

Chemical and physical findings from pollution studies on the East Gallatin River and its tributaries
by Raymond Arthur Soltero

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Botany
Montana State University
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Abstract:
A section of the East Gallatin River and its tributaries in the vicinity of Bozeman, Montana, were studied in an effort to determine, by chemical-physical means, the water quality at various points and to determine the effects of suspected pollutant sources on this system.

Comparison of the detailed chemical analyses at the upstream and downstream stations demonstrated that the tributaries contributed little if any pollution to the East Gallatin River. The major pollutant of the stream was found to be the Bozeman City Sewage effluent.

129

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RAYMOND ARTHUR SOLTERO

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

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in

Botany

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TABLE OF CONTENTS

	Page
VITA	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vi
LIST OF FIGURES	xi
ABSTRACT	xiii
INTRODUCTION	1
DESCRIPTION OF THE STUDY AREA	3
METHODS	7
Water Chemistry	7
Temperature	12
Hydrology	12
Morphometry	14
RESULTS	15
Water Chemistry of Bozeman Creek and Bridger Creek	15
Water Chemistry of Rocky Creek and the East Gallatin River	17
Water Chemistry on Sampling Periods of 24-Hour Duration	36
Water Temperature	42
Hydrology	47
Statistical Analysis	47
DISCUSSION	54

TABLE OF CONTENTS - Continued

Page

SUMMARY 61

APPENDIX 63

LITERATURE CITED 110

LIST OF TABLES

			Page
Table	I.	The date and the station at which 24-hour and single samples were taken during the summer (1967)	8
Table	II.	Average water chemistry for Bozeman Creek and Bridger Creek during the summer for the single sampling periods	16
Table	III.	The downstream distances from station 2 for the Rocky Creek and East Gallatin River sampling stations	19
Table	IV.	Average water temperatures (^{o}C) at the stations sampled during single sampling periods throughout the summer (1967)	46
Table	V.	Average discharge rates for Bridger Creek during the summer (1967)	49
Table	VI.	Average discharge rates for Bozeman Creek during the summer (1967)	50
Table	VII.	Average discharge rates for the sewage effluent during the summer (1967)	51
Table	VIII.	Average discharge rates for the East Gallatin River during the summer (1967)	52
Table	IX.	Water temperatures (^{o}C) at the stations sampled during single sampling periods throughout the summer (1967)	64
Table	X.	Dissolved oxygen concentrations (mg/1) at the stations sampled during single sampling periods throughout the summer (1967).	65
Table	XI.	pH measurements at the stations sampled during single sampling periods throughout the summer (1967)	66
Table	XII.	Total alkalinities (meq/1) at the stations sampled during single sampling periods throughout the summer (1967)	67

LIST OF TABLES - Continued

Page

Table XIII. Conductivities (micromhos) at 25°C for the stations sampled during single sampling periods throughout the summer (1967). 68

Table XIV. Chloride concentrations (mg/1 Cl^-) at the stations sampled during single sampling periods throughout the summer (1967) 69

Table XV. Fluoride concentrations (mg/1 F^-) at the stations sampled during single sampling periods throughout the summer (1967) 70

Table XVI. Turbidity (Standard Jackson Units) at the stations sampled during single sampling periods throughout the summer (1967) 71

Table XVII. Sulfate concentrations (mg/1 $SO_4^=$) at the stations sampled during single sampling periods throughout the summer (1967) 72

Table XVIII. Total carbon concentrations (mg/1 C) at the stations sampled during single sampling periods throughout the summer (1967) 73

Table XIX. Total organic carbon concentrations (mg/1 C) at the stations sampled during single sampling periods throughout the summer (1967). 74

Table XX. Soluble organic carbon concentrations (mg/1 C) at the stations sampled during single sampling periods throughout the summer (1967) 75

Table XXI. Total nitrogen concentrations (mg/1 $N\text{-}NH_3$) at the stations sampled during single sampling periods throughout the summer (1967) 76

Table XXII. Total soluble nitrogen concentrations (mg/1 $N\text{-}NH_3$) at the stations sampled during single sampling periods throughout the summer (1967) 77

LIST OF TABLES - Continued

		Page
Table XXIII.	Free ammonia concentrations (mg/1 $N\text{-}NH_3$) at the stations sampled during single sampling periods throughout the summer (1967).	78
Table XXIV.	Nitrate concentrations (mg/1 $N\text{-}NO_3^-$) at the stations sampled during single sampling periods throughout the summer (1967)	79
Table XXV.	Nitrite concentrations (mg/1 $N\text{-}NO_2^-$) at the stations sampled during single sampling periods throughout the summer (1967).	80
Table XXVI.	Total phosphate concentrations (mg/1 $P\text{-}PO_4^{\equiv}$) at the stations sampled during single sampling periods throughout the summer (1967).	81
Table XXVII.	Soluble inorganic and organic phosphate concentrations (mg/1 $P\text{-}PO_4^{\equiv}$) at the stations sampled during the single sampling periods throughout the summer (1967)	82
Table XXVIII.	Soluble inorganic phosphate concentrations (mg/1 $P\text{-}PO_4^{\equiv}$) at the stations sampled during the single sampling periods throughout the summer (1967)	83
Table XXIX.	Calcium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods	84
Table XXX.	Magnesium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods	85
Table XXXI.	Sodium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods	86
Table XXXII.	Potassium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods	87

LIST OF TABLES - Continued

		Page
Table XXXIII.	Silica concentrations (mg/1 SiO_2) at the stations sampled during 7/25/67 - 9/12/67 for the single sampling periods	88
Table XXXIV.	5-day B.O.D. (mg/1 D.O.) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods	89
Table XXXV.	Dissolved oxygen concentrations (mg/1) at the stations sampled during 24-hour sampling periods throughout the summer (1967).	90
Table XXXVI.	pH measurements at the stations sampled during 24-hour sampling periods throughout the summer (1967)	92
Table XXXVII.	Total alkalinities (meq/1) at the stations sampled during 24-hour sampling periods throughout the summer (1967)	94
Table XXXVIII.	Conductivities (micromhos) at 25°C at the stations sampled during 24-hour sampling periods throughout the summer (1967).	96
Table XXXIX.	Total carbon concentrations (mg/1 C) at the stations sampled during 24-hour sampling periods throughout the summer (1967)	98
Table XXXX.	Total organic carbon concentrations (mg/1 C) at the stations sampled during 24-hour sampling periods throughout the summer (1967)	100
Table XXXXI.	Total nitrogen concentrations (mg/1 $N\text{-}NH_3$) at the stations sampled during 24-hour sampling periods throughout the summer (1967)	102
Table XXXXII.	Total phosphate concentrations (mg/1 $P\text{-}PO_4^{\equiv}$) at the stations sampled during 24-hour sampling periods throughout the summer (1967)	104

LIST OF TABLES - Continued

		Page
Table XXXXIII.	Water temperatures (^{o}C) at the stations sampled during 24-hour sampling periods throughout the summer (1967).	106
Table XXXXIV.	Flow times (minutes) between the stations sampled during 24-hour sampling periods throughout the summer (1967)	108
Table XXXXV.	Mean depths between the stations sampled during 24-hour sampling periods throughout the summer (1967)	109

LIST OF FIGURES

		Page
Figure 1.	Map of the upper East Gallatin River system showing location of study area and stations.	4
Figure 2.	Average conductance at 25°C and total alkalinity at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.	20
Figure 3.	Average % O_2 saturation and dissolved oxygen concentration at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.	21
Figure 4.	An example of a 5-day B.O.D. at the Rocky Creek and East Gallatin River stations during a single sampling period (8/22/67)	23
Figure 5.	Average concentrations of the major metallic cations at the Rocky Creek and East Gallatin River stations during 8/8/67 - 9/12/67 for single sampling periods.	24
Figure 6.	Average concentrations of the major anions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods. .	26
Figure 7.	Average concentrations of the various carbon fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods	28
Figure 8.	Average of the inorganic nitrogen fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.	30
Figure 9.	Average of the organic nitrogen fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods. .	31
Figure 10.	Average of the various phosphate fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods. .	33

LIST OF FIGURES - Continued

		Page
Figure 11.	Average silica concentrations at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods	35
Figure 12.	Mean turbidity at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods	37
Figure 13.	Example of pH curves for the East Gallatin River over a 24-hour period (8/15-16/67).	38
Figure 14.	Average conductance at 25°C during the summer for the 24-hour sampling periods	40
Figure 15.	The net rate of change in dissolved oxygen in the river reaches during a 24-hour sampling period (8/1-2/67)	41
Figure 16.	The rate of change in total carbon in the river reaches during a 24-hour sampling period (8/29-30/67)	43
Figure 17.	The rate of change in total nitrogen in the river reaches during a 24-hour sampling period (8/1-2/67)	44
Figure 18.	The rate of change in total phosphate in the river reaches during a 24-hour sampling period (8/1-2/67)	45
Figure 19.	Mean water temperature at the stations sampled during 24-hour sampling periods throughout the summer	48
Figure 20.	Average current velocity for reaches 7-11 on each 24-hour sampling date	53

ABSTRACT

A section of the East Gallatin River and its tributaries in the vicinity of Bozeman, Montana, were studied in an effort to determine, by chemical-physical means, the water quality at various points and to determine the effects of suspected pollutant sources on this system.

Comparison of the detailed chemical analyses at the upstream and downstream stations demonstrated that the tributaries contributed little if any pollution to the East Gallatin River. The major pollutant of the stream was found to be the Bozeman City Sewage effluent.

INTRODUCTION

Water from streams and lakes in mountainous districts may be relatively free from organic impurities but usually contains varying concentrations of dissolved inorganic salts, while water from lowland rivers and lakes near population centers may be highly polluted. Pollution, in this sense of the word, is anything that renders the water impure or alters the originality of the water in any way.

The growing scarcity of water sources and the ever increasing usage of water for domestic and industrial purposes have been primarily the reasons for the great interest in pollution problems.

The East Gallatin River at Bozeman, Montana provides an excellent opportunity for the study of stream pollution. The major pollutant is the sewage outfall of the Bozeman City Sewage Treatment Plant. This plant is of the primary treatment type, treating an average of 3.5 million gallons per day of raw sewage. Although the sewer system is not of the combined type, during and after heavy storms there is an increase of flow into the plant. During the study period the sewage outfall comprised from 1.4% to 11.8% of the total stream flow.

A slaughter house and stockyards are located upstream from the sewage effluent, both of which are other sources of possible pollution to this river system. The slaughter house discharges unmarketable animal material into the water while the stockyards place the manure pilings from their pens along the stream banks, which when eroded, dump overlying waste material directly into Rocky Creek. Other additional sources of possible pollution are located on the tributaries, Bozeman

Creek and Bridger Creek, which were also sampled in the course of the study.

Since most pollutions that are found in aquatic systems are of a chemical or physical nature, chemical analyses supplemented by physical determinations must in part play a vital role in the detection and estimation of the degree of pollution.

The purpose of the present investigation was to conduct several routine chemical-physical analyses in an attempt to obtain information pertaining to stream quality at the various points sampled. Twenty-four hour sampling periods were also carried out to determine what chemical and physical effects the sewage outfall had on the East Gallatin River.

DESCRIPTION OF THE STUDY AREA

The East Gallatin River is formed by the union of Rocky Creek and Bozeman Creek and flows in a northwesterly direction along the northern margin of Bozeman, a city of some 20,000 people.

The average discharge from this river was 84.7 cfs (2.40 m^3/sec.) for a 22 year period (1939-1961). The discharge normally fluctuates between a fall minimum of approximately 18 cfs (0.51 m^3/sec.) and a spring maximum of 189 cfs (5.35 m^3/sec.). Maximum recorded discharge was 1,230 cfs (35.14 m^3/sec.) on June 4, 1953 and the minimum was 12 cfs (0.34 m^3/sec.) on December 9, 1944 and March 24-26, 1955. The drainage area of this river comprises 148 sq. mi. (384.82 km^2) at an elevation of about 4,701 ft. (1,433.23 m) above mean sea level.

The East Gallatin River is a permanent stream approximately 37 miles (59.58 km) long. It varies from 7 ft. (2.13 m) to 30 ft. (9.15m) in width during low water and varies in depth from a few inches in the riffles to more than 6 ft. in a few pools. The principal natural source of the water is springs and surface runoff from the surrounding mountainous terrain. The flow is augmented, however, by the Bozeman City Sewage Treatment Plant and by Bridger Creek.

The river is of the calcium-magnesium-bicarbonate type, with silica, sodium, and potassium present in small concentrations.

Twelve permanent stations were established during the course of the study (see Figure 1). Station 1 was located on Bozeman Creek 3.7 miles (5.96 km) above its confluence with Rocky Creek.

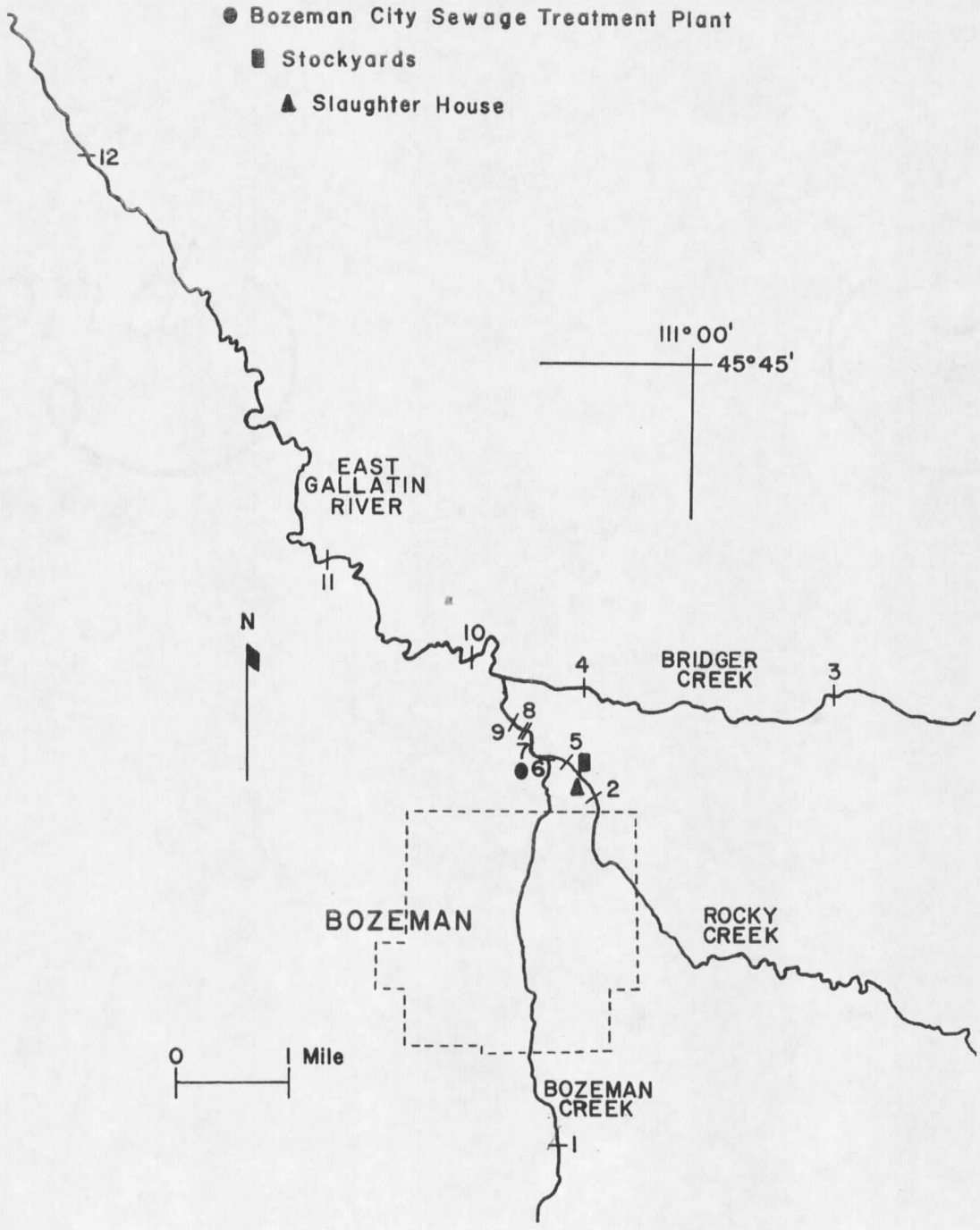


Figure 1. Map of the upper East Gallatin River system showing location of study area and stations

Station 2 was established on Rocky Creek 0.9 miles (1.45 km) upstream from the sewage effluent, 0.4 miles (0.64 km) from the stockyards and 0.2 miles (0.32 km) from the slaughter house.

Station 3 was situated on Bridger Creek 3.4 miles (5.48 km) upstream from its confluence with the East Gallatin River.

Station 4 was also situated on Bridger Creek 0.6 miles (0.97 km) from its confluence with the river. This union with the East Gallatin River is also 0.6 miles (0.97 km) below the sewage outfall.

Station 5 was located on Rocky Creek just downstream from the stockyards, 0.2 miles (0.32 km) from the slaughter house and 0.2 miles (0.32 km) from its confluence with Bozeman Creek.

Station 6 was established on Bozeman Creek about 50 ft. (15.24 m) above its confluence with Rocky Creek. The confluence is 0.4 miles (0.64 km) above the sewage outfall.

Station 7 was situated on the East Gallatin River approximately 100 ft. (30.49 m) upstream from the sewage effluent.

Station 8 was the sewage effluent itself, 0.4 miles (0.64 km) by underground cement pipe from the treatment plant area.

Station 9 was located in the area where the sewage outfall became completely mixed with the rest of the river, 0.3 miles (0.48 km) downstream from the sewage outfall.

Station 10 was established 1.4 miles (2.25 km) downstream from station 9.

Station 11 was situated 2.5 miles (4.02 km) below station 10.

Station 12 was established 6.3 miles (10.15 km) downstream from station 11 and 10.5 miles (16.89 km) from the sewage outfall.

The stream bottom types at these various stations consisted mainly of large to small cobbles and coarse to fine gravel.

METHODS

Water samples and field measurements were taken at the various stations at weekly intervals, when possible, throughout the duration of the study.

Table I shows the date and the station at which 24-hour and single samples were taken. Diurnal sampling at stations 7, 8, 9, 10, and 11 commenced at 0600 hours and proceeded through 0600 hours the following day. Sample collections were made every three hours except between 2400 hours and 0600 hours when samples were not taken. The single samples were generally collected at all stations. Sampling began at 0600 hours and was complete by 0800 hours that same day.

All samples were obtained by lowering an 8 liter polyethylene bucket over the side of a bridge into the middle of the stream. This container was rinsed well with the surface water before a sample was taken. Upon collection, one 300 ml and one-1 liter aliquots were collected in Pyrex glass-stoppered bottles. These storage bottles were rinsed twice before being filled with the water sample.

Water Chemistry

After returning to the laboratory, the one-liter sample was filtered through "Millipore" filters with a pore size of 0.8 microns. After filtering, the samples were placed back in the Pyrex glass-stoppered bottles, which had been rinsed with a small quanity of the filtrate.

Table I. The date and the station at which 24-hour and single samples were taken during the summer (1967).

DATE	24-HOUR SAMPLES	SINGLE SAMPLES
	Stations	Stations
6/13/67	——	1-2, 5-8, 10-11
6/20/67	——	1-12
6/27/67	——	1-8, 10-12
7/11/67	——	1-12
7/18-19/67	7-11	——
7/25/67	——	1-2, 5-12
8/1-2/67	7-11	——
8/8/67	——	1-12
8/15-16/67	7-11	——
8/22/67	——	1-2, 5-12
8/29-30/67	7-11	——
9/12/67	——	1-12

—— Samples were not collected.

The electrical resistance of each sample was measured with a YSI Conductivity Bridge (Model 31). An Industrial Instruments (Model CEL 4) dipping cell was used with the YSI Conductivity Bridge. The cell constant of the dipping cell was approximately 2.1 throughout the study.

The specific conductance of the water at 25°C was computed from the observed resistance which was corrected for temperature and cell resistance.

Measurements of the hydrogen ion concentrations were made with a Beckman Expanded Sclae pH meter (Model 76).

Total alkalinity, Biochemical Oxygen Demand (B.O.D.), chloride, fluoride, nitrite, total and soluble nitrogen, total, soluble and inorganic phosphate, silica, sulfate, and turbidity determinations were made as described by the American Public Health Association (1965). Ammonia was determined by the phenoxide and hypochlorite method as described by Charlot (1964). The colorimetric equipment used in the various analyses was either a Bausch and Lomb "Spectronic 20" or a Klett-Summerson colorimeter.

Nitrate determinations were made according to the method of West and Lyles as described in Analytica Chimica Acta (1960).

Total carbon, total organic carbon and soluble organic carbon were determined by a Beckman Laboratory Carbonaceous Analyzer, following the procedure given in the Beckman Bulletin #1307-6A (February, 1965). Total inorganic carbon was also computed from pH, temperature, and total alkalinity, using the formulae derived by

Saunders et al. (1962).

Calcium, potassium, and sodium were determined by flame emission with a Beckman DU Flame Spectrophotometer, following the procedures given in the Beckman Instruction Manual #334-A (March, 1957), and magnesium was determined by atomic absorption spectroscopy using the Beckman Spectrophotometer.

Bicarbonate ion was determined as described by Hutchinson (1957).

The Precision Galvanic Cell Oxygen Analyser was used for the determination of dissolved oxygen as described in Precision Scientific Company Bulletin #TS-68850. The Oxygen Analyser was calibrated by allowing the electrode system equilibrate in a sample of known oxygen content. The Alsterberg modification of the Winkler technique (APHA, 1965) was the chemical test used to determine the dissolved oxygen of the standardizing sample.

Upon attaining a water sample from the stream the probe was immersed in the sample and gently swirled for several minutes. The meter current and temperature were recorded and the dissolved oxygen of the sample was obtained from a nomograph supplied with the instrument. A nomograph was also used for calculating the percentage saturation of oxygen in the water sample as described by Mortimer (1956).

