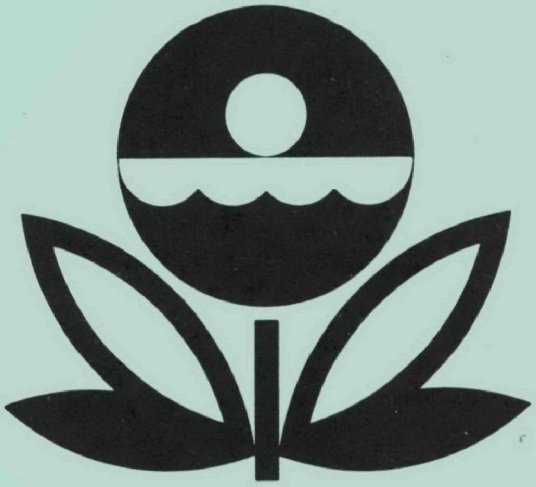
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES



REPORT

ON

SUPERIOR BAY

ST. LOUIS COUNTY, MINNESOTA, AND

DOUGLAS COUNTY, WISCONSIN

EPA REGION V

WORKING PAPER No. 128

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

An Associate Laboratory of the

NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON

and

NATIONAL ENVIRONMENTAL RESEARCH CENTER - LAS VEGAS, NEVADA

☆ GPO—697-032

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WITH THE COOPERATION OF THE

MINNESOTA POLLUTION CONTROL AGENCY

AND THE

MINNESOTA NATIONAL GUARD

MAY, 1975

CONTENTS

F O R E W O R D

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

OBJECTIVES

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

ANALYTIC APPROACH

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

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

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

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

LAKE ANALYSIS

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

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

ACKNOWLEDGMENT

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

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

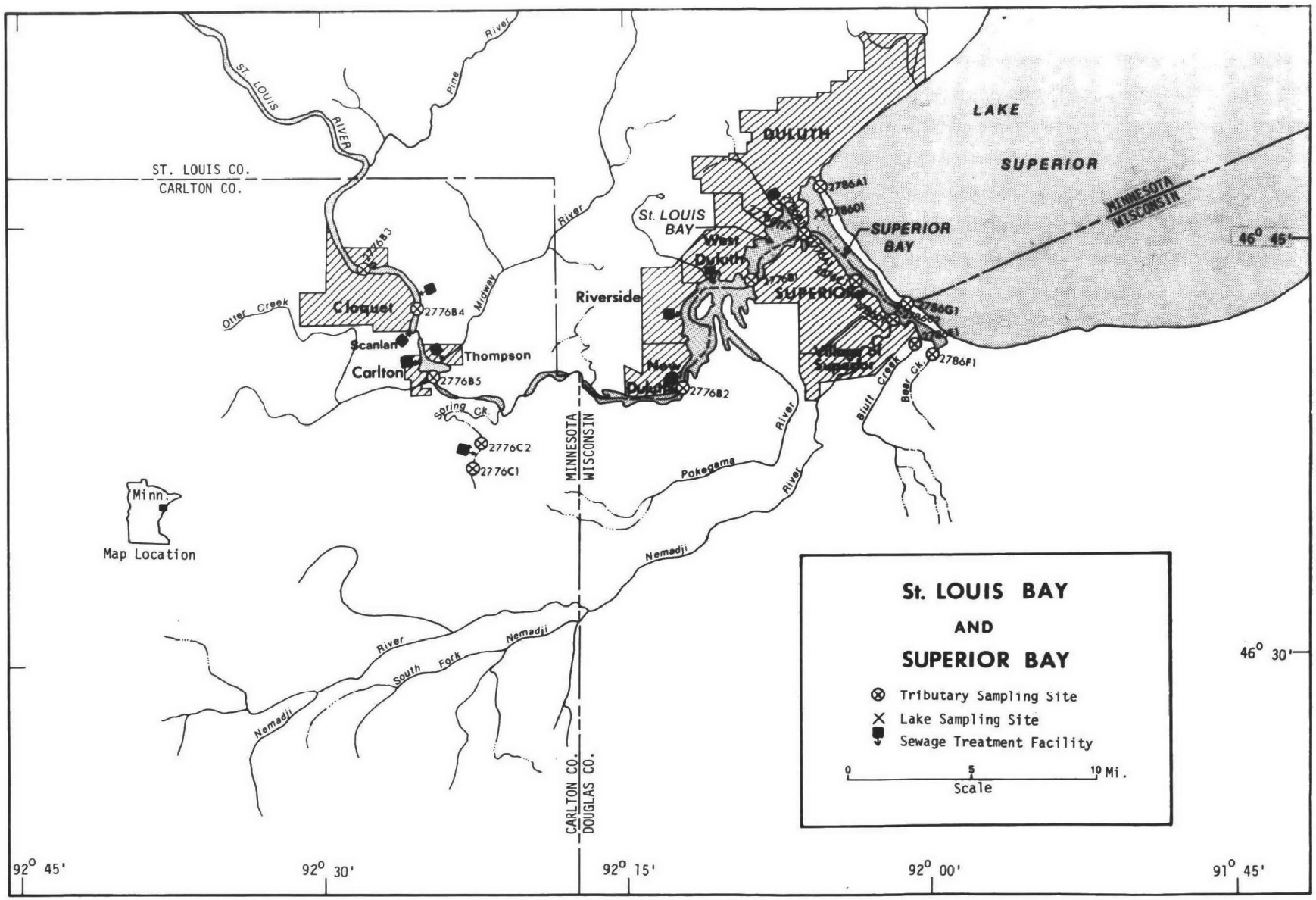
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


