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Nutrient Transport in the Lake Poinsett System

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BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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NUTRIENT TRANSPORT IN THE LAKE POINSETT SYSTEM

Abstract

JACK M. SKILLE

Concentrations and loads of nutrients transported through the Lake Poinsett system were monitored from April 1, 1970 to April 1, 1971. An annual 2.07x 10~ m^3 surface discharge into Lake Poinsett transported 3 OC~,; 1.66×10^4 kg (PO_4) phosphorus, 1.28×10^4 kg nitrate nitrogen, and 3.90×10^5 kg organic carbon. The Big Sioux River-Dry Lake system contributed 63% of the phosphorus, 45% of the nitrate nitrogen, and 43% of the organic carbon load. The remaining portion entered Lake Poinsett from the Lake Albert drainage. Of the annual load of nutrients transported into Lake Poinsett, 33% of the nitrate nitrogen load, 40% of the organic carbon load, and 70% of the phosphorus **load was** retained by the lake or lost by ways other than water discharge. Average annual phosphorus concentrations decreased through the system from 1.9 mg/l (PO_4) in the Big Sioux River to 0.22 mg/l (PO_4) in Lake Poinsett. Soluble inorganic phosphorus constituted 71% of the total phosphorus which entered Lake Poinsett and comprised 50% of the phosphorus in the lake. The average annual concentration of nitrate nitrogen in Lake Poinsett was 0.52 mg/l. Average annual organic carbon concentrations increased through the system from 13.37 mg/l in the Big Sioux River to 18.40 mg/l in Lake Poinsett.

Nutrient concentrations in Lake Poinsett, relative to the needs of aquatic plants in the lake, are in a state of super-saturation. The advanced degree of eutrophication in Lake Poinsett is ascribable to the large annual nutrient load entering and retained by the lake.

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INTRODUCTION

Lake Poinsett and its tributaries are situated in a predominantly agricultural region of South Dakota. The Big Sioux River is a major source of influent to Lake Poinsett and carries extremely high concentrations of orthophosphate and nitrate nitrogen (U. S. Geological Survey, 1968). The lake reflects this nutrient enrichment in its apparent high productivity and advanced stage of eutrophication. Lake Poinsett produces dense blooms of blue-green algae (Applegate, 1971) and high concentrations of zooplankton (Applegate, unpublished data). Commercial harvest of carp and bigmouth buffalo fish was 2.5×10^6 kg from 1961-71 and is indicative of large rough fish populations (Applegate, 1971). The rate and degree of eutrophication in Lake Poinsett are dependent upon the nutrient transport into the lake and the retention of nutrients. The objectives of this study were to measure the transport and retention of phosphorus, nitrate nitrogen, and organic carbon in the Lake Poinsett system during one year.

STUDY AREA

Lake Poinsett is located in Hamlin County and part of northwest Brookings County in east-central South Dakota. Its maximum depth is 6.0 m and its surface area is 3184.6 hectares making it South Dakota's largest natural lake (Smith, 1971). The lake is of glacial origin and is situated in an extensive glacial outwash aquifer (Barari, 1971).

Lake Poinsett receives surface water from two major sources. One is the Lake Albert drainage system which is a network of several intermittent streams connecting Marsh Lake, Lake Norden, Lake St. John, Badger Lake, Thisted Lake, and Lake Albert. Lake Poinsett is on the lower end of this system and receives water from Lake Albert via a marsh (Figure 1). The other water source is the Big Sioux River from which water is diverted to Lake Poinsett via a diversion canal and Dry Lake. The diversion canal was constructed in 1929 between the Big Sioux River and Dry Lake so that both Dry Lake and Lake Poinsett could be used for off-stream storage of river floodwater (Johnston, 1965). The head waters of the Big Sioux River are in Grant County in north-eastern South Dakota. The river flows approximately 150 km through agricultural land before reaching the Lake Poinsett area. A natural water-way from the northeast side of the lake to the Big Sioux River (Figure 1), is the only outlet.

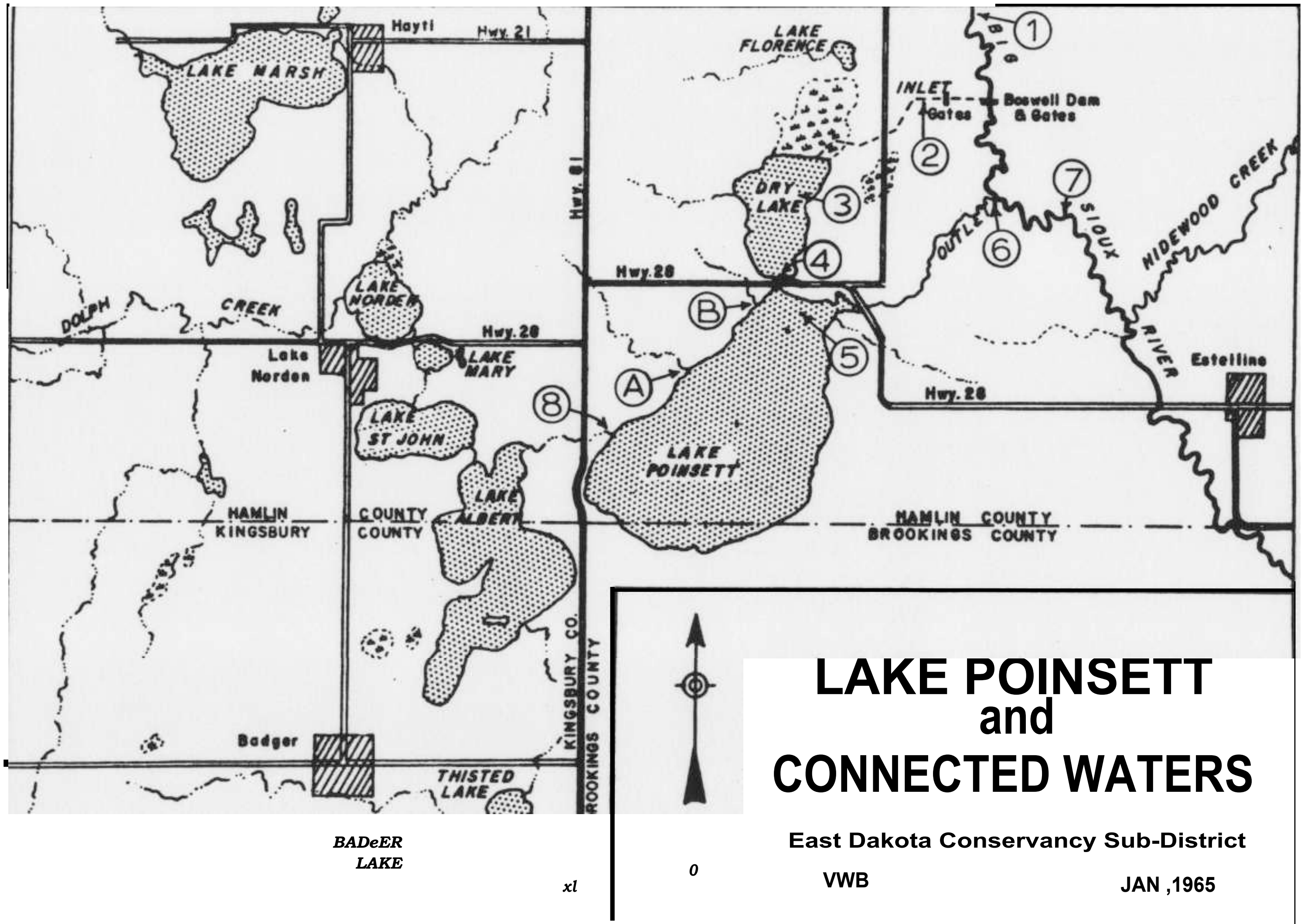

FIGURE 1. STUDY AREA AND SAMPLING STATION LOCATIONS.

METHODS

Eight stations of the Lake Poinsett system were sampled at approximately one week intervals May through November and biweekly December through April. All major surface influents and effluents were monitored for seasonal fluctuation in water discharge, nutrient load, and nutrient concentration. Fluctuations in nutrient concentrations in Lake Poinsett and Dry Lake were also measured. Sampling stations were: on the Big Sioux River 1.6 km north of the Boswell Dam, on the diversion canal 1.5 km west of the Boswell Dam, in Dry Lake 3.3 km northeast of the Stone Bridge, in the Stone Bridge channel between Dry Lake and Lake Poinsett, in Lake Poinsett midway between Stone Bridge and the outlet, in the Lake Poinsett outlet where it enters the Big Sioux River, in the Big Sioux River 1.7 km west of the outlet, and in the Lake Albert drainage where it enters Lake Poinsett (Figure 1). Water samples were taken from 0.3 m below the surface, held in one-liter polyethylene bottles, refrigerated, and analyzed within 24 hours after collecting. Stream velocity was measured with a Gurly[1] current meter each time water samples were collected. Discharge was calculated as the product of stream velocity, depth, and width.

Phosphorus concentrations were measured using a stannous chloride-ammonium molybdate method outlined in Standard Methods (1965). Soluble and insoluble fractions were separated using 0.45,& HA Millipore[1] filters. Filters were pre-rinsed with 200 ml of distilled water to remove traces of inorganic phosphorus (Bigler, 1964). Samples were analyzed for

[1]Registered trademarks

soluble inorganic phosphorus (orthophosphate), soluble organic phosphorus (polyphosphate and metaphosphate), and sestonic phosphorus (that fraction removed with a 0.45, $_{4}$ filter). The total of these fractions was considered to be total phosphorus. Tucker (1957) noted that there is also an insignificant concentration of acid soluble sestonic phosphorus which is inorganic and in suspension as sestonic phosphorus. This fraction is included in both the soluble inorganic fraction and the sestonic fraction. All phosphorus was measured as phosphate by the method described. Therefore, phosphorus concentrations are given as the phosphate equivalent (PO4) unless otherwise labeled.

Nitrate nitrogen was measured by the brucine method from April 1 through August 17, 1970 and the phenoldisulfonic acid method from August 24, 1970 through March 31, 1971 (Standard Methods, 1965). The latter method is sensitive to 0.01 mg/l of nitrate nitrogen and was more applicable to the range of concentrations encountered in this study.

Particulate and dissolved organic carbon samples were analyzed in triplicate using the dichromate oxidation technique outlined by Maciolek (1962). The two fractions were separated with pre-rinsed 0.45 $_{4}$ Millipore filters. Chloride and dissolved oxygen concentrations were measured by the Hach Chemical Company methods (Instruction Manual, 7th edition). Organic carbon oxidation values were corrected for chloride contamination as recommended by Maciolek (1962).

RESULTS AND DISCUSSION

Water Flow Through The System

The Big Sioux River had an average annual flow of 1.05 m^3/sec. at station 1. The total discharge for the year (April 1, 1970-April 1, 1971) was 3.35×10^7 m^3. Monthly discharge ranged from 9.22×10^6 m^3 in March to 6.90×10^4 m^3 in January. Discharge declined in the spring after snow melt and ranged between 6.90×10^4 and 1.71×10^6 m^3 during the summer and winter months. Precipitation in November caused a flow increase from 5.78×10^5 m^3 in October to 1.57×10^6 m^3 in November (Table 1).

The annual discharge from the Big Sioux River into Dry Lake via the diversion canal was 3.87×10^6 m^3 which was 36.2 percent of the annual river discharge. The dam on the canal was closed from May 1, 1970 through November 19, 1970. During this time there was an intermittent flow under and around the gates which amounted to 1.68×10^5 m^3 or 4.3 percent of the annual discharge. Monthly discharge ranged from 1.21×10^4 m^3 in August to 1.99×10^6 m^3 in March (Table 1). The average annual flow in the diversion canal was 0.12 m^3/sec.

Ground water made up a substantial amount of the flow into Dry Lake during the time the diversion canal dam was closed. During July and August I observed ground water seeping into the canal from springs. Ground water temperature was 59 C and Big Sioux River water temperature was 74 C. Ground water had no trace of dissolved oxygen and water in the canal above the springs had 6.0 mg/l dissolved oxygen. Water in the canal below the springs had 2.8 mg/l dissolved oxygen.

Table 1. Water discharge through the Lake Poinsett system, April 1970-March 1971 (m^3)

Date	Big Sioux River (Statio 1) X 10	Diversion Canal (Static X 10'	Stone Bridge Channel (Station 4) X 10^5	Lake Poinsett Outlet (Station 6) X 10^5	Big Sioux River (Station 7) X 10^5	Lake Albert Drainage (Station 8) X 10^5
April	81.3	33.7	23.2	24.2	104.0	6.7
May	59.9	5.3	1.8	22.5	78.0	8.9
June	34.1	3.5	*	19.5	58.5	27.1
July	17.1	2.7	*	17.4	35.2	26.3
Aug.	8.3	1.2	*	13.5	23.2	22.0
Sept.	3.8	1.5	*	7.5	12.0	7.2
Oct.	5.8	1.4	*	5.9	10.5	4.2
Nov.	15.7	30.2	*	6.0	16.9	5.1
Dec.	6.9	42.7	*	5.7	7.6	3.4
Jan.	0.7	6.3	*	1.0	1.7	1.7
Feb.	9.2	59.6	*	0.9	4.9	1.7
March	92.2	199.0	60.6	2.4	18.1	7.2
Total	334.9	387.2	85.6	126.4	370.6	121.5

* No discharge due to sand blockage

Discharge from Dry Lake into Lake Poinsett via the Stone Bridge channel (station 4) from April 1, 1970 to May 9, 1970 and from March 23, 1971 to April 1, 1971 was 8.56 x 10^6 m^3. Surface water flow in the channel between Dry Lake and Lake Poinsett was blocked by sand from May 9, 1970 to March 23, 1971 (Table 1). Of the 8.56 x 10^6 m^3 of water flowing from Dry Lake to Poinsett 3.87 x 10^6 m^3 entered Dry Lake from the Big Sioux River. The remaining 4.69 x 10^6 m^3 that entered Dry Lake is attributable to surface runoff, ground water, and precipitation.

The Lake Albert drainage contributed 1.21 x 10^7 m^3 of water to Lake Poinsett between April 1, 1970 and April 1, 1971. The average annual discharge was 0.38 m^3/sec. Monthly discharges ranged from 1.66 x 10^5 m^3 in January to 2.71 x 10^6 m^3 in June. The high discharge due to the spring thaw did not reach this drainage until June (Table 1).

Discharge from Lake Poinsett to the Big Sioux River during the year was 1.26 x 10^7 m^3. Monthly discharges ranged from 9.04 x 10^4 m^3 in February to 2.42 x 10^6 m^3 in April. The average annual flow was 0.39 m^3/sec. (Table 1).

The annual discharge in the Big Sioux River below the outlet (station 7) was 3.71 x 10^7 m^3 (Table 1). A calculated discharge was determined by subtracting station 2 discharge from station 1 discharge and adding station 6 discharge. This calculated annual discharge was 4.13 x 10^7 m^3 and is 10.2 percent more than the measured discharge at station 7. This difference can be attributed to loss through evaporation, percolation, and error in measuring flow.

The Lake Albert drainage and the Big Sioux River-Dry Lake drainage contributed 2.07 x 10^7 m^3 of water to Lake Poinsett during the study. The precipitation during this time was 47.1 cm (U. S. Weather Bureau Station at Castlewood, South Dakota) which added 1.50 x 10^7 m^3 directly to Lake Poinsett. These two sources added a total of 3.57 x 10^7 m^3 of water to Lake Poinsett during the year.

Surface flow and evaporation removed 4.00 x 10^7 m^3 of water from Lake Poinsett during the year. Discharge from Lake Poinsett to the Big Sioux River via the outlet was 1.26 x 10^7 m^3. Evaporation from lakes in the area averages 86.4 cm/year (Kohler et al., 1959) and at that rate Lake Poinsett lost 2.74 x 10^7 m^3 of water through evaporation during the year. The 4.3 x 10^6 m^3 of annual discharge from Lake Poinsett during this study may be attributed to sources of local surface runoff and ground water. Barari (1971), in a hydrological study of the Lake Poinsett area, found that 2.113 x 10^4 m^3/day of ground water moved into Dry Lake and Lake Poinsett from aquifers to the north and west of the lakes. He also found that ground water moved eastward from Lake Poinsett to the Big Sioux River. His data are limited to August, 1970 but shows the possibility of a substantial ground water-lake water exchange in Lake Poinsett and Dry Lake.

Phosphorus Concentrations and Loads

Station 1 (Big Sioux River)

Total phosphorus concentrations at station 1 on the Big Sioux River were higher and had a greater range than at any other station in the system. The average annual concentration of total phosphorus was 1.92 mg/l (PO_4) and was nine times greater than the average (0.21 mg/l (PO_4))

for river water of the world (Clarke, 1924).

Concentrations of dissolved inorganic phosphorus were lowest in the fall and highest in the winter in the Big Sioux River. The average annual concentration was 1.21 mg/l (PO4) at station 1. The monthly mean concentrations ranged from 0.25 mg/l (PO4) and 0.26 mg/l (PO_4) in September and October to 3.80 mg/l (PO4) in December (Figure 2).

Sestonic phosphorus concentrations were high in late summer and late winter and lowest in early summer and fall (Figure 2). Monthly mean concentrations ranged from 0.27 mg/l (PO_4) in March to 1.13 mg/l (PO4) in January. The average annual concentration was 0.57 mg/l (PO4). There was approximately a one month lag in fluctuation of sestonic phosphorus behind dissolved inorganic phosphorus (Figure 2).

Dissolved organic phosphorus concentrations were relatively low (less than 0.25 mg/l (PO4)) and constant (range 0.01-0.24 mg/l (PO_4)) throughout the year except for a large increase in the early winter when a high of 0.57 mg/l (PO_4) was recorded in December (Figure 2). The average annual concentration of dissolved organic phosphorus was 0.14 mg/l (PO_4).

The percentages of the three phosphorus fractions in the Big Sioux River (station 1) calculated from average annual concentrations were 63.0% dissolved inorganic, 29.6% sestonic, and 7.4% dissolved organic phosphorus. The ratio of these three fractions was 8.6 : 4 : 1, respectively.

