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CHANGES IN WATER QUALITY RESULTING FROM IMPOUNDMENT

U.S. ENVIRONMENTAL PROTECTION AGENCY

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CHANGES IN WATER QUALITY RESULTING FROM IMPOUNDMENT

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ABSTRACT

Changes in stream water quality, resulting from recent impoundment, are presented and discussed. Extensive data reflecting pre- and post-impoundment conditions were statistically analyzed. The extent to which pollutants influence changes in water quality was minimal, since the drainage basin was relatively undisturbed by the activities of man. Chemical, physical, and microbiological parameters at stream stations were evaluated for three discrete periods of time: prior to closure of the dam, during filling of the active conservation pool, and following filling with the surface maintained near the top of the active conservation elevation. Effects of removing treated municipal waste effluents from a tributary were also evaluated. Water quality changes within the impoundment were compared with respect to season, year, station location, and depth of sampling. Critical factors in the impoundment, which contributed to water quality changes, are identified.

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SECTION I

CONCLUSIONS

Overall results do not indicate a particular mechanism causing all water quality changes but, rather many processes, one or more of which may affect a particular parameter. Principal factors responsible for significant changes in water quality are seasonal variations, thermal stratification, sewage effluent removal, stream flow, and decomposition of organic debris. Speculation concerning events responsible for downstream water quality changes following impoundment is strengthened by the large number of parameters selected for study and comparisons with upstream stations.

The major influence on changes in water quality at stream stations was discharge. There was a reduction in concentration for many study parameters at the stream station below Arbuckle Dam following filling of the reservoir due to high stream flow. However, annual amounts for most of these parameters actually increased. Both the concentration and the annual amount of ortho phosphate and total phosphate decreased. Diversion of municipal sewage effluents from a tributary during the period of filling was responsible for the decrease in the annual amount of phosphorus in the system. Based on the respiration rate of the hypolimnion during thermal stratification, Arbuckle Reservoir had a very high rate of oxidative metabolism. Decomposition of the organic debris covering the inundated area produced a high oxygen demand which resulted in a downstream increase in the annual amount of BOD_5 following filling to the active conservation elevation.

Within the impoundment, significant changes in water quality occurred due to the influences of seasonal variation, year, depth, and station location. Seasonal variation appeared to be the major influence, since nearly all parameters analyzed displayed seasonal differences at the 0.05 level of significance. There were significant differences for about one-half of the parameters analyzed for comparison of the two years following filling of the reservoir. In general, chemical and biological changes indicate an improvement in water quality during the second year following filling. Increased concentrations of ammonia, ortho phosphate, and total phosphate, and the decrease in pH with increasing depth were produced by the anoxic conditions of thermal stratification. Station location within the impoundment system had the least influence on water quality parameters analyzed with significant difference among stations occurring only for total and filterable residue.

SECTION II

RECOMMENDATIONS

1. Long-term changes in water quality within the impoundment and at stream stations should be determined for the Arbuckle System. Results of the present study could be used as a basis for establishing the extent of change of water quality parameters due to aging in a hard water reservoir relatively free of pollution.

2. For comparative purposes, immediate and long-term changes resulting from impoundment should be determined for systems receiving significant amounts of industrial, agricultural, and municipal waste material.

SECTION III

INTRODUCTION

Project Objectives

The objectives of this research were to determine immediate changes in stream water quality resulting from construction of a reservoir and to establish critical factors in the reservoir responsible for quality changes. These quality relationships are important for predicting water quality within proposed reservoirs and in planning for flow augmentation for water quality control.

Several studies dealing with the effects of impoundment on water quality have been conducted. Accounting for pollutional effects in relation to other environmental variables presents a major problem. Further difficulties in evaluating past studies arise when such factors as the amount of pre-impoundment data available, changes in water quality of tributary streams, number and type of parameters selected, and methods of data analysis are considered.

The present study is unique since the characteristics of the drainage basin combined with analytical procedures employed permit evaluation of pollutional effects as well as other environmental variables. The extent to which pollutants influence quality changes is minimal as the drainage basin is relatively undisturbed by the activities of man. Municipal wastes from a town having a population of approximately 5,000 were diverted from the system following closure of the dam. Extensive data covering 24 parameters and reflecting chemical, physical, and microbiological conditions at stream stations were statistically analyzed by grouping into three discrete periods. The periods selected were (1) prior to closure of the dam, (2) during filling of the active conservation pool, and (3) following filling with the surface maintained near the top of the active conservation elevation.

Other important features include an evaluation of water quality determinations during the transitional period while the reservoir was filling and a comparison of changes in tributary water quality with those occurring in the stream below the dam.

Critical factors influencing water quality changes within the reservoir are identified by comparing changes in parameters with respect to season, year, station location, and depth of sampling.

Description of Study Area

This investigation was conducted at the Arbuckle Project which is located in the Arbuckle Mountain area of south central Oklahoma. The Arbuckle Project consists of a dam and reservoir on Rock Creek, tributary to the Washita River, just upstream from the town of Doughtery (Figure 1). Arbuckle Reservoir, operated primarily for industrial and municipal water supply and flood control, has a surface area of 2,349 acres and a capacity of 65,250 acre-feet at the top of the active conservation elevation.

A pre-impoundment study of the Arbuckle system was initiated in December 1965. Stream stations were established at four locations for monitoring selected water quality parameters. Station 1 on Buckhorn Creek is located upstream from the influence of the active conservation pool. Station 2 on Rock Creek is downstream from Arbuckle Dam. Stations 3 and 4 are located downstream and upstream, respectively, from the city of Sulphur's sewage treatment plant outfall into Rock Creek.

The city of Sulphur operated a trickling filter treatment plant with effluent discharging into Rock Creek until the fall of 1967. During October, sewage from Sulphur was diverted and effluents were no longer discharged into the system. Arbuckle Dam was closed in January 1967 and filled to near the top of the active conservation pool level by April 1968. After filling, four stations were established in Arbuckle Reservoir to determine changes in selected water quality parameters. Station 5 was located on the Rock Creek Arm, Station 6 on the Buckhorn Creek Arm, Station 7 in the central pool near Arbuckle Dam, and Station 8 on the Guy Sandy Creek Arm. Station 7 was relatively free of influent effects and served to monitor water quality at 1-, 15-, 30-, 45-, 60-, and 75-foot depths. Stations 5, 6, and 8 were used to show the varying influence of influent streams at the one-foot depth.

Methods

Samples were collected bi-weekly at stream stations from December 1965 through December 1967 and at four-week intervals from January 1968 through April 1970. Samples were collected at reservoir stations at four-week intervals from February 1968 through April 1970. Macroinvertebrates were collected using limestone-filled basket samplers described by Mason, Anderson, and Morrison, modified for reservoir use by Kreis and Smith.[1,2] Vertical profiles of dissolved oxygen and temperature were obtained at depth intervals of five feet for Station 7 during the period of thermal stratification. Analysis of water samples for conductivity, total phosphate, magnesium, sulphate, and BOD were according to <u>Federal Water Pollution Control Administration Official Interim Methods</u> with some modifications.[3] Sulphates were determined using the modified turbidimetric method and total phosphates by the sulphate interference method, modified by Barth and Salotto.[4]

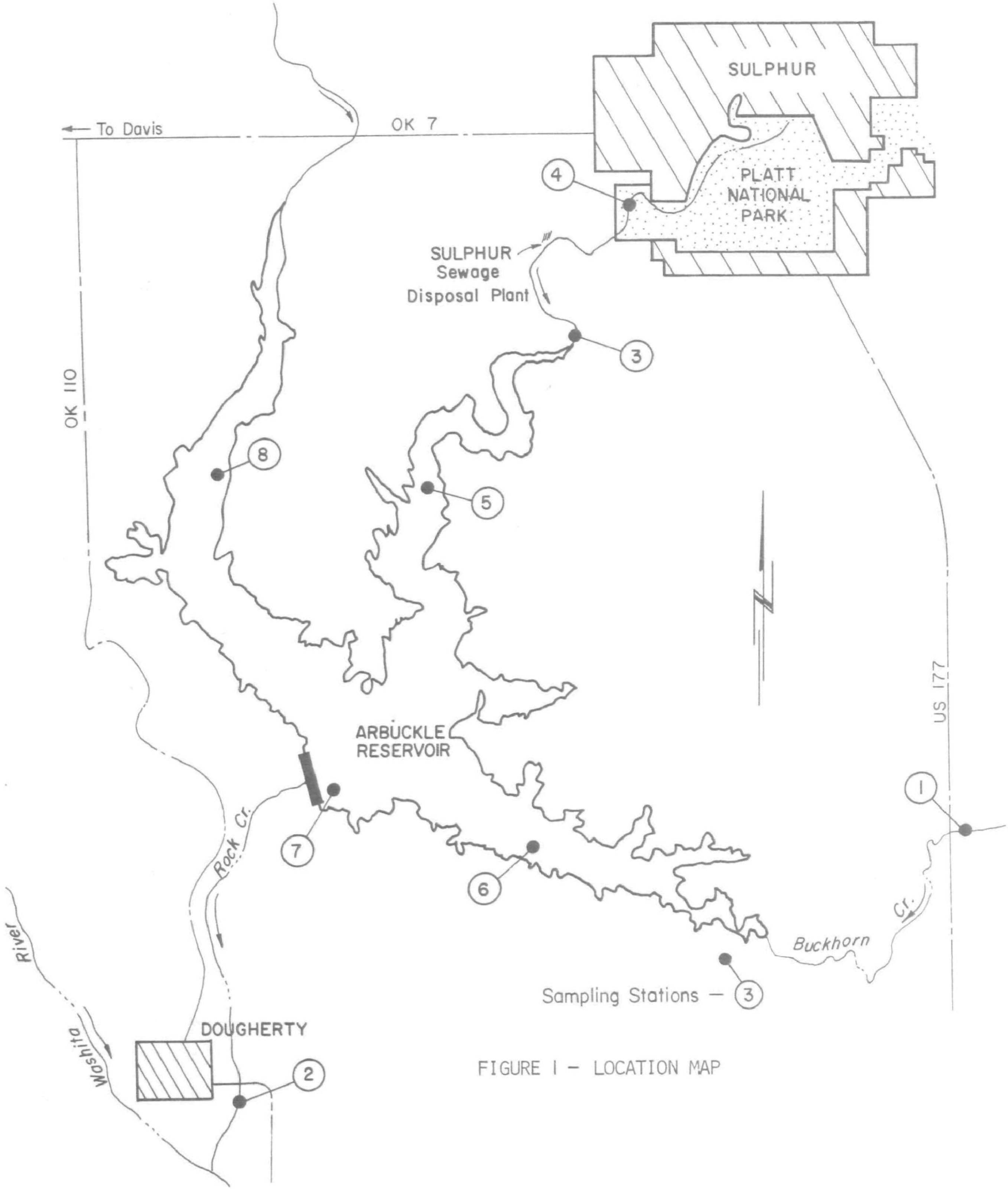

FIGURE I - LOCATION MAP

Nitrite and nitrate were determined by the automated hydrazine reduction method. Other chemical analyses were according to the methods of the American Public Health Association.[5] The techniques employed in microbiological determinations were standard membrane filter techniques approved for the examination of water. Analysis of phytoplankton samples were according to the method of Weber.[6] Analysis of macroinvertebrate samples were according to the method of Kreis, Smith, and Moyer (In Preparation).[7]

SECTION IV

WATER QUALITY CHANGES AT STREAM STATIONS

Two types of statistical analyses were performed on data collected below Arbuckle Dam in order to determine the short-term effects of impoundment on the water quality of Rock Creek. Data representing conditions at upstream stations were also analyzed for comparative purposes. One analysis compares mean values prior to and following closure of the dam (Appendix Table 1). Differences are tested at the 0.05 level of significance. The other analysis, a non-parametric analysis of chi-squares with interaction, groups data into three discrete periods; prior to closure of the dam, during filling of the active conservation pool, and following filling with the surface maintained near the top of the active conservation elevation. Based on medians as a measure of central tendency, this distribution-free analysis is compatible with the previous analysis comparing means in those cases where distributional assumptions can be justified, i.e., normal distribution. The overall median and cell medians are computed, and the total chi-square is partitioned into its assignable components by stations, periods, and interaction between stations and periods (Appendix Table 2). Differences in stations and in periods as well as interactions between the two are inferred on a probability basis at the 0.05 level of significance.

In general, the chi-squares analysis with grouping into three discrete periods provides more insight into water quality changes downstream from Arbuckle Dam and shows a more pronounced effect in the stream below a municipal outfall due to diversion of sewage effluents during filling of the reservoir. Changes during the filling period were often intermediate between the other periods considered. However, some parameters responded in a different manner, and comparisons during the transitional filling period would be misleading.

Conditions before and following closure of Arbuckle Dam at Station 2 are presented in Table I. Mean values are listed only for parameters having a significant difference at the 0.05 level. However, in order to make judgements as to whether or not changes resulted from the upstream impoundment, conditions at tributary stations must be considered in relation to those at Station 2. For example, only pH, conductivity, and nitrate show a significant decrease below the dam with all tributary stations having no significant change. The problem of determining the influence of impoundment on other parameters is more complex, since either a significant difference exists at Station 2 along with a significant difference at one or more tributary stations, or there is no significant difference at Station 2 while some of the tributary stations have a significant difference. This problem is resolved to a large extent by use of the chi-squares analysis. In addition to isolating the transitional filling

TABLE I

MEAN VALUES AT STREAM STATION 2
REPRESENTING CONDITIONS PRIOR TO AND FOLLOWING CLOSURE OF ARBUCKLE DAM*

Parameter	Before Closure	After Closure
Total Plate Count/ml 35°C (log transformation)	3.843	3.214
Total Plate Count/ml 20°C (log transformation)	3.708	2.982
pH	8.4	7.9
Alkalinity-HCO_3, mg/l	209.2	243.6
Alkalinity-CO_3, mg/l	46.4	24.7
Conductivity, micromhos/cm @ 25°C	1442.6	865.4
Magnesium, mg/l	36.4	23.8
Chlorides, mg/l	330.0	136.2
Total Residue, mg/l	1152.8	512.2
Filterable Residue, mg/l	859.7	461.7
Organic Nitrogen, mg/l	0.786	0.361
Nitrate, mg/l	0.674	0.100
Total Phosphate, mg/l	2.643	0.565
Ortho Phosphate, mg/l	2.285	0.405

*All parameters from Appendix Table II having a significant difference at the 0.05 level are listed.

period, one analytical procedure takes into account both stations and periods. Figures 2 through 7 are based on the chi-squares analysis. In those cases, having no significant interaction between stations and periods and having a significant difference for stations and/or periods, cell medians can be summed for the purpose of determining which station(s) or period(s) are different. For example, the sum of cell medians for total and ortho phosphate is much greater for the period prior to closure of the dam than for either of the following periods (Figure 2). Comparing these two parameters among stations, however, indicates that there is no significant difference for ortho phosphate and that the sum of medians for total phosphate is greater at Stations 2 and 3 (Appendix Table II and Figure 3).

