Chemical and Biological Survey of the Upper Gila River System in New Mexico: Preliminary Study of Nutrients in Snow and Quemado Lakes

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Table of Contents

Abstract

Baseline water quality was investigated for a sector of the Gila River System near its headwaters in New Mexico. A part of this system is very heavily used for recreation. In addition, three fishing/recreational lakes were studied to attempt to find the causative factors for destructive algal blooms. Levels of nutrients, heavy metals, bacteria and algae were determined in addition to general water chemistry profiles. It was found that although algal blooms occur, especially in Snow Lake, the nutrient levels were not exceptionally high. Elevated nitrogen concentrations were probably due to fixation of nitrogen by microorganisms. A significant factor seemed to be the available phosphate in Snow Lake. This lake also warmed earlier than Quemado Lake which may have been important in providing a longer period for algae growth. A few heavy metal levels were higher than would have been expected. No correlation appeared between bacterial counts and water chemistry.

List of Figures

List of Tables

INTRODUCTION

The waters studied are a part of the Gila River headwaters with the exception of Quemado Lake. This lake was included because it is in the same recreational use area.

A large portion of the watersheds are in National Forest wilderness. The area is used mainly for recreation such as backpacking, camping, hunting, and fishing. Cattle grazing occurs in the Snow Lake and Quemado Lake drainages and logging was taking place in the Quemado Lake watershed during the study period. No mining operations were in the area nor had any large fires occurred in the watershed recently. The wilderness streams are surrounded by spruce/fir/Ponderosa vegetation while the lakes are in areas dominated by Ponderosa and grassland.

The lakes have been subject to algal blooms in the past with a serious bloom lethal to trout in 1975. (Anderson and Solomon 1977)

The purposes of the study are:

1) To determine the overall quality of the water in the Upper Gila River and Quemado Lake watersheds, and
2) To assess nutrients entering and present in Snow, Wall and Quemado Lakes.

SAMPLING

Sample Sites

The sample site locations are shown in Figure 1 and photographs are presented in the Appendix (Figures 14-18).

Snow Lake normally contains about 1600 acre-feet ($1.97 \times 10^6 m^3$) with a surface area of 100 acres (40.5 hectares). It is located about 25 miles (40 km) southeast of Reserve at an altitude of 7400 feet (2.2 km). It is used very heavily for recreation. The primary water source for this lake is Snow Creek.

The lake effluent flows into the Middle Fork of the Gila River.

Quemado Lake is located about 14 miles (22.5 km) south of Quemado, N.M. on Largo Creek at an altitude of 7630 feet (2.3 km). The lake contains about 2000 acre-feet ($2.47 \times 10^6 m^3$) of water with a surface area of about 130 acres (52.6 hectares). Quemado Lake is another heavily used fishing lake. The effluent from this lake eventually drains into the Little Colorado Rover.

The Willow Creek-Gilita system is another heavily used recreational area with fishing, hiking and camping the main uses. The Gilita along with Snow Creek forms the Middle Fork of the Gila River which is in the Gila Wilderness at this point. There are three campgrounds located along the system upstream from the confluence with Snow Creek as well as a few cabins located above the campgrounds on Willow Creek. Wall Lake, another fishing lake drains into the East Fork of the Gila River and is located 8 miles (12.9 km) south of the Beaverhead Ranger Station and has a campground adjacent to it. Wall Lake is at 6400 feet (1.9 km) and has a surface area of about 20 acres (8.1 hectares).

At the major stations, samples were collected at 4 times of the year to reflect a complete cycle from 11/77 - 11/78. Four samples were collected from Willow Creek above (site 1) and below the campgrounds (site 2), from the Gilita (site 3) before its confluence with Snow Creek, from the Middle Fork of the Gila below the Gilita (site 4), from Snow Creek (site 5), and from Snow and Quemado Lakes. Single samples were collected at Wall Lake and its inlet stream and the San Francisco River south of Reserve (site 6). The sampling sites are shown in Figure 1.

Sample Collection

All water samples were collected by the "grab" method at the same sampling site for each sampling time. The streams were small and well-mixed by turbulence. The lake samples were collected at the surface. Samples for general chemistry

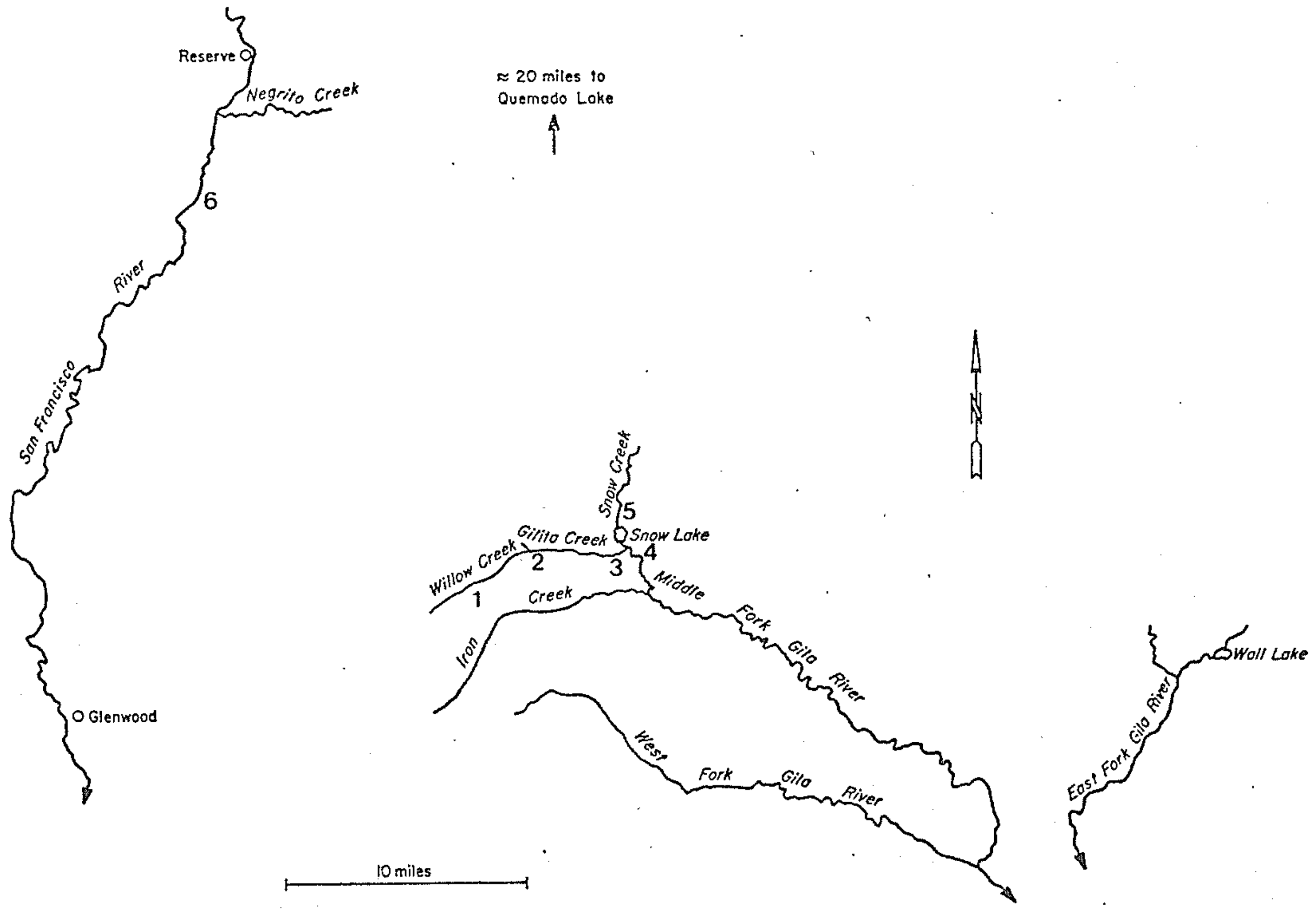


Figure 1

Map of Sampling Area and Sites

and heavy metal analysis were collected in acid-washed bottles. The samples for heavy metal analysis were stabilized to pH 2 with a few drops of concentrated nitric acid. Samples were stored on ice in a cooler for return to the laboratory. Sampling trips lasted 2-3 days.

Water for analysis of nitrogen species was collected in liter bottles containing 5 ml of 3N sulfuric acid saturated with chloroform to inhibit biological nitrogen conversions. Soil samples were collected in the Snow Lake, Wall Lake and Quemado Lake inlet watershed using a coring device. The samples from each drainage were mixed, and a portion removed for analysis according to standard procedures (Hesse, 1971).

Physical Parameters

The physical parameters determined were pH, temperature, specific conductance, dissolved oxygen, total dissolved solids, and sediment. Dissolved oxygen, temperature, and conductivity were determined in the field using a Model 54 oxygen meter and Model 33 conductivity meter manufactured by the Yellow Springs Instrument Company, Yellow Springs, Ohio. The pH values were determined in the field using an Orion Model 407 portable pH meter. Total dissolved solids and sediment were measured following the procedures outlined in Standard Methods for the Examination of Water and Wastewater, 14th Edition (APHA 1975) (hereafter referred to as Standard Methods).

Chemical Parameters

Silica, dissolved phosphate, sulfate, nitrite and chloride were determined according to procedures outlined in Standard Methods - 14th Ed. (1975) or in Methods for Chemical Analysis of Water and Waste (EPA 1974). Mercury was measured using the flameless atomic absorption method of Hatch and Ott (1968) and a Coleman Model MAS-50 Mercury Analyzer, except that tin (II) chloride was used to reduce mercury rather than tin (II) sulfate. Total mercury values were obtained by digesting the samples with sulfuric acid and excess potassium permanganate. Total phosphate was determined by digestion of unfiltered samples with sulfuric acid and hydrogen peroxide as described by Golterman (1970) followed by colorimetric estimation for dissolved orthophosphate. Bicarbonate and carbonate were measured in the field using a field test kit, model AL-AP manufactured by the Hach Chemical Co., Ames, Iowa. The results of the field tests have been checked in the laboratory by titration and found to agree within 5%. It is felt that the field results will be more valid since temperature changes may occur when transporting the sample from field to laboratory, which can affect the carbonate-bicarbonate ratio. Because of the location of the sampling sites, it was often several days before the samples were returned to the laboratory. Heavy metals with the exception of zinc, mercury, boron and uranium were determined using graphite furnace atomic absorption with a Model 2000 HGA graphite furnace attachment to a Model 403 atomic absorption spectrophotometer manufactured by Perkin-Elmer Corp. Calcium, magnesium, sodium, potassium and zinc were analyzed by flame atomic absorption spectroscopy. Uranium and boron were determined colorimetrically by dibenzoylmethane (Horton and White, 1958) and carminic acid (Standard Methods) procedures respectively.

Kjeldahl nitrogen was analyzed by the method of Golterman (1970) except that the Nessler's Reagent was made up according to Hawk (1965). Nitrate, ammonia, and easily hydrolyzed nitrogen were analyzed according to Golterman (1970).

The soil samples were dried at 110°C and digested for Kjeldahl nitrogen and total phosphate analysis. Dissolved phosphate and nitrate measurements were carried out by extracting dried soil with water by Soxholet Apparatus for 24 hours, bringing the sample up to volume and then analyzing by the procedures above.

Bacteriological Studies

The bacteriological quality of the Gila River system and Snow, Quemado, and Wall Lakes was monitored for the purposes of evaluating present water quality and the effect of the various land uses on the water quality.

All samples were stored on ice in a cooler while in the field. Water samples were processed within 24 to 48 hours after return to the laboratory. When necessary, samples were diluted with 0.5% (w/v) peptone in distilled water. Standard Methods Agar (BBL) was used for obtaining a total count of bacteria able to grow aerobically at 35°C after 48 hours incubation. Endo Agar (BBL) was used for counting total and fecal coliform bacteria. The inoculated plates were incubated at 35 and 44°C for the respective determinations. Colony counts were made after 48 hours incubation. Fecal streptococci concentrations were determined using M-Enterococcus Agar (BBL) following 48 hours incubation at 35°C. All bacteria were enumerated using the pour-plate method, and one sample set (5-17-78) was also processed using the membrane-filter method (Millipore, 0.45 μm pore size) for fecal streptococci and fecal coliforms.

Algal Studies

Samples were collected from Snow, Quemado and Wall Lakes for identification of planktonic and attached algae in order to determine if there is correlation among land and water use, chemistry, bacteriology, and algae. The algae were identified using the keys of Prescott (1970) and Smith (1950).

