



Primary productivity of the Madison River in Yellowstone National Park, Wyoming
by Elston Herbert Todd

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY in Botany
Montana State University
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Abstract:

An investigation of the downstream decrease in productivity of the Madison River in northwestern Yellowstone National Park was carried out in an effort to determine the correlation among primary productivity, current velocity, water temperature, light, carbon dioxide concentration, time of day and reach of the river.

Seasonal, daily, and downstream variation in primary productivity over a 14-mile reach of the river was determined by harvesting the standing crop of macrophytes; measuring changes in carbon dioxide concentration; and determining chlorophyll concentration.

Statistical analysis using photosynthesis as the dependent variable and carbon dioxide concentration, light, water temperature, and current velocity as the independent variables, showed carbon dioxide concentration to have the highest partial correlation coefficient followed in decreasing order by temperature, light and velocity.

It was concluded that the downstream decrease in carbon dioxide concentration was of primary importance in accounting for the downstream decline in primary productivity of the river.

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IN YELLOWSTONE NATIONAL PARK, WYOMING

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ELSTON HERBERT TODD

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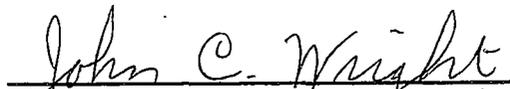
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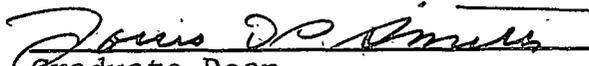
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ABSTRACT

An investigation of the downstream decrease in productivity of the Madison River in northwestern Yellowstone National Park was carried out in an effort to determine the correlation among primary productivity, current velocity, water temperature, light, carbon dioxide concentration, time of day and reach of the river.

Seasonal, daily and downstream variation in primary productivity over a 14-mile reach of the river was determined by harvesting the standing crop of macrophytes; measuring changes in carbon dioxide concentration; and determining chlorophyll concentration.

Statistical analysis using photosynthesis as the dependent variable and carbon dioxide concentration, light, water temperature, and current velocity as the independent variables, showed carbon dioxide concentration to have the highest partial correlation coefficient followed in decreasing order by temperature, light and velocity.

It was concluded that the downstream decrease in carbon dioxide concentration was of primary importance in accounting for the downstream decline in primary productivity of the river.

INTRODUCTION

Until recent years, investigations of primary production in bodies of water dealt almost exclusively with lakes, ponds and seas. With the possible exception of Butcher (1927, 1932a, 1932b, 1933, 1940, 1945, 1947, 1948), whose research pertained primarily to the ecology and taxonomy of English rivers, flowing waters were almost entirely ignored. Recently, however, methods were outlined (Odum, 1956) and demonstrated (Sargent and Austin, 1949, Odum and Odum, 1955, Odum, 1957a, Odum, 1957b) for the effective study of the metabolism of rivers, streams, and other moving masses of water. Since the publication of these exploratory works, there has been a significant increase in investigations of the biology of running water (Odum and Hoskin, 1957, Hoskin, 1959, McConnel and Sigler, 1959, Edwards and Owens, 1960, Owens and Edwards, 1961, Edwards and Owens, 1962, Owens and Edwards, 1962, Copeland and Duffer, 1964, Owens, Edwards and Gibbs, 1964, Kevern and Ball, 1965, Duffer and Doris, 1966).

The Madison River in northwestern Yellowstone National Park, Wyoming, offers an ideal opportunity for the study of an unpolluted stream in which there is a continual decrease in productivity from its headwaters to a point about 14 miles downstream.

The purpose of the present investigation was to determine quantitatively the primary productivity of the Madison River and to compare the measurements with standing crops of macrophytes and periphyton, light, temperature, carbon dioxide concentration, and current velocity utilizing three methods: (1) harvesting the standing crop of macrophytes, (2) measuring the changes of carbon dioxide concentration, and (3) determining chlorophyll concentration. The results are examined to determine what correlation exists among primary productivity, current velocity, water temperature, light, CO₂ concentration, time of day and reach of the river.

The present investigation is one of a group of investigations supported by Public Health Service Research Grant WP-00125 and Training Grant 5T1-WP-1 from the division of Water Supply and Pollution Control.

DESCRIPTION OF THE STUDY AREA

At an elevation of 2,080.6 m (6,826 ft) the Madison River is formed by the union of the Firehole and Gibbon Rivers which serve as the drainage of numerous hot springs and geysers in a northwestern portion of Yellowstone National Park. Allen and Day (1935) estimated that the total amount of thermal waters flowing into the Firehole River was $1.55 \text{ m}^3/\text{sec}$ ($54.92 \text{ ft}^3/\text{sec}$) and that thermal discharge into the Gibbon River amounted to $0.19 \text{ m}^3/\text{sec}$ ($6.85 \text{ ft}^3/\text{sec}$).

The Madison River flows in a westerly direction throughout the study area (Figure 1). For the first 9.7 km (6 mi) it passes through a deep canyon with cliffs and hills of welded tuff on its north and more rugged cliffs and talus slopes from the rhyolite flows of the Madison Plateau to its south. After the river leaves the canyon, it flows through an area of decomposed rhyolite and tuff.

The river bottom is variable, consisting of boulders, large to small cobble, coarse to fine gravel, sand and silt. These may be either cemented together or resting loosely on the bedrock material.

The width of the river ranges from about 25.9 m (85 ft) to about 67.1 m (220 ft) with an average of about 44.5 m (146 ft). The depth varies seasonally and at different loca-

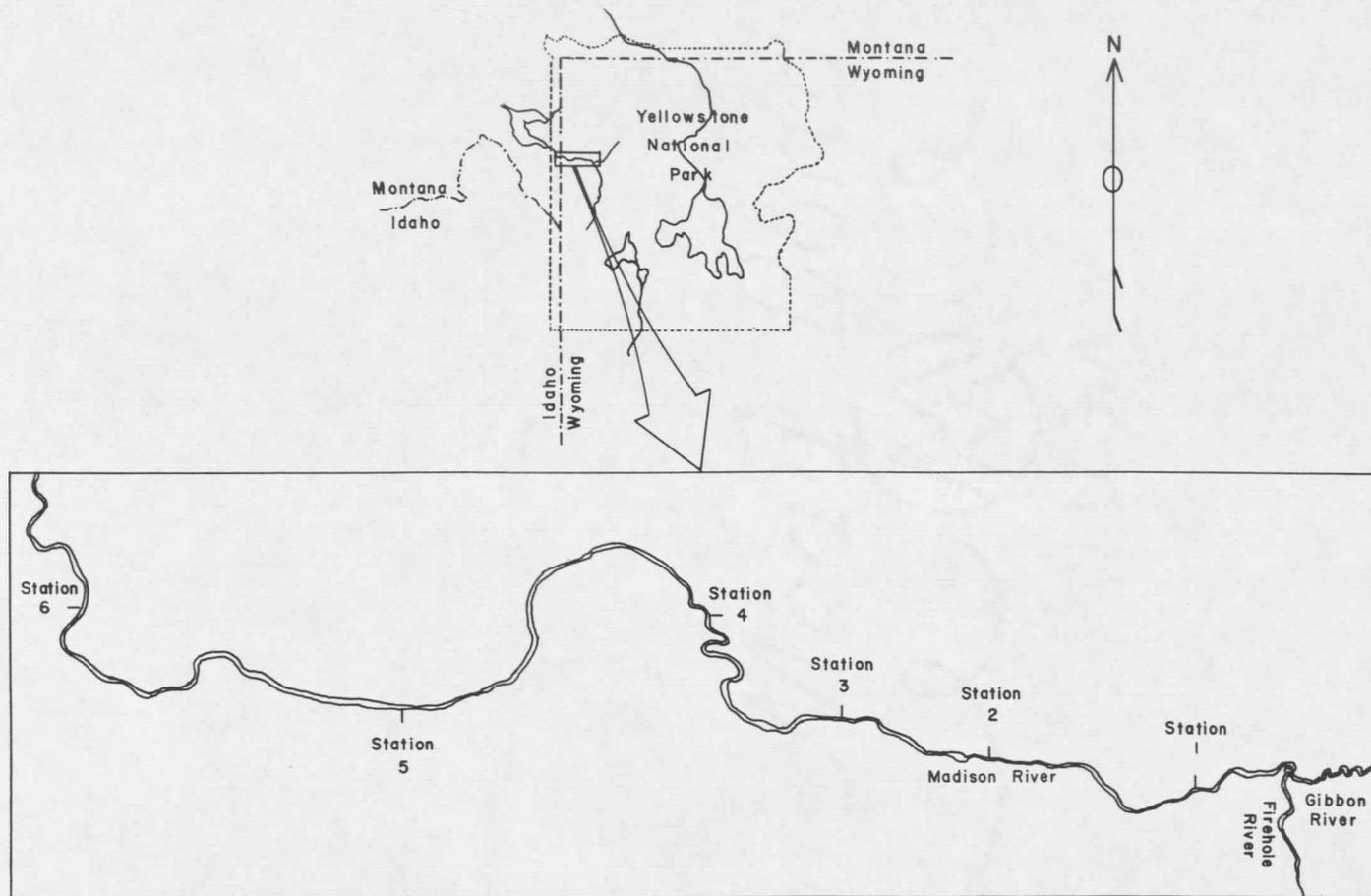


Figure 1: Map of Yellowstone National Park showing location of study area and stations.

tions within the study area. The depth at the most shallow point during dry weather is about 0.2 m (0.5 ft) while the deepest point during the period of greatest runoff is nearly 3.1 m (10 ft). Average depth is about 0.8 m (2.5 ft).

According to the Surface Water Records of Montana (1963-1964), the rate of discharge from the river normally fluctuates between a winter minimum of about 8.5 m³/sec (300 ft³/sec) and a spring maximum of about 43.9 m³/sec (1550 ft³/sec). The extremes recorded are a maximum of 60.9 m³/sec (2,150 ft³/sec) on May 24, 1956, and an estimated minimum of 2.8 m³/sec (100 ft³/sec) on February 7, 1933. The average discharge over a forty-nine year period was 13.4 m³/sec (473 ft³/sec). Maximum discharge usually occurs during late May and early June, at which time the heaviest rainfall of the region coincides with the spring runoff from the heavy snows which cover this mountainous area.

Concentrations of various ions remain quite constant throughout the study area, but show seasonal variation. Chemically, the water is a sodium-bicarbonate-chloride type, with silica concentration remaining close to the saturation level of the water. Calcium and magnesium are present only in small amounts (Roeder, 1966).

Six stations were located on the stream, separating the river into five reaches. Station one was located at the National Park Service pullout designated, "Wild Animals at Home," 1.6 km (1 mi) from the confluence of the Firehole and Gibbon Rivers. At this station, long strands of aquatic macrophytes in dense stands covered about 85% of the substrate. Chara vulgaris was the most abundant plant, but there were conspicuous amounts of Potamogeton filiformis and P. strictifolius as well as Berula erecta. The plants grew from the silt, fine to coarse sand and fine gravel of the river bottom. Mixtures of coarse gravel and cobble up to about 7.6 cm (3 in) in diameter were exposed in scattered patches.

Station two was situated at a National Park Service pullout entitled, "Mt. Haynes," 3.3 km (2.04 mi) below station one. At this point, the vegetation was dense, but there was a smaller percent of the substrate covered by the plants than at station one. Chara and Potamogeton, the co-dominant genera at this station occurred on about 70% of the substrate, but there were large areas of exposed rubble.

Station three was established 2.6 km (1.60 mi) downstream from station two. At this location, the vegetation

was less dense than at the preceding stations, but was still present in strands 0.6 to 0.9 m (2 to 3 ft) long. Chara vulgaris made up about 50% of the vegetative cover. The remainder consisted primarily of Sparganium chlorocarpum, Berula erecta and Glyceria borealis in about equal quantities. There were scattered boulders ranging in size from about 0.9 m (3 ft) to 1.8 m (6 ft) in diameter, but the major portion of the exposed river bottom was made up of coarse gravel and rubble.

Station four was situated about 9.1 m (10 yd) upstream from the 7 Mile Bridge, 3.3 km (2.03 mi) below station three. Less than 50% of the substrate of sand, gravel and cobble was covered by the vegetation. Chara vulgaris was the dominant macrophyte with Sparganium chlorocarpum and Myriophyllum exalbescens present in significant quantities.

Station five was located at the National Park Service pullout designated, "Riverside Soldier Station," 5.1 km (3.19 mi) below station four. The sparse vegetation consisted mainly of the mosses Hygroamblystegium fluviatile and Fissidens grandifrons with significant amounts of Chara vulgaris, Glyceria borealis and Berula erecta. The river bottom included sand, gravel, and small boulders and large

slabs of exposed bedrock.

Station six was established at the old Riverside Ranger Station 5.1 km (3.16 mi) downstream from station five. About 90% of the river bottom supported no vegetation and consisted of unconsolidated cobble 7.6 to 15.2 cm (3 to 6 in) in diameter, small boulders 30.5 to 45.7 cm (12 to 18 in) in diameter, and a few scattered patches of coarse sand and fine gravel. The meager vegetation was dominated by the mosses, Hygroamblystegium fluviatile and Fissidens grandifrons, but Myriophyllum exalbescens and Berula erecta were conspicuous.

METHODS

Carbon Dioxide Concentration

Water samples were obtained from the six river stations at weekly intervals from May 15, to October 30, 1965. On each sampling date, collections were made every three hours at each station, commencing at 0600 hours and proceeding through 0600 hours the following day. All samples were collected in one-liter polypropylene plastic screw-cap bottles which were rinsed twice before being filled with the water sample.

Immediately upon return to the field laboratory, pH measurements were made with a Beckman Model 76 Expanded Scale pH meter. Alkalinity was determined for each set of samples at six hour intervals. The titrations were made on 100 ml of water with 0.1 N hydrochloric acid, using methyl orange as an indicator (Rutner, 1965).

Upon return to the laboratory at Bozeman, Montana, pH changes were correlated with carbon dioxide changes according to the method of Beyers et al. (1963).

A series of graphs was produced for each sampling date by first plotting the carbon dioxide concentration at station one as the ordinate against the time of collection as the abscissa. The carbon dioxide concentration of each succes-

sive station was displaced to the left by a time interval equivalent to the flow time from station one to the station whose data was being plotted.

By plotting the curves in this manner, the vertical distance between two curves corresponded to the carbon dioxide change during the time required to flow through the reach.

The change in carbon dioxide concentration per unit volume per minute from one station to the succeeding one downstream was determined by dividing the change in carbon dioxide concentration per unit volume by the flow time between stations. By multiplying this value by the average depth of the water between the two stations, the rates of change were converted to a unit area basis.

Concentration as parts per million (ppm) of free carbon dioxide for each collection time at each station was calculated by converting the milliequivalents per liter total alkalinity to parts per million alkalinity as HCO_3^- according to the equation derived by Rainwater and Thatcher (1960):

$$\text{ppm CO}_2 = 1.589 \times 10^6 [\text{H}^+] \times \text{ppm alkalinity as HCO}_3^-$$

The concentration in ppm CO_2 was then converted to the equivalent molar concentration per cubic meter.

The exchange coefficient (k) between free carbon dioxide

of the water and that of the atmosphere was computed by dividing the areal rate of change of carbon dioxide in a reach by the difference in concentration of free CO₂ between the water and atmosphere. The computation was made using only the measurements from the samples collected at 2100, 2400 and 0300 hours as pH curves indicated that respiratory rates were minimal at these times. The exchange coefficients calculated for these three sample periods were averaged to produce the values utilized in later calculations.

An exchange coefficient was not calculated for the reach between stations one and two in the above described manner because a few hundred yards above station one, a small hot spring discharged water greatly enriched with carbon dioxide into the river, thus distorting the measurements utilized in determining this parameter. Physical and biological characteristics of the reach between stations one and two and those between stations two and three were so similar that the exchange coefficient computed for the reach between stations two and three was also utilized for the reach between stations one and two.

The change in carbon dioxide due to biological factors was calculated by use of the equation:

$$R = C_c - k(C_f - C_a)$$

where C_c is the change in carbon dioxide concentration per unit area per minute, k is the CO_2 exchange coefficient, C_f is the concentration of free carbon dioxide in the river water, and C_a is the concentration of atmospheric carbon dioxide.

Hydrology and Morphometry

Discharge measurements were obtained from the rating table for the stream gaging station maintained by the U.S. Geological Survey near station six.

Flow times between consecutive stations were measured by introducing a few cubic centimeters of rhodamine-B dye into the main current at the upstream station. The passage of the mass of water into which the dye was introduced was detected fluorometrically at the succeeding downstream station by pumping water through a Turner Fluorometer, Model 110, equipped with a continuous flow cell and recorder. The time which elapsed between the introduction of the dye at the upstream station and the recorded passage of the peak dye concentration at the downstream station was considered to be the flow time between the two stations.

This procedure was repeated for several different river stages. Flow times were plotted against river stage and flow times for water levels intermediate to those measured were calculated from the graphs.

Current velocity was determined by dividing the flow times between stations into the distance separating the stations.

Areas of river reaches were measured by planimetry from aerial photographs.

Solar Radiation

Solar radiation was determined with a recording Eppley Pyroheliometer that was mounted on top of the laboratory at station six.

Temperature

While each sample was being collected, the temperature of the river water was measured with a standard laboratory thermometer.

Standing Crop of Macrophytes

The standing crop of macrophytes was measured periodically at all river stations from April 11, to November 1,

1964. The plants were harvested from a series of eight one-quarter-meter quadrats along a transect across the river and were placed while still moist in air-tight polyethylene plastic bags. The bags and their contents were refrigerated until the plants could be sorted according to species. Sorting was generally completed less than four days after the plants had been harvested.

After the plants were sorted, they were oven dried at a temperature of 105° Centigrade, cooled to room temperature, then weighed on a triple beam balance.

The standing crop at all river stations as well as points intermediate to stations two and three, four and five, and five and six was measured using the same procedure on August 24-25, 1965, except that they were not sorted to species.

Chlorophyll Determination

Glass microscope slides were submerged in modified Catherwood Diatometers (Patrick et al., 1954) at all river stations from May 18, to October 24, 1965. Each slide remained in the water for a span of from two to four weeks before it was replaced by a new slide. Immediately upon

removal from the diatometer, the slide was immersed in 30 ml of 90% acetone in an individual container and refrigerated.

Chlorophyll-a concentration of the extracts was determined according to the method of Richards with Thompson (1952). The spectrophotometric analyses were completed within twenty-four hours after the removal of the slides from the river.

RESULTS

Standing Crop of Macrophytes

Results of harvesting the macrophytic standing crops are recorded in Table I. The extremes and the means are expressed for the samples collected during the summer of 1964, whereas the weights shown for the summer of 1965 represent the collections of a single sampling period.

The mean weights for the stations in the 1964 samples indicate that there was a decrease in the standing crop of macrophytes downstream from station one. The 1965 samples from the stations did not show the downstream decrease so obviously, but it is easily noted in the means for the reaches. Furthermore, a correlation coefficient of $-.9473$ between samples of macrophytic standing crop and stations is significant to the 1% level of probability. With the exception of reach five, standing crops were much greater in 1965 than in 1964.

The floral composition of the community in 1964 also changed downstream as is shown in Table II. The dominant plants at the upper stations were Chara and Potamogeton. At the lower stations, the mosses became dominant. Berula and Myriophyllum were minor components at all stations.

The seasonal variation in standing crops is evident in

Table-I. Oven dry weights (gm/m^2) of macrophytic standing crops in the Madison River.

Station	1964 Samples		Mean for Reach	1965-Samples	
	Mean	Extremes		Station	Mean for Reach
1	360.8	212.0-564.7	310.5	811.3	849.2
2	260.1	238.2-299.4		887.1	
2a			232.6	226.5	517.1
3	205.0	113.9-304.3	165.6	437.8	449.9
4	126.1	80.4-202.5		461.9	
4a			117.4	154.8	238.5
5	108.7	56.1-236.2	81.5	98.8	59.7
5a				51.6	
6	54.2	14.0-115.6		28.7	
Average of Means	185.8			350.9	

Table II. Percent composition of macrophytic standing crop (1964).

Station	<u>Berula</u>	<u>Chara</u>	Mosses	<u>Myriophyllum</u>	<u>Potamogeton</u>	<u>Sparganium</u>	<u>Glyceria</u>
1	18.5	43.4	T	6.8	24.2	7.0	T
2	2.4	47.3	T	1.5	41.2	6.7	T
3	11.2	50.4	0.3	4.4	6.8	15.5	11.3
4	9.5	45.7	T	9.9	11.9	9.2	13.6
5	9.9	22.9	29.4	5.0	2.6	8.4	21.8
6	10.8	2.7	72.3	13.5	0.0	0.6	T

Table III. Averages of the values for stations five and six were used because samples were collected over the longest period from these stations. High water in May and June prevented sampling at the upper stations.

Table III. Oven dry weights (g/m^2) of macrophytes for various dates (1964).

May 9	June 26	July 27	Aug 3	Sept 16	Sept 22
45.2	42.6	55.3	110.1	167.3	124.1

The greatest growth occurred between July 27, and August 3, at which time there was a 99% increase.

Chlorophyll Determination

The average chlorophyll concentration at each station for the summer sampling period is shown in Figure 2. There was a significant decrease downstream from station one. The correlation coefficient between average chlorophyll concentration and stations was $-.8360$, which is significant to the 5% level of probability.

Seasonal fluctuations are portrayed in Figure 3, with maxima occurring in the latter part of July and the middle of October.

Figure 4 shows the rate of change of chlorophyll concen-

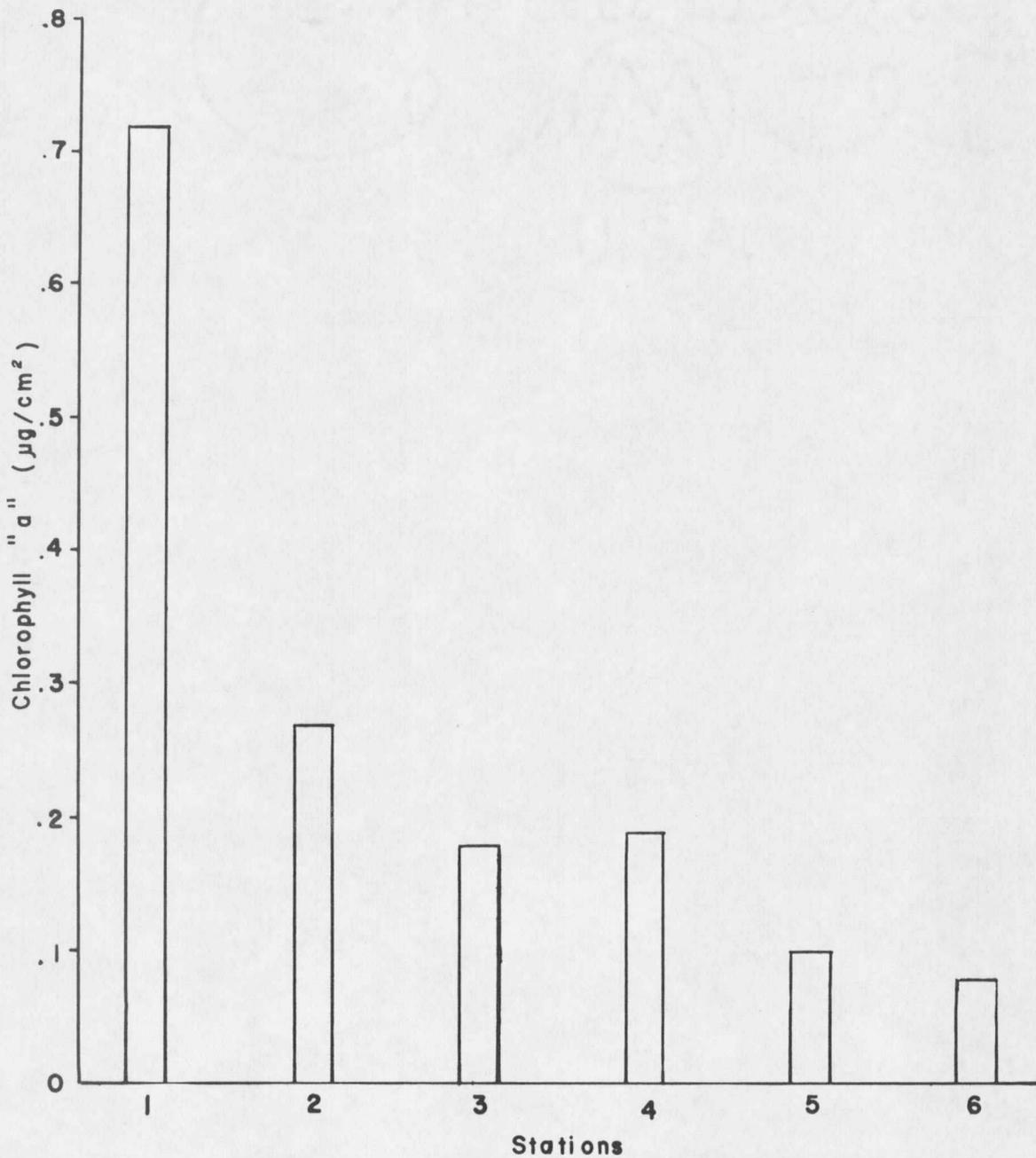


Figure 2: Average chlorophyll "a" concentration for each station during the summer sampling period (1965).