Comparing the means of study parameters, prior to and following closure of the dam, delineates several important conditions of water quality at stream stations. Changes in parameters at the station below the dam include significant decreases in total plate count at $35^{o}C$, pH, carbonate alkalinity, conductivity, and nitrate, and a significant increase in bicarbonate alkalinity. Significant decreases in sulphate and hardness at Stations 3 and 4 were not reflected below the dam. Also there was no significant downstream decrease in total coliforms, fecal coliforms, fecal streptococci, or 5-day BOD. A significant reduction in chlorides occurred at Station 3 below the outfall of the municipal sewage treatment plant and Station 2 below the dam. There was also a significant decrease in organic nitrogen, total phosphate, and ortho phosphate at both Station 2 and Station 3. A significant decrease in ammonia at Station 3, however, is not reflected at the station below the dam. Significant decreases in total plate count at $20^{o}C$ occurred at Stations 1, 2, and 4, and in total and filterable residue at Stations 2, 3, and 4. Significant increases in calcium and COD occurred at Stations 1 and 4, respectively. Although there was a significant difference between mean values for nitrite at Stations 1 and 4, total phosphate at Station 1, and ortho phosphate at Stations 1 and 4, differences in mean values are not meaningful since values are extremely low.

In the analysis which groups data into three periods, changes for several parameters are similar to the analysis which compares two periods. Additional support is provided for decreases in total phosphate, ortho phosphate, organic nitrogen, carbonate alkalinity, magnesium, and total plate count at $20^{o}C$ at Station 2. However, ortho phosphate, carbonate alkalinity, magnesium, and total plate count at $20^{o}C$ decreased at all stations during filling and the period following filling of the impoundment. At Station 3, parameters displaying notable decreases included total phosphate, organic nitrogen, ammonia, hardness, and fecal streptococci. Decreases also occurred in hardness and fecal streptococci at Stations 4 and 1, respectively. The greatest decrease in calcium occurred at Station 1 in the

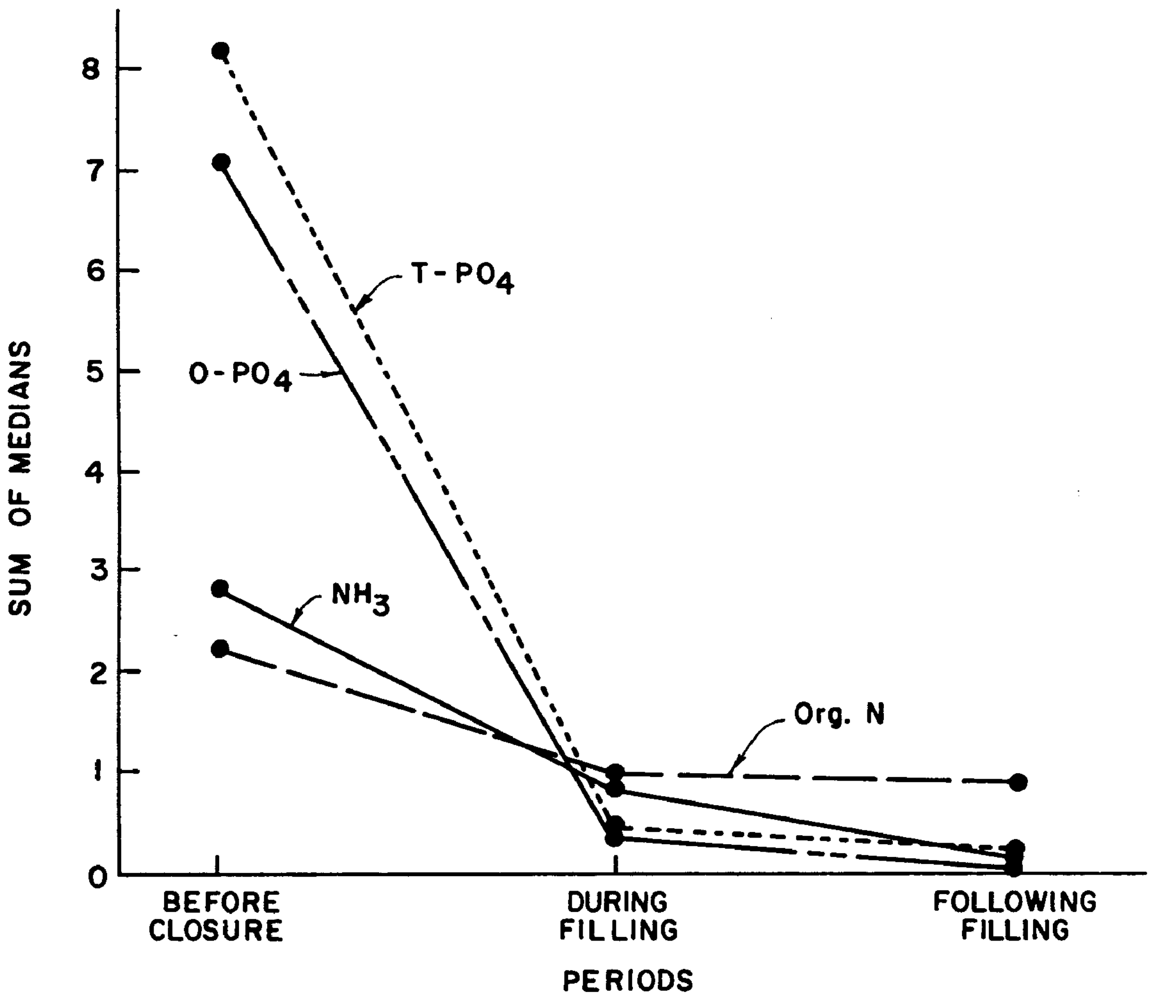

FIGURE 2. SUM OF CELL MEDIANS FOR STREAM STATIONS BY TEST PERIOD FOR TOTAL PHOSPHATE, ORTHO PHOSPHATE, ORGANIC NITROGEN, AND AMMONIA. (BASED ON VALUES IN APPENDIX TABLE II)

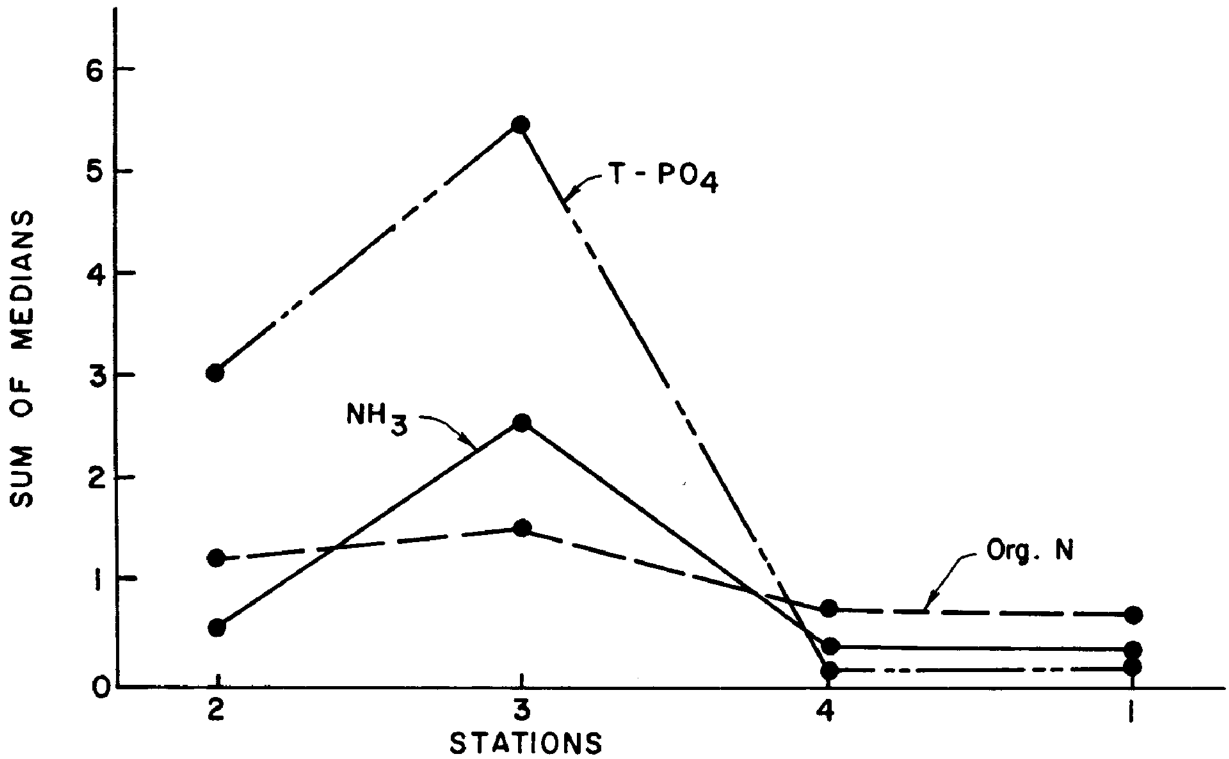

FIGURE 3. SUM OF CELL MEDIANS FOR TEST PERIODS BY STREAM STATION FOR TOTAL PHOSPHATE, AMMONIA, AND ORGANIC NITROGEN.
(BASED ON VALUES IN APPENDIX TABLE II)

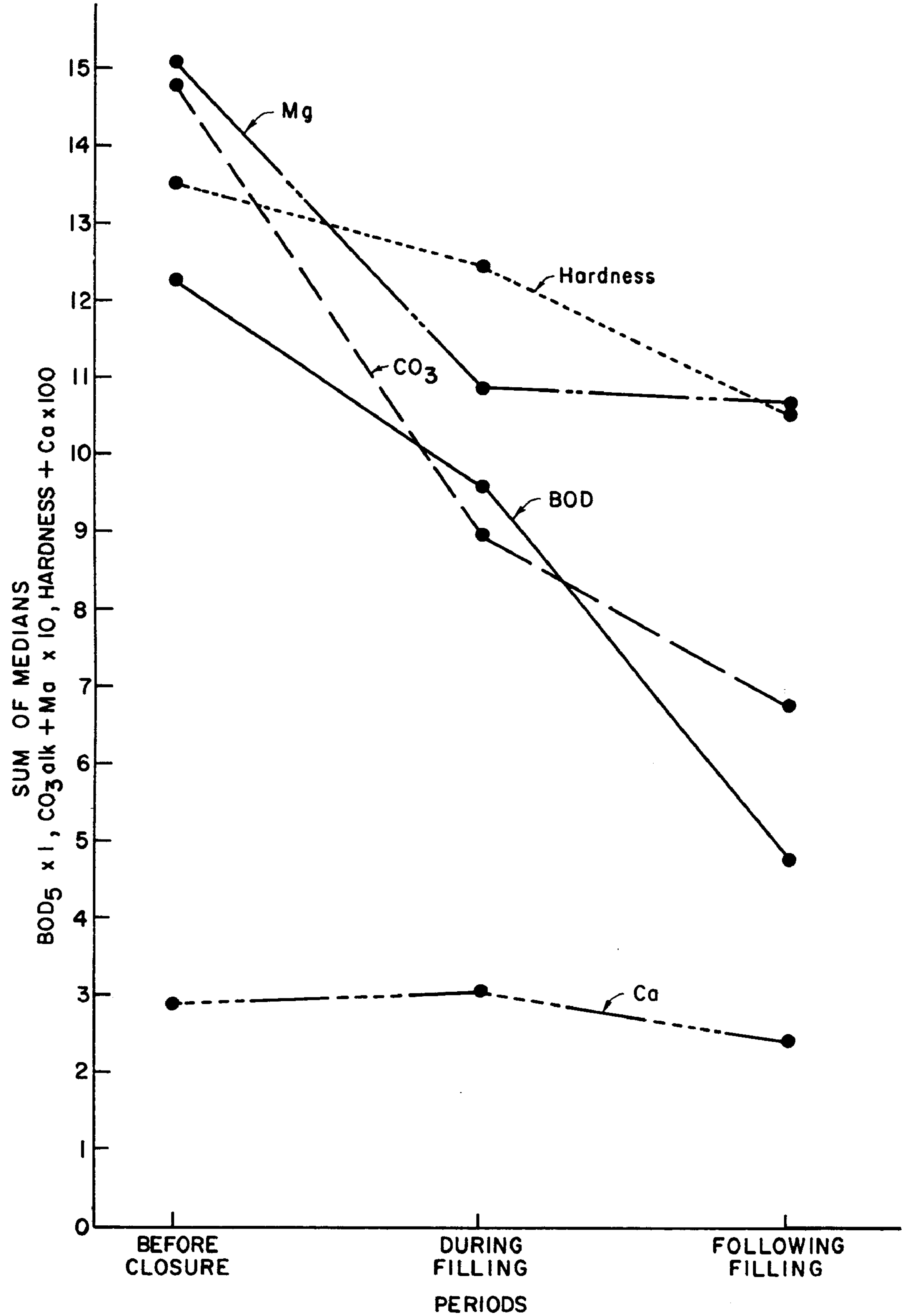

FIGURE 4. SUM OF CELL MEDIANS FOR STREAM STATIONS BY TEST PERIOD FOR MAGNESIUM, CALCIUM, CARBONATE ALKALINITY, HARDNESS, AND BOD_5 (BASED ON VALUES IN APPENDIX TABLE II)