The nutrient load varied much more with amount of discharge than with nutrient concentration at station 1 and at all other stream stations

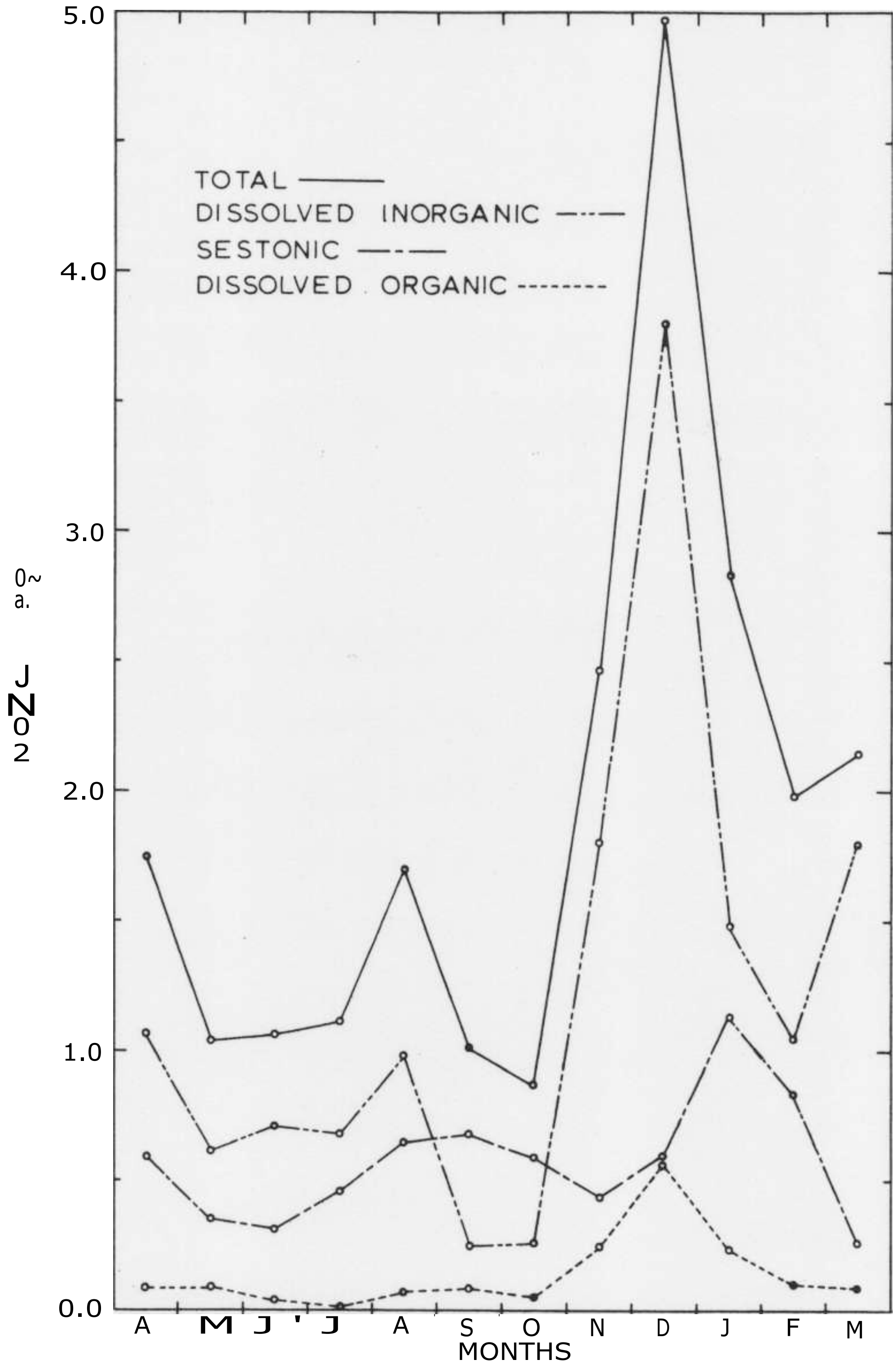

FIGURE 2. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS IN THE BIG SIOUX RIVER (Station 1), (APRIL 1970—MARCH 1971).

in the system. The highest monthly loads of total phosphorus were 1.42×10^4 kg (PO_4) in April and 1.98×10^4 kg (PO_4) in March. Water discharge was also greatest during these months. The lowest monthly phosphorus load was 197 kg in January when water discharge was the least (Table 2).

The annual phosphorus load carried by the Big Sioux River at station 1 was 5.75×10^4 kg (PO_4) which was comprised of 4.01×10^4 **kg** (PO_4) of dissolved inorganic, 1.43×10^4 kg (PO_4) sestonic, and 3.07×10^3 **kg** (PO4) of dissolved organic phosphorus (Table 2).

Station 2 (Diversion Canal)

Phosphorus concentrations in the diversion canal were nearly the same as those in the river during the time the diversion canal dam was open. When the dam was closed from May to mid-November phosphorus concentrations ranged from 0.26-0.81 mg/l which were lower than those in the river (Figures 2 and 3). This was apparently due to ground water low in phosphorus mixing with the river water which seeped past the gates. Barari (1971) found that total phosphorus concentrations in ground water of the area averaged less than 0.1 mg/l.

The total phosphorus concentration for the year averaged 1.21 mg/l (PO_4). The dissolved inorganic fraction averaged 0.78 mg/l (PO_4) and the monthly mean concentration ranged from 0.06 mg/l (PO4) in June to 3.02 mg/l (PO_4) in December (Figure 3).

Monthly mean concentrations of sestonic phosphorus ranged from 0.15 mg/l (PO_4) in June to 0.68 mg/l (PO4) in February and had an average annual concentration of 0.32 mg/l (PO_4) (Figure 3).

Table 2. Phosphorus transported through the Lake Poinsett system, April 1970-March 1971 (Kg PO_4)

Date	Big Sioux River (Station 1)			Diversion Canal (Station 2)			Stone Bridge Channel (Station 4)		
	Dis-solved inor-ganic	Dis-solved organic	Ses-tonic	Dis-solved inor-ganic	Dis-solved organic	Ses-tonic	Dis-solved inor-ganic	Dis-solved organic	**Ses-tonic**
April	8,629	733	4,803	378	54	78	1,230	162	313
May	3,659	480	2,099	24	3	16	65	9	40
June	2,423	102	1,092	2	1	5	*	*	*
July	1,185	17	790	3	1	5	*	*	*
Aug.	812	58	539	3	1	4	*	*	*
Sept.	95	30	261	3	1	7	*	*	*
Oct.	150	29	336	1	3	3	*	*	*
Nov.	2,836	378	677	190	60	91	*	*	*
Dec.	2,630	394	415	1,291	68	109	*	*	*
Jan.	102	17	78	50	16	32	*	*	*
Feb.	971	92	768	555	48	405	*	*	*
March	16,624	739	2,493	3,444	40	565	6,069	121	2,549
Total	40,117	3,069	14,352	5,945	297	1,321	7,364	293	2,902

* No discharge due to sand blockage

Table 2. Continued

Date	Lake Poinsett Outlet (Station 6)			Big Sioux River (Station 7)			Lake Albert Drainage (Station 8)		
	Dis-solved inor-ganic	Dis-solved ganic	Ses-tonic	Dis-solved inor-ganic	Dis-solved organic	Ses-tonic	Dis-solved inor-ganic	Dis-solved organic	Ses-tonic
April	316	121	119	7,306	713	3,924	142	34	49
May	294	135	90	3,046	312	2,374	251	36	68
June	860	59	336	3,048	176	1,659	678	109	269
July	733	70	166	1,481	70	1,128	658	132	155
Aug.	391	67	57	767	209	781	1,056	176	53
Sept.	209	45	44	84	60	475	266	36	64
Oct.	77	12	74	73	21	289	169	21	28
Nov.	42	6	100	712	119	466	157	56	21
Dec.	143	17	53	465	0	210	136	20	14
Jan.	88	11	30	140	51	57	165	2	9
Feb.	142	5	18	752	68	140	193	2	29
March	109	17	56	3,568	235	523	561	36	189
Total	3,404	566	1,144	21,442	2,053	2,026	4,432	658	947

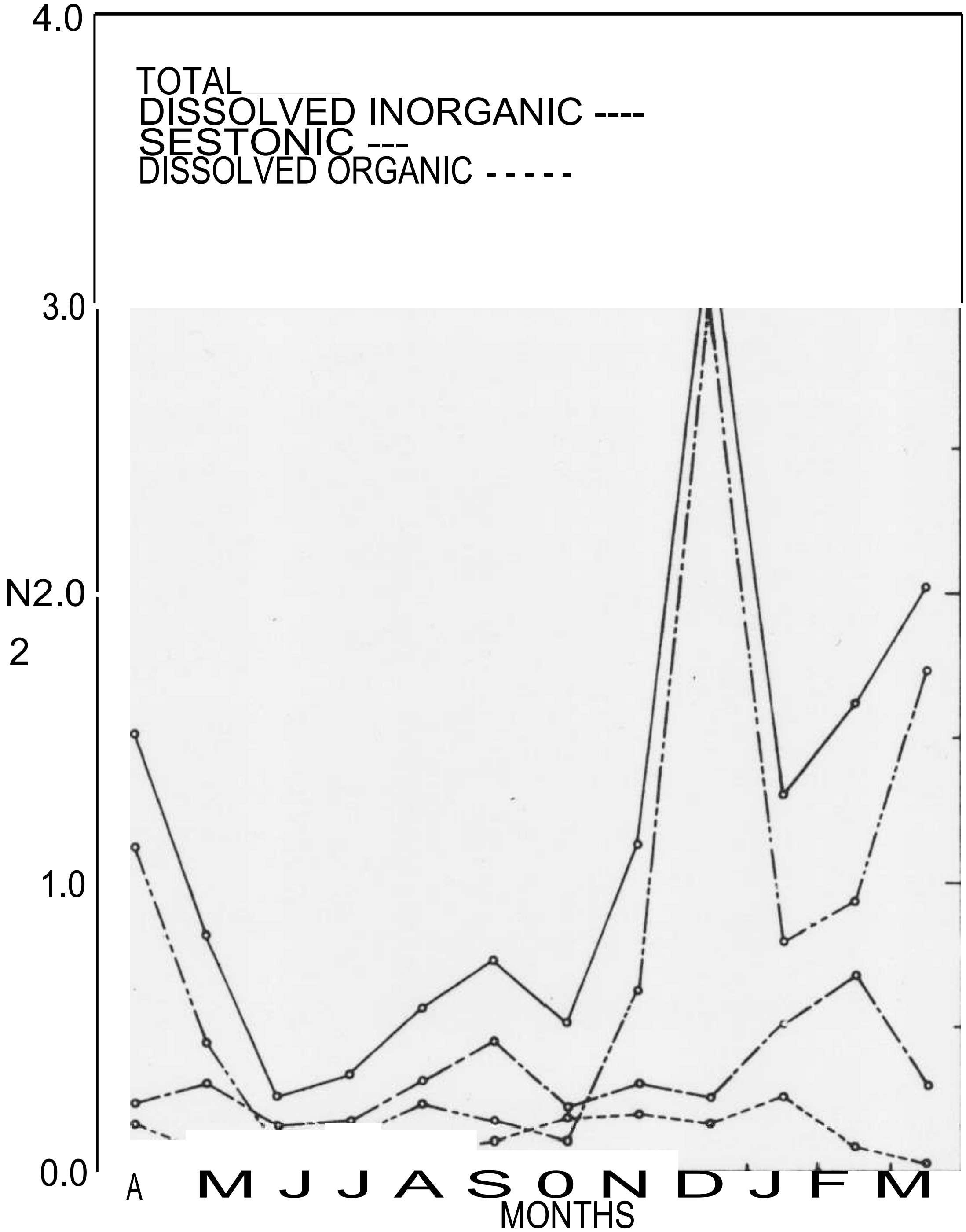

FIGURE 3. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS IN THE DIVERSION **CANAL (Station 2),** (APRIL 1970 — MARCH 1971).

Monthly mean dissolved organic phosphorus concentrations were lowest in June (0.03 mg/l (PO4)) and in March (0.02 mg/l (PO_4)). The highest concentration was 0.26 mg/l (PO_4) in January. The average annual concentration was 0.11 mg/l (PO4) (Figure 3).

The percentages of the three phosphorus fractions calculated from average annual concentrations were 64.5% dissolved inorganic, 26.4% sestonic, and 9.1% dissolved organic. The ratio of these fractions was 7.1 : 2.9 : 1, respectively.

The annual load of phosphorus entering Dry Lake through the diversion canal was 7.56×10^3 kg (PO4). This was comprised of 5.94×10^3 kg (PO4) dissolved inorganic, 1.32×10^3 kg (PO4) sestonic, and 2.97×10^2 kg (PO4) of dissolved organic phosphorus (Table 2).

Station 3 (Dry Lake)

Dissolved inorganic phosphorus concentrations in Dry Lake were low in the fall (less than 0.10 mg/l (PO_4)) and extremely high in the late winter (greater than 1.10 mg/l (PO4)). Concentrations decreased from 0.63 mg/l (PO4), the average concentration for April, to a low monthly average for the year of 0.11 mg/l (PO4) in October. The concentration increased rapidly through November, December, and January to the average concentration of 1.48 mg/l (PO4) in February (Figure 4). This tremendous increase during the fall and winter occurred at the same time the dissolved oxygen dropped sharply from 12.7 mg/l in September to 2.06 mg/l in February (Figure 4). According to Ried (1961) and Ruttner (1952) oxygen depletion accompanies lowering of the redox potential and thus allows inorganic phosphorus to be released from the bottom sediments

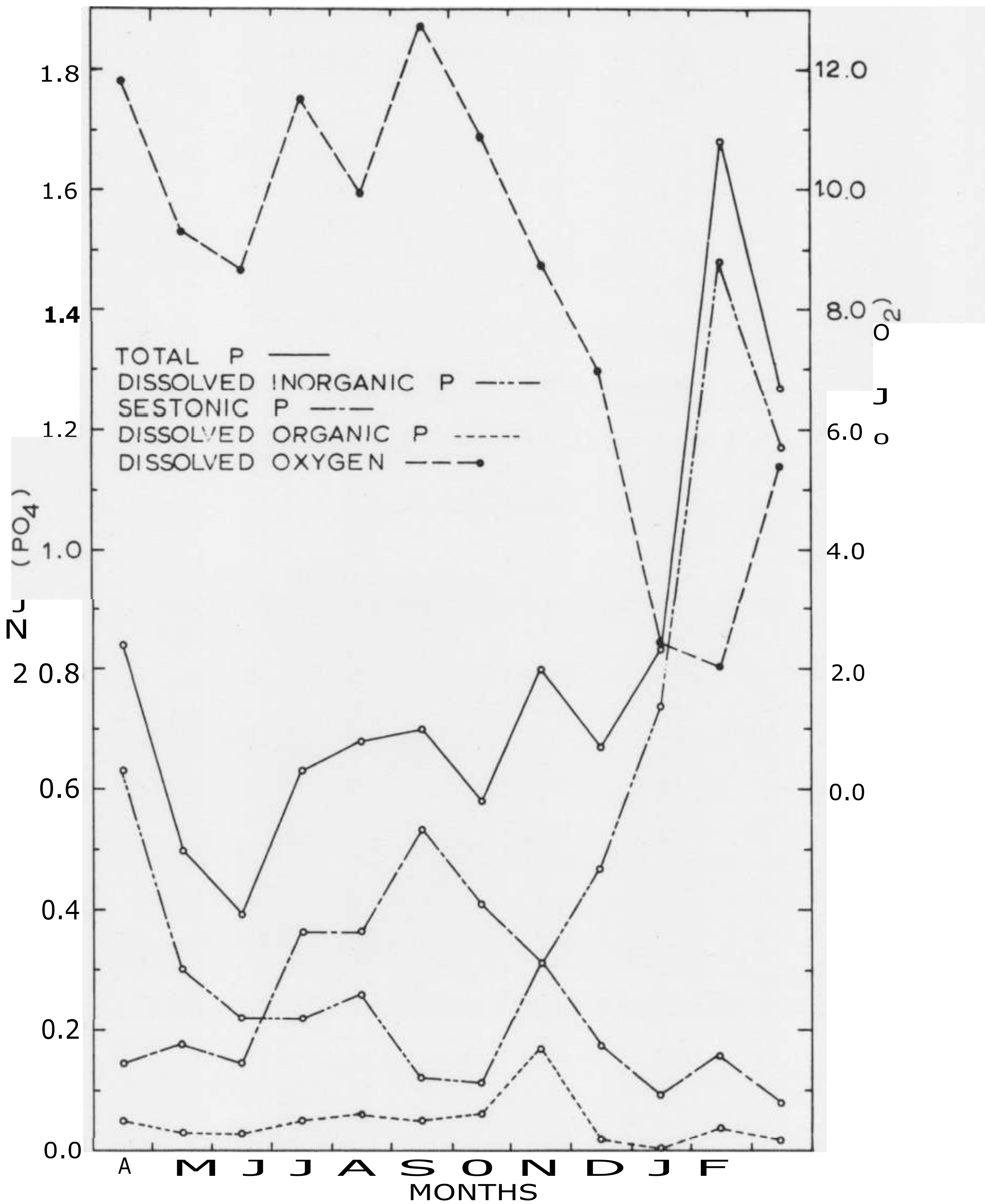

FIGURE 4. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS AND DISSOLVED OXYGEN IN DRY LAKE (Station 3), (APRIL 1970—MARCH 1971).

into the water. This phenomenon may apply to the winter increase in soluble inorganic phosphorus in Dry Lake. The average annual concentration of dissolved inorganic phosphorus was 0.50 mg/l (PO4) in Dry Lake.

Sestonic phosphorus concentrations appeared to be inversely related to dissolved inorganic phosphorus and directly related to particulate organic carbon. Sestonic phosphorus averaged 0.16 mg/l (PO4) in April and increased to 0.53 mg/l (PO_4) in September. When sestonic phosphorus was high the dissolved inorganic fraction was low (Figure 4). The sestonic phosphorus concentration decreased steadily from an average of 0.53 mg/l (PO_4) in September to 0.09 mg/l (PO_4) in January. The lowest monthly average concentration was 0.08 mg/l (PO4) in March (Figure 4).

The monthly average concentration of dissolved organic phosphorus remained below 0.06 mg/l (PO_4) from April through October. In November when sestonic phosphorus was rapidly decreasing dissolved organic phosphorus increased to 0.17 mg/l (PO4) which was the highest monthly mean concentration for the year. Dissolved organic phosphorus concentrations declined in December and January to the low monthly mean concentration for the year of 0.007 mg/l (PO_4) in January. The average annual concentration was 0.05 mg/l (PO_4) (Figure 4).

The percentages of the three phosphorus fractions calculated from average annual concentrations were 62.5% dissolved inorganic, 31.2% sestonic, and 6.3% dissolved organic. The ratio of these three fractions was 10 : 5 : 1, respectively.

Station 4 (Stone Bridge Channel)

The average concentration of total phosphorus in the channel between Dry Lake and Lake Poinsett during the time of flow (March 23-May 9) was 0.94 mg/l (PO4). Total phosphorus was composed of 0.63 mg/l (PO4) dissolved inorganic, 0.26 mg/l (PO4) sestonic, and 0.05 mg/l (PO4) dissolved organic phosphorus.

Phosphorus discharge from Dry Lake to Lake Poinsett via the Stone Bridge channel (station 4) during the year was 1.05×10^4 kg (PO_4). The composition of the phosphorus discharge was 7.36×10^3 kg (PO_4) dissolved inorganic, 2.90×10^3 kg (PO_4) sestonic, and 2.93×10^2 kg (PO_4) dissolved organic phosphorus (Table 2).

The phosphorus discharge from Dry Lake was 139.6% of the inflow into Dry Lake via the diversion canal. The 3.00×10^3 kg (PO_4) difference in outflowing phosphorus and inflowing phosphorus is attributable to phosphorus from surface drainage and sediment of Dry Lake. The sestonic phosphorus fraction showed the greatest variation in outflow as compared to inflow. The sestonic phosphorus discharge into Dry Lake was 1.32×10^3 kg (PO_4) as compared to 2.90×10^3 kg (PO_4) discharge from Dry Lake. This difference between inflowing and outflowing sestonic phosphorus indicates that the high velocity discharge from Dry Lake into Lake Poinsett transports a sediment load rich in sestonic phosphorus.

Station 8 (Lake Albert Drainage)

Total phosphorus concentrations in water entering Lake Poinsett from the Lake Albert drainage averaged 0.62 mg/l (PO_4) for the year. This concentration was about one-half that entering the Dry Lake-Lake

Poinsett system from the river.