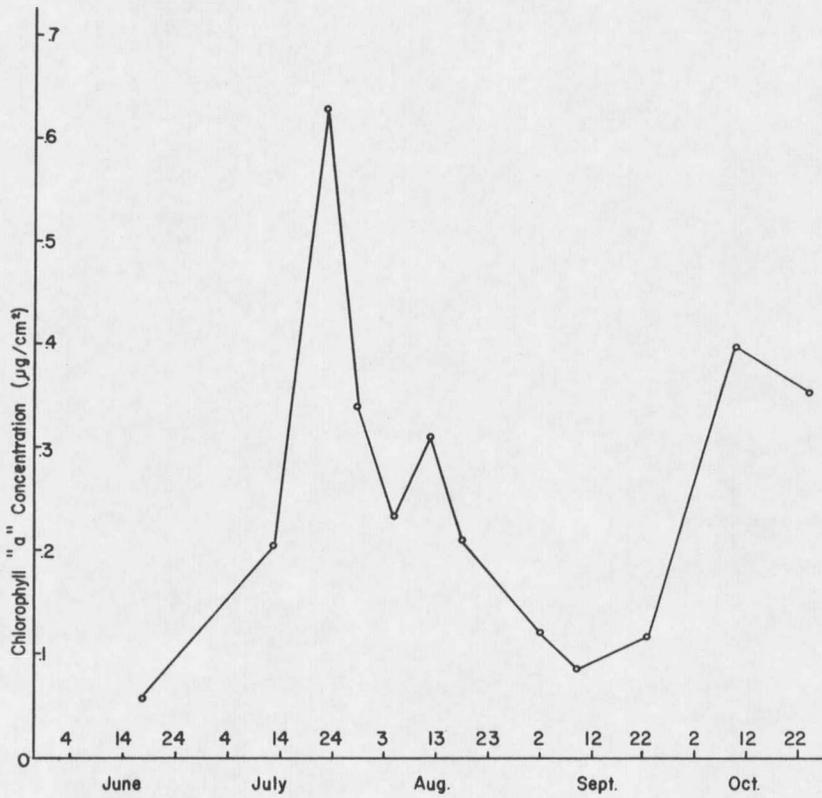


Figure 3: Seasonal fluctuation in chlorophyll "a". The concentration shown for each date is the average computed from the measurements for all stations at that collection time (1965).

tration in micrograms per square centimeter per day that the slides were in the water. Each point represents the average for slides collected from all stations on the indicated date.

Comparison of Figure 4 with Figure 3 reveals that the peak rate of change appeared on July 29, whereas the peak concentration occurred about a week earlier. The slides which were removed on July 23, had been in the water for a period of 35 days, while those removed on July 29, had been in the water for only 16 days. The September 9 minimum is present in both curves, so except for the displacement of the July peak, the two curves are similar.

pH and Alkalinity

Figure 5 is a series of pH curves showing changes which occurred during one sampling date at all stations during the twenty-four hour sampling period. The pH of station one was slightly greater than that at station two, otherwise there was a general increase downstream from station one. A daily cycle of changes is evident with the maxima usually occurring at 1500 hours and minima usually present at 0300 hours.

Figure 6 shows the relationship between total alkalinity and river depth at the gaging station during the summer

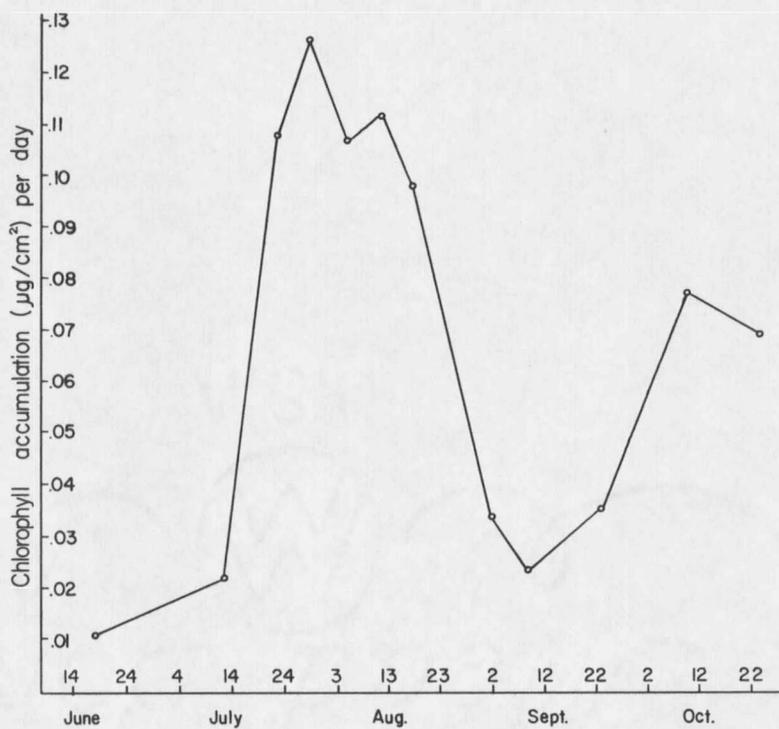


Figure 4: Rate of chlorophyll accumulation ($\mu\text{g}/\text{cm}$) per day on glass microscope slides in the Madison River (1965).

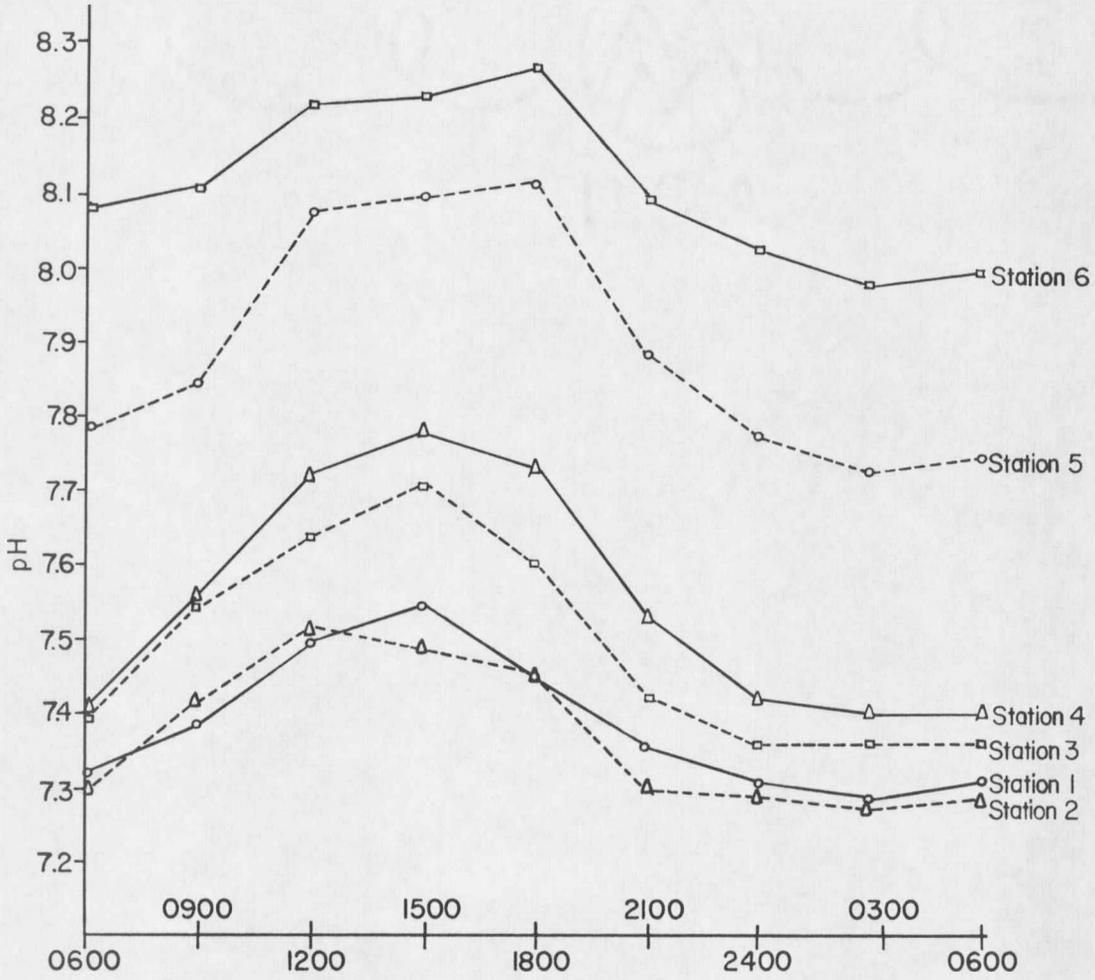


Figure 5: Examples of pH curves for all stations over a twenty-four hour period (July 14-15, 1965).

sampling period. The inverse relationship between alkalinity and river depth was apparently due to the dilution effect of surface runoff from snow melt. Maximum depth occurred on June 5, at which time the total alkalinity was minimal.

Each time the total alkalinity of the river water changed significantly, the relationship between pH change and total dissolved carbon dioxide was determined by titrating a sample with carbon dioxide saturated water as suggested by Beyers et al. (1963). An example of such a CO₂ - pH curve is shown in Figure 7. The CO₂ concentrations were computed from curves similar to Figure 7.

CO₂ Concentration

An example of total CO₂ concentrations is shown in Figure 8. The total CO₂ concentration at pH 8.4 was used as an arbitrary zero point for the calculations.

A significant decrease in total carbon dioxide concentration from the upper stations to those downstream is shown in Figure 8. There was also a daily periodicity with minima generally present between 1200 and 1500 hours and maxima usually occurring at 0300. At the pH ranges which occurred during the study period, the changes in total CO₂ corre-

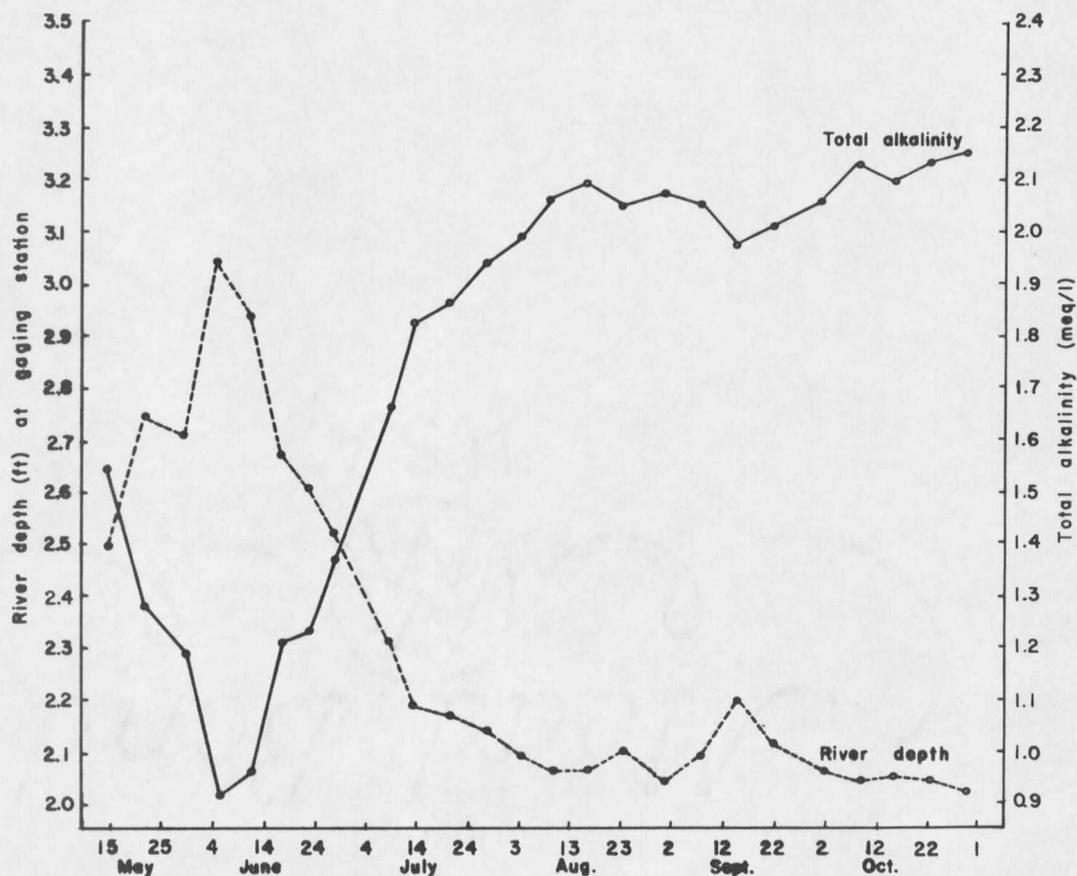


Figure 6: Weekly fluctuations in total alkalinity and river stage at the gaging station on the Madison River during the summer sampling period (1965).

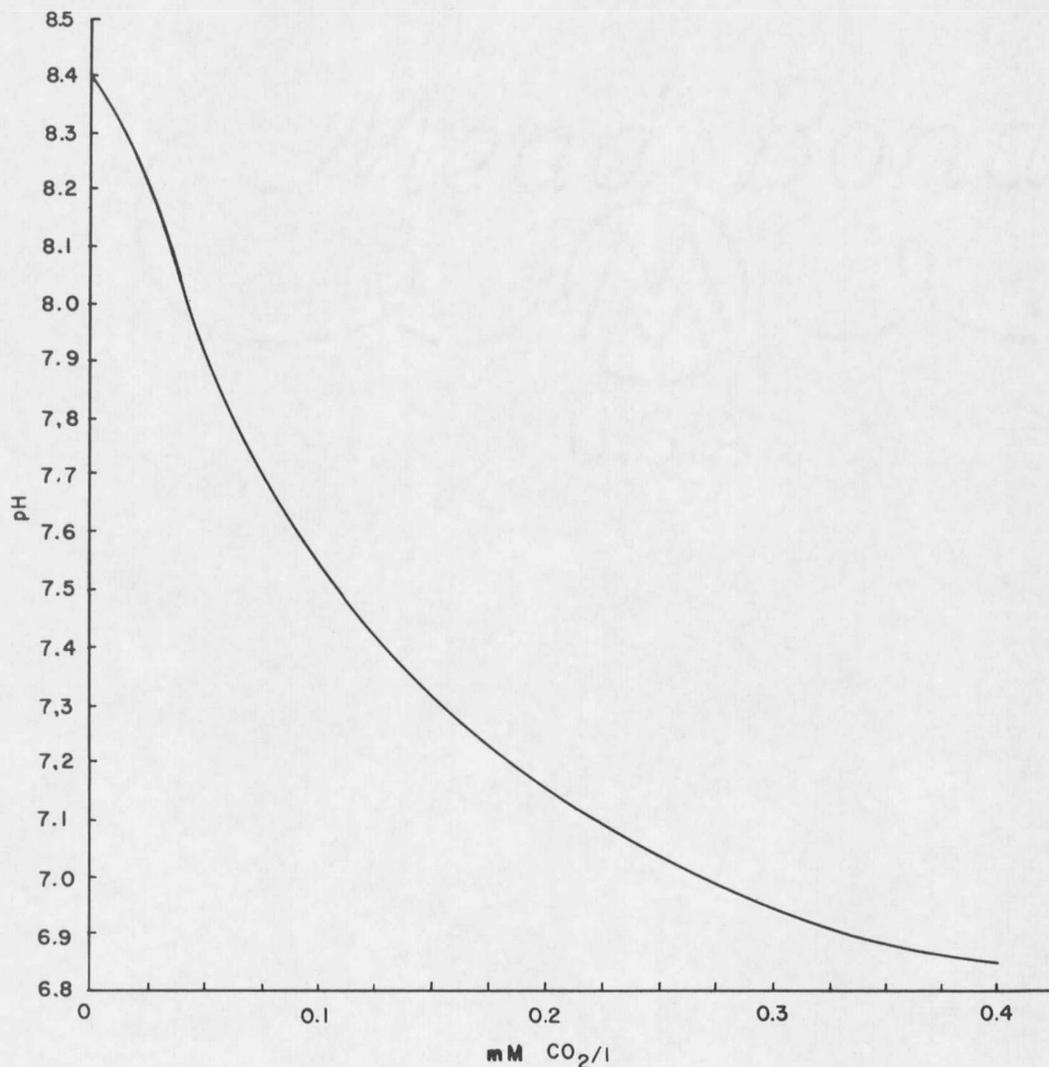


Figure 7: Example of curves produced by titrating a sample of Madison River water with carbon dioxide saturated distilled water.

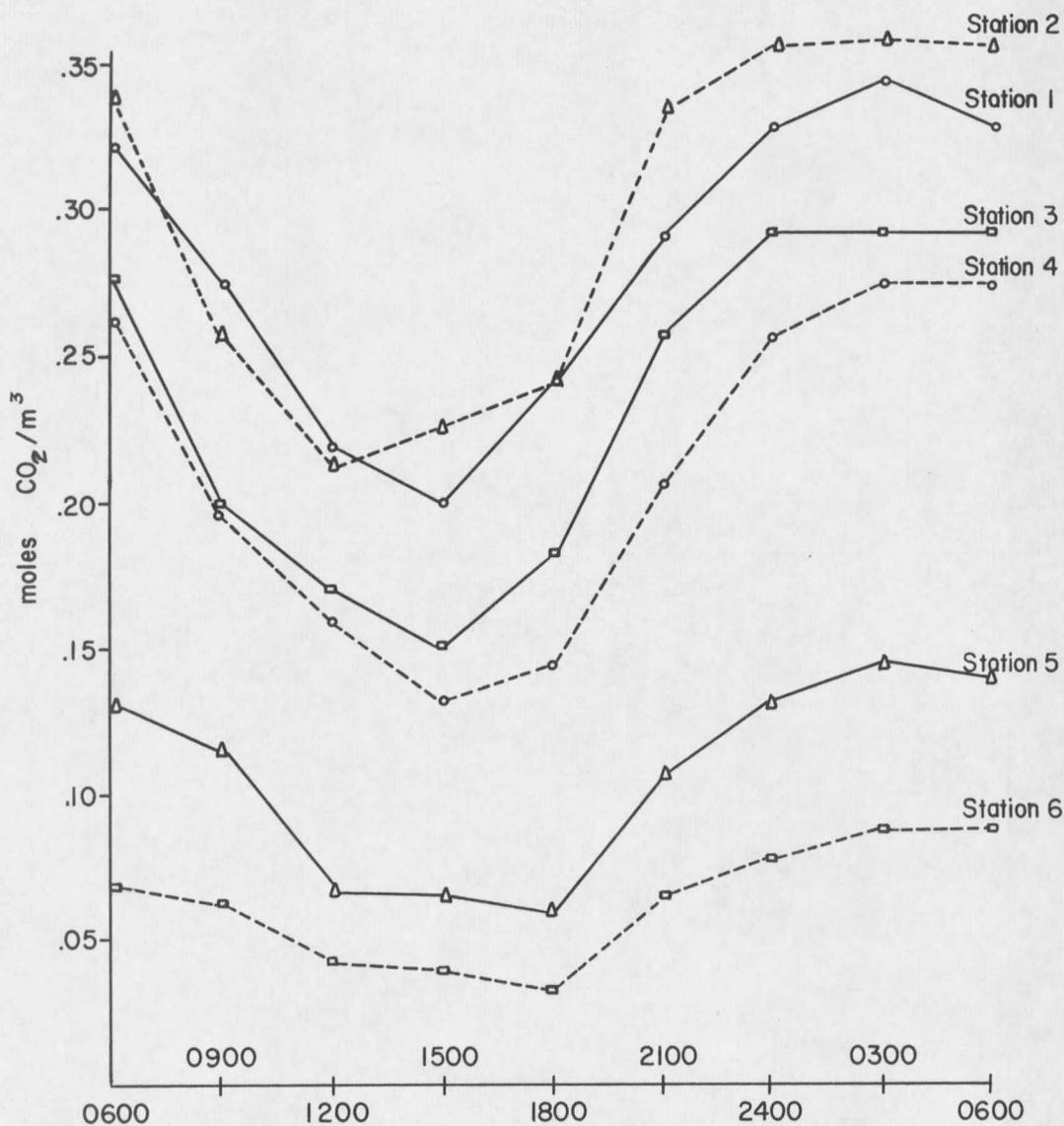


Figure 8: Example of curves showing the concentration of carbon dioxide at all stations during a twenty-four hour sampling period (July 14-15, 1965).

sponded to changes in free CO₂. This is evident if Figure 8 is compared to Figure 9, which portrays the free CO₂ concentrations for the same period. A decrease in free CO₂ from the upper stations to the lower ones is apparent.

Changes in Total CO₂ Concentration

Figure 10 shows the rate of change in total carbon dioxide concentration due to biological factors for each of the reaches during a twenty-four hour period. Each point represents the average of all values measured over the entire summer collection period for the indicated time. It can be seen that the most rapid rates of utilization and production of CO₂ took place in the reach between stations one and two. A progressive downstream diminution is apparent with the lowest rates being exhibited in the reach from station five to station six.

Maximum rates of utilization of CO₂--indicating maximum photosynthetic rates--were achieved from 0900 to 1200 hours for all reaches except that between stations two and three, where it occurred during the interval between 1200 and 1500 hours.

There was a great deal of variation as to the time of

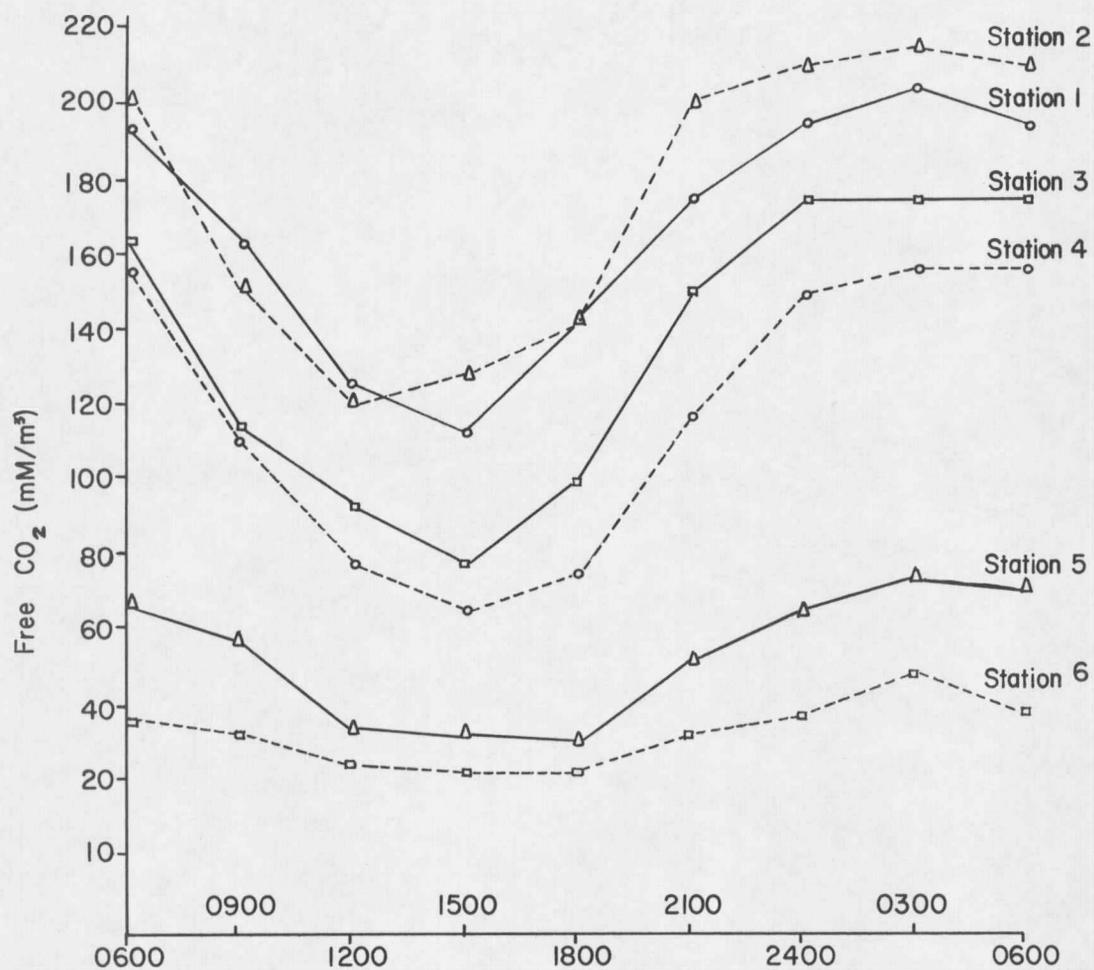


Figure 9: Example of curves showing the concentration of free carbon dioxide at all stations during a twenty-four hour sampling period (July 14-15, 1965).