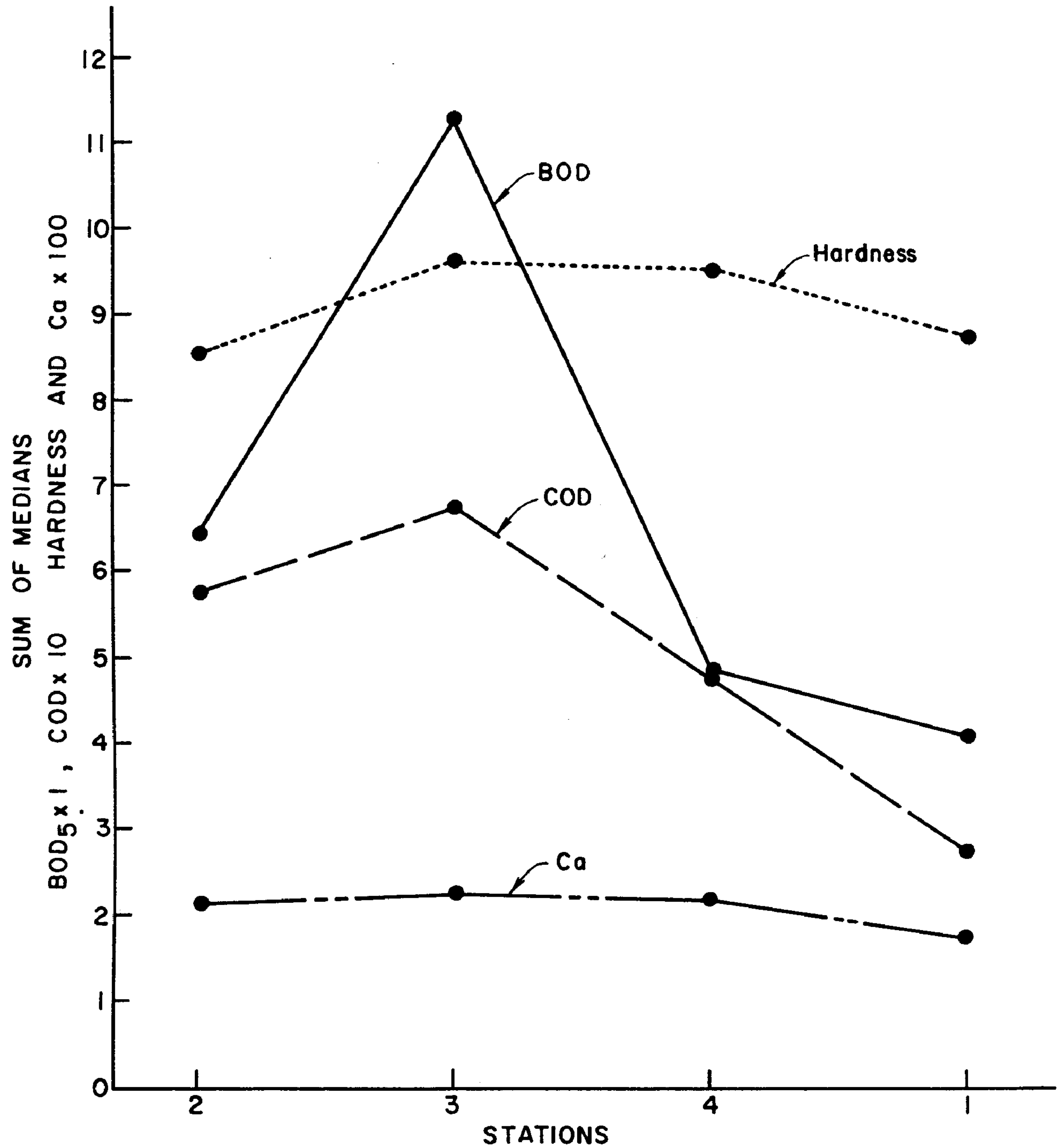

FIGURE 5. SUM OF CELL MEDIANS FOR TEST PERIODS BY STREAM STATION FOR HARDNESS, CALCIUM, BOD_5 AND COD. (BASED ON VALUES IN APPENDIX TABLE II)

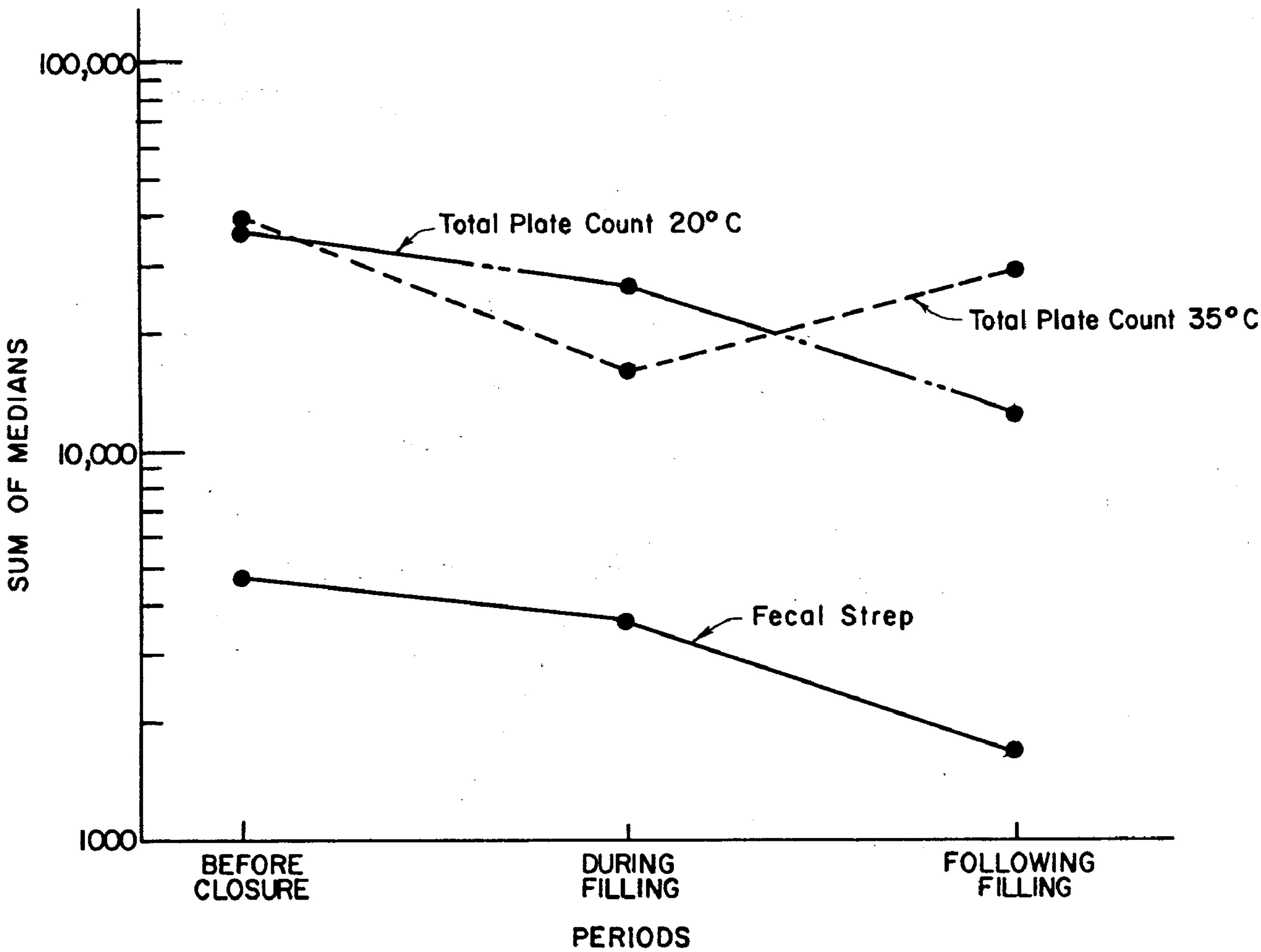

FIGURE 6. SUM OF CELL MEDIANS FOR STREAM STATIONS BY TEST PERIODS FOR FECAL STREPTOCOCCI, TOTAL PLATE COUNT AT 20°C AND TOTAL PLATE COUNT AT 35°C. (BASED ON VALUES IN APPENDIX TABLE II)

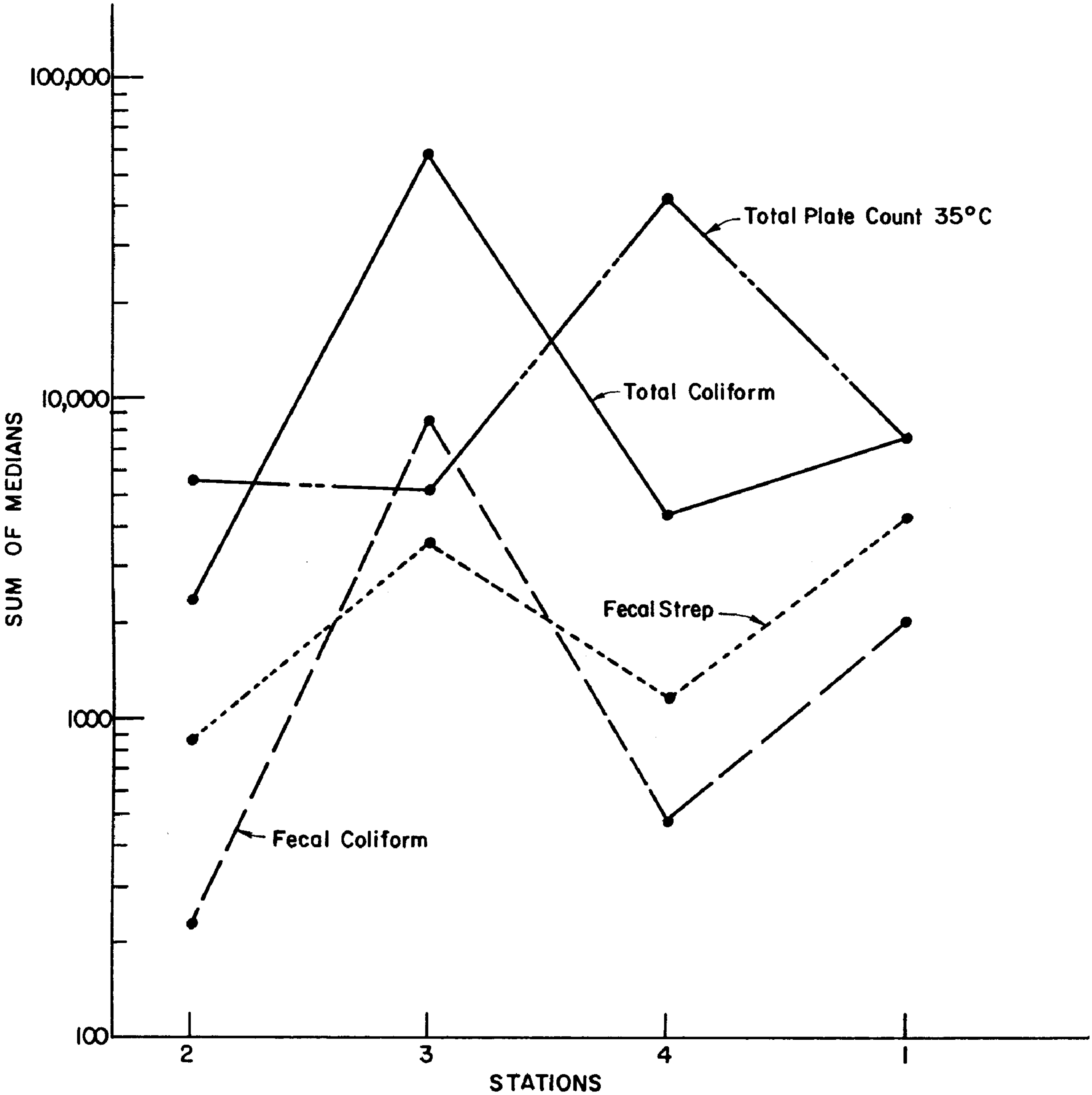

FIGURE 7. SUM OF CELL MEDIANS FOR TEST PERIODS BY STREAM STATION FOR TOTAL COLIFORM, FECAL COLIFORM, FECAL STREPTOCOCCI, AND TOTAL PLATE COUNT AT 35°C. (BASED ON VALUES IN APPENDIX TABLE II)

period following filling, and the greatest decrease in total plate count at 35°C occurred at Station 4 during the filling period.

A significant difference exists in the chi-squares analysis among stations for BOD, Stations 2 and 3 having the highest values. Decreases in BOD occurred during both periods following closure of the dam. Significant differences also exist among stations for COD, total coliform, and fecal coliform, with Stations 2 and 3 having the highest COD values and Stations 1 and 3 having the highest fecal coliform and total coliform values. However, there was no significant difference among periods for these three parameters.

SECTION V

WATER QUALITY CHANGES WITHIN THE IMPOUNDMENT

A non-parametric analysis of chi-squares with interaction was performed on chemical, physical, and biological data collected within the impoundment. Several groupings of data were used in order to determine overall differences among stations at the one-foot sampling depth and effects of season, depth, and year on water quality at the central pool station (Appendix Tables 3, 4, 5, 6, 7, and 8). Differences are inferred on a probability basis at the 0.05 level of significance. Only study parameters, having good data representation for all factors of comparison, were selected for the chi-squares analysis. Data for other parameters are shown in Appendix Table 9.

Several procedures were used to develop input for the chi-squares analysis, which represented the status of phytoplankton and macroinvertebrate populations. Diversity per individual ($\overline{D}$) and redundancy (R) values were computed using information theory techniques.(8,9) Nonparametric classification procedures were used to transform $\overline{D}$ and R values to a single index number.(10,11) The magnitude of the index number obtained indicates the distance from a "desert" in terms of organizational structure of the population. The zero or control point corresponds to the most severe condition possible where R=1 and $\overline{D}$=0 and is standardized by dividing by the ranked variance.(12)

At the one-foot depth, differences were compared with respect to station, season, and year (Table II). Except for filterable and total residue, there was no significant difference in station comparisons with season and year, and interactions for all station comparisons were non-significant. In comparisons of season with station and year, there were significant differences for all parameters analyzed except total phosphate, pH, total residue, and filterable residue. However, interactions were significant for ortho-phosphate, ammonia, bicarbonate alkalinity, phytoplankton, and chloride in the grouping to compare season and year. Differences were significant for pH, bicarbonate alkalinity, total residue, filterable residue, chloride, phytoplankton, macroinvertebrates, and conductivity in comparisons of year with station and season, and interactions were significant for bicarbonate alkalinity, phytoplankton, and chloride for the grouping to compare season and year.

The sum of medians was plotted for all parameters in each grouping having a significant difference where no significant interaction existed (Figures 8 through 17). These plots emphasize the points having the greatest differences for station, season, and year.

TABLE II

SUMMARY OF STATISTICAL INFERENCES FROM CHI-SQUARES ANALYSIS FOR MEASUREMENTS AT THE ONE-FOOT DEPTH AT ALL IMPOUNDMENT STATIONS[a]

		Analytical Groupings[b]								
		ST x SE			ST x Y			SE x Y		
PARAMETERS		ST	SE	I	ST	Y	I	SE	Y	I
Total PO_4		N	N	N	N	N	N	N	N	N
Ortho-PO_4		N	S	N	N	N	N	S	N	S
NO_3		N	S	N	N	N	N	S	N	N
NH_3		N	S	N	N	N	N	S	N	S
Organic Nitrogen		N	S	N	N	N	N	S	N	N
pH		N	N	N	N	S	N	N	S	N
HCO_3 Alkalinity		N	S	N	N	S	N	S	S	S
Total Residue		S	N	N	S	S	N	N	S	N
Filterable Residue		S	N	N	S	S	N	N	S	N
Temperature		N	S	N	N	N	N	S	N	N
Dissolved Oxygen		N	S	N	N	N	N	S	N	N
Cl		N	S	N	N	S	N	S	S	S
SO_4		N	S	N	N	N	N	S	N	N
Conductivity		N	S	N	N	S	N	S	S	N
Macroinvertebrates		N	S	N	N	S	N	S	S	N
Phytoplankton		N	S	N	N	S	N	S	S	S
TOTALS:	S	2	12	0	2	8	0	12	8	5
	N	14	4	16	14	8	16	4	8	11

[a]ST represents Station, SE represents Season, Y represents Year and I represents Interaction.