ST. LOUIS CO.
CARLTON CO.
ST. LOUIS RIVER
Pine River
St. LOUIS BAY
DULUTH
LAKE
SUPERIOR
MINNESOTA
WISCONSIN
SUPERIOR BAY
West Duluth
SUPERIOR
Riverside
Cloquet
Scanlan
Carlton
Thompson
Otter Creek
Midway River
Spring Ck.
Pokegama River
Nemadji River
South Fork Nemadji River
Bluff Creek
Bear Ck.
2776B3
2776B4
2776B5
2776B2
2776C2
2776C1
2786A1
2786G1
2786F1
Minn.
Map Location
St. LOUIS BAY
AND
SUPERIOR BAY
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0 5 10 Mi.
Scale
CARLTON CO.
DOUGLAS CO.
46° 45'
46° 30'
92° 45'
92° 30'
92° 15'
92° 00'
91° 45'

v1

SUPERIOR BAY

STORET NO. 2786

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Superior Bay is eutrophic. Of the 60 Minnesota lakes surveyed in the fall of 1972, when essentially all were well-mixed, 27 had less mean total phosphorus, 25 had less mean dissolved phosphorus, and 38 had less mean inorganic nitrogen. For all Minnesota data, 43 lakes had greater Secchi disc transparency, and only six had less mean chlorophyll *a*. The lack of light penetration (reflected in very low Secchi disc transparency) probably limited algal growth.

Survey limnologists did not note any phytoplankton nuisances; however, much discoloration, floating debris, floating and suspended solids, as well as oil films, were seen on all sampling visits.

B. Rate-Limiting Nutrient:

Because of a significant loss in nitrogen (28%) between the time the sample was collected and the assay was begun, the results of the algal assay are not representative of conditions in the bay at the time the sample was taken. Field data indicate nitrogen limitation in July and September but phosphorus limitation in October.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Superior Bay received a total phosphorus load at a rate about nine times that proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 14). However, Vollenweider's model probably is not applicable to water bodies with short hydraulic retention times, and the mean hydraulic retention time of Superior Bay is a very short eight days. Nonetheless, the existing water quality in the bay is evidence of excessive nutrient loads.

It is calculated that the municipal point sources considered in this study contributed 42% of the total phosphorus input to the bay during the sampling year. Industries and port traffic are believed to have contributed nutrients also, but the significance of these sources was not determined (see page 11).