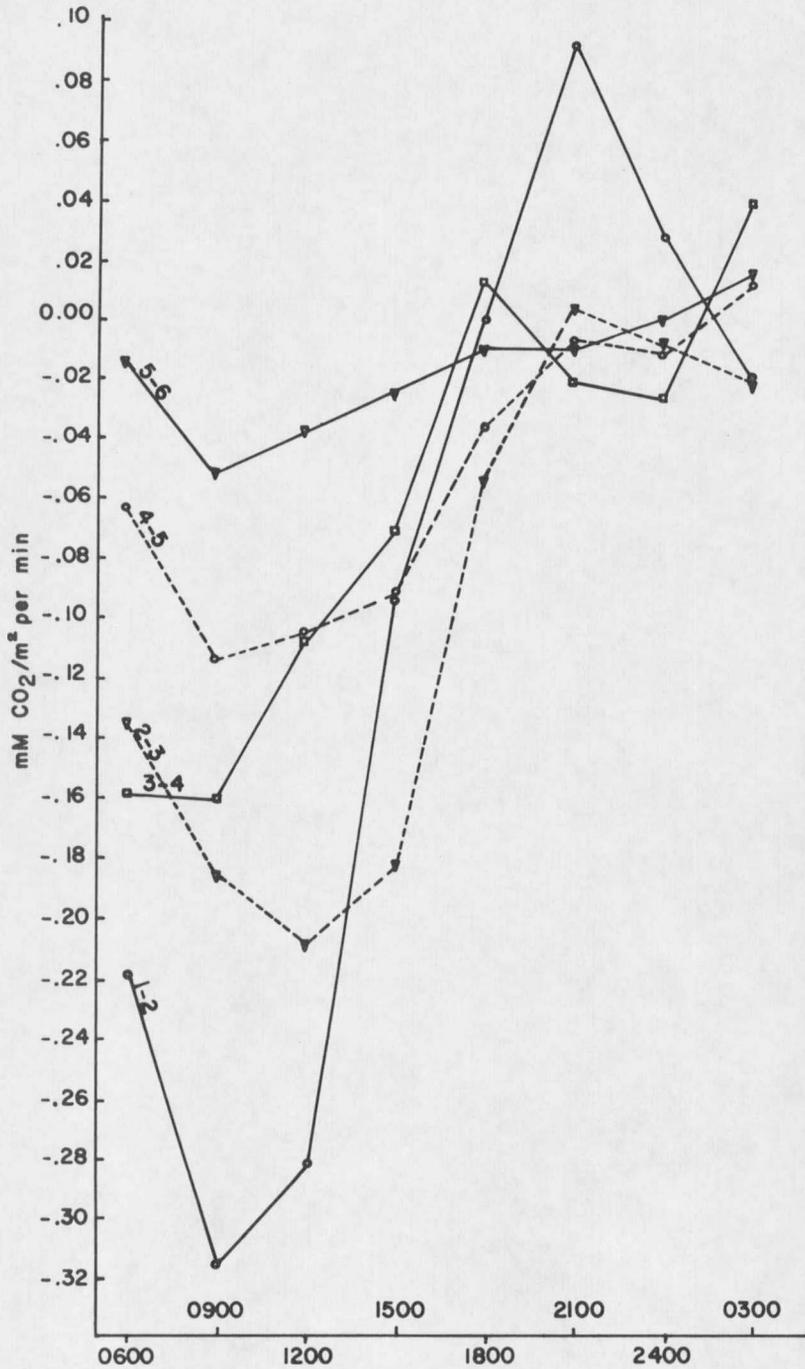


Figure 10: Average rates of change in carbon dioxide concentration due to biological factors in river reaches during a twenty-four hour period (1965).

maximum respiratory rates. The reach between stations one and two and that between two and three showed a peak between 2100 and 2400 hours. The peak respiration of the downstream reaches appeared to occur erratically, probably because of the inaccuracies of the method when small changes in CO₂ concentrations are involved.

The seasonal pattern of net photosynthesis is shown in Figure 11. The maximum rate occurred during the latter portion of June and the early part of July after which time there was a general downward trend toward the minimum achieved in late October during the latter part of the sampling period.

Light Intensity

Figure 12 shows the total light intensity between the hours of 0600 and 1800 for each sampling date through the summer. When Figures 11 and 12 are compared, it will be noted that photosynthesis was low on May 22 and June 5, whereas the light intensity was high. During the rest of the season, the highest photosynthetic rates were correlated with the highest light intensities and there was a gradual trend downward in photosynthesis correlated with de-

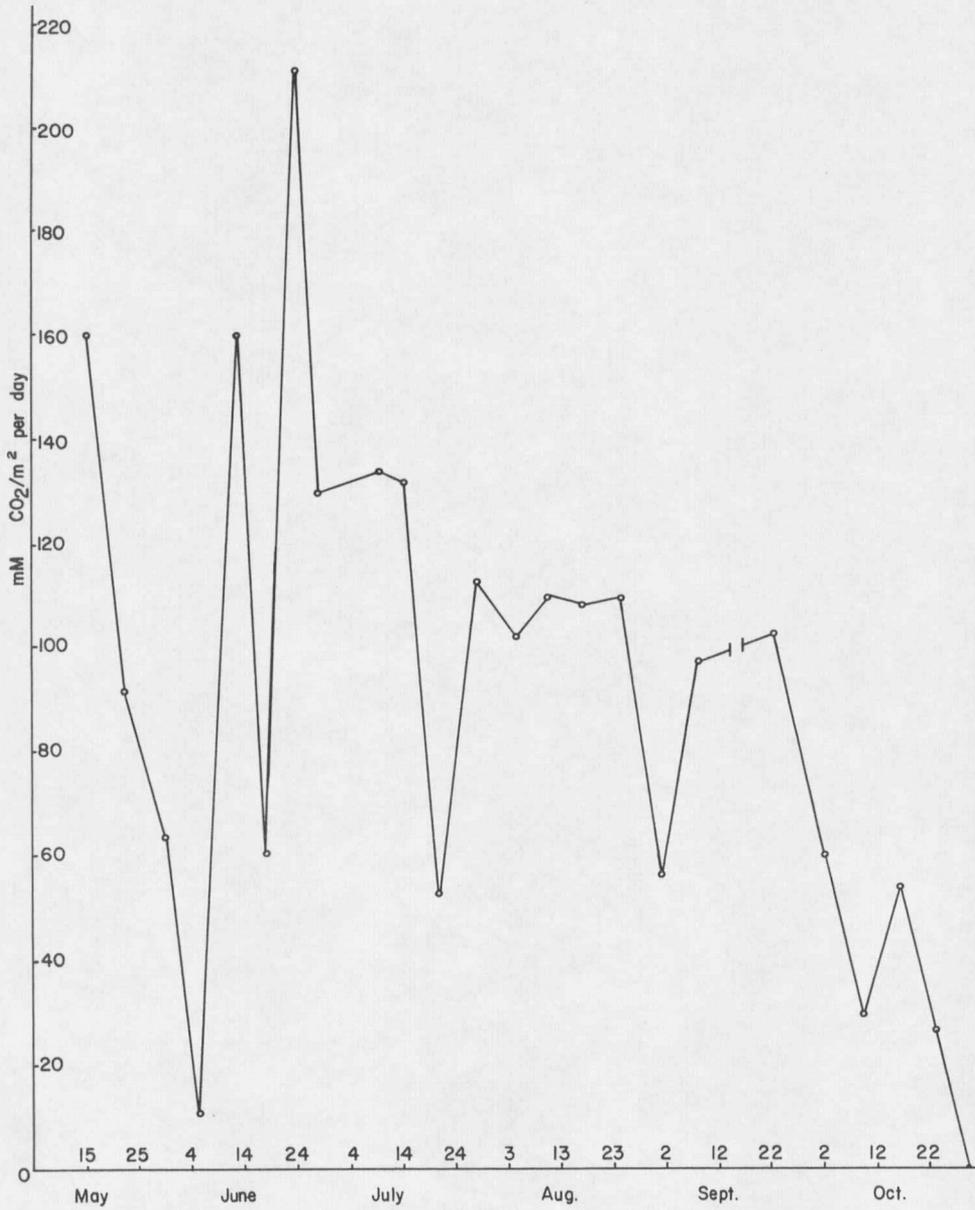


Figure 11: Average daily uptake of carbon dioxide for all stations over the entire summer sampling period on the Madison River (1965).

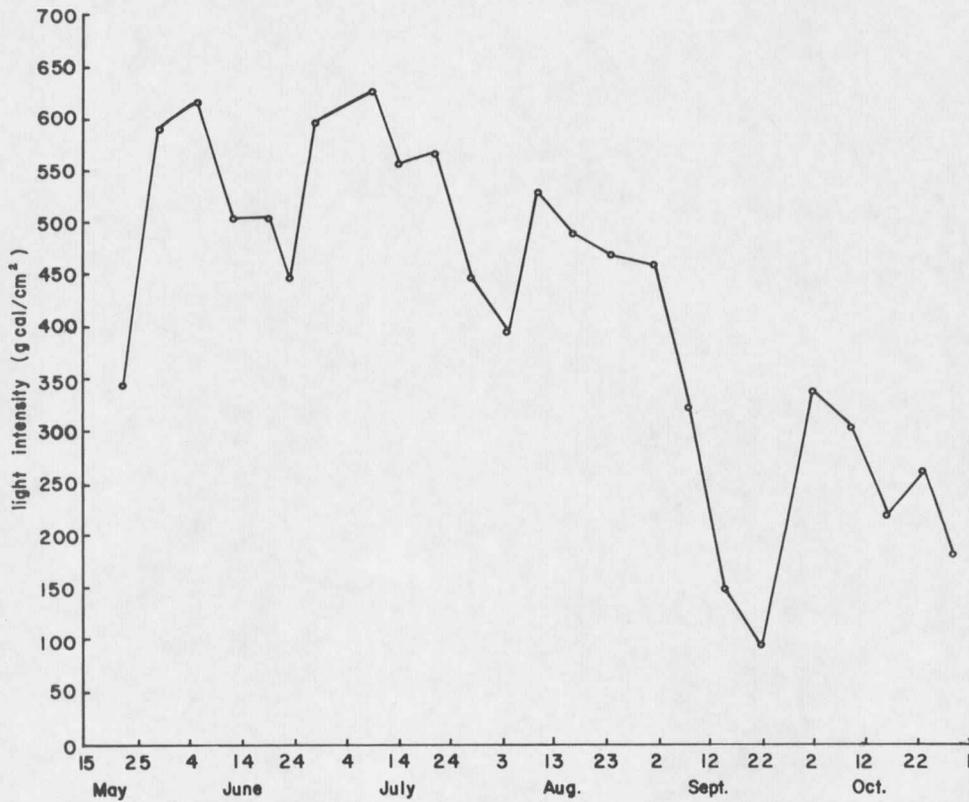


Figure 12: Light intensity (g cal/cm²) per day from 0600 to 1800 hours for each sampling date throughout the summer sampling period (1965).

creasing light intensity.

Water Temperature

There was not a great deal of variation among the stations in their average daily water temperature as is shown in Figure 13. However, there was a general tendency for the downstream stations to become warmer than the upstream stations during warming trends and cooler during cooling conditions. This tendency can be noted in the warmer temperatures in spring and early summer, and the cooler temperatures in the fall at the lower stations.

Seasonally, there was a gradual warming trend toward the maximum which was attained in late July and early August, after which there was a more rapid cooling to the minimum that was reached during the latter part of the sampling period in October.

Current Velocity

Figure 14 shows the average current velocity for reaches between all stations for each sampling date throughout the summer sampling period. Changes occurred simultaneously in all reaches although there was a less abrupt change in the reach between stations two and three than the others. This

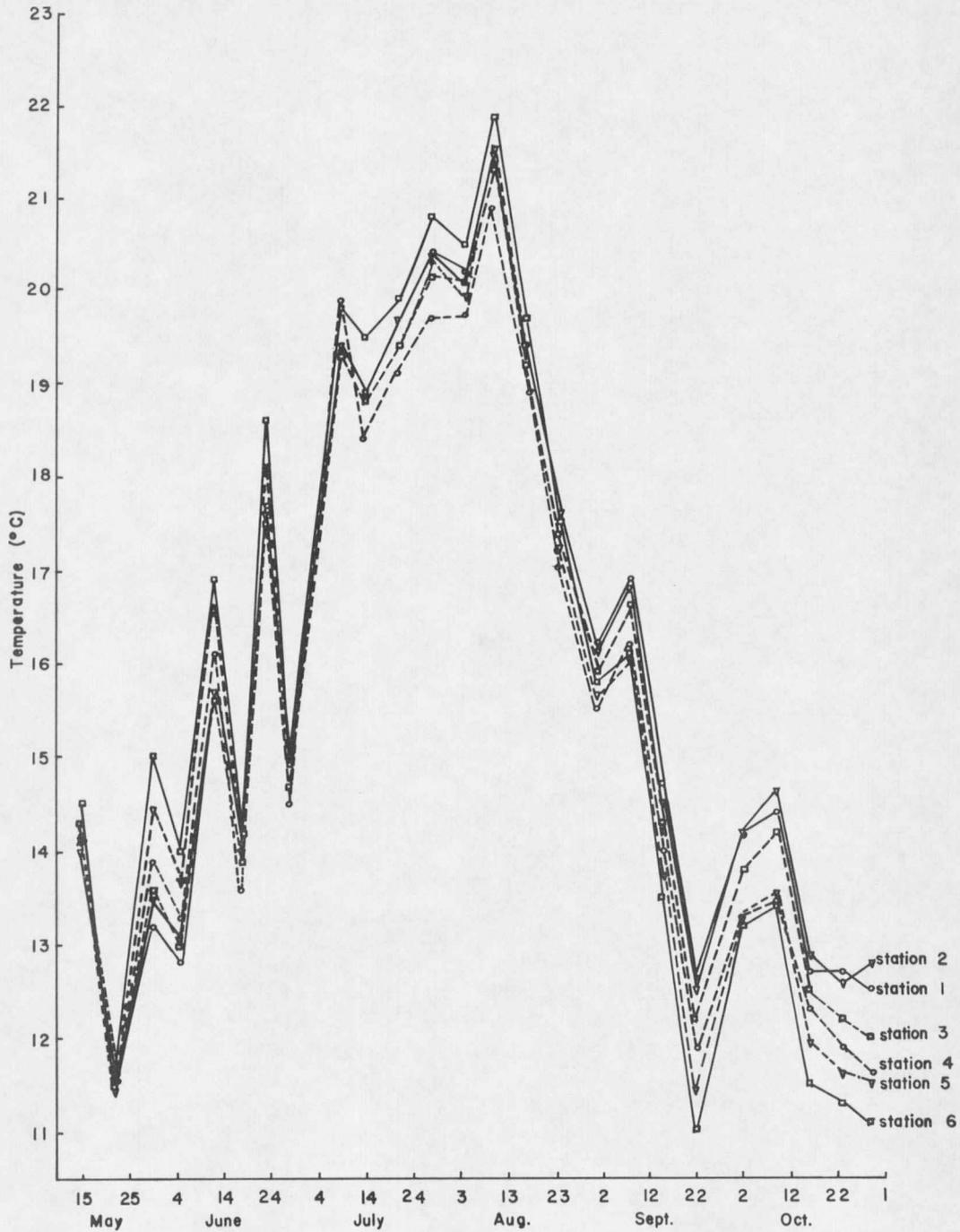


Figure 13: Average daily water temperature (0600 to 1800 hours) for all stations during the summer sampling period (1965).

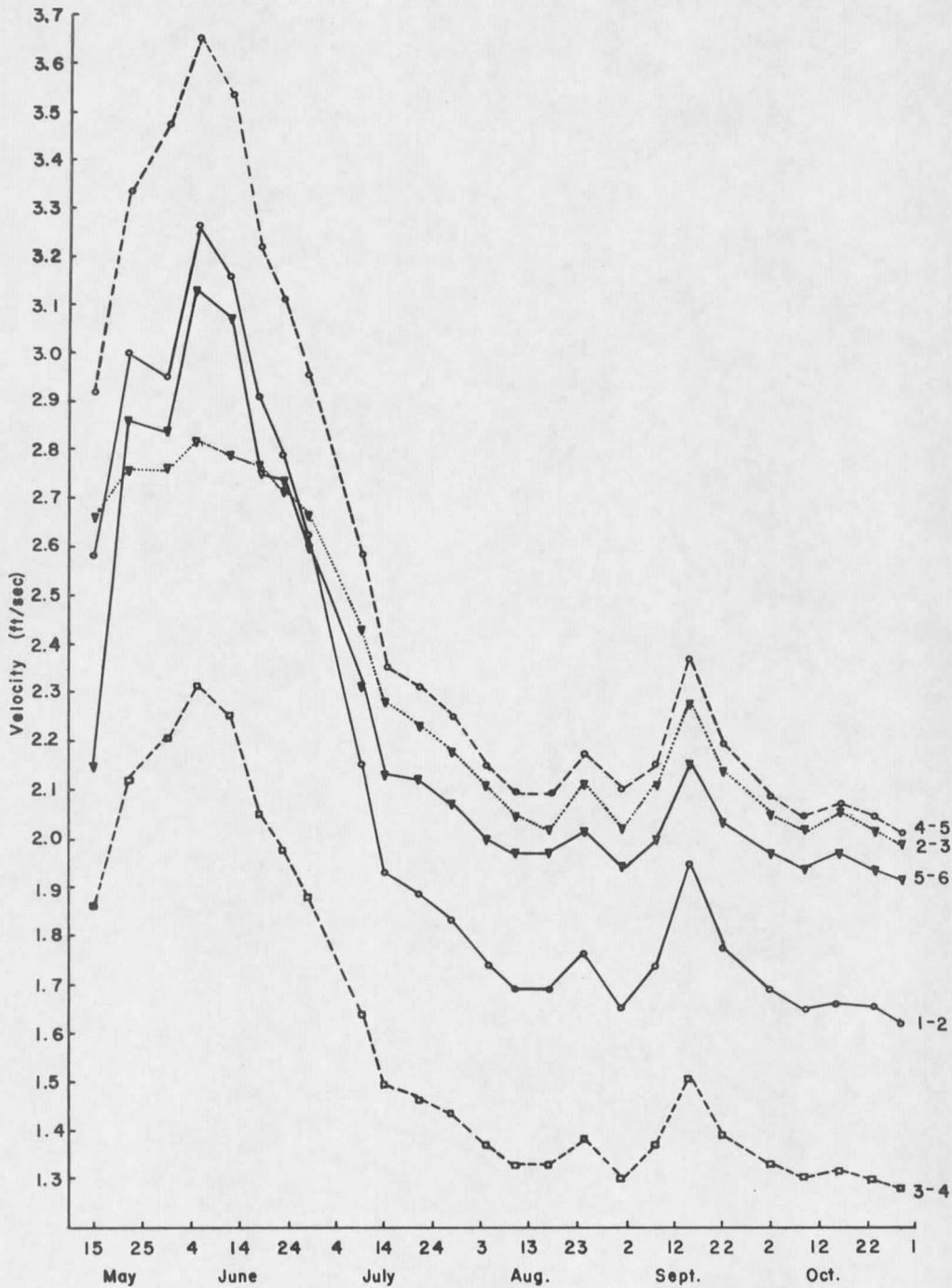


Figure 14: Average current velocity (ft/sec) for all reaches on each sampling date throughout the summer sampling period (1965).

was especially true during the period from mid-May to late June, at which time the maximum velocity was attained in all reaches.

During the spring runoff, when the maximum velocity occurred, the greatest average velocity was found in the reach separating stations four and five. This was followed in order of magnitude by reaches one to two, five to six, two to three and three to four. After the spring runoff, when the river reached its more stable summer level, the greatest average velocity was still found in the reach between stations four and five, but it was followed by reaches two to three, five to six, one to two and three to four.

Statistical Analysis of Data by Reach

A comparison was made of photosynthesis, carbon dioxide concentration, current velocity and temperature between reaches. The average values of these variables for each of the five reaches is given in Table IV.

A correlation coefficient of -0.8202 (significant to the 0.1% level) was obtained between the downstream sequence of reaches and concentration of free carbon dioxide. The correlation coefficient of -0.4540 between reaches and photo-

Table IV. Average values of photosynthesis, carbon dioxide concentration, current velocity and temperature for the various reaches over the entire summer sampling period. (1965)

Reach	Photosynthesis moles/m ² /day	CO ₂ Concentration moles/m ³	Current Velocity m/sec	Temperature °C
1	41.1	145.6	.65	16.0
2	32.1	131.6	.71	15.9
3	22.5	108.6	.52	15.7
4	16.5	78.7	.77	15.6
5	5.8	45.1	.69	15.8

synthesis was also significant to the 0.1% level. Correlation between reaches and current velocity ($R=.1201$) was found to be significant to the 1% level of probability. However, temperatures were not significantly different between the reaches.

The parallelism between photosynthesis, macrophyte standing crop, chlorophyll concentration, and free CO_2 concentration is portrayed in Figure 15.

Statistical Analysis of Pooled Data.

A study was carried out with an IBM 1620 Model II Disk Loaded Routine OMPREG. This program presents the means, standard deviation, variance and sum of the squares of each variable, the linear regression coefficients of the equation, the standard error of the regression coefficients, partial and multiple correlation coefficients, coefficients of determination, standard error of the estimate, t value and F ratios.

Photosynthesis measurements were assumed to be a valid indicator of the primary productivity of the river and were taken as the dependent variable. Light, water temperature, current velocity and carbon dioxide concentration values

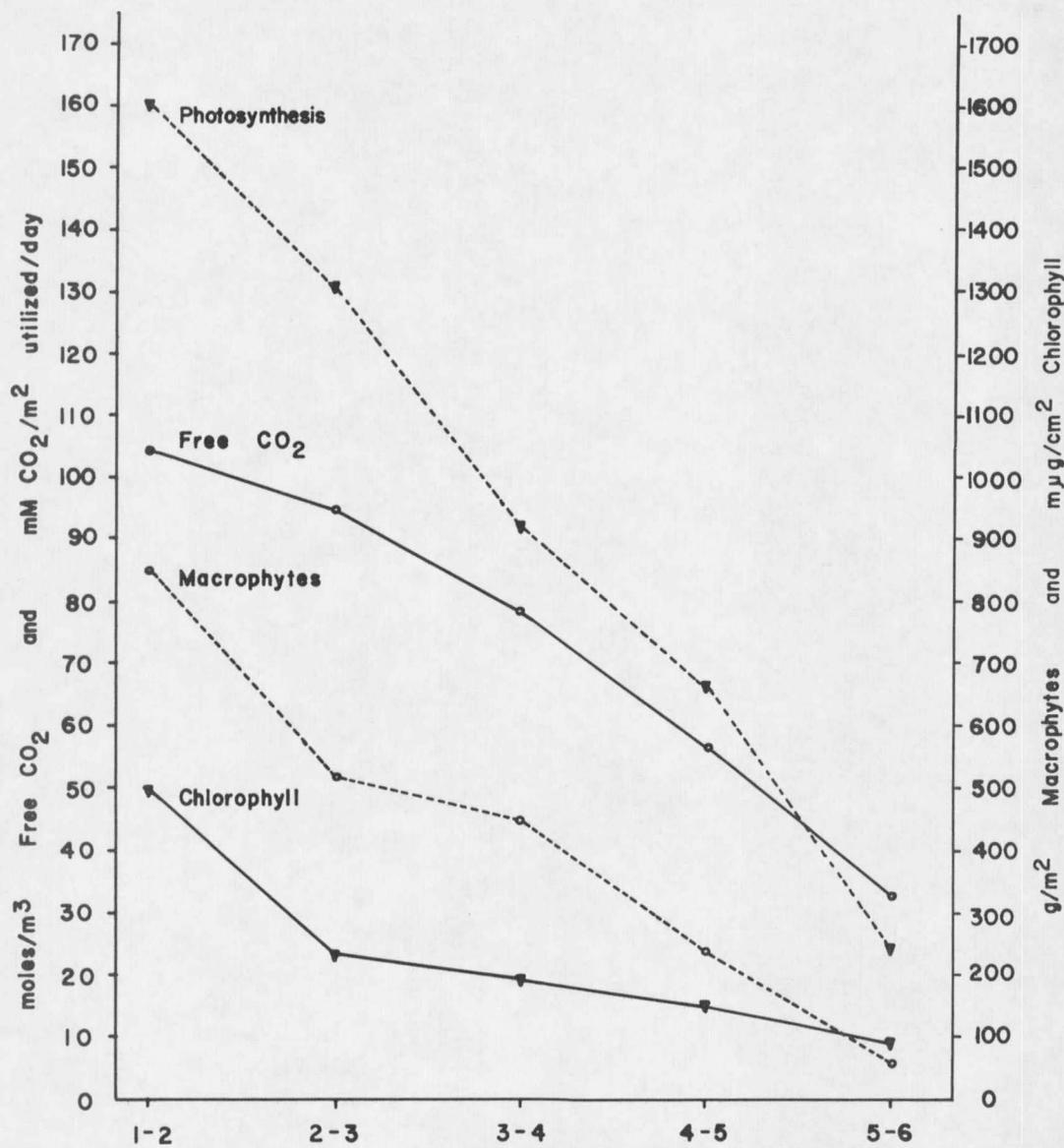


Figure 15: Comparison of free CO₂, photosynthesis, standing crop of macrophytes and chlorophyll concentration in the Madison River. Each point represents an average of the measurements over the entire summer sampling period for the designated reach (1965).

were used as independent variables. In this analysis all of the data for the entire study section were pooled without regard for differences between reaches.