[b]Inferences are at the 0.05 level with listings either as significant (S) or non-significant (N).

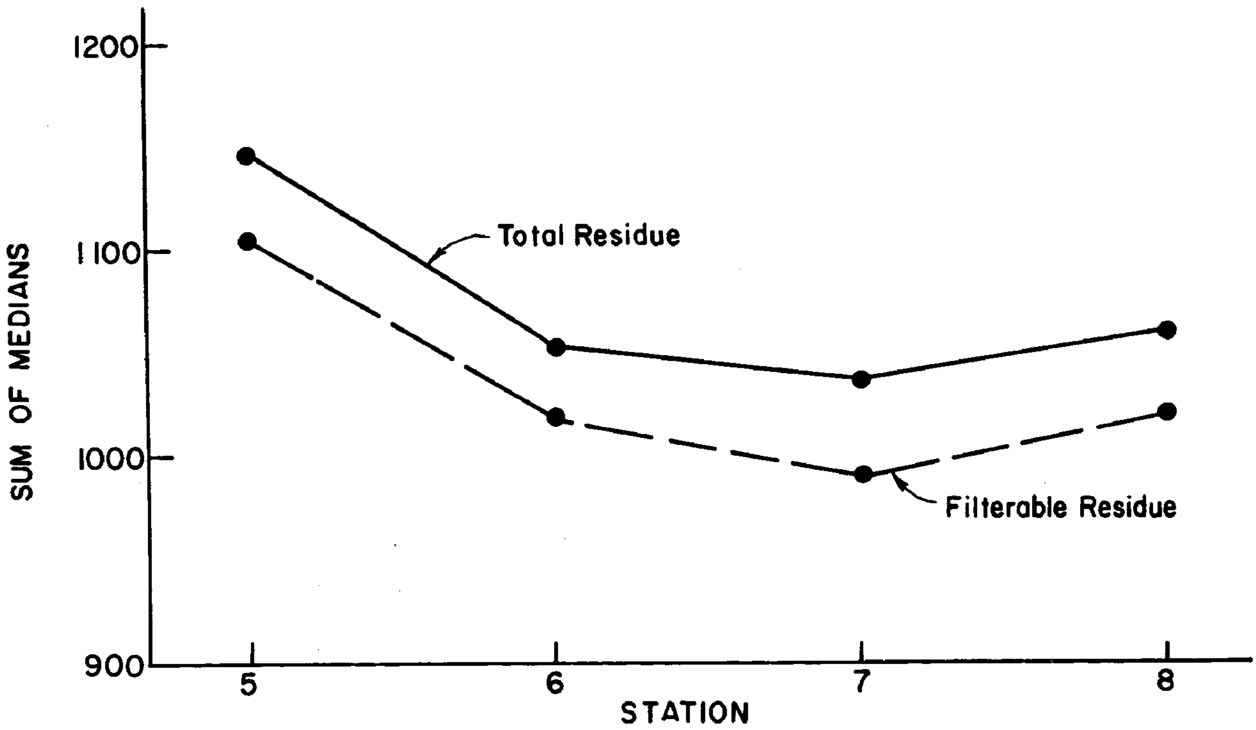

FIGURE 8. SUM OF SEASONAL CELL MEDIANS BY STATION FOR TOTAL RESIDUE AND FILTERABLE RESIDUE.

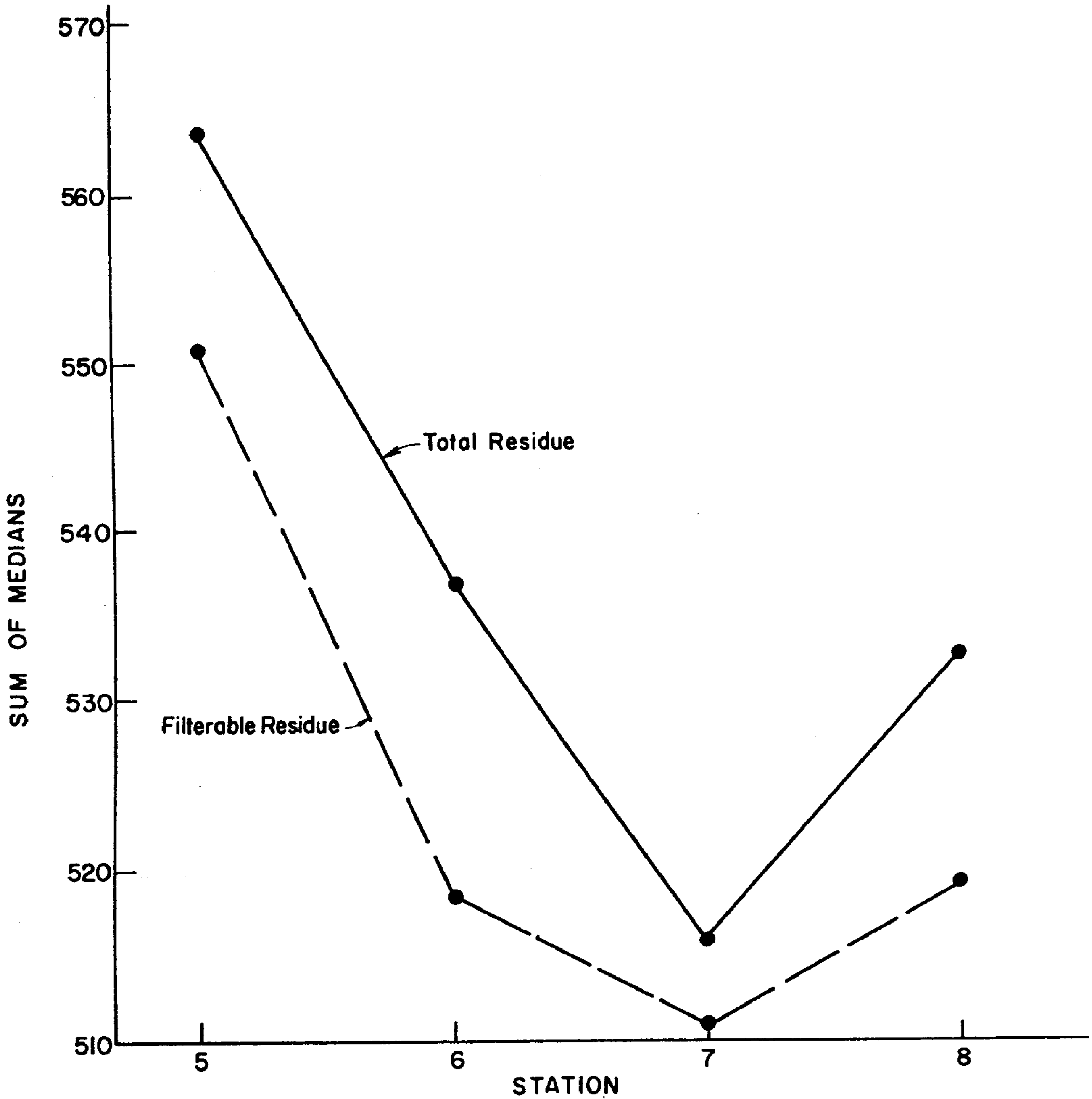

FIGURE 9. SUM OF CELL MEDIANS FOR A TWO-YEAR PERIOD BY STATION FOR TOTAL RESIDUE AND FILTERABLE RESIDUE.

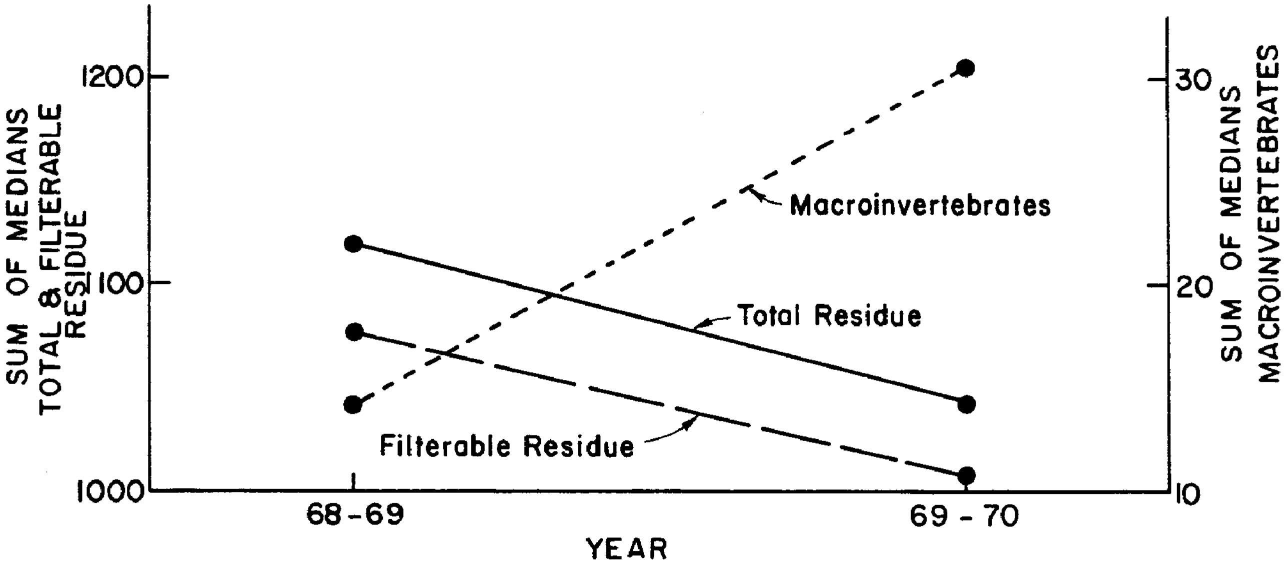

FIGURE 10. SUM OF SEASONAL CELL MEDIANS BY YEAR FOR TOTAL RESIDUE, FILTERABLE RESIDUE, AND MACROINVERTEBRATES.

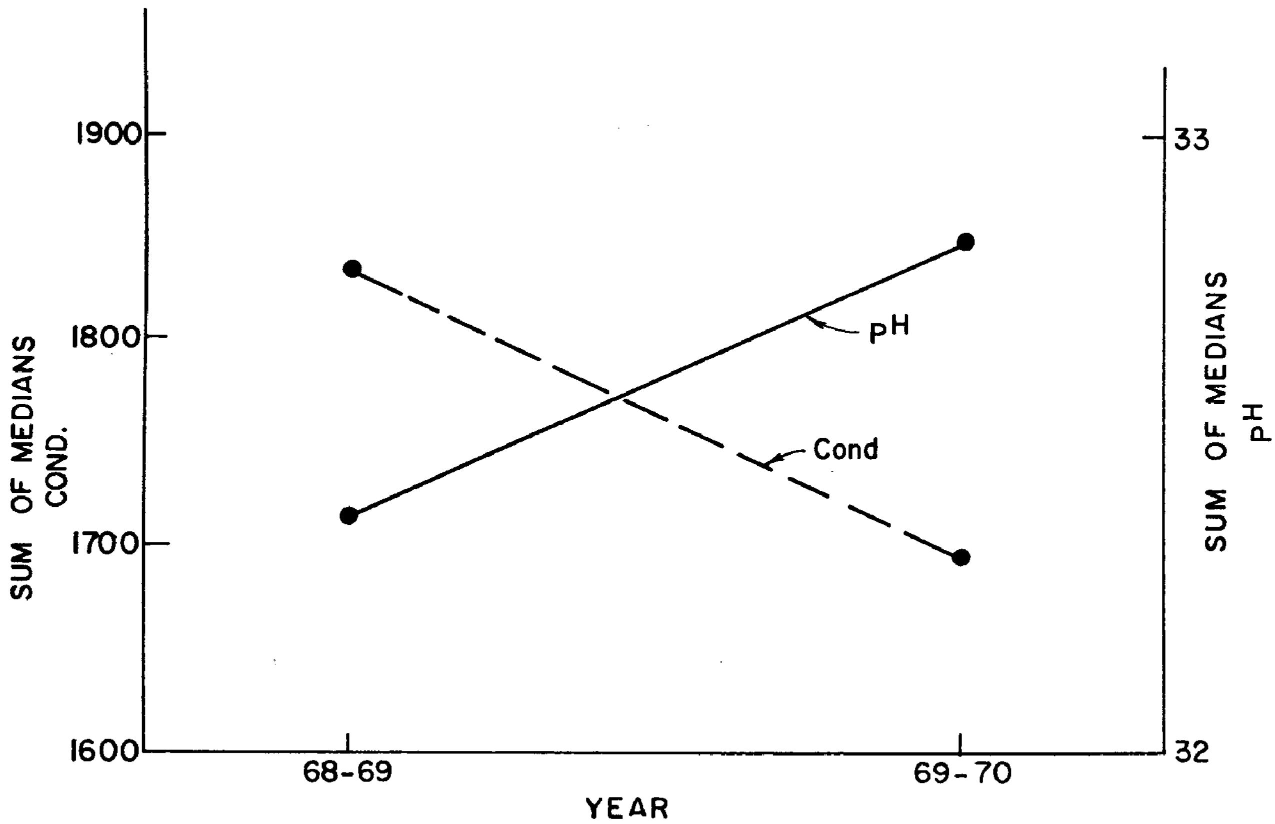

FIGURE 11. SUM OF SEASONAL CELL MEDIANS BY YEAR FOR pH AND CONDUCTIVITY.

