151 P001500
43 26 30.0 083 27 00.0
CARO ST. HOME
26 7.5 CARO
T/CARO RESERVOIR
CASS RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/01	07 00								
CP(T)-			0.940	5.550	0.200	0.790	2.100	0.250	0.184
73/01/01	14 00								
73/02/06	07 00								
CP(T)-			0.250	13.200	2.300	3.900	6.100	0.195	0.216
73/02/06	14 00								
73/03/07	07 00								
CP(T)-			0.175	14.700	4.800	4.100	5.400	0.200	0.177
73/03/07	14 00								
73/04/05	07 00								
CP(T)-			0.230	8.700	1.890	2.100	3.500	0.265	0.246
73/04/05	14 00								
73/05/04	06 00								
CP(T)-			0.530	10.500	0.500	4.000	5.500	0.232	0.222
73/05/04	14 00								
73/06/02	07 00								
CP(T)-			5.040	1.200	0.123	4.890	6.400	0.190	0.222
73/06/02	14 00								
73/07/01			6.400	1.500	0.055	3.600	3.900	0.196	0.200
73/08/06	07 00								
CP(T)-			0.160	14.000	0.660	5.900	7.100	0.148	0.193
73/08/06	14 00								
73/09/04	06 00								
CP(T)-			6.700	4.170		5.700		0.144	0.143
73/09/04	15 00								
73/10/03	07 00								
CP(T)-			0.330	12.600	2.520	6.600	8.000	0.148	0.133
73/10/03	15 00								
73/11/01	06 00								
CP(T)-			0.240	17.500	4.300	5.300	7.800	0.129	0.131
73/11/01	14 30								
73/12/10	06 00								
CP(T)-			0.340	25.000	1.380	5.500	9.300	0.118	0.114
73/12/10	14 30								
74/01/08	07 00								
CP(T)-			0.160	11.500	0.260	3.200	6.700	0.191	0.112
74/01/08	14 00								

STORET RETRIEVAL DATE 75/02/04

26A152 TF26A152 P001975
43 35 00.0 083 11 00.0
CASS CITY
26 7.5 CASS CITY
T/CARO RESERVOIR
CASS RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/08 07 00									
CP(T)-			1.060	15.350	2.900	4.300		0.438	0.278
73/01/08 16 00									
73/02/06 07 00									
CP(T)-			0.880	12.600	2.100	4.700	6.500	0.456	0.432
73/02/06 16 00									
73/03/07 07 00									
CP(T)-			0.920	13.800	2.300	4.700	5.700	0.459	0.390
73/03/07 16 00									
73/04/12 07 00									
CP(T)-			2.700	9.600	0.670	2.850	3.900	0.662	0.493
73/04/12 16 00									
73/05/11 07 00									
CP(T)-			3.500	11.500	0.990	4.400	5.500	0.470	0.493
73/05/11 16 00									
73/06/06 07 00									
CP(T)-			5.400	11.500	0.940	4.500	6.000	0.481	0.470
73/06/06 16 00									
73/07/10 07 00									
CP(T)-			2.700	15.000	3.200	5.900	7.500	0.489	0.470
73/07/10 16 00									
73/08/09 07 00									
CP(T)-			5.000	10.500	0.400	6.300	8.500	0.403	0.419
73/08/09 16 00									
73/09/13 07 00									
CP(T)-			2.060	13.800	2.520	7.525	8.125	0.331	0.384
73/09/13 16 00									
73/10/10 07 00									
CP(T)-			3.060	22.300	13.000	4.400	8.900	0.322	0.317
73/10/10 16 00									
73/11/08 09 00									
CP(T)-			0.690	19.500	7.500	3.800	8.000	0.264	0.293
73/11/08 16 00									
73/12/11 07 00									
CP(T)-			1.400	16.500	5.800	6.600	7.600	0.312	0.269
73/12/11 16 00									

STORET RETRIEVAL DATE 75/02/04

26A152 1F26A152 P001975
43 35 00.0 083 11 00.0
CASS CITY
26 7.5 CASS CITY
T/CARO RESERVOIR
CASS RIVER
TIEPALES 2141204
+ 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	NITROGEN NO2&NO3 N-TOTAL MG/L	NITROGEN TOT KJEL N MG/L	NITROGEN AMMONIA TOTAL MG/L	PHOSPHORUS ORTHO MG/L P	PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/01	07 00								
CP(T)-			1.200	17.500	7.100	7.500	8.100	0.276	0.265
74/01/01	16 00								

U.S. Environmental Protection Agency
Region 5, Library (PL-12J)
77 West Jackson Boulevard, 12th Floor
Chicago, IL 60604-3590