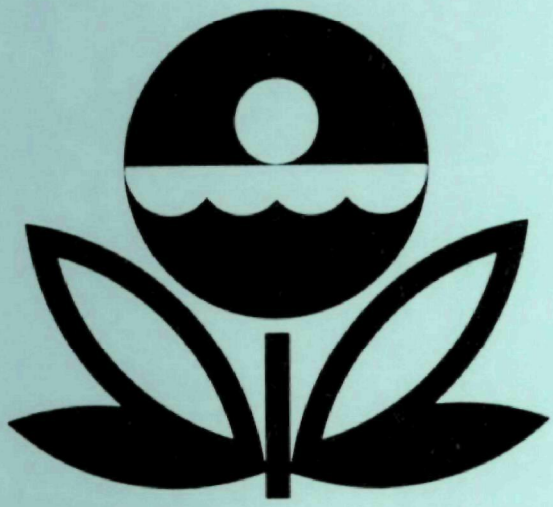
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES



REPORT

ON

LAKE ALVIN

LINCOLN COUNTY

SOUTH DAKOTA

EPA REGION VIII

WORKING PAPER No. 599

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

☆G.P.O. 699-440

REPORT

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EPA REGION VIII

WORKING PAPER No. 599

WITH THE COOPERATION OF THE

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENTAL PROTECTION

AND THE

SOUTH DAKOTA NATIONAL GUARD

DECEMBER, 1976

CONTENTS

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater 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 freshwater 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 South Dakota Departments of Environmental Protection and Game, Fish and Parks for professional involvement, to the South Dakota National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

Allyn Lockner, Secretary, and Blaine Barker and Duane Murphy, Department of Environmental Quality; Douglas Hansen, Department of Game, Fish and Parks; and James Hayden, Director, State Lakes Preservation Committee provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

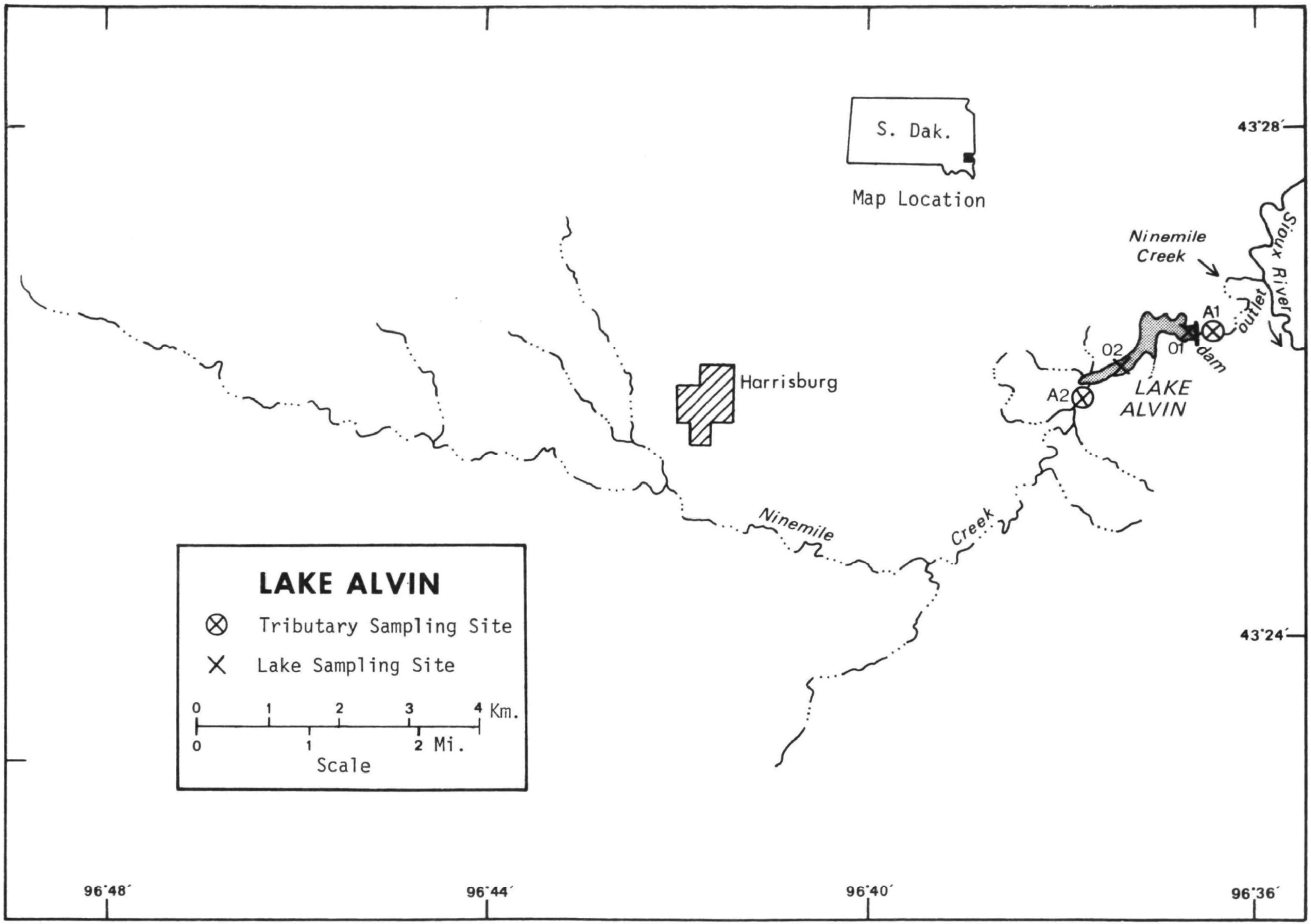
Major General Duane L. Corning, the Adjutant General of South Dakota, and Project Officer Colonel Robert D. Chalberg, who directed the volunteer efforts of the South Dakota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF SOUTH DAKOTA