All of the above mentioned analyses were run on the single samples within 30 hours after field collection. Free ammonia, total alkalinity, total carbon, total and soluble organic carbon, total and soluble nitrogen, nitrate, nitrite, total, soluble, and inorganic

phosphate, and pH determinations were made within 5 hours after collection.

In the sampling periods of 24-hour duration determinations of temperature, dissolved oxygen, conductivity, pH, total alkalinity, total carbon, total organic carbon, total nitrogen, and total phosphate were made at 3 hour intervals.

The net changes in total carbon, total nitrogen, total phosphate, and dissolved oxygen were computed by the upstream-downstream method (Odum, 1956; Wright et al, 1967).

For each 24-hour sampling period a series of graphs were produced by first plotting the total carbon, total nitrogen, total phosphate, or dissolved oxygen concentrations at station 7 as the ordinate against the time of collection as the abscissa. At each successive station, carbon, nitrogen, phosphate, or dissolved oxygen concentrations were displaced to the left by a time interval equivalent to the flow time from station 7 to the station whose data was being plotted.

The vertical distance between the two curves will give the net change in concentration of the substance (total carbon, total nitrogen, total phosphate, or dissolved oxygen) during the time required for it to flow through the reach.

The net changes in concentration per unit area per minute of total carbon and etc. were computed according to equation 1:

$$C = \frac{h\ (c_1 - Rc_2)}{t} \qquad (1)$$

Where:

C = net change in concentration per unit area per minute, $g/m^2/min.$

h = average depth of the reach, m.

c_1 = upstream concentration, g/m^3.

c_2 = downstream concentration, g/m^3.

R = ratio obtained from dividing the discharge (cfs) at the upper station of the reach by the discharge (cfs) at the lower one.

t = flow time, min.

Temperature

The temperature of the sample upon collection was measured with the Precision Galvanic Cell Oxygen Analyser which had a thermistor attachment. The themistor used with the Oxygen Analyser had an accuracy within $0.1^{\circ}C$.

Hydrology

Discharge measurements on the East Gallatin River were obtained from the rating table for the gauging station maintained by the U. S. Geological Survey 500 ft. below the confluence of Rocky Creek and Bozeman Creek.

Vertical staff gauges were installed at station 4 on Bridger Creek and station 6 on Bozeman Creek. The average stream velocity was

computed by obtaining sufficient point velocities. The average velocity multiplied by the cross-sectional area was used for computing the total discharge. Velocity measurements were determined by using a Gurley Current Meter (No. 622).

The above procedure was repeated numerous times for various stream stages. The stage record was then transformed to a discharge record by calibration.

The sewage discharge measurements were made by means of a free flow discharge Parshall 12" flume and a float level recorder located at the Bozeman City Sewage Treatment Plant.

Rate of flow between consecutive stations on the East Gallatin River was determined by introducing an appropriate quantity of fluorescent dye (rhodamine-B) in the main current of the stream at an upstream station. At the downstream station the water was pumped through a Turner Fluorimeter (Model 110) which was equipped with a Rustrak recorder and continuous flow cell to determine the passage of the peak dye concentration. The elapsed time for the dye to flow from the upstream station to the downstream station was considered to be the flow time.

This procedure was repeated for several different river stages. Flow times were plotted against the river stage during that period and flow times for water levels between those measured were obtained from the graphs.

Morphometry

Aerial photographs were measured for the lengths and widths used in calculating the area of the different river reaches. Average depths were computed according to equation 2:

$$h = \frac{d\ (t)}{A} \qquad (2)$$

Where:

h = average depth of the reach, m.

d = discharge, m^3/min.

t = flow time, min.

A = area of the reach, m^2.

The average current velocity was determined by dividing the flow time between two stations into the length of the reach.

RESULTS

Water Chemistry of Bozeman Creek and Bridger Creek

The average results of the water chemistry of Bozeman Creek and Bridger Creek for single sampling periods are recorded in Table II. This table includes both the inorganic and organic fractions that were analyzed.

Upon examination of the various cations found in both drainage systems, calcium was found to be dominant with magnesium, sodium, and potassium following in that order. Potassium is usually the least dominant cation in natural waters because of several processes which remove it from solution.

Bicarbonate and sulfate were less concentrated in Bozeman Creek than in Bridger Creek, but in both creeks the dominance order of the anions was the same, bicarbonate being most dominant, then sulfate, chloride, and fluoride.

The carbon determinations showed inorganic carbon to be higher in Bridger Creek. Soluble organic carbon was approximately the same for both streams (4-5 mg/l C). A decline in particulate carbon was noted at both stations 4 and 6.

Soluble organic nitrogen was higher than any of the other nitrogen fractions analyzed in Bozeman and Bridger Creeks. The mean particulate nitrogen differed from 0.24 mg/l at station 4 to 0.65 mg/l at station 1. Nitrates were consistently higher than free ammonias and nitrites which were essentially void in each creek.

Table II. Average water chemistry for Bozeman Creek and Bridger Creek during the summer for the single sampling periods.

STATION	1	3	4	6
Ca++ (meq/1)	1.48	1.83	1.85	1.67
Mg++ (meq/1)	1.15	1.17	1.39	1.32
Na+ (meq/1)	0.16	0.68	0.51	0.25
K+ (meq/1)	0.07	0.04	0.04	0.08
HCO_3^- (meq/1)	2.38	3.32	3.32	2.71
SO_4^{-2} (meq/1)	0.19	0.32	0.34	0.20
Cl^- (meq/1)	0.03	0.04	0.04	0.04
F^- (meq/1)	less than 0.01 for all stations			
Inorganic Carbon (C) (mg/1)	24.70	37.00	39.70	33.30
Soluble Organic C (mg/1)	4.80	5.00	4.80	4.30
Particulate C (mg/1)	2.80	2.30	0.90	1.90
$N\text{-}NO_3^-$ (mg/1)	0.20	0.41	0.33	0.31
$N\text{-}NO_2^-$ (mg/1)	less than 0.01 for all stations			
$N\text{-}NH_3$ (mg/1)	0.11	0.02	0.04	0.07
Soluble Organic $N\text{-}NH_3$ (mg/1)	0.95	1.40	1.49	1.20
Particulate $N\text{-}NH_3$ (mg/1)	0.65	0.46	0.24	0.51
Inorganic $P\text{-}PO_4^{-3}$ (mg/1)	0.36	0.12	0.11	0.39
Soluble Organic $P\text{-}PO_4^{-3}$ (mg/1)	0.01	0.08	0.03	0.15
Particulate $P\text{-}PO_4^{-3}$ (mg/1)	0.23	0.21	0.17	0.32
Silica (mg/1)	20.60	10.50	9.50	22.00
Dissolved Oxygen (mg/1)	9.26	9.53	9.41	9.48
% O_2 Saturation	70.50	73.80	73.60	73.10
Conductance (micromhos)	247.40	340.70	343.50	284.70
pH Ranges	8.14	8.25	8.29	8.18

The average of the phosphate analyses showed inorganic phosphate and particulate phosphate to be lower in Bridger Creek. Mean soluble organic phosphate values for Bozeman Creek varied from 0.01 mg/1 at station 1 to 0.15 mg/1 at station 6, with Bridger Creek values falling within these limits.

Silica concentrations were higher in Bozeman Creek. This apparently was due to the flowing of these waters over a basic igneous area. The lower silica content of Bridger Creek was attributed to its drainage basin being primarily sedimentary.

The dissolved oxygen content of both systems was usually greater than 9.0 mg/1 with an oxygen saturation of about 73%.

The mean specific conductance and pH range was usually greater in Bridger Creek than in Bozeman Creek.

An examination of the concentrations of the various chemical fractions at both the upstream and downstream stations indicates that there was no gross addition of pollution to either of the systems at the time of the study.

Water Chemistry of Rocky Creek and the East Gallatin River

In the following section, many of the graphs may have both solid and broken line curves. The solid lines represent the concentration of chemical factors in the length of Rocky Creek and the East Gallatin River that was sampled. Broken lines indicate the contributions from the major tributaries of the East Gallatin River system at appropriate

points. Station 2 was selected as the starting point (0 miles) in making graphs. The downstream distances of the remaining Rocky Creek and East Gallatin River stations from station 2 are recorded in Table III.

The average specific conductance and total alkalinity for Rocky Creek and the East Gallatin River during the study period are shown in Figure 2. An increase in the conductance and total alkalinity was noted within 0 to 0.4 miles, then a definite decrease between 0.4 and 0.9 miles. The decline was primarily due to the dilution effect of Bozeman Creek (station 6). Another increase in conductance and alkalinity was observed from 0.9 to 1.2 miles because of the added enrichment of the sewage outfall. Alkalinity and conductance both decreased within 1.2 to 2.6 miles downstream from station 2 which was attributed to the dilution effect from Bridger Creek (station 4). Between 2.6 miles and 11.4 miles there was a slight rise in both conductance and alkalinity.

Figure 3 shows the mean % O_2 saturation and dissolved oxygen for the single sampling periods during the summer. Fluctuations are noticed from 0 to 0.9 miles, the highest O_2 saturation being at 0.4 miles and a dissolved oxygen high near 9.1 mg/l between 0.4 and 0.9 miles. A decline in O_2 saturation and dissolved oxygen was noted from 0.9 to 2.6 miles and then a gradual increase of the two between 5.1 and 11.4 miles.

As can be seen from Figure 3, the greatest oxygen depletion was in the vicinity of the sewage effluent. This demand for oxygen was of such magnitude that the stream at 11.4 miles had still not regained its original O_2 concentration. If it were not for the highly oxygenated

Table III. The downstream distances from station 2 for the Rocky Creek and East Gallatin River sampling stations.

STATION	DISTANCE (miles)
2	0
5	0.4
7	0.9
9	1.2
10	2.6
11	5.1
12	11.4

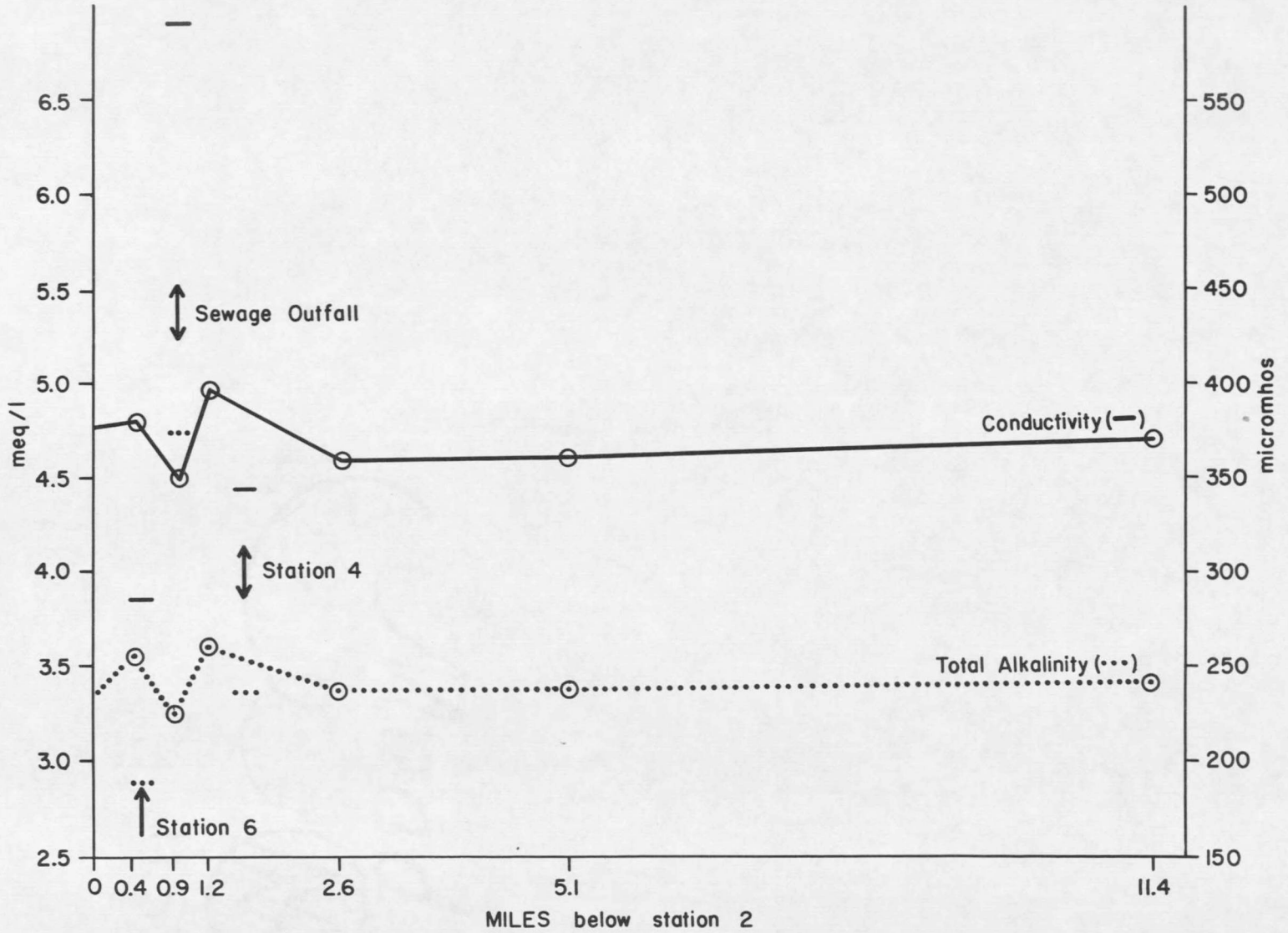


Figure 2. Average conductance at 25°C and total alkalinity at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

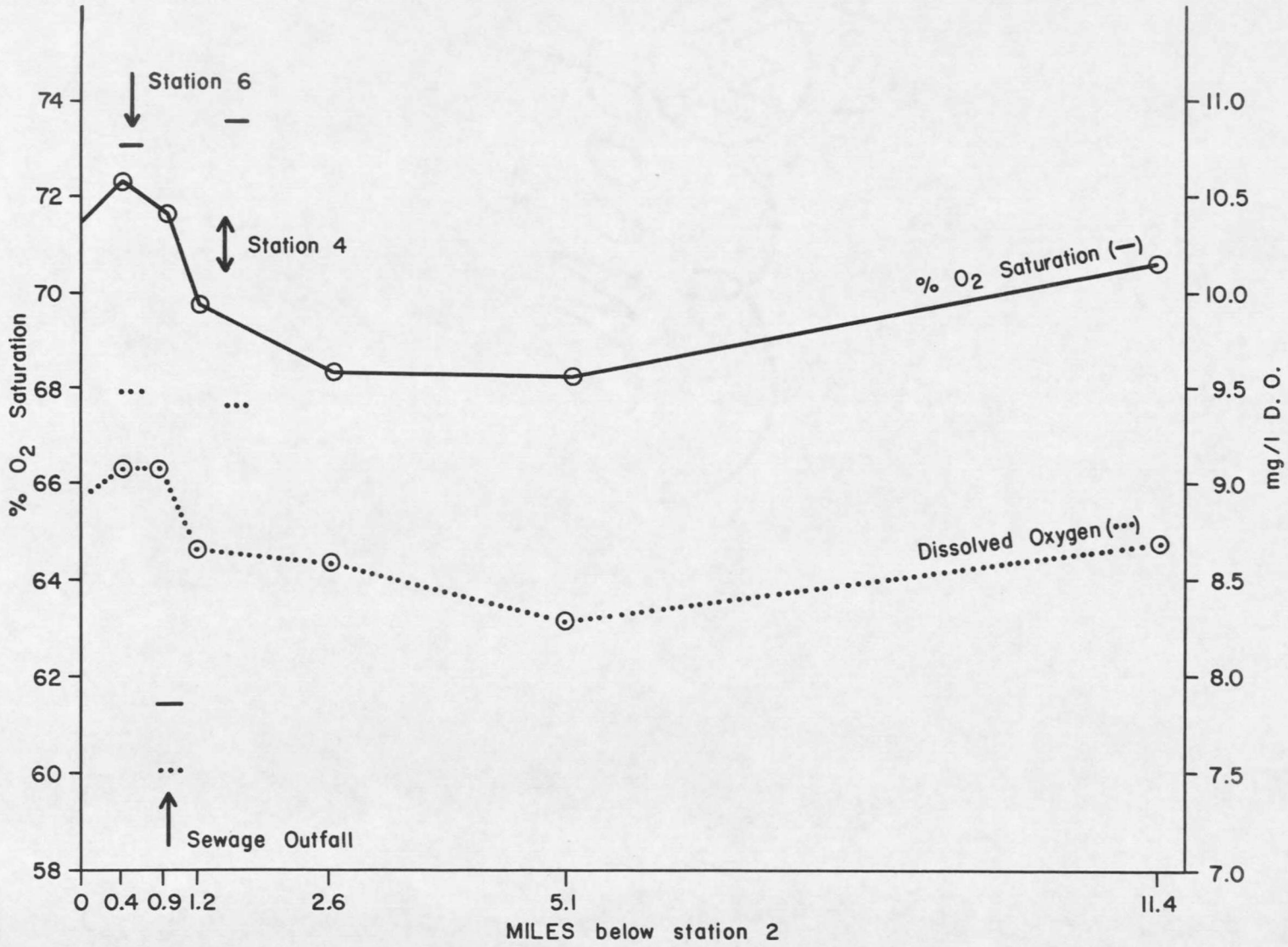


Figure 3. Average % O_2 saturation and dissolved oxygen concentration at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

waters of Bozeman Creek and Bridger Creek conditions would have been considerably worse.

The results of a 5-day B.O.D. for the Rocky Creek and East Gallatin River sampling stations is shown in Figure 4. Low B.O.D.'s are observed for 0.9 miles below station 2. A three fold rise is noted between 0.9 and 1.2 miles. This increase is probably due to the sewage outfall (Figure 4). The suspected low B.O.D. of Bridger Creek would explain the decrease between 1.2 and 2.6 miles. Another boost in the B.O.D. is noticed within 2.6 and 5.1 miles and a reduction from 5.1 to 11.4 miles.

Only forty per-cent of the B.O.D. was satisfied in the ten miles of stream sampled below the sewage outfall. Other sampling runs revealed some variation in the B.O.D. values obtained. The amount of sewage dilution, water temperature, and time of flow greatly influence B.O.D. satisfaction and the rate of stream purification (Weston, 1947).

Mean concentrations of the major metallic cations found in Rocky Creek and the East Gallatin River for the summer single sampling periods are given in Figure 5. Overall there was a reduction of calcium and magnesium downstream except for the rise in magnesium at 0.4 miles below station 2. The general reduction of these ions was attributed to the dilution effects of Bozeman Creek, Bridger Creek, and the sewage outfall in the case of magnesium. The average concentration of calcium ion at the sewage outfall was approximately 0.3 meq/l higher than that found in the river, but since the volume of flow from the river was much greater than that of the outfall, one would expect a limited masking of the

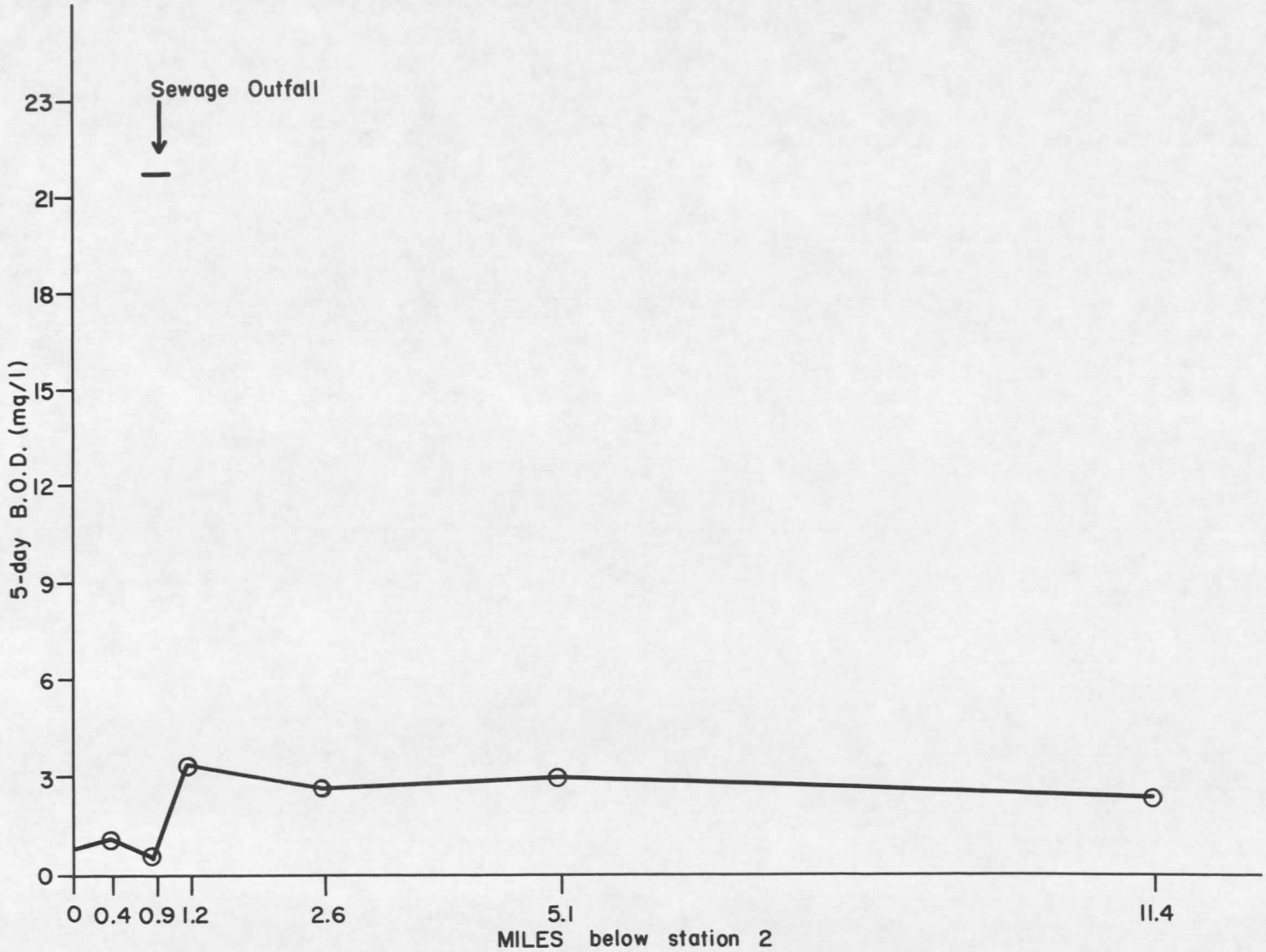


Figure 4. An example of a 5-day B.O.D. at the Rocky Creek and East Gallatin River stations during a single sampling period (8/22/67).