At this time, the City of Superior, Wisconsin, wastewater treatment plant is being expanded to include secondary treatment plus phosphorus removal and is designed to meet the Wisconsin Department of Natural Resources' mean effluent phosphorus limit of 1 mg/l (ca. 85% removal). Also, in regard to the Minnesota indirect point sources, the Western Lake Superior Sanitary District, organized in 1974, will ultimately construct a tertiary

wastewater treatment plant at the site of the existing Duluth main plant (McGuire, 1975). The new plant will provide treatment for all of the Minnesota point sources considered in this report, as well as a few additional small discharges, and will be required to meet the Minnesota Pollution Control Agency's mean effluent phosphorus limitation of 1 mg/l total phosphorus.

It is calculated that when the new Minnesota and Wisconsin wastewater treatment plants become operative, the overall total phosphorus load to Superior Bay will be reduced by 35%. This reduction should result in a significant improvement in the water quality of the bay as well as provide protection for the high-quality waters of Lake Superior.

2. Non-point sources (see page 14)--During the sampling year, the phosphorus export rates of the four Wisconsin tributaries to Superior Bay ranged from three to nine times the export rate of the St. Louis Bay outlet and from over two to more than six times the export rate of the St. Louis River at the inlet to St. Louis Bay (96 lbs $P/mi^2/yr$). It is not known whether these high phosphorus exports are due to urban runoff, storm drains, unknown point sources, or insufficient sampling, but a need for further study is indicated.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 3,630 acres.
2. Mean depth: 12.5 feet.
3. Maximum depth: 30 feet.
4. Volume: 45,375 acre-feet.
5. Mean hydraulic retention time: 8 days.

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

1. Tributaries -

Name	Drainage area*	Mean flow*
St. Louis Bay outlet	3,690.0 mi^2	2,396.4 cfs
Nemadji River	444.0 mi^2	472.8 cfs
Bluff Creek	19.6 mi^2	20.3 cfs
Bear Creek	6.9 mi^2	7.0 cfs
Unnamed Stream (C-1)	4.9 mi^2	4.1 cfs
Minor tributaries & immediate drainage -	9.8 mi^2	16.0 cfs
Totals	4,175.2 mi^2	2,916.6 cfs

2. Outlet -

Superior Bay - Lake Superior Ship Channels	4,180.9 mi^2**	2,916.6 cfs

C. Precipitation***:

1. Year of sampling: 25.5 inches.
2. Mean annual: 25.0 inches.

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† Planimetered from U.S.G.S. map (1954); mean depth by random-dot method.

* Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.

** Includes area of lake; total drainage area adjusted to equal sum of subdrainage areas.

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

III. LAKE WATER QUALITY SUMMARY

Superior Bay 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 bay and from a number of depths at each station (see map, page vi). During each visit, a single depth-integrated (15 feet to surface) sample was composited from the two stations for phytoplankton identification and enumeration; and during the last 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 25 feet at station 1 and 26 feet at station 2.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the bay 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 B.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (10/18/72)		
Temperature (Cent.)	6.1	6.3	6.3	6.5
Dissolved oxygen (mg/l)	8.8	9.6	9.7	10.2
Conductivity (μmhos)	120	128	130	140
pH (units)	7.3	7.4	7.4	7.6
Alkalintiy (mg/l)	41	46	47	49
Total P (mg/l)	0.035	0.051	0.051	0.070
Dissolved P (mg/l)	0.013	0.024	0.026	0.032
NO_2 + NO_3 (mg/l)	0.180	0.207	0.205	0.240
Ammonia (mg/l)	0.090	0.174	0.180	0.250
		ALL VALUES		
Secchi disc (inches)	12	22	24	32

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/13/72	1. Melosira	1,646
	2. Achnanthes	633
	3. Ulothrix	434
	4. Anabaena	380
	5. Cryptomonas	362
	Other genera	722
	Total	4,177
09/07/72	1. Flagellates	85
	2. Dinobryon	67
	3. Cryptomonas	20
	4. Chroococcus	18
	5. Synedra	18
	Other genera	81
	Total	289
10/18/72	1. Flagellates	2,340
	2. Dinobryon	2,260
	3. Anabaena	755
	4. Fragilaria	528
	5. Kirchneriella	490
	Other genera	2,495
	Total	8,868