Concentrations of dissolved inorganic phosphorus were low in the spring and fall and high in late summer to extremely high in winter. The lowest monthly mean concentration of dissolved inorganic phosphorus was 0.21 mg/l (PO_4) in April. This fraction increased to a summer peak of 0.48 mg/l (PO_4) in August. The concentration decreased in the fall to 0.31 mg/l (PO_4) in November and then increased greatly over the winter to the high for the year of 1.14 mg/l (PO4) in February. The average annual concentration was 0.49 mg/l (PO4) at station 8 (Figure 5).

Sestonic and dissolved organic phosphorus concentrations remained relatively stable during the year except for a rise in sestonic and a decline in dissolved organic during February and March (Figure 5). The average annual concentration was 0.09 mg/l (PO4) sestonic and 0.05 mg/l (PO4) dissolved organic phosphorus.

Water flowing from Lake Albert carried 6.04×10^3 kg (PO4) of phosphorus into Lake Poinsett during the year. This was comprised of 4.43×10^3 kg (PO_4) dissolved inorganic, 947 kg (PO_4) sestonic, and 658 kg (PO_4) dissolved organic phosphorus (Table 2).

The percentages of the three phosphorus fractions calculated from average annual concentrations were 79.0% dissolved inorganic, 14.5% sestonic, and 6.5% dissolved organic. The ratio of these three fractions was 9.8 : 1.8 : 1, respectively.

Station 6 (Lake Poinsett Outlet)

Phosphorus concentrations flowing out of Lake Poinsett and those flowing into the lake from Lake Albert were similar (Figures 5 and 6).

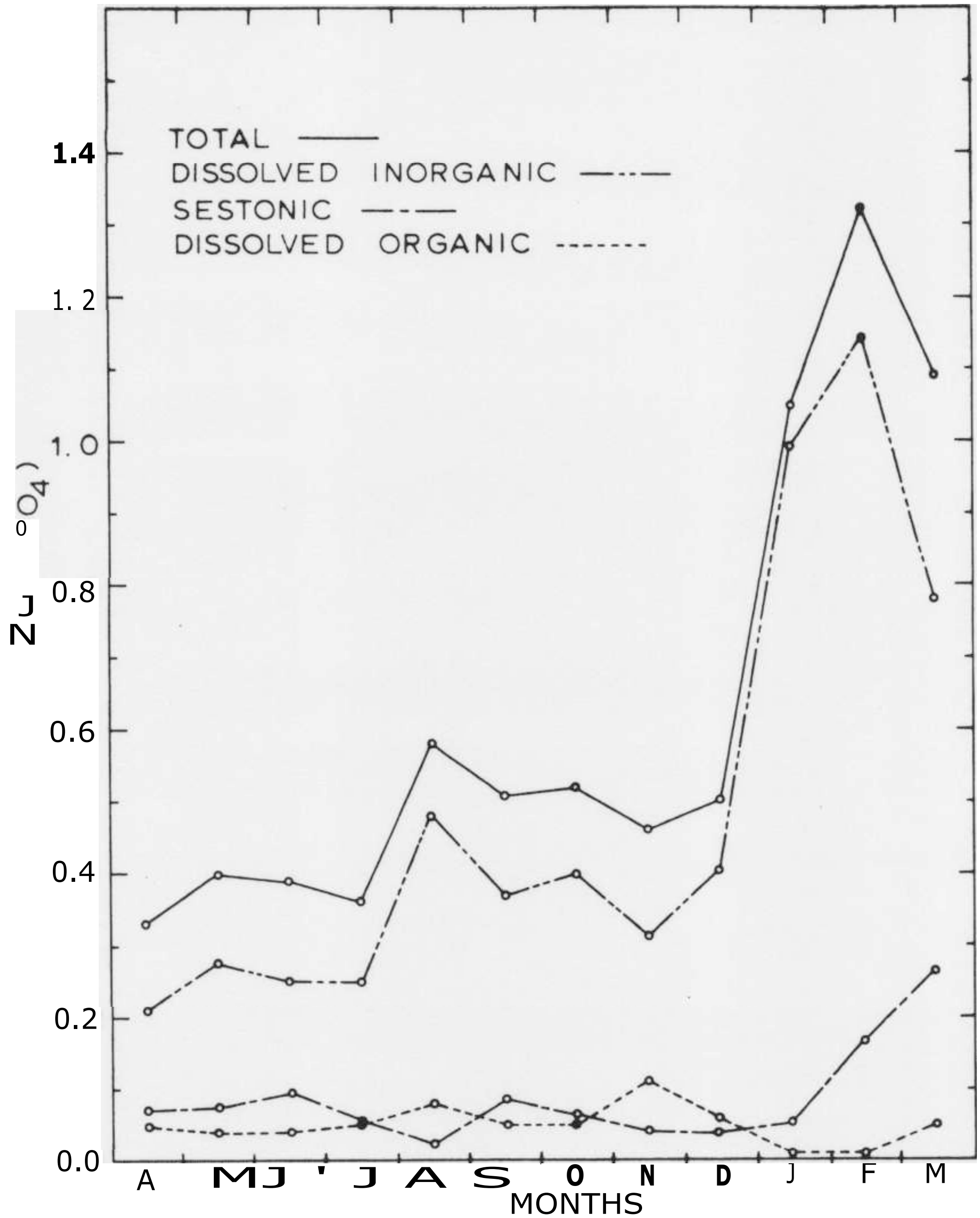

FIGURE 5. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS IN THE LAKE ALBERT DRAINAGE (Station 8), (APRIL 1970 – MARCH 1971).

The average annual concentration of total phosphorus at station 6 was 0.60 mg/l (PO_4).

Dissolved inorganic concentrations were low in the spring and fall and high in early summer and extremely high in late winter. The summer high monthly mean concentration was 0.44 mg/l (PO4) in June which decreased during the summer to a low for the year of 0.07 mg/l (PO4) in November. The concentration increased from November through the winter to the high for the year of 1.57 mg/l (PO_4) in February (Figure 6).

Sestonic phosphorus concentrations were more erratic with highs in June, November, and January. The average annual concentration of sestonic phosphorus at station 6 was 0.13 mg/l (PO_4) and ranged from a monthly mean concentration of 0.04 mg/l (PO_4) in May to 0.31 mg/l (PO_4) in January (Figure 6).

Dissolved organic phosphorus was also in highest concentration in January with a monthly mean concentration of 0.11 mg/l (PO4). The low was in November at 0.01 mg/l (PO_4) and the average annual concentration was 0.05 mg/l (PO_4) (Figure 6).

The Lake Poinsett outlet transported 5.11 x 10^3 kg (PO4) of phosphorus to the Big Sioux River between April 1, 1970 and April 1, 1971. This was comprised of 3.40 x 103 kg (PO_4) dissolved inorganic, 1.14 x 10^3 kg (PO_4) sestonic, and 566 kg (PO_4) dissolved organic phosphorus (Table 2).

The percentages of the three phosphorus fractions calculated from average annual concentrations were 70.0% dissolved inorganic, 21.7% sestonic, and 8.3% dissolved organic phosphorus. The ratio of these

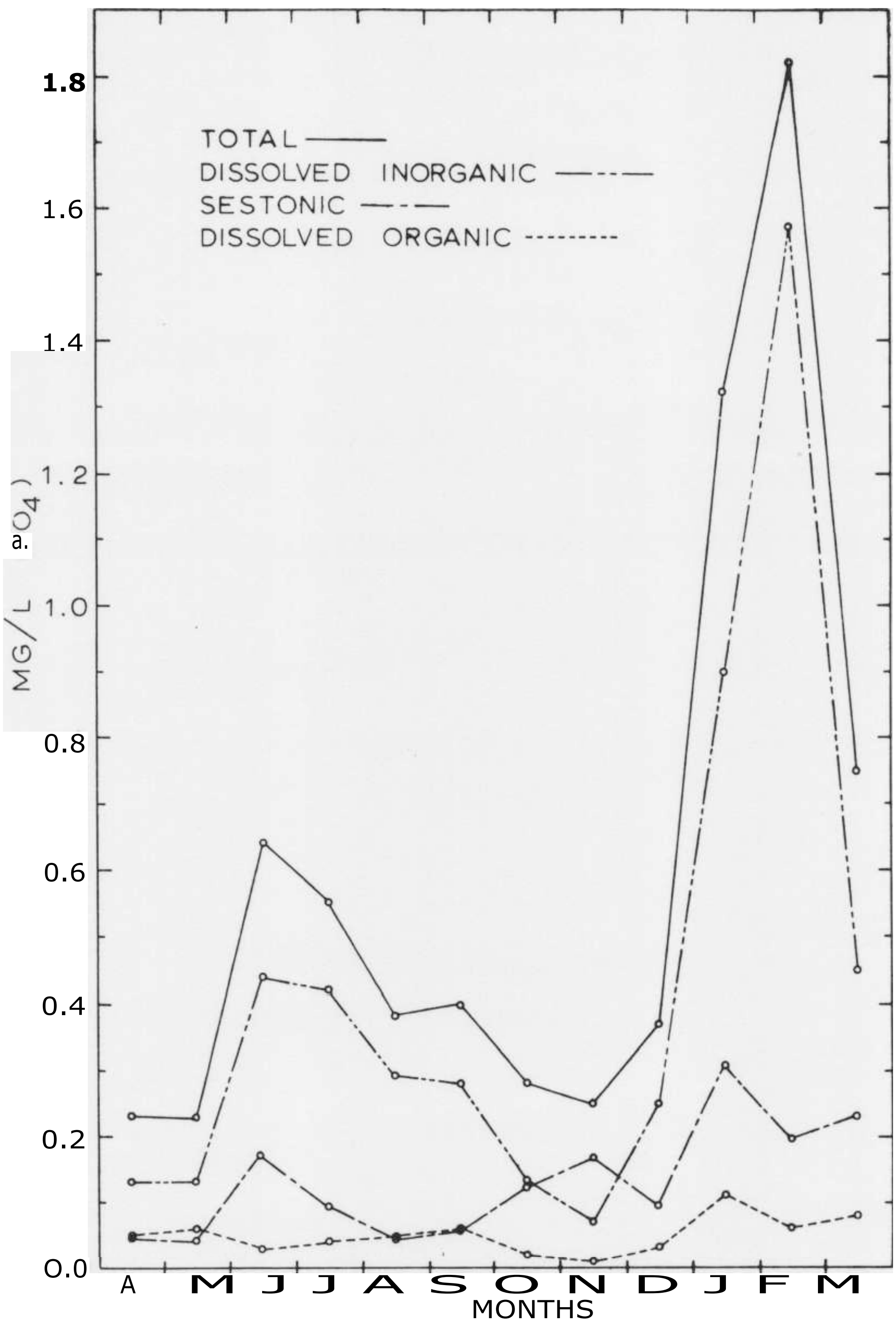

FIGURE 6. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS IN THE LAKE POINSETT OUTLET (Station 6), (APRIL 1970—MARCH 1971).

three fractions was 8.4 : 2.6 : 1, respectively.

Station 7 (Big Sioux River)

Water in the Big Sioux River below the Lake Poinsett outlet was a mixture of river water and outlet water and its nutrient concentrations reflected those of the river above the outlet and the discharge from Lake Poinsett.

The average annual concentration of dissolved inorganic phosphorus was 0.65 mg/l (PO_4) and ranged from a monthly mean concentration of 0.07 mg/l (PO4) in September and October to 1.97 mg/l (PO4) in March (Figure 7).

Sestonic phosphorus concentrations varied little throughout the year. They averaged 0.31 mg/l (PO4) and ranged from a monthly mean concentration of 0.27 mg/l (PO4) in October, November, and December to 0.39 mg/l (PO4) in September (Figure 7).

Dissolved organic phosphorus averaged 0.06 mg/l (PO_4) for the year with a monthly mean range from 0.00 mg/l (PO4) in December to 0.14 mg/l (PO4) in February (Figure 7).

The Big Sioux River at station 7 transported 2.55×10^4 kg (PO_4) of phosphorus from April 1, 1970 to April 1, 1971. This was comprised of 2.14×10^4 kg (PO_4) dissolved inorganic, 2.03×10^3 kg (PO4) sestonic, and 2.05×10^3 kg (PO4) dissolved organic phosphorus (Table 2).

The percentages of the three phosphorus fractions calculated from average annual concentrations were 63.7% dissolved inorganic, 30.4% sestonic, and 5.9% dissolved organic phosphorus. The ratio of these three fractions was 10.8 : 5.2 : 1, respectively.

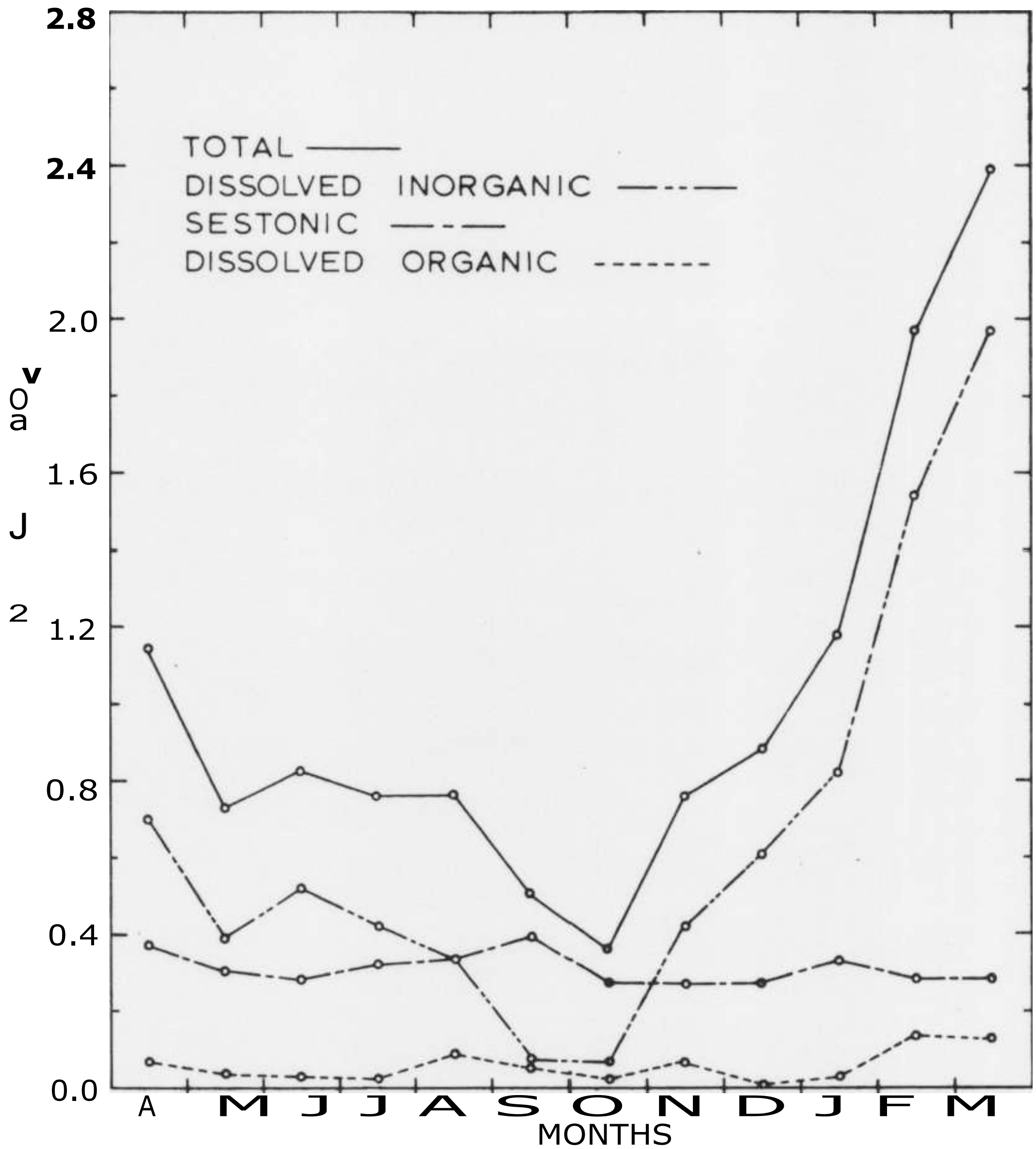

FIGURE 7. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS IN THE BIG SIOUX RIVER (Station 7), (APRIL 1970—MARCH 1971).

Station 5 (Lake Poinsett)

Total phosphorus concentrations in Lake Poinsett were high in the spring (April), in mid-summer (July), and in the fall (October). The extreme lows were in late summer (August and September) and during the winter (Figure 8). Monthly average concentrations of dissolved inorganic phosphorus were highest in the early spring. There was 0.20 mg/l (PO_4) in March and 0.18 mg/l (PO_4) in April. The concentration decreased through the summer months to 0.05 mg/l (PO_4) in September then increased to 0.10 mg/l (PO_4) in October and decreased to 0.05 mg/l (PO_4) in November. Dissolved inorganic phosphorus increased during the winter to the March high of 0.20 mg/l (PO_4) (Figure 8). Tressler and Domogalla (1931) observed this fraction to be low in summer and high in winter in Lake Wingra, Wisconsin. This trend was apparent in both Dry Lake and Lake Poinsett. The average annual dissolved inorganic phosphorus in Lake Poinsett was 0.11 mg/l (PO4).

Sestonic phosphorus concentrations were low in the winter with monthly average concentrations less than 0.09 mg/l (PO_4) from November through May. The high monthly mean concentration for the year was 0.25 mg/l (PO_4) in July (Figure 8). High summer and low winter sestonic phosphorus concentrations were apparent in both Dry Lake and Poinsett (Figures 4 and 8). This trend was also observed by Tressler and Domogalla (1931) in Lake Wingra, Wisconsin. The average annual sestonic phosphorus concentration was 0.08 mg/l (PO_4) in Lake Poinsett.