LAKE NAME	COUNTY
Albert	Kingsbury
Alvin	Lincoln
Angostura	Fall River
Brant	Lake
Byron	Beadle
Clear	Marshall
Clear	Minnehaha
Cochrane	Deuel
Cottonwood	Spink
Deerfield	Pennington
Enemy Swim	Day
Herman	Lake
John	Hamlin
Kampeska	Codington
Madison	Lake
Mitchell	Davidson
Norden	Hamlin
East Oakwood	Brookings
West Oakwood	Brookings
Pactola	Pennington
Pickerel	Day
Poinsett	Brookings, Lake
Red Iron South	Marshall
Richmond	Brown
Roy	Marshall
Sand	Brown
Sheridan	Pennington
Stockdale	Custer
East Vermillion	McCook
Wall	Minnehaha
Waubay	Day


S. Dak.
Map Location
43°28´
Ninemile Creek
Sioux River
outlet
A1
dam
O1
O2
A2
LAKE ALVIN
Harrisburg
Ninemile Creek
LAKE ALVIN
Tributary Sampling Site
Lake Sampling Site
0 1 2 3 4 Km.
0 1 2 Mi.
Scale
43°24´
96°48´
96°44´
96°40´
96°36´

LAKE ALVIN

STORET NO. 4602

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake Alvin is eutrophic. It ranked twelfth in overall trophic quality when the 31 South Dakota lakes sampled in 1974 were compared using a combination of six lake parameters*. Ten of the lakes had less median total phosphorus, 11 had less median dissolved phosphorus, all of the other lakes had less median inorganic nitrogen, three had less mean chlorophyll a, and 13 had greater mean Secchi disc transparency.

Survey limnologists noted littoral beds of macrophytes and abundant zooplankton in July, and surface concentrations of algae were observed in September.

B. Rate-Limiting Nutrient:

The algal assay results indicate that the lake was phosphorus limited when sampled in April and September. However, the lake data indicate nitrogen limitation in July.