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)
07/13/72	01	8.9
	02	22.7
09/07/72	01	0.7
	02	0.8
10/18/72	01	1.7
	02	2.4

C. Limiting Nutrient Study:

There was a 28% loss of nitrogen in the assay sample between the time of collection to the beginning of the assay; consequently, the results are not representative of conditions in the bay at the time the sample was taken. However, the field data indicate nitrogen limitation in July (N/P = 9/1) and September (N/P = 8/1) and phosphorus limitation in October (N/P = 16/1).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota 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 June when two 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 Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

Except for the two outlet channels, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. The outlet flow provided by U.S.G.S. is the combined flow of the Duluth channel at station 86A-1 and the Superior channel at station 86G-1; the portion of the total flow carried by each channel was not determined. Therefore, the outlet nutrient loads were calculated using the mean of the nutrient concentrations in the samples from both channels and the mean total flow.

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 $lbs/mi^2/year$, in Bluff Creek at station E-1 and multiplying the means by the ZZ area in mi^2.

* See Working Paper No. 1.

In the following tables, the nutrient loads given for the St. Louis Bay outlet and the Nemadji River are those measured minus upstream point-source loads.

It is noted that there was an apparent high degree of retention of phosphorus (59%) and nitrogen (31%) in Superior Bay during the sampling year. This probably was due to periodic dilution of the outlet samples by high-quality Lake Superior waters when on-shore winds occurred. This resulted in lower calculated outlet nutrient loads and, conversely, greater apparent nutrient retention.

The City of Superior and the Village of Superior, Wisconsin, did not participate in the Survey, and nutrient loads were estimated at 2.5 lbs P and 7.5 lbs N/capita/year. The indirect Minnesota point sources impact upstream St. Louis Bay. The nutrient loads attributed to these sources are the measured or estimated loads reduced by the amount of phosphorus retention (29%) and nitrogen retention (1%) in St. Louis Bay (see Working Paper No. 123, "Report on St. Louis Bay").

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served††	Treatment	Mean Flow (mgd)	Receiving Water
City of Superior, WI	32,237	prim. clarifier	3.224*	Superior Bay
Vill. of Superior, WI	476	stab. pond	0.476*	Nemadji River

Indirect sources in Minnesota**:

Duluth Main	100,578	prim. clarifier	16.125	St. Louis Bay
Cloquet	8,699	prim. clarifier	1.649	St. Louis River
Duluth West plants	11,490	prim. clarifier	1.149	St. Louis Bay
Scanlan	1,132	Imhoff tank	0.113*	St. Louis River
Carlton	844	prim. clarifier	0.084*	St. Louis River
Thompson Township	159	act. sludge	0.016*	St. Louis River
Wrenshall	147	stab. pond	0.015*	Silver Creek

2. Industrial - A number of industries discharge wastes either directly to Superior Bay, to St. Louis Bay, to the St. Louis River, or to municipal wastewater treatment plants impacting those waters (Anonymous, 1969a); because of Survey constraints***, nutrient contributions from these sources were not evaluated.

Also, nutrients may be contributed by ships in port (Miller, 1965), but the significance of these sources was not assessed.

† Schraufnagel, et al., 1966; Anonymous, 1974.
†† 1970 Census.
* Estimated at 100 gal/capita/day.
** See Working Paper No. 123, "Report on St. Louis Bay".
*** See Working Paper No. 1.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
St. Louis Bay outlet	254,110	32.6
Unnamed Stream (C-1)	1,330	0.2
Nemadji River	184,130	23.7
Bluff Creek	4,570	0.6
Bear Creek	4,270	0.5
b. Minor tributaries & immediate drainage (non-point load) -	2,280	0.3
c. Known municipal STP's -		
City of Superior	80,590	10.4
Village of Superior	1,190	0.2
Port traffic* - Unknown	?	-
Indirect sources:		
Duluth Main	192,520	24.7
Cloquet	32,380	4.2
Duluth West plants	16,490	2.1
Scanlan	2,010	0.3
Carlton	1,500	0.2
Thompson Township	280	<0.1
Wrenshall	260	<0.1
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation** -	570	<0.1
Total	778,480	100.0