RESULTS AND DISCUSSION

Nutrients

Nutrient data for the lakes are presented for comparison in Figures 2-7. The most striking findings were high levels of Kjeldahl nitrogen (Fig. 6) and ammonia (Fig. 7) found in Snow Lake and to a lesser extent in Quemado Lake. These elevated values were roughly coincident with algal blooms. The patterns were similar in both lakes, however, Quemado Lake peaked later than Snow Lake. These high nitrogen levels may be caused by the nitrogen fixing algae *Anabeana* and *Aphanizomenon*. As the nitrogen values were increasing, the total phosphate

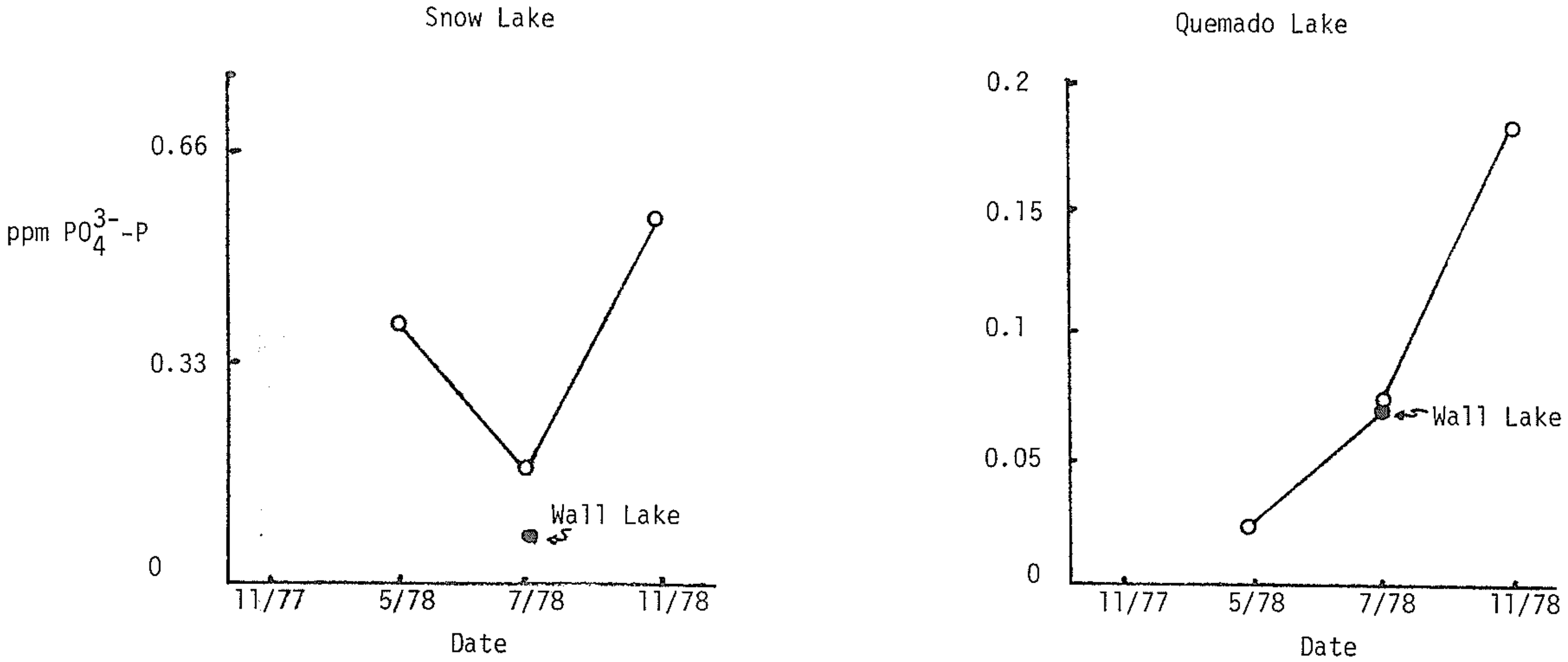


Figure 2 - Total Phosphate-P

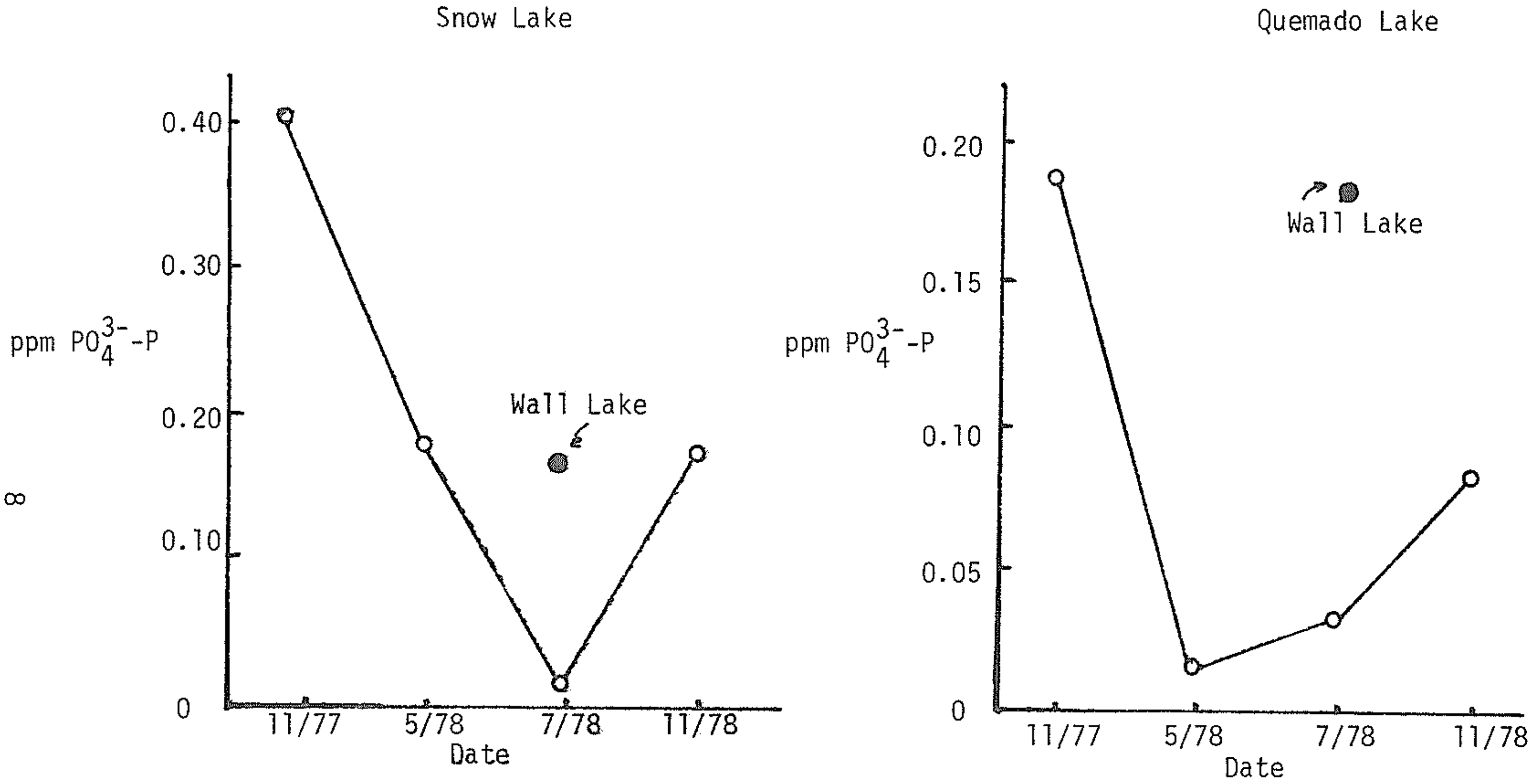


Figure 3 - Dissolved Phosphate-P

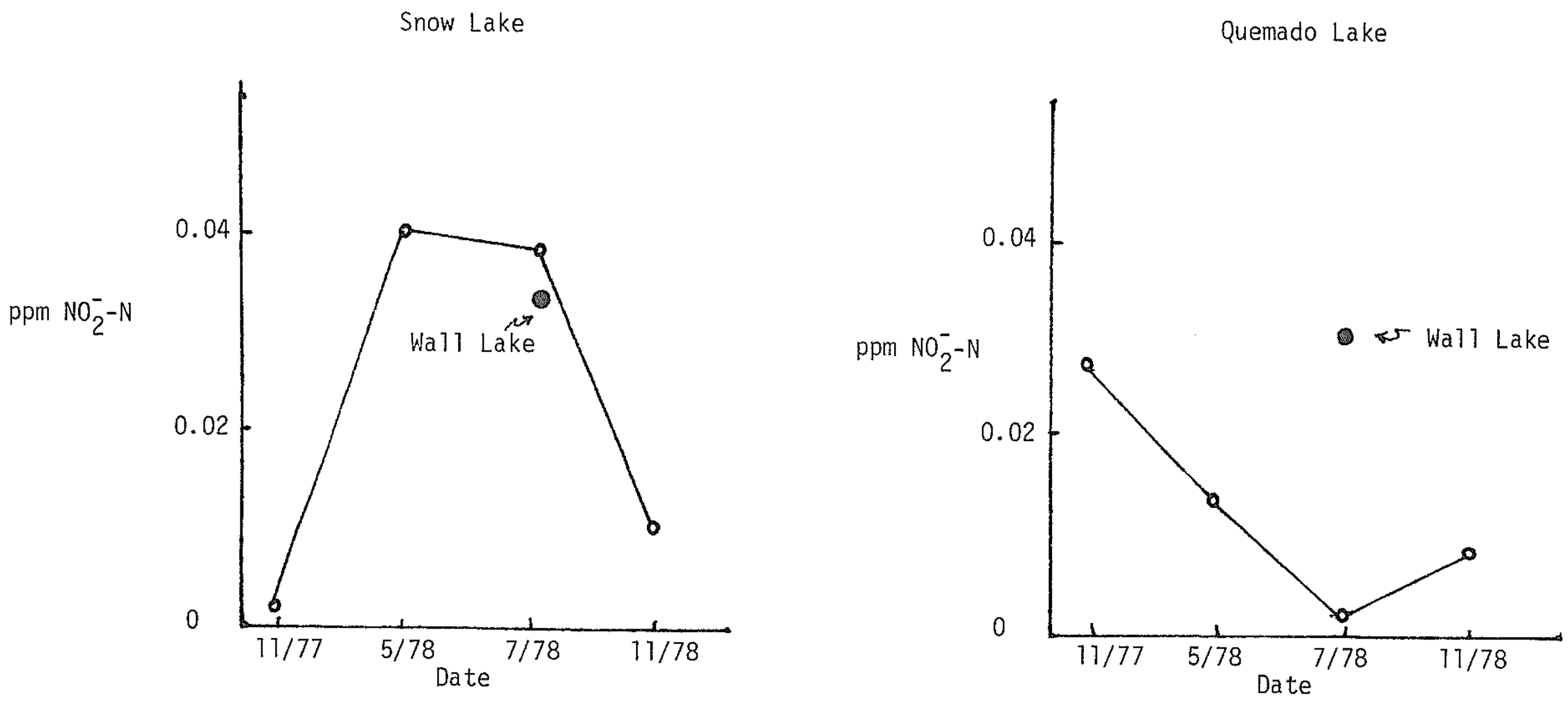


Figure 4 - Nitrite-N

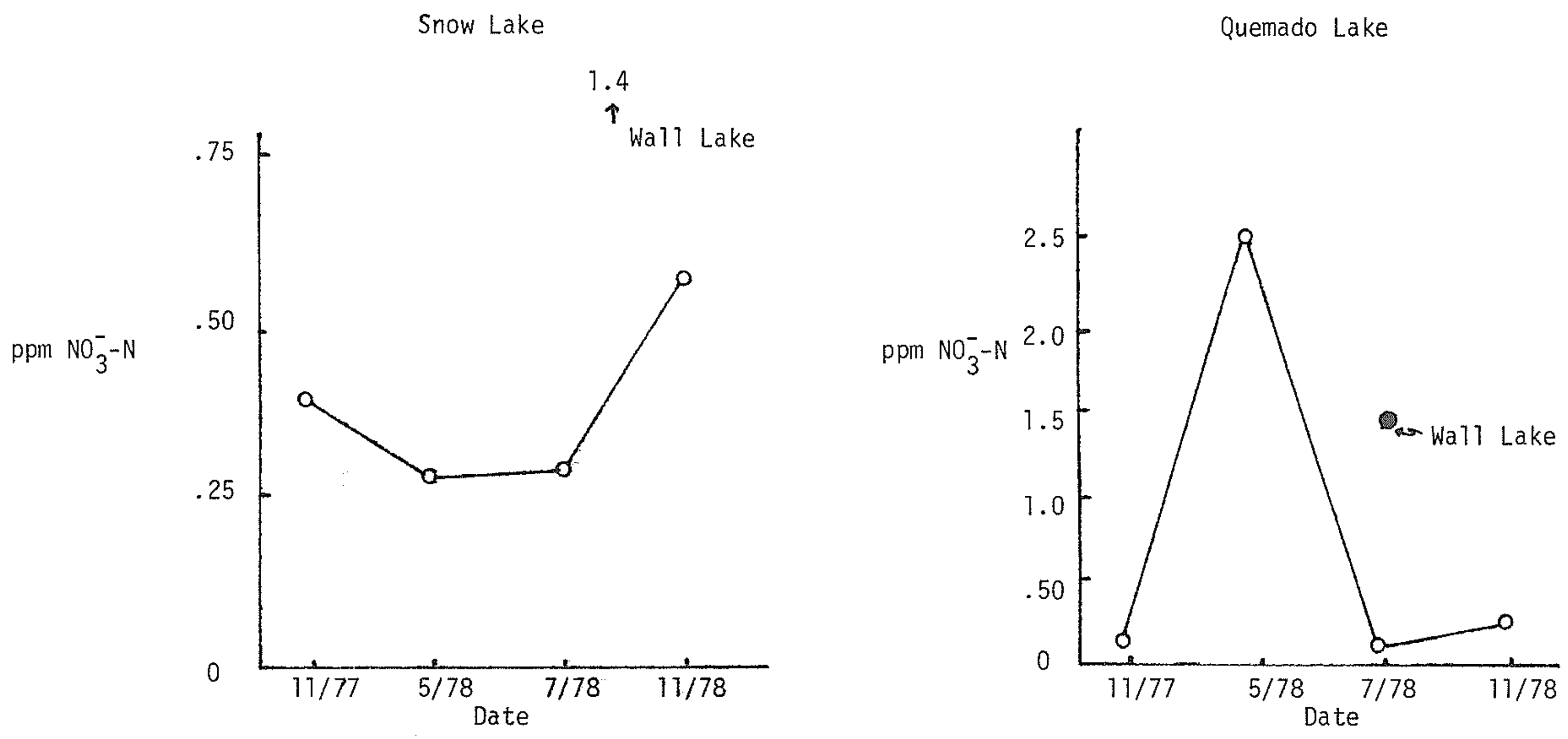


Figure 5 - Nitrate-N

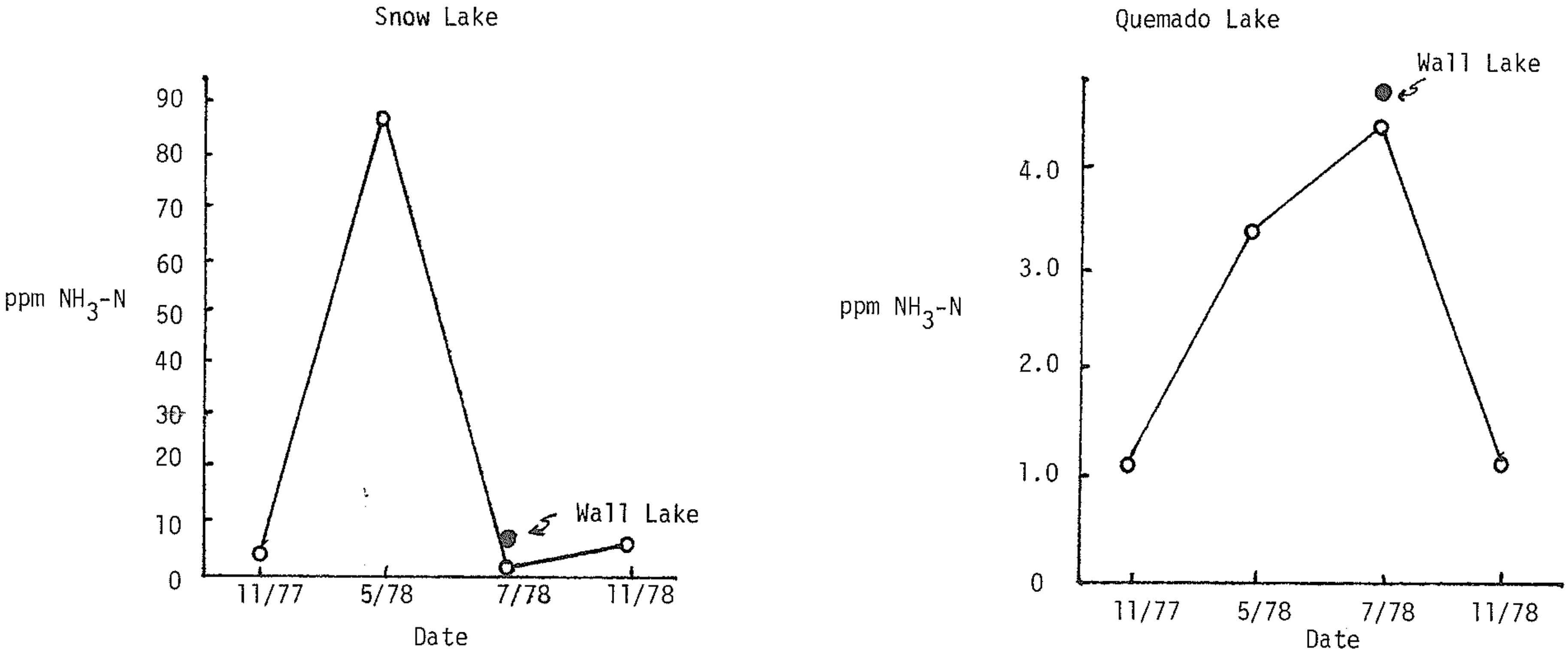


Figure 6 - Kjeldahl N

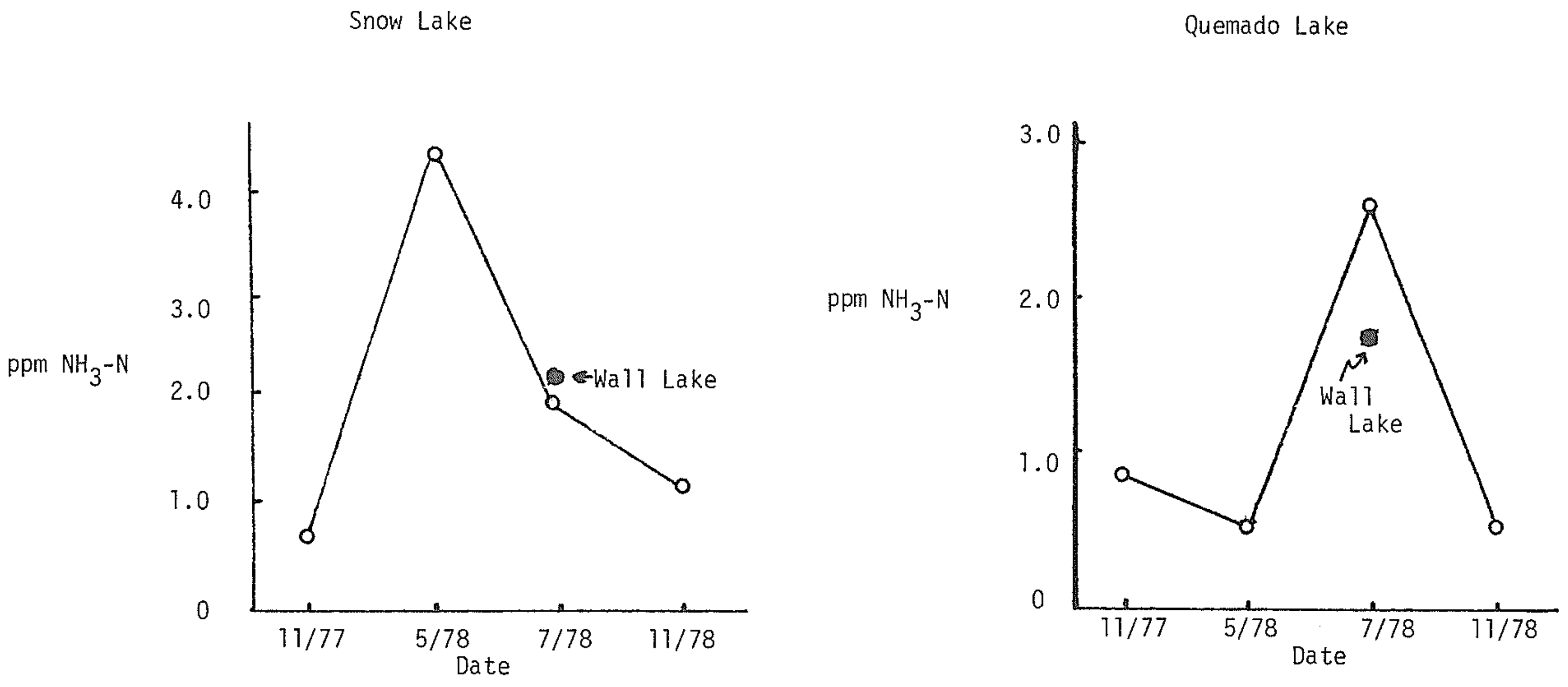


Figure 7 - Ammonia-N

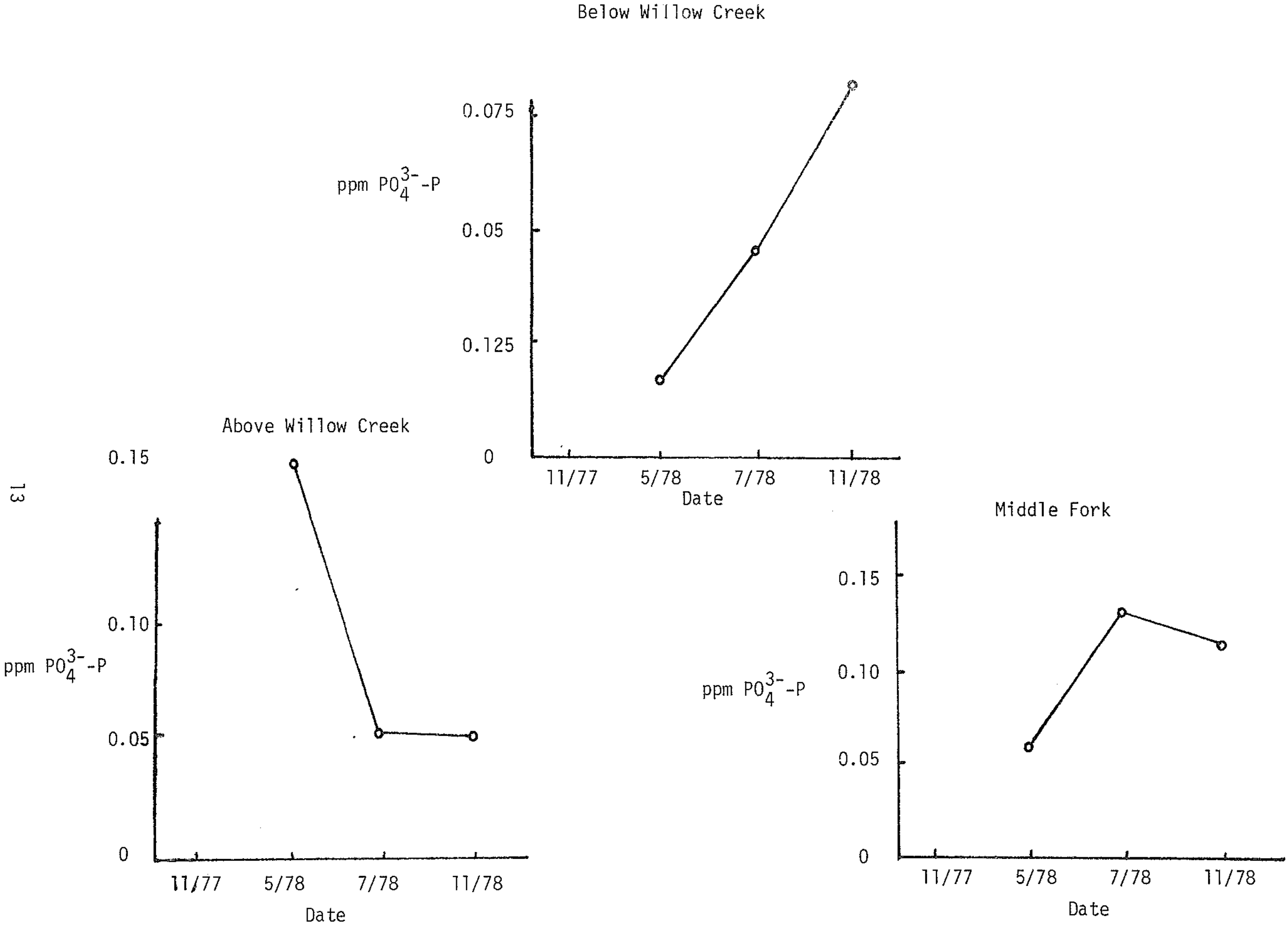


Figure 8 - Total Phosphate-P

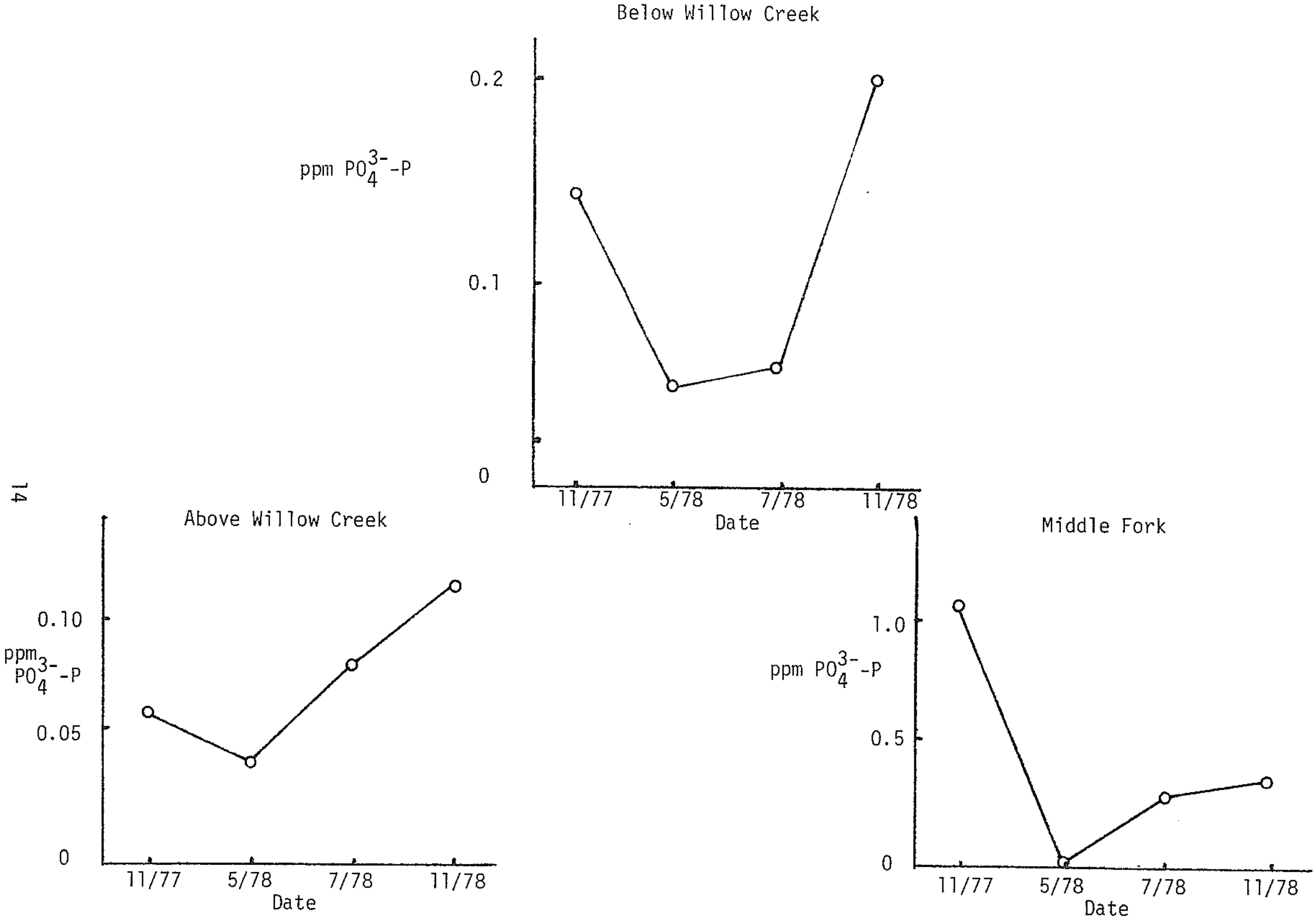


Figure 9 - Dissolved Phosphate-P

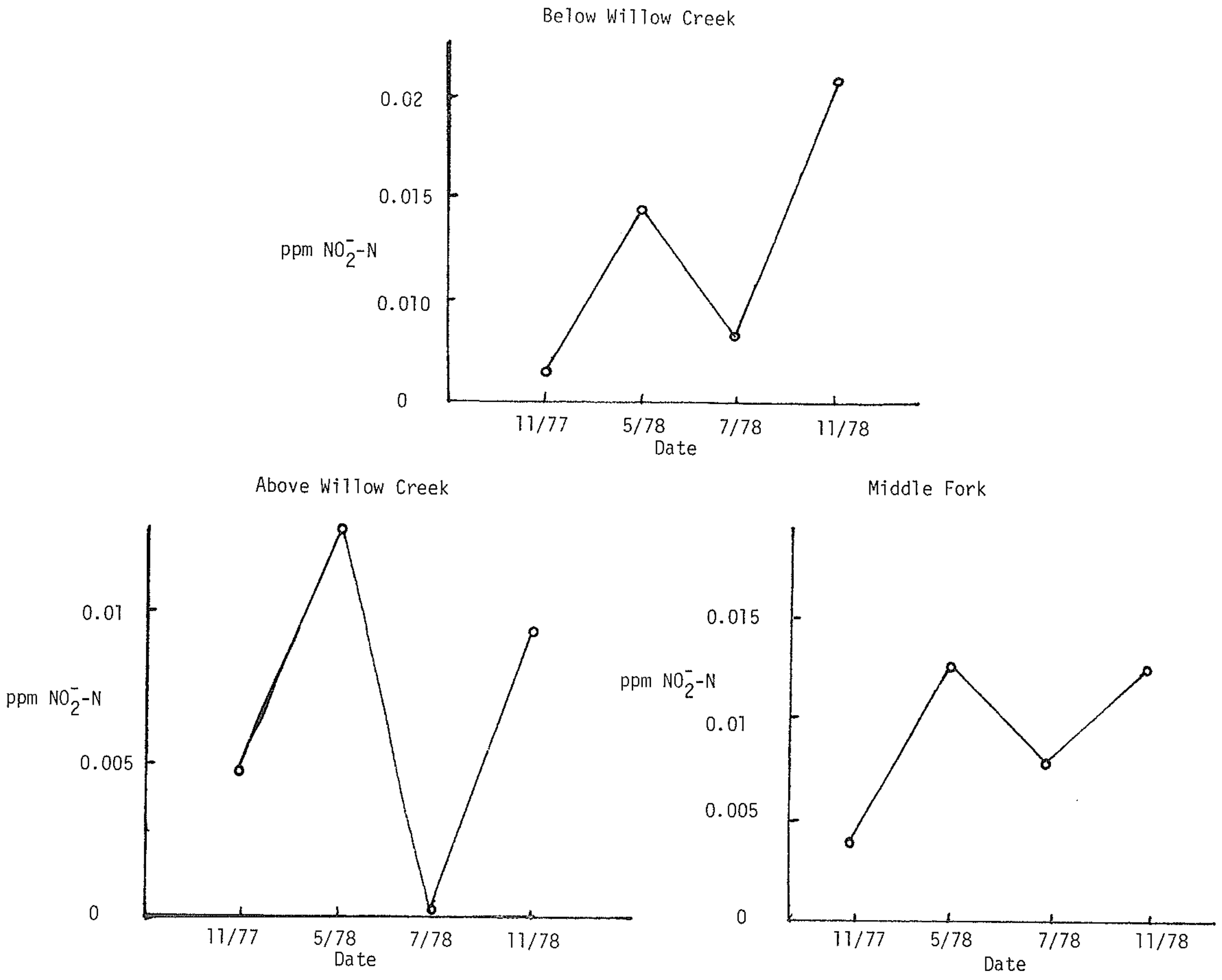


Figure 10 - Nitrite-N

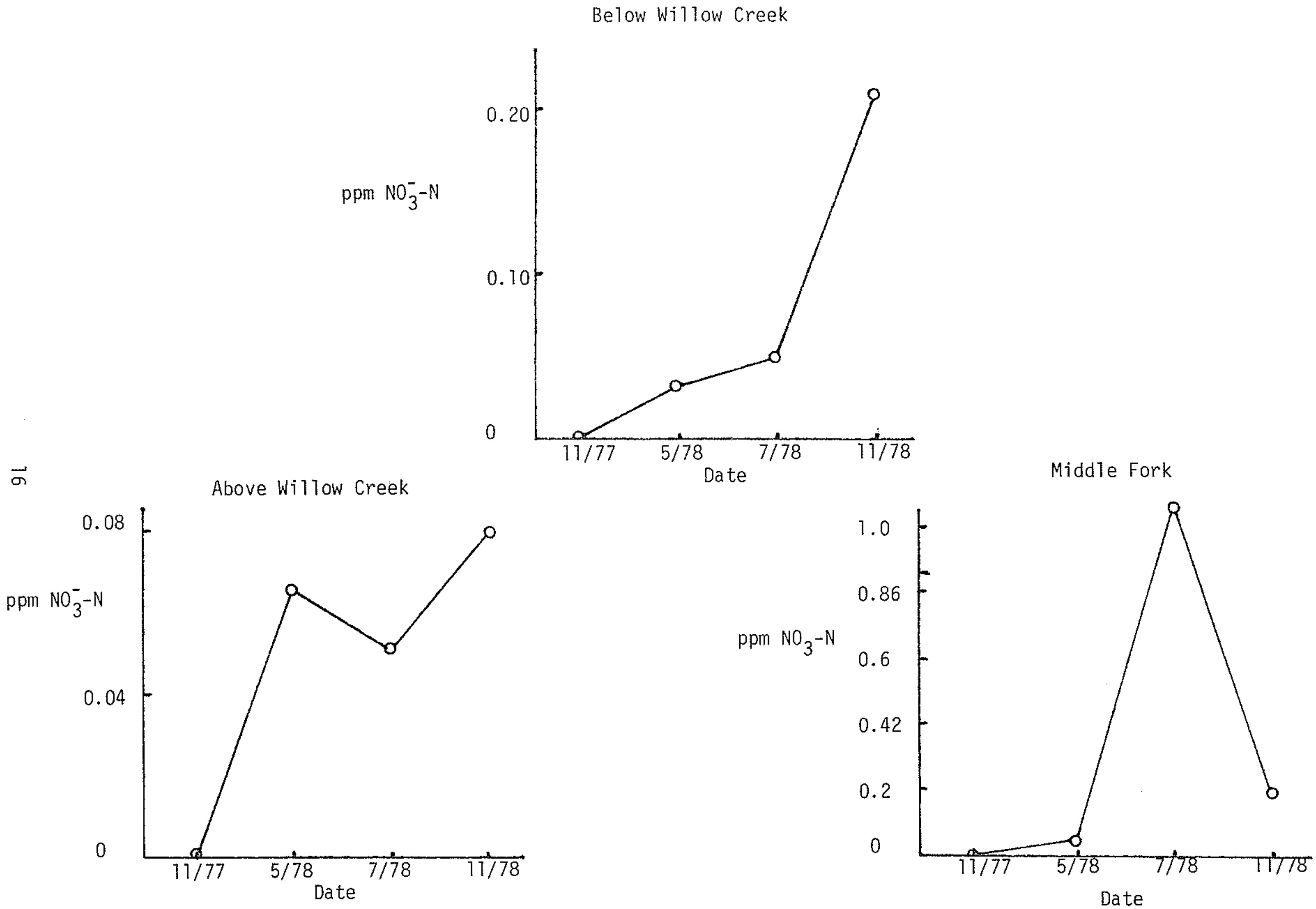


Figure 11 - Nitrate-N

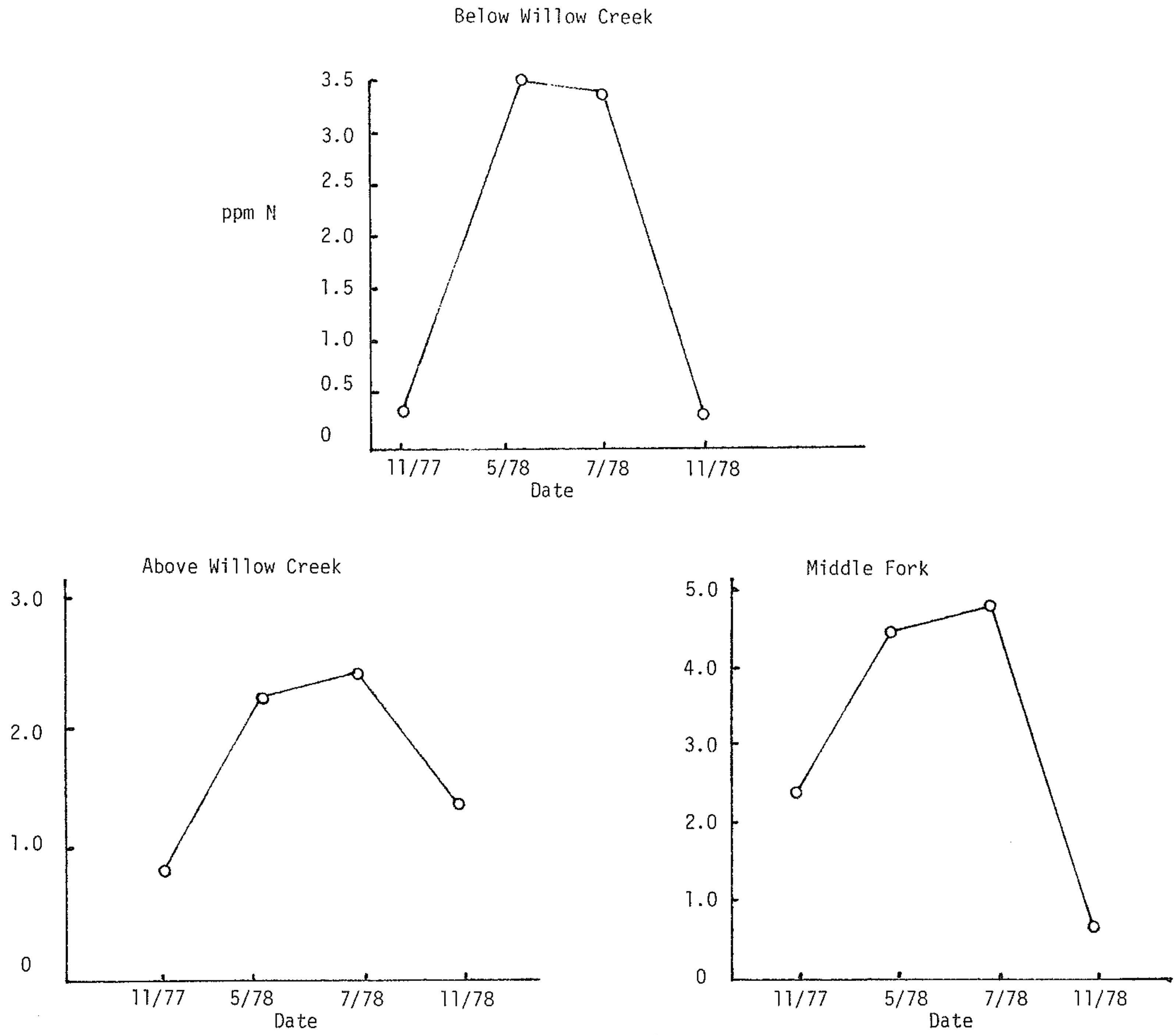


Figure 12 - Kjeldahl N

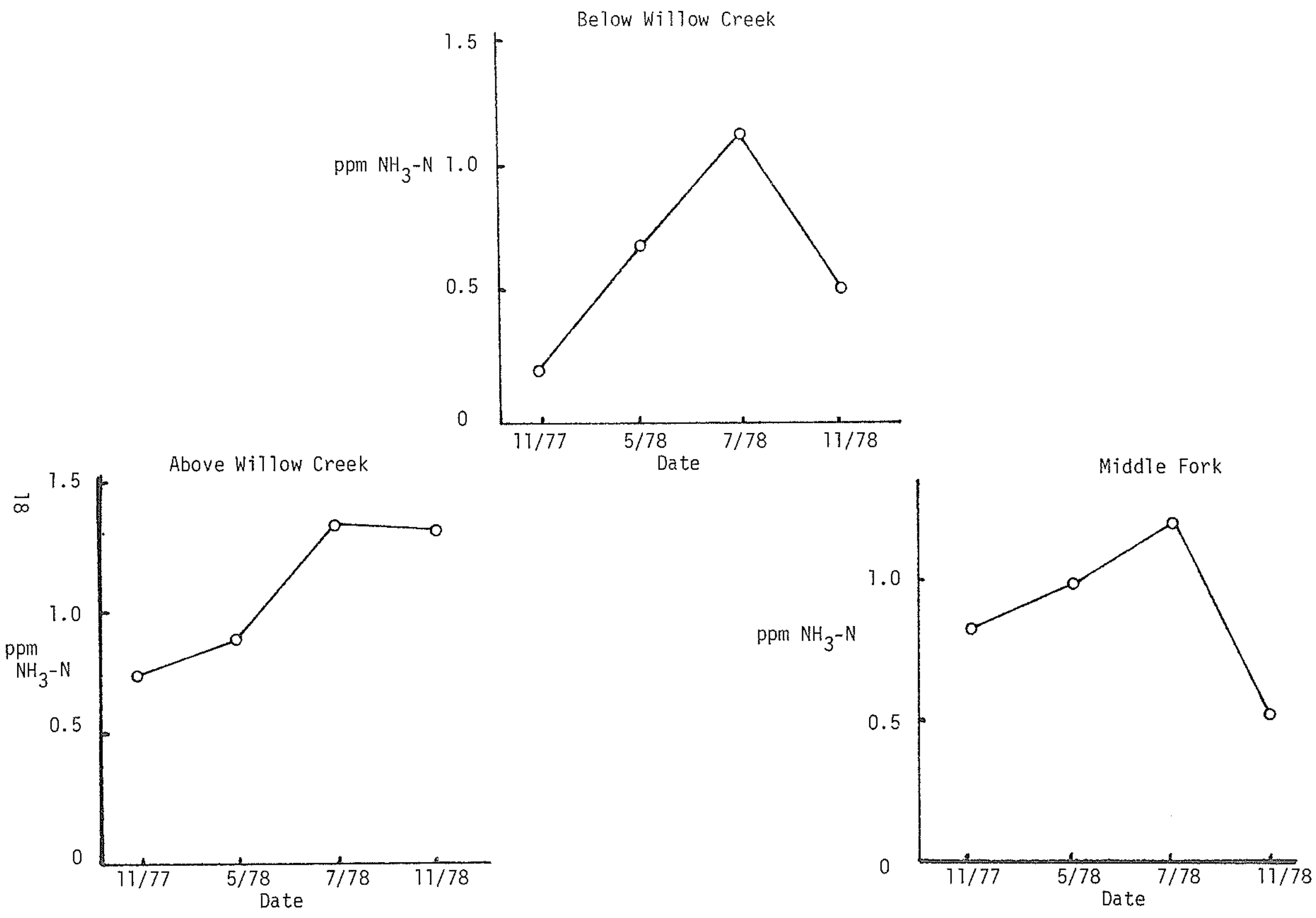


Figure 13 - Ammonia-N

Soils	KN as N	NO_3 - N	Extractable PO_4 - P	Total PO_4 - P
Quemado Lake (5/17/78) (1)	42.9	0.88	15.4	203
Quemado Lake (5/17/78) (2)	43.7	0.46	13.8	451
Snow Creek Drain (5-17-78)	10.7	0.83	33.9	65
Wall Lake (8/2/78)			2.0	21

Table 1

Nutrients in Soil Samples
From Lake Inflows
Values in ppb

(1) Campgrounds Drain

(2) Largo Creek

(Fig.2) and dissolved phosphate (Fig. 3) levels were decreasing. This may also have been related to the algal population. The total phosphate and dissolved phosphate in Snow Lake were signficantly higher than in Quemado Lake. The earlier and more severe bloom in Snow Lake may be at least partially due to these higher phosphate values.