Light intensity, which was measured by a single pyrheliometer located at station six, was considered as being the same for all stations. Doubtless, there was variation in the light over the 14 miles which separated station six from station one, but the difference was assumed to be negligible. Regressions were run, however, between the photosynthesis which occurred at a particular time of day and the light at the same time.

When a simple regression analysis was carried out using each independent variable individually, a correlation coefficient which was significant to the 0.1% level of probability was obtained for all factors except current velocity. The correlation coefficient for velocity was not significantly different from zero. By far the largest correlation coefficient was found for carbon dioxide concentration.

A multiple regression equation using each of the factors as separate independent variables gave a coefficient of determination of .2658 over the entire length of the river studied. This indicates that about 27% of the variation in

the photosynthesis was associated with the variables used in the equation. Carbon dioxide concentration was found to have a much larger partial correlation coefficient than any of the other three factors (see Table V). It was followed in order by temperature, light and velocity. All except velocity were significant to the 0.1% level of probability. The partial correlation coefficient of velocity was not significantly different from zero.

Table VI portrays the constants of the multiple regression equation relating photosynthesis to light, water temperature, current velocity and CO₂ concentration. All t values except that for velocity indicate significance to the 0.1% level of probability. The t value for velocity shows no significant difference from zero.

In subsequent equations involving the entire length of the study area, when carbon dioxide occurred in combination with any of the other independent variables, its partial correlation coefficient was consistently larger than that of the others, and was in all cases significant to the 0.1% level of probability.

Table V. Correlation coefficients for various combinations of independent variables over the entire length of the study area. Photosynthesis as dependent variable. (Significance levels: ***better than 0.001, **Better than 0.01, *better than 0.05)

Independent Variables	Simple Cor. Coefficient	Multiple Cor. Coefficient	Partial Correlation Coefficients			
			Light	Temp.	Velocity	CO ₂
Light	.1798***					
Temp.	.1700***					
Vel.	-.0271					
CO ₂	.4091***					
Light, Temp		.2212***	.1437**	.1312**		
Light, Vel.		.1902***	.1883***		-.0632	
Light, CO ₂		.4710***	.2560***			.4426***
Temp, Vel.		.1699***		.1678***	.0003	
Temp., CO ₂		.4850***		.2855***		.4609***
Vel., CO ₂		.4099***			.0294	.4091***
Light, Temp., Vel.		.2239***	.1480**	.1204**	-.0355	
Light, Temp., CO ₂		.5167***	.2037***	.2407***		.4787***
Light, Vel., CO ₂		.4712***	.2548***		.0161	.4392***
Temp., Vel., CO ₂		.4914***		.2971***	.0904*	.4678***
Light, Temp., Vel., CO ₂		.5181***	.1887***	.2442***	.0455	.4797***

Table VI. Constants of the regression equation relating photosynthesis to light, water temperature, current velocity and CO₂ concentration (Sample size 480, mean photosynthesis -23.6 mM CO₂/m² per three hours).

Independent Variable	Regression Coefficient	Standard Error of Regression Coefficient	t Value	Mean Value of Variable	Partial Correlation Coefficient
Light	-.0649	0.0166	-4.18	110.04	-.1887
Temperature	-1.8692	0.3405	-5.48	15.80	-.2442
Velocity	-2.0305	1.2042	-0.99	2.18	-.0455
CO ₂	-0.2977	0.0250	-11.90	101.91	-.4794

DISCUSSION

A downstream decrease in the productivity of the Madison River from its headwaters to Station 6 was demonstrated by a progressive decline in macrophyte standing crop, chlorophyll concentration, and photosynthesis. A discussion of the probable cause of this phenomenon now remains.

Since the light regime could be assumed to be the same for all reaches and since temperature differences between the reaches were statistically nonsignificant, these factors may be ruled out.

There were significant differences in current velocity between the reaches; however, both the simple and partial correlation coefficients between photosynthesis and current velocity were statistically nonsignificant. There was also no significant correlation between current velocity and macrophyte standing crop, or between current velocity and chlorophyll concentration.

It has been stated that current velocity has some effect on growth of macrophytes and periphyton. Blum (1956) concluded that although rapid current presented mechanical danger for phytoplankton organisms, benthic algae were in some way benefitted by moderate current. Whitford (1960) designated 15.2 cm/sec (0.5 ft/sec) as the lower limit which pro-

duced the current effect, but he did not indicate an upper limit.

Figure 14 shows that during the entire study period, the average current velocity of all reaches exceeded the lower limit designated by Whitford. As there was no significant difference between current velocity and chlorophyll concentration, there must have been no important difference in benefits to the algae of the various reaches, or if there was, it was hidden by some undetected variable.

Blum (1957), in his work on the Saline River in Michigan, found an increased growth of Cladophora glomerata at the crest of certain riffles, whereas it was either absent or reduced elsewhere. The only observable or measurable difference between the crest and other portions was a slight increase in current rate at the crest. The average velocity on the riffles was from 0.30 to 0.90 m/sec (0.98 to 2.95 ft/sec). Maximum occurred at low water where the rate was 1/35 m/sec (4.43 ft/sec) and at this point, sterilized rocks developed algal colonies within eight weeks after their placement.

Concentration of free carbon dioxide was the only measured variable that had a highly significant correlation

with photosynthesis and which also declined downstream in a manner consistent with the observed downstream decrease in photosynthesis.

Duffer and Doris (1966) from their work on the Blue River in Oklahoma, felt that productivity was determined by the bottom material of the various reaches. This was not considered to be true in the upper Madison River as this river system occurs almost completely within rhyolite lava flows (Boyd, 1961). There was some variation in the size of the materials making up the river bottom with the larger boulders occurring in the intermediate reaches, but the parent material throughout the length of the study area was the same.

When all of the data were pooled and reaches were disregarded, highly significant correlation coefficients were obtained between photosynthesis and each of the following: free carbon dioxide concentration, light and temperature. The highest partial correlation coefficient value was found between photosynthesis and carbon dioxide concentration (see Table V). However, the multiple correlation coefficient between photosynthesis and carbon dioxide concentration, light and temperature was considerably greater.

The results of the statistical analysis indicated that the temperature was more highly correlated with photosynthesis than was light. Comparison of Figures 6, 11 and 12 shows that the rise in photosynthesis from June 5 to June 23 accompanied an increase in temperature during the same period. During this time, light intensities decreased. Since the light reaction of photosynthesis is not temperature dependent and the dark reaction is temperature dependent, the increase in photosynthesis during this period may have been a result of the synergistic effect of an increase in temperature and carbon dioxide concentration. The higher correlation coefficient obtained between photosynthesis and temperature than between photosynthesis and light may be due to the close parallelism between temperature and photosynthesis at this time.

After June 23, there was no corresponding increase in photosynthesis as temperatures increased to the July maximum. Instead, there was a gradual downward trend of photosynthesis associated with declining light intensity. Temperatures also exhibited a decline after early August. However, it is difficult to clearly separate the interactions between the three variables during this period. Ra-

diant heating of the water would become less as light declined resulting in lower temperatures. Since carbon dioxide concentrations were high as indicated by the high alkalinity levels at this time, declining temperatures would appear to have had less effect on the dark reaction than declining light had on the light reaction. Thus it would appear that the effect of temperature would depend upon whether the system was light limited or carbon dioxide limited. In June, carbon dioxide limitation seems to be more important and more photosynthesis occurred with higher temperatures. From August on, light limitation seems to be more important.

If river stage (Figure 6) is compared with net photosynthesis (Figure 11), the high water period in May and early June was correlated with declining photosynthetic rates. Chlorophyll concentration was also minimal at this time (Figure 3). Light certainly was not limiting during this period (Figure 12). On the basis of this evidence, it would appear that high current velocity depressed plant growth and photosynthesis. However, during this time, the dilution effect produced a low concentration of carbon dioxide. In view of the higher correlation coefficients be-

tween carbon dioxide concentration and net photosynthesis, it would appear more likely that the low photosynthesis rates were due to the markedly lower carbon dioxide concentrations rather than to the current velocity.

When Figure 3 and Figure 11 are compared a rather anomalous situation appears, since the greatest amount of chlorophyll on July 2, lagged behind peak photosynthesis by a month and was harvested at a time when photosynthesis was minimal. The peak chlorophyll concentration in October occurred after photosynthesis declined abruptly in late September. This was an entirely unsuspected result since one would expect maximal photosynthesis to occur with the greatest standing crop. However, one can only measure the difference between photosynthesis and respiration during the daylight hours, and it may be that as the periphyton developed more fixed carbon was utilized in respiratory processes which would lower the net photosynthetic rate even though gross photosynthesis remained high. As the periphyton became senescent, perhaps most of the photosynthate was respired, accounting for the low photosynthetic rates when chlorophyll was maximal. The relationship between standing crops of periphyton and photosynthesis needs more investiga-

tion.

Since the coefficient of determination for the multiple linear regression equation was 0.2685, only about 27% of the variation in photosynthesis of the river is accounted for by these independent variables of the equation. Concurrent measurement of standing crop of macrophytes and periphyton with collection of samples would probably greatly increase the value of the coefficient of determination. These measurements could not be made simultaneously, therefore over 70% of the variation in productivity remains to be ascribed to factors other than those measured in this study or to an inadequate statistical approach.

In the statistical approach used, it was assumed that the relationship between photosynthesis and the independent variables was linear. However, this is a biologically unrealistic assumption, since the relationship between light and photosynthesis and carbon dioxide and photosynthesis can be expected to be nonlinear. It is quite possible that much higher correlation coefficients could have been obtained if a nonlinear analysis had been made. However, the complexity and expense of performing such an analysis limited its feasibility at the time of this study.

The results of this study confirm the preliminary investigation by Wright (1964, unpublished) indicating that with the exception of free CO₂ concentration, there was no significant change downstream among the macroelements which could account for the decline in productivity.

SUMMARY

Samples of the standing crop of macrophytes were collected periodically through the summer of 1964 from six stations on the Madison River. The first station was located about one mile below the confluence of the Firehole and Gibbon Rivers with the lowermost station located about 14 miles downstream. Samples from these stations as well as from three stations intermediate to them were collected once during the summer of 1965. A significant decrease in downstream productivity was found, with the greatest growth occurring in late July and early August.

During the summer of 1965, a downstream decrease in productivity of periphyton was found by determination of chlorophyll concentration upon glass microscope slides submerged at each of the six stations. Two periods of increased productivity occurred; one in late July, the other in mid-October.

Measurement of changes in carbon dioxide concentration over twenty-four hour periods at weekly intervals through the summer of 1965 also indicated a downstream decrease in productivity. A daily periodicity was noted with minima usually present between 1200 and 1500 hours and maxima usually occurring at 0300.

In statistical analyses, photosynthesis measurements were assumed to be a valid indicator of the primary productivity of the river and were taken as the dependent variable, while light, water temperature, current velocity, and carbon dioxide concentration values were used as independent variables. Simple regression analyses showed carbon dioxide concentration to have a much larger correlation coefficient than any of the other independent variables. The correlation coefficient between photosynthesis and current velocity was not significantly different from zero.

The results of the statistical analysis indicated that temperature was more highly correlated with photosynthesis than was light. It is proposed that this result may be due in part to the assumption of a uniform light climate along the river as measured by a pyroheliometer at only one station while temperature was measured for each river reach and time interval. Thus there was more variation in the temperature data than in the light data to correlate with variation in photosynthetic data.

There was a period in mid-summer when temperatures increased with no resulting increase in photosynthesis. Instead there was a gradual downward trend of photosynthesis

associated with declining light intensity. Because of this, it is suggested that the effect of temperature would depend upon whether the system was light limited or carbon dioxide limited. In early summer, carbon dioxide limitation seemed to be more important, while in late summer light limitation seemed to be more important.

Evidence from this study conclusively demonstrates that carbon dioxide concentration was of primary importance in determining the productivity of the Madison River.

APPENDIX

Table VII. pH measurements at all stations during twenty four hour periods on weekly intervals through the summer of 1965.

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
May 15-16	0600	7.30	7.22	7.22	7.30	7.50	7.68
	0900	7.25	7.20	7.25	7.30	7.53	7.70
	1200	7.42	7.45	7.48	7.53	7.72	7.91
	1500	7.45	7.41	7.47	7.55	7.78	7.98
	1800	7.45	7.40	7.51	7.45	7.67	7.92
	2100	7.41	7.33	7.36	7.38	7.57	7.81
	2400	7.36	7.32	7.34	7.38	7.58	7.77
	0300	7.36	7.32	7.34	7.38	7.54	7.73
	0600	7.28	7.26	7.31	7.33	7.51	7.72
May 22-23	0600	7.27	7.31	7.32	7.32	7.50	7.66
	0900	7.29	7.33	7.35	7.36	7.55	7.73
	1200	7.33	7.36	7.42	7.43	7.63	7.79
	1500	7.33	7.33	7.39	7.43	7.66	7.83
	1800	7.33	7.32	7.35	7.40	7.61	7.81
	2100	7.29	7.28	7.29	7.33	7.51	7.70
	2400	7.31	7.29	7.33	7.33	7.53	7.70
	0300	7.29	7.30	7.34	7.34	7.50	7.64
	0600	7.32	7.32	7.35	7.36	7.51	7.64
May 29-30	0600	7.28	7.28	7.30	7.31	7.52	7.76
	0900	7.30	7.33	7.37	7.40	7.59	7.82
	1200	7.31	7.33	7.40	7.43	7.64	7.82
	1500	7.33	7.35	7.40	7.45	7.67	7.85
	1800	7.34	7.31	7.37	7.43	7.67	7.87
	2100	7.26	7.23	7.27	7.31	7.53	7.71
	2400	7.25	7.23	7.27	7.28	7.46	7.65
	0300	7.25	7.26	7.28	7.29	7.48	7.66
	0600	7.23	7.24	7.26	7.26	7.44	7.63
June 5-6	0600	7.23	7.23	7.27	7.29	7.45	7.62
	0900	7.31	****	7.36	7.35	7.51	7.67
	1200	7.26	7.28	7.33	7.36	7.53	7.69
	1500	7.30	7.31	7.37	7.42	7.61	7.74
	1800	7.28	7.27	7.32	7.36	7.59	7.75

Table VII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	2100	7.19	7.20	7.26	7.27	7.47	7.67
	2400	7.19	7.20	7.24	7.25	7.43	7.60
	0300	7.18	7.21	7.24	7.25	7.40	7.56
	0600	7.19	7.22	7.24	7.25	7.42	7.58
June 12-13	0600	7.17	7.18	7.20	7.22	7.40	7.57
	0900	7.29	7.28	7.32	7.31	7.50	7.67
	1200	7.34	7.30	7.36	7.39	7.57	7.71
	1500	7.31	7.28	7.33	7.39	7.60	7.75
	1800	7.22	7.22	7.27	7.31	7.54	7.71
	2100	7.23	7.23	7.25	7.28	7.49	***
	2400	7.19	7.19	7.21	7.22	7.42	7.60
	0300	7.17	7.19	7.21	7.21	7.40	7.59
	0600	7.17	7.17	7.21	7.21	7.40	7.57
June 18-19	0600	7.24	7.23	7.30	7.32	7.52	7.40
	0900	7.34	7.31	7.38	7.39	7.60	7.79
	1200	7.35	7.32	7.40	7.41	7.67	7.84
	1500	7.35	7.32	7.40	7.46	7.72	7.89
	1800	7.28	7.29	7.37	7.42	7.70	7.89
	2100	7.25	7.21	7.28	7.32	7.59	7.80
	2400	7.23	7.21	7.27	7.27	7.51	7.72
	0300	7.23	7.22	7.28	7.27	7.50	7.69
	0600	7.21	7.19	7.25	7.27	7.49	7.68
June 23-24	0600	7.13	7.14	7.22	7.21	7.46	7.68
	0900	7.31	7.31	7.39	7.39	7.61	7.84
	1200	7.33	7.34	7.44	7.46	7.71	7.85
	1500	7.31	7.30	7.40	7.47	7.74	7.93
	1800	7.28	7.32	7.37	7.41	7.67	7.91
	2100	7.24	7.25	7.28	7.31	7.55	7.76
	2400	7.24	7.21	7.25	7.28	7.51	7.73
	0300	7.20	7.23	7.27	7.28	7.51	7.71
	0600	7.19	7.18	7.24	7.24	7.49	7.71
June 28-29	0600	7.31	7.27	7.34	7.34	7.57	7.79
	0900	7.30	7.30	7.37	7.39	7.59	7.82

Table VII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1200	7.34	7.34	7.44	7.48	7.72	7.89
	1500	7.35	7.38	7.48	7.54	7.82	7.97
	1800	7.31	7.32	7.45	7.51	7.83	8.03
	2100	7.29	7.26	7.32	7.40	7.67	7.92
	2400	7.26	7.23	7.28	7.31	7.58	7.82
	0300	7.28	7.24	7.29	7.33	7.55	7.79
	0600	7.22	7.21	7.28	7.28	7.56	7.79
July 9-10	0600	7.32	7.32	7.41	7.42	7.71	7.95
	0900	7.38	7.41	7.53	7.52	7.83	8.07
	1200	7.44	7.45	7.61	7.66	7.95	8.10
	1500	7.47	7.47	7.62	7.69	8.03	8.19
	1800	7.36	7.38	7.54	7.62	7.97	8.20
	2100	7.34	7.30	7.38	7.47	7.81	8.04
	2400	7.26	7.25	7.32	7.37	7.69	7.93
	0300	7.31	7.26	7.35	7.38	7.69	7.91
	0600	7.28	7.24	7.31	7.34	7.67	7.93
July 14-15	0600	7.32	7.30	7.39	7.41	7.79	8.08
	0900	7.39	7.42	7.55	7.56	7.85	8.11
	1200	7.50	7.52	7.64	7.72	8.08	8.22
	1500	7.55	7.49	7.71	7.78	8.10	8.23
	1800	7.45	7.45	7.60	7.73	8.12	8.27
	2100	7.36	7.30	7.42	7.53	7.89	8.10
	2400	7.31	7.29	7.36	7.42	7.78	8.03
	0300	7.29	7.27	7.36	7.40	7.73	7.98
	0600	7.31	7.28	7.36	7.40	7.75	8.00
July 21-22	0600	7.51	7.48	7.57	7.58	7.92	8.15
	0900	7.51	7.51	7.65	7.66	7.94	8.17
	1200	7.66	7.64	7.82	7.90	8.21	8.38
	1500	7.52	7.49	7.62	7.72	8.02	8.16
	1800	7.45	7.44	7.57	7.69	8.05	8.25
	2100	7.33	7.29	7.38	7.50	7.83	8.04
	2400	7.28	7.25	7.33	7.40	7.71	7.95
	0300	7.26	7.23	7.30	7.37	7.66	7.90
	0600	7.30	7.27	7.35	7.40	7.72	7.94

Table VII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
July 28-29	0600	7.34	7.31	7.39	7.46	7.80	8.07
	0900	7.41	7.44	7.58	7.56	7.91	8.12
	1200	7.51	7.53	7.71	7.78	8.09	8.29
	1500	7.53	7.54	7.74	7.82	8.14	8.25
	1800	7.49	7.47	7.61	7.76	8.18	8.25
	2100	7.36	7.32	7.44	7.56	7.90	8.10
	2400	7.33	7.30	7.39	7.47	7.82	8.03
	0300	7.33	7.32	7.38	7.49	7.79	8.03
	0600	7.35	7.32	7.42	7.47	7.84	8.10
Aug 4-5	0600	7.36	7.34	7.42	7.49	7.84	8.10
	0900	7.47	7.46	7.61	7.62	7.97	8.18
	1200	7.52	7.51	7.72	7.82	8.16	8.27
	1500	7.54	7.50	7.65	7.81	8.17	8.32
	1800	7.50	7.46	7.57	7.69	8.14	8.30
	2100	7.38	7.34	7.45	7.54	7.89	8.12
	2400	7.35	7.34	7.43	7.50	7.86	8.11
	0300	7.36	7.32	7.42	7.47	7.82	8.06
	0600	7.37	7.32	7.41	7.48	7.79	9.02
Aug 10-11	0600	7.35	7.34	7.44	7.46	7.82	8.08
	0900	7.45	7.48	7.62	7.62	7.97	8.21
	1200	7.52	7.54	7.76	7.83	8.22	8.34
	1500	7.62	7.57	7.78	7.89	8.31	8.38
	1800	7.56	7.49	7.63	7.82	8.13	8.36
	2100	7.40	7.36	7.45	7.60	7.93	8.17
	2400	7.35	7.34	7.46	7.51	7.84	8.10
	0300	7.35	7.32	7.43	7.48	7.82	8.06
	0600	7.36	7.34	7.43	7.49	7.88	8.13
Aug 17-18	0600	7.37	7.36	7.45	7.51	7.86	8.06
	0900	7.48	7.47	7.61	7.62	8.07	8.24
	1200	7.52	7.52	7.75	7.82	8.14	8.24
	1500	7.65	7.59	7.78	7.91	8.21	8.32
	1800	7.62	7.53	7.67	7.86	8.26	8.38
	2400	7.44	7.38	7.50	7.63	7.98	8.19
	2400	7.42	7.34	7.42	7.52	7.85	8.09

Table VII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	0300	7.38	7.33	7.42	7.50	7.82	8.05
	0600	7.39	7.33	7.43	7.51	7.82	8.04
Aug 24-25	0600	7.40	7.31	7.44	7.49	7.82	8.04
	0900	7.53	7.50	7.65	7.62	7.96	8.16
	1200	7.55	7.55	7.75	7.83	8.13	8.26
	1500	7.62	7.59	7.77	7.89	8.29	8.36
	1800	7.53	7.51	7.64	7.83	8.22	8.36
	2100	7.47	7.38	7.47	7.56	7.94	8.12
	2400	7.37	7.34	7.44	7.50	7.80	8.03
	0300	*	*	*	*	*	*
	0600	7.46	7.42	7.48	7.52	7.85	8.06
Sept 1-2	0600	7.46	7.44	7.53	7.65	7.94	8.12
	0900	7.51	7.51	7.61	7.64	7.98	8.18
	1200	7.57	7.59	7.78	7.83	8.07	8.21
	1500	7.71	7.62	7.80	7.91	8.22	8.35
	1800	7.69	7.60	7.73	7.89	8.19	8.36
	2100	7.49	7.43	7.55	7.66	7.99	8.26
	2400	7.46	7.40	7.53	7.61	7.88	8.09
	0300	*	*	*	*	*	*
	0600	7.43	7.40	7.50	7.54	7.90	8.11
Sept 8-9	0600	7.38	7.36	7.46	7.51	7.83	8.06
	0900	7.49	7.47	7.57	7.62	7.95	8.17
	1200	7.61	7.58	7.72	7.76	8.05	8.23
	1500	7.68	7.59	7.75	7.87	8.18	8.30
	1800	7.67	7.59	7.70	7.83	8.12	8.31
	2100	7.54	7.50	7.59	7.67	7.96	8.15
	2400	7.42	7.44	7.53	7.60	7.90	8.10
	0300	*	*	*	*	*	*
	0600	7.43	7.40	7.48	7.51	7.84	8.05
Sept 15-16	0600	7.43	7.40	7.47	7.52	7.83	8.07
	0900	7.56	7.49	7.55	7.55	7.90	8.15
	1200	7.60	7.59	7.70	7.72	7.91	8.14
	1500	7.55	7.56	7.67	7.76	8.07	8.28

Table VII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1800	7.47	7.48	7.55	7.67	7.94	8.10
	2100	7.49	7.47	7.50	7.58	7.90	8.10
	2400	**	**	**	**	**	**
	0300	**	**	**	**	**	**
	0600	**	**	**	**	**	**
Sept 22-23	0600	7.36	7.35	7.43	7.49	7.78	7.98
	0900	7.42	7.42	7.52	7.59	7.85	8.06
	1200	7.46	7.46	7.58	7.64	7.94	8.13
	1500	7.46	7.46	7.51	7.54	7.98	8.19
	1800	7.43	7.43	7.50	7.65	7.92	8.04
	2100	7.43	7.42	7.47	7.58	7.83	8.04
	2400	7.32	7.41	7.40	7.49	7.77	8.03
	0300	7.41	7.40	7.45	7.55	7.86	8.05
	0600	7.40	7.39	7.46	7.51	7.81	8.02
Oct. 2-3	0600	7.44	7.38	7.50	7.58	7.89	8.09
	0900	7.49	7.43	7.57	7.61	7.94	8.14
	1200	7.51	7.49	7.68	7.74	8.06	8.23
	1500	7.57	7.46	7.67	7.80	8.08	8.26
	1800	7.53	7.42	7.56	7.69	8.09	8.27
	2100	7.46	7.38	7.51	7.59	7.91	8.11
	2400	7.39	7.34	7.50	7.55	7.87	8.07
	0300	*	*	*	*	*	*
	0600	7.39	7.35	7.49	7.55	7.87	8.08
Oct 9-10	0600	7.43	7.38	7.51	7.58	7.90	8.11
	0900	7.46	7.41	7.53	7.58	7.90	8.09
	1200	7.52	7.47	7.66	7.69	8.09	8.13
	1500	7.59	7.50	7.63	7.78	8.08	8.26
	1800	7.56	7.45	7.60	7.72	8.02	8.19
	2100	7.49	7.36	7.49	7.56	7.85	8.07
	2400	7.43	7.36	7.47	7.54	7.88	8.02
	0300	7.42	7.34	7.49	7.56	7.87	8.09
	0600	7.40	7.33	7.47	7.53	7.86	8.06
Oct 16-17	0600	7.44	7.39	7.51	7.56	7.88	8.08

Table VII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	0900	7.49	7.42	7.55	7.59	7.95	8.14
	1200	7.51	7.48	7.67	7.74	8.06	8.22
	1500	7.55	7.46	7.68	7.80	8.09	8.25
	1800	7.53	7.42	7.57	7.73	8.04	8.23
	2100	7.48	7.40	7.53	7.60	7.93	8.15
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	7.45	7.38	7.52	7.57	7.88	8.09
Oct. 23-24	0600	7.43	7.38	7.47	7.53	7.85	8.05
	0900	7.46	7.42	7.54	7.57	7.93	8.14
	1200	7.50	7.45	7.65	7.71	8.00	8.19
	1500	7.51	7.45	7.66	7.77	8.09	8.25
	1800	7.51	7.42	7.56	7.68	8.02	8.22
	2100	7.46	7.39	7.56	7.57	7.91	8.10
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	7.45	7.38	7.53	7.58	7.91	8.10
Oct 29-30	0600	7.43	7.36	7.49	7.55	7.89	8.08
	0900	7.46	7.40	7.57	7.60	7.96	8.16
	1200	7.51	7.47	7.68	7.71	9.02	8.21
	1500	7.54	7.45	7.65	7.78	8.10	8.26
	1800	7.50	7.40	7.61	7.71	8.02	8.22
	2100	7.46	7.38	7.51	7.59	7.93	8.12
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
		0600	7.41	7.37	7.50	7.58	7.89

* Samples were not collected at this time because the change in pH between succeeding periods was found to be too small to be detected by the methods used.