C. Nutrient Controllability:

1. Point sources--There were no point sources known to be impacting Lake Alvin during the sampling year.

The present phosphorus loading of 1.42 $g/m^2/yr$ is nearly 3.6 times that proposed by Vollenweider (Vollenweider and Dillon,

* See Appendix A.

1974) as a eutrophic loading (see page 11).

2. Non-point sources--Non-point sources accounted for all of the total phosphorus load reaching Lake Alvin during the sampling year. Ninemile Creek contributed 98.4% of the total load.

The phosphorus export rate of Ninemile Creek was 6 $kg/km^2/yr$ (see page 10). This high rate indicates the possibility of an unsampled point source impacting this creek. The town of Harrisburg is located near Ninemile Creek, but the impact of the community on the creek is not known.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 0.44 kilometers^2.
2. Mean depth: 3.7 meters.
3. Maximum depth: 9.1 meters.
4. Volume: 1.628 x 10^6 m^3.
5. Mean hydraulic retention time: 325 days.

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

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Ninemile Creek	108.8	0.058
Minor tributaries & immediate drainage -	4.8	<0.001
Totals	113.6	0.058

2. Outlet -

Ninemile Creek	114.0**	0.058

C. Precipitation***:

1. Year of sampling: 36.8 centimeters.
2. Mean annual: 63.9 centimeters.

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† Table of metric conversions--Appendix B.
†† Murphey, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Lake Alvin was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at two stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter 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 6.1 meters at station 1 and 1.8 meters at station 2.

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

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR ALVIN LAKE
STORET CODE 4602

PARAMETER	1ST SAMPLING (4/23/74) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/11/74) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/20/74) 2 SITES RANGE	MEAN	MEDIAN
TEMP (C)	10.5 - 11.2	10.9	10.9	24.8 - 25.8	25.3	25.1	17.6 - 18.3	18.0	18.0
DISS OXY (MG/L)	8.4 - 9.0	8.8	8.9	5.6 - 6.2	5.9	6.0	8.4 - 8.8	8.6	8.6
CNDCTVY (MCROMO)	887. - 918.	904.	904.	1206. - 1358.	1318.	1337.	1165. - 1177.	1172.	1172.
PH (STAND UNITS)	7.9 - 8.0	8.0	8.0	8.1 - 8.4	8.3	8.3	8.1 - 8.2	8.1	8.1
TOT ALK (MG/L)	148. - 152.	150.	150.	152. - 185.	159.	153.	158. - 160.	159.	160.
TOT P (MG/L)	0.044 - 0.067	0.052	0.047	0.091 - 0.161	0.128	0.128	0.043 - 0.078	0.058	0.055
ORTHO P (MG/L)	0.013 - 0.017	0.015	0.014	0.071 - 0.138	0.100	0.100	0.004 - 0.024	0.012	0.011
NO2+NO3 (MG/L)	0.580 - 0.640	0.612	0.620	0.090 - 0.500	0.397	0.450	0.440 - 0.460	0.452	0.455
AMMONIA (MG/L)	0.360 - 0.410	0.379	0.360	0.450 - 1.610	0.680	0.500	0.230 - 0.260	0.245	0.245
KJEL N (MG/L)	1.200 - 1.300	1.260	1.300	1.500 - 2.000	1.617	1.550	1.300 - 1.600	1.450	1.450
INORG N (MG/L)	0.980 - 1.000	0.990	0.990	0.870 - 1.700	1.077	0.965	0.670 - 0.720	0.697	0.700
TOTAL N (MG/L)	1.790 - 1.930	1.872	1.880	1.980 - 2.090	2.013	2.000	1.760 - 2.050	1.902	1.900
CHLRPYL A (UG/L)	0.9 - 1.2	1.0	1.0	1.9 - 6.4	4.1	4.1	8.9 - 8.9	8.9	8.9
SECCHI (METERS)	1.2 - 2.4	1.8	1.8	0.9 - 1.8	1.4	1.4	0.8 - 1.5	1.2	1.2