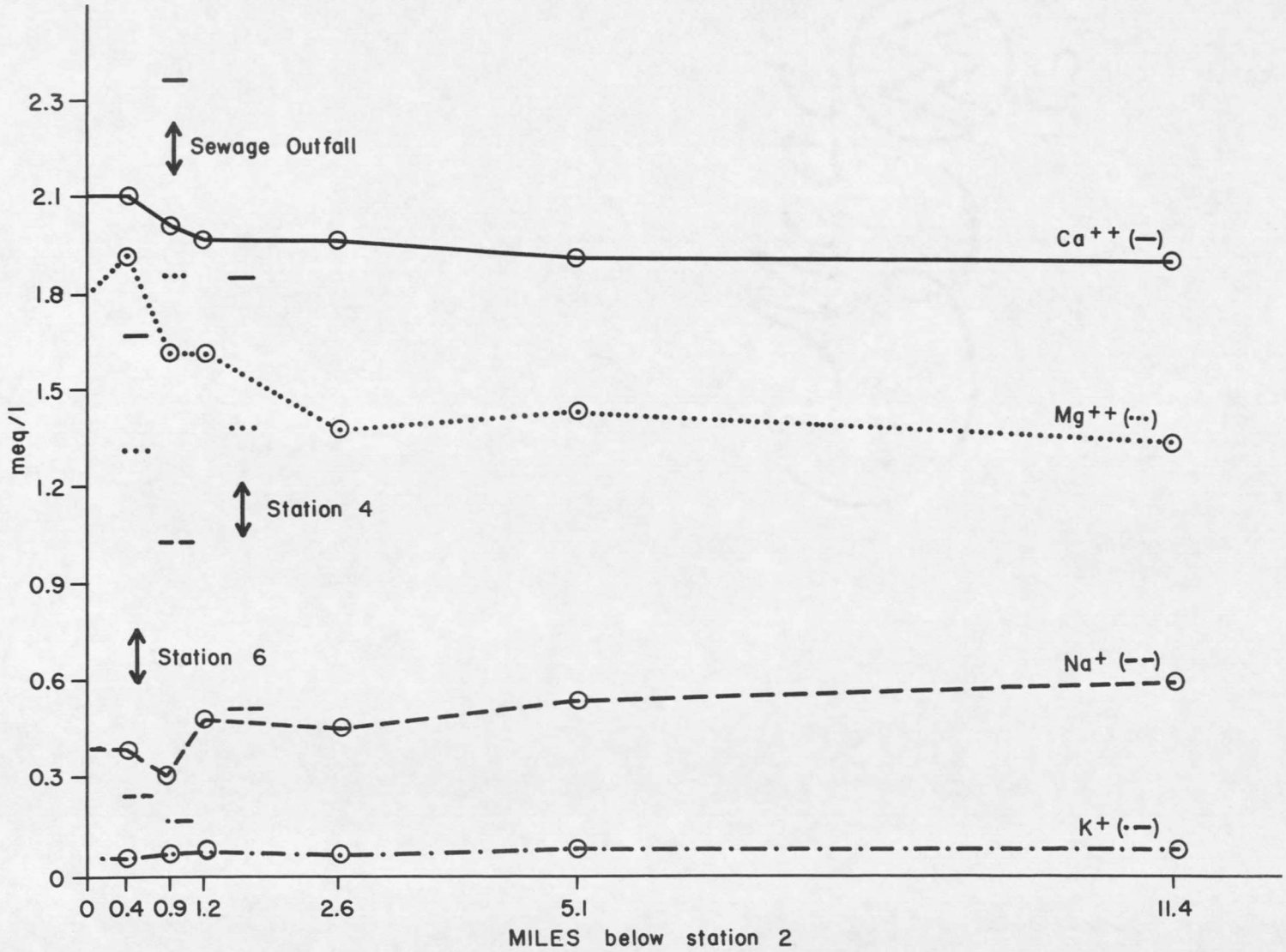


Figure 5. Average concentrations of the major metallic cations at the Rocky Creek and East Gallatin River stations during 8/8/67 - 9/12/67 for single sampling periods.

higher Ca++ concentrations found in the sewage effluent flow. Sodium was relatively constant for 0.4 miles below station 2 and declined within 0.4 and 0.9 miles due to the lesser concentrations in Bozeman Creek. Between 0.9 and 1.2 miles the stream was fortified with more sodium by the sewage outfall. This fortification was strong enough to increase the sodium ion concentrations for the ten miles sampled below the sewage outfall. Potassium ion concentrations remained essentially the same for Rocky Creek and the East Gallatin River.

Bicarbonate was the major anion for the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods as indicated in Figure 6. The effect of the Bozeman Creek outflow was noted by the decline of bicarbonate ion concentration in the reach of 0.4 to 0.9 miles. The increase of bicarbonate within 0.9 to 1.2 miles was attributed to the sewage discharge. Another decrease in concentration was shown between 1.2 and 2.6 miles, this being due again to the dilution effect of Bridger Creek. Bicarbonate remained at approximately 3.35 meq/1 at 2.6 miles through 11.4 miles.

Sulfate became less abundant downstream and it attained a new lower level of 0.42 meq/1 as compared to the higher concentration of 0.59 meq/1 found for the first 0.4 miles (Figure 6). Bozeman Creek had an average sulfate concentration of about 0.20 meq/1 while Bridger Creek had an average of approximately 0.33 meq/1. The average sulfate content of the sewage outfall for the summer was 0.59 meq/1.

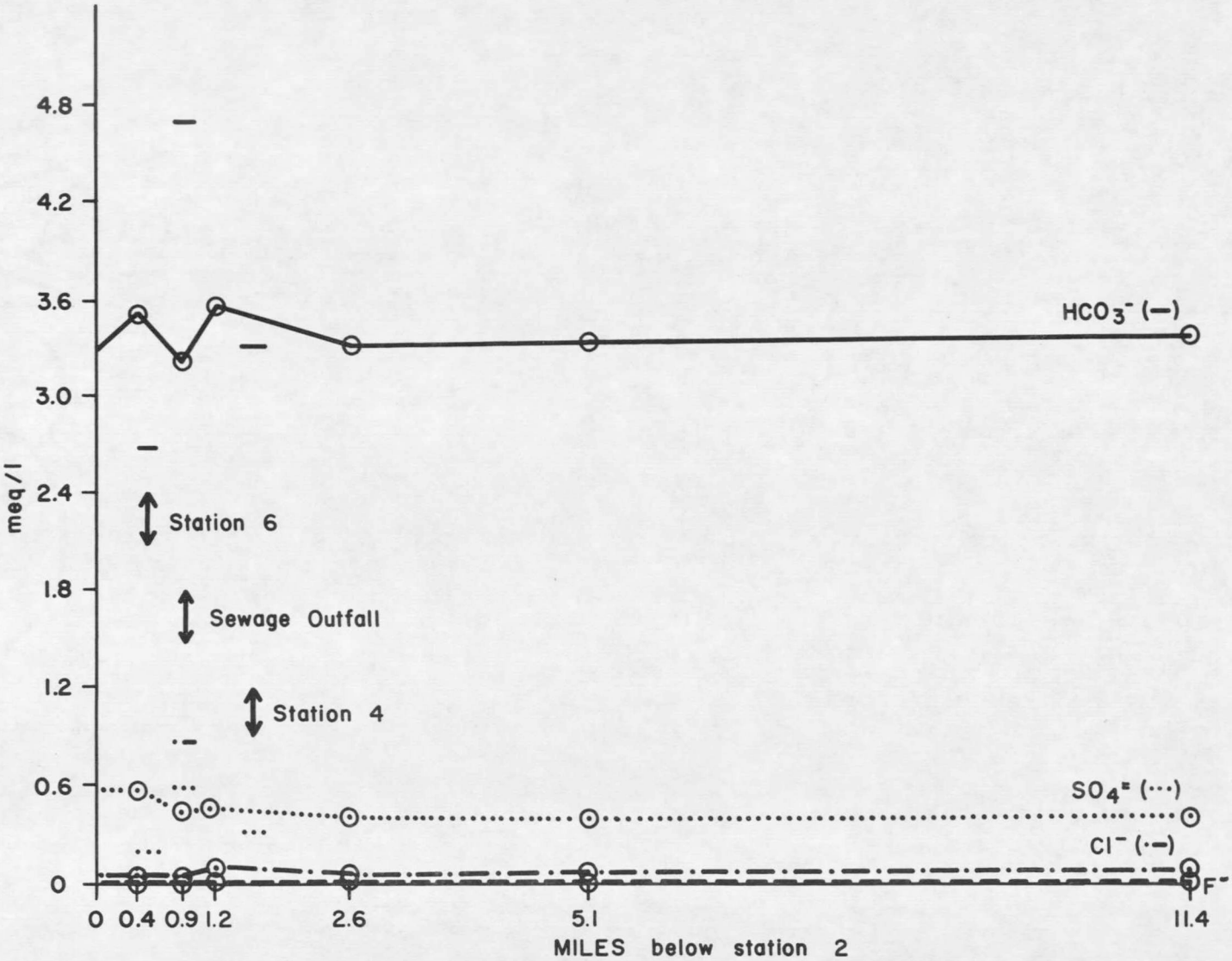


Figure 6. Average concentrations of the major anions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

The average chloride content in the upper reaches stayed relatively constant as shown in Figure 6. It increased between 0.9 and 1.2 miles and decreased between 1.2 to 2.6 miles, then remained at a level higher than that found at any of the other stations above the sewage effluent.

During the study fluoride remained essentially the same throughout the stream (Figure 6.)

Figure 7 shows the average concentration of the various carbon fractions analyzed during the summer for the single sampling periods. No major changes in the carbon content of the stream took place until the area of the sewage outfall was encountered. Due to the latter there was an increase in inorganic and soluble organic carbon and a decrease in particulate carbon. A decline in both inorganic and soluble organic carbon was noted from 1.2 through 2.6 miles, presumably because of the dilution by Bridger Creek. A small rise in particulate carbon was noted between 1.2 and 2.6 miles. Inorganic carbon increased within 2.6 to 5.1 miles and slightly from 5.1 miles to 11.4 miles. The soluble organic and particulate carbon concentrations from 2.6 miles through 11.4 miles remained about the same.

The mean inorganic carbon content at 11.4 miles was 40.8 mg/1 while that at 0 miles was 38.1 mg/1 (Figure 7). Soluble organic and particulate carbon had nearly the same concentration at 0 and 11.4 miles. It was found that the sewage outfall had an average of 63.9 mg/1 inorganic carbon, 62.4 mg/1 soluble organic carbon, and 16.3 mg/1 particulate carbon for the summer.

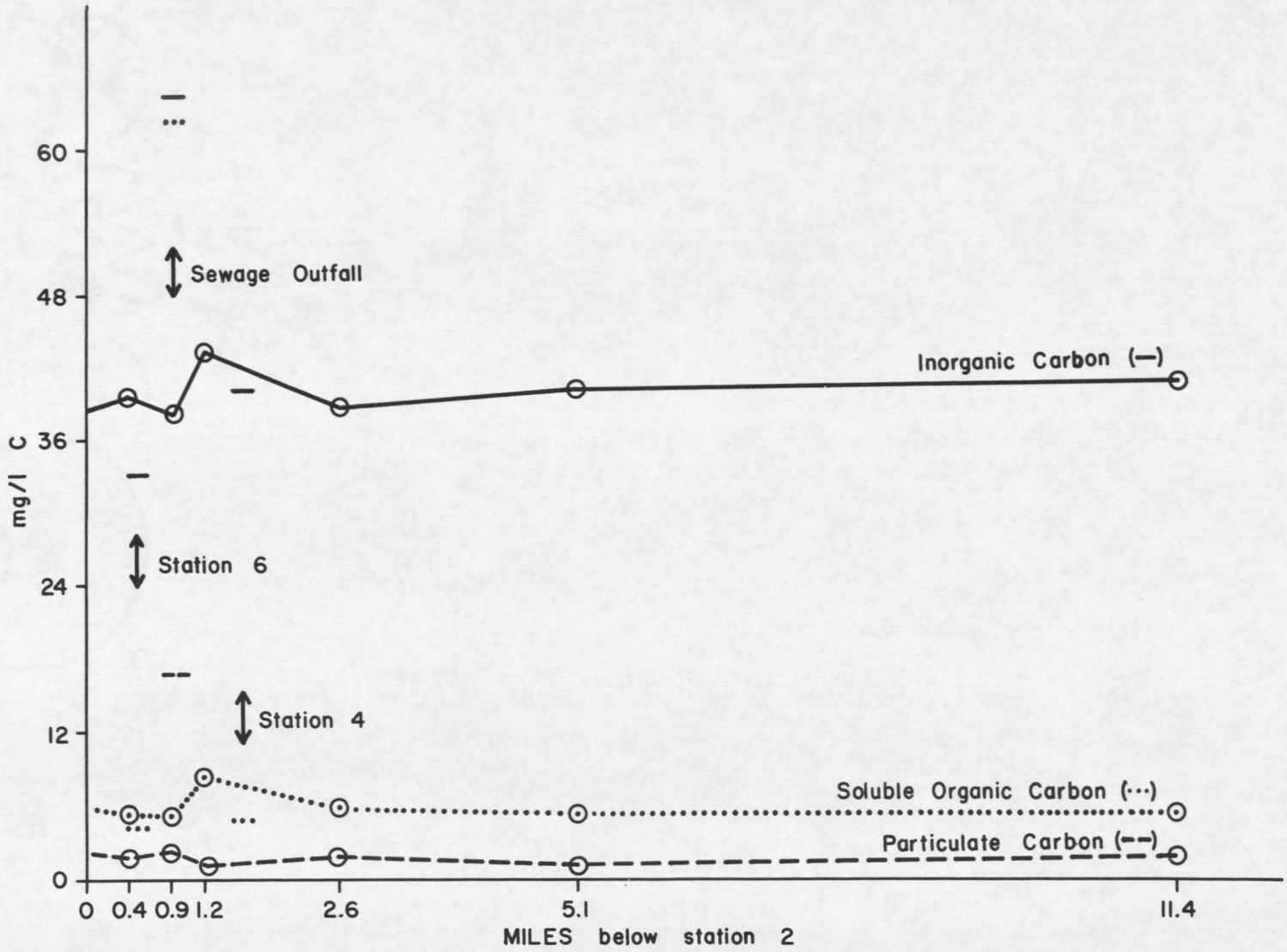


Figure 7. Average concentrations of the various carbon fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

The average of the different inorganic nitrogen fractions analyzed at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods are given in Figure 8. The mean ammonia and nitrate nitrogen concentrations fluctuated for the first 0.9 miles. There is an increase of both because of the predominant influence of the sewage outfall within the reach of 0.9 miles to 1.2 miles. The dilution effect of Bridger Creek is noted between 1.2 and 2.6 miles with the nitrate and ammonia concentrations becoming less in this section of the stream. From 2.6 miles to 5.1 miles ammonia remains approximately 0.22 mg/l while nitrate still decreases within this reach. There is a definite loss of ammonia with a corresponding increase of nitrate from 5.1 to 11.4 miles. The concentration of both substances at station 12 exceeds that found at station 2.

For the single sampling periods during the summer the sewage outfall had an average concentration of 3.13 mg/l nitrate and 2.39 mg/l ammonia.

Nitrite was almost absent in the stream until the sewage entered (Figure 8). The sewage outfall had a mean content of 0.02 mg/l of nitrite for the summer. A rise in nitrite was observed from the sewage outfall area through the remaining stations that were sampled.

The organic nitrogen analyses for the summer single sampling periods are shown in Figure 9. Soluble organic nitrogen sharply increased and particulate nitrogen abruptly decreased within the first 0.4 miles below station 2. Just the opposite of the above was observed from 0.4 miles through 2.6 miles with more gradual changes in the reach of 2.6 to 5.1

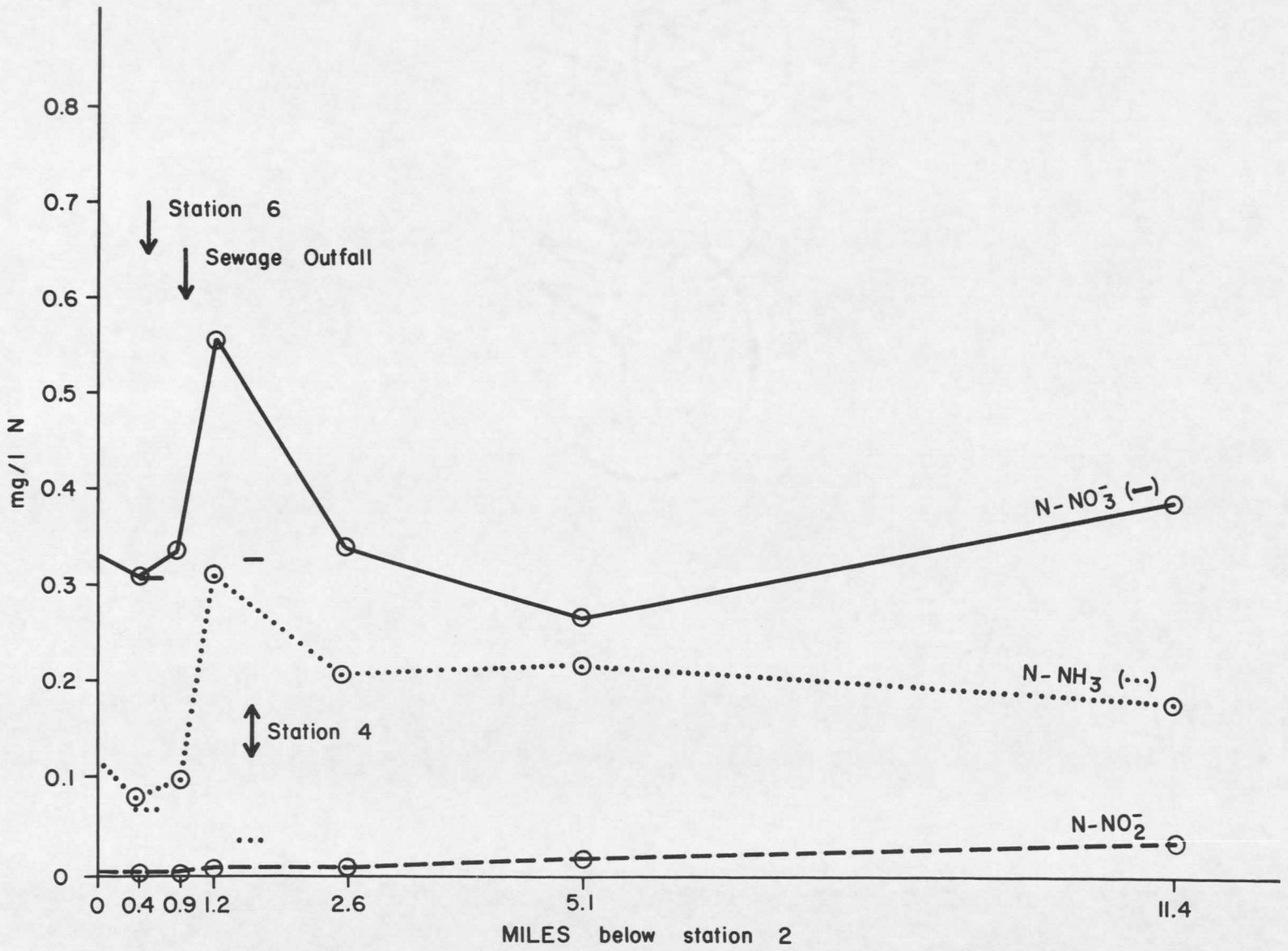


Figure 8. Average of the inorganic nitrogen fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

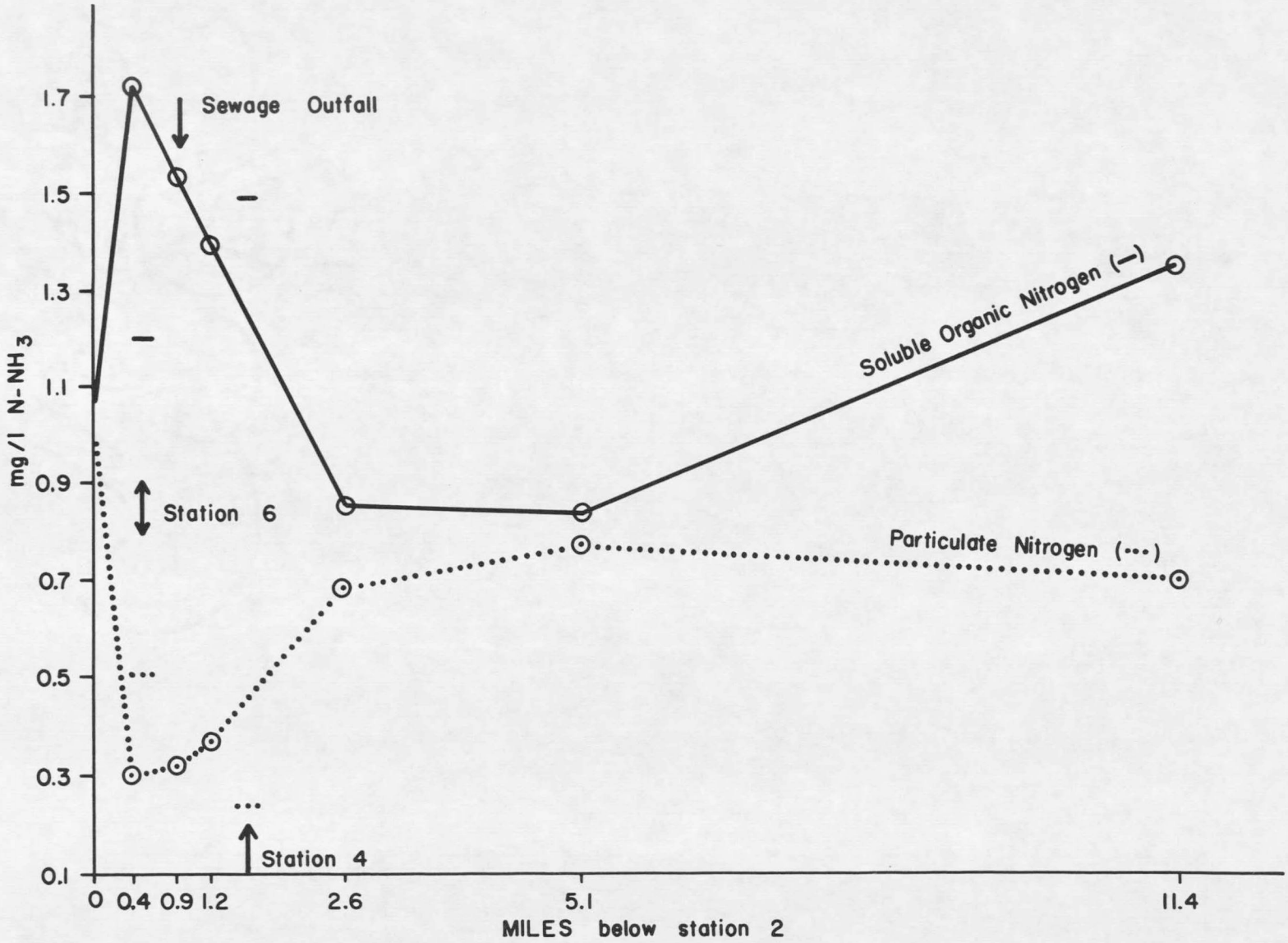


Figure 9. Average of the organic nitrogen fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

miles. Between 5.1 and 11.4 miles there was another increase of soluble organic nitrogen and a comparable decrease of particulate nitrogen.