** Samples were not collected at this time because excessive snow made the highway impassable.

**** Samples lost.

Table VIII. Total alkalinities at all stations during twenty-four hour periods on weekly intervals through the summer of 1965.

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
May 15-16	0600	1.05	1.55	1.70	1.60	1.60	1.60
	1200	1.55	1.60	1.65	1.60	1.65	1.65
	1800	1.55	1.60	1.55	1.60	1.55	1.60
	2400	*	*	*	*	*	*
	0600	1.30	1.50	1.40	1.40	1.40	1.45
May 22-23	0600	1.20	1.20	1.30	1.30	1.30	1.30
	1200	1.20	1.20	1.30	1.30	1.30	1.25
	1800	1.30	1.25	1.25	1.30	1.20	1.30
	2400	1.20	1.30	1.40	1.30	1.25	1.25
	0600	1.10	1.30	1.20	1.20	1.30	1.30
May 29-20	0600	1.10	1.25	1.25	1.30	1.30	1.30
	1200	1.00	1.25	1.15	1.30	1.20	1.30
	1800	1.10	1.30	1.20	1.30	1.20	1.20
	2400	*	*	*	*	*	*
	0600	1.00	1.00	1.00	1.00	1.20	1.20
June 5-6	0600	0.80	0.90	0.90	0.90	0.90	0.90
	1200	0.80	0.90	0.90	0.90	0.90	0.90
	1800	0.90	1.00	0.95	0.90	0.90	0.95
	2400	0.90	0.95	1.00	0.95	0.90	1.00
	0600	0.85	0.85	0.90	0.90	0.95	0.95
June 12-13	0600	1.10	0.90	0.90	1.00	1.00	1.00
	1200	0.90	0.90	0.95	0.90	1.00	0.90
	1800	1.10	0.90	1.00	1.00	0.90	0.90
	2400	0.90	1.00	1.00	1.00	2.00	1.00
	0600	0.85	0.95	0.90	1.00	1.00	1.00
June 18-19	0600	1.15	1.20	1.20	1.20	1.20	1.20
	1200	1.10	1.25	1.20	1.25	1.20	1.20
	1800	1.20	1.20	1.25	1.25	1.20	1.20
	2400	1.15	1.25	1.25	1.20	1.25	1.20
	0600	1.20	1.20	1.15	1.25	1.20	1.20

Table VIII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
June 23-24	0600	1.20	1.20	1.30	1.25	1.30	1.25
	1200	1.15	1.20	1.15	1.20	1.20	1.20
	1800	1.15	1.20	1.20	1.15	1.15	1.20
	2400	1.20	1.30	1.25	1.25	1.35	1.25
	0600	1.25	1.30	1.30	1.30	1.30	1.30
June 28-29	0600	1.20	1.30	1.25	1.25	1.25	1.25
	1200	1.20	1.40	1.30	1.40	1.30	1.30
	1800	1.40	1.40	1.40	1.40	1.40	1.40
	2400	1.35	1.45	1.50	1.50	1.45	1.45
	0600	1.35	1.45	1.50	1.50	1.45	1.45
July 9-10	0600	1.65	1.65	1.65	1.75	1.55	1.65
	1200	1.55	1.60	1.70	1.65	1.55	1.65
	1800	1.60	1.65	1.65	1.70	1.65	1.75
	2400	1.65	1.70	1.65	1.65	1.70	2.15
	0600	1.65	1.70	1.70	1.70	1.60	1.70
July 14-15	0600	1.75	1.75	1.80	1.80	1.80	1.80
	1200	1.65	1.90	1.90	1.70	1.75	1.85
	1800	1.85	1.85	1.85	1.80	1.85	1.90
	2400	1.75	1.90	1.85	1.85	1.85	1.75
	0600	1.75	1.85	1.85	1.85	1.85	1.85
July 21-22	0600	1.80	1.85	1.80	1.90	1.85	1.85
	1200	1.80	1.85	1.80	1.80	1.80	1.90
	1800	1.90	1.80	1.90	1.90	1.90	1.90
	2400	1.80	1.80	1.90	1.80	1.90	1.90
	0600	1.80	1.90	1.85	1.90	1.90	1.90
July 28-29	0600	1.90	1.85	1.90	1.90	1.90	1.90
	1200	1.80	1.95	1.90	1.90	1.85	1.90
	1800	1.90	2.00	2.00	1.95	2.00	1.95
	2400	2.00	2.00	2.00	2.00	2.05	1.95
	0600	1.90	1.95	1.90	1.95	2.00	1.90

Table VIII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
Aug 4-5	0600	1.50	1.75	1.80	1.80	1.90	2.00
	1200	1.90	2.00	2.00	2.00	2.00	2.00
	1800	2.00	2.05	2.05	2.05	2.05	2.05
	2400	2.05	2.05	2.05	2.10	2.10	2.10
	0600	2.05	2.05	2.05	2.05	2.05	2.10
Aug 10-11	0600	2.00	2.00	2.10	2.00	2.00	2.00
	1200	2.05	2.15	2.10	2.05	2.10	2.05
	1800	2.00	2.10	2.05	2.05	2.05	2.10
	2400	2.10	2.15	2.15	2.10	2.00	2.05
	0600	2.00	2.05	2.05	2.00	2.05	2.05
Aug 17-18	0600	2.00	2.10	2.10	2.10	2.10	2.00
	1200	2.00	2.10	2.10	2.10	2.10	2.10
	1800	2.05	2.10	2.05	2.05	2.10	2.15
	2400	2.10	2.10	2.15	2.10	2.05	2.10
	0600	2.05	2.15	2.10	2.10	2.10	2.10
Aug 24-25	0600	2.05	2.05	2.05	2.10	2.05	2.05
	1200	1.95	2.00	2.10	2.00	2.00	2.10
	1800	1.95	1.95	2.05	2.00	1.95	2.05
	2400	2.05	2.10	2.10	2.00	2.10	2.00
	0600	2.00	2.05	2.05	2.05	2.05	2.05
Sept 1-2	0600	2.05	2.10	2.10	2.00	2.00	2.00
	1200	2.00	2.10	2.10	2.10	2.00	2.10
	1800	2.10	2.10	2.10	2.10	2.10	2.10
	2400	2.05	2.10	2.10	2.05	2.05	2.05
	0600	2.10	2.10	2.10	2.05	2.10	2.10
Sept 8-9	0600	2.00	2.10	2.10	2.00	2.10	2.05
	1200	2.00	2.10	2.05	2.05	2.05	2.05
	1800	2.10	2.05	2.15	2.10	2.10	2.10
	2400	2.00	2.10	2.10	2.05	2.10	2.15
	0600	1.90	2.00	1.90	2.00	2.00	2.00
Sept 15-16	0600	2.00	2.00	2.05	2.05	2.00	2.00

Table VIII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1200	2.00	2.05	2.05	2.00	2.00	2.00
	1800	1.80	1.90	2.00	1.95	2.05	2.00
	2400	**	**	**	**	**	**
	0600	**	**	**	**	**	**
Sept 22-23	0600	2.00	2.05	2.05	1.95	2.00	2.05
	1200	1.90	2.00	2.00	2.00	2.00	2.00
	1800	1.95	2.05	2.00	2.05	2.00	2.00
	2400	2.10	2.00	2.00	2.00	2.00	2.00
	0600	2.00	2.00	2.00	2.00	2.00	2.00
Oct 2-3	0600	2.00	2.00	2.10	2.05	2.05	2.05
	1200	2.00	2.10	2.10	2.00	2.00	2.05
	1800	2.00	2.10	2.10	2.10	2.05	2.10
	2400	2.05	2.20	2.10	2.10	2.10	2.10
	0600	2.00	2.15	2.05	2.05	2.05	2.05
Oct 9-10	0600	2.05	2.15	2.15	2.10	2.05	2.15
	1200	2.00	2.10	2.10	2.10	2.10	2.00
	1800	2.05	2.15	2.20	2.10	2.10	2.10
	2400	*	*	*	*	*	*
	0600	2.10	2.20	2.05	2.10	2.15	2.10
Oct 16-17	0600	2.10	2.15	2.10	2.10	2.10	2.00
	1200	2.00	2.10	2.15	2.15	2.10	2.10
	1800	2.05	2.15	2.10	2.10	2.15	2.15
	2400	*	*	*	*	*	*
	0600	2.00	2.20	2.10	2.10	2.10	2.00
Oct 23-24	0600	2.05	2.10	2.20	2.20	2.10	2.10
	1200	2.05	2.20	2.20	2.10	2.10	2.10
	1800	2.05	2.20	2.20	2.10	2.10	2.10
	2400	*	*	*	*	*	*
	0600	2.10	2.20	2.15	2.10	2.20	2.10
Oct 29-30	0600	2.10	2.30	2.10	2.10	2.10	2.20
	1200	2.10	2.20	2.20	2.10	2.10	2.10

Table VIII. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1800	2.20	2.20	2.10	2.20	2.10	2.20
	2400	*	*	*	*	*	*
	0600	2.10	2.20	2.15	2.10	2.15	2.10

* Alkalinity not determined at this sample period.

** Samples were not collected at this time because excessive snow made the highway impassable.

Table IX. Concentration of CO₂ (moles/m³) at all stations during twenty-four periods on weekly intervals through the summer of 1965.

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
May 15-16	0600	.228	.264	.264	.228	.159	.117
	0900	.249	.274	.249	.228	.152	.113
	1200	.183	.173	.166	.152	.108	.078
	1500	.173	.187	.168	.146	.098	.069
	1800	.173	.190	.163	.173	.118	.076
	2100	.187	.216	.209	.197	.142	.093
	2400	.204	.219	.212	.197	.139	.099
	0300	.204	.219	.212	.197	.149	.107
	0600	.237	.244	.223	.216	.157	.108
May 22-23	0600	.189	.175	.171	.171	.120	.092
	0900	.183	.168	.161	.157	.109	.082
	1200	.168	.157	.138	.137	.096	.076
	1500	.168	.168	.148	.137	.092	.072
	1800	.168	.171	.161	.146	.099	.073
	2100	.183	.186	.183	.168	.117	.086
	2400	.175	.183	.168	.168	.113	.086
	0300	.183	.179	.163	.163	.119	.094
	0600	.171	.171	.161	.157	.118	.091
May 29-20	0600	.162	.162	.156	.153	.106	.068
	0900	.156	.148	.138	.131	.093	.061
	1200	.153	.148	.131	.124	.085	.061
	1500	.148	.143	.131	.119	.080	.058
	1800	.145	.153	.138	.124	.080	.056
	2100	.167	.177	.164	.153	.103	.074
	2400	.171	.177	.164	.162	.118	.083
	0300	.171	.167	.162	.159	.113	.082
	0600	.177	.173	.167	.167	.122	.087
June 5-6	0600	.193	.197	.188	.173	.128	.096
	0900	.167	****	.152	.154	.116	.091
	1200	.188	.179	.166	.152	.112	.084
	1500	.170	.167	.152	.136	.098	.077
	1800	.178	.178	.163	.152	.101	.076

Table IX. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	2100	.208	.204	.182	.182	.126	.087
	2400	.208	.204	.189	.186	.133	.098
	0300	.212	.201	.189	.189	.142	.108
	0600	.208	.201	.189	.186	.137	.102
June 12-13	0600	.217	.217	.204	.201	.142	.104
	0900	.173	.177	.164	.167	.117	.087
	1200	.158	.169	.152	.139	.104	.081
	1500	.167	.177	.161	.144	.098	.076
	1800	.197	.197	.179	.167	.109	.081
	2100	.193	.193	.186	.177	.119	****
	2400	.208	.208	.201	.197	.136	.098
	0300	.217	.208	.201	.201	.142	.101
	0600	.217	.217	.201	.201	.142	.109
June 18-19	0600	.239	.244	.213	.204	.142	.177
	0900	.197	.208	.183	.179	.122	.086
	1200	.194	.204	.177	.173	.108	.078
	1500	.197	.204	.177	.158	.098	.072
	1800	.222	.217	.187	.171	.102	.072
	2100	.233	.255	.221	.204	.125	.084
	2400	.244	.255	.229	.224	.144	.098
	0300	.244	.249	.221	.224	.149	.104
	0600	.255	.262	.234	.224	.149	.106
June 23-24	0600	.299	.294	.249	.254	.158	.106
	0900	.208	.208	.179	.179	.119	.078
	1200	.201	.197	.164	.158	.099	.077
	1500	.208	.213	.177	.156	.089	.067
	1800	.221	.204	.187	.173	.108	.068
	2100	.239	.233	.221	.208	.139	.091
	2400	.239	.255	.238	.221	.149	.092
	0300	.262	.239	.225	.222	.144	.100
	0600	.267	.272	.239	.239	.149	.100
June 28-29	0600	.223	.241	.212	.212	.142	.096
	0900	.232	.228	.201	.193	.137	.091

Table IX. Continued.

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1200	.206	.203	.157	.144	.086	.061
	1500	.207	.197	.166	.152	.092	.071
	1800	.224	.219	.174	.157	.089	.062
	2100	.232	.245	.219	.191	.121	.077
	2400	.245	.258	.237	.224	.142	.092
	0300	.237	.254	.232	.216	.147	.096
	0600	.264	.269	.237	.237	.144	.096
July 9-10	0600	.253	.253	.217	.213	.133	.086
	0900	.228	.217	.178	.181	.111	.066
	1200	.206	.203	.157	.144	.086	.061
	1500	.196	.196	.154	.138	.072	.046
	1800	.236	.228	.175	.154	.082	.043
	2100	.244	.262	.228	.191	.112	.071
	2400	.279	.284	.252	.232	.141	.089
	0300	.257	.279	.241	.228	.138	.093
	0600	.271	.289	.257	.244	.147	.094
July 14-15	0600	.322	.339	.274	.263	.131	.068
	0900	.274	.257	.199	.197	.114	.063
	1200	.220	.212	.171	.151	.068	.042
	1500	.200	.224	.151	.133	.064	.039
	1800	.242	.242	.183	.146	.061	.032
	2100	.292	.338	.257	.207	.108	.064
	2400	.330	.357	.293	.257	.133	.078
	0300	.348	.359	.293	.274	.146	.088
		0600	.329	.357	.293	.274	.141
July 21-22	0600	.217	.228	.198	.189	.101	.054
	0900	.217	.217	.171	.164	.097	.052
	1200	.164	.171	.123	.106	.043	.005
	1500	.212	.224	.176	.148	.081	.053
	1800	.242	.247	.193	.156	.074	.036
	2100	.314	.348	.279	.221	.122	.076
	2400	.357	.392	.314	.268	.151	.097
	0300	.379	.420	.339	.287	.164	.106
		0600	.339	.368	.300	.268	.148

Table IX. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
July 28-29	0600	.262	.277	.239	.212	.121	.069
	0900	.231	.218	.174	.181	.098	.062
	1200	.196	.189	.141	.127	.067	.027
	1500	.189	.187	.138	.117	.058	.037
	1800	.202	.207	.167	.129	.051	.021
	2100	.252	.272	.218	.180	.101	.065
	2400	.267	.282	.239	.207	.116	.077
	0300	.267	.272	.243	.202	.088	.077
	0600	.262	.272	.226	.208	.112	.065
Aug 4-5	0600	.254	.263	.228	.203	.122	.074
	0900	.209	.213	.168	.166	.099	.057
	1200	.194	.197	.143	.125	.062	.036
	1500	.188	.200	.158	.127	.064	.023
	1800	.200	.218	.179	.149	.066	.028
	2100	.245	.263	.217	.187	.113	.069
	2400	.258	.267	.224	.200	.118	.072
	0300	.254	.273	.228	.209	.125	.082
	0600	.249	.273	.237	.207	.131	.089
Aug 10-11	0600	.242	.246	.207	.200	.113	.067
	0900	.203	.193	.158	.156	.086	.042
	1200	.182	.176	.124	.111	.039	.013
	1500	.156	.168	.121	.099	.021	.002
	1800	.171	.191	.153	.112	.057	.009
	2100	.226	.237	.203	.161	.092	.049
	2400	.242	.246	.200	.184	.109	.063
	0300	.242	.254	.211	.194	.113	.069
	0600	.237	.246	.211	.191	.101	.057
Aug 17-18	0600	.233	.237	.203	.184	.106	.070
	0900	.194	.197	.158	.156	.068	.037
	1200	.182	.182	.127	.113	.054	.035
	1500	.148	.163	.121	.096	.042	.018
	1800	.156	.179	.144	.105	.033	.004
	2100	.207	.229	.188	.153	.084	.046
	2400	.214	.246	.214	.182	.107	.064

Table IX. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	0300	.229	.250	.214	.188	.113	.072
	0600	.226	.250	.211	.184	.113	.073
Aug 24-25	0600	.237	.278	.221	.203	.125	.086
	0900	.191	.200	.158	.166	.101	.061
	1200	.184	.184	.137	.123	.068	.048
	1500	.166	.173	.133	.113	.031	.012
	1800	.191	.197	.161	.123	.047	.012
	2100	.209	.246	.209	.182	.104	.069
	2400	.249	.263	.221	.200	.128	.088
	0300	*	*	*	*	*	*
	0600	.213	.228	.209	.194	.120	.082
Sept 1-2	0600	.200	.207	.179	.148	.191	.059
	0900	.184	.184	.158	.151	.089	.047
	1200	.168	.163	.121	.111	.068	.042
	1500	.135	.156	.117	.096	.039	.012
	1800	.139	.161	.131	.099	.046	.009
	2100	.191	.211	.173	.141	.082	.032
	2400	.200	.222	.179	.158	.101	.064
	0300	*	*	*	*	*	*
	0600	.213	.228	.207	.194	.120	.082
Sept 8-9	0600	.245	.253	.213	.197	.123	.082
	0900	.203	.210	.179	.166	.101	.059
	1200	.168	.177	.143	.136	.084	.046
	1500	.152	.174	.137	.117	.057	.028
	1800	.154	.173	.147	.123	.069	.026
	2100	.188	.200	.173	.154	.101	.068
	2400	.228	.221	.191	.171	.112	.074
	0300	*	*	*	*	*	*
	0600	.224	.237	.207	.197	.122	.089
Sept 15-16	0600	.222	.234	.208	.192	.112	.069
	0900	.181	.202	.183	.183	.100	.056
	1200	.169	.172	.143	.138	.098	.058
	1500	.183	.179	.151	.129	.069	.029

Table IX. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1800	.208	.204	.183	.151	.092	.070
	2100	.202	.208	.198	.174	.100	.070
	2400	**	**	**	**	**	**
	0300	**	**	**	**	**	**
	0600	**	**	**	**	**	**
Sept 22-23	0600	.254	.258	.224	.203	.132	.097
	0900	.228	.228	.194	.174	.119	.082
	1200	.213	.213	.177	.161	.104	.069
	1500	.217	.217	.197	.187	.097	.054
	1800	.224	.224	.200	.158	.108	.086
	2100	.224	.228	.209	.176	.123	.086
	2400	.272	.232	.237	.203	.138	.088
	0300	.232	.237	.217	.189	.118	.084
	0600	.237	.241	.213	.197	.128	.089
Oct 2-3	0600	.207	.229	.188	.166	.099	.064
	0900	.191	.211	.168	.158	.091	.055
	1200	.184	.191	.142	.128	.068	.039
	1500	.166	.201	.144	.117	.067	.032
	1800	.179	.214	.171	.139	.064	.029
	2100	.200	.229	.184	.163	.098	.061
	2400	.226	.246	.188	.173	.103	.068
	0300	*	*	*	*	*	*
	0600	.226	.242	.191	.173	.103	.067
Oct 9-10	0600	.211	.229	.184	.166	.098	.061
	0900	.200	.218	.179	.166	.098	.064
	1200	.182	.197	.147	.139	.064	.057
	1500	.163	.188	.153	.121	.067	.031
	1800	.171	.203	.161	.133	.077	.046
	2100	.191	.237	.191	.171	.107	.068
	2400	.211	.237	.197	.176	.101	.077
	0300	.214	.246	.191	.171	.103	.064
	0600	.222	.250	.197	.178	.104	.069
Oct 16-17	0600	.207	.226	.184	.171	.101	.067

Table IX. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	0900	.191	.214	.176	.163	.089	.055
	1200	.189	.193	.144	.128	.069	.039
	1500	.176	.200	.142	.117	.064	.033
	1800	.179	.214	.168	.131	.073	.037
	2100	.193	.223	.179	.161	.092	.053
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	.203	.229	.182	.168	.101	.064
Oct 23-24	0600	.211	.229	.197	.179	.107	.072
	0900	.200	.214	.176	.168	.092	.055
	1200	.188	.203	.148	.135	.081	.046
	1500	.184	.203	.146	.122	.064	.033
	1800	.184	.214	.171	.142	.077	.039
	2100	.200	.226	.171	.168	.096	.063
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	.203	.229	.179	.166	.091	.063
Oct 29-30	0600	.211	.237	.191	.173	.099	.062
	0900	.200	.222	.168	.161	.087	.052
	1200	.184	.197	.142	.135	.077	.042
	1500	.176	.203	.148	.121	.063	.032
	1800	.188	.222	.158	.136	.077	.039
	2100	.200	.229	.184	.163	.092	.059
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
		0600	.218	.233	.188	.166	.099

* Samples were not collected at this time because change in CO₂ concentration between succeeding periods was found to be too small to be detected by the methods used.

** Samples were not collected at this time because excessive snow made the highway impassable.

Table IX. Continued

**** Sample lost.

Table X. Flow times (minutes) between stations on sampling dates.