2. Outputs -

Lake outlet - Lake Superior 318,090

3. Net annual P accumulation - 460,390 pounds

* Wastes discharged from ships in port.
** 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) -		
St. Louis Bay outlet	6,458,790	69.7
Unnamed Stream (C-1)	11,780	0.1
Nemadji River	1,231,730	13.3
Bluff Creek	52,490	0.6
Bear Creek	17,910	0.2
b. Minor tributaries & immediate drainage (non-point load) -	26,240	0.3
c. Known municipal STP's -		
City of Superior	241,780	2.6
Village of Superior	3,570	<0.1
Port traffic* - Unknown	?	-
Indirect sources:		
Duluth Main	944,040	10.2
Cloquet	135,210	1.6
Duluth West plants	90,590	1.0
Scanlan	8,410	0.1
Carlton	6,270	<0.1
Thompson Township	1,180	<0.1
Wrenshall	1,090	<0.1
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation** -	34,970	0.4
Total	9,266,050	100.0

2. Outputs -

Lake outlet - Lake Superior 6,373,290

3. Net annual N accumulation - 2,892,760 pounds

* Wastes discharged from ships in port.
** See Working Paper No. 1.

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

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
St. Louis Bay outlet	69	1,750
Unnamed Stream (C-1)	271	2,404
Nemadji River	415	2,774
Bluff Creek	233	2,678
Bear Creek	619	2,596

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 than 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	214.5	126.8	2,552.6	796.9
grams/m^2/yr	24.04	14.22	286.1	89.3

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

"Dangerous" (eutrophic rate) 2.60
"Permissible" (oligotrophic rate) 1.30

* The apparent high degree of accumulation (retention) of phosphorus (59%) and nitrogen (31%) during the sampling year is attributed to periodic dilution of outlet samples by high-quality Lake Superior waters (see page 10).

V. LITERATURE REVIEWED

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VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2786 SUPERIOR BAY

TOTAL DRAINAGE AREA OF LAKE 4180.00

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2786AG	4180.00	1229.40	1169.30	1609.20	6546.60	6976.30	4917.40	2788.50	2088.90	2228.80	2288.80	1719.10	1389.30	2916.65
2786B1	3690.00	1004.00	988.00	1395.00	5656.00	5553.00	3873.00	2306.00	1798.00	1797.00	1785.00	1420.00	1148.00	2396.45
2786C1	4.91	0.26	0.16	0.97	8.34	13.70	12.80	3.76	1.32	3.21	2.61	1.21	0.62	4.09
2786D1	444.00	215.00	173.00	200.00	810.00	1276.00	925.00	437.00	275.00	395.00	458.00	274.00	223.00	472.79
2786E1	19.60	4.30	3.20	6.10	35.20	64.00	49.00	18.20	9.55	17.20	19.30	9.74	6.91	20.28
2786F1	6.86	1.21	0.82	1.95	11.80	22.50	17.80	6.46	3.24	6.82	6.26	3.00	2.23	7.03
2786ZZ	15.50	3.40	2.53	4.82	27.80	50.60	38.70	14.40	7.54	13.60	15.20	7.69	5.46	16.02

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 4180.00
SUM OF SUB-DRAINAGE AREAS = 4180.86
TOTAL FLOW IN = 34951.39
TOTAL FLOW OUT = 34951.59

NOTE *** TRIB 86B1=76A1

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2786AG	10	72	3480.00	14	3130.00				
	11	72	3970.00	4	5720.00				
	12	72	1710.00	2	1740.00				
	1	73	1920.00						
	2	73	1890.00	3	2020.00				
	3	73	3320.00						
	4	73	4440.00	7	3150.00				
	5	73	7140.00	20	11570.00				
	6	73	3530.00	21	2440.00	24	2790.00		
	7	73	1650.00	28	275.00				
	8	73	2450.00	25	2210.00				
	9	73	2460.00	23	1570.00				
2786B1	10	72	2720.00	14	2450.00				
	11	72	3300.00	4	4750.00				
	12	72	2710.00	2	2760.00				
	1	73	1800.00						
	2	73	1790.00	4	1890.00				
	3	73	3230.00						
	4	73	3830.00	7	2730.00				
	5	73	5690.00	20	9250.00				
	6	73	2780.00	24	2180.00				
	7	73	1640.00						
	8	73	2430.00	25	1900.00				
	9	73	2430.00	23	1560.00				