Dissolved organic phosphorus concentrations were stable throughout the year in Lake Poinsett. The annual average was 0.03 mg/l (PO_4). The

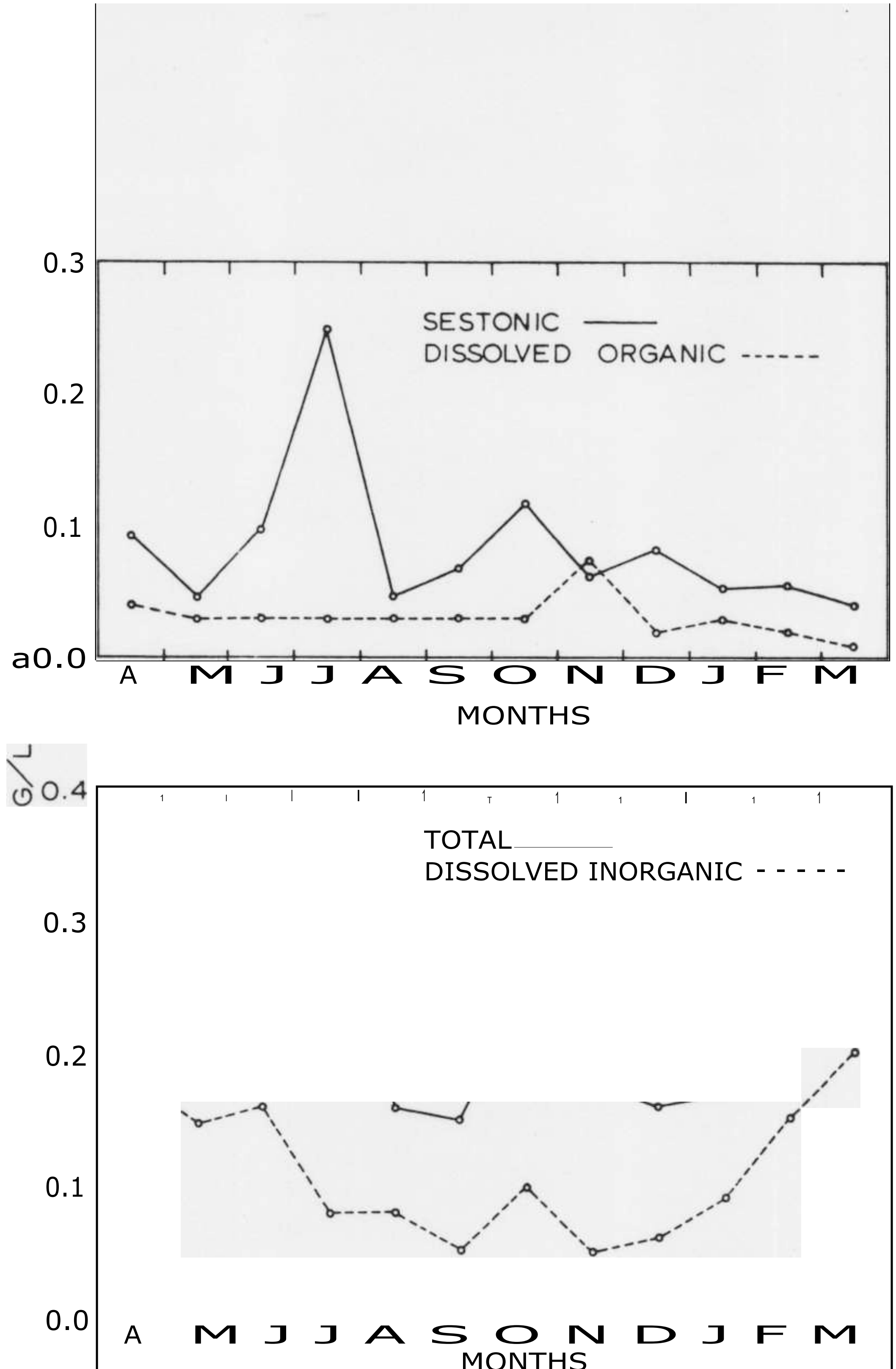

FIGURE B. WEIGHTED MONTHLY MEAN PHOSPHORUS FRACTIONS IN LAKE POINSETT (Station 5), (APRIL 1970 MARCH 1971).

monthly mean concentration ranged from 0.01 mg/l (PO4) in March to 0.07 mg/l (PO4) in November (Figure 8).

Total phosphorus averaged 0.22 mg/l (PO4) during the year in Lake Poinsett. The percentages of the three fractions calculated from average annual concentrations were 50.0% dissolved inorganic, 36.4% sestonic, and 13.6% dissolved organic phosphorus, Hutchinson (1957) estimates the surface waters of relatively uncontaminated lakes to have 0.031-0.092 mg/l (PO4) phosphorus. He estimates the soluble inorganic phosphorus to make up about 10% of the total and the sestonic and dissolved organic fractions to be highly variable.

In work on Ontario Lakes, Bigler (1964), concluded that when the same method is applied to waters from a diversity of lakes the percent of total phosphorus appearing as soluble organic is "remarkably constant". Of nine lakes in his study, eight had soluble organic phosphorus making up 25-32% of the total phosphorus. The one exception in his study was Grenadier Lake which was "grossly eutrophic" due to urban drainage. It had 12.5% soluble organic phosphorus. The soluble organic fraction in Lake Poinsett averaged 13.5% of the total. However, the soluble inorganic phosphorus was 0.006 mg/l (P) (4.8%) in Grenadier Lake compared to 0.036 mg/l (P) (50.0%) in Lake Poinsett (Table 3). Both Grenadier Lake and Lake Poinsett are highly eutrophic with approximately equal percentages of soluble organic phosphorus but the inorganic phosphorus level in Lake Poinsett far exceeds that of Grenadier Lake.

One would suspect that the extremely high levels of inorganic phosphorus are responsible in part for the large blooms of blue-green algae

Table 3. The percentage of the total phosphorus of epilimnetic water found in each of three fractions by different workers

Lakes	(mg/1) Total P	Percent of total phosphorus in each form: Inorganic	Soluble organic	sestonic
Grendadier Lake, Ontario (Rigler, 1964)	.133	4.8	12.5	82.7
Eight Ontario Lakes (Rigler, 1964)	.019	5.9	28.7	65.4
Linsley Pond, Connecticut (Hutchinson, 1957)	.021	9.5	28.6	61.9
Five Michigan Lakes (Tucker, 1957)	.0119	10.9	49.6	39.5
479 N. Wisconsin Lakes (Juday and Birge, 1931)	.023	13.0	60.9	26.1
Lake Poinsett, South Dakota	.073	50.0	13.6	36.4
Dry Lake, South Dakota	.264	62.5	6.3	31.2

witnessed in Lake Poinsett each summer. The major genera are *Aphamizomenon*, *Anacystis*, and *Anabaena*. Sawyer (1966) theorized that 0.015 mg/l (P) or greater inorganic phosphorus would result in nuisance algal blooms. With an inorganic phosphorus level averaging 0.11 mg/l (PO4) (0.036 mg/l (P)) Lake Poinsett has a phosphorus level far in excess of limiting levels for algal blooms in this region.

Lake Poinsett has extremely high phosphorus concentrations, especially the soluble inorganic fraction, because of the large quantities flowing into the lake. There was an annual discharge of 1.05×10^4 kg (PO_4) total phosphorus of which 7.36×10^3 kg (PO_4) was dissolved inorganic that entered Lake Poinsett from Dry Lake during the year (Table 2). Another 6.04×10^3 kg (PO_4), of which 4.43×10^3 kg (PO_4) was dissolved inorganic, entered from Lake Albert (Table 2). The total annual inflow from both sources was 1.66×10^4 kg (PO_4) total phosphorus and 1.18×10^4 (PO4) (71.1%) soluble inorganic phosphorus.

There was a total annual outflow of 5.11×10^3 kg (PO4) total phosphorus from Lake Poinsett into the Big Sioux River. The soluble inorganic phosphorus outflow was 3.40×10^3 kg (PO4) or 66.6% of the total phosphorus outflow (Table 2). There was a net annual gain of 1.15×10^4 kg (PO4) total phosphorus in Lake Poinsett. The soluble inorganic phosphorus fraction was 8.39×10^3 kg (PO4) or 73.1% of this total. If all of the soluble inorganic phosphorus had remained in solution the concentration in Lake Poinsett would have been increased by approximately 0.86 mg/l (PO_4). Since the actual concentration of soluble inorganic phosphorus averaged 0.11 mg/l (PO4) a large amount of inorganic phosphorus must have been incorporated in bottom sediments and biomass.

The quantity of phosphorus added to Lake Poinsett from local runoff was not intensively studied. However, the total phosphorus concentration in a small runoff stream entering Lake Poinsett west of the Stone Bridge (stream labeled B, figure 1) was 2.52 mg/l (PO_4) on March 15, 1971. Another stream entering the lake southwest of Grape's Point (labeled A, figure 1) contained 5.79 mg/l (PO_4) total phosphorus on February 26, 1971. These high phosphorus concentrations indicate that drainage from the local area may have also added substantially to the total phosphorus loads in Dry Lake and Lake Poinsett.

Nitrate Nitrogen Concentrations and Loads

Station 1 (Big Sioux River)

Nitrate nitrogen concentrations in the Big Sioux River at station 1 remained below 2.0 mg/l from Janaury through October. The monthly mean concentrations increased in the early part of the winter from 0.56 mg/l in October to 5.00 mg/l in November and to the high for the year of 7.75 mg/l in December. The concentration decreased to 1.77 mg/l in January. The monthly mean concentrations of nitrate in the upper Big Sioux River ranged from 0.49 mg/l in September to 7.75 mg/l in December. The average annual concentration was 1.93 mg/l (Figure 9).

The early winter increase in nitrate appears to correlate with the increased discharge at this time of year. This discharge increase was apparently due to a rain of 3.3 cm on November 8, 1970 (U. S. Weather Bureau Station at Castlewood, South Dakota). The ground was frozen at this time and runoff was very great. This suggests that the increased runoff carried with it the high nitrate concentrations.

The nitrate nitrogen to total phosphorus (measured as PO_4) ratio calculated from average annual concentrations was 1 : 1.

Monthly loads of nitrate ranged from 122 kg in January to 1.11 x 10^4 kg in March. The total annual load transported by the river at station 1 was 4.57 x 10^4 kg (Table 4).

Station 2 (Diversion Canal)

Nitrate concentrations in the diversion canal generally showed the same fluctuations as concentrations in the Big Sioux River (station 1). Monthly mean concentrations ranged from 0.31 mg/i in August to 7/91 mg/l in December. The average annual concentration was 2.08 mg/l (Figure 9).

The nitrate to phosphorus ratio calculated from average annual concentrations was 1.7 : 1. This is much higher than the 1 : 1 ratio in the river and is probably due to the influence of ground water during the summer months when the dam blocked most of the river water from entering the diversion canal. Ground water in the area averages 23.3 mg/l nitrogen (Barari, 1971).

The monthly mean nitrate loads ranged from 3.8 kg in August to 3.38 x 10^3 kg in December. This is an example of concentration having more influence than discharge on nutrient load carried. Although the discharge was approximately five times greater in March (1.99 x 10^6 m^3) than in December (4.27 x 10^5 m^3) the concentration of nitrate was nearly six times greater in December (Figure 9, Table 4).

The annual nitrate load transported into Dry Lake via the diversion canal was 9.97 x 10^3 kg. There was 117.6 kg (1.2% of total) nitrate

Table 4. Nitrate loads transported through the Lake P'Ansett system, April 1970-March 1971 (Kg NO3)

Date	Big Sioux River (Station 1)	Diversion Canal (Station 2)	Stone Bridge Channel (Station 4)	Lake Poinsett Outlet (Station 6)	Big Sioux River (Station 7)	**Lake Albert Drainage (Station** 8)
April	8,466	530	2,019	923	15,969	656
May	4,799	50	107	1,378	6,561	456
June	3,583	26	*	1,916	6,917	1,438
July	1,546	15	*	751	2,257	1,342
Aug.	555	4	*	904	1,557	946
Sept.	185	7	*	687	950	668
Oct.	324	6	*	548	745	365
Nov.	7,878	725	*	616	3,931	369
Dec.	5,363	3,383	*	608	1,495	204
Jan.	122	299	*	33	73	58
Feb.	1,748	2,095	*	43	943	68
March	11,082	2,827	3,641	159	2,264	432
Total	45,653	9,966	5,768	8,567	43,661	7,002

*No discharge due to sand blockage

transported to Dry Lake while the canal gates were closed from May 1 to November 19, 1970.

Station 3 (Dry Lake)

No general trend in nitrate concentration was obvious in Dry Lake during the year. Monthly mean concentrations ranged from 0.43 mg/l in May to 1.35 mg/l in February. The average annual concentration was 0.76 mg/l (Figure 10).

The nitrate to total phosphorus (PO4) ratio was .95 : 1 calculated from average annual concentrations. This ratio was much lower than the 1.7 : 1 ratio in the water entering Dry Lake through the diversion canal and slightly higher than the .72 : 1 ratio in the water leaving Dry Lake. The average annual nitrate concentration decreased from 2.08 mg/l entering the lake to 0.76 mg/l within the lake to 0.60 mg/l leaving the lake. Studies by Mortimer (1939) in the English Lake District indicate that this is due to high productivity. He noted that low production lakes have influents containing equal or greater mean concentrations of nitrate than effluents but in more productive lakes the effluents are definitely lower in nitrate concentration. He reasoned that in more productive lakes denitrification tends to take place more rapidly than do processes of fixation. The annual nitrate load entering Dry Lake was 9.97×10^3 kg compared to 5.77×10^3 kg leaving via Stone Bridge channel (station 4) (Table 4).

Station 8 (Lake Albert Drainage)

The nitrate nitrogen concentrations in water flowing from Lake

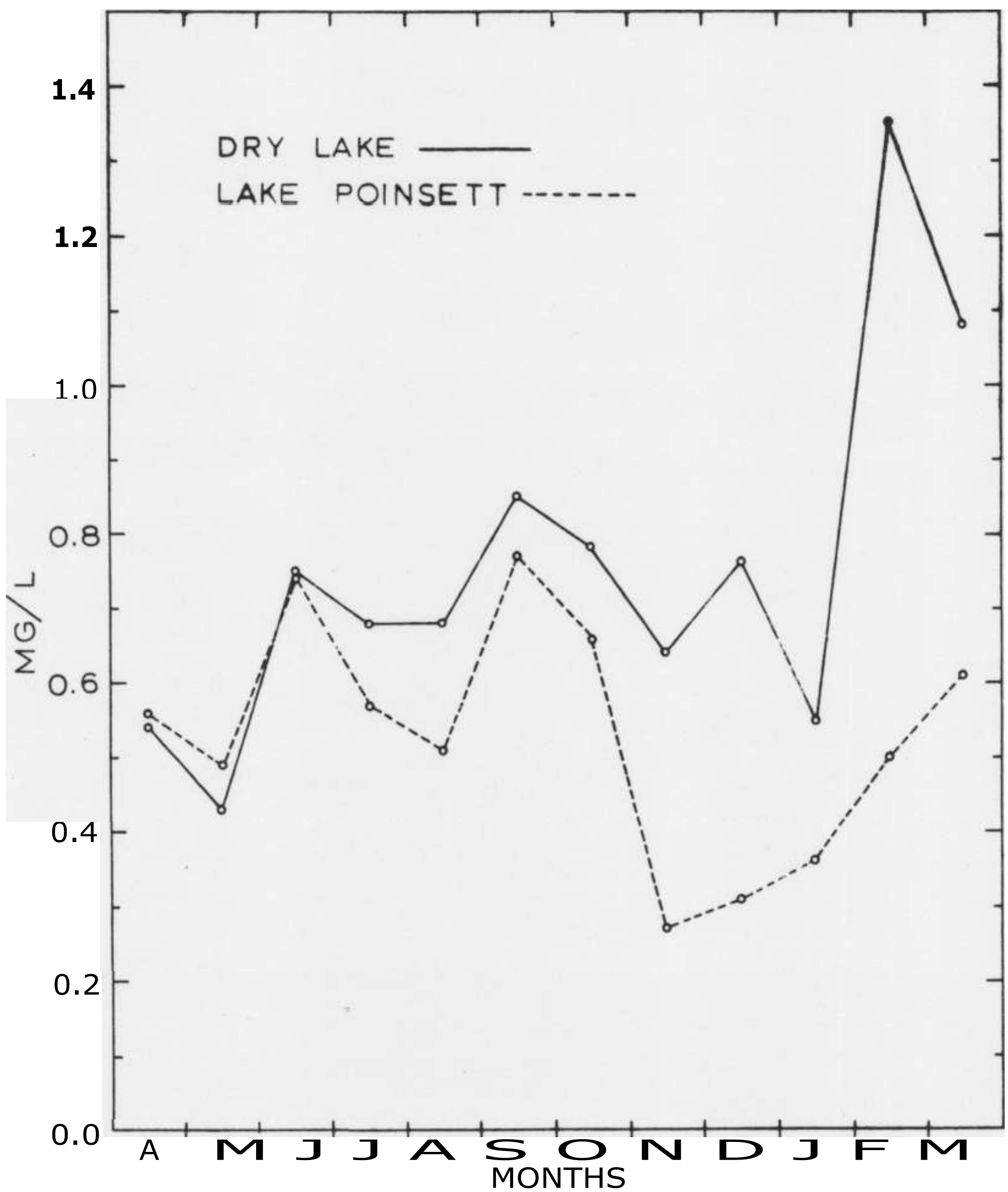

FIGURE 10. WEIGHTED MONTHLY MEAN NITRATE NITROGEN CONCENTRATIONS IN DRY LAKE (Station 3) AND LAKE POINSETT (Station 5), (APRIL 1970—MARCH 1971).

Albert, to Lake Poinsett were highest in the spring and early fall and lowest in the summer. Nitrate nitrogen concentrations averaged 0.97 mg/l in April and 0.93 mg/l in September. Nitrate nitrogen concentrations averaged 0.49 mg/l from May through August. Concentrations decreased through the winter months to 0.35 mg/l in January which was the lowest during the year (Figure 11). The average annual concentration was 0.62 mg/l.

The nitrate to total phosphorus (PO_4) ratio calculated from average annual concentrations was 1 : 1. This is the same ratio as that in the Big Sioux River at station 1.

Nitrate nitrogen discharge to Lake Poinsett from the Lake Albert drainage during the year was 7.00×10^3 kg. The monthly load ranged from 58 kg in January to 1.44×10^3 kg in June (Table 4).

Station 6 (Lake Poinsett Outlet)

Mean monthly nitrate nitrogen concentrations in the Lake Poinsett outlet were highly variable and showed no definite seasonal trends. They ranged from 0.34 mg/l in January to 1.06 mg/l in December. The average annual concentration was 0.71 mg/l. This average is higher than the 0.52 mg/l in Lake Poinsett and indicates that ground water high in nitrate nitrogen was entering the outlet. This would also explain the irregular fluctuations in concentration in the outlet that do not correspond to nitrate fluctuations in Lake Poinsett (Figure 10 and 11).

The nitrate nitrogen to total phosphorus ratio was 1.2 : 1 in the Lake Poinsett outlet.