It may be risky to draw conclusions from only one set of data, but if one looks at the nutrient data for the soil samples there is one major difference in the influent (Table 1). The extractable phosphate available in the Snow Creek drainage was double that of the Quemado drainages. Phosphate is often believed to be the limiting factor in eutrophic systems without N-fixing bacteria.

Nitrate and nitrite data (Figs. 4,5) do not allow for any conclusions. The trends in Snow Lake and Quemado Lake were opposed. The nutrient data on the streams are presented in an upstream to downstream format (Figs. 8-13) and showed these general trends: dissolved phosphate was higher in the winter than in summer, Kjeldahl nitrogen and ammonia increased during the summer months and decreased in the fall, nitrite and nitrate levels were high in May, lower in July and increased somewhat in November of 1978. Willow Creek had a high nitrate content in the fall of 1978. Total phosphate values increased in the summer below the Willow Creek campgrounds and in the Middle Fork. This increase did not take place above the campgrounds. The change may reflect camper use. There was an increase in Kjeldahl nitrogen and ammonia from upstream to downstream especially evident in the Middle Fork. This was probably due to nitrogen outflow from Snow Lake. Dissolved phosphate also exhibited this behavior to a degree. None of the other nutrient species appeared to increase significantly downstream.

Comparative Data for Nutrients in Snow, Wall, and Quemado Lakes