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/23/74	1. Chroomonas sp.	182
	Total	182
07/11/74	1. Chroomonas sp.	183
	2. Centric diatoms	46
	3. Aphanizomenon sp.	23
	4. Synedra sp.	23
	5. Schroederia sp.	23
	Total	298
09/20/74	1. Aphanizomenon sp.	1,108
	2. Chroomonas sp.	623
	3. Cryptomonas sp.	173
	4. Schroederia sp.	35
	Total	1,939

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/23/74	1	1.2
	2	0.9
07/11/74	1	1.9
	2	6.4
09/20/74	1	8.9
	2	8.9

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. April sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.015	0.790	0.3
0.050 P	0.065	0.790	10.5
0.050 P + 1.0 N	0.065	1.790	21.6
1.0 N	0.015	1.790	0.4

b. September sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.035	0.740	11.1
0.050 P	0.085	0.740	22.5
0.050 P + 1.0 N	0.085	1.740	58.1
1.0 N	0.035	1.740	10.9

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Lake Alvin was moderate in April and was high in November. Also, the significant increases in yield with the addition of phosphorus alone indicate that the lake was limited by phosphorus at those times.

The lake data also indicate phosphorus limitation in the spring and fall; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 66/1 and 58/1, respectively. However, the July mean N/P ratio of 11/1 indicates nitrogen limitation at that time.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the South Dakota National Guard collected monthly near-surface grab samples when possible from each of the tributary sites indicated on the map (page v), except for the high runoff month of June when two samples were collected. Sampling was begun in October, 1974, and was completed in October, 1975.

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

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Flow measurements for minor tributaries and immediate drainage were negligible, and no loads were calculated.

No known point sources impacted Lake Alvin during the sampling year.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Ninemile Creek	615	98.4
b. Minor tributaries & immediate drainage (non-point load) -		
None	-	-
c. Known municipal STP's - None	-	-
d. Septic tanks - Unknown	?	-
e. Known industrial - None	-	-
f. Direct precipitation* -	10	1.6
Total	625	100.0

2. Outputs -

Lake outlet - Ninemile Creek 295

3. Net annual P accumulation - 330 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Ninemile Creek	5,005	91.3
b. Minor tributaries & immediate drainage (non-point load) -		
None	-	-
c. Known municipal STP's - None	-	-
d. Septic tanks - Unknown	?	-
e. Known industrial - None	-	-
f. Direct precipitation* -	475	8.7
Total	5,480	100.0

2. Outputs -

Lake outlet - Ninemile Creek	4,160

3. Net annual N accumulation - 1,320 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Ninemile Creek	6	46

* See Working Paper No. 175.

E. Yearly Loads:

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

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

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	1.42	0.75	12.5	3.0

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake Alvin:	
"Dangerous" (eutrophic loading)	0.40
"Permissible" (oligotrophic loading)	0.20

V. LITERATURE REVIEWED

Murphey, Duane B., 1974. Personal communication (lake morphometry). SD Dept. of Env. Prot., Pierre.

Schmidt, Artwin E., 1967. Limnology of selected South Dakota lakes. MS thesis, SD St. U., Brookings.