The annual load of nitrate nitrogen entering the Big Sioux River

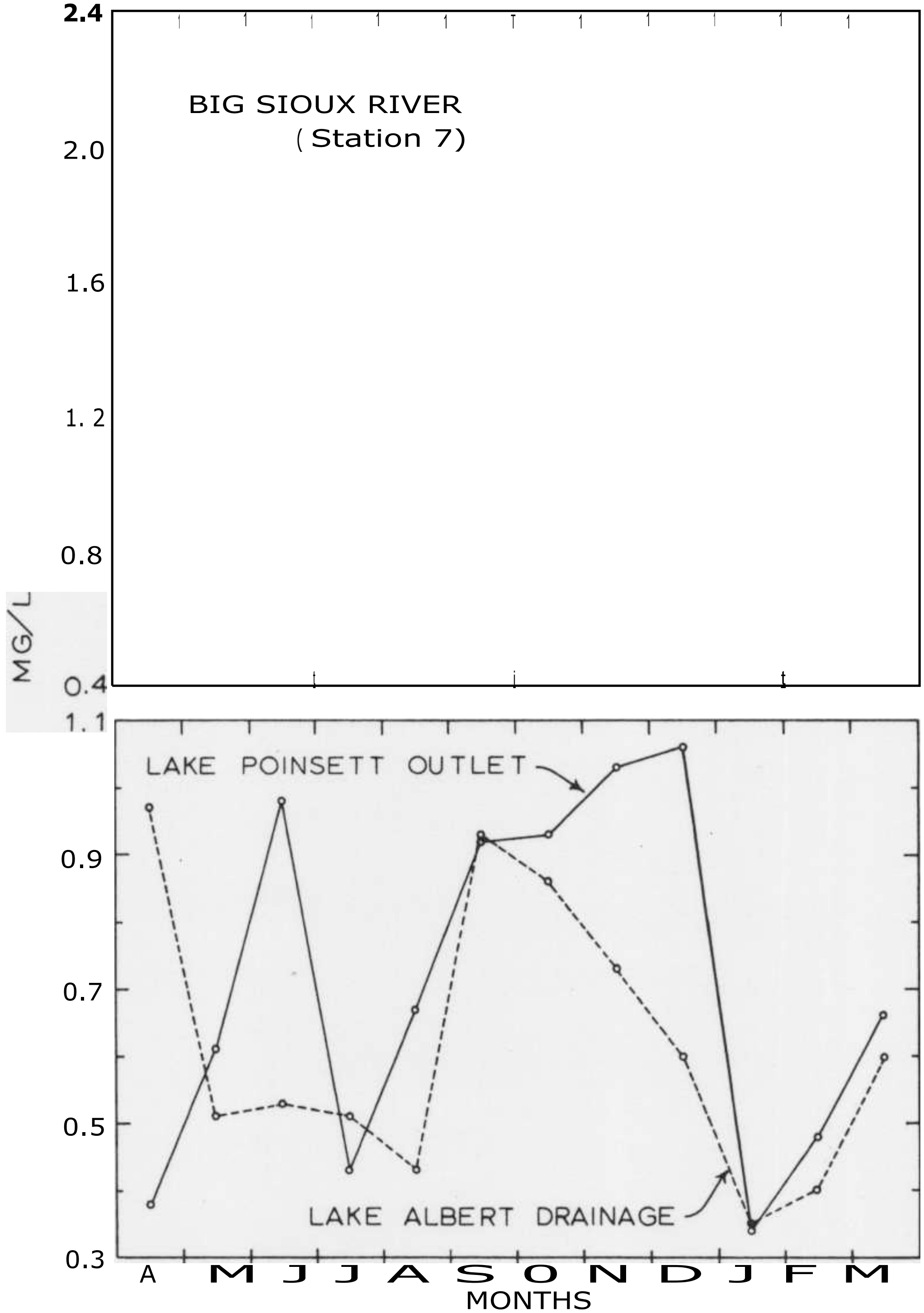

FIGURE 11. WEIGHTED MONTHLY MEAN NITRATE NITROGEN CONCENTRATIONS IN THE BIG SIOUX RIVER (Station 7), THE LAKE POINSETT OUTLET (Station 6), AND THE LAKE ALBERT DRAINAGE (Station 8), (APRIL 1970—MARCH 1971).

from the outlet was 8.57 x 10^3 kg (Table 4).

Station 7 (Big Sioux River Below Outlet)

The average annual nitrate nitrogen concentration was 1.19 mg/l at station 7 on the Big Sioux River (Figure 11). Fluctuation in concentration at station 7 is affected by concentrations of nitrate nitrogen at station 1 and 6.

The nitrate to total phosphorus (PO4) ratio calculated from average annual concentrations was 1.2 : 1.

The annual load of nitrate nitrogen transported by the Big Sioux River at station 7 was 4.37 x 10^4 kg.

Station 5 (Lake Poinsett)

Nitrate nitrogen concentrations in lakes have been reported to be high in the winter and low in the summer (Tressler and Domogalla, 1931; Hutchinson, 1957). Lake Poinsett's nitrate nitrogen concentrations do not follow this trend. The lowest monthly mean concentrations were 0.27 mg/l in November, 0.31 mg/l in December, and 0.36 mg/l in January. The highest concentrations were 0.77 mg/l in September and 0.74 mg/l in June (Figure 10).

The large amount of ground water passing through Lake Poinsett and its high nitrogen concentrations (23.3 mg/l average) indicated by Barari (1971) would have a tremendous influence on the concentration and fluctuation of nitrate nitrogen in Lake Poinsett. The concentrations and seasonal fluctuations would not compare to those of lakes not so affected by ground water.

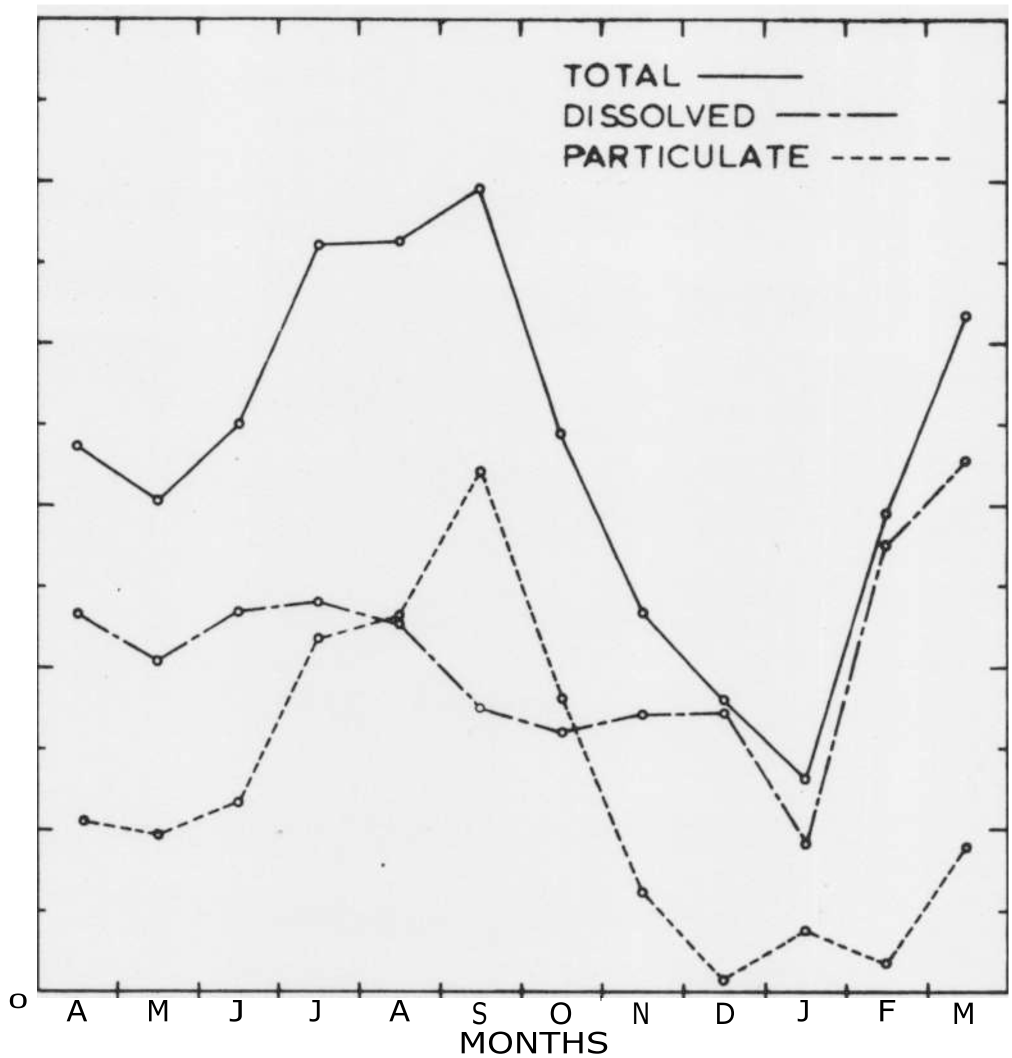

FIGURE 12. WEIGHTED MONTHLY MEAN ORGANIC CAR— BON FRACTIONS IN THE BIG SIOUX RIVER (Station 1), (APRIL 1970 — MARCH 1971).

relationship to the fluctuations of the particulate fraction. Dissolved organic carbon concentrations were low in the winter and high in the spring. This fraction averaged 3.77 mg/l in January and 13.13 mg/l in March. The average annual concentration was 8.40 mg/l (Figure 12).

The ratio of dissolved to particulate organic carbon in the upper Big Sioux River was 1.7 : 1. This was the lowest ratio of any station in the study (Figure 13).

The annual load of organic carbon transported by the Big Sioux River was 4.78×10^5 kg. This was comprised of 3.35×10^5 kg dissolved and 1.43×10^5 kg particulate organic carbon (Table 5).

Station 2 (Diversion Canal)

Organic carbon concentrations in the diversion canal were nearly equal to those in the Big Sioux River (station 1) when the diversion canal gates were open from November 19, 1970 through May 1, 1971. When the gates were closed and the canal water was a mixture of river water and ground water both dissolved and particulate organic carbon concentrations decreased. Consequently, summer concentrations of both fractions were low and late winter and spring concentrations were high (Figure 14).

The average annual concentration of organic carbon in the diversion canal was 8.19 mg/l. The average annual concentration consisted of 24.4% particulate and 75.6% dissolved organic carbon with a ratio of 1 : 3.1. Due to the diluting influence of ground water in the canal the organic carbon concentration was the lowest throughout the system (Figure 13).

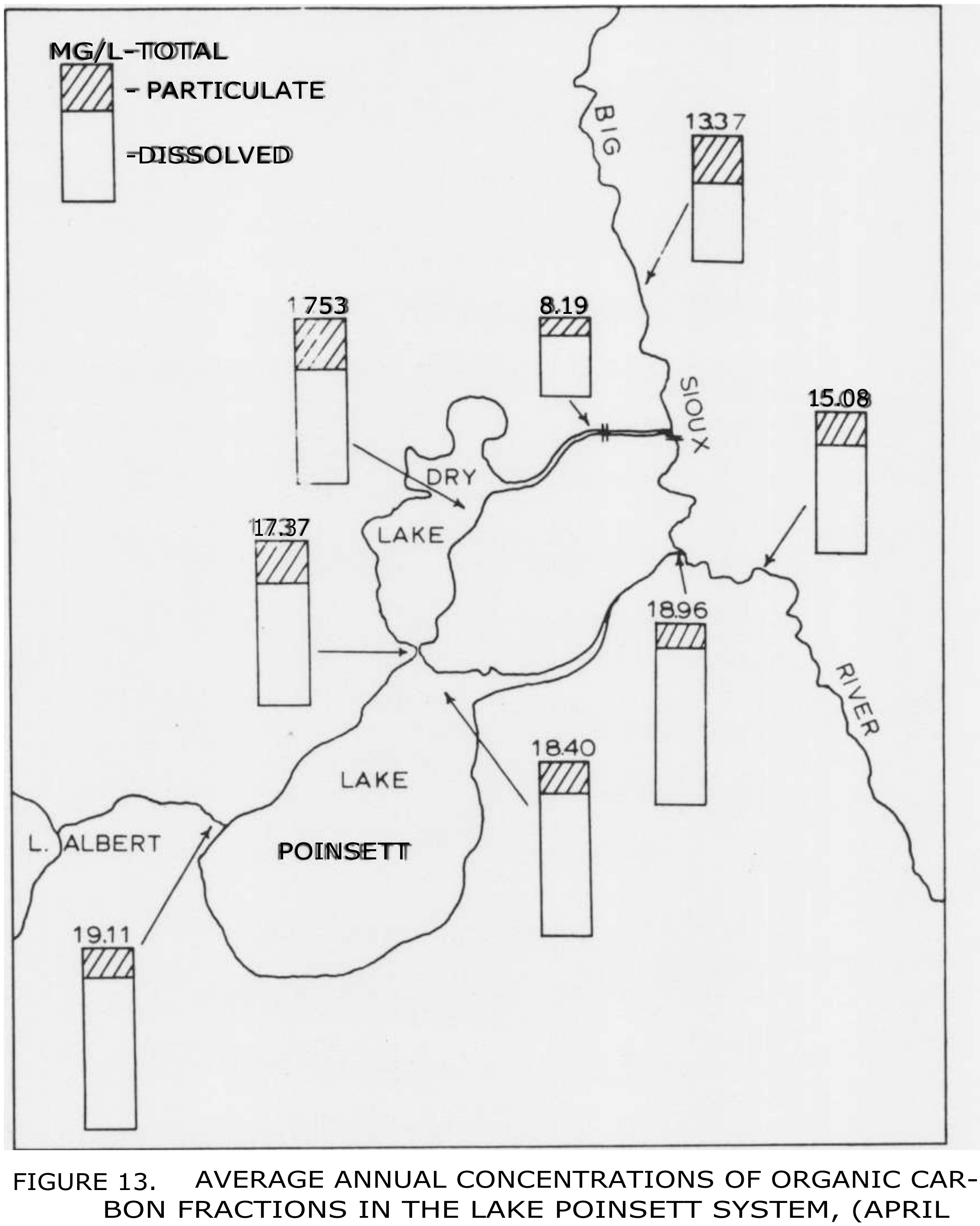

FIGURE 13. AVERAGE ANNUAL CONCENTRATIONS OF ORGANIC CARBON FRACTIONS IN THE LAKE POINSETT SYSTEM, (APRIL 1970-MARCH 1971).

Tables. Organic carbon loads transported through the Lake Poinsett system, **April** 1970-March 1971 (Kg C)

Date	Big Sioux River (Station 1) Dis-solved	Partic-ulate	Diversion Canal (Station 2) Dis-solved	Partic-ulate	Stone Bridge Channel (Station 4) Dis-solved	Partic-ulate
April	75,544	34,272	3,158	1,147	27,921	8,703
May	48,649	23,635	463	165	2,069	718
June	31,942	15,937	205	56	*	*
July	16,598	15,017	103	54	*	*
Aug.	7,608	7,757	47	4		*
Sept.	2,649	4,844	63	25	*	*
Oct.	3,716	4,249	47	28	*	*
Nov.	10,808	3,813	1,689	508	*	*
Dec.	4,803	187	2,583	590	*	*
Jan.	767	48	180	71	*	*
Feb.	10,267	638	5,665	1,934	*	*
March	121,260	32,970	22,358	5,236	98,262	30,589
Total	334,611	143,366	36,563	9,819	128,251	40,011

* No discharge due to sand blockage

Table 5. Continued

Date	Lake Poinsett Outlet (Station 6)		Big Sioux River (Station 7)		Lake Albert Drainage (Station 8)	
	Dissolved	Particulate	Dissolved	Particulate	Dissolved	Particulate
April	37,857	13,890	112,304	42,062	10,132	3,321 ,
May	38,098	4,110	82,009	46,784	16,679	1,969
June	33,323	4,322	67,641	27,783	41,489	7,272
July	27,016	2,847	41,573	13,681	39,654	3,815
Aug.	18,074	2,794	27,916	10,878	31,194	6,775
Sept.	10,730	1,343	13,715	6,503	10,702	3,347
Oct.	8,317	1,698	9,588	4,196	6,434	1,055
Nov.	9,940	1,364	19,165	1,389	8,239	1,214
Dec.	9,474	516	9,205	1,464	5,690	1,167
Jan.	1,938	232	2,189	349	3,011	374
Feb.	1,901	341	7,123	757	3,093	308
March	3,647	1,027	21,659	3,604	12,243	2,424
Total	200,316	34,484	414,088	159,451	188,561	33,043

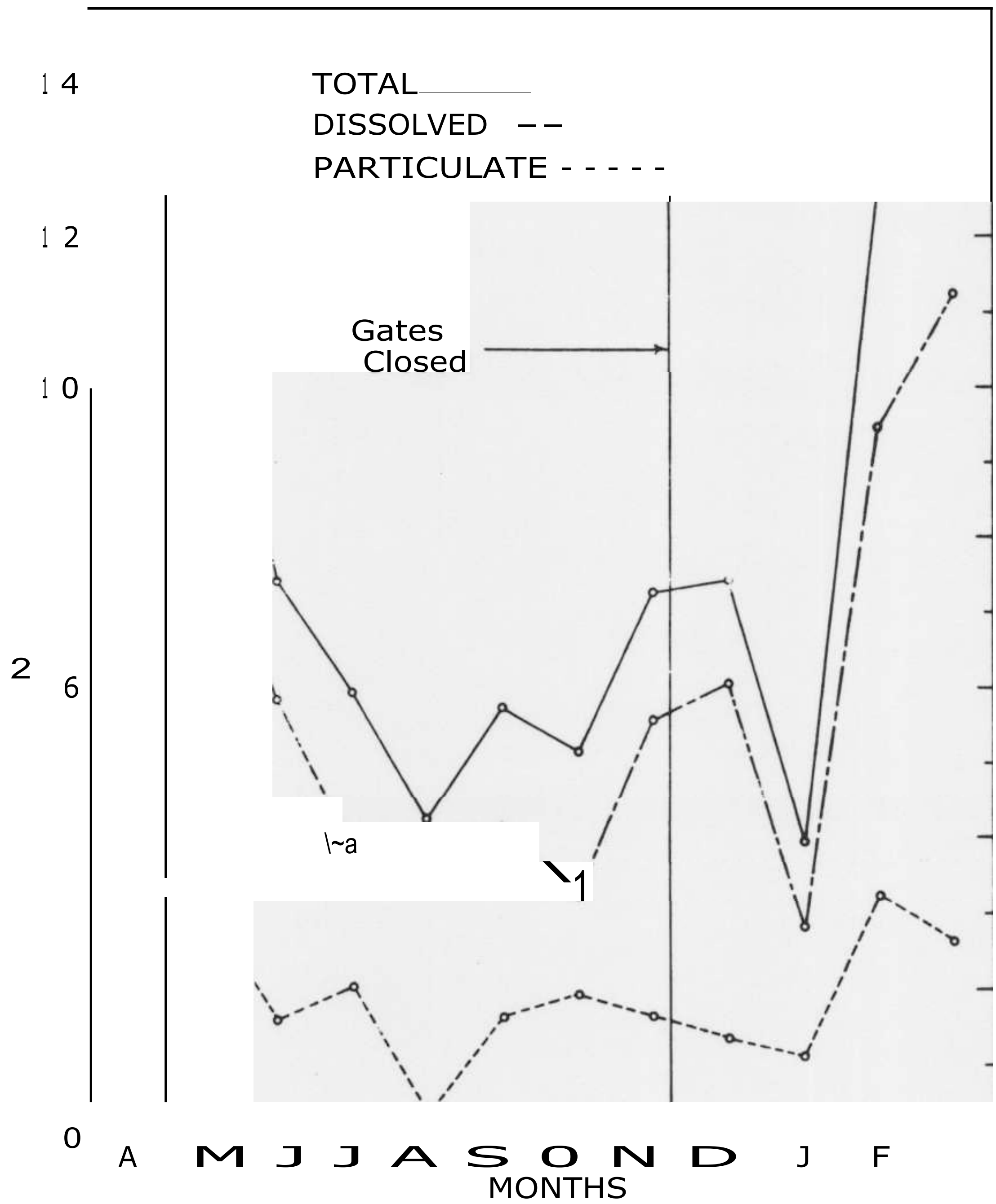

FIGURE 14. WEIGHTED MONTHLY MEAN ORGANIC CARBON FRACTIONS IN THE DIVERSION CANAL (Station 2), (APRIL 1970—MARCH 1971).

The annual load of organic carbon transported into Dry Lake via the diversion canal was 4.64 x 10^4 kg. Only 1.29 x 10^3 kg (3.6%) of this load was transported from May 1 to November 19 when the canal gates were closed. The annual load of organic carbon entering Dry Lake was 9.7% of the annual load transported by the Big Sioux River at station 1 (Table 5).

Station 3 (Dry Lake)

Particulate organic carbon concentrations in Dry Lake were high in the summer and low during the winter. This trend correlates with the fluctuations in dissolved oxygen (Figure 15) and with sestonic phosphorus (Figure 4). This suggests that the increase in all three are due to phytoplankton pulses during the summer months. Particulate organic carbon averaged 5.40 mg/l for the year and ranged from 1.47 mg/l in March to 14.51 mg/l in September (Figure 15).