On the sampling trip in May, 1978, Snow Lake was already experiencing an algal bloom while Quemado Lake was not. This prompted inclusion of Wall Lake into the sampling schedule for July, 1978, to obtain a comparison of the beheavior of nutrients in the three lakes and these values are presented in Table 2. In May, Snow Lake (23°C) had much higher Kjeldahl N and higher ammonia and phosphorus values than Quemado Lake (12°C) and it is probable that N-fixing cyanobacteria were much more active in Snow Lake due to the water temperature difference.

In July when the water temperatures were essentially the same the nutrient values were much more equivalent in the three lakes and pH values had risen as a function of increased photosynthesis. The nitrate values were higher in both Snow and Wall Lakes than in Quemado Lake for the July sampling whereas the opposite effect was shown in Quemado and Snow Lake in May. A more detailed study of the three lakes would be necessary to determine the extent of the trends indicated in this limited sampling but there appears to be significant difference in the nutrient flux.

The nutrient data does not indicate a cause for the bloom conditions of Snow and Quemado Lakes since the nutrient levels in Wall Lake, which did not have an apparent bloom, are all comparable. However, it would be better to obtain data before the blooms since the July values are essentially past bloom.

Microbiology

The "total" counts of microorganisms in the river and lake waters of the Gila system are quite variable and do not appear to exhibit any seasonal pattern (Table 3). The greatest concentration of microbes occurs in Quemado and Snow Lakes; these lakes are considered to be eutrophic (Dr. Douglas Caldwell, personal communication). The concentrations of bacteria in the flowing waters are not greatly different than values determined for high-mountain streams in

	NO_2^--N	NO_3^--N	NH_3-N	Kjeldahl N	Diss. PO_4-P	Total PO_4-P	pH	Temp
Wall Lake - 7/78	.003	1.40	1.12	4.1	.06	.18	9.2	25
Snow Lake - 7/78	.036	2.55	1.04	1.4	.02	.19	9.3	22
Quemado Lake - 7/78	.000	.16	1.60	3.7	.03	.07	9.3	20
Snow Lake - 5/78	.036	.3	2.24	56[b]	.19	.40	7.8	23