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

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P
4601	LAKE ALBERT	0.321	0.170	489.111	106.289	9.200	0.019
4602	ALVIN LAKE	0.067	0.970	442.833	4.700	9.400	0.017
4603	ANGOSTURA RESERVOIR	0.019	0.160	423.333	3.717	13.000	0.005
4604	BRANT LAKE	0.194	0.130	432.833	34.150	11.800	0.113
4605	LAKE BYRON	0.443	0.370	488.333	149.350	9.000	0.146
4606	CLEAR LAKE	0.027	0.075	430.167	11.983	8.800	0.009
4607	CLEAR LAKE	1.400	0.270	495.333	691.000	7.000	0.468
4608	COCHRANE LAKE	0.037	0.150	446.000	15.683	15.000	0.008
4609	COTTONWOOD LAKE	0.685	0.265	490.333	112.017	8.600	0.417
4610	DEERFIELD RESERVOIR	0.033	0.080	303.333	3.650	15.000	0.022
4611	ENEMY SWIM LAKE	0.037	0.085	442.600	14.200	8.200	0.013
4612	LAKE HERMAN	0.340	0.155	485.000	58.733	8.600	0.174
4613	ST JOHN LAKE	0.348	0.080	489.400	120.880	9.800	0.025
4614	LAKE KAMPESKA	0.220	0.105	468.889	20.567	8.200	0.128
4615	MADISON LAKE	0.259	0.090	445.555	22.578	14.000	0.107
4616	LAKE MITCHELL	0.099	0.085	465.833	14.883	13.800	0.015
4617	LAKE NORDEN	0.256	0.165	488.667	46.800	10.000	0.050
4618	OAKWOOD LAKE EAST	0.146	0.175	487.000	113.600	10.000	0.009
4619	OAKWOOD LAKE WEST	0.181	0.135	485.833	159.667	9.600	0.021
4620	PACTOLA RESERVOIR	0.011	0.070	248.444	1.478	11.000	0.006
4621	PICKEREL LAKE	0.049	0.095	439.833	15.833	9.600	0.009
4622	LAKE POINSETT	0.115	0.315	468.444	40.211	10.000	0.023
4623	LAKE RED IRON SOUTH	0.042	0.110	430.333	6.883	7.600	0.010
4624	RICHMOND LAKE	0.187	0.150	410.000	18.467	10.000	0.144
4625	ROY LAKE	0.034	0.070	431.000	13.333	11.000	0.010
4626	SAND LAKE	0.489	0.110	471.800	65.790	12.800	0.288
4627	SHERIDAN LAKE	0.053	0.105	394.000	15.433	15.000	0.016
4628	STOCKADE LAKE	0.233	0.150	432.000	25.400	15.000	0.109

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4629	LAKE VERMILLION	0.211	0.100	472.833	100.800	9.200	0.092
4630	WALL LAKE	0.194	0.160	441.667	55.267	7.400	0.076
4631	WAUBAY LAKE NORTH	0.098	0.145	469.555	127.033	11.400	0.023