LAKE CODE 2786 SUPERIOR BAY

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2786C1	10	72	3.96	14	3.60				
	11	72	2.80	4	4.00				
	12	72	0.76	2	0.80				
	1	73	0.25						
	2	73	0.04	3	0.10				
	3	73	0.42	3	0.40				
	4	73	5.67	7	4.00				
	5	73	14.00	20	23.00				
	6	73	9.22	24	7.30				
	7	73	2.67	28	2.10				
	8	73	1.78	25	1.40				
	9	73	4.33	23	2.80				
2786D1	10	72	696.00	14	625.00				
	11	72	633.00	4	911.00				
	12	72	274.00	2	280.00				
	1	73	120.00						
	2	73	95.20	3	100.00				
	3	73	86.00	3	90.00				
	4	73	551.00	7	391.00				
	5	73	1300.00	20	2110.00				
	6	73	666.00	24	526.00				
	7	73	310.00	28	251.00				
	8	73	371.00	25	289.00				
	9	73	533.00	23	341.00				
2786E1	10	72	29.30	14	26.00				
	11	72	22.50	4	32.00				
	12	72	8.50	2	8.70				
	1	73	2.41						
	2	73	1.75	3	1.80				
	3	73	2.62	3	2.80				
	4	73	23.90						
	5	73	45.30	20	106.00				
	6	73	35.30	24	28.00				
	7	73	12.90	28	10.50				
	8	73	12.90	25	10.10				
	9	73	23.20	23	14.80				
2786F1	10	72	9.51	14	8.60				
	11	72	6.93	4	10.00				
	12	72	2.74	2	2.80				
	1	73	0.68						
	2	73	1.45	3	0.50				
	3	73	0.84	3	0.90				
	4	73	8.62						
	5	73	23.00	20	37.00				
	6	73	12.86	21	6.80				
	7	73	4.59	28	3.70				
	8	73	4.37	25	3.40				
	9	73	9.21	23	5.90				

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2786 SUPERIOR BAY

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2786ZZ	10	72	23.10	14	21.00				
	11	72	17.80	4	26.00				
	12	72	6.72	2	6.80				
	1	73	1.90						
	2	73	1.49	3	1.50				
	3	73	2.07						
	4	73	18.90	7	13.00				
	5	73	51.60	20	84.00				
	6	73	27.90	21	19.00	24	22.00		
	7	73	10.20	28	8.30				
	8	73	10.20	25	8.00				
	9	73	18.40	23	11.80				

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

278601
46 45 33.0 092 05 30.0
SUPERIOR BAY
27 MINNESOTA

11EPALES 2111202
3 0024 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
72/07/13	06	35 0000			32	150	6.60	46	0.240	0.420	0.103	0.080
	06	35 0004	17.4	6.0		150	6.60	46	0.240	0.420	0.111	0.083
	06	35 0015	17.1	4.2		150	6.50	46	0.230	0.410	0.115	0.086
	06	35 0020	15.7	7.4		140	6.40	45	0.240	0.290	0.088	0.054
72/09/07	09	35 0000			18	137	7.00	26	0.130	0.340	0.083	0.065
	09	35 0004	16.4	5.3		117	7.00	27	0.120	0.330	0.082	0.064
	09	35 0015	16.4	5.3		124	7.00	30	0.130	0.330	0.089	0.064
	09	35 0020	16.1	4.2		120	7.00	31	0.140	0.350	0.085	0.062
	09	35 0025	15.6	5.4			7.00	33	0.160	0.260	0.078	0.045
72/10/18	16	20 0000			30	140	7.35	41	0.240	0.100	0.040	0.016
	16	20 0004	6.4	10.0		120	7.35	43	0.230	0.090	0.035	0.013
	16	20 0015	6.5	9.2		120	7.25	47	0.230	0.110	0.041	0.017
	16	20 0025	6.5	10.1		120	7.40	45	0.220	0.140	0.047	0.021