The sewage outfall had an average concentration of 11.61 mg/l soluble organic nitrogen and 6.90 mg/l particulate nitrogen during the single sampling periods for the summer.

The mean concentrations of the various phosphate fractions are given in Figure 10 for the summer single sampling periods. Some fluctuation was observed for the first 0.4 miles downstream for all of the phosphate substances analyzed. An increase in particulate and inorganic phosphate was noted between 0.4 and 0.9 miles which was attributed to the higher concentrations found in Bozeman Creek, but a decrease in soluble organic phosphate was observed even though the average Bozeman Creek concentrations of the above was higher.

During the summer, the sewage outfall had an average of 1.28 mg/l soluble organic phosphate, 2.02 mg/l particulate phosphate, and 7.17 mg/l inorganic phosphate.

The sewage effluent discharge between 0.9 and 1.2 miles caused a rise in both inorganic and soluble organic phosphate, but a decline in the mean particulate phosphate content was found in this reach even when the sewage outfall concentrations of this fraction were greater. Apparently a sedimentation of the particulate phosphate had occurred in this stretch of stream.

The dilution effect of Bridger Creek on the river was noted with inorganic and soluble organic phosphate concentrations decreasing

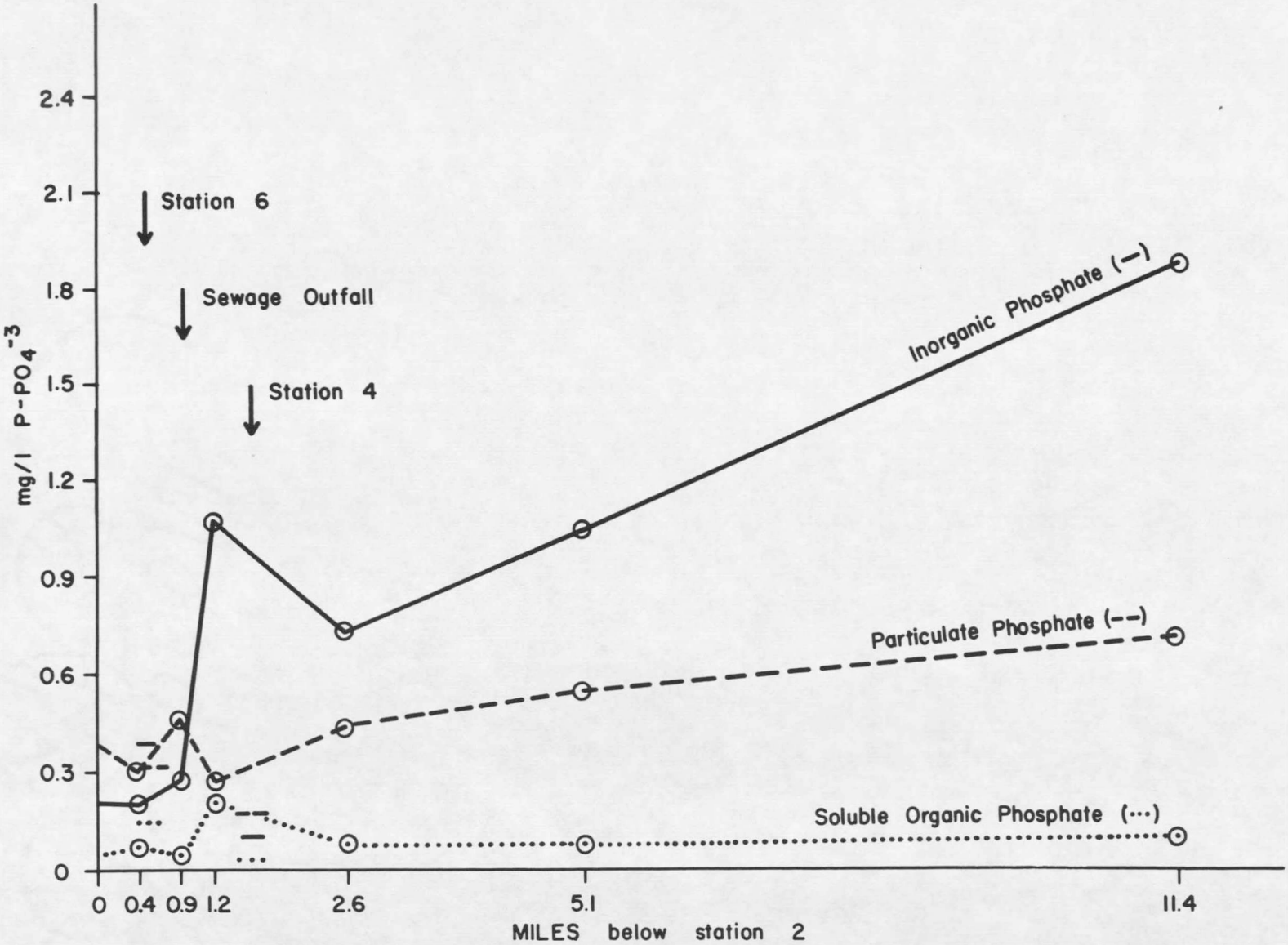


Figure 10. Average of the various phosphate fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

between 1.2 and 2.6 miles. Figure 10 shows that the average concentration of particulate phosphate in Bridger Creek was considerably lower than that found in the East Gallatin River between 1.2 and 2.6 miles and highly suggests that the former had no dilution effect on the latter. All of the phosphate fractions progressively increased from 2.6 miles through 11.4 miles with the inorganic phosphate enrichment being almost 9.5 times greater at station 12 than at station 2.

Synthetic detergents (syndets) are common constituents in solution that enter sewage and water treatment plants. A typical syndet formulation is illustrated below.

30% alky benzene sulfonate
28% polyphosphate
6% sodium silicate
35% sodium sulfate
1% carboxymethyl cellulose

The polyphosphates are used as binders and will vary with the different products (McKinny, 1957). The majority of the polyphosphates used in syndets are not detectable with the specific phosphate test (orthophosphate - stannous chloride method) employed during the course of the study.

The rapid increase downstream from the sewage outfall of inorganic phosphate (Figure 10) could be due to the hydrolysis of these polyphosphates by microbial activity to orthophosphate.

The average silica concentrations for the Rocky Creek and East Gallatin River stations during the summer single sampling periods are indicated in Figure 11. A decline is noted from 0 to 0.4 miles. The

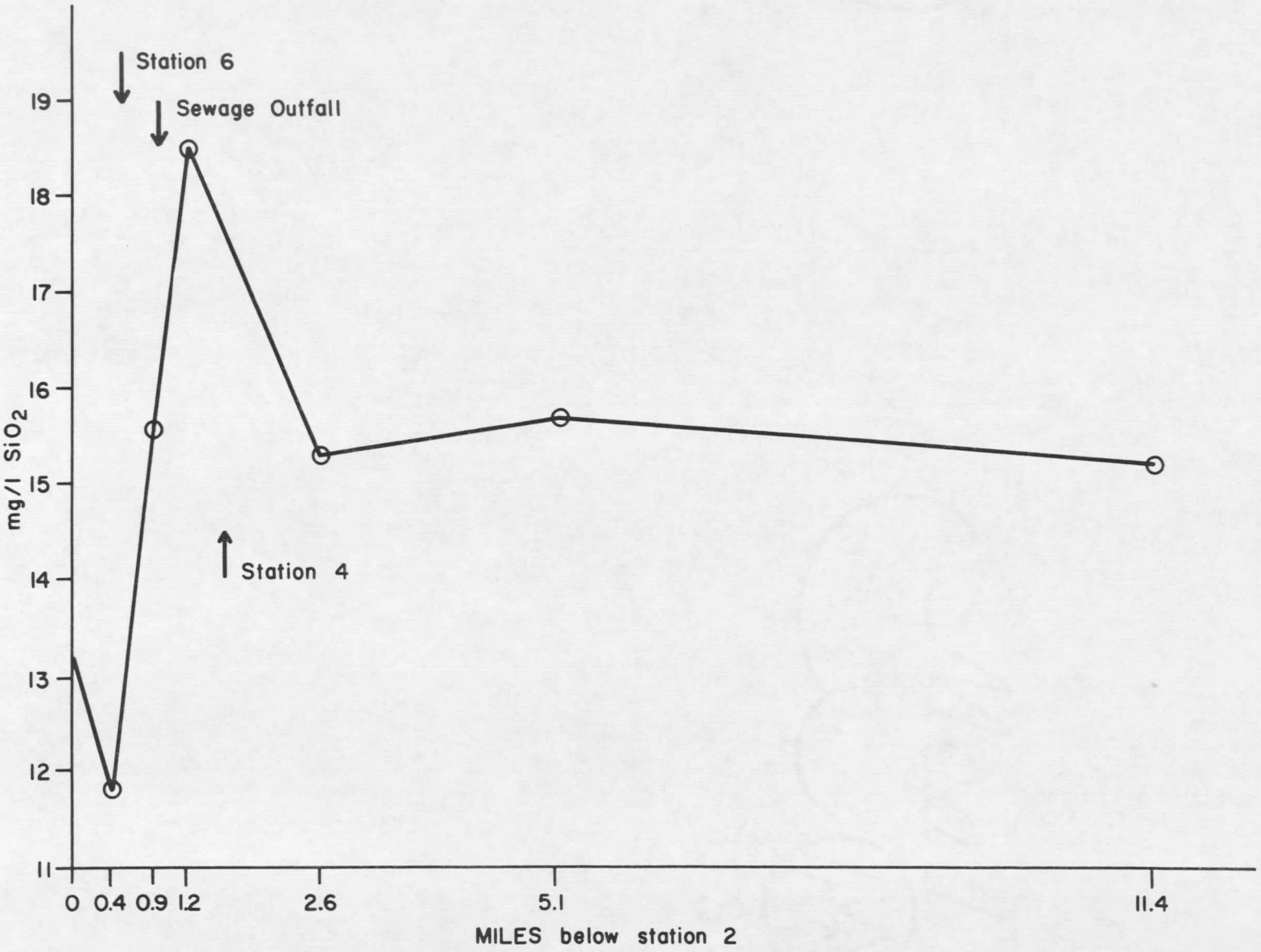


Figure 11. Average silica concentrations at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

effect of both the Bozeman Creek and sewage outflows is indicated by the increase in concentration within the reach 0.4 to 1.2 miles below station 2. This conspicuous rise is presumed to be due to Bozeman Creek and the City of Bozeman's water supply originating in the same watershed which is composed largely of igneous material. The loss of silica between 1.2 and 2.6 miles is attributed to the dilution effect from Bridger Creek which had an average concentration of 10 mg/1. The amount of silica from 2.6 through 11.4 miles stayed approximately the same (15.5 mg/1).

Figure 12 shows there was a general increase of turbidity downstream from mile 0. The highest level of 69.0 Jackson units was attained at 11.4 miles as compared to the lowest level of 54.0 Jackson units at mile 2.6. Some fluctuations occurred from 0 to 2.6 miles, but are small when compared to the magnitude of change which took place between 2.6 and 11.4 miles.

Water Chemistry on Sampling Periods of 24-Hour Duration

A series of pH curves showing changes which occurred during a sampling period of 24-hour duration at stations 7 through 11 are shown in Figure 13. The pH at station 7 was higher during the entire 24-hour period than any of the other stations sampled on this date. Diurnal changes for this station are evident with the maximum pH occurring at 1500 hours and the minimum pH at 0600 hours. pH fluctuations of the sewage effluent (station 8) are not as pronounced, but had a maximum at

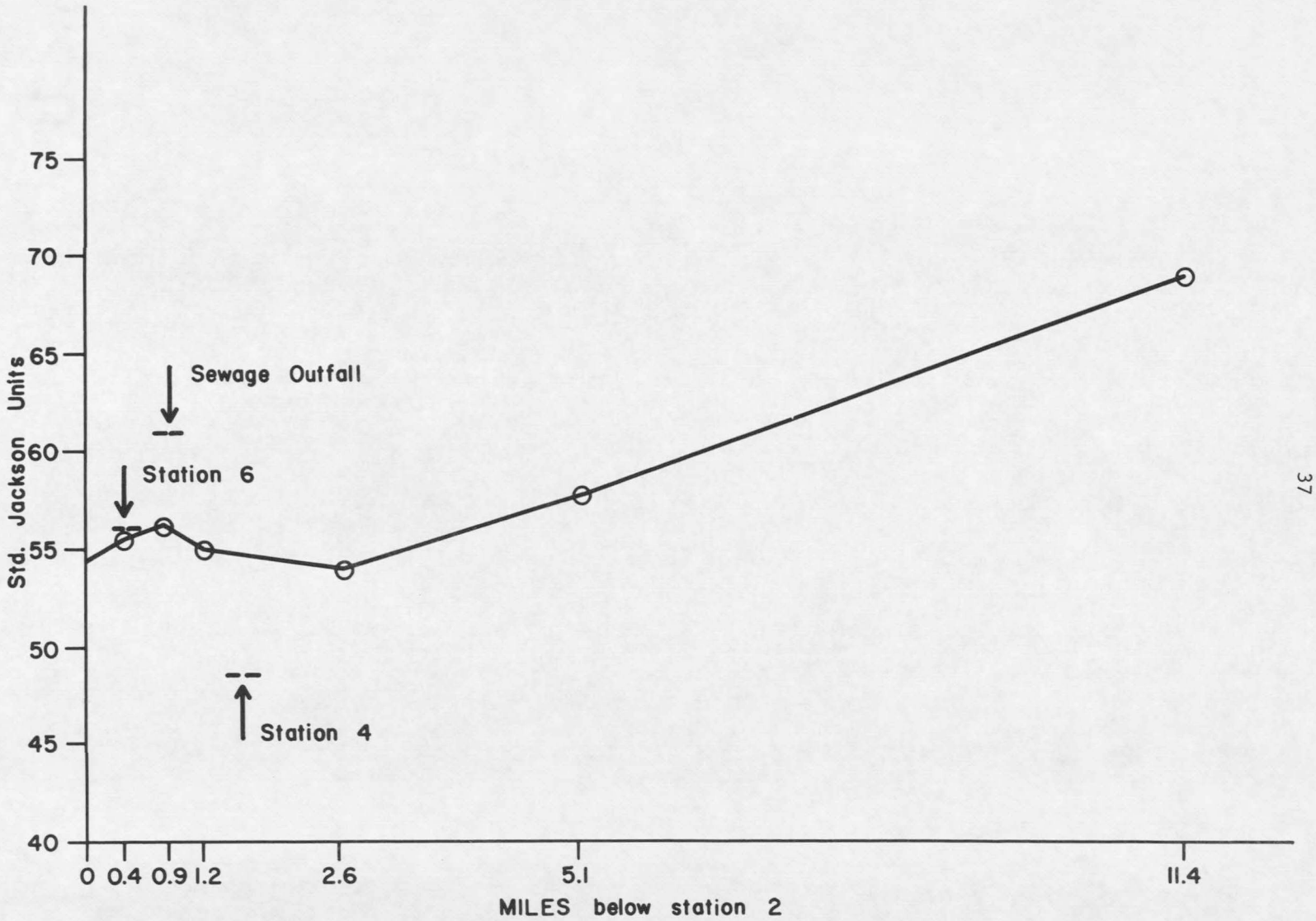


Figure 12. Mean turbidity at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

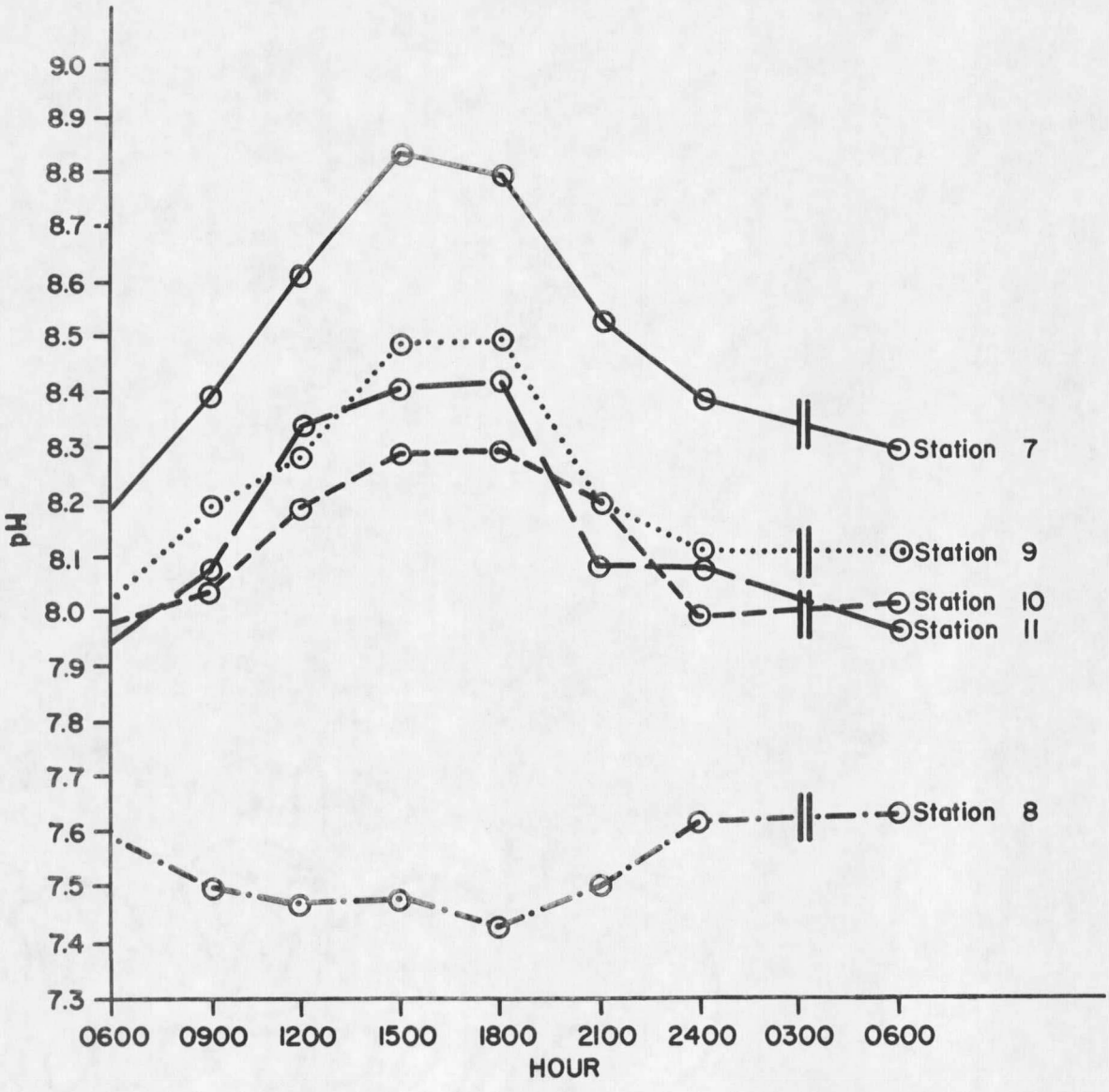


Figure 13. Example of pH curves for the East Gallatin River over a 24-hour period (8/15-16/67).

0600 hours and a minimum at 1800 hours. A daily cycle of pH was also seen in the stations (9, 10, and 11) downstream from station 8. Maximum pH values at these stations occurred between 1500 and 1800 hours and minima at 0600 hours, but these pH values are less than those found at station 7 because of the strong influence of the sewage outfall.

The mean conductance of the water at the stations sampled during the 24-hour sampling periods are shown in Figure 14. In general, conductance remained somewhat the same throughout the day for the various stations. Conductance at station 7 was less in all cases, while station 8 was markedly higher than any of the others. The values at station 9 were higher than those at either station 10 or 11, with station 10 having lower values because of the dilution effect from Bridger Creek.