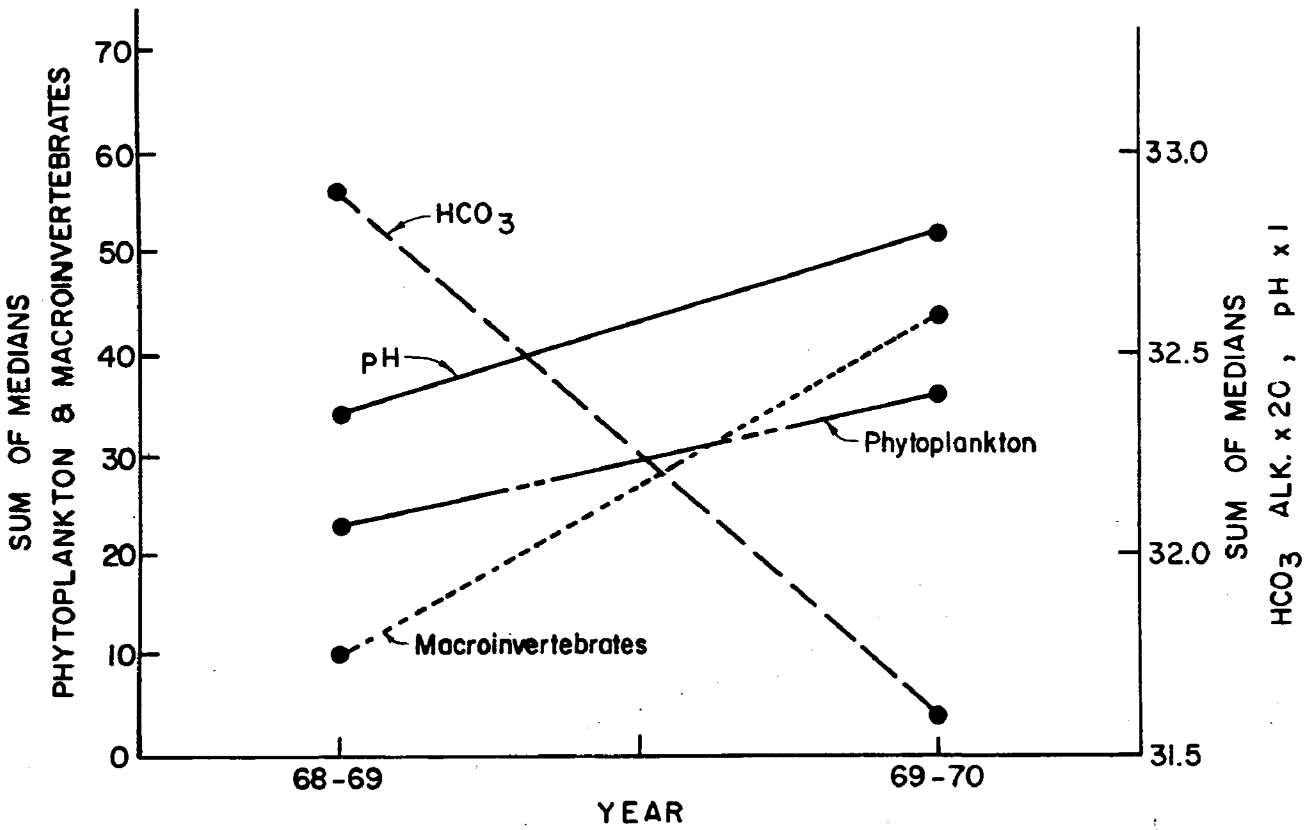

FIGURE 12. SUM OF CELL MEDIANS FOR IMPOUNDMENT STATIONS BY YEAR FOR pH, BICARBONATE ALKALINITY, PHYTOPLANKTON, AND MACROINVERTEBRATES.

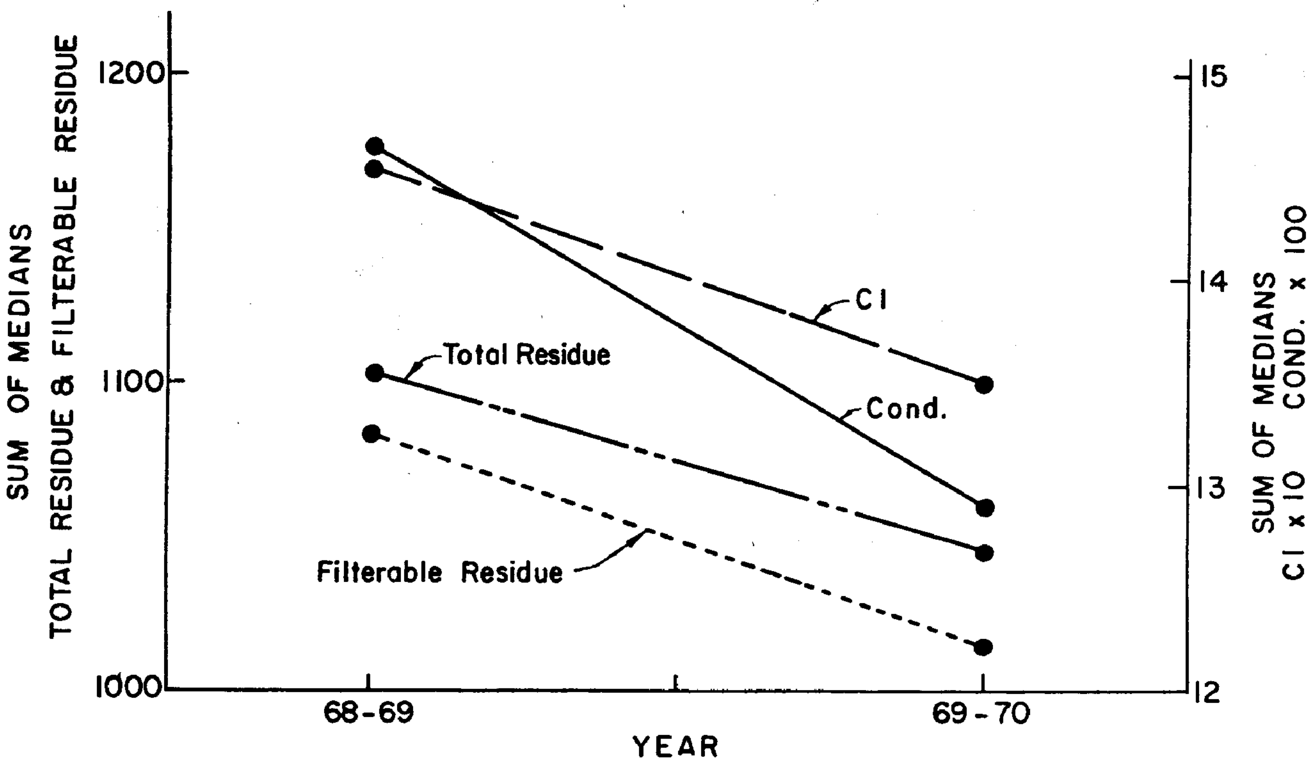

FIGURE 13. SUM OF CELL MEDIANS FOR IMPOUNDMENT STATIONS BY YEAR FOR CHLORIDE, CONDUCTIVITY, TOTAL RESIDUE, AND FILTERABLE RESIDUE.

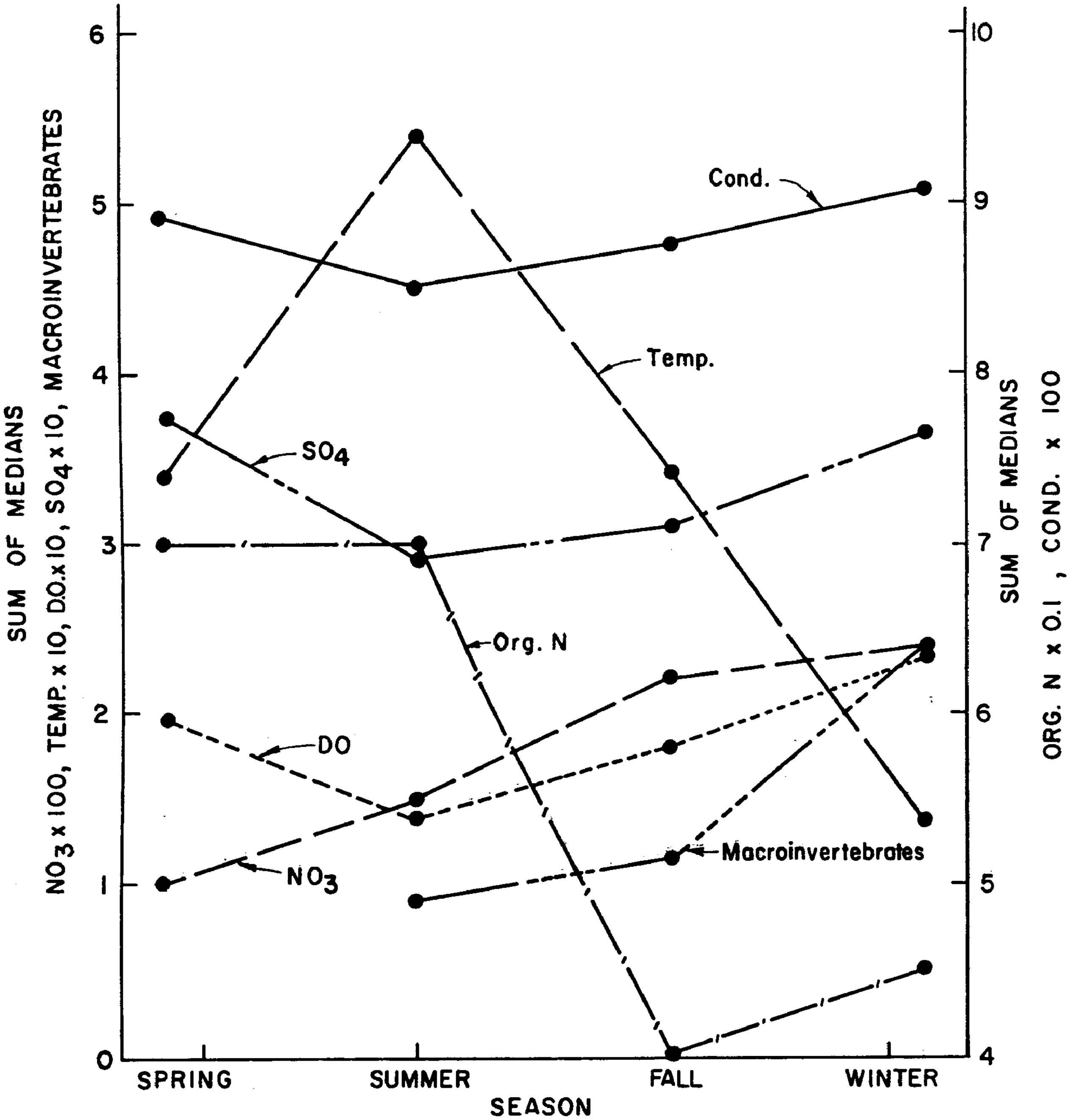

FIGURE 14. SUM OF CELL MEDIANS FOR A TWO-YEAR PERIOD BY SEASON FOR NITRATE, ORGANIC NITROGEN, TEMPERATURE, DISSOLVED OXYGEN, SULPHATE, CONDUCTIVITY, AND MACROINVERTEBRATES.

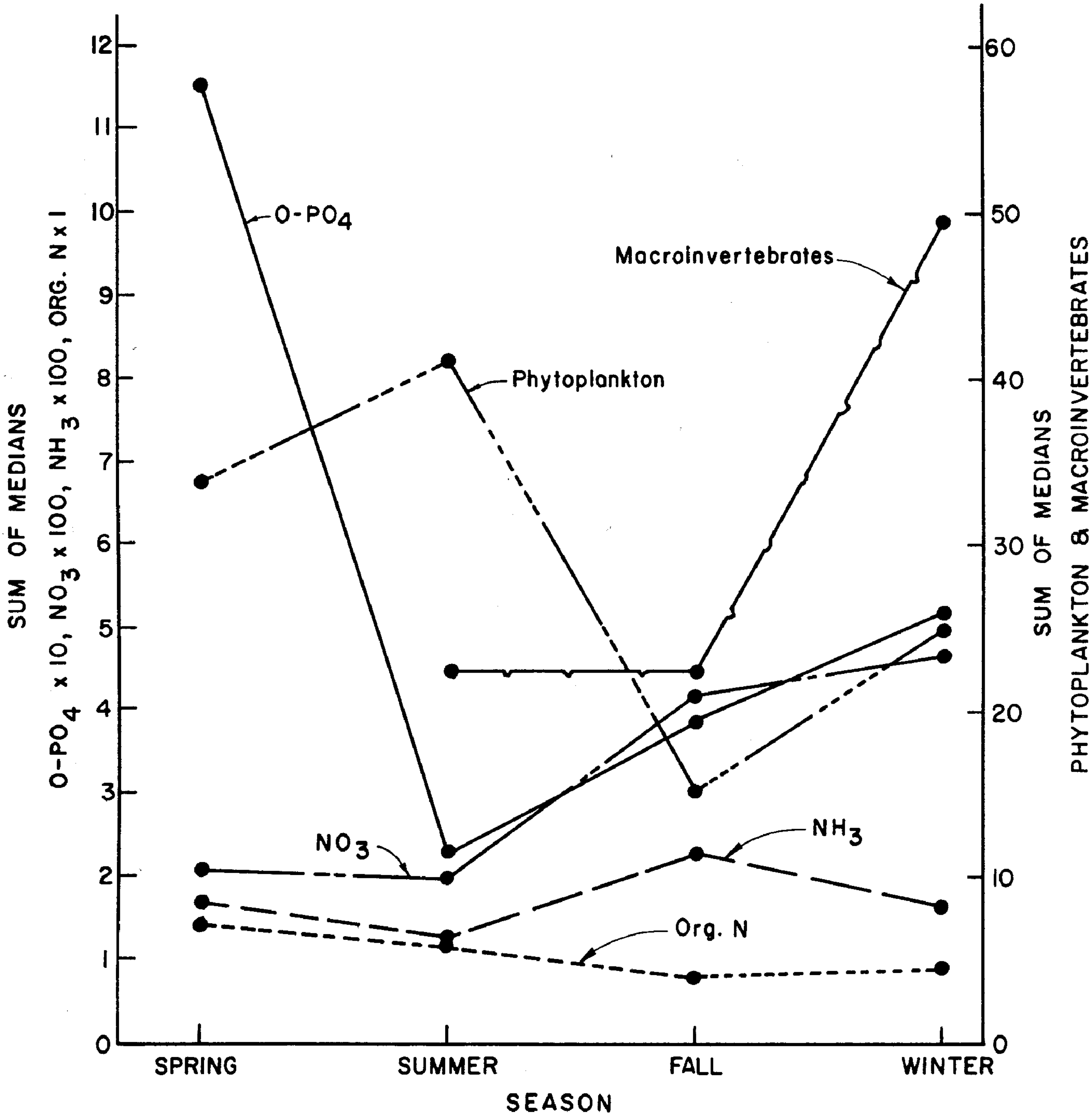

FIGURE 15. SUM OF CELL MEDIANS FOR IMPOUNDMENT STATIONS BY SEASON FOR ORTHO PHOSPHATE, NITRATE, AMMONIA, ORGANIC NITROGEN, PHYTOPLANKTON, AND MACROINVERTEBRATES.