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

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4601	LAKE ALBERT	20 (6)	20 (6)	10 (3)	23 (7)	68 (20)	60 (18)	201
4602	ALVIN LAKE	67 (20)	0 (0)	57 (17)	90 (27)	63 (19)	63 (19)	340
4603	ANGOSTURA RESERVOIR	97 (29)	30 (9)	87 (26)	93 (28)	20 (6)	100 (30)	427
4604	BRANT LAKE	40 (12)	53 (16)	70 (21)	47 (14)	27 (8)	23 (7)	260
4605	LAKE BYRON	10 (3)	3 (1)	17 (5)	7 (2)	73 (22)	13 (4)	123
4606	CLEAR LAKE	93 (28)	93 (28)	83 (25)	83 (25)	77 (23)	90 (27)	519
4607	CLEAR LAKE	0 (0)	10 (3)	0 (0)	0 (0)	100 (30)	0 (0)	110
4608	COCHRANE LAKE	83 (25)	40 (11)	50 (15)	67 (20)	5 (0)	93 (28)	338
4609	COTTONWOOD LAKE	3 (1)	13 (4)	3 (1)	20 (6)	82 (24)	3 (1)	124
4610	DEERFIELD RESERVOIR	90 (27)	88 (26)	97 (29)	97 (29)	5 (0)	53 (16)	430
4611	ENEMY SWIM LAKE	80 (24)	82 (24)	60 (18)	77 (23)	88 (26)	73 (22)	460
4612	LAKE HERMAN	17 (5)	33 (10)	27 (8)	33 (10)	82 (24)	10 (3)	202
4613	ST JOHN LAKE	13 (4)	88 (26)	7 (2)	13 (4)	53 (16)	43 (13)	217
4614	LAKE KAMPESKA	33 (10)	65 (19)	40 (12)	57 (17)	88 (26)	20 (6)	303
4615	MADISON LAKE	27 (8)	77 (23)	53 (16)	53 (16)	13 (4)	30 (9)	253
4616	LAKE MITCHELL	60 (18)	82 (24)	47 (14)	73 (22)	17 (5)	70 (21)	349
4617	LAKE NORDEN	23 (7)	23 (7)	13 (4)	40 (12)	45 (12)	40 (12)	184
4618	OAKWOOD LAKE EAST	53 (16)	17 (5)	20 (6)	17 (5)	45 (12)	85 (25)	237
4619	OAKWOOD LAKE WEST	50 (15)	50 (15)	23 (7)	3 (1)	58 (17)	57 (17)	241
4620	PACTOLA RESERVOIR	100 (30)	98 (29)	100 (30)	100 (30)	35 (10)	97 (29)	530
4621	PICKEREL LAKE	73 (22)	73 (22)	67 (20)	63 (19)	58 (17)	85 (25)	419
4622	LAKE POINSETT	57 (17)	7 (2)	43 (13)	43 (13)	45 (12)	47 (14)	242
4623	LAKE RED IRON SOUTH	77 (23)	58 (17)	80 (24)	87 (26)	93 (28)	78 (23)	473
4624	RICHMOND LAKE	47 (14)	40 (11)	90 (27)	60 (18)	45 (12)	17 (5)	299
4625	ROY LAKE	87 (26)	98 (29)	77 (23)	80 (24)	35 (10)	78 (23)	455
4626	SAND LAKE	7 (2)	58 (17)	33 (10)	30 (9)	23 (7)	7 (2)	158
4627	SHERIDAN LAKE	70 (21)	65 (19)	93 (28)	70 (21)	5 (0)	67 (20)	370
	ADE	(	11	73	[illegible]	[illegible] 0)	[illegible]	[illegible]

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

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4629	LAKE VERMILLION	37 (11)	70 (21)	30 (9)	27 (8)	68 (20)	33 (10)	265
4630	WALL LAKE	43 (13)	27 (8)	63 (19)	37 (11)	97 (29)	37 (11)	304
4631	WAUBAY LAKE NORTH	63 (19)	47 (14)	37 (11)	10 (3)	30 (9)	50 (15)	237

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4620	PACTOLA RESERVOIR	530
2	4606	CLEAR LAKE	519
3	4623	LAKE RED IRON SOUTH	473
4	4611	ENEMY SWIM LAKE	460
5	4625	ROY LAKE	455
6	4610	DEERFIELD RESERVOIR	430
7	4603	ANGOSTURA RESERVOIR	427
8	4621	PICKEREL LAKE	419
9	4627	SHERIDAN LAKE	370
10	4616	LAKE MITCHELL	349
11	4602	ALVIN LAKE	340
12	4608	COCHRANE LAKE	338
13	4630	WALL LAKE	304
14	4614	LAKE KAMPESKA	303
15	4624	RICHMOND LAKE	299
16	4629	LAKE VERMILLION	265
17	4604	BRANT LAKE	260
18	4615	MADISON LAKE	253
19	4622	LAKE POINSETT	242
20	4619	OAKWOOD LAKE WEST	241
21	4631	WAUBAY LAKE NORTH	237
22	4618	OAKWOOD LAKE EAST	237
23	4628	STOCKADE LAKE	225
24	4613	ST JOHN LAKE	217
25	4612	LAKE HERMAN	202
26	4601	LAKE ALBERT	201
27	4617	LAKE NORDEN	184

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4609	COTTONWOOD LAKE	124
30	4605	LAKE BYRON	123
31	4607	CLEAR LAKE	110