Quemado Lake - 5/78	.012	2.61	.32	2.9	.01	.03	8.3	12

Table 2

Comparison of Wall Lake, Quemado Lake and Snow Lake
Nutrient Species, pH and Temperature - 5/78[a] and 7/78
Values in ppm except pH and Temperature

a - A sample was not collected at Wall Lake on this sampling trip.

b - An unfiltered sample had a value of 59 ppm.

Table 3

Gila Bacterial Counts: Standard Plate Count

Colony Count ml^{-1}

Sample	11/20/78	5/17/78	7/23/78	11/11/78	$\bar{M}$
Quemado Lake	4.4×10^3	1.6×10^4	4.7×10^3	2.9×10^3	$1.7 \pm 1.9 \times 10^4$
Snow Lake	1.0×10^3	2.0×10^3	2.4×10^5	1.1×10^4	$6.3 \pm 11.8 \times 10^4$
Above Willow Creek	1.0×10^2	2.4×10^3	2.2×10^2	3.2×10^3	$1.5 \pm 1.5 \times 10^3$
Below Willow Creek	1.0×10^2	5.7×10^3	4.0×10^2	1.3×10^4	$4.8 \pm 6.0 \times 10^3$
Gilita Above Willow Creek	----	6.7×10^3	----	----	-----
Gilita	----	1.5×10^3	3.3×10^2	1.7×10^4	$6.3 \pm 9.3 \times 10^3$
Middle Fork Gila	7.5×10^2	6.9×10^2	1.4×10^3	1.3×10^4	$3.9 \pm 6.0 \times 10^3$
Snow Creek	----	5.2×10^3	1.9×10^3	----	$3.5 \pm 2.3 \times 10^3$
San Francisco River	----	4.8×10^3	----	----	-----
Wall Lake	----	----	3.8×10^3	----	-----
Wall Lake Effluent	----	----	3.2×10^3	----	-----

Table 4

Gila Bacterial Counts: Total Coliform Count

Colony Count ml^{-1}

Sample	11/20/77	5/17/78	7/23/78	11/11/78	$\overline{M}$
Quemado Lake	5.7×10^2	1.1×10^3	1.0×10^3	3.4×10^1	$6.8 \pm 4.8 \times 10^2$
Snow Lake	1.5×10^1	4.6×10^2	2.2×10^2	1.6×10^1	$1.8 \pm 2.1 \times 10^2$
Above Willow Creek	<1	1.2×10^2	2.3×10^1	7	$3.7 \pm 5.6 \times 10^1$
Below Willow Creek	<1	4.8×10^2	1.7×10^1	1.2×10^1	$1.3 \pm 2.3 \times 10^2$
Gilita Above Willow Creek	--	3.7×10^2	--	--	--
Gilita	--	1.8×10^2	1.3×10^1	2	$6.5 \pm 9.9 \times 10^1$
Middle Fork Gila	1.0×10^1	9.7×10^1	7.8×10^1	4	$4.7 \pm 4.7 \times 10^1$
Snow Creek	--	3.4×10^2	1.1×10^2	--	$2.2 \pm 1.6 \times 10^2$
San Francisco River	--	3.1×10^2	--	--	--
Wall Lake	--	--	5.2×10^2	--	--
Wall Lake Effluent	--	--	2.7×10^2	--	--