Figure 15 shows the net rate of change in dissolved oxygen in the river reaches during a 24-hour sampling period. It can be seen that the most rapid rate of oxygen utilization occurred at 1500 hours within reach 7-9. Figure 13 suggests that at station 7 photosynthesis was highest at 1500 hours while Figure 14 indicates that the greatest oxidation demands by the sewage outfall occurred within reach 7-9 at this time also.

A maximum rate of oxygen production for reach 9-10 took place at 0900 hours after which time there was a general downward trend to a minimum at 2400 hours (Figure 14). The highly oxygenated waters of

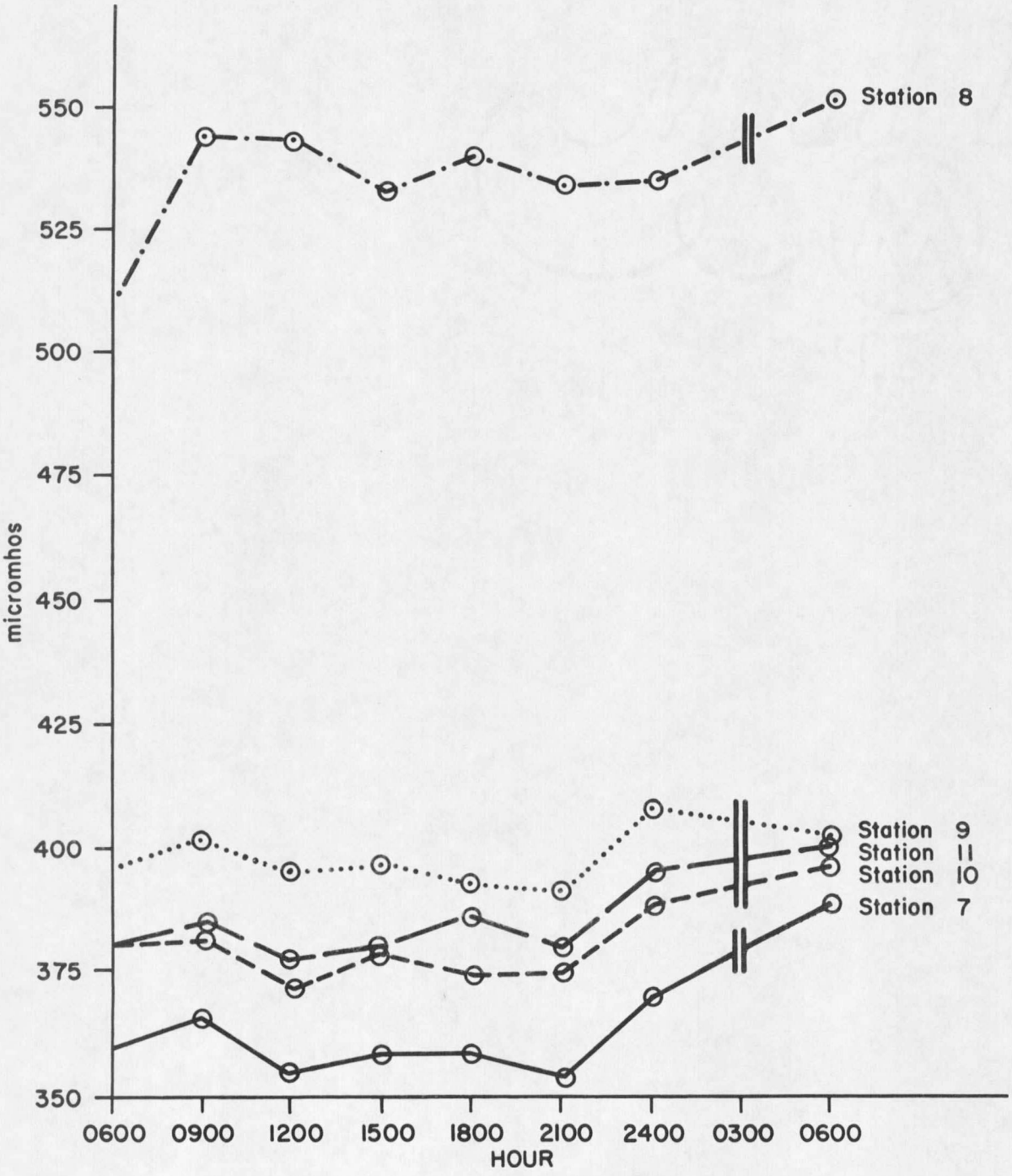


Figure 14. Average conductance at 25°C during the summer for the 24-hour sampling periods.

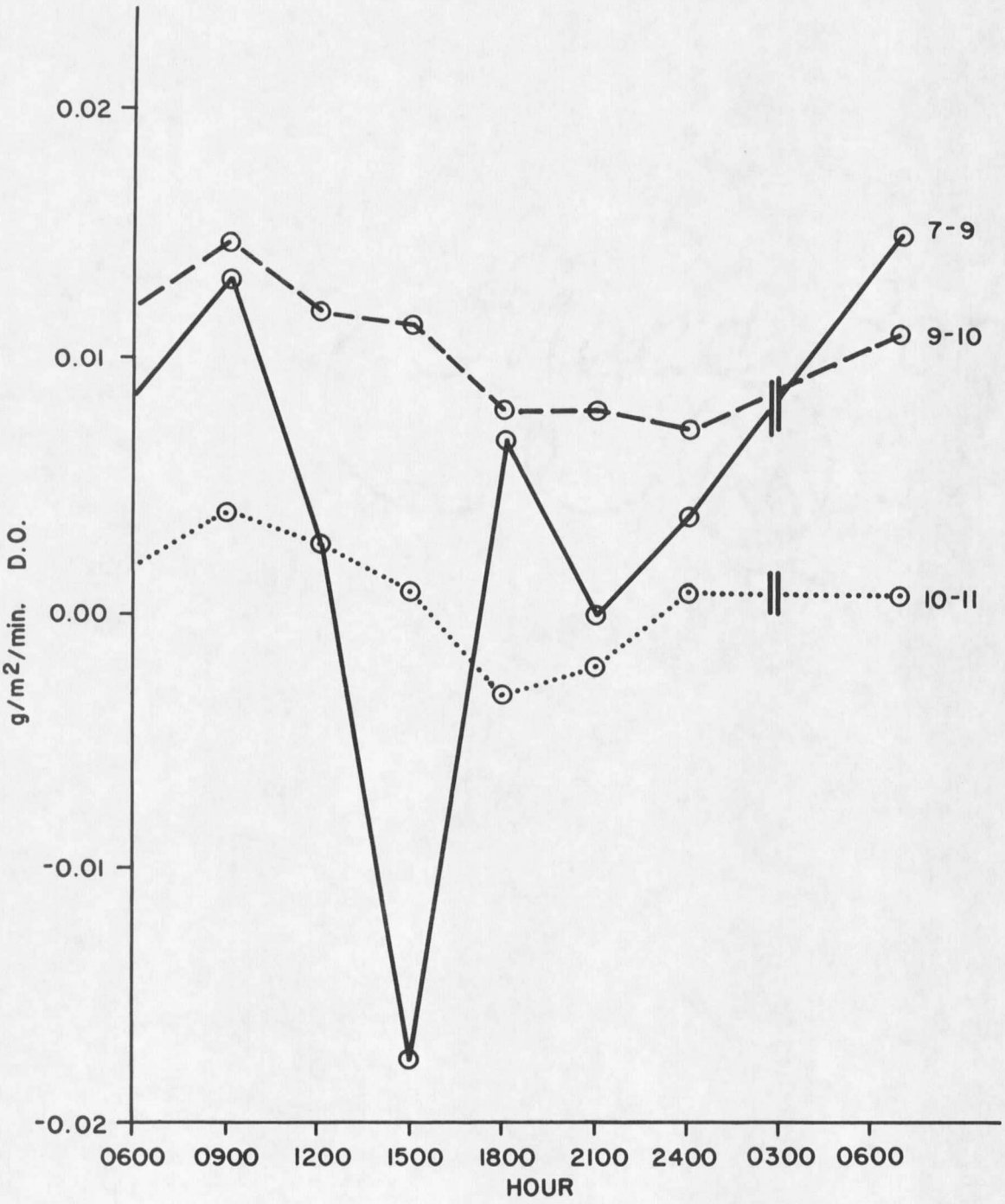


Figure 15. The net rate of change in dissolved oxygen in the river reaches during 2 24-hour sampling period (8/1-2/67).

Bridger Creek are assumed to account for the reoxygenation of the stream within this reach.

A significant decrease in the net rate of change in dissolved oxygen occurred within reach 10-11 as can be observed in Figure 14. The rate of change curve for D.O. in this stretch of stream oscillates around zero, which indicates that the stream was starting to equilibrate at this point throughout most of the day.

Figures 16, 17, and 18 show the rates of change in total carbon, nitrogen, and phosphate over a 24-hour period. Examination of the three graphs for reach 7-9 shows that there was a positive increase of the above substances in the stream due to the inflow of the sewage effluent. Diurnal variations are noted with the maximum rates of change taking place some where between 1200 hours and 2100 hours. There was a positive rate of change for total carbon through reach 9-10. This was presumed to be due to the influx of additional carbonaceous material from Bridger Creek. The rate of change in total nitrogen and phosphate in this stretch of stream was approximately zero. Oscillations around the zero point can be seen for all three of the substances within reach 10-11.

Water Temperature

An overall average of the water temperatures for the single sampling periods is given in Table IV. Some differences were observed among the stations with Bozeman Creek (station 1) having the lowest temperature and station 12 on the East Gallatin River having the highest.

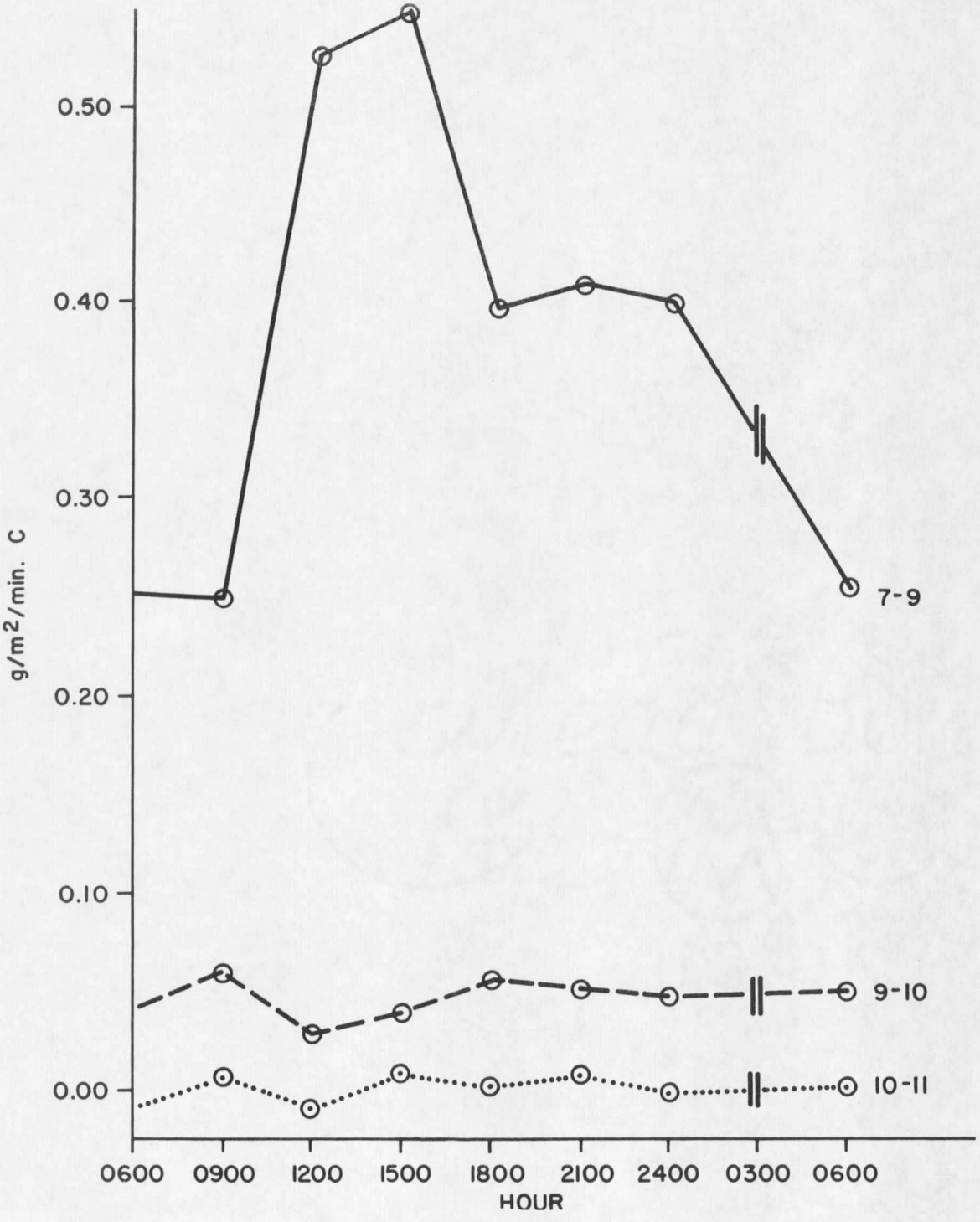


Figure 16. The rate of change in total carbon in the river reaches during a 24-hour sampling period (8/29-30/67).

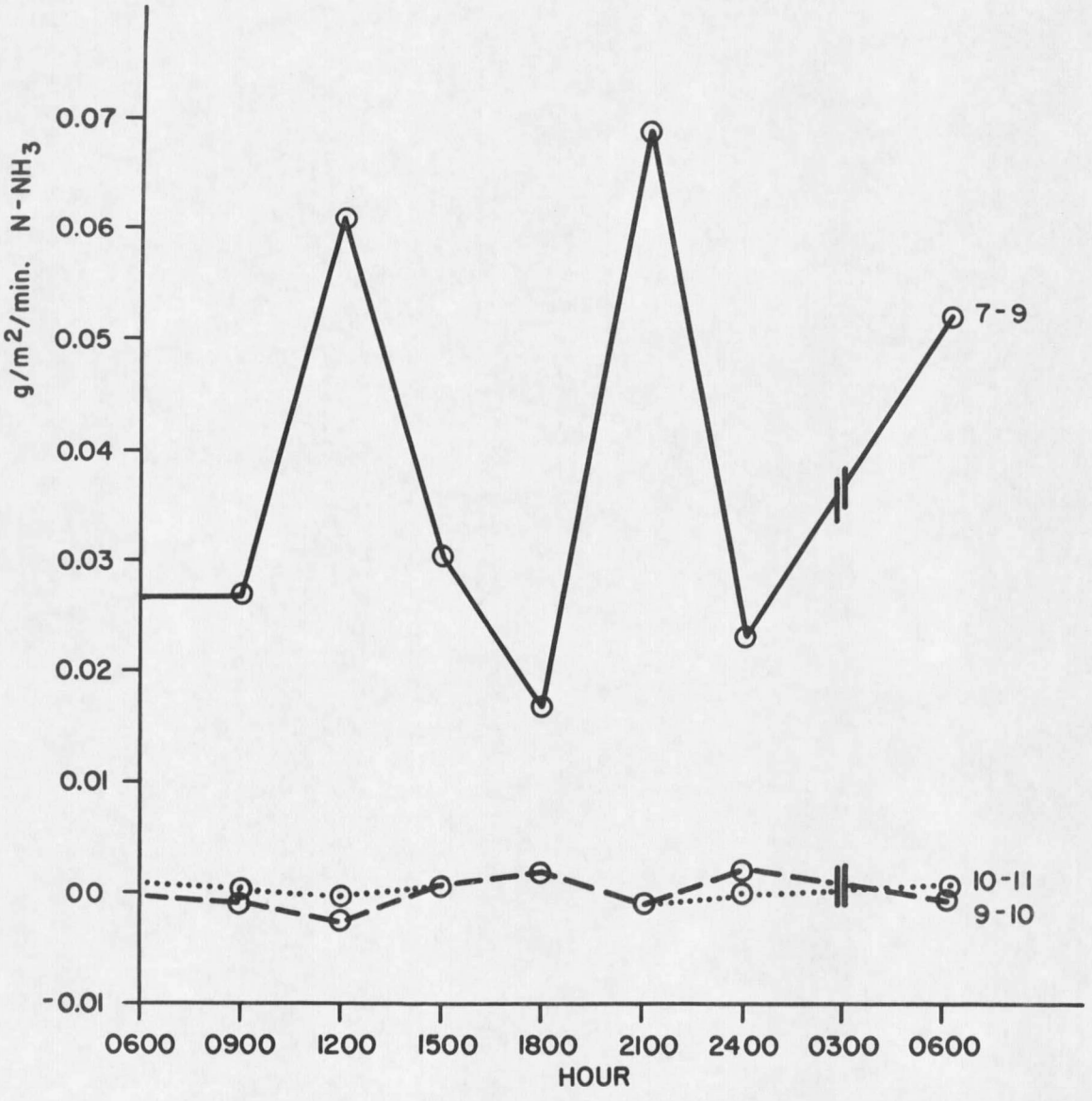


Figure 17. The rate of change in total nitrogen in the river reaches during a 24-hour sampling period (8/1-2/67).

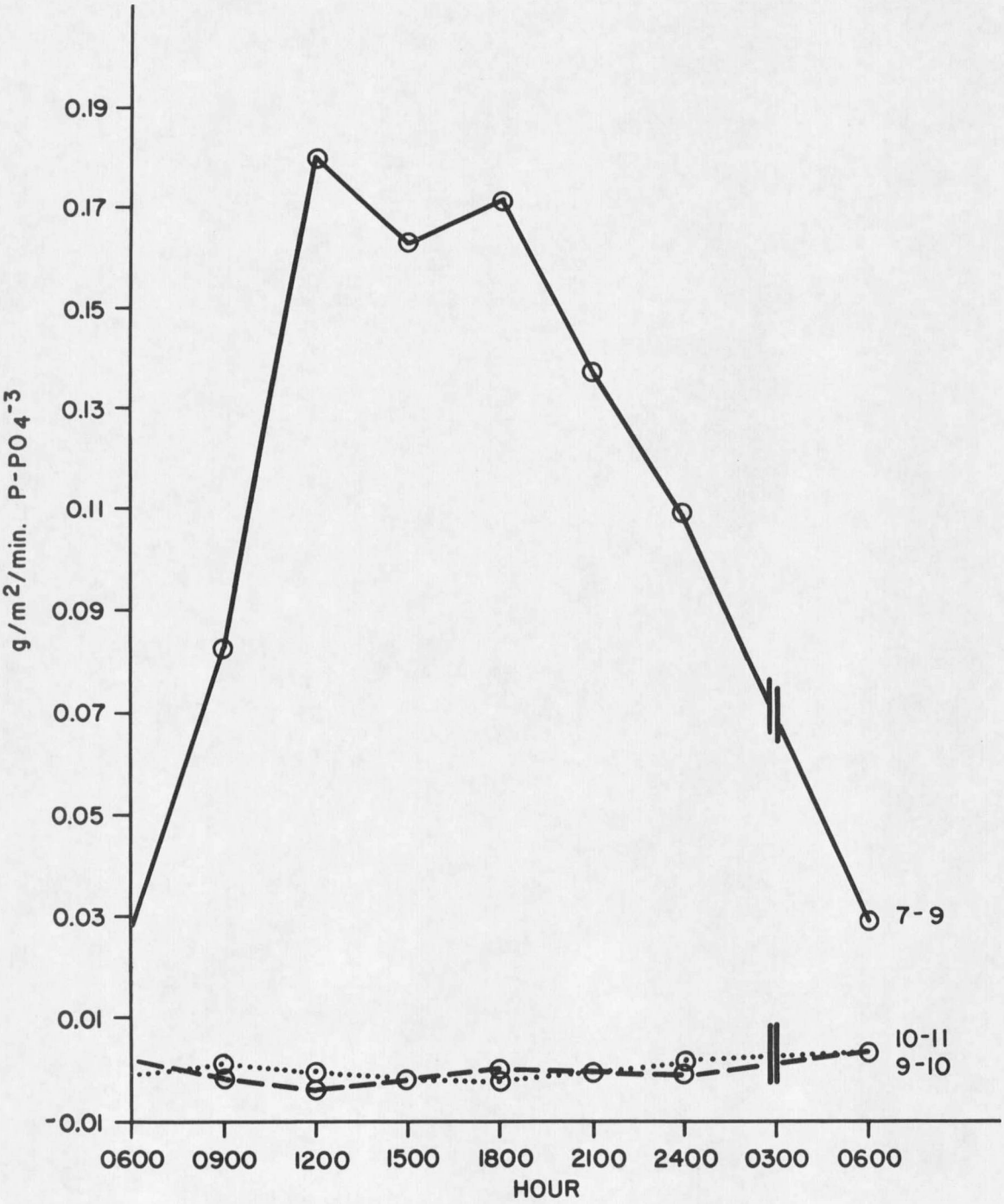


Figure 18. The rate of change in total phosphate in the river reaches during a 24-hour sampling period (8/1-2/67).

Table IV. Average water temperatures (^{o}C) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	TEMPERATURE
1	9.5
2	11.5
3	10.1
4	10.8
5	11.4
6	10.0
7	10.9
8	12.8
9	11.7
10	11.1
11	12.3
12	13.1

Figure 19 shows the mean water temperature at stations 7, 8, 9, 10, and 11 during the 24-hour sampling periods. Little variation was evident among these stations except for the sewage effluent which remained cooler between 1500 and 2100 hours.

Hydrology

The average discharge rates during the study for Bridger Creek, Bozeman Creek, the sewage effluent, and the East Gallatin River are listed in Tables V, VI, VII, and VIII respectively.

Figure 20 shows the average current velocity for the reaches between stations 7 and 11 on each of the 24-hour sampling dates. The mean velocity of the stream was greatest within reach 7-9 while reach 9-10 had the lowest velocity throughout the course of the study.