Date	STATIONS				
	1-2	2-3	3-4	4-5	5-6
May 15-16	71.0	54.0	98.0	110.0	85.0
May 22-23	61.0	52.0	86.0	99.0	77.0
May 29-30	62.0	52.0	82.5	100.0	78.0
June 5-6	56.0	51.0	78.5	90.5	72.0
June 12-13	58.0	51.5	81.0	92.5	73.0
June 18-19	63.0	52.0	89.0	103.0	79.0
June 23-24	65.5	53.0	92.0	104.0	81.0
June 28-29	70.0	54.0	97.0	109.0	84.0
July 9-10	85.0	59.0	111.0	123.0	96.0
July 14-15	95.0	63.0	122.0	133.0	104.0
July 21-22	97.0	64.5	124.0	134.0	106.0
July 28-29	100.0	66.0	127.5	137.0	108.5
Aug 4-5	105.0	68.0	133.0	141.5	113.0
Aug 10-11	108.5	70.0	137.0	144.0	115.5
Aug 17-18	108.5	70.0	137.0	144.0	115.5
Aug 24-25	104.0	68.0	132.0	141.0	112.0
Sept 1-2	111.0	71.0	140.0	146.0	117.0
Sept 8-9	105.0	68.0	133.0	141.5	113.0

Table X. Continued

Date	STATIONS				
	1-2	2-3	3-4	4-5	5-6
Sept 15-16	94.0	63.0	121.0	132.0	103.5
Sept 22-23	103.0	67.0	131.0	140.0	110.0
Oct 2-3	108.5	70.0	137.0	144.0	115.5
Oct 9-10	111.0	71.0	140.0	146.0	117.0
Oct 16-17	110.0	70.0	138.5	145.0	116.0
Oct 23-24	111.0	71.0	140.0	146.0	117.0
Oct 29-30	113.0	72.0	142.5	148.0	119.5

Table XI. Average depth (centimeters) between stations on sampling dates

Date	STATIONS				
	1-2	2-3	3-4	4-5	5-6
May 15-16	109.6	95.6	151.5	70.1	52.7
May 22-23	121.8	112.7	171.4	79.9	60.7
May 29-30	119.4	110.6	168.9	77.4	59.7
June 5-6	134.7	134.0	196.0	92.6	70.8
June 12-13	130.1	126.8	187.8	87.9	67.4
June 18-19	117.6	107.7	165.6	75.5	58.4
June 23-24	114.8	103.6	160.6	72.8	56.4
June 28-29	110.6	97.1	153.2	68.7	53.4
July 9-10	100.8	82.2	135.9	59.1	43.3
July 14-15	95.2	73.6	126.0	52.6	42.3
July 21-22	94.2	72.3	124.4	52.7	41.6
July 28-29	92.8	70.0	121.9	51.3	40.6
Aug 4-5	90.6	66.6	117.8	49.1	39.0
Aug 10-11	89.2	64.5	115.4	47.7	38.0
Aug 17-18	89.2	64.5	115.4	47.7	38.0
Aug 24-25	91.0	67.4	118.6	49.5	39.3
Sept 1-2	88.2	63.1	113.9	46.8	37.3
Sept 8-9	90.6	66.6	117.9	49.1	39.0

Table XI. Continued

Date	STATIONS				
	1-2	2-3	3-4	4-5	5-6
Sept 15-16	95.6	74.4	126.8	54.1	42.7
Sept 22-23	91.4	68.0	119.5	49.9	39.6
Oct 2-3	89.2	64.5	115.4	47.7	38.0
Oct 9-10	88.2	63.1	113.9	46.8	37.3
Oct 16-17	88.6	63.7	114.6	47.3	37.6
Oct 23-24	88.2	63.1	113.9	46.8	37.3
Oct 29-30	87.3	61.6	112.3	45.9	36.6

Table XII. Change in CO₂ concentration per unit volume (moles/m³) between all stations during twenty-four hour periods on weekly intervals through the summer of 1965.

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
May 15-16	0600	+0.040	-0.005	-0.036	-0.074	-0.044
	0900	-0.008	-0.046	-0.056	-0.099	-0.052
	1200	-0.003	-0.006	-0.018	-0.052	-0.034
	1500	+0.016	-0.021	-0.011	-0.038	-0.026
	1800	+0.027	-0.020	+0.023	-0.040	-0.035
	2100	+0.020	-0.018	+0.003	-0.057	-0.047
	2400	+0.015	-0.007	-0.015	-0.053	-0.039
	0300	+0.025	-0.004	-0.004	-0.043	-0.041
May 22-23	0600	-0.017	-0.006	-0.006	-0.057	-0.031
	0900	-0.019	-0.013	-0.013	-0.055	-0.029
	1200	-0.008	-0.017	-0.001	-0.044	-0.022
	1500	+0.001	-0.017	-0.007	-0.142	-0.020
	1800	+0.008	-0.005	-0.006	-0.038	-0.022
	2100	+0.002	-0.006	-0.015	-0.054	-0.031
	2400	+0.007	-0.016	-0.002	-0.052	-0.024
	0300	-0.007	-0.019	-0.003	-0.045	-0.026
May 29-30	0600	-0.002	-0.011	-0.013	-0.055	-0.041
	0900	-0.008	-0.012	-0.010	-0.043	-0.033
	1200	-0.007	-0.017	-0.009	-0.042	-0.025
	1500	-0.002	-0.010	-0.010	-0.039	-0.023
	1800	+0.015	-0.008	-0.002	-0.032	-0.017
	2100	+0.011	-0.013	-0.008	-0.042	-0.026
	2400	+0.003	-0.013	-0.003	-0.046	-0.036
	0300	-0.001	-0.004	0.000	-0.041	-0.030
June 5-6	0600	-0.005	-0.018	-0.023	-0.051	-0.034
	0900	-0.003	-0.008	+0.001	-0.040	-0.030
	1200	-0.020	-0.006	-0.020	-0.048	-0.030
	1500	0.000	-0.013	-0.010	-0.038	-0.091
	1800	+0.008	-0.008	+0.002	-0.038	-0.021
	2100	-0.004	-0.012	-0.008	-0.054	-0.035
	2400	-0.005	-0.015	-0.003	-0.049	-0.031

Table XII. Continued

TIME		STATIONS				
Date	Hour	1-2	2-3	3-4	4-5	5-6
	0300	-.011	-.012	-.001	-.050	-.036
June 12-13	0600	-.013	-.023	-.017	-.072	-.044
	0900	+.002	-.016	-.009	-.057	-.032
	1200	+.014	-.014	-.011	-.038	-.024
	1500	+.016	-.012	-.007	-.040	-.020
	1800	-.001	-.023	+.003	-.053	-.036
	2100	+.004	-.003	-.002	-.050	-.029
	2400	0.000	-.007	-.003	-.058	-.037
	0300	-.007	-.007	0.000	-.058	-.038
June 18-19	0600	-.007	-.038	-.021	-.073	-.018
	0900	+.010	-.026	-.007	-.065	-.040
	1200	+.010	-.026	-.011	-.071	-.032
	1500	+.012	-.025	-.013	-.058	-.026
	1800	+.009	-.021	-.001	-.057	-.026
	2100	+.022	-.031	-.007	-.069	-.034
	2400	+.009	-.028	-.005	-.077	-.044
	0300	+.009	-.025	+.004	-.076	-.044
June 23-24	0600	-.034	-.061	-.029	-.116	-.062
	0900	-.004	-.033	-.010	-.071	-.041
	1200	+.002	-.030	-.007	-.065	-.026
	1500	+.002	-.035	-.011	-.057	-.022
	1800	-.008	-.009	0.000	-.051	-.042
	2100	+.002	-.007	-.006	-.068	-.047
	2400	+.011	-.020	-.017	-.078	-.049
	0300	-.011	-.010	+.004	-.076	-.044
June 28-29	0600	+.013	-.032	-.099	-.076	-.048
	0900	-.010	-.033	-.022	-.074	-.050
	1200	-.005	-.038	-.018	-.067	-.032
	1500	-.002	-.029	-.012	-.062	-.025
	1800	+.004	-.033	0.000	-.051	-.021
	2100	+.018	-.021	-.010	-.057	-.037
	2400	+.012	-.022	-.015	-.080	-.048
	0300	+.022	-.020	-.005	-.071	-.051

Table XII. Continued

TIME		STATIONS				
Date	Hour	1-2	2-3	3-4	4-5	5-6
July 9-10	0600	-.016	-.047	-.023	-.094	-.056
	0900	-.017	-.046	-.019	-.087	-.048
	1200	-.006	-.046	-.016	-.067	-.032
	1500	+.014	-.036	-.006	-.060	-.027
	1800	+.007	-.036	+.001	-.052	-.024
	2100	+.028	-.036	-.013	-.061	-.033
	2400	+.003	-.034	-.022	-.093	-.051
	0300	+.027	-.033	-.004	-.083	-.045
July 14-15	0600	-.018	-.079	-.048	-.143	-.066
	0900	-.043	-.065	-.036	-.121	-.064
	1200	-.002	-.046	-.032	-.087	-.028
	1500	+.033	-.066	-.010	-.071	-.029
	1800	+.045	-.043	0.000	-.053	-.013
	2100	+.057	-.073	-.016	-.080	-.036
	2400	+.028	-.065	-.026	-.116	-.050
	0300	+.010	-.066	-.019	-.132	-.058
July 21-22	0600	+.007	-.040	-.025	-.090	-.050
	0900	-.018	-.048	-.045	-.105	-.068
	1200	+.032	-.032	+.010	-.040	-.012
	1500	+.023	-.041	-.022	-.073	-.037
	1800	+.036	-.027	+.005	-.050	-.018
	2100	+.055	-.056	-.030	-.090	-.050
	2400	+.047	-.070	-.035	-.110	-.053
	0300	+.006	-.083	-.047	-.135	-.063
July 28-29	0600	-.014	-.059	-.046	-.108	-.056
	0900	-.028	-.055	-.030	-.105	-.054
	1200	-.008	-.049	-.021	-.067	-.034
	1500	+.008	-.040	-.013	-.064	-.030
	1800	+.038	-.026	-.005	-.049	-.006
	2100	+.026	-.048	-.019	-.068	-.028
	2400	+.009	-.042	-.037	-.111	-.039
	0300	+.005	-.037	-.036	-.097	-.018

Table XII. Continued

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
Aug 4-5	0600	-.015	-.053	-.048	-.097	-.056
	0900	-.005	-.053	-.033	-.098	-.055
	1200	+.005	-.049	-.017	-.062	-.033
	1500	+.022	-.036	-.015	-.061	-.037
	1800	+.041	-.027	-.005	-.050	-.016
	2100	+.021	-.043	-.020	-.069	-.042
	2400	+.012	-.041	-.018	-.077	-.041
	0300	+.019	-.041	-.018	-.080	-.039
Aug 10-11	0600	-.024	-.055	-.037	-.106	-.060
	0900	-.019	-.047	-.034	-.106	-.061
	1200	-.010	-.052	-.022	-.086	-.033
	1500	+.025	-.036	-.012	-.051	-.015
	1800	+.044	-.020	-.006	-.030	-.025
	2100	+.016	-.035	-.025	-.056	-.035
	2400	+.099	-.042	-.008	-.072	-.043
	0300	+.008	-.043	-.012	-.090	-.052
Aug 17-18	0600	-.019	-.050	-.039	-.107	-.056
	0900	-.005	-.049	-.033	-.099	-.032
	1200	-.010	-.057	-.026	-.068	-.029
	1500	+.025	-.033	-.018	-.064	-.033
	1800	+.050	-.019	-.007	-.036	-.006
	2100	+.032	-.032	-.014	-.052	-.027
	2400	+.034	-.031	-.028	-.070	-.038
	0300	+.021	-.037	-.029	-.075	-.040
Aug 24-25	0600	-.017	-.077	-.044	-.093	-.052
	0900	-.005	-.039	-.023	-.090	-.048
	1200	-.006	-.048	-.021	-.083	-.040
	1500	+.021	-.030	-.012	-.070	-.019
	1800	+.032	-.022	0.000	-.037	-.006
	2100	+.047	-.033	-.014	-.060	-.024
	2400	+.004	-.043	-.023	-.075	-.041
	0300	*	*	*	*	*

Table XII. Continued

TIME		STATIONS				
Date	Hour	1-2	2-3	3-4	4-5	5-6
Sept 1-2	0600	-.006	-.035	-.029	-.058	-.039
	0900	-.012	-.040	-.039	-.079	-.046
	1200	-.009	-.043	-.022	-.064	-.043
	1500	+.024	-.034	-.019	-.052	-.029
	1800	+.048	-.017	-.005	-.028	-.024
	2100	+.026	-.035	-.017	-.043	-.028
	2400	+.022	-.041	-.014	-.058	-.038
Sept 8-9	0600	-.015	-.051	-.036	-.090	-.053
	0900	-.011	-.043	-.034	-.078	-.050
	1200	+.008	-.037	-.020	-.072	-.048
	1500	+.022	-.034	-.015	-.051	-.030
	1800	+.033	-.018	-.003	-.031	-.020
	2100	+.025	-.021	-.007	-.044	-.029
	2400	-.003	-.028	-.010	-.055	-.034
0300	*	*	*	*	*	
Sept 15-16	0600	-.005	-.034	-.021	-.088	-.049
	0900	+.003	-.032	-.031	-.085	-.043
	1200	+.007	-.027	-.010	-.058	-.052
	1500	+.012	-.016	-.006	-.042	-.015
	1800	-.001	-.016	-.017	-.053	-.022
	2100	**	**	**	**	**
	2400	**	**	**	**	**
0300	**	**	**	**	**	
Sept 22-23	0600	-.012	-.044	-.041	-.081	-.044
	0900	-.008	-.039	-.029	-.066	-.045
	1200	+.002	-.029	0.000	-.062	-.043
	1500	+.004	-.019	-.030	-.082	-.027
	1800	+.002	-.021	-.030	-.039	-.022
	2100	+.006	-.010	-.015	-.042	-.036
	2400	-.037	0.000	-.043	-.080	-.052
0300	+.007	-.021	-.023	-.064	-.031	

Table XII. Continued

TIME		STATIONS				
Date	Hour	1-2	2-3	3-4	4-5	5-6
Oct 2-3	0600	+0.011	-0.049	-0.028	-0.074	-0.039
	0900	+0.008	-0.052	-0.032	-0.085	-0.044
	1200	+0.013	-0.048	-0.022	-0.061	-0.034
	1500	+0.043	-0.047	-0.010	-0.052	-0.037
	1800	+0.043	-0.037	-0.017	-0.053	-0.019
	2100	+0.040	-0.039	-0.013	-0.060	-0.032
	2400	+0.018	-0.057	-0.015	-0.069	-0.035
	0300	*	*	*	*	*
Oct 9-10	0600	+0.012	-0.047	-0.018	-0.068	-0.035
	0900	+0.005	-0.051	-0.034	-0.096	-0.038
	1200	+0.010	-0.048	-0.021	-0.073	-0.023
	1500	+0.034	-0.032	-0.022	-0.046	-0.026
	1800	+0.050	-0.032	-0.004	-0.035	-0.019
	2100	+0.046	-0.044	-0.017	-0.068	-0.033
	2400	+0.031	-0.043	-0.025	-0.074	-0.031
	0300	+0.034	-0.054	-0.015	-0.068	-0.036
Oct 16-17	0600	+0.011	-0.046	-0.020	-0.082	-0.043
	0900	+0.010	-0.050	-0.043	-0.091	-0.044
	1200	+0.014	-0.050	-0.024	-0.063	-0.033
	1500	+0.034	-0.048	-0.013	-0.046	-0.029
	1800	+0.040	-0.043	-0.017	-0.045	-0.027
	2100	+0.032	-0.044	-0.016	-0.066	-0.038
	2400	*	*	*	*	*
	0300	*	*	*	*	*
Oct 23-24	0600	+0.008	-0.041	-0.028	-0.086	-0.048
	0900	+0.008	-0.048	-0.032	-0.084	-0.042
	1200	+0.016	-0.055	-0.023	-0.067	-0.044
	1500	+0.026	-0.046	-0.007	-0.046	-0.027
	1800	+0.036	-0.042	-0.013	-0.053	-0.026
	2100	+0.027	-0.054	-0.003	-0.074	-0.033
	2400	*	*	*	*	*
	0300	*	*	*	*	*

Table XIII. Free CO₂ (millimoles/m³) at all stations during twenty-four hour periods on weekly intervals through the summer of 1965.

Date	TIME	STATIONS					
	Hour	1	2	3	4	5	6
May 15-16	0600	170.8	205.0	205.0	170.8	106.8	70.5
	0900	192.2	213.5	192.2	170.8	100.4	68.3
	1200	128.1	121.7	113.2	100.4	66.2	42.7
	1500	121.7	132.4	115.3	96.1	55.5	36.3
	1800	121.7	134.5	104.6	121.7	72.6	40.6
	2100	132.4	160.2	149.5	140.9	91.8	53.4
	2400	149.5	164.4	178.6	140.9	89.7	57.6
	0300	149.5	164.4	178.6	140.9	98.2	64.1
	0600	179.4	187.9	166.5	160.2	104.6	66.2
May 22-23	0600	152.6	138.4	136.7	136.7	88.7	62.1
	0900	145.5	133.1	127.8	124.2	79.9	53.2
	1200	133.1	124.2	106.5	104.7	67.4	46.1
	1500	133.1	133.1	115.4	104.7	62.1	42.6
	1800	133.1	136.7	127.8	111.8	69.2	44.4
	2100	145.5	149.1	145.5	133.1	87.0	55.7
	2400	138.4	145.5	133.1	133.1	83.4	55.7
	0300	145.5	142.0	129.6	129.6	88.7	65.7
	0600	136.7	136.7	127.8	124.2	87.0	60.3
May 29-30	0600	138.6	138.6	132.0	128.7	79.2	46.2
	0900	132.0	123.7	112.2	103.9	67.6	39.6
	1200	128.7	123.7	103.9	97.4	61.1	39.6
	1500	123.7	118.8	103.9	94.1	56.1	38.0
	1800	120.4	128.7	112.2	97.4	56.1	36.3
	2100	145.2	155.1	141.9	128.7	77.6	51.1
	2400	148.5	155.1	141.9	138.6	90.7	59.4
	0300	148.5	145.2	138.6	135.3	87.4	57.8
	0600	155.1	151.8	145.2	145.2	95.7	62.7
June 5-6	0600	118.6	118.6	108.5	103.5	71.9	47.9
	0900	98.4	*****	88.3	90.9	61.8	44.2
	1200	111.0	106.0	94.6	88.3	59.3	41.6
	1500	100.9	98.4	85.8	75.7	49.2	36.6
	1800	106.0	108.5	97.1	88.3	51.7	36.6

Table XIII. Continued

TIMES		STATIONS					
Date	Hour	1	2	3	4	5	6
	2100	130.0	126.2	110.0	63.1	68.1	42.9
	2400	130.0	126.2	116.1	113.6	74.4	50.5
	0300	132.5	123.7	116.1	113.6	79.5	55.5
	0600	130.0	121.1	116.1	113.6	75.7	53.0
June 12-13	0600	143.9	139.9	133.2	129.9	83.9	57.3
	0900	109.3	111.9	102.6	103.9	66.6	45.3
	1200	97.3	106.6	93.3	86.6	57.3	41.3
	1500	103.9	111.9	99.9	86.6	53.3	38.6
	1800	127.9	127.9	114.6	103.9	61.3	41.3
	2100	125.2	125.2	119.9	111.9	68.0	*****
	2400	157.7	164.4	144.3	144.3	82.2	52.0
	0300	143.9	137.2	130.6	130.6	83.9	54.6
	0600	143.9	143.9	130.6	130.6	83.9	57.3
June 18-19	0600	154.4	157.7	134.2	129.2	80.5	105.7
	0900	122.5	130.9	110.7	109.1	67.1	43.6
	1200	120.8	129.2	105.7	104.0	57.1	38.6
	1500	120.8	129.2	105.7	92.3	52.0	35.2
	1800	140.9	137.6	114.1	100.7	53.7	35.2
	2100	151.0	164.4	140.9	129.2	68.8	41.9
	2400	157.7	164.4	144.3	144.3	82.2	52.0
	0300	157.7	161.1	140.9	144.3	83.9	55.4
	0600	164.4	172.8	151.0	144.3	85.6	55.4
June 23-24	0600	201.3	197.8	163.7	167.3	93.8	56.3
	0900	133.0	133.0	110.9	110.9	66.5	39.2
	1200	127.9	124.5	98.9	93.8	52.9	39.2
	1500	133.0	136.4	107.4	92.1	49.5	30.7
	1800	143.3	131.3	116.0	105.7	56.3	34.1
	2100	156.9	153.5	143.3	133.0	76.7	47.8
	2400	156.9	167.1	153.5	143.3	83.6	51.2
	0300	170.5	160.3	146.7	143.3	83.6	52.9
	0600	175.7	179.1	156.9	156.9	87.0	52.9
June 28-29	0600	146.3	159.6	138.7	138.7	81.7	49.4
	0900	152.0	152.0	129.2	123.5	77.9	45.6

Table XIII. Continued

Date	TIMES	STATIONS					
	Hour	1	2	3	4	5	6
	1200	138.7	138.7	110.2	100.7	58.9	39.9
	1500	136.8	125.4	100.7	87.4	45.6	32.3
	1800	148.2	146.3	108.3	93.1	45.6	28.5
	2100	155.8	167.2	146.3	119.7	64.6	36.1
	2400	167.2	178.6	159.6	148.2	79.8	45.6
	0300	159.6	174.7	155.8	142.5	85.5	49.4
	0600	182.4	186.2	159.6	159.6	83.6	49.4
July 9-10	0600	177.2	177.2	142.7	138.1	71.3	41.4
	0900	151.9	142.7	108.2	110.5	55.2	32.2
	1200	133.5	131.2	89.8	80.6	41.4	29.9
	1500	124.3	124.3	87.5	76.0	34.5	23.0
	1800	161.1	151.9	105.9	87.5	39.1	23.0
	2100	168.0	184.1	151.9	124.3	57.6	34.5
	2400	202.5	207.1	177.2	156.5	76.0	41.4
	0300	179.5	202.5	165.7	151.9	76.0	46.0
	0600	193.3	211.8	179.5	168.0	78.3	41.4
July 14-15	0600	194.3	201.9	164.0	156.5	65.6	35.3
	0900	164.0	151.4	113.6	111.0	58.0	32.8
	1200	126.2	121.1	93.4	78.2	35.3	25.2
	1500	113.6	128.7	78.2	65.6	32.8	22.7
	1800	143.8	143.8	100.9	75.7	30.3	22.7
	2100	176.6	201.9	151.4	118.6	53.0	32.8
	2400	196.8	212.0	176.6	151.4	65.6	37.8
	0300	206.9	217.0	176.6	159.0	75.7	49.9
	0600	196.8	212.0	176.6	159.0	73.2	40.4
July 21-22	0600	126.4	136.7	110.9	108.3	49.0	31.0
	0900	126.4	126.4	92.9	90.3	46.4	28.4
	1200	90.3	95.4	61.9	51.6	25.8	15.5
	1500	123.8	131.5	98.0	79.9	38.7	28.4
	1800	147.0	149.6	110.9	85.1	36.1	23.2
	2100	193.3	211.5	170.2	128.9	61.9	38.7
	2400	216.6	232.1	193.4	162.5	79.9	46.4
	0300	227.0	242.4	206.3	175.4	90.3	51.6
	0600	206.3	221.8	185.7	162.5	79.9	46.4

Table XIII. Continued

TIME		STATIONS					
Date	Hour	1	2	3	4	5	6
July 28-29	0600	196.4	209.8	174.8	147.9	67.3	37.7
	0900	166.8	156.0	113.0	118.4	53.8	32.3
	1200	131.8	126.4	83.4	69.9	35.0	21.5
	1500	126.4	123.7	78.0	64.6	32.3	24.2
	1800	137.2	145.2	104.9	75.3	29.6	21.5
	2100	188.3	207.1	156.0	118.4	53.8	35.0
	2400	201.8	215.2	174.8	145.2	64.6	40.3
	0300	201.8	207.1	177.5	137.2	69.9	40.3
	0600	193.7	207.1	161.4	145.2	61.9	35.0
Aug 4-5	0600	193.1	201.4	165.5	140.7	63.5	35.9
	0900	149.0	151.7	107.6	104.9	46.9	30.3
	1200	132.4	135.2	85.5	66.2	30.3	24.8
	1500	126.9	138.0	99.3	69.0	30.3	22.1
	1800	138.0	151.7	118.7	91.1	33.1	22.1
	2100	182.1	201.4	157.3	126.9	57.9	33.1
	2400	198.7	201.4	162.8	138.0	60.7	35.9
	0300	193.1	212.5	165.5	149.0	66.2	38.6
	0600	187.6	212.4	171.1	146.2	71.7	41.4
Aug 10-11	0600	205.7	208.5	165.7	157.1	68.6	40.0
	0900	162.8	151.4	108.5	108.5	48.6	28.6
	1200	137.1	131.4	80.0	68.6	28.6	20.0
	1500	108.5	122.8	74.3	60.0	22.8	17.1
	1800	125.7	145.7	108.5	68.6	34.3	20.0
	2100	180.0	199.9	162.8	114.2	51.4	31.4
	2400	205.7	208.5	157.1	139.9	65.7	37.1
	0300	205.7	219.9	168.5	151.4	68.6	40.0
	0600	199.9	208.5	168.5	145.7	60.0	34.3
Aug 17-18	0600	197.0	203.0	165.2	142.0	63.8	40.6
	0900	153.6	156.5	113.0	110.1	40.6	26.1
	1200	139.0	139.1	84.0	69.6	34.8	26.1
	1500	104.3	118.8	75.3	58.0	29.0	23.2
	1800	110.1	136.2	98.5	63.8	26.1	17.4
	2100	168.1	191.3	144.9	110.1	49.3	29.0
	2400	173.9	211.5	173.9	139.1	66.6	37.7