Table 5

Gila Bacterial Counts: Fecal Coliform Count

Colony Count ml^{-1}

Sample	11/20/78	5/17/78	Colonies $100\ ml^{-1}$ 5/17/78	7/23/78	11/11/78	$\overline{M}$
Quemado Lake	4.5	<1	2	<1	2	1.3 ± 2.0
Snow Lake	<1	1	27	5	13	4.7 ± 5.9
Above Willow Creek	<1	<1	2	2.5	2	1.1 ± 1.3
Below Willow Creek	<1	<1	6	1.5	1	0.6 ± 0.7
Gilita Above Willow Creek	--	<1	2	--	--	--
Gilita	--	<1	3	1	5	2.0 ± 2.6
Middle Fork Gila	<1	<1	5	2.5	9	2.9 ± 4.2
Snow Creek	--	1	3	1	--	1.0 ± 0
San Francisco River	--	1	24	--	--	--
Wall Lake	--	--	--	<1	--	--
Wall Lake Effluent	--	--	--	1	--	--

Table 6

Gila Bacterial Counts: Fecal Streptococci

Colony Count ml^{-1}

Sample	11/20/77	5/17/78	Colony 100 ml^{-1} 5/17/78	7/23/78	11/11/78	$\overline{M}$
Quemado Lake	<1	<1	<1	<1	66	$1.6 \pm 3.3 \times 10^1$
Snow Lake	<1	<1	<1	14.5	3.5	4.5 ± 6.9
Above Willow Creek	<1	<1	2	2	2	1.0 ± 1.1
Below Willow Creek	<1	<1	15	1.5	6.5	2.0 ± 3.1
Gilita Above Willow Creek	--	<1	7	--	--	--
Gilita	--	<1	5	2.5	1.5	1.3 ± 1.2
Middle Fork Gila	<1	<1	4	3.5	3	1.6 ± 1.9
Snow Creek	--	<1	13	5	--	2.5 ± 3.5
San Francisco River	--	1	129	--	--	--
Wall Lake	--	--	--	1	--	----
Wall Lake Effluent	--	--	--	<1	--	----

Table 7

Algae Present in Lakes Samples

Date	Snow Lake	Quemado Lake
11/20/77	No Bloom	No Bloom
5/17/78	Bloom: _Anabeana_ Other Algae noted: _Spirogyra_ _Rhizoclonium_ _Pandorina_	No Bloom Algae noted: _Cladophora_
7/25/78*	Bloom: _Anabeana_ _Polycystis_ Other Algae noted: _Cladophora_	Bloom: _Aphanizomenon_ _Anabeana_
11/27/78	No Bloom	No Bloom Algae noted: _Aphanizomenon_

* Wall Lake samples
No Bloom
Algae noted:
Spirogyra
Rhizoclonium

Montana watersheds (Stuart et al., 1971). However, the Gila stream bacterial concentrations are much less than those for the high-sediment Rio Grande water (Brierley et al., 1975).

The concentrations of bacterial populations associated with pollution conditions are presented in Tables 4, 5, and 6. Higher values for total coliform and fecal streptococci concentrations are also noted for the eutrophic Snow and Quemado Lakes. However, it is not clear from this study whether these higher concentrations reflect processes which lead to eutrophication or are a result of nutrient enrichment. The influence of an established, well-used,campground on water quality is indicated comparing the data for samples taken above the Willow Creek campground (Tables 4, 5, and 6). There does not appear to be any significant contribution of indicator microorganisms to Willow Creek from the campground. Established campgrounds with sanitary facilities do not appear to cause significant water pollution (Aukerman and Springer, 1976 reported by Varness et al., 1978). A possible source of the coliform group microorganisms may be the sanitary facilities of the cabins near Willow Creek. However, large animal populations (both domestic and wild) also contribute to bacterial stream pollution (Stuart, et al., 1971). The relatively high counts of total coliforms and fecal streptococci in Snow Creek may reflect an animal source, but this is not certain.

Algae

The identified algae and bloom conditions are presented in Table 7 and photographs of selected algae identified are presented in the Appendix (Fig. 17, 18).

Distinct algae blooms were noted in Snow Lake during the May and July samplings, in Quemado Lake during the July sampling, but not in Wall Lake during

July. The photographs in Figure 14 (Appendix) illustrate the condition of the lakes. The nitrogen fixing *Anabeana* were dominant in Snow Lake during the bloom and *Anabeana* and *Aphanizomenon* were most abundant in the Quemado Lake bloom. These Cyanophyta (blue-green algae) were previously noted to be present in the blooms of these lakes with *Aphanizomenon* dominating the Quemado Lake bloom (D. Caldwell, personal communication). *Anabeana* and *Aphanizomenon* were also predominant in blooms occurring at Cochiti and Abiquiu Reservoirs in New Mexico (Johnson and Barton, 1978) and *Anabeana* was predominant in the shallow, alkaline Lagunitas Lakes in northern New Mexico (Johnson and Foster, 1978). The *Polycystis* noted occurring in Snow Lake has potential of causing toxicity problems. Prescott (1970) states that some *Polycystis* (syn. *Microcystis*) species produce a toxin that could cause death of cattle, birds, and possibly fish. However, it is not known if the *Polycystis* observed in Snow Lake is toxigenic.

The basis for nuisance blooms of algae particularly the Cyanophyta, is undoubtedly complex and not well defined. Increased temperature plus some nutrient factor has been reported to lead to algae blooms (Konopka and Brock, 1978) and this could well be one factor in the summer blooms of algae noted for Snow and Quemado Lakes. Snow Lake warms earlier in the season than Quemado Lake, (Table 2) and this may well account for the earlier appearance of the algae bloom in Snow Lake (Table 7). Increased alkalinity of water, thereby increasing available CO_2, has been implicated as a basis for blooms of the cyanophyta as this group is more efficient in utilization of limiting nutrients (Shapiro, 1973). Certainly increased nutrient availability leads to the eutrophication and algae bloom problems. The cyanophyta noted are nitrogen fixing, thereby they can directly influence nutrient cycles. Factors which could possibly lead to nutrient enrichment of lakes in the Gila area would be construction of forest roads, logging and overgrazing which increase erosion input and concomitant nutrient addition (Bartsch, 1970).

Heavy Metals

Heavy metal analyses are reported in Tables 8 and 9. The data in Table 8 is for filtered water samples and the data in Table 9 is for acid digested whole water samples. Because of the pristine, low sediment character of these waters, very little difference should be expected between the metal analysis for the filtered and whole water digestions and this is borne out in general by examining the two tables. Occasionally anomalously high values occur in the whole water digestions such as for chromium in the samples below Willow Creek and the Wall Lake inlet stream and for copper in the Middle Fork, Snow Creek and Wall Lake inlet stream samples. It is difficult to ascribe much significance to these apparent anomalies because only one sample was digested. Also, the values for metals are so low in these samples that the digestion procedure may introduce more metal as contaminant in the reagents than is present in the water.

A comparison of the metal values in the Gila area waters to typical values determined for the Rio Grande near Bernardo, N.M. can be made by referring to Table 10. Most metal concentrations in the study area are considerably lower than those in the Rio Grande. However, concentrations of cadmium, chromium, mercury and zinc are quite similar to the Rio Grande analysis. These could turn out to be problem species and should be monitored on a longer basis. Also, fish from the waters containing these species should be analyzed to ascertain whether or not biomagnification is occurring.

In addition to the high metal values mentioned above, the results for arsenic in Snow Creek and in the Wall Lake inlet and Wall Lake itself exhibit much higher values than any of the other waters. These localized areas may require further monitoring to determine the extent of the contamination. Also, a single high

Table 8

Heavy Metals In Filtered Water Samples
Values in ppb Followed by Standard Deviation
Three Samples Were Analyzed Unless Otherwise
Indicated by the Number in Parentheses
or in Table Heading

Site Key:

A.W.C. - Above Willow Creek
B.W.C - Below Willow Creek
Gil - Gilita Above Snow Creek
M.F. - Middle Fork Gila River Below Snow Creek
S.C. - Snow Creek Above Snow Lake
S.L. - Snow Lake
Q.L. - Quemado Lake
W.L.I.- Wall Lake Inlet
W.L. - Wall Lake
S.F.R.- San Francisco River

	Sample Sites[a]					
	S.C. (1 Sample)	S.L.	Q.L.	W.L.I. (1 Sample)	W.L. (1 Sample)	S.F.R. (1 Sample)
Arsenic	130.	53. ± 53.	30. ± 38.	120.	170.	33.
Boron	50.	150. ± 110.	740. ± 680.	170.	250.	220.
Beryllium	.07	.18 ± .06	.14 ± .10	.07	.06	.41
Barium	40.	77. (2)	33. ± 9.	4.6	8.1	25.
Cadmium	.24	29. (2)	.35 ± .33	1.2	.76	.5
Cobalt	11.	6.3 ± 3.3	3.8 ± .8	7.3	9.8	4.2
Chromium	4.5	2.9 ± 1.2	5.8 ± 6.5	4.6	22.	1.5
Copper	2.8	7.3 ± 1.6	4.5 ± 1.0	2.8	3.4	2.2
Mercury		3.0 ± 4.7	2.1 ± 3.3	0.8	1.4	1.0
Manganese		68. (2)	170. (2)			47.
Molybdenum		8.1 (2)	4.9 (2)			5.8
Nickel		9.7 (2)	5.5 (2)			14.
Lead	8.4	3.7 ± .6	1.9 ± .3	7.1	6.6	1.2
Selenium	8.7	7.0 ± 6.2	10. ± 11.	9.4	11.	54.
Vanadium	13.	8.2 (2)	5.3 (2)	14.	14.	14.
Zinc	82.	11. (2)	42. ± 22.	9.	27.	20.
Uranium	2.0	.77 (1)	59.		8.5	

a See Sample Site Code in Table Cover Sheet

Table 8

	Sample Sites[a]			
	AWC	BWC	Gil	MF
Arsenic	24. ± 33.	42.5 (2)	81.	39. ± 55.
Boron	960. (1)	85. (2)	400.	650. (2)
Beryllium	.035 ± .050	.075 (2)	0.000	.047 ±
Barium	20. ± 9.	41. (2)	14.	18. ± 3.
Cadmium	2.2 ± 2.7	.97 ± .7	.45	.28 ± .17
Cobalt	3.2 ± 3.1	3.6 ± 1.7	5.5	1.8 (2)
Chromium	1.1 ± .3	1.6 ± .5	1.8	4.0 ± 4.3
Copper	2.2 ± 1.4	4.1 (2)	3.2	1.6 ± .7
Mercury	3.3 ± 3.7	1.8 ± 2.4	2.6 (2)	3.0 ± 3.0
Manganese	8.2 (2)	38.		9.3 (2)
Molybdenum	5.9 (2)	4.6 (2)		6.1 (2)
Nickel	28. (2)	3.8 (2)		28. (2)
Lead	2.3 ± 1.2	3.6 ± 2.0	4.3	1.1 ± .5
Selenium	5.9 ± 7.2	.35 (2)	1.8	1.4 ± 1.0
Vanadium	4.2 (2)	9. (2)	8.8	4.8 ± 4.4
Zinc	20. ± 9.	31. ± 1.	52.	35. ± 27.
Uranium	.33 (1)	0.00 (1)		.99 (1)

a See Sample Site Code in Table Cover Sheet

Table 8 (Continued)

Table 9

Heavy Metals - Whole Water Digestions

Values in ppb - One Sample

Site Key:

A.W.C. - Above Willow Creek

B.W.C. - Below Willow Creek

GIL - Gilita Above Snow Creek

M.F. - Middle Fork Gila River Below Snow Creek

S.C. - Snow Creek Above Snow Lake

S.L. - Snow Lake

Q.L. - Quemado Lake

W.L.I. - Wall Lake Inlet

W.L. - Wall Lake

Sample Sites [a]

	AWC	BWC	GIL.	MF.	S.C.	S.L.	Q.L.	W.L.I.	W.L.
Arsenic	105	13	0	35	170	155	0	50	140
Barium	240	162	49	80	19	130	95	15	17
Cadmium	0.80	1.4	0.02	1.7	1.6	1.8	1.5	1.4	1.4
Chromium	0.6	58	3.8	5.3	4.4	5.9	16	54	4.4
Copper		1.2	39	43	40	6	1.2	41	4.0
Manganese	0.54	4.2	3.7	72	12	86	48	6.9	27
Lead	20	12	13	16	8.2		15	14	0.4
Selenium	11	0.0	5	18	23	0	15	2.6	18
Zinc	21	6	27	43	55	21	13		27

[a] See Site Code on Title Page

Table 9

Metal	Concentration - ppb
As	150
B	300
Be	1.0
Ba	120
Cd	.24
Co	28
Cr	2.9
Cu	16
Pb	17
Mn	570
Mg	1.6
Mo	13
Ni	40
Se	27
U	33
V	250
Zn	30

Table 10

Typical Values for Heavy Metals in Filtered Waters
of the Rio Grande at Bernardo, N.M.
Values are Average of four Analyses

value for uranium in Quemado Lake was obtained. Additional samples need to be analyzed for this metal to determine whether the anomaly is real or not.