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

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

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA 05/03/76

LAKE CODE 4602 ALVIN

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 114.0

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4602A1	114.0	0.0	0.0	0.085	0.227	0.142	0.113	0.085	0.028	0.014	0.006	0.0	0.0	0.058
4602A2	108.8	0.0	0.0	0.085	0.227	0.142	0.113	0.085	0.028	0.014	0.006	0.0	0.0	0.058
4602ZZ	5.2	0.0	0.0	0.0	0.003	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 114.0
SUM OF SUB-DRAINAGE AREAS = 114.0
TOTAL FLOW IN = 0.71
TOTAL FLOW OUT = 0.70

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4602A1	10	74	0.0	13	0.0				
	11	74	0.0	10	0.0				
	12	74	0.0	8	0.0				
	1	75	0.0	19	0.0				
	2	75	0.0	1	0.0				
	3	75	0.057	23	0.057				
	4	75	0.085	6	0.142				
	5	75	0.028	18	0.057				
	6	75	0.014	3	0.003	8	0.003		
	7	75	0.0	20	0.014				
	8	75	0.227	23	0.085				
	9	75	0.014	20	0.011				
4602A2	10	74	0.0	13	0.0				
	11	74	0.0	10	0.0				
	12	74	0.0	8	0.0				
	1	75	0.0	19	0.0				
	2	75	0.0	1	0.0				
	3	75	0.028	23	0.085				
	4	75	0.085	4	0.170				
	5	75	0.014	18	0.028				
	6	75	0.003	3	0.014	6	0.014		
	7	75	0.0	20	0.0				
	8	75	0.113	23	0.142				
	9	75	0.006	20	0.011				
4602ZZ	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.0						
	4	75	0.0						
	5	75	0.0						
	6	75	0.0						
	7	75	0.0						
	8	75	0.014						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/05/03

460201
43 26 15.0 096 36 30.0 4
ALVIN LAKE
46063 SOUTH DAKOTA
090791

11EPALES 2111202
0022 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/23	13 00	0000	10.8		96	892	8.00	148	0.360	1.300	0.620	0.013
	13 00	0005	10.8	9.0		892	7.95	148	0.360	1.300	0.630	0.014
	13 00	0017	10.5	8.4		887	7.95	150	0.360	1.200	0.640	0.014
74/07/11	16 00	0000	25.1	6.0	72	1337	8.30	152	0.480	1.500	0.480	0.105
	16 00	0005	25.1	6.2			8.20	152	0.480	1.500	0.490	0.071
	16 00	0015	24.8	5.6		1327	8.10	153	0.520	1.500	0.500	0.099
	16 00	0020				1208		185	1.610	2.000	0.090	0.138
74/09/20	15 15	0000	18.3	8.4	60	1177	8.15	160	0.240	1.600	0.450	0.004
	15 15	0015	18.3	8.8		1175	8.21	159	0.230	1.400	0.440	0.011

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/23	13 00	0000	0.044	1.2	
	13 00	0005	0.045		
	13 00	0017	0.047		
74/07/11	16 00	0000	0.128	1.9	
	16 00	0005	0.091		
	16 00	0015	0.136		
	16 00	0020	0.161		
74/09/20	15 15	0000	0.043	8.9	
	15 15	0002			50.0
	15 15	0008			5.0
	15 15	0014			1.0
	15 15	0015	0.052		

STORET RETRIEVAL DATE 76/05/03

460202
43 26 00.0 096 38 00.0 4
ALVIN LAKE
46083 SOUTH DAKOTA

090791

11EPALES 2111202
0010 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/23	13 20	0000	11.2		48	918	8.00	151	0.400	1.200	0.590	0.016
	13 20	0002	11.2	8.8		918						
	13 20	0006	11.1	9.0		916	8.00	152	0.410	1.300	0.580	0.017
74/07/11	15 45	0000	25.8	5.8	36	1358	8.40	152	0.450	1.600	0.420	0.088
	15 45	0006	25.7	6.0		1358	8.30	158	0.540	1.600	0.400	0.102
74/09/20	15 00	0000	17.8	8.6	31	1165	8.07	158	0.260	1.300	0.460	0.011
	15 00	0006	17.6	8.6		1169	8.09	160	0.250	1.500	0.460	0.024