Statistical Analysis

Two methods for the estimation of total inorganic carbon (Carbonaceous Analyzer and Saunders) were compared by means of Students t-test for paired observations. This comparison included all the inorganic carbon data collected during the length of the study. Results of these analyses showed a highly significant difference between the average concentrations found by using the two different methods.

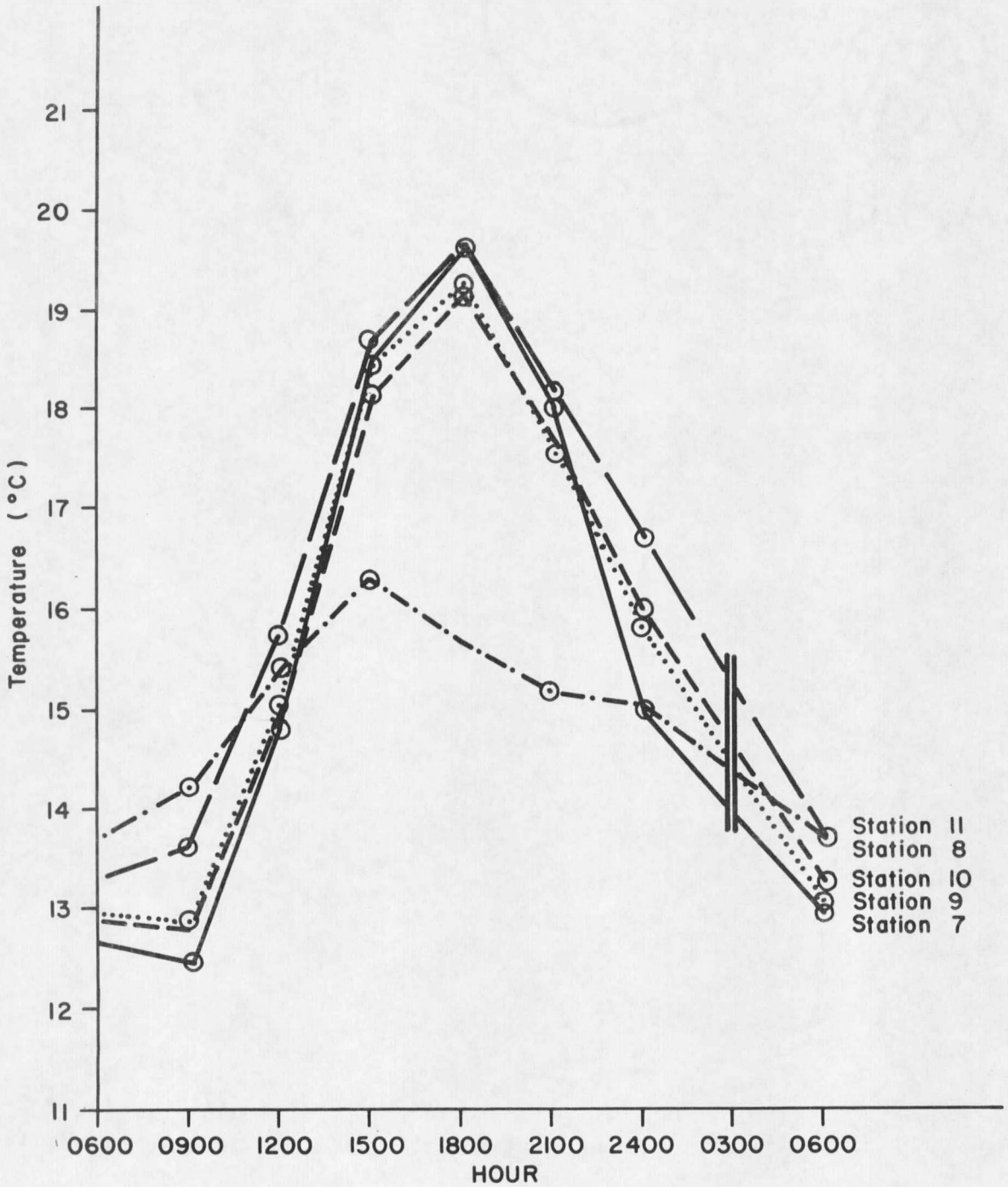


Figure 19. Mean water temperature at the stations sampled during 24-hour sampling periods throughout the summer.

Table V. Average discharge rates for Bridger Creek during the summer (1967).

DATE	DISCHARGE (cfs)	DISCHARGE (m^3/sec)	STAGE
6/13	____	____	____
6/20	____	____	____
6/27	____	____	____
7/12	65.19	1.85	0.97
7/20	26.69	0.75	0.74
7/26	____	____	____
8/2	30.34	0.85	0.58
8/9	23.16	0.66	0.52
8/15	19.21	0.55	0.40
8/23	15.95	0.45	0.36
8/30	14.52	0.41	0.37
9/12	14.52	0.41	0.37

____ Discharge rates not determined on this date.

Table VI. Average discharge rates for Bozeman Creek during the summer (1967).

DATE	DISCHARGE		STAGE
	(cfs)	(m^3/sec)	
6/13	____	____	____
6/20	____	____	____
6/27	____	____	____
7/12	26.23	0.75	1.49
7/20	____	____	____
7/26	____	____	____
8/2	12.92	0.37	1.29
8/9	17.59	0.50	1.28
8/15	15.20	0.43	1.26
8/23	11.52	0.33	1.20
8/30	14.87	0.42	1.28
9/12	21.60	0.61	1.40

____ Discharge rates not determined on this date.

Table VII. Average discharge rates for the sewage effluent during the summer (1967).

DATE	DISCHARGE	
	(cfs)	(m^3/sec)
6/13	2.95	0.08
6/20	5.22	0.15
6/27	4.95	0.14
7/12	4.99	0.14
7/20	5.38	0.15
7/26	5.15	0.15
8/2	5.19	0.15
8/9	5.03	0.14
8/15	5.45	0.15
8/23	5.42	0.15
8/30	5.49	0.16
9/12	5.34	0.15

Table VIII. Average discharge rates for the East Gallatin River during the summer (1967).

DATE	DISCHARGE		STAGE
	(cfs)	(m^3/sec)	
6/13	374	10.59	4.38
6/20	306	8.67	3.96
6/27	280	7.93	3.84
7/12	140	3.97	2.96
7/20	110	3.12	2.82
7/26	92	2.61	2.70
8/2	76	2.15	2.64
8/9	56	1.59	2.48
8/15	46	1.30	2.42
8/23	38	1.08	2.34
8/30	44	1.25	2.40
9/12	74	2.10	2.62

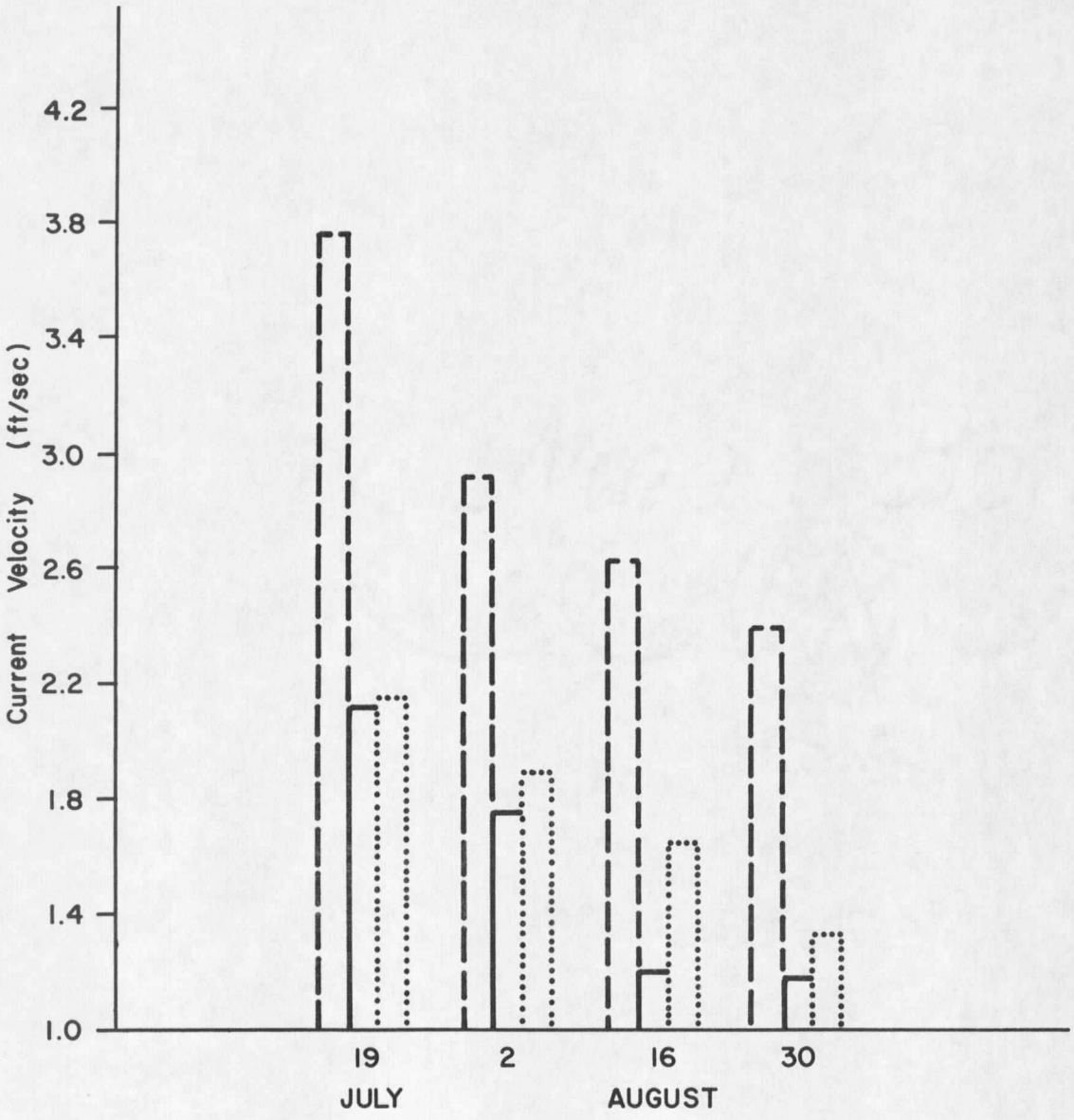


Figure 20. Average current velocity for reaches 7-11 on each 24-hour sampling date.

DISCUSSION

It was inferred from chemical and physical determinations (Table II) that Bozeman Creek and Bridger Creek contributed little if any of the pollution present in the East Gallatin River during the course of the study. This does not, however, eliminate the possibility of intermittent disposal of substances from these systems which would cause periodic pollution.

A survey of the various determinations made on the Rocky Creek stations also reveals no definite indication of pollution caused by the possible sources (slaughter house and stockyards) on this stretch of stream.

Because of the above, in this section of the paper, major emphasis will be placed on the downstream effects and some of the possible biological implications of the sewage outfall on the East Gallatin River.

An overall review of the chemistry shows that conductivity, total alkalinity, calcium, magnesium, bicarbonate, sulfate, and fluoride either did not change or if so, became less concentrated below the sewage outfall.

The development of an oxygen "sag" downstream from a pollutant source has been used in the past as one of the better indications of pollution. A decline in dissolved oxygen was observed 1.7 through 4.2 miles below the sewage outfall (Figure 3). The river was relatively deep and slow in this stretch. It should be kept in mind that surface sampling was employed throughout the study and that an even greater

depletion of oxygen could have occurred at the gravel-water interface because of organic deposits undergoing decomposition.

Relatively unpolluted streams exhibit a noticeable diurnal variation in their dissolved oxygen content. A diurnal change in oxygen concentration was observed at station 7, while downstream the variation became less because of the large oxygen demand placed on the river by the sewage outfall. The demand seemed to be greatest at 1500 hours within reach 7-9 (Figure 15).

The dissolved oxygen content at a given time depends on the amount of oxidizable material, temperature, sunlight, stream flow, and turbidity. The widest variation in the concentration of dissolved oxygen was found during periods of high temperature and low flow.

Large algal growths may develop below organic effluents and due to the photosynthetic and respiratory activity of these organisms a diurnal variation in the dissolved oxygen content results. Algae will generally supersaturate the water with dissolved oxygen during daylight hours while concentrations may approach zero at night (Klein, 1959).

In large slow moving rivers, algae may be the major factor in the reaeration of a system below an organic effluent. No intense algal blooms occurred during the course of this study and the turbulence of the stream and the highly oxygenated waters of Bridger Creek were considered to be more important in reaerating the river water.

There is a great deal of literature pertaining to the minimum dissolved oxygen concentration necessary to sustain healthy aquatic

life. Ellis (1937, 1946) indicated that in a relatively unpolluted stream, 3.0 mg/1 of dissolved oxygen, or less, should be regarded as lethal to fish. He also points out that to maintain a varied fish fauna in good condition the dissolved oxygen concentration should remain at 5.0 mg/1 or higher. At no time when samples were taken did the dissolved oxygen content drop below 5.0 mg/1, suggesting that the stream's biota would not be limited by lack of oxygen.

The B.O.D. data that were gathered during the summer unmistakeably indicated the presence of organic pollution. B.O.D. is an estimation of the amount of oxygen required to stabilize the demands of aerobic bio-chemical action in the decomposition of organic matter. Naturally the B.O.D. in the river was highest immediately below the sewage outfall, but values obtained 10.5 miles below (Figure 4) showed that a complete oxidation of the sewage or self purification of the stream had not taken place.

High B.O.D. is not a pollutant in itself but the subsequent reduction of dissolved oxygen to minimal levels can be harmful. This depletion, however, may be beneficial in the case of saprophytic bacteria.

In surface waters, ammonia generally results from the aerobic decomposition of nitrogenous organic matter. Unpolluted streams usually contain small concentrations of ammonia, which was true for all the stations sampled except those downstream from the sewage outfall. These sampling points below the effluent had a mean concentration of about

0.20 mg/1 (Figure 8).

The toxicity of ammonia and ammonium salts to fish is a highly complex problem which is not completely understood. Toxicity has been reported at 0.3 mg/1 and up depending upon other concurrent conditions such as pH, temperature, D.O., etc. (Jones, 1964). In the vicinity of the sewage outfall ammonia concentrations are high but are diluted out to approximately 0.30 mg/1 at station 9.

According to the California Water Quality Criteria (1963) a generally accepted limit for free ammonia for sanitary purity of water supplies is between 0.05 and 0.10 mg/1. Concentrations which exceed 0.10 mg/1 are suggestive that the water supply has been recently polluted.

The toxicity of ammonia and ammonium compounds to aquatic animals is related to the amount of undissociated ammonium hydroxide in solution. This in turn is a function of pH. Thus, as the pH increases the toxicity becomes greater and a decrease in pH results in less toxicity (Doudoroff et al., 1950).

Carbon dioxide (15-60 mg/1) seems to reduce the toxicity of ammonia presumably by lowering the pH, thereby reducing the undissociated ammonium hydroxide (Alabaster, 1954).

Low dissolved oxygen concentrations can further complicate the problem by markedly increasing ammonia toxicity (Merkens et al., 1957).

Downstream from the sewage effluent ammonia usually decreased in concentration with a corresponding increase of both nitrate and nitrite.

An increase in these substances can be considered another indication of pollution.

Nitrate represents the final oxidation product of ammonia, nitrite being an intermediate in this process. Nitrite can also be formed by the oxidation of organic nitrogen (Alexander, 1961).

Nitrates and nitrites are seldom abundant in natural surface waters. They serve as essential nutrient sources for all types of plants. High nitrate concentrations in sewage effluents have been shown by Buswell (1948) to stimulate the growth of plankton and aquatic macrophytes.

A generally accepted upper limit for nitrate is 45 mg/1 (NO_3^-) and 2 mg/1 nitrite (NO_2^-) in domestic water supplies.

Examination of Figure 10 shows that phosphate was definitely not limiting at any of the stations below the sewage outfall. Phosphates are a major component of municipal sewage as the result of the utilization of syndets.

In natural waters phosphate is seldom found in significant concentrations. The discharge of excessive amounts of phosphates into streams may result in excessive growth of algae with detriment to fish (Stangenberg, 1944). Fuller (1949) has demonstrated that phosphates are seldom toxic to fish and other aquatic life and, as Brinley (1943) has stated, may even be beneficial to fish production by increasing algal and streambenthos populations.

The nutrient content of the water just below the sewage outfall (see Figures 16, 17, and 18) varied considerably depending upon the time of day, the amount of dilution, the temperature, and other factors. In general, however, the water analyses showed that total carbon concentrations were approximately the same or slightly lower above the sewage effluent than those below, although large quantities were added by the sewage. Total nitrogen and total phosphate were present only in small quantities upstream from the sewage outfall, but again were added in large amounts by the sewage. A comparison of the phosphate and nitrogen values found above the sewage effluent area and those 10.5 miles below are indicative that the river has not returned to its original "normal" condition.

This discharge of organic nutrients can be immediately utilized by saprobic feeding organisms (e.g., Sphaerotilus sp.) of the stream. Due to the increased fertility of the stream such organisms can soon develop troublesome growths. Algal blooms may develop or the normal number of aquatic invertebrate species may be reduced or eliminated (Gaufin et al., 1956).

Another indication of stream pollution is a sudden rise in the sodium and chloride content (Klein, 1962). Increases in concentration of chloride may be due to streams passing through a salt-bearing inclusion or from sea water contamination, but neither of the above is thought to be the case here. Instead, the increase observed is attributable to the sewage outfall (Figures 5 and 6). Sodium chloride

is present in human urine and as a result sodium and chloride ion were found in higher concentrations at station 8 than at any of the other stations sampled. Sodium is a common constituent of most household detergents and would also attribute for the higher sodium concentrations below the effluent. Concentrations of both sodium and chloride below the sewage outfall remained essentially unaltered except for a slight dilution effect from Bridger Creek.

The literature reviewed in California Water Quality Criteria (1963) suggests that the concentrations of both sodium and chloride below the effluent are well below toxic levels to aquatic life.

SUMMARY

During a twelve week period water samples were collected at sampling stations established on Bozeman Creek, Rocky Creek, Bridger Creek, and the East Gallatin River. Single samples, where all stations were sampled, and 24-hour samples, which were restricted to a "clean" water station above the sewage outfall and three stations below it on the East Gallatin River, were taken throughout the course of the study.

The water samples were analyzed for conductivity, total alkalinity, pH, dissolved oxygen, calcium, magnesium, sodium, potassium, sulfate, chloride, fluoride, silica, turbidity, B.O.D., and the various forms of carbon, nitrogen, and phosphorous. Samples obtained during the 24-hour sampling periods were analyzed only for conductivity, pH, total alkalinity, total carbon, total organic carbon, total nitrogen, and total phosphate.

Results of the chemical analyses showed by means of a comparison of the upstream and downstream concentrations, that Bozeman Creek, Bridger Creek, and Rocky Creek are not chemically polluted to any great extent. Similar comparisons revealed that the East Gallatin River is polluted by the Bozeman City Sewage Treatment Plant and that there is a significant rise in concentration of sodium, chloride, ammonia, nitrate, nitrite, soluble organic nitrogen, inorganic phosphate, and particulate phosphate as far as 10.5 miles below the sewage outfall. An oxygen sag developed below the outfall and B.O.D. determinations showed that the stream had not completely recovered 10.5 miles downstream from this area.

The 24-hour sampling periods demonstrated that maximum discharge of carbon, nitrogen, and phosphorus containing compounds from the sewage outfall occurred between 1200 and 2100 hours. Estimation of the net rate of change in dissolved oxygen showed that the sewage outfall components placed the greatest oxygen demand on the stream at 1500 hours.