Table XIII. Continued

TIME		STATIONS					
Date	Hour	1	2	3	4	5	6
	0300	191.3	217.3	173.9	144.9	69.6	40.6
	0600	188.4	217.3	171.0	142.0	69.6	43.5
Aug 24-25	0600	179.1	221.7	164.9	145.0	68.2	42.6
	0900	133.6	142.1	102.3	108.0	51.2	31.3
	1200	127.9	127.9	82.4	68.2	34.1	25.6
	1500	108.0	116.5	76.7	59.7	22.7	19.9
	1800	133.6	139.3	105.2	68.2	28.4	19.9
	2100	153.5	187.6	153.5	125.1	51.2	34.1
	2400	193.3	207.5	164.9	142.1	71.1	42.6
	0300	*	*	*	*	*	*
	0600	156.3	170.5	150.7	136.4	65.4	39.8
Sept 1-2	0600	157.9	166.5	134.9	103.3	51.7	34.4
	0900	140.6	140.6	111.9	106.2	48.8	31.6
	1200	123.4	117.7	74.6	68.9	40.1	28.7
	1500	89.0	109.1	71.8	57.4	28.7	20.1
	1800	94.7	114.8	86.1	60.3	28.7	20.1
	2100	146.4	169.3	129.2	100.4	45.9	25.8
	2400	157.9	180.8	134.9	134.7	60.3	37.3
	0300	*	*	*	*	*	*
	0600	169.3	180.8	143.5	132.0	57.4	37.3
Sept 8-9	0600	187.6	199.0	156.3	139.3	68.2	39.8
	0900	145.0	153.5	122.2	108.0	51.2	31.3
	1200	110.9	119.4	88.1	79.6	39.8	25.6
	1500	93.8	116.5	82.4	62.5	31.3	22.7
	1800	96.6	116.5	91.0	68.2	34.1	22.7
	2100	130.7	142.1	116.5	96.6	51.2	34.1
	2400	170.5	164.9	133.6	113.7	56.8	37.0
	0300	*	*	*	*	*	*
	0600	167.7	179.1	150.7	139.3	65.4	39.8
Sept 15-16	0600	161.2	172.1	147.5	131.1	65.6	38.2
	0900	120.2	139.3	122.9	122.9	54.6	32.8
	1200	109.3	112.0	87.4	84.7	59.6	32.8
	1500	122.9	120.2	92.9	76.5	38.2	21.8

Table XIII. Continued

Date	TIME	STATIONS					
	Hour	1	2	3	4	5	6
	1800	147.5	144.8	122.9	92.9	49.2	35.5
	2100	139.3	147.5	136.6	114.7	54.6	35.5
	2400	**	**	**	**	**	**
	0300	**	**	**	**	**	**
	0600	**	**	**	**	**	**
Sept 23-24	0600	195.1	200.7	164.4	142.1	72.5	47.4
	0900	167.2	167.2	133.8	114.3	64.1	39.0
	1200	153.3	153.3	117.1	103.1	50.2	33.4
	1500	153.3	153.3	136.6	128.2	47.4	27.9
	1800	164.4	164.4	139.4	100.3	53.0	41.8
	2100	164.4	167.2	150.5	117.1	66.9	41.8
	2400	214.6	172.8	175.6	142.1	75.2	41.8
	0300	172.8	175.6	158.9	125.4	61.3	39.0
	0600	175.6	181.2	153.3	136.6	69.7	41.8
Oct 2-3	0600	165.7	188.5	142.8	120.0	60.0	37.1
	0900	145.7	168.5	122.8	111.4	51.4	34.3
	1200	139.9	145.7	94.3	82.8	40.0	25.7
	1500	122.8	157.1	97.1	71.4	40.0	25.7
	1800	134.2	171.4	125.7	94.3	37.1	25.7
	2100	157.1	188.5	139.9	117.1	57.1	37.1
	2400	185.7	208.5	142.8	128.5	62.8	40.0
	0300	*	*	*	*	*	*
	0600	185.7	205.7	145.7	128.5	62.8	40.0
Oct 9-10	0600	174.2	194.9	144.7	124.0	59.1	38.4
	0900	162.4	183.1	138.8	124.0	59.1	38.4
	1200	141.8	159.5	103.9	97.5	38.4	35.4
	1500	121.1	147.7	112.2	76.8	41.3	26.6
	1800	129.9	168.3	118.1	91.6	44.3	29.5
	2100	150.6	206.7	150.6	129.9	67.9	41.3
	2400	174.2	206.7	159.5	139.5	62.0	44.3
	0300	177.2	215.6	150.2	130.0	65.0	38.4
	0600	186.1	221.5	159.5	138.8	65.0	41.3
Oct 16-17	0600	168.9	189.3	142.7	128.1	61.1	40.8

Table XIII: Continued

Date	TIME	STATIONS					
	Hour	1	2	3	4	5	6
	0900	148.5	174.7	131.0	119.4	52.4	34.9
	1200	142.7	154.3	99.0	84.4	40.8	29.1
	1500	131.0	160.2	96.1	72.8	37.8	26.2
	1800	136.9	174.7	125.2	87.4	43.7	26.2
	2100	154.3	183.4	136.9	116.5	52.4	34.9
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	166.0	192.2	139.8	125.2	61.1	37.5
Oct 23-24	0600	174.2	194.9	159.5	138.8	67.9	41.3
	0900	162.4	177.2	135.9	127.0	53.2	35.4
	1200	147.7	168.3	106.3	91.6	47.3	29.5
	1500	144.7	168.3	103.4	79.7	38.4	38.4
	1800	144.7	177.2	129.9	97.5	44.3	29.5
	2100	162.4	192.0	129.9	127.0	59.1	38.4
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	168.3	194.9	138.8	124.1	59.1	38.4
Oct 29.30	0600	175.9	208.7	152.0	134.2	62.6	41.7
	0900	164.0	187.8	128.2	119.2	53.7	32.8
	1200	146.1	161.0	98.4	92.4	44.7	29.8
	1500	137.1	169.9	107.3	77.5	38.8	26.8
	1800	149.1	187.8	116.3	92.4	44.7	29.8
	2100	164.0	196.8	146.1	122.2	53.7	35.8
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	184.8	202.7	149.1	125.2	62.6	38.8

* Free CO₂ not calculated at this time because samples were not collected.

** Samples were not collected at this time because excessive snow made the highway impassable.

Table XIV. Exchange coefficients between the free carbon dioxide of the water and that of the atmosphere for all reaches through the summer of 1965.

DATE	STATIONS				
	1-2	2-3	3-4	4-5	5-6
May 15-16	-.0011	-.0011	-.0006	-.0040	-.0057
May 22-23	-.0025	-.0025	-.0011	-.0054	-.0045
May 29-30	-.0016	-.0016	-.0006	-.0045	-.0053
June 5-6	-.0033	-.0033	-.0016	-.0084	-.0090
June 12-13	-.0012	-.0012	-.0004	-.0080	-.0083
June 18-19	-.0044	-.0044	-.0004	-.0082	-.0079
June 23-24	-.0017	-.0017	-.0012	-.0074	-.0083
June 28-29	-.0027	-.0027	-.0013	-.0067	-.0091
July 9-10	-.0032	-.0032	-.0012	-.0065	-.0067
July 14-15	-.0058	-.0058	-.0016	-.0087	-.0069
July 21-22	-.0044	-.0044	-.0026	-.0067	-.0060
July 28-29	-.0029	-.0029	-.0017	-.0067	-.0040
Aug 4-5	-.0027	-.0027	-.0013	-.0052	-.0058
Aug 10-11	-.0024	-.0024	-.0011	-.0047	-.0058
Aug 17-18	-.0020	-.0020	-.0016	-.0044	-.0048
Aug 24-25	-.0026	-.0026	-.0014	-.0049	-.0042
Sept 1-2	-.0026	-.0026	-.0013	-.0039	-.0056

Table XIV. Continued

DATE	STATIONS				
	1-2	2-3	3-4	4-5	5-6
Sept 1-2	-.0026	-.0026	-.0013	-.0039	-.0056
Sept 8-9	-.0024	-.0024	-.0008	-.0040	-.0045
Sept 15-16	*	*	*	*	*
Sept 22-23	-.0007	-.0007	-.0020	-.0039	-.0049
Oct 2-3	-.0034	-.0034	-.0011	-.0045	-.0041
Oct 9-10	-.0030	-.0030	-.0013	-.0042	-.0036
Oct 16-17	-.0032	-.0032	-.0013	-.0053	-.0053
Oct 23-24	-.0041	-.0041	-.0002	-.0023	-.0039
Oct 29-30	-.0028	-.0028	-.0014	-.0051	-.0040

* Samples not collected at 2100, 2400 and 0300 hours on this date.

Table XV. Change in carbon dioxide concentration due to biological factors (millimoles/m² per minute) at all stations during twenty-four hour periods on weekly intervals through the summer of 1965.

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
May 15-16	0600	+.2866	+.1244	-.4609	-.0469	+.0635
	0900	-.4451	-.6156	-.7701	-.2753	+.0014
	1200	-.4690	+.0057	-.2250	-.1126	-.0330
	1500	-.1638	-.2576	-.1192	-.0662	-.0198
	1800	+.0083	-.2517	-.2895	-.0105	-.0511
	2100	-.0715	-.1668	+.0318	-.0421	-.0526
	2400	-.1440	+.0599	-.1537	-.0429	+.0210
	0300	+.0103	+.1130	+.0164	+.0728	+.0456
May 22-23	0600	-.4550	+.1829	+.0181	-.0432	-.1988
	0900	-.5082	+.1090	-.1352	-.0745	-.0409
	1200	-.3107	-.1309	+.0827	-.0532	-.0177
	1500	-.1088	-.1086	-.0370	-.0657	-.0176
	1800	+.0399	-.1824	-.0093	+.0049	-.0253
	2100	-.0488	+.2049	-.1615	-.0282	-.0455
	2400	+.0420	-.0428	+.0939	-.0319	+.0097
	0300	-.2463	-.3823	+.0701	+.0538	+.0389
May 29-30	0600	-.1109	-.0411	-.1959	-.1210	-.1299
	0900	-.2502	-.0942	-.1493	-.0803	-.1037
	1200	-.2310	-.2138	-.1328	-.1019	-.1424
	1500	-.1426	-.0649	-.1551	-.1012	-.0356
	1800	+.2006	-.0090	+.0106	-.0470	+.0013
	2100	+.1643	-.0679	-.0935	-.0276	+.0109
	2400	+.1103	-.0679	+.0088	+.0004	-.0216
	0300	-.0810	+.1183	+.0703	+.0243	+.0258
June 5-6	0600	+.0547	-.1528	-.4271	-.0144	-.0067
	0900	***	+.0432	+.1519	+.0132	-.0007
	1200	-.3475	+.1166	-.3765	-.0897	-.0241
	1500	+.1084	-.0964	-.1470	-.0721	+.0391
	1800	+.3342	+.0723	+.1727	-.0511	+.0194
	2100	+.1039	+.0101	-.1171	-.0771	-.0616
	2400	+.0798	-.0489	+.0885	+.0271	+.0461

Table XV. Continued

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
	0300	+0.0459	+0.0299	+0.1385	+0.0596	+0.0420
June 12-13	0600	-0.5798	-0.4203	-0.3476	-0.1050	-0.0261
	0900	-0.1394	-0.2847	-0.1716	-0.1008	-0.0150
	1200	-0.0141	-0.2464	-0.2250	+0.0053	+0.0257
	1500	+0.3710	-0.1893	-0.1323	-0.0457	+0.0402
	1800	-0.3253	-0.4426	-0.0325	-0.1053	-0.0851
	2100	-0.0991	+0.0562	-0.0062	-0.0231	***
	2400	-0.2915	-0.0294	-0.0229	-0.0039	-0.0054
	0300	-0.4485	-0.0294	+0.0476	+0.0281	+0.0069
June 18-19	0600	-0.3275	-0.2472	-0.3437	+0.0307	+0.6112
	0900	-0.1281	-0.1020	-0.0913	-0.0206	-0.0421
	1200	-0.1356	-0.1240	-0.1677	-0.1465	-0.0225
	1500	-0.0982	-0.1033	-0.2096	-0.0930	-0.0050
	1800	-0.1172	+0.0165	+0.0172	-0.0718	-0.0050
	2100	+0.2434	-0.0727	-0.0832	-0.0359	-0.0112
	2400	+0.0008	+0.0043	-0.0400	+0.0153	-0.0053
	0300	-0.0138	+0.0516	+0.1275	+0.0366	+0.0215
June 23-24	0600	-0.6945	-0.9336	-0.3192	-0.2030	-0.0599
	0900	-0.2788	+0.4760	-0.0533	-0.0900	+0.0399
	1200	-0.1882	-0.4378	-0.0234	-0.1486	-0.1444
	1500	+0.1680	-0.5212	-0.0954	-0.1178	+0.0062
	1800	-0.4788	+0.0018	+0.1130	-0.0255	-0.1048
	2100	-0.1389	+0.0872	+0.0411	+0.0065	-0.0259
	2400	+0.0419	-0.0150	-0.1374	-0.0125	+0.0117
	0300	-0.3550	+0.0343	+0.0895	+0.0015	+0.0372
June 28-29	0600	-0.0764	-0.2320	+0.0232	-0.0087	+0.0398
	0900	-0.4603	-0.2756	-0.2019	-0.0215	-0.0075
	1200	-0.4173	-0.4168	-0.1683	-0.1047	+0.0549
	1500	-0.4058	-0.2903	-0.0908	-0.1623	+0.0304
	1800	-0.2645	-0.3320	+0.1061	-0.0929	+0.0212
	2100	+0.0231	-0.0136	-0.0172	-0.0034	-0.0113
	2400	-0.0409	+0.0043	-0.0591	-0.0466	+0.0052
	0300	+0.1065	+0.0299	+0.0914	+0.0483	+0.0207

Table XV. Continued

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
July 9-10	0600	-.3823	-.2350	-.1280	-.0629	-.0523
	0900	-.5050	-.3315	-.1125	-.1339	-.0778
	1200	-.4112	-.3903	-.1118	-.1275	-.0210
	1500	-.1960	-.2584	+0.0042	-.1388	-.0447
	1800	-.1906	-.1995	+0.0790	-.0705	-.0312
	2100	+0.1616	-.0523	-.0228	+0.0066	+0.0352
	2400	+0.0615	+0.0565	-.0927	-.0276	-.0298
	0300	+0.2083	+0.0337	+0.1364	+0.0205	+0.0282
July 14-15	0600	-.2727	-.0384	-.2637	-.1056	-.1042
	0900	-.8161	-.1672	-.2126	-.0831	-.1133
	1200	-.5800	-.0624	-.2238	-.1435	-.0194
	1500	-.1861	-.6995	-.0167	-.1008	-.0406
	1800	+0.0217	+0.0162	+0.1027	+0.0500	+0.0244
	2100	+0.4789	-.0414	+0.0062	+0.0387	+0.0006
	2400	+0.2411	+0.1983	-.0447	+0.0032	+0.0219
	0300	+0.0955	-.1920	+0.0398	+0.0266	+0.0291
July 21-22	0600	-.3672	-.0110	+0.0009	-.1026	-.0792
	0900	-.3059	-.1789	-.2465	-.1792	-.1655
	1200	-.3736	-.3112	+0.0040	-.0934	-.0472
	1500	-.2350	-.0790	-.0429	-.1049	-.0438
	1800	-.0291	+0.1348	+0.1413	-.0318	-.0004
	2100	+0.4278	+0.0706	+0.0043	-.0162	-.0330
	2400	+0.4699	+0.0157	+0.0414	+0.0256	+0.0014
	0300	+0.0880	-.0733	-.0454	-.0030	-.0066
July 28-29	0600	-.1874	-.1521	-.2079	-.0305	-.1047
	0900	-.4733	-.2889	-.1051	-.1098	-.1189
	1200	-.3736	-.3112	-.1015	-.0934	-.0472
	1500	-.2330	-.2314	-.0340	-.1003	-.0615
	1800	+0.1077	-.0048	+0.0607	-.0435	-.0175
	2100	+0.1759	-.0900	+0.0001	+0.0287	-.0108
	2400	+0.0416	+0.0281	-.1265	-.0598	-.0343
	0300	-.0190	+0.0890	+0.0305	+0.0281	+0.0478

Table XV. Continued

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
Aug 4-5	0600	-.2625	-.1033	-.2535	-.0662	-.0518
	0900	-.3103	-.2596	-.1709	-.1559	-.0808
	1200	-.2686	-.2801	-.0794	-.1174	-.0368
	1500	-.1143	-.1155	-.0581	-.1139	-.0662
	1800	+.0866	-.0294	+.0592	-.0612	+.0063
	2100	+.0482	-.0275	-.0272	+.0019	-.0197
	2400	-.0294	+.0070	+.0051	-.0114	0.0000
	0300	+.0610	+.0143	+.0194	+.0108	+.0226
Aug 10-11	0600	-.2762	-.1367	-.1515	-.0827	-.0321
	0900	-.3721	-.2003	-.1797	-.1767	-.1015
	1200	-.3461	-.3148	-.1225	-.2045	-.0593
	1500	-.0791	-.1810	-.0477	-.1159	-.0169
	1800	+.1321	-.0515	+.0123	+.0078	-.0330
	2100	+.0321	+.0406	-.0976	+.0020	+.0003
	2400	-.0050	-.0376	+.0738	+.0162	+.0070
	0300	+.0142	-.0194	+.0716	-.0297	-.0058
Aug 17-18	0600	-.3219	-.1468	-.1197	-.1244	-.0445
	0900	-.3018	-.2421	-.1202	-.1999	-.0352
	1200	-.3757	-.3728	-.1276	-.1227	-.0253
	1500	-.1286	-.1722	-.0772	-.1350	-.0524
	1800	-.0272	+.0014	+.0247	-.0569	+.0086
	2100	+.0740	-.0239	+.0399	-.0059	-.0048
	2400	+.1309	+.0432	-.0317	+.0105	+.0008
	0300	+.0355	-.0113	-.0229	+.0072	+.0081
Aug 24-25	0600	-.2194	-.3644	-.2084	-.0487	-.0519
	0900	-.3213	-.1504	-.0715	-.1215	-.0852
	1200	-.3670	-.2915	-.1093	-.1807	-.0811
	1500	-.1604	-.1279	-.0403	-.1909	-.0314
	1800	-.0048	+.0256	+.0794	-.0472	+.0142
	2100	+.2520	+.0421	+.0332	-.0161	+.0107
	2400	-.0725	-.0274	-.0238	+.0287	-.0133
	0300	*	*	*	*	*

Table XV. Continued

TIME		STATIONS				
Date	Hour	1-2	2-3	3-4	4-5	5-6
Sept 1-2	0600	-.1335	+.0097	-.1166	-.0291	+.0039
	0900	-.2484	-.0954	-.1942	-.1077	-.0341
	1200	-.2842	-.2180	-.1043	-.0937	-.0408
	1500	-.0443	-.1454	-.0949	-.0996	-.0443
	1800	+.1612	+.0426	+.0227	-.0227	-.0283
	2100	+.0685	-.0051	-.0454	-.0036	-.0125
	2400	+.0890	+.0195	+.0465	+.0044	+.0233
	0300	*	*	*	*	*
	Sept 8-9	0600	-.1617	-.1520	-.2165	-.0855
0900		-.2363	-.1555	-.1356	-.1118	-.0835
1200		-.1542	-.1786	-.1228	-.1366	-.1022
1500		-.0404	-.1628	-.0922	-.0978	-.0531
1800		+.0546	+.0145	+.0188	-.0172	-.0186
2100		+.0747	+.0463	+.0061	+.0061	+.0016
2400		-.1265	-.0293	-.0069	-.0072	-.0026
0300		*	*	*	*	*
Sept 22-23		0600	-.2637	-.3396	-.1128	-.0508
	0900	-.2516	-.3102	-.0590	-.0301	-.0272
	1200	-.1726	-.2204	+.1832	-.0701	-.0475
	1500	-.1548	-.1052	-.0403	-.1522	-.0129
	1800	-.1649	-.1236	-.0961	+.0229	+.0693
	2100	-.1273	-.0042	+.0744	+.0664	+.0189
	2400	-.1035	+.1149	-.1310	-.0367	-.0386
	0300	-.0787	-.1099	+.0180	-.0339	+.0232
	Oct 2-3	0600	-.1238	-.0051	-.1164	-.0268
0900		-.2165	-.1008	-.1597	-.1020	-.0513
1200		-.2528	-.1608	-.1069	-.0738	-.0537
1500		+.0325	-.1421	-.0183	-.0439	-.0635
1800		+.0812	+.0474	-.0521	-.0604	-.0043
2100		+.1147	+.0773	+.0067	+.0469	-.0007
2400		+.0018	-.0788	+.0023	+.0023	+.0018
0300		*	*	*	*	*

Table XV. Continued

Date	TIME	STATIONS				
	Hour	1-2	2-3	3-4	4-5	5-6
Oct 9-10	0600	-.1167	-.0181	-.0002	-.0181	-.0148
	0900	-.2077	-.0713	-.1304	-.1078	-.0244
	1200	-.2387	-.1509	-.0591	-.1210	+.0127
	1500	-.0834	+.0177	-.0940	-.0223	-.0285
	1800	+.1055	+.0354	+.0715	+.0255	+.0042
	2100	+.1889	+.0263	+.0156	+.0189	+.0021
	2400	+.0697	+.0619	-.0464	-.0251	+.0193
	0300	+.1203	-.0638	+.0321	+.0067	-.0180
Oct 16-17	0600	-.1261	+.0012	-.0139	+.0046	+.0160
	0900	-.1818	-.0736	-.2147	-.0801	-.0186
	1200	-.2139	-.1750	-.1038	-.0502	-.0508
	1500	-.0340	-.1661	-.0279	-.0106	-.0161
	1800	+.0606	-.0243	-.0419	+.0239	-.0096
	2100	+.0241	-.0311	+.0041	+.0015	+.0008
	2400	*	*	*	*	*
	0300	*	*	*	*	*
Oct 23-24	0600	+.0178	+.2424	-.2023	-.1460	-.0368
	0900	-.0547	+.0834	-.2373	-.1733	-.0407
	1200	-.0277	-.1001	-.1710	-.1325	-.0701
	1500	+.0518	-.0320	-.0430	-.0856	-.0188
	1800	+.1676	+.1122	-.0886	-.0945	+.0127
	2100	+.1569	+.0054	-.0113	-.1277	-.0003
	2400	*	*	*	*	*
	0300	*	*	*	*	*
Oct 29-30	0600	-.1632	-.0857	-.0563	-.0030	-.0170
	0900	-.2914	-.2208	-.0699	-.0391	-.0434
	1200	-.2891	-.2101	-.0207	-.0447	-.0524
	1500	-.0865	-.1681	-.0179	-.0004	-.0184
	1800	-.0518	-.1857	+.0817	+.0173	-.0095
	2100	-.0884	-.0005	-.0027	-.0019	-.0008
	2400	*	*	*	*	*
	0300	*	*	*	*	*

* Calculations not made for this period because samples were not collected.

Table XV. Continued

*** Samples lost.

Table XVI. Water temperature ($^{\circ}$ Centigrade) at all stations during twenty-four hour periods on weekly intervals through the summer of 1965.