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/13	06	35 0000	8.9J
72/09/07	09	35 0000	0.7J
72/10/18	16	20 0000	1.7J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 74/10/30

278602
46 42 18.0 092 01 18.0
SUPERIOR BAY
27 MINNESOTA

11EPALES 2111202
3 0026 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 N02&N03 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/13	06 50	0000			30	140	6.80	39	0.220	0.160	0.099	0.043
	06 50	0004	17.8	5.2		140	6.70	44	0.220	0.160	0.087	0.039
	06 50	0015	15.8	9.0		140	6.70	44	0.220	0.130	0.042	0.032
	06 50	0020	15.5	8.6		140	6.70	44	0.220	0.120	0.050	0.023
72/09/07	10 05	0000			12	125	7.20	39	0.180	0.270	0.079	0.056
	10 05	0004	15.7	6.8		128	7.20	28	0.200	0.300	0.079	0.053
	10 05	0015	15.6	6.3		123	7.20	32	0.210	0.310	0.080	0.053
	10 05	0022	15.5	6.9		123	7.10	33	0.200	0.260	0.080	0.049
	10 05	0026	14.1	7.4		118	7.20	32	0.220	0.230	0.059	0.038
72/10/18	15 50	0000			12	130	7.40	47	0.180	0.250	0.056	0.032
	15 50	0004	6.1	8.8		130	7.40	48	0.180	0.240	0.058	0.031
	15 50	0015	6.2	9.4		130	7.40	49	0.190	0.240	0.070	0.031
	15 50	0021	6.1	10.2		130	7.60	49	0.190	0.220	0.063	0.031

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/13	06 50	0000	22.7J
72/09/07	10 05	0000	0.8J
72/10/18	15 50	0000	2.4J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/30

2786A1 LS2786A1
46 47 00.0 092 05 30.0
SHIP CANAL BETW DULUTH & MINN PT
27005 15 DULUTH
0/SUPERIOR BAY
AT AERIAL BRIDGE
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
72/10/14	13 30		0.299	0.250	0.054	0.005K	0.012
72/11/04	13 20		0.250	0.390	0.046	0.014	0.058
72/12/02			0.199	0.960	0.091	0.018	0.050
73/03/02	10 00		0.290	0.210	0.034	0.022	0.022
73/04/07	12 30		0.230	0.780	0.044	0.012	0.065
73/05/20	12 50		0.250		0.500	0.005K	0.025
73/06/24	11 30		0.160	2.730	0.154	0.015	0.040
73/07/28	12 00		0.273	0.880	0.044	0.026	0.065
73/08/25	10 45		0.250	0.440	0.039	0.006	0.020

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 74/11/30

2786R1 LS2786R1
46 45 00.0 092 06 00.0
ST LOUIS BAY/SUPERIOR BAY CONNFC
27 15 DULUTH/SUPRIR
I/SUPERIOR BAY
AT US 53 BRDG BETW RICES & CONNORS PTS
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
72/10/14	12 30		0.110	1.300	0.310	0.035	0.115
72/11/04	10 00		0.260	0.380	0.054	0.014	0.068
72/12/02	10 30		0.115	1.290	0.176	0.036	0.126
73/03/02	09 30		0.180	0.800	0.210	0.040	0.075
73/05/20	08 30		0.066	2.200	0.115	0.033	0.113
73/06/24	11 00		0.140	3.200	0.315	0.048	0.075
73/07/28	08 45		0.315	1.250	0.300	0.092	0.145
73/08/25	13 00		0.210	1.100	0.300	0.075	0.115
73/09/23	08 00		0.260	1.400	0.240	0.072	0.120