APPENDIX

Table IX. Water temperatures (°C) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	7.5	8.0	8.3	10.8	11.5	9.6	10.9	9.5
2	8.5	12.4	11.0	12.5	13.7	11.8	12.3	9.5
3	___	9.4	8.9	11.4	___	11.9	___	9.1
4	___	9.9	9.9	12.2	___	11.9	___	9.9
5	9.0	12.2	10.1	12.3	14.0	11.6	12.3	9.5
6	7.7	8.9	9.1	10.9	13.0	10.4	10.6	9.0
7	8.3	11.0	10.3	11.7	13.6	11.3	11.7	9.4
8	10.9	12.0	11.8	12.7	13.5	13.5	14.0	13.8
9	___	11.3	___	11.9	13.6	11.4	12.0	9.7
10	8.3	10.8	10.3	12.3	13.9	11.7	12.0	9.8
11	___	11.5	10.9	14.0	14.5	12.2	12.7	10.1
12	___	12.5	12.1	14.0	15.6	13.4	13.5	10.5

___ Samples were not collected.

Table X. Dissolved oxygen (mg/l) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	9.44	10.88	10.44	8.98	9.10	8.64	8.44	8.17
2	9.47	9.74	10.00	8.82	8.77	8.36	8.14	8.26
3	___	10.94	10.28	9.41	___	8.63	___	8.39
4	___	10.91	10.13	9.07	___	8.63	___	8.29
5	9.39	10.19	10.52	9.17	8.62	8.42	8.14	8.17
6	9.59	11.29	10.53	9.50	9.08	8.61	8.60	8.67
7	9.74	10.03	10.13	9.42	8.93	8.32	7.89	8.24
8	8.09	8.89	8.25	7.00	7.14	7.08	6.82	6.71
9	___	10.48	___	9.06	8.67	8.07	7.67	8.00
10	9.47	10.63	10.26	8.96	7.93	7.57	6.55	7.41
11	___	10.25	10.22	8.25	8.24	7.75	6.20	7.10
12	___	10.24	10.29	8.75	8.44	8.20	7.03	7.83

___ Samples were not collected.

Table XI. pH measurements at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	8.00	8.00	8.05	8.22	8.23	8.21	8.19	8.23
2	8.10	8.11	8.10	8.22	8.30	8.34	8.23	8.31
3	___	8.15	8.10	8.35	___	8.31	___	8.34
4	___	8.18	8.18	8.36	___	8.37	___	8.35
5	8.05	8.10	8.19	8.34	8.24	8.30	8.20	8.29
6	8.00	8.05	8.03	8.26	8.31	8.33	8.19	8.27
7	8.14	8.15	8.10	8.30	8.28	8.29	8.19	8.27
8	7.40	7.49	7.41	7.48	8.34	7.60	7.51	7.58
9	___	8.00	___	8.21	8.20	8.12	7.96	8.12
10	8.05	8.11	8.10	8.25	8.14	8.16	7.98	8.10
11	___	8.05	8.08	8.20	8.20	8.17	7.90	8.01
12	___	8.00	8.08	8.27	8.22	8.20	8.00	8.12

___ Samples were not collected.

Table XII. Total alkalinities (meq/1) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	1.84	1.87	2.01	2.45	2.34	2.87	3.11	2.73
2	2.60	3.06	3.01	3.33	3.36	3.93	3.99	3.53
3	___	2.89	2.88	3.47	___	3.84	___	3.70
4	___	2.85	2.97	3.69	___	3.70	___	3.65
5	2.61	3.15	3.05	4.27	3.84	3.90	3.96	3.75
6	2.00	1.79	2.22	2.04	3.88	3.51	3.60	2.90
7	2.41	2.62	2.79	3.33	3.88	3.78	3.85	3.41
8	4.68	4.64	4.62	4.82	5.16	4.70	4.61	4.62
9	___	2.73	___	3.38	3.98	3.96	4.01	3.58
10	2.58	2.82	2.84	3.48	3.82	3.86	3.97	3.58
11	___	2.71	2.89	3.42	3.92	3.93	3.99	3.57
12	___	2.79	2.58	3.42	3.86	3.86	3.86	3.56

___ Samples were not collected.

Table XIII. Conductivities (micromhos) at 25°C for the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE															
	6/13		6/20		6/27		7/11		7/25		8/8		8/22		9/12	
	°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}
1	10.0	188	14.0	180	14.0	208	14.2	243	15.1	275	12.6	287	12.0	310	9.8	287
2	10.6	279	14.5	310	15.2	318	14.4	406	15.5	408	12.5	415	12.2	433	9.7	423
3	----	---	13.0	283	13.5	300	13.2	370	----	---	11.9	377	----	---	9.9	374
4	----	---	13.0	295	13.4	304	13.2	370	----	---	12.2	374	----	---	10.0	370
5	10.5	285	14.0	318	14.5	323	13.9	411	15.1	412	12.1	419	12.0	429	9.9	430
6	10.4	210	13.0	205	13.6	230	12.9	273	14.9	373	12.0	336	11.5	354	9.8	296
7	10.4	256	13.5	274	14.2	294	13.0	367	15.2	399	12.2	400	11.8	407	9.7	374
8	12.0	592	14.0	587	14.5	494	14.0	715	15.0	629	13.2	577	12.8	547	11.9	582
9	----	---	14.0	293	----	---	13.3	395	15.0	426	12.5	427	12.0	436	10.0	400
10	10.8	277	14.0	287	14.9	305	13.7	375	15.5	408	13.0	403	12.1	422	9.8	392
11	----	---	15.5	289	14.4	302	14.2	375	15.8	405	13.2	420	12.8	427	11.0	400
12	----	---	15.0	292	15.0	305	14.6	376	16.5	399	14.0	405	13.1	411	11.0	411

---- Samples were not collected.

Table XIV. Chloride concentration (mg/l Cl^-) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.30	0.50	0.55	1.05	1.15	1.45	1.45	2.35
2	0.80	1.05	2.30	1.80	1.55	1.65	1.85	2.25
3	___	0.60	1.40	1.30	___	1.65	___	2.50
4	___	1.10	1.25	1.40	___	1.70	___	1.95
5	0.80	1.30	1.55	1.75	1.55	1.75	1.80	2.55
6	0.65	0.90	1.20	1.25	1.45	1.45	1.55	1.50
7	0.95	0.95	1.30	1.45	1.65	1.55	1.95	1.70
8	25.70	29.40	28.15	47.95	31.15	34.95	23.20	29.90
9	___	3.40	___	4.00	4.05	5.25	4.90	4.70
10	1.25	1.55	2.00	2.60	2.55	3.55	3.70	2.75
11	___	1.65	1.75	2.10	2.55	4.90	5.95	3.50
12	___	1.35	1.10	3.05	3.70	4.65	4.85	6.10

___ Samples were not collected.

Table XV. Fluoride concentrations (mg/l F^-) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.13	0.18	0.29	*	0.34	0.01	0.25	0.25
2	0.16	0.16	0.30	0.01	0.29	0.27	0.34	0.16
3	___	0.02	0.23	*	___	0.16	___	0.13
4	___	0.09	0.23	*	___	0.06	___	0.16
5	0.13	0.13	0.57	0.01	0.32	0.13	0.18	0.16
6	0.13	0.13	0.29	*	0.20	*	0.16	0.16
7	0.14	0.18	0.54	0.02	0.34	0.01	0.20	0.16
8	0.80	0.43	0.78	1.96	0.89	0.69	0.90	0.54
9	___	0.20	___	0.69	0.59	0.01	0.28	0.16
10	0.16	0.22	0.30	0.01	0.38	0.36	0.27	0.23
11	___	0.13	0.23	0.01	0.36	0.16	0.32	0.18
12	___	0.15	0.27	0.01	0.66	0.16	0.34	0.16

___ Samples were not collected.

* Concentration was below the detectable limits (0.01 mg/L) of the test employed.

Table XVI. Turbidity (Stanard Jackson Units) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE						
	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	68.0	47.0	32.0	42.0	49.0	30.0	57.0
2	83.0	81.0	40.5	34.0	36.0	42.0	65.0
3	66.5	57.5	39.0	___	31.0	___	59.0
4	71.0	60.0	42.0	___	26.0	___	43.0
5	83.0	81.0	44.0	36.0	36.0	39.0	69.5
6	68.0	57.5	56.0	42.0	40.5	40.5	56.0
7	92.0	75.0	49.0	36.0	37.5	39.0	64.0
8	44.0	54.0	128.0	62.5	45.5	47.0	45.5
9	84.0	___	57.5	39.0	44.0	44.0	61.0
10	75.0	75.0	48.0	39.0	42.0	39.0	61.0
11	84.0	78.5	45.0	45.5	42.0	40.5	68.0
12	112.0	97.0	59.0	44.0	44.0	42.0	85.0

___ Samples were not collected.

Table XVII. Sulfate concentrations (mg/l $SO_4^{=}$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	8.8	9.3	9.0	7.8	6.7	9.5	9.0	11.3
2	19.2	22.5	21.4	25.0	27.5	33.4	36.7	40.8
3	___	12.3	12.5	12.6	___	16.9	___	23.1
4	___	12.7	12.5	14.8	___	16.8	___	25.1
5	18.0	23.8	20.0	24.5	27.0	32.8	36.5	41.4
6	9.0	10.0	9.5	8.5	8.8	9.8	10.4	12.6
7	15.5	17.3	16.3	18.2	22.8	27.3	28.5	29.7
8	27.5	30.8	27.4	36.8	23.2	26.9	25.8	30.4
9	___	18.5	___	19.4	23.0	27.1	28.5	30.4
10	14.3	15.8	15.8	16.8	19.8	24.8	27.0	28.5
11	___	17.0	14.8	15.9	18.3	24.4	26.5	30.0
12	___	15.6	14.3	16.3	19.6	25.0	26.0	30.5

___ Samples were not collected.

Table XVIII. Total carbon concentrations (mg/l C) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	25.0	26.5	30.4	31.4	33.5	34.6	37.3	38.7
2	41.2	40.7	44.3	51.6	47.3	42.5	43.8	54.7
3	___	39.7	40.0	46.9	___	40.0	___	54.8
4	___	40.0	43.0	49.5	___	40.6	___	54.3
5	40.3	40.5	42.0	49.3	48.5	47.7	45.7	55.0
6	34.6	30.7	31.4	44.5	49.3	43.0	41.3	41.3
7	42.0	36.0	41.5	45.7	50.0	47.5	47.4	50.1
8	113.0	91.2	86.2	440.0	100.0	93.4	89.0	92.0
9	___	37.0	___	64.4	52.6	46.1	55.4	52.6
10	43.5	34.5	37.3	47.5	50.9	46.0	53.4	53.5
11	___	38.4	36.2	39.7	50.0	48.2	54.7	56.5
12	___	40.2	40.0	46.1	51.2	46.7	54.5	54.2

___ Samples were not collected.

Table XIX. Total organic carbon concentrations (mg/l C) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	11.2	8.2	7.0	6.3	6.4	7.2	6.6	7.3
2	11.4	9.2	8.7	7.7	5.7	5.2	5.2	7.9
3	___	9.0	7.3	6.1	___	4.8	___	9.2
4	___	6.1	6.1	5.5	___	5.0	___	6.8
5	11.0	8.5	6.1	5.3	5.5	4.4	4.5	9.2
6	7.0	8.7	4.8	5.8	5.4	6.0	6.0	5.9
7	8.3	13.2	6.3	7.2	5.0	5.0	4.5	6.4
8	46.0	36.0	24.0	344.0	44.1	28.0	33.2	38.1
9	___	8.1	___	20.7	7.4	4.9	4.0	7.7
10	11.1	10.3	6.9	7.6	5.0	4.7	4.8	7.4
11	___	8.0	6.0	4.2	5.1	4.9	4.8	8.4
12	___	9.5	7.2	5.9	5.5	5.0	5.5	9.0

___ Samples were not collected.

Table XX. Soluble organic carbon concentrations (mg/1 C) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	5.5	4.3	5.3	3.7	3.7	4.4	4.6	6.7
2	7.1	7.4	6.2	5.0	4.5	4.1	4.2	6.5
3	___	5.6	4.4	3.5	___	4.2	___	7.2
4	___	5.5	4.8	4.5	___	3.7	___	5.7
5	6.6	6.5	4.8	4.4	4.5	4.8	4.1	5.6
6	4.7	4.6	4.4	3.4	4.0	4.1	4.0	5.1
7	5.2	5.2	4.3	5.4	5.1	4.7	4.1	5.9
8	31.5	19.7	14.8	36.4	38.3	26.2	14.4	14.4
9	___	5.7	___	20.5	5.3	4.9	5.9	6.0
10	8.0	5.0	5.0	6.4	5.1	4.6	4.7	6.3
11	___	5.8	4.3	4.5	4.3	4.5	4.9	5.9
12	___	5.0	4.3	6.2	4.3	5.2	5.0	6.7

___ Samples were not collected.

Table XXI. Total nitrogen concentrations (mg/l $N\text{-}NH_3$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	*	1.46	1.18	0.79	1.21	3.18	4.10	3.71
2	*	1.66	1.30	1.58	0.59	4.00	3.29	3.79
3	___	1.36	1.18	1.18	___	2.35	___	3.27
4	___	1.31	1.08	0.24	___	2.05	___	2.60
5	*	1.26	1.03	1.58	0.59	2.84	2.86	2.39
6	*	0.94	1.08	2.37	0.70	1.47	2.86	2.11
7	*	1.05	1.03	2.13	0.99	2.35	3.92	2.26
8	*	15.6	9.80	20.6	7.60	35.1	29.8	18.0
9	___	1.45	___	1.74	1.10	1.86	3.98	2.25
10	*	1.56	0.88	0.09	0.59	1.33	3.98	2.60
11	___	1.15	1.40	0.56	0.82	2.40	3.96	2.74
12	___	1.15	2.50	1.42	1.10	1.86	4.05	2.82

___ Samples were not collected.

* Samples were lost.

Table XXII. Total soluble nitrogen concentrations (mg/l $N\text{-}NH_3$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.46	1.36	0.51	0.33	1.10	3.57	1.85	2.51
2	0.32	1.26	0.51	1.26	0.25	2.65	0.75	2.34
3	___	0.79	0.77	0.03	___	2.56	___	3.00
4	___	1.21	0.77	*	___	1.47	___	2.64
5	*	1.10	1.08	*	0.25	4.49	1.44	2.56
6	1.08	0.69	0.41	*	0.00	3.04	1.31	2.45
7	0.56	1.21	0.82	*	0.70	3.70	2.41	2.12
8	*	3.68	8.20	*	4.70	22.1	13.8	17.2
9	___	1.31	___	*	0.42	2.21	2.60	2.20
10	0.56	0.90	0.41	*	0.42	1.76	1.26	2.20
11	___	0.84	0.56	*	0.70	2.21	0.90	2.38
12	___	1.15	0.66	*	0.70	2.15	2.23	2.47

___ Samples were not collected.

* Samples were lost.

Table XXIII. Free ammonia concentrations (mg/l $N\text{-}NH_3$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.03	0.03	0.14	0.03	0.08	0.10	0.45	0.00
2	0.03	0.06	0.08	0.03	0.00	0.00	0.50	0.30
3	___	0.06	0.03	0.03	___	0.00	___	0.00
4	___	0.03	0.03	0.03	___	0.10	___	0.00
5	0.03	0.06	0.03	0.03	0.08	0.00	0.45	0.00
6	0.03	0.06	0.03	0.03	0.00	0.00	0.45	0.00
7	0.03	0.03	0.24	0.03	0.00	0.00	0.50	0.00
8	2.70	1.81	1.35	3.85	1.68	2.46	2.73	2.45
9	___	0.18	___	0.09	0.25	0.35	0.83	0.16
10	0.03	0.00	0.14	0.03	0.19	0.16	1.00	0.08
11	___	0.03	0.14	0.03	0.31	0.20	0.88	0.16
12	___	0.23	0.14	0.03	0.08	0.10	0.45	0.26

___ Samples were not collected.

Table XXIV. Nitrate concentrations (mg/l $N\text{-}NO_3$) at the stations sampled during the single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.10	0.04	0.25	0.50	0.09	0.20	0.04	0.39
2	0.60	0.14	0.49	0.40	0.60	0.00	0.00	0.44
3	___	0.39	1.00	0.20	___	0.05	___	0.39
4	___	0.29	0.59	0.40	___	0.00	___	0.34
5	0.10	0.19	0.50	0.30	0.30	0.20	0.59	0.34
6	0.10	0.34	0.54	0.45	0.59	0.05	0.00	0.44
7	0.00	0.90	0.50	0.50	0.44	0.10	0.00	0.29
8	2.77	3.37	2.67	11.4	1.47	1.29	0.58	1.48
9	___	0.64	___	1.00	0.69	0.39	0.00	0.64
10	0.20	0.29	0.49	0.45	0.64	0.19	0.00	0.48
11	___	0.54	0.39	0.50	0.27	0.22	0.00	0.17
12	___	0.49	0.64	0.29	0.51	0.20	0.02	0.58

___ Samples were not collected.

Table XXV. Nitrite concentrations (mg/l $N\text{-}NO_2^-$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.001	0.006	0.005	0.001	0.006	0.003	0.008	0.007
2	0.005	0.008	0.006	0.001	0.005	0.001	0.008	0.006
3	___	0.006	0.006	0.001	___	0.001	___	0.007
4	___	0.006	0.006	0.001	___	0.002	___	0.007
5	0.005	0.006	0.005	0.001	0.005	0.001	0.008	0.007
6	0.003	0.006	0.006	0.002	0.008	0.004	0.010	0.009
7	0.004	0.005	0.006	0.001	0.006	0.002	0.008	0.008
8	0.029	0.026	0.026	0.017	0.034	0.013	0.020	0.020
9	___	0.008	___	0.003	0.010	0.007	0.013	0.011
10	0.004	0.008	0.007	0.002	0.013	0.013	0.024	0.018
11	___	0.008	0.006	0.001	0.028	0.031	0.052	0.033
12	___	0.011	0.008	0.006	0.044	0.049	0.083	0.071

___ Samples were not collected.

Table XXVI. Total phosphate concentrations (mg/l $P\text{-}PO_4^{\equiv}$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.64	0.82	0.51	0.38	0.34	0.72	0.39	0.60
2	1.34	1.22	0.62	0.32	0.29	0.30	0.34	0.74
3	___	0.38	0.48	0.20	___	0.13	___	0.64
4	___	0.36	0.53	0.21	___	0.12	___	0.35
5	0.80	1.17	0.72	0.27	0.33	0.25	0.33	0.72
6	1.42	0.73	0.72	0.53	0.62	0.76	0.60	0.58
7	2.42	0.56	0.71	0.42	0.52	0.32	0.48	0.70
8	15.0	17.5	7.50	4.94	10.8	11.1	9.30	7.20
9	___	1.35	___	1.40	1.14	1.23	1.59	1.28
10	1.82	1.25	0.78	0.79	0.91	1.19	1.85	1.34
11	___	1.38	0.84	0.93	1.26	1.73	3.08	2.23
12	___	2.14	1.33	1.60	2.39	3.36	4.20	2.60

___ Samples were not collected.

Table XXVII. Soluble inorganic and organic phosphate (mg/l $P\text{-}PO_4^{\equiv}$) at the stations sampled during single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.48	0.19	0.33	0.37	0.00	0.42	0.30	0.49
2	0.43	0.26	0.23	0.27	0.18	0.18	0.16	0.34
3	___	0.10	0.14	0.15	___	0.33	___	0.25
4	___	0.15	0.17	0.16	___	0.10	___	0.13
5	0.54	0.30	0.25	0.20	0.24	0.17	0.18	0.29
6	0.60	0.33	0.36	1.46	0.44	0.29	0.37	0.45
7	0.52	0.30	0.30	0.29	0.28	0.16	0.28	0.33
8	13.6	11.4	6.00	4.82	9.00	7.80	8.50	6.50
9	___	0.97	___	1.34	0.94	0.96	1.17	0.99
10	0.96	0.58	0.33	0.66	0.66	0.90	1.47	0.88
11	___	0.40	0.32	0.64	0.96	1.45	2.67	1.47
12	___	0.35	0.46	1.11	2.00	3.04	4.01	2.62

___ Samples were not collected.

Table XXVIII. Soluble inorganic phosphate (mg/l $P\text{-}PO_4^{\equiv}$) at the stations sampled during the single sampling periods throughout the summer (1967).

STATION	DATE							
	6/13	6/20	6/27	7/11	7/25	8/8	8/22	9/12
1	0.46	0.11	0.34	0.37	0.30	0.49	0.33	0.49
2	0.44	0.10	0.25	0.22	0.18	0.10	0.16	0.26
3	___	0.10	0.14	0.10	___	0.09	___	0.17
4	___	0.10	0.15	0.13	___	0.09	___	0.07
5	0.43	0.15	0.23	0.14	0.20	0.12	0.13	0.22
6	0.62	0.17	0.37	0.44	0.46	0.28	0.36	0.45
7	0.60	0.11	0.29	0.26	0.27	0.15	0.24	0.31
8	12.2	8.00	5.60	4.56	8.50	6.10	6.60	5.80
9	___	0.00	___	2.66	1.01	0.85	1.07	0.90
10	1.08	0.29	0.35	0.69	0.65	0.75	1.33	0.81
11	___	0.35	0.34	1.08	0.98	1.31	2.36	1.36
12	___	0.62	0.50	1.08	1.93	2.74	3.92	2.38

___ Samples were not collected.

Table XXIX. Calcium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods.

STATION	DATE		
	8/8	8/22	9/12
1	1.50	1.59	1.35
2	2.28	2.07	1.96
3	1.88	——	1.77
4	1.90	——	1.80
5	2.32	2.01	1.98
6	1.76	1.77	1.47
7	2.24	1.95	1.76
8	2.85	2.08	2.17
9	2.16	1.98	1.76
10	2.12	1.93	1.83
11	2.06	1.93	1.77
12	2.06	1.87	1.77

—— Samples were not collected.

Table XXX. Magnesium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods.

STATION	DATE		
	8/8	8/22	9/12
1	1.04	1.19	1.22
2	1.59	1.62	2.22
3	1.04	——	1.30
4	1.31	——	1.47
5	1.60	1.61	2.83
6	1.28	1.25	1.42
7	1.50	1.51	1.86
8	1.55	1.42	2.63
9	1.50	1.43	1.92
10	1.43	1.27	1.52
11	1.55	1.26	1.56
12	1.45	1.23	1.46

—— Samples were not collected.

Table XXXI. Sodium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods.

STATION	DATE		
	8/8	8/22	9/12
1	0.16	0.19	0.14
2	0.38	0.37	0.47
3	0.56	——	0.79
4	0.43	——	0.59
5	0.38	0.39	0.47
6	0.25	0.27	0.23
7	0.35	0.22	0.37
8	1.17	0.99	1.30
9	0.45	0.45	0.53
10	0.43	0.45	0.47
11	0.49	0.54	0.57
12	0.56	0.54	0.68

—— Samples were not collected.

Table XXXII. Potassium concentrations (meq/1) at the stations sampled during 8/8/67 - 9/12/67 for the single sampling periods.

STATION	DATE		
	8/8	8/22	9/12
1	0.076	0.079	0.066
2	0.049	0.063	0.073
3	0.027	———	0.059
4	0.032	———	0.037
5	0 049	0.057	0.054
6	0.076	0.097	0.078
7	0.062	0.075	0.065
8	0.189	0.112	0.200
9	0.076	0.087	0.077
10	0.058	0.079	0.065
11	0.067	0.095	0.078
12	0.062	0.102	0.093

——— Samples were not collected.

Table XXXIII. Silica concentrations (mg/l $Si\,O_2$) at the stations sampled during 7/25/67 - 9/12/67 for the single sampling periods.

STATION	DATE			
	7/25	8/8	8/22	9/12
1	20.0	20.0	20.5	22.0
2	12.6	12.0	13.0	15.0
3	——	9.5	——	11.5
4	——	9.0	——	10.0
5	7.8	12.0	12.5	14.8
6	22.0	22.0	21.0	23.0
7	13.9	14.0	15.0	19.5
8	33.0	30.0	29.0	32.0
9	16.8	18.0	18.0	21.0
10	13.8	13.5	15.0	19.0
11	13.3	14.0	15.5	20.0
12	14.7	12.5	12.5	21.0

—— Samples were not collected.