Dissolved organic carbon was in highest concentration during the winter. It remained between 10-12 mg/l from March through October then increased to a high of 15.41 mg/l in February. The low monthly average was 10.38 mg/l in March (Figure 15). Skopintsev and Bakulina (1964) also reported highest dissolved (filtered) organic carbon during winter months in the Rybinsk Reservoir. This fraction was in greatest concentration in February when dissolved oxygen levels were the lowest in Dry Lake. It appears that winter decomposition may have been using up dissolved oxygen and causing organic carbon to be released into solution. The average annual concentration of dissolved organic carbon was 12.13 mg/l.

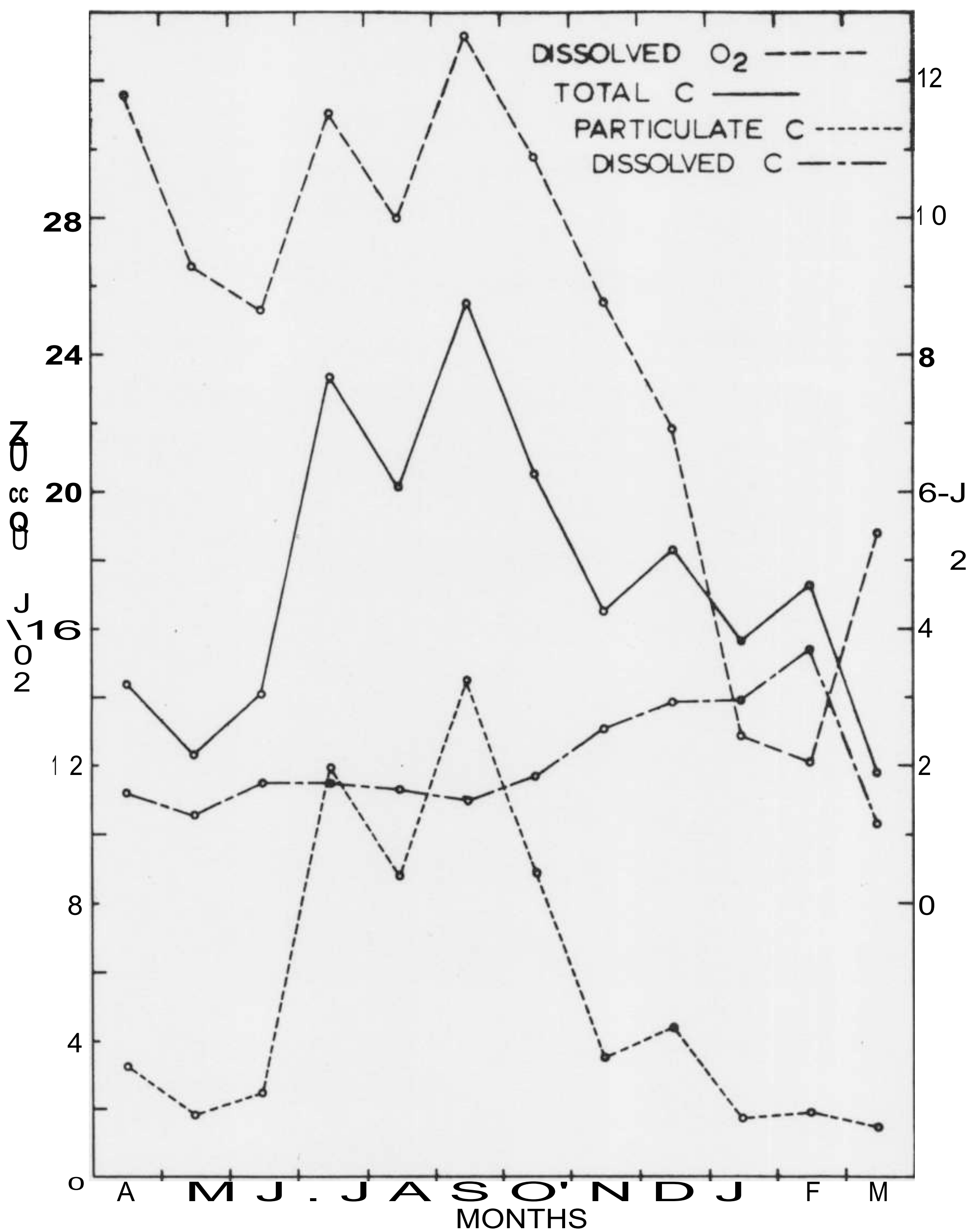

FIGURE 15. WEIGHTED MONTHLY MEAN ORGANIC CARBON FRACTIONS AND DISSOLVED OXYGEN CONCENTRATIONS IN DRY LAKE (Station 3), (APRIL 1970—MARCH 1971).

The average annual concentration of total organic carbon was 17.53 mg/l in Dry Lake. The fractions making up this total were in the ratio of 2.3 dissolved : 1 particulate (Figure 13).

Station 4 (Stone Bridge Channel)

Total organic carbon concentrations in water flowing from Dry Lake to Lake Poinsett averaged 17.37 mg/l during the year. This level was nearly the same as the 17.53 mg/l average annual concentration in Dry Lake (station 3). However, the ratio of dissolved to particulate organic carbon changed from 2.3 : 1 in Dry Lake to 3.1 : 1 at station 4 (Figure 13).

The annual organic carbon load transported from Dry Lake to Lake Poinsett was 1.68×10^5 kg. This was 1.22×10^5 kg more than that which entered Dry Lake via the diversion canal (Table 5).

Station 8 (Lake Albert Drainage)

Commercial fishermen had approximately 80 meters of the Lake Albert drainage above station 8 fenced off as a carp trap from April 9 to July 27, 1970. Carp stirred up bottom material when they moved into the stream and concentrated in the trap in April. Particulate organic carbon concentrations averaged 4.91 mg/l in April and by May most of this turbidity had been flushed out of the carp trap area. Particulate organic carbon concentrations decreased to an average of 2.20 mg/l in May and remained low until fall when they increased to the high for the year of 4.66 mg/l in September (Figure 16). Organic carbon levels were constant through the year except for the relatively high levels in April

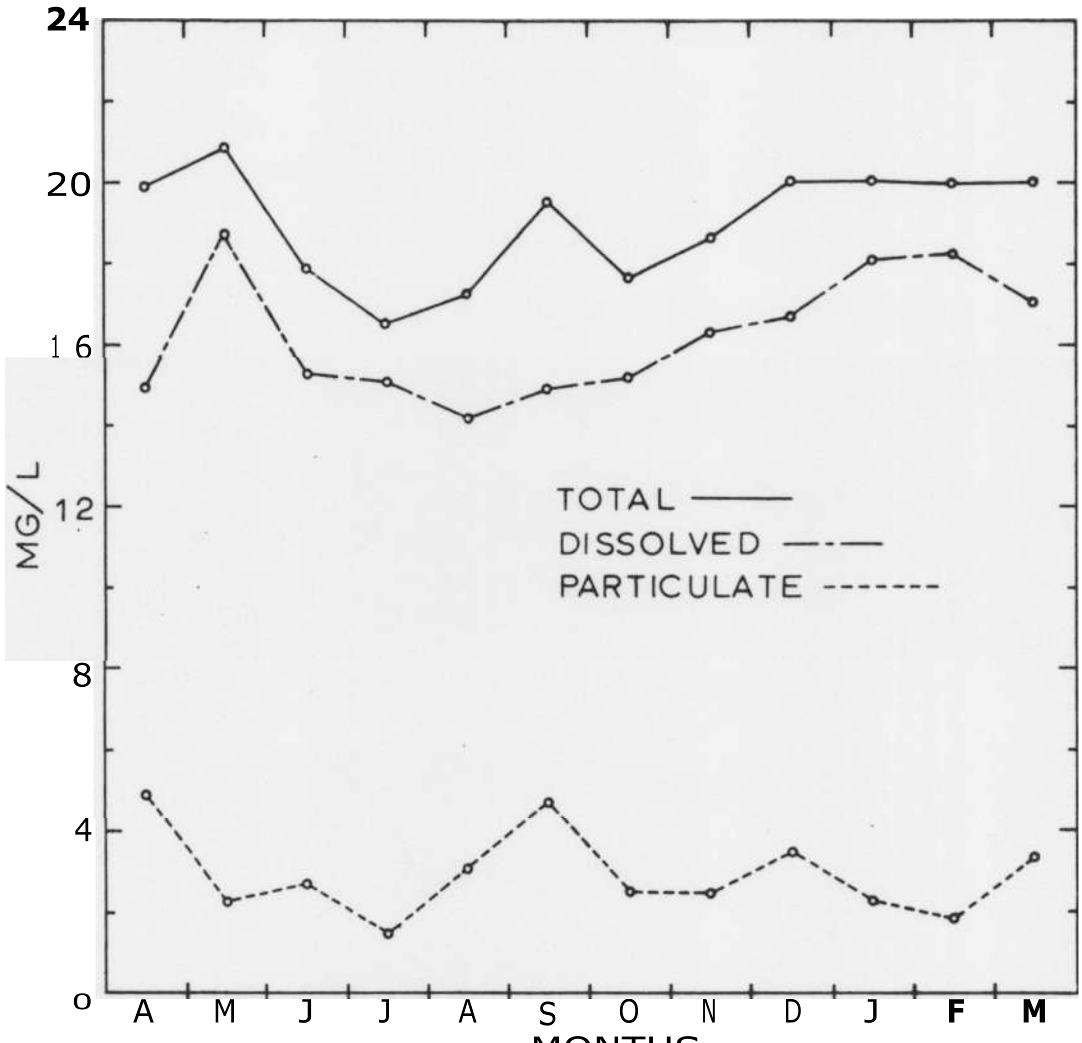

FIGURE 16. WEIGHTED MONTHLY MEAN ORGANIC CARBON FRACTIONS IN THE LAKE ALBERT DRAINAGE (Station 8), (APRIL 1970—MARCH 1971).

and in the fall when water temperatures lowered.

Summer stagnation became evident in May when dissolved oxygen concentrations decreased from a mean of 6.57 mg/l in April to 0.49 mg/l in June. During this time dissolved organic carbon peaked at 18.64 mg/l the mean concentration in May. After May the concentration decreased gradually to 14.18 mg/l in August. Concentrations increased from August through the fall and winter to 18.25 mg/l in February (Figure 16). The general trend of dissolved organic carbon was low concentrations in the summer and high concentrations in the winter except for the brief increase in May.

The average annual concentration of total organic carbon was 19.11 mg/l which was the highest average annual concentration measured throughout the system. The dissolved to particulate organic carbon ratio averaged 5.6 : 1 which was also very high relative to other stations in the system (Figure 13).

Station 6 (Lake Poinsett Outlet)

Dissolved organic carbon concentrations in the Lake Poinsett outlet were characterized by being high in late winter and early summer and low during the spring and late summer. Monthly mean concentrations ranged from 13.39 mg/l in August to 20.99 mg/l in February. The average annual concentration was 16.32 mg/l (Figure 17).

Particulate organic carbon concentrations were relatively constant except for a high concentration in late winter and early spring. Monthly mean concentrations ranged from 0.90 mg/l in December to 5.72 mg/l in April. The average annual concentration was 2.64 mg/l (Figure 17).

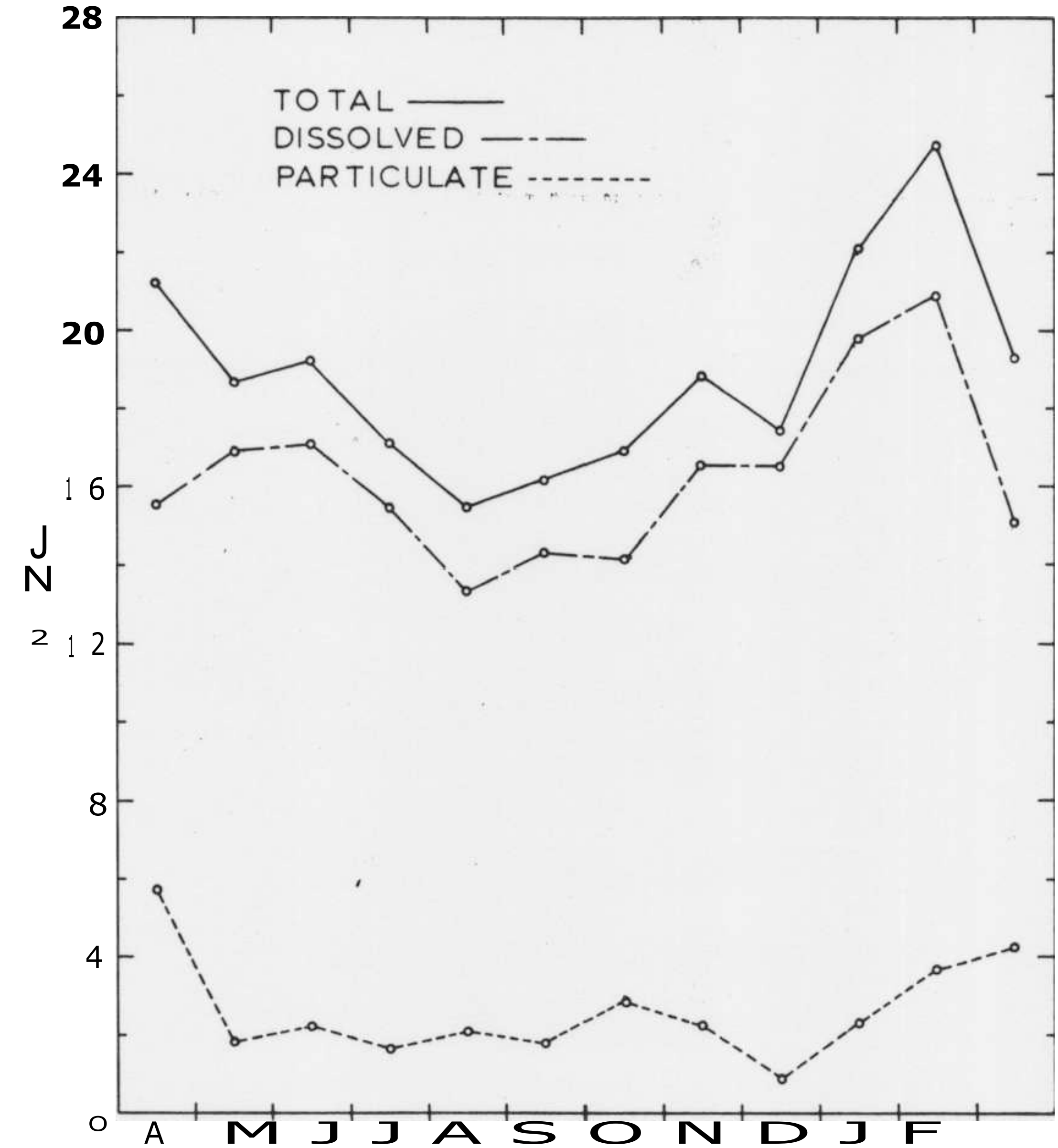

FIGURE 17. WEIGHTED MONTHLY MEAN ORGANIC CARBON FRACTIONS IN THE LAKE POINSETT OUTLET (Station 6), (APRIL 1970—MARCH 1971).

Total organic carbon concentrations averaged 18.96 mg/l during the study. The dissolved to particulate organic carbon ratio averaged 6.2 : 1, which was the highest ratio throughout the study area (Figure 13). Station 8 and 6 had organic carbon levels and ratios which were very similar. This is not surprising since both stations have lakes as water sources and both receive waters which flow through approximately the same distance of marshland.

The annual load of organic carbon transported into the Big Sioux River via the outlet was 2.35×10^5 kg (Table 5).

Station 7 (Big Sioux River below Outlet)

The average annual concentration of organic carbon in the Big Sioux River below the outlet was 15.08 mg/l. This was comprised of 11.66 mg/l dissolved and 3.42 mg/l particulate organic carbon (Figure 18).

The annual load of organic carbon transported by the Big Sioux River at station 7 was-5.73×10^5 kg (Table 5). This was an increase of 9.56×10^4 kg over the organic carbon load transported by the river at station 1.

Station 5 (Lake Poinsett)

The highest concentrations of dissolved organic carbon in Lake Poinsett occurred in the early summer (June and July) and winter months. The lowest concentrations occurred in August, September, and October. Monthly mean concentrations of dissolved organic carbon showed little fluctuation ranging from 13.17 mg/l in August to 17.62 mg/l in February (Figure 19). The average annual concentration was 15.08 mg/l.

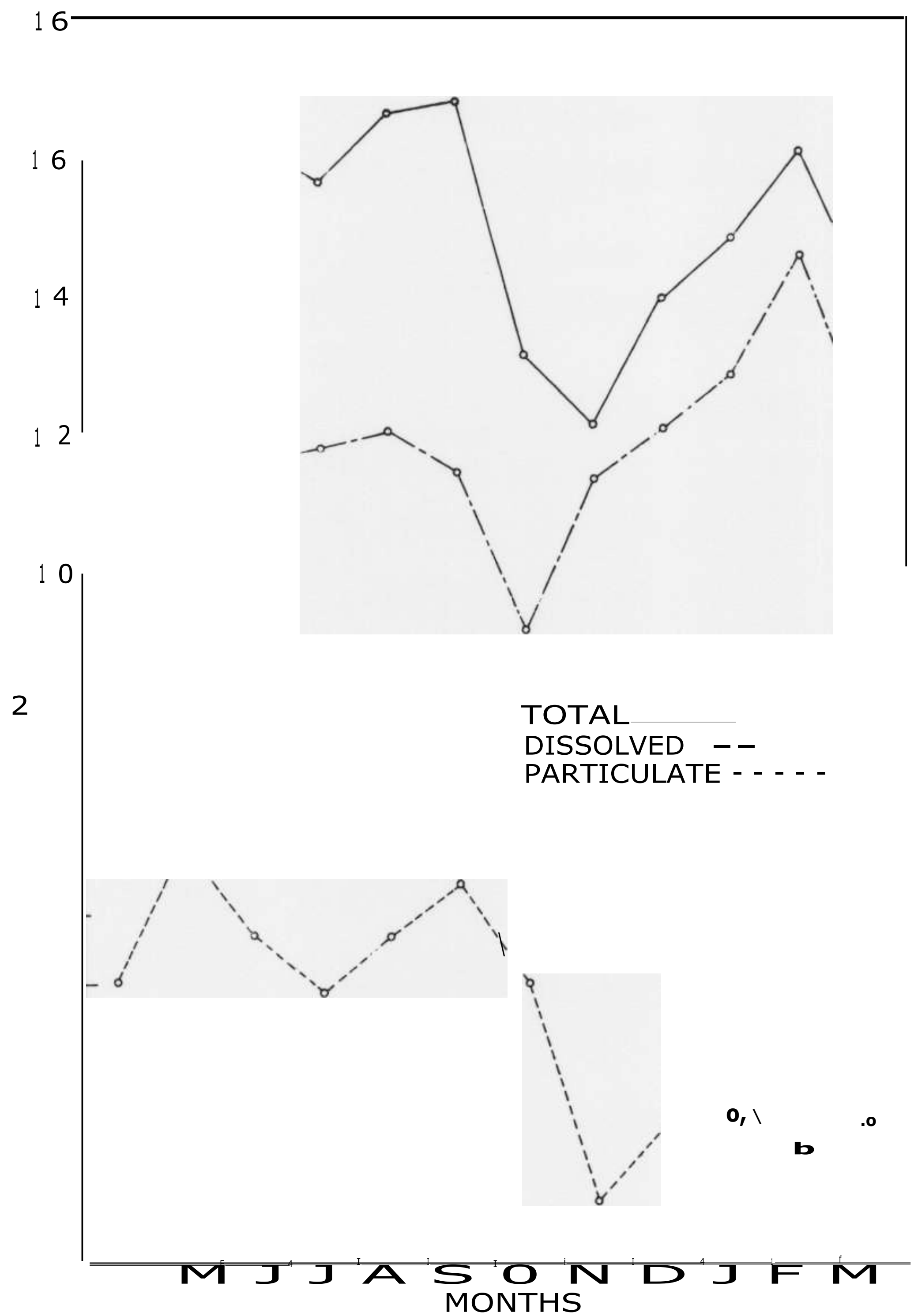

FIGURE 18. WEIGHTED MONTHLY MEAN ORGANIC CAR— BON FRACTIONS IN THE BIG SIOUX RIVER (Station 7), (APRIL 1970—MARCH 1971).