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
May 15-16	0600	11.8	12.0	12.0	12.0	12.0	12.0
	0900	12.8	12.3	13.0	13.0	13.2	13.5
	1200	15.0	15.0	15.0	15.2	15.2	16.0
	1500	17.0	16.8	17.0	16.5	16.0	16.5
	1800	17.0	17.0	17.5	17.3	17.0	16.5
	2100	14.5	14.5	15.0	15.0	15.0	15.0
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	13.0	13.0	13.0	13.0	13.0	13.0
May 22-23	0600	9.4	9.6	9.6	9.6	9.8	9.8
	0900	10.2	10.4	10.4	10.4	10.6	10.8
	1200	12.4	12.6	12.6	12.8	12.6	12.8
	1500	13.4	13.8	13.6	13.2	12.8	12.6
	1800	13.2	13.2	13.2	13.2	13.2	12.8
	2100	*	*	*	*	*	*
	2400	*	*	*	*	*	*
	0300	*	*	*	*	*	*
	0600	10.2	10.6	10.8	11.0	11.4	11.6
May 29-30	0600	11.2	11.6	12.0	12.6	13.6	13.8
	0900	11.4	11.8	12.0	12.4	13.2	14.2
	1200	14.0	14.0	14.0	14.2	14.6	15.5
	1500	16.0	16.4	16.2	16.2	16.2	16.4
	1800	16.6	17.0	16.8	16.8	16.4	16.2
	2100	14.0	15.0	15.0	15.0	14.0	13.0
	2400	12.0	11.0	11.0	11.0	11.0	10.0
	0300	10.0	8.0	10.0	11.0	10.0	12.0
	0600	10.4	10.8	11.2	11.8	12.6	13.2
June 5-6	0600	10.4	10.8	10.8	11.6	12.0	12.2
	0900	11.0	11.4	11.4	11.8	12.2	12.8
	1200	13.6	13.8	13.8	13.8	14.2	14.8
	1500	16.0	16.2	16.0	15.8	15.8	16.0
	1800	17.0	17.0	16.8	16.6	16.2	16.0

Table XVI. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	2100	12.0	13.0	13.0	14.0	13.0	10.0
	2400	11.0	11.0	11.0	12.0	12.0	12.0
	0300	9.0	10.0	10.0	11.0	11.0	13.0
	0600	12.4	12.8	12.8	13.8	14.2	14.4
June 12-13	0600	14.2	14.4	14.5	15.2	15.6	15.8
	0900	14.6	14.8	14.8	15.2	15.8	16.4
	1200	16.3	16.4	16.2	16.6	17.1	17.6
	1500	17.2	17.2	17.0	17.2	17.7	17.9
	1800	17.4	17.4	17.4	17.3	17.4	17.4
	2100	16.3	16.0	16.0	16.5	16.5	16.2
	2400	15.6	16.0	16.0	15.9	15.8	15.5
	0300	15.0	15.2	15.2	15.4	15.4	15.4
	0600	13.6	13.9	14.0	14.4	14.7	14.7
June 18-19	0600	12.0	12.2	12.4	12.6	12.8	12.8
	0900	12.4	12.6	12.7	12.7	13.0	13.7
	1200	15.0	15.0	14.6	13.4	14.7	15.2
	1500	16.5	16.2	16.0	15.6	15.2	15.2
	1800	16.8	16.7	16.6	16.2	15.8	15.4
	2100	16.3	16.2	16.2	16.0	15.6	15.2
	2400	15.7	15.8	15.7	15.5	15.2	15.0
	0300	14.4	13.8	14.9	14.8	14.7	14.4
	0600	13.3	13.7	13.8	14.0	14.2	14.0
June 23-24	0600	15.9	16.4	16.6	16.7	16.8	16.8
	0900	16.2	16.4	16.7	16.8	17.3	18.3
	1200	17.8	18.0	17.8	17.9	18.6	19.2
	1500	*	*	*	*	*	*
	1800	18.8	19.1	19.0	18.8	18.8	18.8
	2100	17.6	17.6	17.7	17.8	17.9	17.6
	2400	16.8	17.1	17.1	17.0	16.9	16.8
	0300	15.8	16.0	16.0	16.1	16.1	15.8
	0600	15.0	15.3	15.4	15.6	15.8	15.6
June 28-29	0600	12.4	12.6	12.5	12.5	12.6	12.6
	0900	13.3	13.4	13.4	13.2	13.4	14.0

Table XVI. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1200	15.6	15.5	15.4	14.9	15.2	15.8
	1500	18.0	17.9	17.6	17.2	16.8	17.1
	1800	18.7	18.8	18.6	18.4	17.6	17.6
	2100	17.4	17.6	17.5	17.6	17.2	16.5
	2400	16.4	16.6	16.5	16.7	16.4	15.6
	0300	15.4	15.6	15.6	15.5	15.3	15.2
	0600	14.8	15.1	15.0	15.1	15.0	14.8
July 9-10	0600	17.4	17.7	17.5	17.5	17.5	17.3
	0900	17.8	18.2	18.2	17.8	18.6	19.0
	1200	19.9	19.9	20.0	19.4	20.3	21.2
	1500	22.1	21.8	21.6	21.2	21.2	21.8
	1800	22.6	22.5	22.3	21.8	21.4	21.4
	2100	21.4	21.4	21.4	21.2	20.6	19.9
	2400	20.0	20.2	20.1	20.2	19.8	19.2
	0300	18.8	19.1	18.8	19.0	18.8	18.4
	0600	17.8	17.9	17.8	17.9	18.1	17.9
July 14-15	0600	16.6	17.0	16.8	16.8	17.0	16.8
	0900	16.7	17.1	17.2	17.0	17.7	18.4
	1200	20.0	19.7	19.7	19.0	20.0	21.2
	1500	22.0	21.8	21.4	20.6	20.7	21.5
	1800	22.8	22.7	22.4	21.8	21.1	21.0
	2100	21.8	21.8	21.5	21.4	20.4	19.7
	2400	20.4	20.6	20.4	20.5	19.9	19.2
	0300	*	*	*	*	*	*
	0600	17.9	18.0	18.0	18.2	18.2	17.8
July 21-22	0600	17.8	18.0	17.8	17.8	17.8	17.6
	0900	18.2	18.4	18.4	18.1	18.6	19.2
	1200	20.8	20.3	20.0	19.8	20.2	21.4
	1500	21.8	21.9	21.4	20.8	20.9	21.2
	1800	22.0	22.0	21.9	21.8	21.2	21.4
	2100	21.0	21.0	20.8	20.8	20.4	19.7
	2400	20.0	20.2	19.9	19.8	19.5	19.1
	0300	18.8	18.9	18.8	18.8	18.5	18.0
	0600	18.2	18.4	18.2	18.2	18.0	17.6

Table XVI. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
July 28-29	0600	18.2	18.3	18.2	18.1	18.0	18.0
	0900	18.4	18.7	18.6	18.2	19.0	19.6
	1200	21.6	21.2	21.0	20.4	21.8	22.8
	1500	23.5	23.4	23.0	21.9	22.2	22.6
	1800	24.2	23.8	23.4	23.0	22.3	22.2
	2100	22.8	22.9	22.8	22.4	21.6	20.9
	2400	21.4	21.8	21.6	21.7	21.2	20.4
	0300	20.4	20.4	20.4	20.4	20.4	19.8
	0600	19.2	19.6	19.3	19.4	19.4	19.2
Aug 4-5	0600	19.0	19.2	19.0	19.1	18.8	18.4
	0900	19.0	19.1	19.1	18.8	19.7	20.0
	1200	*	*	*	*	*	*
	1500	21.8	21.2	21.1	20.4	20.2	20.1
	1800	21.2	21.2	21.2	20.5	20.2	20.0
	2100	20.0	20.2	19.9	20.0	19.2	18.8
	2400	19.5	19.4	19.2	19.2	18.8	18.2
	0300	18.5	18.6	18.3	18.2	17.8	17.5
	0600	18.0	18.1	17.8	17.6	17.3	17.1
Aug 10-11	0600	20.0	20.2	19.8	19.8	19.8	19.4
	0900	20.0	20.3	20.4	19.9	20.7	21.2
	1200	21.9	21.9	21.6	21.4	22.0	23.0
	1500	23.9	23.4	23.2	22.5	23.2	23.9
	1800	24.4	24.0	23.4	22.8	22.1	22.2
	2100	*	*	*	*	*	*
	2400	21.4	21.7	21.7	21.6	20.8	19.9
	0300	20.0	20.1	20.0	20.4	19.9	19.2
	0600	19.0	19.2	19.0	19.2	19.1	18.6
Aug 17-18	0600	17.7	18.0	17.7	17.8	17.4	16.8
	0900	17.8	18.1	18.2	17.8	18.2	18.8
	1200	19.8	19.6	19.6	19.2	20.3	21.1
	1500	22.2	21.8	21.3	20.6	21.4	22.0
	1800	22.6	22.3	21.8	21.2	20.5	20.4
	2100	21.6	21.6	21.3	20.9	19.9	19.0
	2400	19.4	19.7	19.7	20.0	19.0	18.2

Table XVI. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	0300	18.7	18.9	18.7	19.0	18.5	17.6
	0600	17.6	17.8	17.6	17.7	17.4	16.9
Aug 24-25	0600	16.4	16.5	16.2	16.0	15.2	14.8
	0900	16.2	16.4	16.5	16.2	16.6	16.7
	1200	18.0	17.8	17.8	17.5	18.2	19.3
	1500	19.8	19.8	19.2	18.4	18.8	19.3
	1800	20.0	20.0	19.5	19.2	18.2	18.2
	2100	18.9	19.0	18.8	18.6	17.7	16.8
	2400	18.0	18.1	17.9	17.8	17.3	16.5
	0300	**	**	**	**	**	**
0600	16.8	16.8	16.6	16.5	16.0	15.5	
Sept 1-2	0600	14.6	14.8	14.6	14.5	14.0	13.2
	0900	14.3	14.6	14.6	14.2	14.6	14.9
	1200	16.6	16.2	16.2	15.8	16.4	17.2
	1500	19.1	18.6	18.2	17.3	17.5	18.0
	1800	19.2	18.9	18.5	17.8	16.7	16.6
	2100	18.5	18.7	18.0	17.8	16.4	15.4
	2400	16.9	17.1	16.9	16.9	16.0	15.1
	0300	**	**	**	**	**	**
	0600	*	*	*	*	*	*
Sept 8-9	0600	16.0	16.0	15.8	15.8	15.2	14.8
	0900	16.1	16.2	15.8	15.5	15.5	15.8
	1200	*	*	*	*	*	*
	1500	18.1	17.8	17.4	16.9	16.5	16.5
	1800	18.1	17.8	17.4	17.1	16.1	15.7
	2100	17.1	17.1	16.7	16.5	15.8	14.8
	2400	16.2	16.6	16.2	16.2	15.4	14.6
	0300	**	**	**	**	**	**
	0600	15.0	15.2	15.0	15.0	14.6	14.4
Sept 15-16	0600	14.4	14.4	14.4	14.2	13.4	13.2
	0900	14.2	14.1	13.9	13.7	13.7	13.4
	1200	14.8	14.4	14.0	13.8	13.5	13.5
	1500	15.2	15.0	15.0	14.4	14.0	14.0

Table XVI. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	1800	14.1	14.0	14.0	13.9	13.3	12.9
	2100	13.4	13.6	13.2	13.2	13.0	14.4
	2400	***	***	***	***	***	***
	0300	***	***	***	***	***	***
	0600	***	***	***	***	***	***
Sept. 22-23	0600	12.8	12.4	12.0	11.8	11.2	10.8
	0900	12.2	12.1	11.9	11.5	10.9	10.6
	1200	12.4	12.3	12.0	11.8	11.3	10.9
	1500	13.2	13.0	13.0	12.6	12.0	11.6
	1800	12.8	12.7	12.2	11.9	11.1	10.7
	2100	12.4	12.6	12.2	12.0	11.0	10.4
	2400	11.6	11.6	11.3	11.2	10.5	9.9
	0300	11.0	11.0	11.0	11.0	10.3	9.4
	0600	10.2	10.2	10.0	10.0	9.3	8.8
Oct 2-3	0600	12.6	13.0	12.9	12.4	12.0	11.3
	0900	12.8	13.1	12.7	12.3	12.2	12.0
	1200	14.8	14.6	14.2	13.8	14.0	14.4
	1500	16.5	16.2	15.5	14.6	14.4	15.0
	1800	17.0	16.8	16.0	15.0	14.0	13.8
	2100	16.0	16.0	15.4	15.0	13.8	12.5
	2400	15.0	15.0	15.0	14.4	13.4	12.2
	0300	**	**	**	**	**	**
	0600	13.0	13.2	13.0	12.9	12.2	11.6
Oct 9-10	0600	13.2	13.4	13.0	13.0	12.4	11.8
	0900	13.0	13.4	13.0	12.8	12.4	12.4
	1200	15.0	15.0	14.6	14.0	14.0	14.2
	1500	16.4	16.4	16.0	15.0	15.0	15.0
	1800	16.4	16.2	16.0	15.0	14.0	13.6
	2100	16.0	16.0	15.4	15.0	14.0	12.6
	2400	15.0	15.0	14.8	14.6	13.6	12.4
	0300	14.0	14.2	13.8	14.0	13.0	12.0
	0600	13.4	13.4	13.2	13.2	12.8	11.8
Oct 16-17	0600	12.0	12.4	12.0	12.0	11.0	10.0

Table XVI. Continued

Date	TIME	STATION					
	Hour	1	2	3	4	5	6
	0900	12.0	12.2	12.0	11.8	11.2	10.8
	1200	13.0	13.0	12.6	12.0	12.2	12.2
	1500	13.6	14.0	13.4	13.2	13.0	13.0
	1800	14.0	14.0	13.0	12.6	12.0	11.8
	2100	13.6	13.8	13.2	12.8	11.6	11.0
	2400	**	**	**	**	**	**
	0300	**	**	**	**	**	**
	0600	12.2	12.4	12.0	12.0	10.8	10.0
Oct 23-24	0600	11.6	12.0	11.6	11.6	10.8	9.8
	0900	11.1	10.8	11.2	11.0	10.4	10.2
	1200	13.0	13.0	12.6	12.1	12.1	12.1
	1500	15.0	14.4	13.4	13.0	13.0	13.0
	1800	15.0	14.8	14.0	12.8	12.0	12.0
	2100	14.6	14.4	14.0	13.0	11.4	10.4
	2400	**	**	**	**	**	**
	0300	**	**	**	**	**	**
	0600	11.6	12.0	11.6	11.4	11.0	10.0
Oct 29-30	0600	11.6	12.0	11.6	11.2	10.8	10.0
	0900	11.6	12.0	11.2	11.0	10.8	10.2
	1200	12.8	13.0	12.2	11.8	12.0	12.0
	1500	14.0	14.0	13.0	12.4	12.4	12.0
	1800	14.0	14.0	13.0	12.4	11.4	11.0
	2100	13.6	14.0	13.4	13.0	11.2	10.4
	2400	**	**	**	**	**	**
	0300	**	**	**	**	**	**
	0600	11.8	12.0	11.8	11.6	10.6	9.8

* Temperature was not determined at this time because the thermometer was broken during the collection of samples.

** Temperature was not determined at this time because no samples were collected at this sampling period.

*** Temperature was not determined at this time because excessive snow made the highway impassable.

Table XVII. Light intensity (gram-calories/cm²) for three hour intervals during twenty-four hour periods on sampling dates through the summer of 1965.

DATE	HOURS	LIGHT INTENSITY
May 15-16	0600-0900	86.7
	0900-1200	173.1
	1200-1500	188.5
	1500-1800	99.7
	1800-2100	10.9
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	5.5
May 22-23	0600-0900	63.5
	0900-1200	180.0
	1200-1500	82.3
	1500-1800	19.5
	1800-2100	5.1
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	1.4
May 29-30	0600-0900	89.1
	0900-1200	178.6
	1200-1500	200.1
	1500-1800	123.2
	1800-2100	19.8
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	4.4
June 5-6	0600-0900	102.1
	0900-1200	186.4
	1200-1500	200.4
	1500-1800	126.3
	1800-2100	22.2
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	7.2

Table XVII. Continued

DATE	HOURS	LIGHT INTENSITY
June 12-13	0600-0900	79.2
	0900-1200	173.4
	1200-1500	183.7
	1500-1800	66.2
	1800-2100	17.1
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	3.4
June 18-19	0600-0900	91.8
	0900-1200	217.1
	1200-1500	138.3
	1500-1800	57.4
	1800-2100	17.4
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	5.8
June 23-24	0600-0900	88.4
	0900-1200	162.2
	1200-1500	156.7
	1500-1800	40.3
	1800-2100	4.4
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	7.2
June 28-29	0600-0900	105.8
	0900-1200	192.2
	1200-1500	190.8
	1500-1800	106.9
	1800-2100	12.3
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	11.6
July 9-10	0600-0900	91.2
	0900-1200	185.0

Table XVII. Continued

DATE	HOURS	LIGHT INTENSITY
	1200-1500	220.5
	1500-1800	128.4
	1800-2100	11.9
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	9.2
July 14-15	0600-0900	86.0
	0900-1200	164.2
	1200-1500	185.4
	1500-1800	120.5
	1800-2100	23.6
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	4.1
July 21-22	0600-0900	72.4
	0900-1200	159.4
	1200-1500	208.3
	1500-1800	125.6
	1800-2100	25.6
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	24.2
July 28-29	0600-0900	67.3
	0900-1200	156.0
	1200-1500	146.8
	1500-1800	74.8
	1800-2100	20.8
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	4.8
Aug 4-5	0600-0900	65.9
	0900-1200	163.5
	1200-1500	126.3
	1500-1800	38.6

Table XVII. Continued

DATE	HOURS	LIGHT INTENSITY
	1800-2100	6.5
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	3.8
Aug 10-11	0600-0900	92.2
	0900-1200	148.8
	1200-1500	187.8
	1500-1800	98.7
	1800-2100	18.4
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	2.4
Aug 17-18	0600-0900	58.0
	0900-1200	146.8
	1200-1500	178.6
	1500-1800	105.5
	1800-2100	11.6
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	1.7
Aug 24-25	0600-0900	48.8
	0900-1200	150.9
	1200-1500	173.4
	1500-1800	99.4
	1800-2100	7.2
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	0.7
Sept 1-2	0600-0900	62.5
	0900-1200	145.4
	1200-1500	170.0
	1500-1800	82.6
	1800-2100	5.8
	2100-2400	0.0

Table XVII. Continued

DATE	HOURS	LIGHT INTENSITY
	2400-0300	0.0
	0300-0600	1.0
Sept 8-9	0600-0900	35.8
	0900-1200	149.5
	1200-1500	83.0
	1500-1800	52.9
	1800-2100	2.7
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	0.7
Sept 15-16	0600-0900	22.9
	0900-1200	86.4
	1200-1500	34.1
	1500-1800	7.2
	1800-2100	0.7
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	2.0
Sept 22-23	0600-0900	16.4
	0900-1200	29.0
	1200-1500	31.4
	1500-1800	17.8
	1800-2100	4.4
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	2.4
Oct 2-3	0600-0900	38.6
	0900-1200	121.2
	1200-1500	122.3
	1500-1800	55.6
	1800-2100	6.1
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	0.7

Table XVII. Continued

DATE	HOURS	LIGHT INTENSITY
Oct 9-10	0600-0900	33.5
	0900-1200	95.9
	1200-1500	122.9
	1500-1800	50.2
	1800-2100	0.7
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	0.7
Oct 16-17	0600-0900	13.0
	0900-1200	63.8
	1200-1500	120.2
	1500-1800	22.2
	1800-2100	4.4
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	4.1
Oct 23-24	0600-0900	31.8
	0900-1200	98.7
	1200-1500	99.7
	1500-1800	30.4
	1800-2100	4.1
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	2.7
Oct 29-30	0600-0900	13.7
	0900-1200	35.2
	1200-1500	100.0
	1500-1800	30.7
	1800-2100	3.1
	2100-2400	0.0
	2400-0300	0.0
	0300-0600	0.7

LITERATURE CITED

- Allen, E. T. and Day, A. L., 1935. Hot springs of the Yellowstone National Park. Carnegie Institute, Washington, D. C. Pub. No. 466. 525 pp.
- Beyers, Robert J., Larimer, James L., Odum, Howard T., Parker, Richard B. and Armstrong, Neal E., 1963. Directions for the determination of changes in carbon dioxide concentration from changes in pH. Pub. Inst. Mar. Sci., Univ. Tex., 9:454-489.
- Blum, John L., 1956. The ecology of river algae. Bot. Rev. 22(5):291-341.
- Blum, John L., 1957. An ecological study of the algae of the Saline River, Michigan. Hydrobiologia 9(4):361-408.
- Boyd, F. R., 1961. Welded tuffs and flows in the rhyolite plateau of Yellowstone Park, Wyoming. Geol. Soc. Am. Bull., 72:387-426.
- Brownlee, K. A., 1960. Industrial experimentation. Her Majesty's Stationery Office. 4th Ed., 194 pp.
- Butcher, R. W., 1927. A preliminary account of the vegetation of the River Itchen. Journ. Ecol. 15:55-65.
- Butcher, R. W., 1932a. Studies in the ecology of rivers. II. The microflora of rivers with special reference to the algae on the river bed. Annal. Bot. 46:813-861.
- Butcher, R. W., 1932b. Notes on new and little known algae from the beds of rivers. New Phytol. 31(5):289-309.
- Butcher, R. W., 1933. Studies in the ecology of rivers. I. On the distribution of macrophytic vegetation in the rivers of Britain. Journ. Ecol. 21:58-91.
- Butcher, R. W., 1940. Studies in the ecology of rivers. IV. Observations on the growth and distribution of the sessile algae in the river Hull, Yorkshire. Journ. Ecol. 28(1):210-223.

- Butcher, R. W., 1945. Studies in the ecology of rivers. VI. The algal growth in certain highly calcareous streams. *Journ. Ecol.* 33(2):268-283.
- Butcher, R. W., 1947. Studies in the ecology of rivers. VII. The algae of organically enriched waters. *Journ. Ecol.* 35(1&2):186-191.
- Butcher, R. W., 1948. Problems of distribution of sessile algae in running water. *Proc. Intern. Assn. Theor. and App. Limnol.* 10:98-103.
- Copeland, B. J. and Duffer, W. R., 1964. Use of a clear plastic dome to measure gaseous diffusion rates in natural waters. *Limnol. and Oceanog.* 9(4):494-499.
- Duffer, W. R. and Dorris, T. C., 1966. Primary productivity in a southern Great Plains stream. *Limnol. and Oceanog.* 11(2):143-151.
- Edwards, R. W. and Owens, M., 1960. The effects of plants on river conditions. I. Summer crops and estimates of net productivity of macrophytes in a chalk stream. *Journ. Ecol.* 48:151-160.
- Edwards, R. W. and Owens, M., 1962. The effects of plants on river conditions. IV. The oxygen balance of a chalk stream. *Journ. Ecol.* 50:207-220.
- Hoskin, Charles M., 1959. Studies of oxygen metabolism of streams of North Carolina. *Pub. Inst. Mar. Sci., Univ. Tex.* 6:186-192.
- Kevern, N. R. and Ball, R. C., 1965. Primary productivity and energy relationships in artificial streams. *Limnol. and Oceanog.* 10(1):74-87.
- McConnell, W. J. and Sigler, W. F., 1959. Chlorophyll and productivity in a mountain river. *Limnol. and Oceanog.* 4(3):335-351.

- McFadden, J. T., 1963. An example of inaccuracies inherent in interpretation of ecological field data. *Amer. Nat.* 97:99-116.
- Odum, H. T., 1956. Primary production in flowing water. *Limnol. and Oceanog.* 1(2):102-117.
- Odum, H. T., 1957a. Trophic structure and productivity of Silver Springs, Florida. *Ecol. Monog.* 27(1):55-112.
- Odum, H. T., 1957b. Primary production measurements in eleven Florida springs and a marine turtle-grass community. *Limnol. and Oceanog.* 2(2):85-97.
- Odum, H. T. and Hoskin, Charles M., 1957. Metabolism of a laboratory stream microcosm. *Pub. Inst. Mar. Sci., Univ. Tex.* 4(2):115-133.
- Odum, H. T. and Odum, E. P., 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. *Ecol. Monog.* 25(3):291-320.
- Owens, M. and Edwards, R. W., 1961. The effect of plants on river conditions. II. Further crop studies and estimates of net productivity of macrophytes in a chalk stream. *Journ. Ecol.* 49:119-126.
- Owens, M. and Edwards, R. W., 1962. The effects of plants on river conditions. III. Crop studies and estimates of net productivity of macrophytes in four streams in southern England. *Journ. Ecol.* 50:157-162.
- Owens, M., Edwards, R. W. and Gibbs, J. W., 1964. Some reaeration studies in streams. *Intern. Journ. Air and Water Poll.* 8:469-486.
- Patrick, R., Horn, Mathew H. and Wallace, John H., 1954. A method for determining the pattern of diatom flora. *Not. Nat., Phil. Acad. Nat. Sci.* 259:1-12.
- Rainwater, F. H. and Thatcher, L. L., 1960. Methods for collection and analysis of water samples. *Geol. Surv. Water-Supply Paper 1454.* 301 pp.

- Richards, F. A. with Thompson, T. G., 1952. The estimation and characterization of plankton populations by pigment analyses. II. A spectrometric method for the estimation of plankton pigments. *Journ. Mar. Res.* 11:156-172.
- Richmond, Samuel B., 1964. *Statistical Analysis*. Ronald Press 2nd Ed. 633 pp.
- Roeder, T. S., 1966. Ecology of the diatom communities of the upper Madison River system, Yellowstone National Park. Unpublished Ph. D. Thesis, Montana State Univ. Library. 85 pp.
- Rutner, Franz., 1965. *Fundamentals of Limnology*. Univ. Toronto Press 3rd Ed. 295 pp.
- Sargent, M. C. and Austin, T. S., 1949. Organic productivity of an atoll. *Trans. Amer. Geophys. Union* 30(2):245-249.
- Snedecor, George W., 1946. *Statistical Methods applied to experiments in agriculture and biology*. Iowa St. Col. Press 4th Ed. 485 pp.
- Surface Water Records of Montana. 1963, 1964. U. S. Dept. Int., Geol. Survey.
- Whitford, L. A., 1960. The current effect and growth of fresh water algae. *Trans. Amer. Microscop. Soc.* 79:302-309.
- Wright, J. C., 1964. Progress Report. The hydrobiology of the Madison River and its headwaters. (Unpublished) 34 pp.

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