Table XXXIV. 5-Day B.O.D. (mg/l D.O.) at the station sampled during 8/8/67 - 9/12/67 for the single sampling periods.

STATION	DATE		
	8/8	8/22	9/12
1	——	——	——
2	——	0.87	2.88
3	——	——	——
4	——	——	——
5	——	1.23	1.71
6	——	——	——
7	0.90	0.66	1.68
8	16.80	21.80	23.00
9	4.02	3.36	4.62
10	2.58	2.70	4.29
11	3.18	3.06	5.01
12	3.18	2.28	6.24

—— Samples were not collected.

Table XXXV. Dissolved oxygen concentrations (mg/1) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATIONS				
Date	Hour	7	8	9	10	11
July 18-19	0600	11.17	9.47	11.08	10.44	10.65
	0900	12.09	8.80	11.28	10.97	11.47
	1200	12.09	8.80	9.38	8.17	8.64
	1500	7.69	5.91	7.11	6.54	6.18
	1800	8.73	6.13	8.31	7.67	7.73
	2100	7.74	5.74	7.46	6.82	6.67
	2400	7.44	6.53	7.46	6.67	6.72
	0300	———	———	———	———	———
	0600	8.04	7.00	7.79	7.40	7.84
August 1-2	0600	8.23	6.81	7.86	7.35	7.04
	0900	9.27	6.39	8.93	8.39	8.63
	1200	10.71	5.78	10.16	9.52	10.23
	1500	10.51	5.78	9.38	8.91	10.44
	1800	9.12	6.08	8.67	8.24	8.88
	2100	7.37	5.70	6.84	6.55	6.15
	2400	7.25	5.70	6.89	5.88	5.82
	0300	———	———	———	———	———
	0600	8.00	5.55	7.89	7.23	7.08

Table XXXV. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	8.10	7.16	7.16	6.46	5.83
	0900	9.83	6.72	9.03	8.06	8.53
	1200	11.34	6.08	10.28	9.45	11.13
	1500	11.18	5.23	10.28	9.43	11.09
	1800	9.90	5.95	8.49	7.50	9.19
	2100	7.51	5.89	6.82	5.35	5.56
	2400	7.50	5.48	6.71	5.06	5.25
	0300	———	———	———	———	———
	0600	7.99	7.22	7.81	6.46	6.09
August 29-30	0600	7.46	6.47	7.22	5.75	5.66
	0900	8.52	5.93	7.86	6.75	6.98
	1200	10.15	5.34	8.82	7.37	8.59
	1500	10.67	5.63	9.21	7.99	9.41
	1800	10.34	5.77	7.87	6.45	7.79
	2100	6.92	5.52	8.33	4.94	5.53
	2400	6.83	5.24	6.26	4.86	5.00
	0300	———	———	———	———	———
	0600	7.46	6.52	6.23	5.92	5.67

——— Samples were not collected.

Table XXXVI. pH measurements at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	8.25	7.60	8.20	8.23	8.15
	0900	8.33	7.60	8.31	8.20	8.25
	1200	8.53	7.52	8.40	8.34	8.35
	1500	8.50	7.50	8.53	8.45	8.42
	1800	8.75	7.62	8.63	8.54	8.50
	2100	8.65	7.59	8.50	8.43	8.41
	2400	8.51	7.66	8.31	8.25	8.30
	0300	———	———	———	———	———
	0600	8.35	7.62	8.27	8.24	8.20
August 1-2	0600	8.20	7.61	8.13	8.11	8.02
	0900	8.39	7.51	8.23	8.23	8.26
	1200	8.63	7.52	8.44	8.35	8.40
	1500	8.82	7.43	8.60	8.51	8.56
	1800	8.79	7.48	8.65	8.55	8.64
	2100	8.64	7.56	8.41	8.38	8.35
	2400	8.50	7.71	8.29	8.28	8.23
	0300	———	———	———	———	———
	0600	8.39	7.62	8.10	8.14	8.09

Table XXXVI. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	8.19	7.59	8.02	7.98	7.95
	0900	8.40	7.50	8.19	8.04	8.08
	1200	8.62	7.47	8.28	8.19	8.35
	1500	8.84	7.48	8.49	8.29	8.41
	1800	8.80	7.43	8.50	8.30	8.42
	2100	8.53	7.50	8.20	8.20	8.09
	2400	8.39	7.62	8.12	7.99	8.08
	0300	———	———	———	———	———
	0600	8.30	7.63	8.11	8.02	7.97
August 29-30	0600	8.18	7.58	8.03	7.96	7.94
	0900	8.29	7.44	8.03	8.00	8.00
	1200	8.61	7.43	8.29	8.03	8.33
	1500	8.78	7.43	8.49	8.28	8.42
	1800	8.78	7.50	8.51	8.29	8.39
	2100	8.48	7.48	8.19	8.09	8.11
	2400	8.29	7.45	7.92	7.93	7.95
	0300	———	———	———	———	———
	0600	8.19	7.50	8.01	7.93	7.92

——— Samples were not collected.

Table XXXVII. Total alkalinities (meq/l) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	3.62	4.61	3.78	3.71	3.63
	0900	3.55	3.96	3.45	3.62	3.70
	1200	4.12	4.15	3.70	3.64	3.66
	1500	3.69	4.67	3.74	3.63	3.67
	1800	3.55	5.29	3.71	3.59	3.71
	2100	3.55	4.51	3.67	3.67	3.65
	2400	3.73	4.67	3.66	3.72	3.78
	0300	———	———	———	———	———
	0600	3.66	4.61	3.68	3.69	3.77
August 1-2	0600	3.50	4.61	3.69	3.68	3.61
	0900	3.62	4.51	3.61	3.64	3.73
	1200	3.53	4.58	3.69	3.80	3.67
	1500	3.86	4.39	3.69	3.64	3.73
	1800	3.56	4.38	3.71	3.65	3.70
	2100	3.68	4.41	3.72	3.69	3.70
	2400	3.75	4.43	3.82	3.79	3.76
	0300	———	———	———	———	———
	0600	3.57	4.78	3.84	3.85	3.85

Table XXXVII. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	3.70	4.29	3.92	3.88	3.92
	0900	3.85	4.32	3.93	3.90	3.98
	1200	3.80	4.34	3.88	3.85	3.91
	1500	3.77	4.39	3.78	3.92	3.89
	1800	3.66	4.53	3.83	3.80	3.99
	2100	3.66	4.46	3.80	3.81	3.92
	2400	3.74	4.53	3.87	3.90	3.91
	0300	———	———	———	———	———
	0600	3.79	4.26	4.03	3.89	3.93
August 29-30	0600	3.67	4.58	3.90	3.90	3.86
	0900	3.55	4.63	3.88	3.86	3.93
	1200	3.64	4.45	3.84	3.85	3.95
	1500	3.58	4.52	3.82	3.83	3.89
	1800	3.63	4.49	3.60	3.76	3.85
	2100	3.60	4.50	3.84	3.92	3.84
	2400	3.71	4.40	3.85	3.89	3.89
	0300	———	———	———	———	———
	0600	3.74	4.54	3.86	3.81	3.89

——— Samples were not collected.

Table XXXVIII. Conductivities (micromhos) at 25°C at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION									
Date	Hour	7		8		9		10		11	
		°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}	°C	K_{25}
July 18-19	0600	14.0	343	13.7	518	12.6	380	12.7	360	13.0	356
	0900	16.4	350	15.4	574	15.0	383	14.8	364	14.8	359
	1200	20.2	345	20.4	606	19.0	371	18.0	337	17.8	348
	1500	24.0	344	23.0	573	22.0	390	22.0	365	21.0	361
	1800	22.9	341	20.2	593	21.1	391	21.0	361	20.2	361
	2100	18.7	351	16.6	583	17.4	397	17.3	374	17.7	365
	2400	12.0	352	11.2	612	11.0	394	11.0	376	12.0	371
	0300	—	—	—	—	—	—	—	—	—	—
	0600	14.5	372	13.5	553	13.6	381	14.0	371	14.6	376
August 1-2	0600	16.0	347	14.1	539	13.8	397	13.9	379	14.3	381
	0900	17.0	352	16.8	553	16.2	397	15.9	371	16.0	376
	1200	19.7	345	18.9	538	18.9	384	18.0	369	18.0	369
	1500	22.6	344	21.6	519	22.7	385	21.0	368	21.0	373
	1800	23.2	346	20.7	530	21.5	388	22.0	360	21.9	372
	2100	21.5	337	19.3	534	19.8	377	19.7	361	19.9	360
	2400	13.0	383	11.9	505	11.5	416	11.0	398	12.2	396
	0300	—	—	—	—	—	—	—	—	—	—
	0600	16.0	405	16.0	529	15.7	402	15.9	394	16.5	400

Table XXXVIII. Continued

TIME Date	Hour	STATION 7 °C	K_{25}	8 °C	K_{25}	9 °C	K_{25}	10 °C	K_{25}	11 °C	K_{25}
August 15-16	0600	15.8	389	14.8	477	14.8	417	14.8	398	15.0	402
	0900	16.2	397	16.0	508	15.7	415	15.3	400	15.4	405
	1200	20.7	382	20.0	514	19.5	420	18.7	392	18.4	395
	1500	24.0	363	22.0	540	23.0	419	22.3	395	21.5	395
	1800	24.3	366	21.9	541	22.2	411	22.3	402	22.4	416
	2100	22.0	372	20.0	526	20.5	397	20.3	392	20.2	406
	2400	11.0	388	11.2	515	11.3	418	11.5	393	10.8	418
	0300	—	—	—	—	—	—	—	—	—	—
	0600	15.3	400	14.8	593	14.2	430	14.7	412	15.0	422
August 29-30	0600	15.5	363	15.1	513	15.4	391	15.5	385	15.5	385
	0900	15.3	364	15.5	540	14.6	412	14.3	390	14.3	402
	1200	17.5	346	17.4	516	16.5	406	16.2	390	16.2	396
	1500	21.7	334	20.7	501	20.1	394	20.0	388	19.9	389
	1800	21.2	343	20.0	498	19.7	384	20.0	375	20.0	395
	2100	19.0	354	18.3	494	18.0	392	18.0	374	18.0	392
	2400	16.3	356	16.0	512	15.8	406	15.6	384	15.8	394
	0300	—	—	—	—	—	—	—	—	—	—
	0600	17.0	377	15.9	535	15.3	399	15.3	392	15.0	401

— Samples were not collected.

Table XXXIX. Total carbon concentrations (mg/1 C) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	47.3	89.0	48.0	47.4	49.0
	0900	47.2	119.0	48.7	47.7	47.1
	1200	43.0	150.0	48.0	46.5	45.9
	1500	44.5	136.0	48.8	46.4	44.4
	1800	41.2	137.0	44.3	41.3	41.4
	2100	44.3	120.0	40.0	39.0	39.9
	2400	39.2	115.0	42.5	40.5	40.3
	0300	—	—	—	—	—
	0600	38.8	81.0	40.4	39.4	40.6
August 1-2	0600	46.6	94.0	50.0	48.5	52.0
	0900	44.5	120.0	51.0	48.5	48.0
	1200	44.0	134.0	51.0	45.7	45.1
	1500	43.2	133.0	48.3	46.9	47.5
	1800	41.3	124.0	46.8	47.6	47.0
	2100	44.6	120.0	49.6	47.7	49.0
	2400	44.6	104.0	46.9	46.5	44.7
	0300	—	—	—	—	—
	0600	42.5	75.0	46.0	44.8	46.9

Table XXXIX. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	45.0	93.0	53.2	54.1	56.7
	0900	49.1	122.0	57.0	52.5	54.5
	1200	47.7	132.0	59.0	52.8	49.5
	1500	47.5	138.0	57.6	53.3	54.7
	1800	45.5	135.0	52.0	53.7	54.3
	2100	46.4	134.0	50.1	49.4	50.2
	2400	45.2	106.0	52.7	50.2	48.1
	0300	———	———	———	———	———
	0600	47.2	94.0	46.9	50.3	42.3
August 29-30	0600	56.0	97.0	61.3	65.0	66.8
	0900	50.4	97.0	55.2	53.0	57.5
	1200	51.6	141.0	68.9	62.1	56.2
	1500	50.4	125.0	68.9	60.0	57.5
	1800	54.7	102.0	65.6	66.6	64.4
	2100	56.5	111.0	68.7	64.3	66.2
	2400	60.9	105.0	71.7	68.9	68.3
	0300	———	———	———	———	———
	0600	63.2	93.0	67.7	66.4	67.3

——— Samples were not collected.

Table XXXX. Total organic carbon concentrations (mg/1 C) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	6.3	29.0	6.0	4.3	4.6
	0900	9.0	59.0	8.4	6.2	4.9
	1200	5.3	88.0	11.2	10.7	10.6
	1500	5.2	97.0	12.3	9.5	10.3
	1800	7.5	63.0	9.5	7.4	6.0
	2100	10.3	62.0	7.2	5.8	6.3
	2400	7.5	60.0	7.9	6.6	7.1
	0300	———	———	———	———	———
	0600	5.2	34.0	6.2	5.0	5.5
August 1-2	0600	7.4	50.0	7.3	6.0	6.2
	0900	8.4	66.0	9.0	5.8	5.0
	1200	6.7	77.0	11.0	7.5	6.3
	1500	7.8	73.0	10.0	8.3	7.3
	1800	7.6	71.0	10.0	8.4	8.1
	2100	7.4	67.0	9.2	6.6	6.8
	2400	7.6	51.0	7.2	6.1	5.7
	0300	———	———	———	———	———
	0600	5.0	27.0	5.6	5.1	5.8

Table XXXX. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	6.5	37.2	6.4	7.4	6.4
	0900	6.3	60.9	12.5	6.3	6.4
	1200	7.2	72.0	19.1	9.3	7.1
	1500	7.5	77.3	16.4	9.5	9.3
	1800	8.0	65.0	12.9	7.5	11.2
	2100	6.3	65.0	11.3	9.3	8.6
	2400	6.8	41.8	8.4	8.0	7.6
	0300	———	———	———	———	———
	0600	5.5	43.7	4.8	5.0	6.5
August 29-30	0600	7.0	35.3	7.3	7.1	7.5
	0900	5.3	81.0	9.5	6.8	7.1
	1200	7.1	85.0	15.0	8.6	5.3
	1500	6.8	76.0	13.0	8.2	8.1
	1800	8.8	71.0	11.2	8.4	8.5
	2100	8.2	53.0	10.5	6.8	7.3
	2400	7.6	45.0	9.0	8.3	8.1
	0300	———	———	———	———	———
	0600	5.1	32.0	5.3	6.3	8.0

——— Samples were not collected.

Table XXXXI. Total nitrogen concentrations (mg/l $N\text{-}NH_3$) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	1.74	18.8	2.20	2.24	1.88
	0900	1.97	19.7	1.88	0.74	1.42
	1200	1.28	15.6	2.20	1.28	1.46
	1500	2.29	11.1	1.15	1.06	1.37
	1800	1.28	10.6	1.60	0.96	1.11
	2100	1.46	15.6	1.24	0.92	1.11
	2400	1.37	12.8	1.65	1.28	1.74
	0300	—	—	—	—	—
	0600	1.06	10.2	1.28	0.83	1.60
August 1-2	0600	1.05	11.2	1.72	1.19	1.49
	0900	1.38	16.8	1.98	1.46	1.68
	1200	1.49	20.9	3.13	1.31	1.46
	1500	1.34	20.5	2.13	1.76	1.08
	1800	1.72	6.1	2.05	1.57	2.54
	2100	1.57	12.7	2.97	2.20	2.16
	2400	1.31	16.8	1.84	1.57	1.57
	0300	—	—	—	—	—
	0600	1.31	14.2	2.61	1.80	1.76

Table XXXXI. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	3.29	22.5	2.61	2.34	2.52
	0900	2.29	27.0	3.41	2.39	2.56
	1200	2.92	27.0	3.14	2.70	1.74
	1500	1.74	17.8	2.52	1.83	2.10
	1800	2.39	11.0	1.96	2.56	2.48
	2100	2.28	32.8	3.29	2.75	2.52
	2400	1.79	24.7	2.88	2.75	2.39
	0300	——	——	——	——	——
	0600	3.28	22.8	3.01	2.96	2.75
August 29-30	0600	1.90	24.8	2.56	2.15	1.76
	0900	0.59	27.0	3.00	1.81	1.85
	1200	0.93	14.1	2.82	1.90	0.93
	1500	1.20	14.5	2.65	2.32	1.81
	1800	2.45	23.2	2.49	2.15	1.53
	2100	1.70	15.3	2.06	2.79	1.98
	2400	1.86	19.8	1.81	2.23	1.76
	0300	——	——	——	——	——
	0600	1.36	14.5	2.40	1.32	1.81

—— Samples were not collected.

Table XXXXII. Total phosphate concentrations (mg/l $P\text{-}PO_4^{\equiv}$) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	0.73	9.5	1.54	1.22	1.90
	0900	1.32	23.7	3.10	2.03	1.53
	1200	0.59	51.9	4.86	2.61	1.66
	1500	0.54	48.9	4.26	2.66	2.53
	1800	0.56	55.7	5.14	2.94	2.72
	2100	0.45	34.1	3.42	1.97	2.16
	2400	0.51	31.3	3.06	2.38	2.19
	0300	———	———	———	———	———
	0600	0.45	8.7	0.84	0.98	1.14
August 1-2	0600	0.78	14.1	1.47	1.66	2.18
	0900	0.58	24.3	2.54	0.95	1.14
	1200	0.56	48.2	5.46	2.89	1.53
	1500	0.66	45.8	5.04	3.94	3.15
	1800	0.63	51.8	5.28	3.60	3.38
	2100	0.50	37.3	4.22	3.10	2.89
	2400	0.38	31.0	3.41	2.38	2.78
	0300	———	———	———	———	———
	0600	0.55	12.2	1.27	1.41	2.35

Table XXXXII. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	0.66	8.4	1.79	2.32	6.00
	0900	2.18	24.7	4.86	1.52	2.34
	1200	0.55	45.2	7.40	3.68	1.56
	1500	0.94	48.2	8.40	5.66	2.75
	1800	0.68	43.4	7.24	5.00	4.84
	2100	0.57	35.3	5.88	4.94	4.25
	2400	0.46	29.6	4.64	3.82	4.00
	0300	———	———	———	———	———
	0600	0.62	10.7	1.75	2.09	3.19
August 29-30	0600	0.86	14.7	2.31	2.20	2.57
	0900	0.72	23.5	3.98	1.75	3.00
	1200	0.70	53.4	9.18	4.17	2.78
	1500	0.50	41.7	6.70	4.84	3.01
	1800	0.78	44.8	7.46	5.50	4.61
	2100	0.64	26.8	6.18	4.75	4.68
	2400	0.80	27.3	4.50	3.97	4.23
	0300	———	———	———	———	———
	0600	0.53	9.9	1.76	2.22	3.15

——— Samples were not collected.

Table XXXXIII. Temperature (°C) at the stations sampled during 24-hour sampling periods throughout the summer (1967).

TIME		STATION				
Date	Hour	7	8	9	10	11
July 18-19	0600	11.6	12.8	11.5	11.8	12.3
	0900	12.0	13.5	12.5	12.3	12.7
	1200	15.2	14.8	15.5	15.0	16.3
	1500	18.4	15.2	18.5	18.0	18.6
	1800	20.0	15.2	19.9	19.5	20.0
	2100	18.2	14.6	17.8	17.6	18.1
	2400	16.5	14.5	16.0	16.3	16.7
	0300	—	—	—	—	—
	0600	13.5	13.2	14.0	13.7	14.0
August 1-2	0600	13.0	13.7	13.1	13.3	13.6
	0900	12.8	14.0	13.2	13.2	14.8
	1200	15.1	15.3	15.3	15.1	15.7
	1500	18.6	15.4	18.9	18.5	18.9
	1800	20.1	15.6	19.5	19.5	20.0
	2100	18.6	15.3	18.1	18.2	18.7
	2400	16.5	15.0	16.2	16.3	16.6
	0300	—	—	—	—	—
	0600	12.7	13.5	12.6	13.0	13.5

Table XXXXIII. Continued

TIME		STATION				
Date	Hour	7	8	9	10	11
August 15-16	0600	13.0	14.0	14.1	13.3	13.7
	0900	12.4	14.5	12.7	12.6	13.4
	1200	15.0	15.7	15.3	15.5	16.0
	1500	19.6	18.5	19.0	18.6	19.3
	1800	20.5	16.3	20.1	19.7	20.4
	2100	18.7	15.5	18.0	18.2	18.8
	2400	16.6	15.4	16.3	16.5	17.0
	0300	——	——	——	——	——
	0600	13.4	14.0	13.3	13.5	14.0
August 29-30	0600	13.0	14.3	13.1	13.3	13.5
	0900	12.6	14.7	13.0	13.0	13.5
	1200	14.0	15.6	14.3	14.4	15.0
	1500	17.6	16.0	17.6	17.2	18.0
	1800	18.0	15.8	17.6	18.0	18.3
	2100	16.6	15.4	16.4	16.6	17.1
	2400	15.0	15.4	14.7	15.0	15.3
	0300	——	——	——	——	——
	0600	12.5	14.2	12.6	12.9	13.2

—— Samples were not collected.

Table XXXXIV. Flow times (minutes) between the stations sampled during 24-hour sampling periods throughout the summer (1967).

DATE	STATIONS		
	7-9	9-10	10-11
July 18-19	7	58	103
August 1-2	9	70	116
August 15-16	10	103	133
August 29-30	11	104	165

Table XXXXV. Mean depths between the stations sampled during 24-hour sampling periods throughout the summer (1967).

DATE	STATIONS					
	7-9		9-10		10-11	
	(ft)	(m)	(ft)	(m)	(ft)	(m)
July 18-19	1.11	0.34	1.26	0.38	1.38	0.42
August 1-2	1.00	0.31	1.07	0.33	1.09	0.33
August 15-16	0.71	0.22	1.00	0.31	0.79	0.24
August 29-30	0.75	0.23	0.97	0.30	0.94	0.29

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