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/23	13 20	0000	0.058	0.9	
	13 20	0006	0.067		
74/07/11	15 45	0000	0.128	6.4	
	15 45	0006	0.122		
74/09/20	15 00	0000	0.058	8.9	
	15 00	0006	0.078		

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/05/04

46J2A1
43 26 25.0 096 36 30.0 4
NINEMILE CREEK
46 7.5 KLONDIKE
O/ALVIN LAKE 090791
SEC RD BRDG 4.5 MI ENE OF HARRISBURG
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/03/23	10 00		0.175	1.300	0.387	0.042	0.110
75/04/06	09 05		0.140	3.300	0.230	0.040	0.100
75/05/18	09 45		0.055	2.900	0.110	0.010	0.140
75/06/03	14 10		0.025	1.400	0.040	0.010	0.070
75/06/08	09 25		0.015	1.500	0.035	0.010	0.390
75/07/20	12 50		0.005	1.750	0.025	0.025	0.160
75/08/23	14 05		0.050	2.900	0.035	0.035	0.180
75/09/20	09 20		0.210	3.000	0.190	0.005K	0.110
75/10/05	10 10		0.345	1.400	0.070	0.010	0.180

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

460242
43 25 50.0 096 38 00.0 4
NINEMILE CREEK
46 7.5 HARRISBURG
T/ALVIN LAKE 090791
SEC RD BRDG 3 MI E OF HARRISBURG
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/03/23	09	50	1.005	1.900	0.462	0.135	0.190
75/04/04	09	00	1.570	2.200	0.800	0.490	0.560
75/05/18	09	55	0.005	2.600	0.045	0.030	0.240
75/06/03	13	50	0.025	3.450	0.075	0.075	0.440
75/06/06	09	45	0.015	2.700	0.040	0.045	0.382
75/07/20	10	35	0.005	1.550	0.025	0.030	0.170
75/08/23	13	50	0.890	2.700	0.085	0.590	0.780
75/09/20	09	10	0.060	2.400	0.075	0.020	0.120
75/10/05	10	00	0.050	1.500	0.085	0.030	0.140

STORET RETRIEVAL DATE 76/05/04

460216
43 20 35.0 096 39 50.0 4
UNNAMED CREEK
46 LINCOLN CO HWY
T/ALVIN LAKE 090792
SEC RD BRDG .8 MI W OF SD HWY 11
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	13 15		0.144	0.300	0.075	0.020	0.055
74/11/10	10 35		0.208	1.400	0.170	0.055	0.170
74/12/08	10 50		0.416	1.700	0.460	0.012	0.030
75/03/23	10 45		0.975	1.450	0.444	0.033	0.120
75/04/06	09 40		0.860	2.100	0.375	0.060	0.140
75/05/18	10 40		0.020	0.550	0.055	0.015	0.120
75/06/03	14 30		0.040	0.650	0.040	0.020	0.170
75/06/08	10 30		0.015	1.150	0.045	0.020	0.080
75/07/20	13 30		0.115	1.350	0.095	0.080	0.230
75/08/23	11 40		0.260	2.700	0.110	0.675	0.750
75/09/20	10 00		0.090	0.700	0.050	0.010	0.480
75/10/05	10 40		0.155	0.700	0.040	0.065	0.120

STORET RETRIEVAL DATE 76/05/04

46021C
43 20 35.0 096 32 20.0 4
UNNAMED CREEK
46 LINCOLN CO HWY
T/ALVIN LAKE 090791
SEC RD BRDG 4.5 MI NE OF CANTON
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/03/23	10 20		1.665	0.950	0.129	0.089	0.130
75/04/06	09 25		1.400	1.050	0.055	0.055	0.060
75/06/03	14 50		0.040	0.350	0.045	0.010	0.120
75/08/23	14 30		0.375	1.800	0.230	0.210	0.250