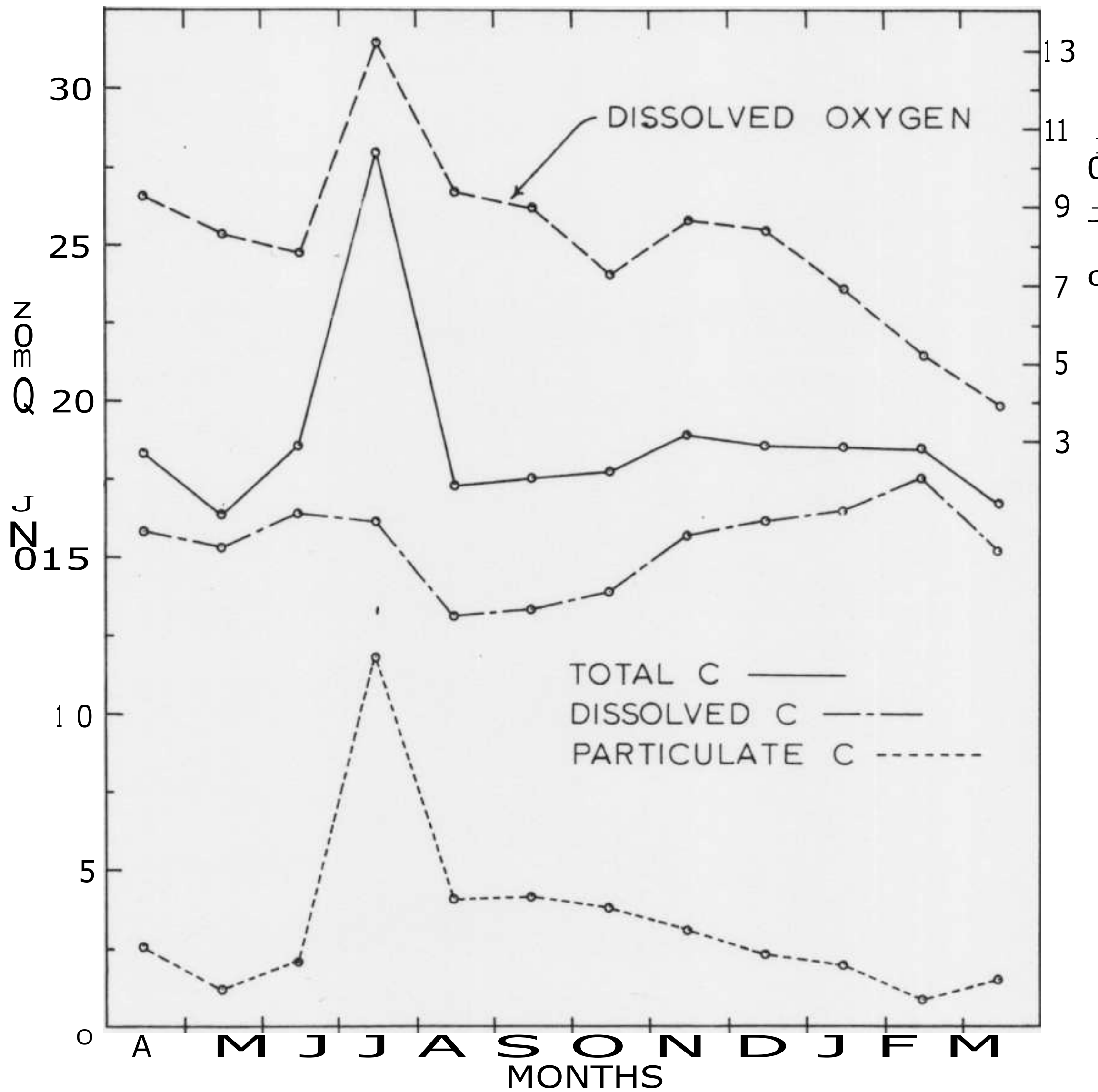

FIGURE 19. WEIGHTED MONTHLY MEAN ORGANIC CARBON FRACTIONS AND DISSOLVED OXYGEN CONCENTRATIONS IN LAKE POINSETT (Station 5), (APRIL 1970—MARCH 1971).

Particulate organic carbon concentrations were high in the summer and low in the winter. Monthly mean concentrations ranged from 0.88 mg/l in February to 11.82 mg/l in July (Figure 19). The July high was due to extremely dense algal blooms in Lake Poinsett. This high corresponds to the high July concentration of sestonic phosphorus (Figure 8) and dissolved oxygen (Figure 19). Juday and Birge (1931), in their studies on Northern Wisconsin lakes, noted a definite positive correlation between organic carbon and organic phosphorus. The average annual concentration of particulate organic carbon was 3.32 mg/l in Lake Poinsett.

The average annual concentration of total organic carbon was 18.40 mg/l. Dissolved to particulate organic carbon fractions were in an average ratio of 4.5 i 1 during the year. Total organic carbon concentrations were approximately three times greater in Lake Poinsett than the average concentration of organic carbon in other regions of the world (Table 6).

Total organic carbon and ratios of dissolved to particulate organic carbon increased through the Big Sioux River-Dry Lake-Lake Poinsett system. Particulate organic carbon decreased through the system and the dissolved fraction increased. Stations 2 and 7 do not fit these general trends since the diversion canal is affected by ground water and the Big Sioux River at station 7 is a mixture of river water and outlet water (Figure 14 and Table 7).

Table 6. Mean total organic carbon content in lakes of different regions of the world

Region	Total Organic Carbon (mg/l)
Bull Shoals Reservoir, Arkansas (Applegate and Mullan, 1967)	3.43
Beaver Reservoir, Arkansas (Applegate and Mullan, 1967)	3.71
California Reservoirs, (Connors and Baker, 1969)	4.5
Lake Fures, Denmark (Krogh and Lange, 1932)	5.52
N. E. Wisconsin Lakes (Bilge and Juday, 1934)	8.2
Lake Wingra, Wisconsin (Tressler and Domogalla, 1931)	9.0
Rybinsk Reservoir, U. S. S. R. (Skopintsev and Bakulina, 1964)	10.0
Lake Poinsett, South Dakota	18.40

Table 7. Comparison of average annual organic carbon concentrations and ratios of fractions at the stations in the Lake Poinsett system

Station	Organic Carbon (mg/l)			Dissolved: Particulate
	Total	Dissolved	Particulate	Ratio
Big Sioux River (Station 1)	13.37	8.40	4.97	1.7:1
Diversion Canal (Station 2)	8.19	6.19	2.00	3.1:1
Dry Lake (Station 3)	17.53	12.13	5.40	2.3:1
Stone Bridge Channel (Station 4)	17.37	13.14	4.23	3.1:1
Lake Poinsett (Station 5)	18.40	15.08	3.32	4.5:1
Lake Poinsett Outlet (Station 6)	18.96	16.32	2.64	6.2:1
Big Sioux River (Station 7)	15.08	11.66	3.42	3.4:1
Lake Albert Drainage (Station 8)	19.11	16.22	2.89	5.6:1

SUMMARY AND CONCLUSION

Concentrations and loads of nutrients transported through the Lake Poinsett system were monitored from April 1, 1970 to April 1, 1971. The annual 2.07×10^6 m^3 surface discharge into Lake Poinsett transported 1.66 x 104rkg (PO_4) phosphorus, 1.28×10^4 kg nitrate nitrogen, and 3.90×10^5 kg organic carbon. The Big Sioux River-Dry Lake system contributed 63% of the phosphorus, 45% of the nitrate nitrogen, and 43% of the organic carbon load. The remaining portion entered Lake Poinsett from the Lake Albert drainage. Of the annual load of nutrients transported into Lake Poinsett, 33% of the nitrate nitrogen load, 40% of the organic carbon load, and 70% of the phosphorus load was retained by the lake or lost by ways other than water discharge. Ground water and surface runoff were also found to be significant nutrient contributors to Lake Poinsett.

Phosphorus concentrations in the Big Sioux River averaged 1.9 mg/l (PO4) which is nine times greater than the phosphorus concentrations in the average river water of the world (Clarke, 1924). Phosphorus concentrations decreased through the system to the average annual concentration of 0.22 mg/l (PO_4) in Lake Poinsett. The dissolved inorganic fraction averaged 0.11 mg/l (PO_4) in Lake Poinsett which is seven times greater than the level considered necessary to cause nuisance algal blooms (Sawyer, 1966). Soluble inorganic phosphorus constituted 71% of the total phosphorus which entered Lake Poinsett. This fraction comprised 50% of the phosphorus in Lake Poinsett which is five times greater than the percentage in relatively uncontaminated waters (Hutchinson, 1957).

Lake Poinsett's retention of 4.20 x 10^3 kg nitrate nitrogen is indicative of high productivity in the lake (Mortimer, 1939). The average annual concentration of 0.52 mg/l nitrate nitrogen in Lake Poinsett exceeds the 0.30 mg/l total nitrogen estimated by Sawyer (1966) as the critical level required for algal blooms.

Concentrations of organic carbon increased through the system from an annual average of 13.37 mg/l in the Big Sioux River to 18.40 and 18.96 mg/l in Lake Poinsett and the Lake Poinsett outlet, respectively. Organic carbon concentrations in Lake Poinsett averaged three times greater than the average concentration of organic carbon in lakes of other regions of the world. High summer concentrations of particulate organic carbon correlated with high dissolved oxygen and sestonic phosphorus concentrations in Dry Lake and Lake Poinsett. These correlations are indicative of increased phytoplankton productivity (Juday and Birge, 1931).

The advanced degree of eutrophication in Lake Poinsett is ascribable to a large annual nutrient load entering and retained by the lake. Nutrient concentrations, relative to the needs of aquatic plants in Lake Poinsett, are in a state of super-saturation (Sawyer, 1966). The rate and degree of eutrophication in Lake Poinsett can be expected to continue unless a drastic reduction in influent nutrients occurs.

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Appendix A. Nutrient concentrations and water discharge in the Big Sioux River (Station 1), April 1970 - March 1971

Date	Water discharge (m^3/sec)	Organic Carbon (mg/1) Dissolved	Organic Carbon (mg/1) Particulate	Phosphorus (sag PO_4/i) Dis• solved inorganic	Phosphorus (sag PO_4/i) Dis• solved organic	Phosphorus (sag PO_4/i) Sestonic	Nitrate nitrogen (mg/1)	Dissolved oxygen (mg/1)
4-4-70	-- ,	11.25	2.93	1.98	0.09	0.73	1.20	8.6
4-10-70	2.15	10.93	4.98	--	--	--	--	6.8
4-17-70	3.98	6.35	5.58	--	--	--	•-	10.6
4-24-70	3.89	9.39	3.26	--	--	--	-•	12.0
5-1-70	3.38	8.54	4.29	--	--	--	--	12.8
5-8-70	2.31	7.87	3.78	-•	--	--	--	8.6
5-15-70	2.02	8.09	3.15	0.56	0.08	0.27	0.65	12.6
5-22-70	2.02	8.11	3.95	0.52	0.08	0.41	0.75	11.6
6-5-70	0.97	8.14	5.56	0.57	0.02	0.33	1.25	8.2
6-15-70	1.17	10.28	3.36	0.73	0.05	0.30	0.94	7.9
60221070	1.68	10.47	4.46	0.83	0.05	0.32	1.35	8.9
6-29-70	--	10.48	3.86	0.75	0.02	0.35	0.46	--
7-6.70	0.75	9.18	3.67	0.58	0.03	0.33	0.57	9.3
7-13-70	0.64	10.54	8.04	0.70	0.00	0.61	--	7.0
7-20-70	0.65	14.47	11.26	0.70	0.00	0.34	--	14.0
7-27-70	0.37	3.42	3.67	0.65	0.02	0.54	1.33	10.7
8-3-70	0.43	11.70	9.92	1.21	0.10	0.71	0.73	11.5
8-10-70	0.46	7.02	8.26	0.84	0.12	0.51	0.50	9.1
8-17-70	0.25	9.26	8.82	1.36	0.00	0.66	1.04	7.7
8-24-70	0.19	8.95	9.24	--	--	--	0.53	8.4
8-31-70	0.17	10.35	12.60	0.42	0.05	0.76	0.40	9.6
9-7-70	--	8.00	15.26	0.37	0.14	0.70	0.43	--
9-14-70	0.14	7.74	11.34	0.24	0.06	0.75	0.40	10.5
9-21-70	--	4.11	9.38	0.27	0.02	0.60	0.59	--
9-28-70	0.13	6.73	15.96	0.04	0.08	0.69	0.59	11.8
10-5-70	0.15	6.31	14.56	0.11	0.02	0.52	0.66	--
10-19-70	0.17	4.69	3.32	0.35	0.04	0.63	0.59	10.4
10-26-70	0.38	8.68	2.52	0.13	0.10	0.46	0.40	14.6
11-2-70	0.27	8.05	2.70	2.18	0.03	0.89	0.46	11.4
11-9-70	1.02	--	--	1.62	0.48	0.48	2.80	--
11-16-70	0.61	6.86	3.08	1.81	0.06	0.19	9.75	12.0
11-23-70	--	5.39	2.10	2.10	0.09	0.28	5.40	--
12-3-70	0.27	8.05	0.14	2.50	0.26	0.56	5.40	4.4
12-15-70	0.29	8.05	0.14	3.84	0.36	0.44	10.80	3.6
12-28-70	0.09	5.98	0.28	4.60	0.44	0.84	5.28	2.3
1-9-71	0.01	5.46	2.52	2.36	0.00	1.16	2.60	1.4
1-21-71	--	2.19	1.40	0.11	0.12	1.17	0.32	2.6
2-4-71	0.03	2.25	0.14	0.26	0.10	1.18	0.96	0.5
2-24-71	0.48	19.44	0.98	1.80	0.08	0.52	2.88	3.4
3-12-71	5.76	16.78	5.60	1.70	0.12	0.20	1.20	7.2
3-28-71	1.40	5.96	1.81	1.84	0.04	0.28	0.61	3.6

Appendix B. Nutrient concentrations and water discharge in the Diversion Canal (Station 2), April 1970 - March 1971

		Organic Carbon (mg/1)		Phosphorus Ong PO_4/1)				
Date	Water Dix- charge (n^3/sin)	Dix- solved	Part- iculate	Dix- solved inor- gaaic	Dis- solved organic	Sestonic	Nitrate nitrogen (mg/1)	Dissolved oxygen (mg/1)
4.4-70	-•	11.08	3.91	1.40	0.20	0.18	1.83	7.4
4-10-70	9.80	11.09	3.70	●-	--	--	--	7.8
4-17-70	6.06	6.35	2.72	--	--	--	--	12.0
4-24-70	7.45	9.31	3.55	--	--	--	--	11.4
5˙1-70 •	--	9.64	3.43	-●		--	--	10.6
5-8-70	0.64	8.77	2.65	--	--	--	--	8.0
5-15-70	--	9.35	3.72	0.46	0.06	0.36	--	8.2
5-22-70	--	7.89	3.78	0.26	0.06	0.26	0.75	5.6
6-5-70	1.10	6.87	2.02	0.10	0.03	0.27	0.94	9.5
6-15-70	0.49	5.70	1.60	0.07	0.03	0.10	0.75	13.5
6-22-70	0.78	4.97	1.15	0.08	0.02	0.10	0.87	9.0
6-29-70	--	4.97	1.16	0.05	0.02	0.08	0.25	--
7.6-70	0.70	4.97	1.17	0.04	0.09	0.12	0.57	10.4
7-13-70	0.65	4.28	0.45	0.11	0.01	0.19	--	4.8
7-20-70	0.59	3.27	2.57	0.13	0.04	0.14	--	10.1
7-27.70	0.47	2.26	4.70	0.18	0.03	0.25	0.62	9.9
8-3-70	0.34	5.55	0.29	0.23	0.06	0.22	0.44	9.7
8-10-70	0.39	3.88	0.21	0.16	0.08	0.27	0.10	5.3
8-17-70	0.25	2.21	0.14	0.24	0.07	0.47	0.44	--
8-24.70	0.19	3.70	0.35	--	--	--	0.40	2.8
8-31-70	0.15	5.20	0.56	0.27	0.08	0.21	0.07	3.2
9-7-70	--	3.78	0.42	0.23	0.06	0.33	0.43	--
9-14-70	0.41	4.02	3.08	0.13	0.07	0.84	0.38	3.6
9-21-70	--	3.68	1.68	0.15	0.05	0.57	0.53	--
9-28-70	--	4.61	1.96	0.16	0.22	0.15	0.53	9.2
10-5-70	--	3.77	1.12	0.13	0.30	0.12	0.46	--
10-19-70	0.41	2.38	1.96	0.10	0.11	0.21	0.46	13.6
10-26-70	0.10	3.27	3.08	0.08	0.07	0.35	0.33	10.0
11-2-70	0.29	3.82	2.10	0.08	0.21	0.45	0.20	3.0
11-9-70	0.27	--	●-	0.09	0.50	0.22	0.44	--
11-16-70	0.24	6.64	1.54	0.08	0.02	0.32	1.20	9.0
11-23-70 *	--	6.64	1.54	1.32	0.14	0.31	5.40	--
12-3˙70	18.59	7.54	0.57	1.35	0.03	0.19	5.40	10.0
12-15-70	9.64	6.72	1.26	3.12	0.08	0.36	10.80	3.5
12-28-70	3.29	3.96	2.24	3.64	0.36	0.16	6.56	--
1-9-71	1.77	3.91	1.12	0.84	0.28	0.48	4.00	0.6
1-21-71	--	2.03	0.14	0.28	0.24	0.40	5.76	2.2
2-4-71	.17	1.59	3.36	0.10	0.14	1.26	2.26	0.4
2-24-71	26.49	16.97	3.22	1.70	0.02	0.16	4.72	3.0
3-12-71	71.76	13.73	3.50	1.82	0.0	0.32	1.16	3.2
3-28-71	15.04	5.82	1.26	0.62	0.04	0.28	0.58	3.6

+ Diversion canal gates closed 5-1-70
* Diversion canal gates opened 11-19-70

Appendix C. Nutrient concentrations in Dry Lake (Station 3), April 1970 - March 1971