STORET RETRIEVAL DATE 74/10/30

2786C1 LS2786C1
46 43 30.0 092 04 00.0
UNNAMED STREAM
27 15 SUPERIOR
T/SUPERIOR BAY
2ND AVE BRDG NE LINCOLN SCHOOL
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
72/10/14	13 00		0.170	1.400	0.336	0.066	0.189
72/11/04	10 30		0.250	1.200	0.294	0.058	0.170
72/12/02			0.176	1.300	0.150	0.064	0.126
73/03/03	09 30		0.027	1.800	0.510	0.273	0.400
73/04/07	09 00		0.176	1.150	0.085	0.069	0.160
73/05/20	10 00		0.017	2.500	0.062	0.012	0.145
73/07/28	09 00		0.154	0.860	0.120	0.075	0.125
73/08/25	15 00		0.120	1.540	0.075	0.069	0.195
73/09/23	07 30		0.180	1.000	0.086	0.056	0.150

STORET RETRIEVAL DATE 74/10/30

27860I LS2786DI
46 42 00.0 092 02 00.0
NEMADJI RIVER
27 15 SUPERIOR
T/SUPERIOR BAY
AT US 53 & 2 BRDG EAST END & ALLOVEZ
DIFPALES 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
72/10/14	13 15		0.092	0.650	0.150	0.009	0.054
72/11/04	10 00		0.219	1.200	0.169	0.027	0.260
72/12/02	09 20		0.126	0.600	0.011	0.015	0.066
73/03/03	10 00		0.980	3.500	0.720	0.840	1.100
73/04/07	10 45		0.022	2.100	0.017	0.025	0.155
73/05/20	10 15		0.010K	0.940	0.013	0.006	0.085
73/06/24	09 00		0.044	0.775	0.063	0.008	0.040
73/07/28	09 30		0.054	0.420	0.040	0.031	0.055
73/08/25	08 30		0.120	1.150	0.066	0.069	0.155
73/09/23	08 45		0.026	0.460	0.030		0.077

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

2786E1 LS2786E1
46 41 00.0 092 01 00.0
BLUFF CREEK
27 15 SUPERIOR
T/SUPERIOR BAY
US 53 & 2 BRDG BETWEEN ALLOUEZ & ITASCA
11EPALES 2111204
→ 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
72/10/14	13 30		0.120	0.950	0.160	0.013	0.115
72/11/04	11 30		0.110	1.500	0.273	0.013	0.058
72/12/02	10 00		0.130	1.380	0.126	0.081	0.210
73/05/20	13 45		0.011	2.310	0.005K	0.021	0.120
73/06/24	09 00		0.044	0.880	0.036	0.056	0.125
73/07/28	10 30		0.025	0.980	0.069	0.060	0.110
73/08/25	08 45		0.083	0.850	0.038	0.026	0.070
73/09/23	08 15		0.180	1.150	0.071	0.056	0.135

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

2786F1 LS2786F1
46 40 30.0 092 00 30.0
REAR CREEK
27 15 SUPERIOR
T/SUPERIOR BAY
AT US 53 & 2 BRDG JUST SE OF ITASCA
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
72/10/14	13 45		0.470	1.280	0.231	0.138	0.256
72/11/04	11 00		0.105	1.470	0.220	0.010	0.071
73/05/20	11 00		0.094	.	0.100	0.470	0.620
73/07/28	11 00		0.040	1.100	0.078	0.066	0.105
73/08/25	09 00		0.082	0.870	0.017	0.022	0.070
73/09/23	07 00		0.042	1.200	0.046	0.031	0.810

STORET RETRIEVAL DATE 74/10/30

2786G1 LS2786G1
46 42 30.0 092 01 00.0
SUPERIOR ENTRY TO SUP HRBR BASIN
27 15 SUPERIOR
0/SUPERIOR BAY
AT EXTREME END OF MINNESOTAPOINT
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
72/10/14	14 00		0.160	1.150	0.250	0.036	0.098
72/11/04			0.200	1.680	0.252	0.025	0.154
73/05/20	12 45		0.240	0.580	0.160	0.010	0.015
73/07/28	13 00		0.280	1.050	0.154	0.070	0.115
73/08/25	10 15		0.240	0.980	0.023	0.031	0.060
73/09/23	07 45		0.231	0.160	0.120	0.019	0.032