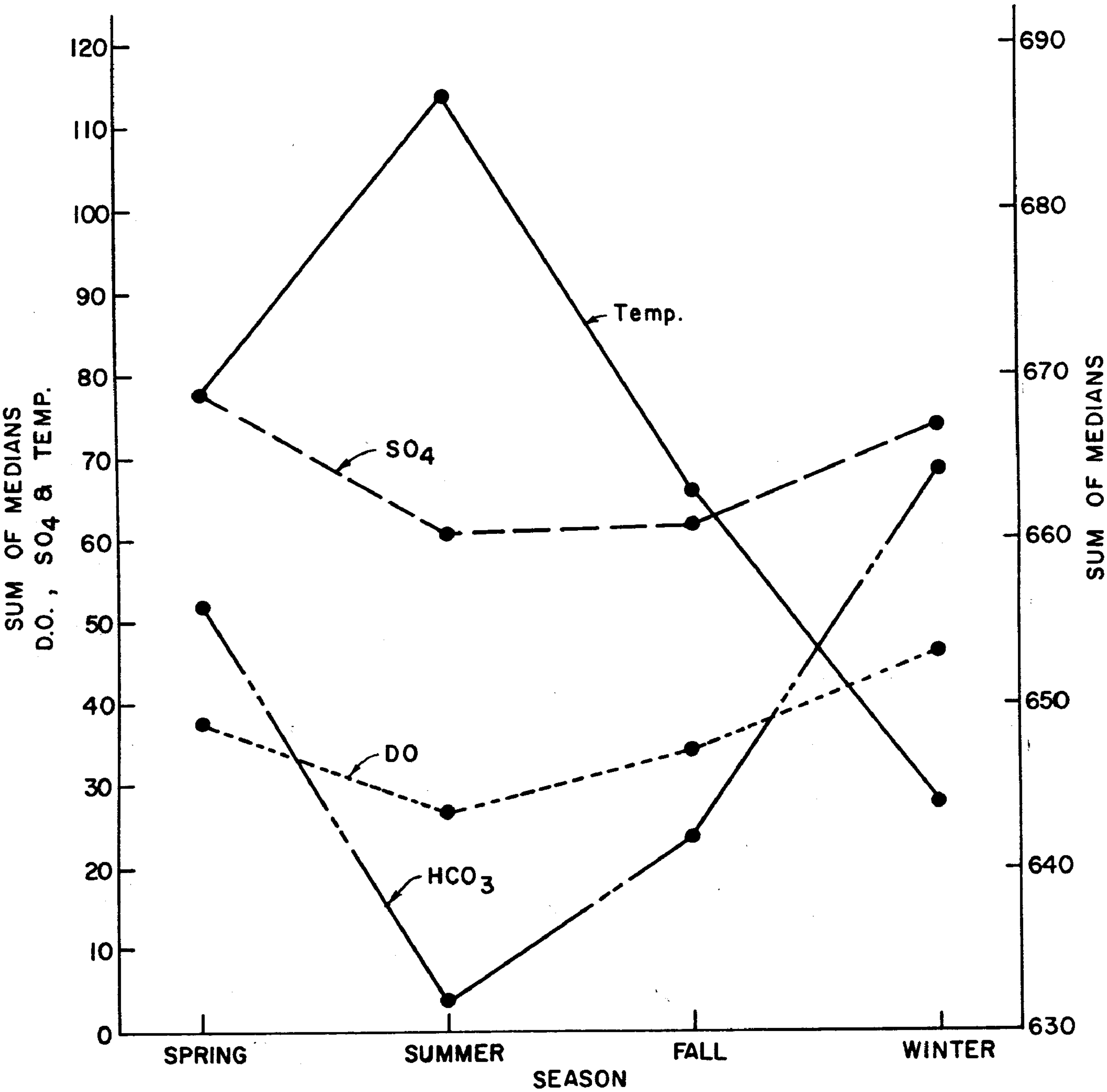

FIGURE 16. SUM OF CELL MEDIANS FOR IMPOUNDMENT STATIONS BY SEASON FOR TEMPERATURE, SULPHATE, DISSOLVED OXYGEN, AND BICARBONATE ALKALINITY.

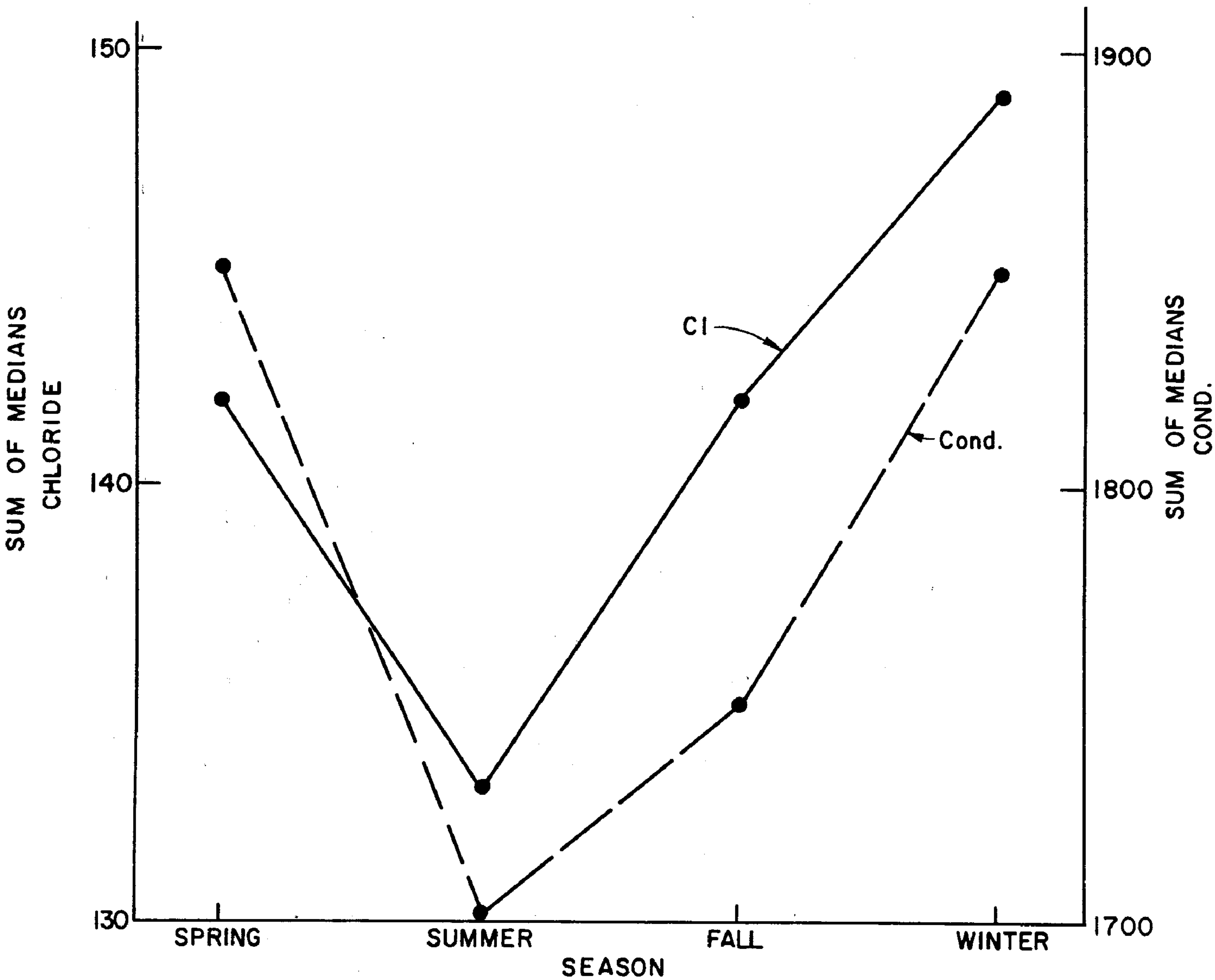

FIGURE 17. SUM OF CELL MEDIANS FOR IMPOUNDMENT STATIONS BY SEASON FOR CHLORIDE AND CONDUCTIVITY.

In station groupings, values for total residue and filterable residue were highest in the Rock Creek Arm in comparisons with both season and year (Figures 8 and 9). The central pool had the lowest values for total residue and filterable residue in both comparisons.

In groupings by year, values for total residue, filterable residue, and conductivity decreased and values for macroinvertebrates and pH increased for the second year in comparisons with both season and station (Figures 10 through 13). Values for bicarbonate alkalinity and chloride decreased and phytoplankton increased for the second year only in comparisons with stations.

The largest number of significant differences occurred in seasonal groupings (Figures 14 through 17). Values for temperature show the expected seasonal variations in comparisons with year and station. The sum of medians in both comparisons was lowest in the summer for conductivity, dissolved oxygen, and sulphate, and in the fall for organic nitrogen. Values for nitrate and macroinvertebrates were highest in winter in comparisons of season with year and station. In seasonal comparisons with station, values for chloride, ortho-phosphate, bicarbonate alkalinity, and ammonia were lowest in the summer and values for ortho-phosphate and ammonia were highest in the spring and fall, respectively. The sum of medians at stations for phytoplankton was highest in the summer.

Vertical profile measurements at the central pool station were compared with respect to depth, season, and year (Table III). Significant differences in depth comparisons with season and year include total phosphate, ortho-phosphate, ammonia, and pH, and interactions for all depth comparisons were non-significant. In comparisons of season with depth, there were significant seasonal differences for all parameters analyzed except ammonia, bicarbonate alkalinity, total residue, phytoplankton, and conductivity, while in comparisons of season with year, significant seasonal differences occurred for all parameters except ortho-phosphate, ammonia, bicarbonate alkalinity, and filterable residue, and significant interactions occurred for organic nitrogen, temperature, chloride, and conductivity. Differences between years were significant for pH, bicarbonate alkalinity, total residue, filterable residue, chloride, phytoplankton, and conductivity in comparisons of year with depth and season, and interactions were significant for bicarbonate alkalinity, phytoplankton, chloride and conductivity for the grouping to compare season and year.

The sum of medians was plotted for all parameters in each grouping having a significant difference where no significant interaction existed (Figures 18 through 28). These plots emphasize points having the greatest differences at the central pool station for depth, season, and year.

TABLE III

SUMMARY OF STATISTICAL INFERENCES
FROM CHI-SQUARES ANALYSIS FOR VERTICAL PROFILE MEASUREMENTS AT STATION 7[a]

		Analytical Groupings[b]								
		D x SE			D x Y			SE x Y		
Parameters		D	SE	I	D	Y	I	SE	Y	I
Total PO_4		S	S	N	S	N	N	S	N	N
Ortho-PO_4		S	S	N	S	N	N	N	N	N
NO_3		N	S	N	N	N	N	S	N	N
NH_4		S	N	N	S	N	N	N	N	S
Organic Nitrogen		N	S	N	N	N	N	S	N	S
pH		S	S	N	S	S	N	S	S	N
HCO_3 Alkalinity		N	N	N	N	S	N	N	S	S
Total Residue		N	N	N	N	S	N	S	S	N
Filterable Residue		N	S	N	N	S	N	N	S	N
Temperature		N	S	N	N	N	N	S	N	S
Dissolved Oxygen		N	S	N	N	N	N	S	N	N
Cl		N	S	N	N	S	N	S	S	S
SO_4		N	S	N	N	N	N	S	N	N
Conductivity		N	N	N	N	S	N	S	S	S
Phytoplankton		N	N	N	N	S	N	N	S	S
TOTALS	S	4	10	0	4	7	0	10	7	7
	N	11	5	15	11	8	15	5	8	8

[a]Inferences are at the 0.05 level with listings either as significant (S)or non-significant (N).

[b]D represents depth, SE represents Season, Y represents Year and I represents Interaction.

In groupings by depth values for total phosphate, ortho-phosphate and ammonia were highest at the 75-foot level in comparisons for both season and year (Figures 18 through 20). In general, values for the parameters increased with increasing depth beyond the 30-foot level. The 75-foot level had the lowest value for pH and values decreased with increasing depth beyond the 15-foot level in both comparisons.

Values for total residue and filterable residue decreased and pH increased for the second year in comparisons of year with season and depth (Figures 21 through 23). Values for bicarbonate alkalinity, chloride, and conductivity decreased and phytoplankton increased for the second year only in comparisons of year with depth.

The largest number of significant differences occurred in seasonal groupings (Figures 24 through 28). Values of temperature and dissolved oxygen show the expected seasonal variations in comparisons with depth. Vertical profiles for selected dates during the two-year sampling period provide additional support for seasonal differences in dissolved oxygen and temperature (Figures 29 through 32). The sum of medians in comparisons of season with depth and year was lowest for pH and sulphate, and highest for total phosphate in the summer. Values for nitrate were higher in the fall and winter in comparisons of season with depth and year. Spring and winter values were higher for total residue in grouping season with year and for filterable residue in grouping season with depth. In seasonal comparisons with depth, ortho-phosphate was highest in the summer and organic nitrogen and chloride were highest in the spring and winter, respectively.

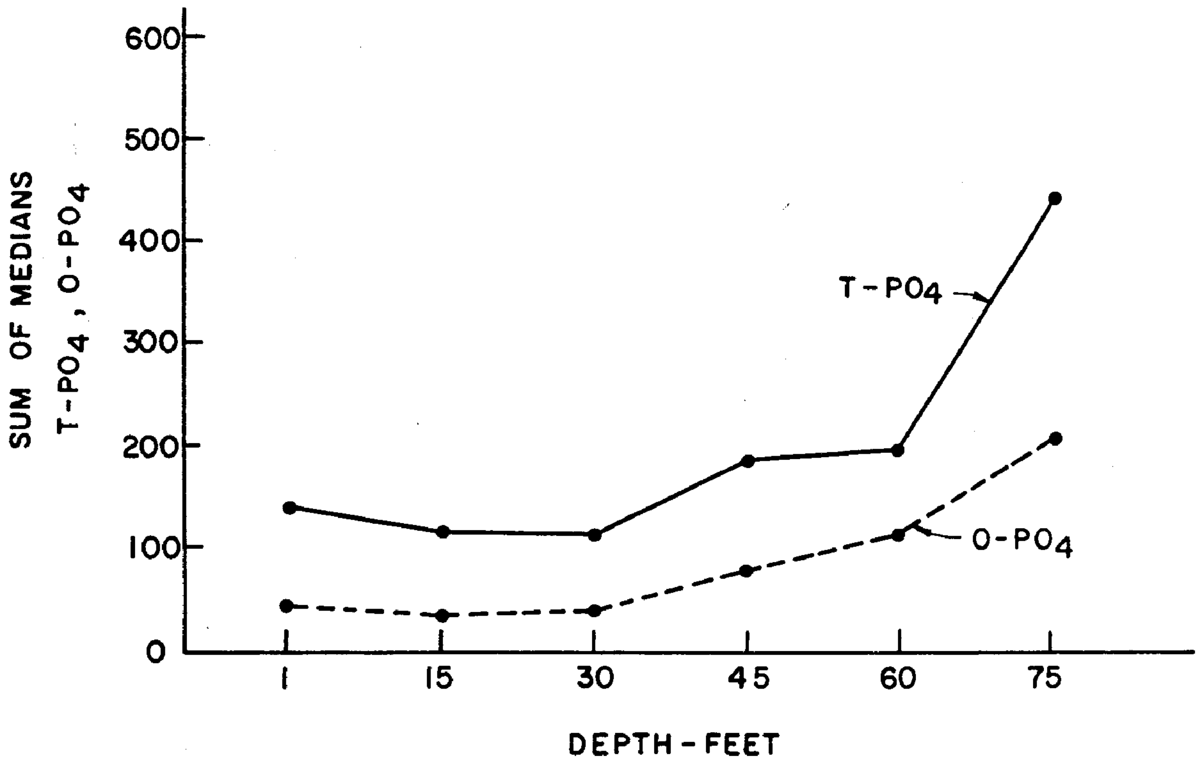

FIGURE 18. SUM OF SEASONAL CELL MEDIANS BY DEPTH AT STATION 7 FOR TOTAL PHOSPHATE AND ORTHO PHOSPHATE.