Date	Organic Carbon (mg/1) Dis-solved	Part-iculate	Phosphorus (mg PO_4/1) Dis-solved inor-ganic	solved organic	Sestonic	Nitrate nitrogen (mg/1)	Dissolved oxygen (mg/1)
4-4-70	13.69	1.46	0.78	0.06	0.13	0.75	11.8
4-24-70	9.29	4.96	--	--	--	--	12.4
5-8-70	9.12	1.39	--	--	--	--	8.8
5-16-70	11.34	1.72	0.30	0.02	0.22	0.05	10.8
5-23-70	11.37	1.68	0.22	0.04	0.13	0.44	8.2
6-5-70	11.39	1.65	0.18	0.00	0.09	0.75	8.0
6-15-70	11.42	1.61	0.26	0.06	0.11	1.10	8.0
6-22-70	11.85	4.03	0.26	0.00	0.24	0.73	10.0
6-29-70	11.95	3.26	0.18	0.02	0.15	0.25	9.1
7-6-70	11.51	14.54	0.04	0.14	0.41	0.90	14.9
7-13-70	10.78	6.71	0.29	0.04	0.28	0.90	6.6
7-20-70	15.75	20.88	0.32	0.03	0.53	0.53	13.6
7-27-70	7.67	9.10	0.14	0.04	0.37	0.53	12.1
8-3-70	11.65	18.12	0.34	0.05	0.22	0.73	11.1
8-10-70	10.64	5.34	0.43	0.05	0.17	0.20	10.6
8-17-70	10.64	12.60	0.16	0.08	0.48	0.73	8.4
8-24-70	12.44	9.52	--	--	--	1.12	8.6
8-31-70	11.88	10.36	0.18	0.06	0.48	0.59	12.2
9-7-70	10.90	29.26	0.07	0.06	0.99	0.79	--
9-14-70	10.82	9.38	0.20	0.05	0.45	0.95	12.7
9-21-70	10.90	9.94	0.10	0.03	0.38	0.99	--
9-28-70	11.04	10.78	0.07	0.06	0.29	0.79	13.2
10-5-70	11.32	9.66	0.07	0.04	0.40	0.82	12.4
10-19-70	11.88	11.06	0.07	0.06	0.52	0.92	10.8
10-26-70	11.88	5.18	0.20	0.06	0.27	0.53	8.8
11-2-70	12.30	5.46	0.26	0.06	0.50	0.66	10.0
11-9-70	--	--	0.24	0.44	0.44	0.53	9.0
11-23-70	13.45	2.52	0.39	0.00	0.17	0.68	8.0
12-3-70	13.87	1.12	0.40	0.03	0.16	0.82	7.2
12-15-70	14.39	6.69	0.39	0.03	0.28	0.65	8.8
12-28-70	13.33	4.34	0.62	0.00	0.07	0.84	4.4
1-9-71	13.59	12.66	0.73	0.00	0.05	0.72	3.2
1-21-71	13.85	0.98	0.75	0.00	0.14	0.38	1.8
2-4-71	15.23	0.28	0.81	0.05	0.08	0.41	1.0
2-24-71	15.64	19.14	1.12	0.04	0.24	2.26	3.0
3-12-71	15.31	1.40	0.67	0.00	0.09	1.32	3.8

Appendix D. Nutrient concentrations and water discharge in the Stone Bridge Channel (Station 4), April 1970 - March 1971

		Organic Carbon (mg/1)		Phosphorus On PO_4/1)				
Date	Water dis- charge (.3/sec)	Dis- solved	Part- iculate	Dis- solved inor- sonic	Die- solved organic	Sestonic	Nitrate nitrogen (.g/1)	Dissolved oxygen (ag/1)
4-4-70	0.59	16.32	1.61	0.64	0.08	0.08	1.05	7.0
4-10-70	0.97	14.79	1.60				--	6.0
4-17-70	1.31	8.'▶2	4.15				•-	13.0
4-24-70	0.91	9.43	5.11	w.	mft		--	15.2
5-1-70	--	10.11	8.57		ft.		••	9.8
5-8-70 *	0.00	10.98	1.39					7.0
5-15-70	--	12.73	3.58	0.26	0.04	0.26	0.407	8.4
5·23-70	0.00			0.24	0.06	0.13	0.30	6.8
6-5-70	0.00	16.3'.1	1 ,.43	0.18	0.03	0.05	0.94	8.5
3-28-71	10.78	16.19	5.,04	1.00	0.02	0.42	0.60	6.0

* Discharge was blocked by a sand bar during May 9, 1970 - March 23, 1971

Appendix S. Nutrient concentrations in Lake Poinaett (Station 5), April 1970 - March 1971

Date	Organic Carbon (me/ 1) Dis- solved	Part- iculate	Phosphorus Ong PO4/1) Dix- solved !nor- gamic	Dis- solved organic	Sestonic	Nitrate nitrogen (a$/1)	Dissolved oxygen (mg/1)
4-4-70	19.23	1.63	0.22	0.02	0.12	0.60	4.6
4-24-70	12.88	3.55	--	--	--	--	13.4
5-7-70	14.21	1.64					-.
5-15-70	16.20	0.29	0.10	0.04	0.02	0.48	8.4
5.23-70	--	--	0.22	0.02	0.08	0.44	5.8
6-5-70	15.74	1.68	0.16	0.04	0.04	0.75	6.84
6-15-70	18.01	0.15	0.21	0.04	0.09	0.75	7.7
6-22-70	18.01	0.15	0.18	0.03	0.13	0.73	8.8
6-29-70	14.34	7.94	0.05	0.00	0.16	--	8.6
7-6-70	16.59	23.22	0.04	0.03	0.43	0.80	14.9
7-13-70	16.43	10.72	0.08	0.04	0.22	0.80	14.2
7-20-70	18.25	8.60	0.07	0.00	0.24	--	13.6
7-27-70	14.99	7.14	0.15	0.04	0.16	0.35	12.0
8.3-70	11.76	5.61	0.07	0.05	0.08	0.14	--
8-10-70	13.77	4.34	0.05	0.02	0.08	0.10	10.2
8-17-70	11.39	5.88	0.10	0.02	0.01	0.73	8.5
8.24-70	14.71	2.10	--	--	--	0.92	8.8
8-31-70	14.31	1.82	0.08	0.04	0.04	0.66	8.2
9-7.70	13.23	6.30	0.04	0.03	0.11	0.73	--
9-14-70	13.43	3.64	0.04	0.04	0.10	0.73	8.8
9-21-70	12.93	4.75	0.04	0.03	0.05	0.92	--
9-28-70	13.16	2.94	0.05	0.02	0.02	0.73	10.0
10-5-70	13.44	3.92	0.17	0.03	0.03	0.73	--
10-19-70	14.21	4.62	0.08	0.04	0.23	0.79	7.0
10-26-70	13.61	3.36	0.07	0.03	0.10	0.46	4.2
11·2-70	16.17	1.54	0.07	0.01	0.09	0.36	8.8
11-9-70	--	--	0.04	0.24	0.01	0.24	-•
11-15-70	16.45	4.20	0.05	0.03	0.03	0.26	8.4
11-23-70	14.84	3.92	0.04	0.01	0.10	0.26	--
12-3-70	14.81	1.26	0.135	0.019	0.10	0.273	9.2
12-15-70	17.92	2.66	0.05	0.03	0.10	0.29	8.6
12-28.70	15.18	2.94	0.08	0.00	0.05	0.37	7.4
1-9·71	15.99	1.82	0.12	0.03	0.01	0.38	7.1
1-21-71	16.91	2.24	0.04	0.03	0.09	0.34	6.8
2-4.71	17.67	1.30	0.15	0.03	0.06	0.40	6.5
2-24-71	17.73	0.42	0.14	0.02	0.05	0.60	4.0
3-12-71	14.81	1.74	0.21	0.01	0.04	0.61	3.6
3-2841	2.88	1.54	0.09	0.03	0.07	0.30	4.4

Appendix F. Nurtient concentrations and water discharge in the Lake Poinsett Outlet (Station 6), April 1970 - March 1971

		Organic Carbon (ag/1)		Phosphorus (agPO4/1)				
Date	Water discharge (.3/sec)	Dis-solved	Part-iculate	Dis-solved inor-ganic	Dis-solved organic	Sestonic	Nitrate nitrogen (sig/1)	Dissolved oxygen (ng/i)
4-440	0.79	19.07	3.26	0.14	0.06	0.06	0.45	3.6
4-10-70	0.88	16.55	3.38	-•	--	--	-•	7.2
4-17-70	0.93	13.79	6.30	-•	--	--	--	10.4
4-24-70	1.12	13.13	10.22	--	-•	--	-•	8.4
5-1.70	0.97	16.09	3.94	--	••	--		10.8
5-8-70	0.77	16.73	0.26	--	--	--	--	7.6
5-15-70	0.86	16.91	2.01	0.10	0.04	0.02	0.20	9.6
5·2340	-	--	--	0.16	0.10	0.00	1.10	5.2
6-5-70	--	17.42	1.81	0.18	0.02	0.28	1.41	6.9
6-9-70	0.77	-•	--	•-	--	--	--	--
6-15-70	0.70	16.99	1.61	0.69	0.04	0.15	0.94	8.4
6-22-70	0.78	18.75	1.58	0.42	0.03	0.13	0.87	11.5
6.29-70	--	14.00	4.90	0.54	0.00	0.10	0.43	10.95
7·6-70	0.63	16.61	3.09	0.25	0.03	0.14	0.35	10.4
7-13-70	0.77	16.21	1.49	0.61	0.06	0.10	--	1.6
7.20-70	0.60	17.30	1.77	0.32	0.03	0.09	--	6.6
7-27-70	0.06	-•	•-	0.50	0.01	0.06	0.43	6.7
8-3-70	0.55	15.30	0.86	0.25	0.06	0.03	1.33	6.6
8-10·70	0.54	10.33	4.90	0.32	0.03	0.04	0.10	7.9
8-17-70	0.50	13.13	1.40	0.26	0.06	0.03	0.44	4.5
8-24-70	0.50	14.71	1.10	--	--	•-	.99	7.2
8-31-70	0.35	14.41	1.96	0.33	0.02	0.07	0.59	7.0
9-7-70	-•	14.79	2.10	0.30	0.04	0.11	1.12	6.4
9-14·70	0.26	14.97	0.70	0.24	0.09	0.01	0.79	5.8
9-21-70	--	13.69	2.24	0.43	0.04	0.06	1.06	--
948-70	0.28	14.27	1.82	0.13	0.05	0.05	0.86	7.2
10-4-70	0.21	13.43	3.93	0.12	0.04	0.08	0.95	10.0
10·19·70	0.25	14.87	2.60	0.07	0.01	0.16	1.15	8.8
10-26-70	0.21	13.61	1.82	0.27	0.02	0.14	0.66	--
11-2-70	0.13	14.99	2.52	0.05	0.02	0.19	0.72	9.2
11-16.70	0.24'	18.15	2.80	0.10	0.02	0.12	1.13	7.2
11·23-70	--	16.58	1.96	0.04	0.01	0.21	1.03	--
12-3-70	0.33	15.96	0.56	0.12	0.01	0.15	1.64	3.4
12-15-70	0.21	17.05	0.42	0.18	0.02	0.01	1.32	1.2
12-28-70	0.13	16.17	1.68	0.42	0.06	0.14	0.26	0.8
1-9-71	0.03	18.91	3.08	1.00	0.04	0.30	0.38	0.4
1-21-71	--	20.81	1.81	0.73	0.19	0.40	0.31	0.0
2-4-71	0.02	21.76	3.08	1.62	0.06	0.14	0.37	0.0
2-24-71	0.05	20.45	4.48	1.60	0.04	0.24	0.58	0.0
3-12-71	0.02	17.14	3.50	0.43	0.11	0.11	0.84	4.2
3-28-71	0.20	10.45	5.18	0.07	0.01	0.39	0.46	5.2

Appendix G. Nutrient concentrations and water discharge In the Big Sioux River below the outlet (Station 7), April 1970 - March 1971

		Organic Carbon (ˈg/1)		Phosphorus Ong PO4/1)				
Date	Water dis-charge (a^3/sec)	Dis-solved	Part-iculate	Dis-solved inor-ganic	Dis-solved organic	Sestonic	Nitrate nitrogen ('g/1)	Dissolved oxygen (mg/1)
4-3-70	--	12.71	3.91	0.86	0.08	0.43	2.0	6.6
4-10-70	2.73	12.54	4.50	--	0.08	0.43	2.0	9.2
4-17-70	4.96	7.92	4.72	--	--	--	--	11.8
4-24-70	3.91	10.03	3.41	--	--	--	--	10.8
5-1-70	3.77	10.87	3.77	--	--	--	--	11.8
5-8-70	3.44	9.48	7.57	--	-•	--	--	8.8
5-15-70	2.74	10.14	6.72	0.32	0.04	0.43	0.44	10.8
5-23-70	--	--	--	0.36	0.06	0.33	1.10	--
6.5-70	--	12.13	4.14	0.34	0.03	0.35	1.25	7.7
6-9-70	1.96	--	--	--	--	--	--	--
6-15-70	2.08	11.37	3.33	0.65	0.04	0.25	1.25	8.0
6-22-70	2.83	11.83	6.04	0.56	0.03	0.19	1.35	6.8
6-29-70	--	10.48	6.27	0.55	0.00	0.35	0.70	--
7-6-70	1.48	11.41	1.76	0.43	0.02	0.17	0.80	7.5
7-13-70	1.44	12.61	4.50	0.54	0.00	0.39	0.80	4.2
7.20-70	1.26	14.17	7.11	0.25	0.02	0,50	0.43	9.7
7-27-70	0.87	8.93	1.10	0.40	0.03	0.19	0.43	7.6
8-3-70	0.98	13.41	4.17	0.54	0.07	0.36	1.04	7.8
8-10-70	1.18	12.79	5.18	0.54	0.06	0.41	0.50	4.2
8-17-70	0.88	9.57	4.62	0.32	0.11	0.26	0.44	8.6
8-24-70	0.56	12.21	4.20	--	-•	--	0.86	8.0
8-31-70	0.66	12.93	5.88	0.05	0.11	0.36	0.59	9.0
9-7-70	--	12.87	5.18	0.04	0.09	0.56	0.92	--
9˙14-70	0.43	11.54	4.48	0.05	0.03	0.45	0.73	8.4
9-21-70	-•	9.62	5.88	0.13	0.02	0.28	0.86	9.5
9-28-70	0.38	10.99	5.88	0.04	0.04	0.29	0.73	10.6
10.5-70	0.36	9.03	7.70	0.04	0.01	0.30	0.73	10.68
109-70	0.45	8.36	1.26	0.05	0.02	0.24	0.95	10.84
10-26-70	0.33	9.52	2.94	0.07	0.03	0.25	0.33	10.92
11-2-70	0.42	10.47	1.12	0.28	0.04	0.39	0.59	11.0
11-9-70	0.83	••	--	0.62	0.22	0.15	3.20	--
11.16-70	0.83	11.11	0.28	0.58	0.04	0.34	3.32	12.2
11-23-70	--	11.90	1.12	0.12	0.03	0.26	1.64	8.80
12-3-70	0.31	12.69	0.98	0.57	0.02	0.27	2.74	6.6
12.15-70	0.35	--	1.72	0.56	0.00	0.22	2.25	2.4
12-28-70	0.17	11.41	2.80	0.70	0.00	0.35	1.00	2.00
1-9-71	0.07	15.17	1.96	0.67	0.04	0.33	0.50	1.6
1-21-71	--	11.32	2.10	1.02	0.00	0.30	0.26	0.0
2-4-71	0.02	11.74	1.54	1.00	0.12	0.42	0.30	0.0
2-24-71	0.37	17.36	1.54	1.04	0.16	0.16	3.56	3.2
3-12-71	0.41	14.32	1.82	2.52	0.15	0.30	1.10	1.4
3-28-71	1.14	6.87	2.38	1.22	0.08	0.32	0.63	4.0

Appendix H. Nutrient concentrations and water discharge in the Lake Albert Drainage (Station 8), April 1970 - March 1971

		Organic Carbon (mg/1)		Phosphorus (mg PO4/1)				
Date	Water dis-charge (m^3/min)	Dis-solved	Part-iculate	Dis-solved !nor-ganic	Dix-solved organic	Sestonic	Nitrate nitrogen (mg/1)	Dissolved oxygen (mg/1)
4-4-70	16.35	17.76	4.40	0.16	0.06	0.06	1.20	7.2
4-10-70	19.95	15.75	4.98	mow				6.4
4-17-70	--	12.07	6.58					7.8
4-24-70	13.47	13.68	4.40	ft.				6.2
5-1-70	7.64	16.97	3.60					3.8
5-8-70	19.53	17.20	2.65			ft.		4.0
5-15-70	13.75	19.04	1.97	0.30	0.02	0.11	0.44	2.4
5-22-70	--	20.88	1.29	0.30	0.09	0.01	0.44	1.6
6-5-70	--	16.17	2.72	0.24	0.03	0.12	0.60	0.4
6-9-70	49.24							
6-15-70	55.86	14.05	2.79	0.34	0.06	0.13	0.60	0.2
6-22-70	90.50	16.10	1.44	0.21	0.05	0.06	0.40	0.6
6-29-70	--	13.85	4.45	0.16	0.02	0.08	0.55	0.8
7-6-70	58.41	15.70	2.22	0.04	0.09	0.16	0.70	1.0
7-13-70	52.47	17.55	0.00	0.34	0.03	0.00	--	0.0
7-20-70	55.35	16.41	1.78	0.24	0.03	0.05	0.35	0.0
7-27-70	63.84	11.08	('.55	0.40	0.02	0.03	0.35	0.0
8-3-70	62.32	13.60	2.88	0.43	0.08	0.00	0.14	0.0
8-10-70	57.73	14.21	2.10	0.50	0.09	0.00	0.10	0.6
8-17-70	50.57	14.07	3.50	0.43	0.11	0.00	0.44	2.2
8-24-70	41.40	14.63	3.08				0.92	0.6
8-31-70	29.80	14.65	4.62	0.57	0.03	0.10	0.53	1.0
9-7-70	--	15.21	6.16	0.52	0.05	0.10	1.12	--
9-14-70	13.92	14.33	4.76	0.22	0.07	0.12	0.99	1.4
9-21-70	--	14.68	3.92	0.37	0.06	0.08	0.92	--
9-28-70	11.83	15.59	3.78	0.25	0.06	0.04	0.86	2.8
10-5-70	8.17	15.73	1.96	0.37	0.06	0.10	0.79	1.8
10-19-70	9.56	14.89	2.52	0.35	0.03	0.02	1.15	4.0
10-26-70	10.88	14.57	2.94	0.61	0.06	0.10	0.59	1.0
11-2-70	9.08	15.68	2.52	0.28	0.07	0.06	0.59	5.8
11-9-70	13.58	--	--	0.35	0.37	0.03	0.86	5.3
11-15-70	13.26	17.58	2.37	0.29	0.02	0.04	0.66	4.8
11-23-70	--	15.39	2.10	0.29	0.02	0.02	0.82	--
12-3-70	6.54	16.08	3.09	0.32	0.08	0.10	0.61	5.4
12-15-70	9.47	16.83	4.20	0.29	0.02	0.03	0.56	2.4
12-28-70	6.04	17.10	2.80	0.59	0.11	0.00	0.66	2.0
1-9-71	3.35	17.73	2.45	1.02	0.00	0.06	0.32	0.0
1-21-71	--	18.36	2.10	1.02	0.00	0.03	0.32	0.0
2-4-71	3.70	19.14	1.82	1.14	0.00	0.14	0.35	0.0
2-24-71	4.47	17.40	1.82	1.14	0.02	0.20	0.44	0.0
3-12-71	8.83	18.63	1.26	1.22	0.60	0.10	0.78	1.8
3-28-71	29.97	14.75	6.72	0.06	0.05	0.50	0.41	9.2