General Chemical and Physical Character of the Water

The values obtained for macrochemical and physical properties of the water are summarized in Tables 12 and 13. Standard deviations are calculated where at least three samples were analyzed. The nutrient data has been discussed. It is clear upon examining Table 13 that the chemical character of Snow and Wall Lakes (excepting nutrients) is a reflection of the inlet streams. Dissolved oxygen values indicated saturation in all cases. In general, the values are quite low and again assert the relatively pristine character of these waters. A slight increase in dissolved solids occurs on the Willow Creek-Middle Fork portion of the Gila River system from upstream to downstream. This is a common phenomenon in streams. The Gila Wilderness streams (Willow Creek, Gilita, Middle Fork) have much lower concentrations of major ions and nutrients than Snow Creek or the Wall Lake inlet. This probably is due to the cattle grazing allowed on the latter two lake watersheds.

Summary and Conclusions

The project looked into various physical, chemical and biological characteristics of part of the Gila drainage Snow Lake, Wall Lake and Quemado Lake.

During the year, both Snow Lake and Quemado Lake had algal blooms with the Snow Lake bloom occurring much earlier. Possible contributing factors are earlier warming and more available phosphate. The nitrogen levels at times in Snow Lake were also high, however this could be due to algal fixation of nitrogen. The streams did not have significant levels of nutrients. Wall Lake did not seem to follow the trends in either Snow Lake or Quemado Lake. Similarities and differences need to be studied in more detail to obtain correlation among the lakes. Heavy metal values were mostly low. However a few metal levels were as high as in the Rio Grande at Bernardo, New Mexico. These metals are cadmium, chromium, mercury and zinc and should be monitored on a longer basis. Fish in these waters should be analyzed for the metals to determine if biomagnification is occurring.

The microbiological indicators of pollution conditions do not reflect any gross contamination of the water sampled. The highest mean value counts for total bacterial count occurred in the lake waters sampled. The lakes are nutrient rich and dense bacterial populations would not be unexpected. The nutrient rich Snow and Quemado Lakes have summer blooms of the nitrogen-fixing cyanophyta _Anabeana_ and _Aphanizomenon_. The cause of the bloom conditions could not be precisely established. The presence of these algae will lead to further nitrification as they can increase the total nitrogen content of the lake system.

	Above Willow Creek	Below Willow Creek	Gilita	Middle Fork
Major Cations				
Ca^{2+}	4.7 ± .5	6.3 ± .6	5.6 (2)	7.1 ± 1.1
Mg^{2+}	1.4 ± .5	1.9 ± .6	1.8 (2)	2.2 ± .7
Na^{+}	3.7 ± .5	2.9 ± .8	3.1 (2)	4.2 ± 1.2
K^{+}	1.6 ± .4	1.3 ± .2	1.3 (2)	1.4 ± .2
Major Anions				
HCO_3^{2-}	24. ± 6. (4)	26. ± 7. (4)	25 ± 9.	33. ± 8. (4)
SO_4^{2-}	9.2 ± 3.9	10. ± 7.	15. (2)	9.4 ± .6
Cl^{-}	4.2 ± 2.1 (4)	3.9 ± 2.3 (4)	2.1 ± .7	3.4 ± 1.5 (4)
Nutrients				
NO_3^- (as N)	.07 ± .03	.11 ± .09 (4)	.60 ± .68	.40 ± .5 (4)
NO_2^- (as N)	.003 ± .004 (4)	.007 ± .005 (4)	.001 ± .0003	.0087 ± .003 (4)
Diss. PO_4^{3-}-P	.07 ± .05 (4)	.11 ± .09 (4)	.06 ± .04	.13 ± .12 (4)
Total PO_4^{3-}-P	.14 ± .12	.23 ± .14	.13 ± .04	.10 ± .03
Kjeldahl N (as N)	1.1 ± .7 (4)	1.5 ± 1.1 (4)	1.6 ± 1.1	2.4 ± 1.3 (4)
NH_3 (as N)	.57 ± .34 (4)	.49 ± .25	.61 ± .56	.75 ± .23 (4)
Misc.				
pH	7.2 ± 0.1 (4)	7.3 ± .2 (4)	7.4 ± .2	7.3 ± .2 (4)
Cond. (μmho)	22. ± 7.	30. ± 7.	42. (2)	36. ± 8.
T.D.S.	56. (1)	44. (1)		64. (1)
Diss. O_2	8.9 ± 1.4	9.0 ± 1.1	9.4 (2)	9.5 ± .5
SiO_2	18. ± 6.	23.0 ± 9.0	20. (2)	21. ± 5.

Table 12

Summary of Chemical Analysis Data
Averages in ppm Followed by Standard Deviation
Number of Samples is Three Unless Otherwise Indicated in Parentheses

	Snow Creek (2 Samples)	Snow Lake (3 or 4 Samples)	Quemado Lake (3 or 4 Samples)	Wall Lake Inlet (1 Sample)	Wall Lake (1 Sample)	S.F. River (1 Sample)
Major Cations						
Ca^{2+}	11.3	13. ± 3.1	18. ± 3.1	18.	21.	36.
Mg^{2+}	3.6	3.7 ± .6	7.9 ± 6.7	1.4	2.3	.73
Na^{+}	4.5	5.8 ± 1.8	24. ± 4.	32.	29.	31.
K^{+}	3.7	3.7 ± .1	4.5 ± .7	1.7	2.1	2.6
Major Anions						
HCO_3^{2-}	41.	46. ± 11.(4)	140. ± 33. (4)	69.	58.	180.
SO_4^{2-}	17.	23. ± 6.	16. ± 12.	49.	21.	17.
Cl^{-}	5.1	8.5 ± 2.8 (4)	9.8 ± 5.4 (4)	11.	13.	4.3
Nutrients						
NO_3^- (as N_3^-)	.78	1.05 ± 1.07	.92 ± 1.1 (4)	1.32	1.45	.13
NO_2^- (as N_2^-)	.017	.027± .015 (4)	.009 ± .009(4)	.018	.003	0.000
Diss. PC_4^{3-}-P	.15	.21 ± .25 (4)	.08 ± 1.4 (4)	.09	.18	.10
Total PO_4^{3-}-P	.25	.4 ± .16	.09 ± .07	.05	.06	.16
Kjeldahl N (as N)	1.9	16. ± 23. (4)	2.4 ± 1.2		4.1	2.1
NH_3 (as N)	.81	1.36 ± .90 (4)	.86 ± .77 (4)	1.2	1.4	0.26
Misc.						
pH	7.5	8.0 ± .77 (4)	8.6 ± .7 (4)	8.5	9.23	7.6
Cond. (μmho)	90.	85. ± 20.	170. ± 49. (4)			190.
T.D.S.		72. (1)	169. (1)			
Diss. O_2	7.1	9.5 ± .21	9.3 ± 1.0	7.8	9.1	
SiO_2	29.	14. ± 3.	5.9 (2)	35.	26.	9.2

Table 13

Summary of Chemical Analysis Data

Averages in ppm Followed by Standard Deviation

Number of Samples Indicated in Column Heading or in Parentheses

References

Anderson, B.L. and Solomon, R.M. (1977) USDA Forest Service Environmental Statement Algeacide Treatment of Snow and Quemado Lakes. USDA-FS-R2.

Aukerman, R. and W.T. Springer. (1976) Effect of recreation on water quality in wildlands. Eisenhower Consortium Bull. 2. National Technical Information Service, Springer field, VA.

Bartsch, A.F. (1970) Accelerated eutrophication of lakes in the United States: ecological response to human activities. Environ. Pollut. 1: 133-140.

Brierley, J.A., D.K. Brandvold and C.J. Popp. (1975). Waterflow refuge effect on water quality: I. Bacterial populations. Jour. WPCF 47: 1892-1900.

Golterman, H.L. (Ed.), (1970) Methods for chemical Analysis of Fresh Waters, Blackwell Scientific Publications, Oxford, England, 76.

Hatch, W.R. and Ott, W.L., (1968) Determination of Sub-Microgram Quantities of Mercury b y Atomic Absroption Spectroscopy "Anal". Chem. 40, 2085.

Hesse, P.R. (1971) Soil Chemical Analysis. Chemical Publishing Co. NY, NY.

Horton, C.A. and White, T.C. (1958). Separation of Uranium by Solvent Extraction with tri-n-octyl phosphine oxide. Anal. Chem. 30: 1979-1984.

Johnson, G.V. and E.W. Foster, (1978). Characteristics of the algal and bacterial populations in the Lagunitas Lakes of northern New Mexico. Bull of the N.M. Acad. of Sci. 18: 12.

Johnson, G.V. and L.L. Barton, (1978). Characteristics of blue-green algal populations at Cochiti and Abiquiu reservoirs, New Mexico. Bull. of the N.M. Acad. of Sci. 18: 13.

Knopka, A. and T.D. Brock. (1978). Effect of temperature on blue-green algae (Cyanobacteria) in Lake Mendota. Appl. Environ. Microbiol. 36: 572-576.

Methods for Chemical Analysis of Water and Waste, United States Environmental Protection Agency, Washington, D.C. (1974).

Oser, B.L., (Ed.) Hawks Physiological Chemistry, 14th Ed., McGraw-Hill, 1326 (1965).

Prescott, G.W. (1970). How to know the freshwater algae, 2nd Ed. Wm. C. Brown Co., Dubuque, IA.

Shapiro, J. (1973). Blue-Green Algae: Why They Become Dominant. Science 179 382-384.

Smith, G.M. (1950). The Fresh-Water Algae of the United States. 2nd Ed. McGraw-Hill Book Co., Inc. New York.

Standard Methods for the Examination of Water and Wastewater, 14th Edition, (1975) American Public Health Association, Washington, D.C. (1975)

Stuart, D.G., G.K. Bissonnette, T.D. Goodrich and W.G. Walter. (1971) Effects of Multiple Use on Water Quality of High-Mountain Watershed: Bacteriological Investigations of Mountain Streams. Appl. Microbiol. 22: 1048-1054.

Varness, K.J., R.R. Pacha and R.F. Lapen. (1978). Effects of Dispersed Recreational Activities on the Microbiological Quality of Forest Surface Water. Appl. Environ. Microbiol. 36: 95-104.

Appendix I

Photographs of Sampling, Sampling Sites and Algae

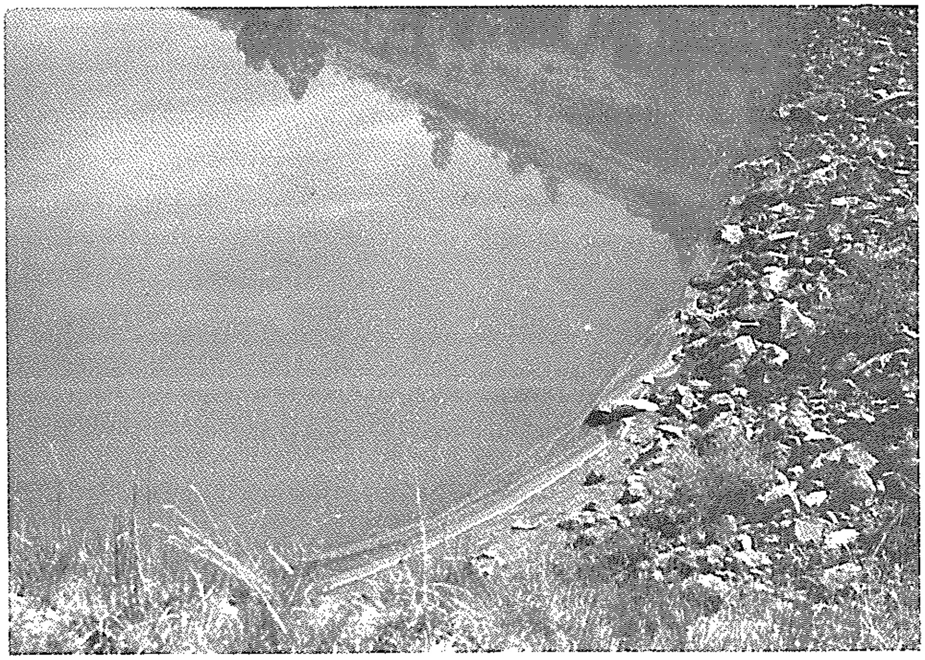
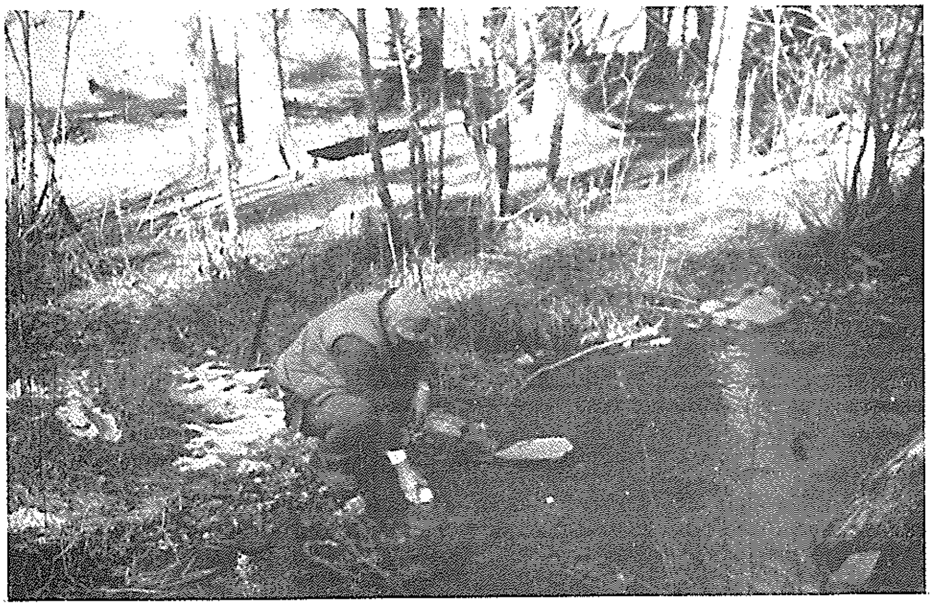