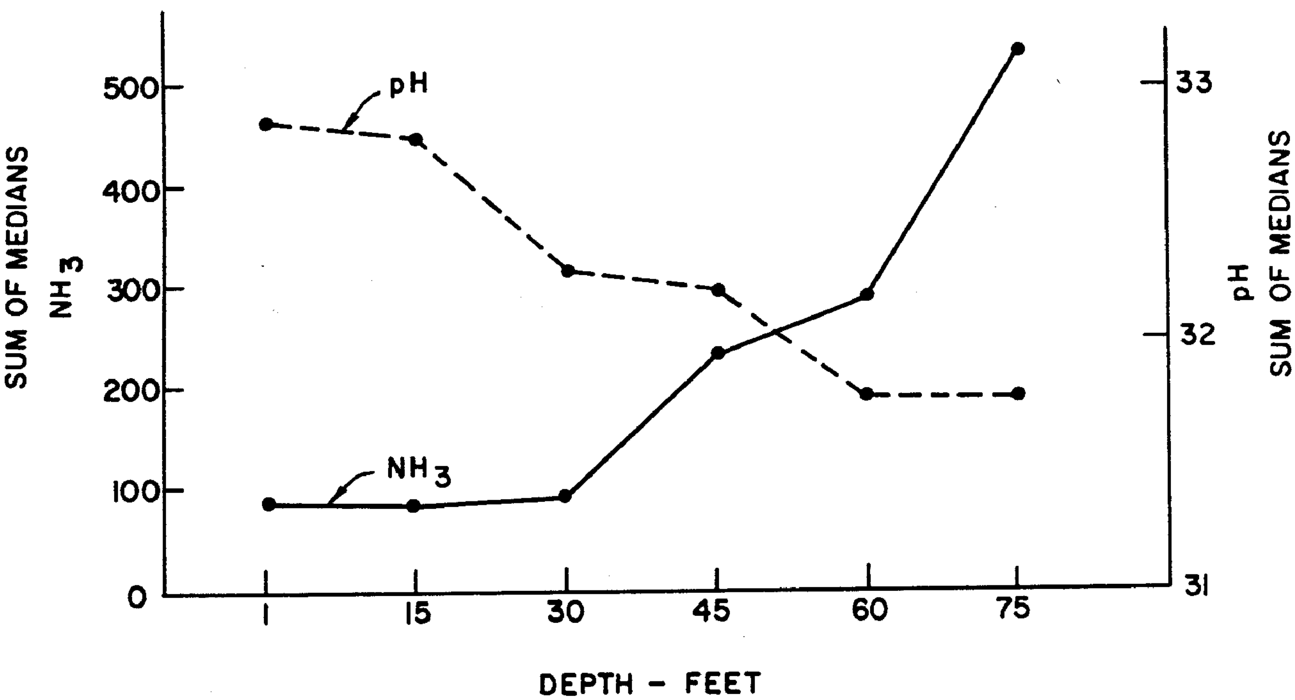

FIGURE 19. SUM OF SEASONAL CELL MEDIANS BY DEPTH AT STATION 7 FOR pH AND AMMONIA.

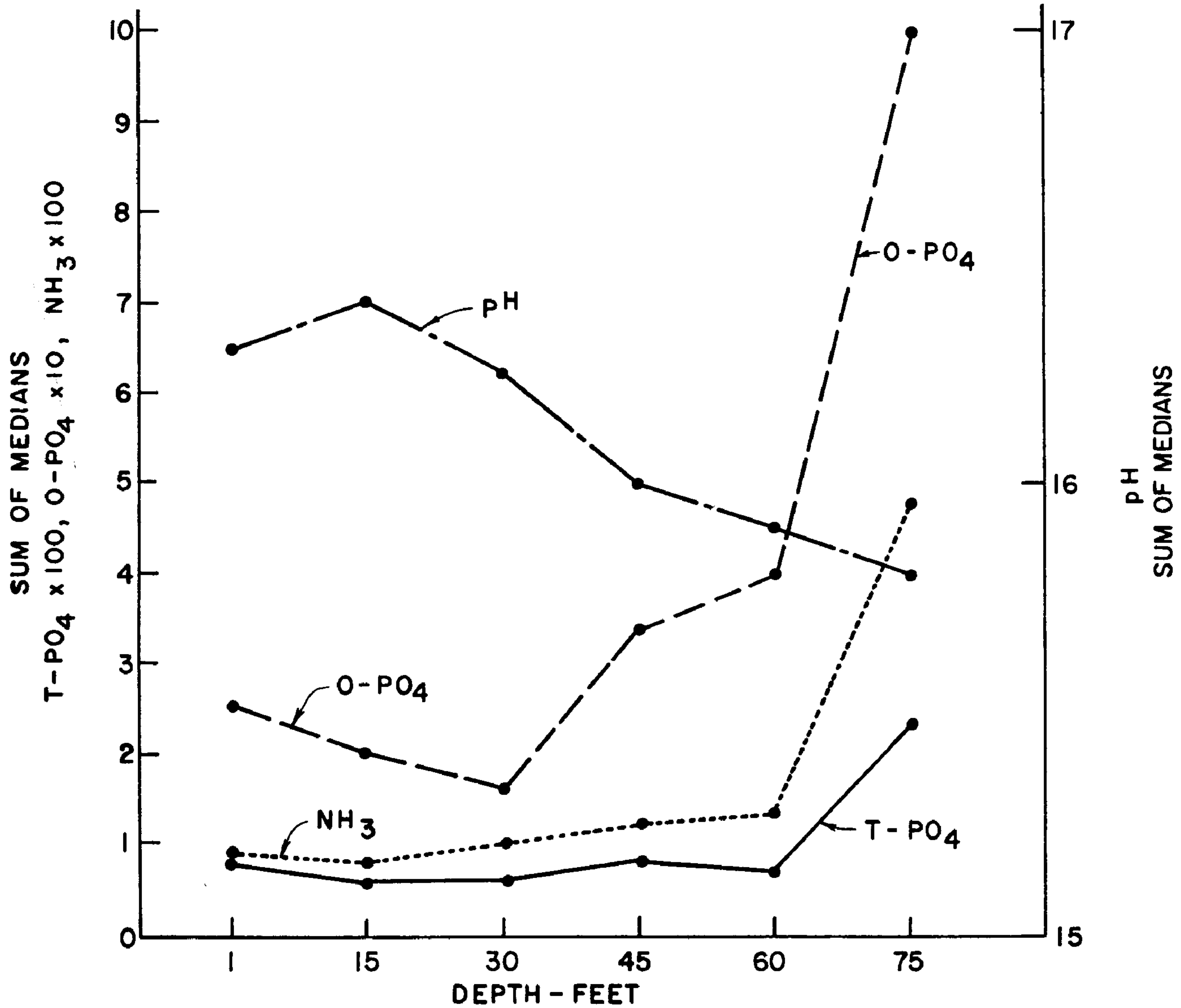

FIGURE 20. SUM OF CELL MEDIANS FOR A TWO-YEAR PERIOD BY DEPTH AT STATION 7 FOR pH, AMMONIA, TOTAL PHOSPHATE AND ORTHO PHOSPHATE.

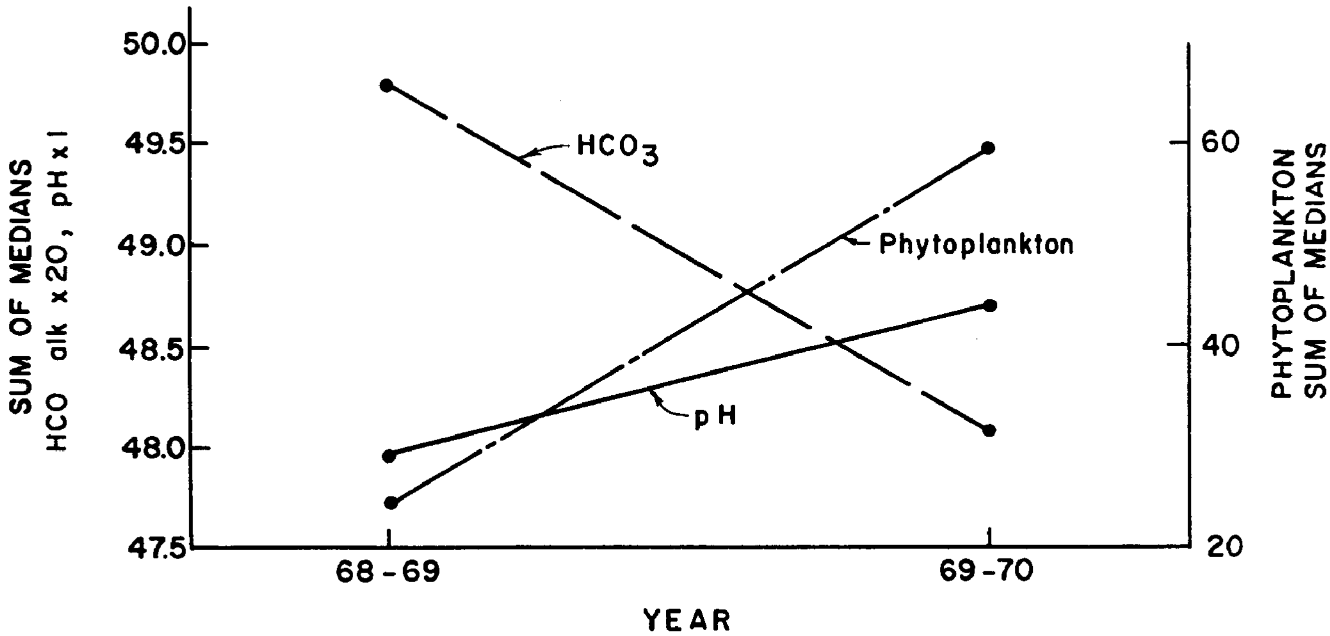

FIGURE 21. SUM OF VERTICAL PROFILE CELL MEDIANS BY YEAR AT STATION 7 FOR pH AND BICARBONATE ALKALINITY.

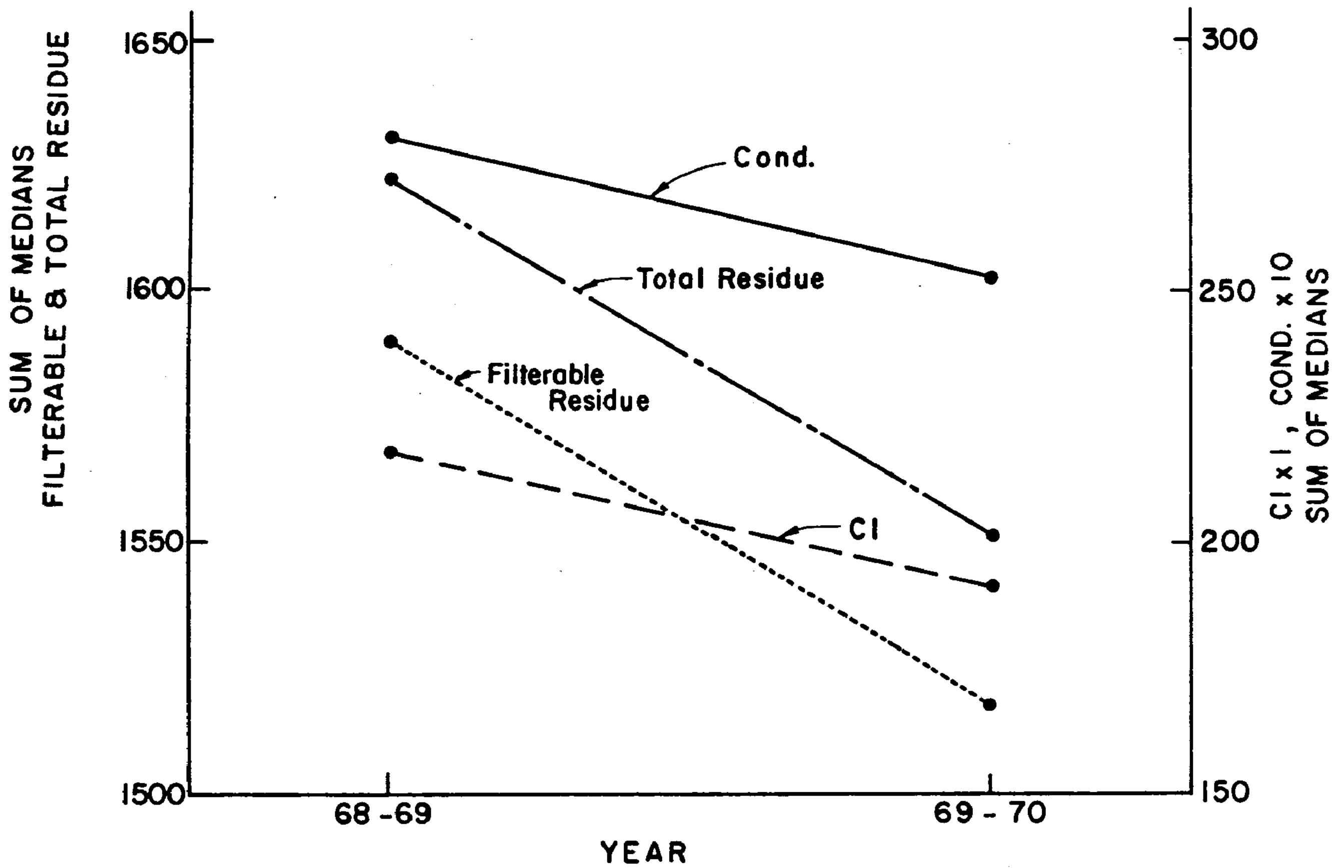

FIGURE 22. SUM OF VERTICAL PROFILE CELL MEDIAN BY YEAR AT STATION 7 FOR CHLORIDE, CONDUCTIVITY, TOTAL RESIDUE AND FILTERABLE RESIDUE.