Figure XIV- Snow Lake: Top: 5/78 Showing Algae Bloom
Bottom: 11/78 No Bloom



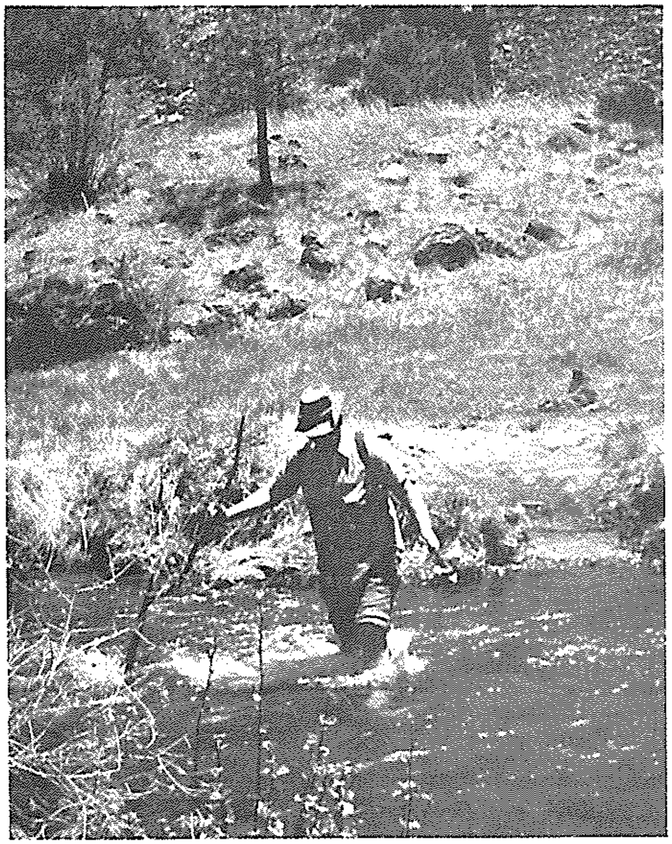


Figure XV-Top: Sampling Willow Creek
Bottom: Sampling Gilita Above Snow Lake Effluent

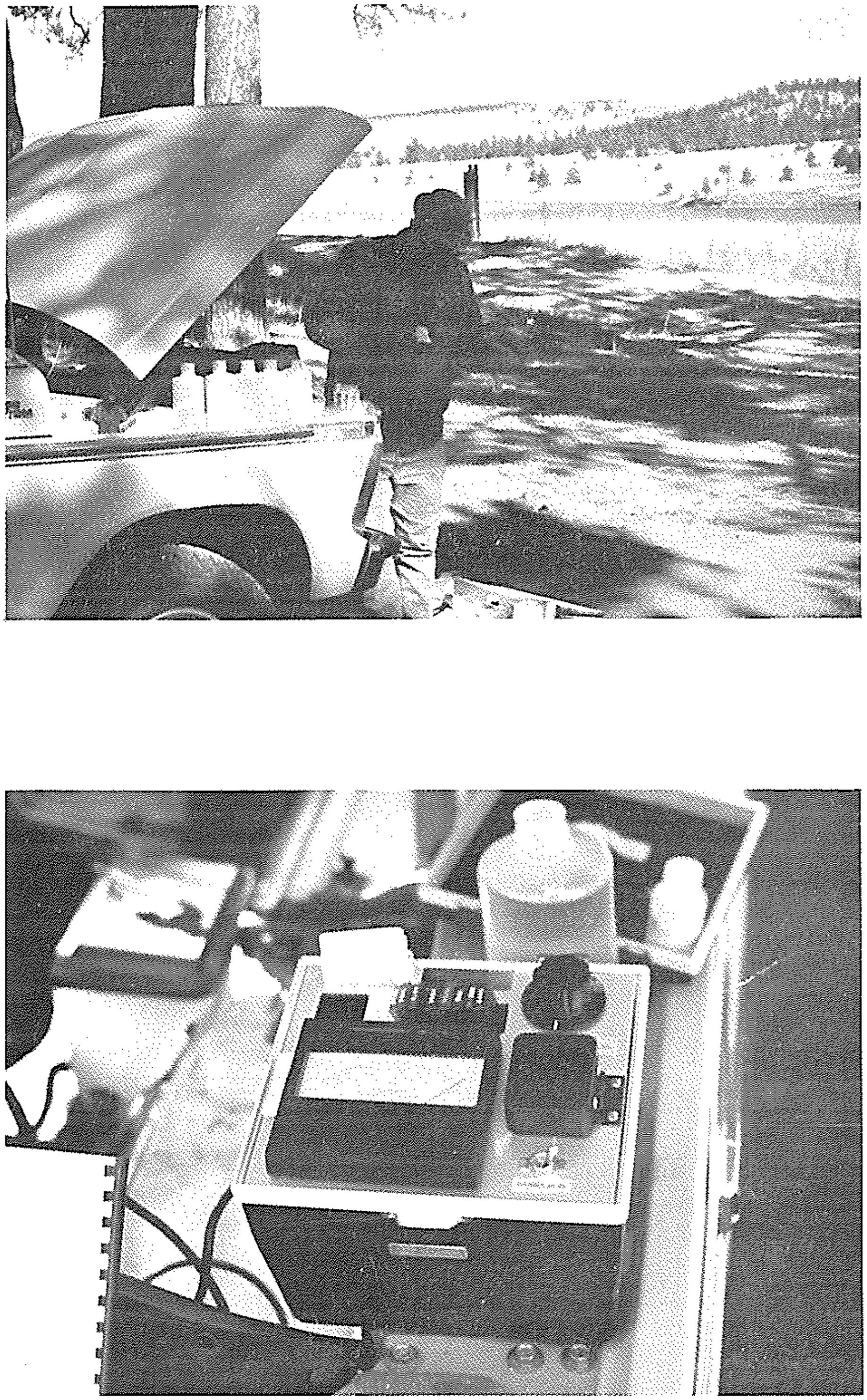
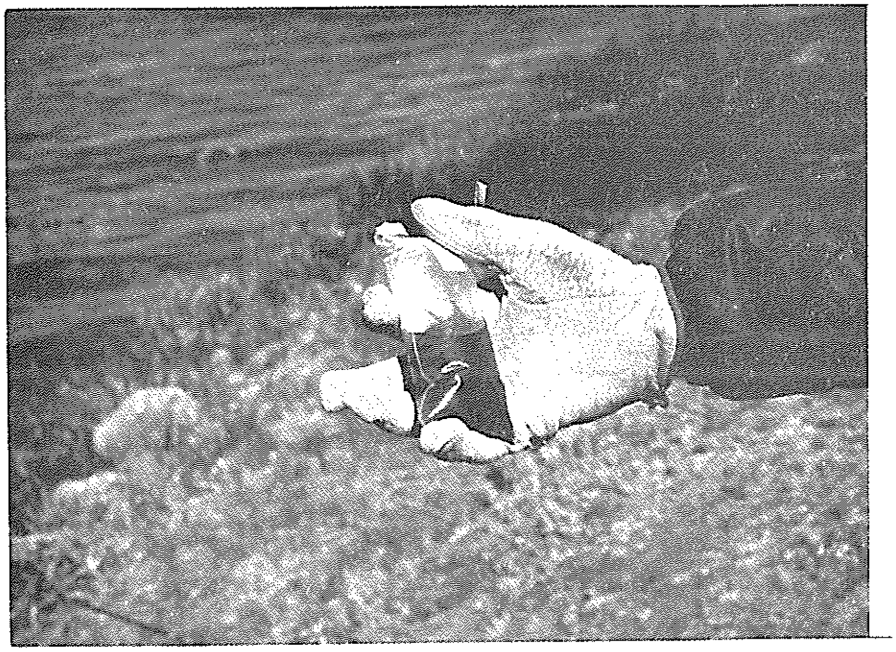


Figure XVI-Field Sample analysis- Snow Lake



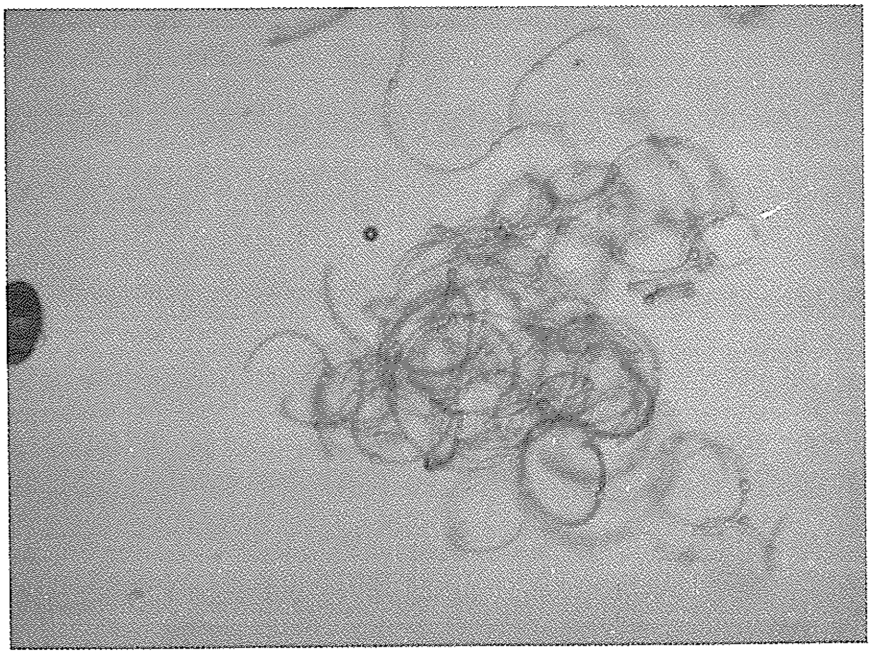


Figure XVII-Top: Algae Sample-Quemado Lake
Bottom: Anabeana Algae-400x

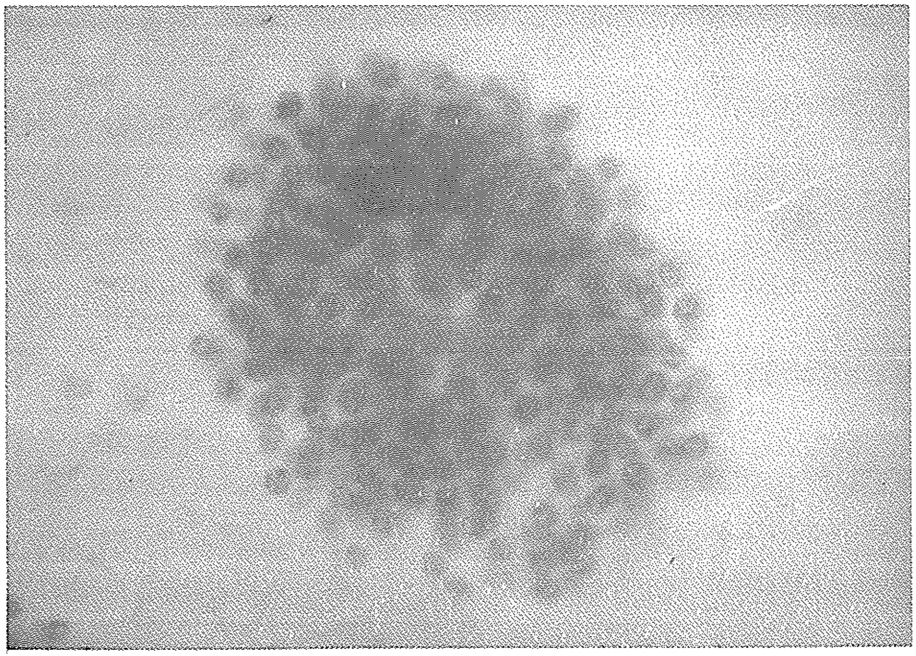


Figure XVIII-Top: Aphanizomenon-400X
Botton: Polycystis-400x