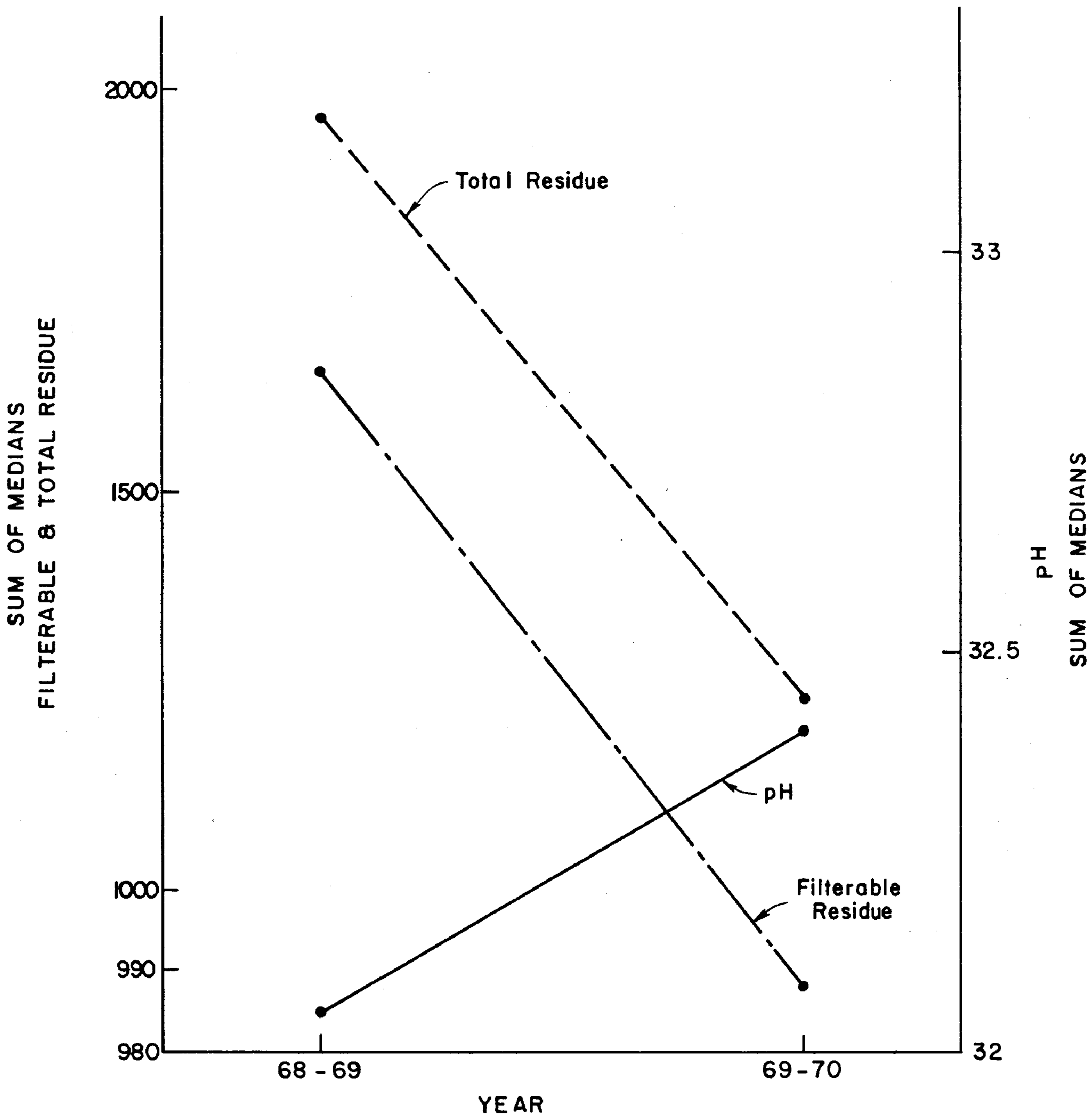

FIGURE 23. SUM OF SEASONAL CELL MEDIANS BY YEAR AT STATION 7 FOR pH, TOTAL RESIDUE AND FILTERABLE RESIDUE.

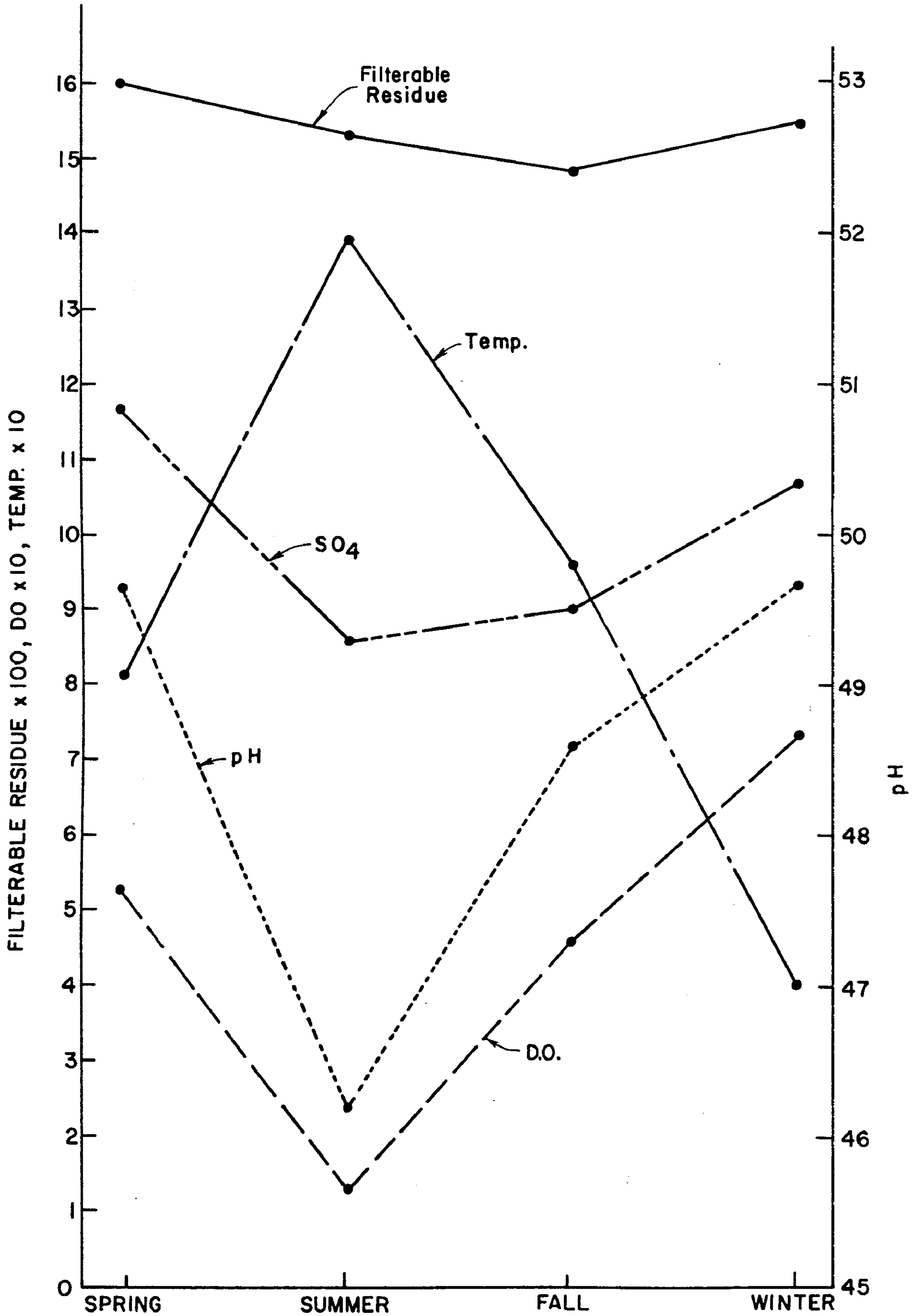

FIGURE 24. SUM OF VERTICAL PROFILE CELL MEDIANS BY SEASON AT STATION 7 FOR FILTERABLE RESIDUE, pH, TEMPERATURE, DISSOLVED OXYGEN, AND SULPHATE.

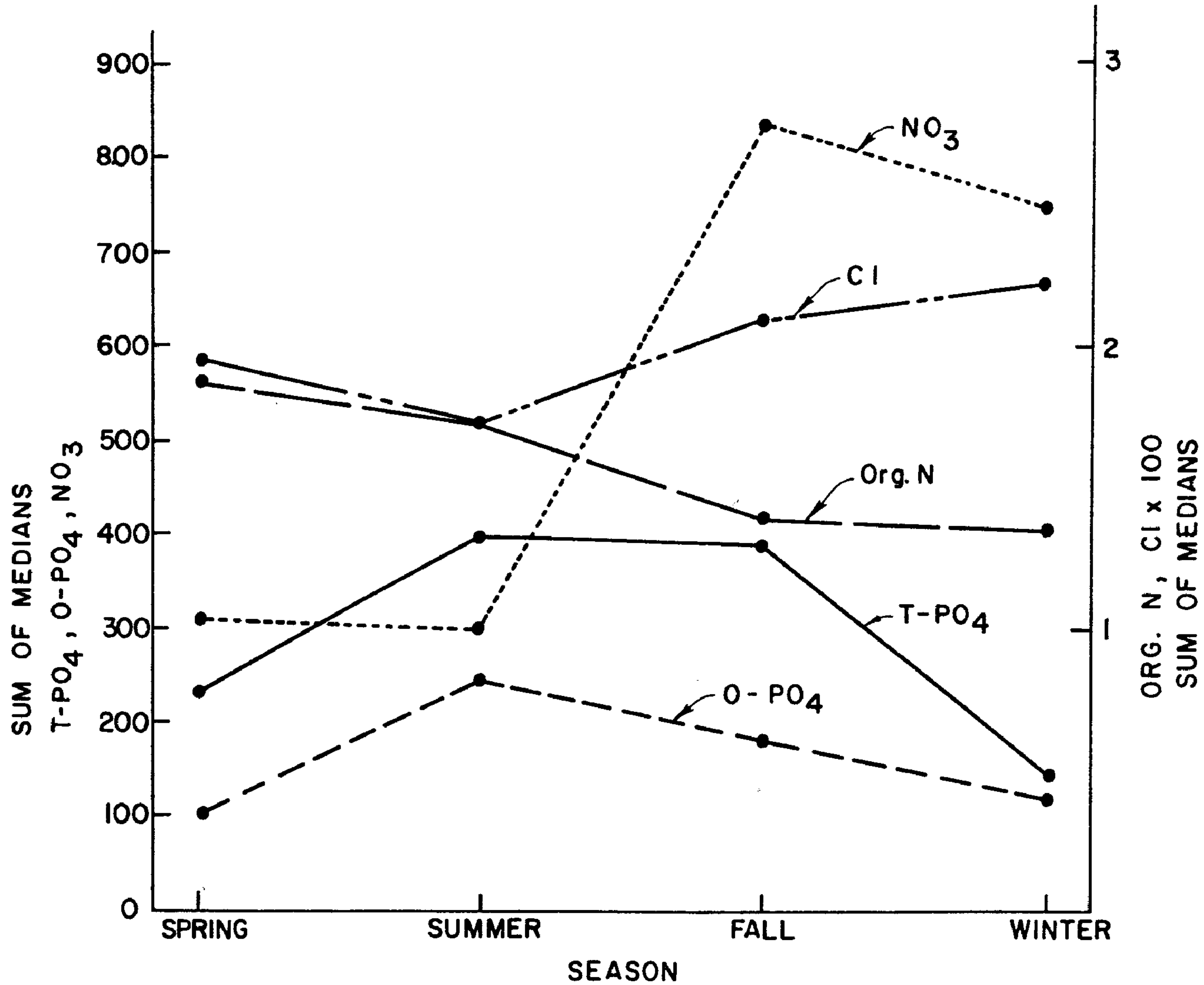

FIGURE 25. SUM OF VERTICAL PROFILE CELL MEDIANS BY SEASON AT STATION 7 FOR CHLORIDE, NITRATE, ORGANIC NITROGEN, TOTAL PHOSPHATE, AND ORTHO PHOSPHATE.

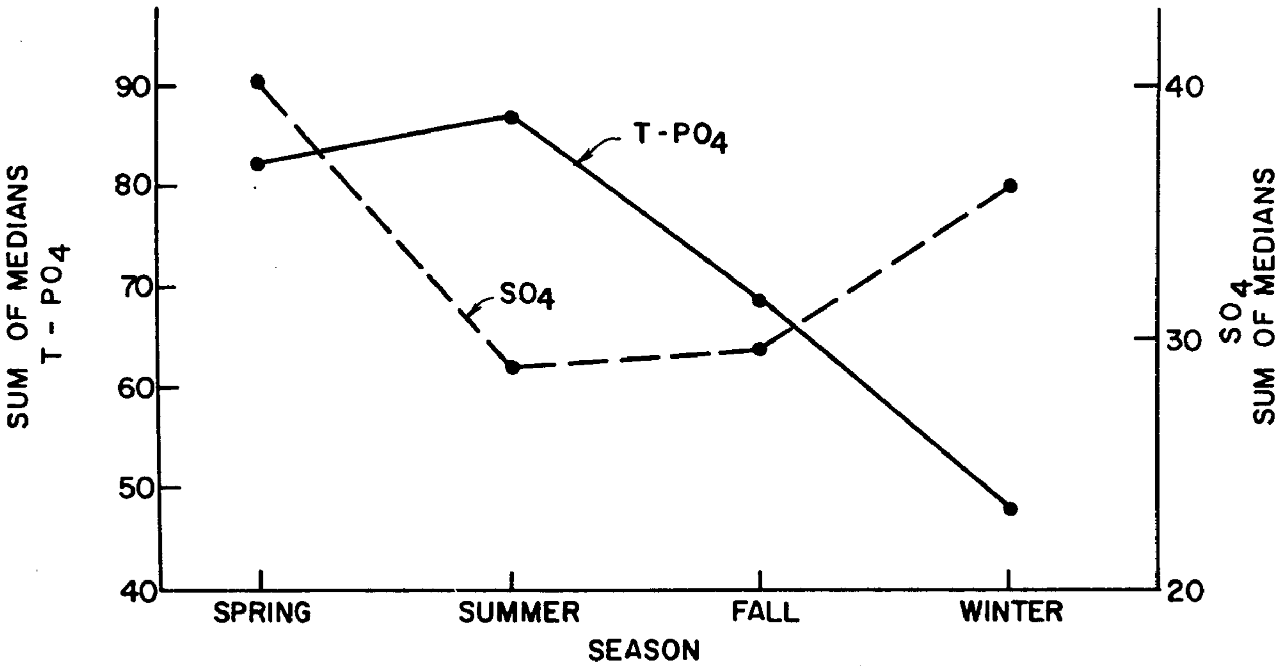

FIGURE 26. SUM OF CELL MEDIANS FOR A TWO-YEAR PERIOD BY SEASON AT STATION 7 FOR TOTAL PHOSPHATE AND SULPHATE.

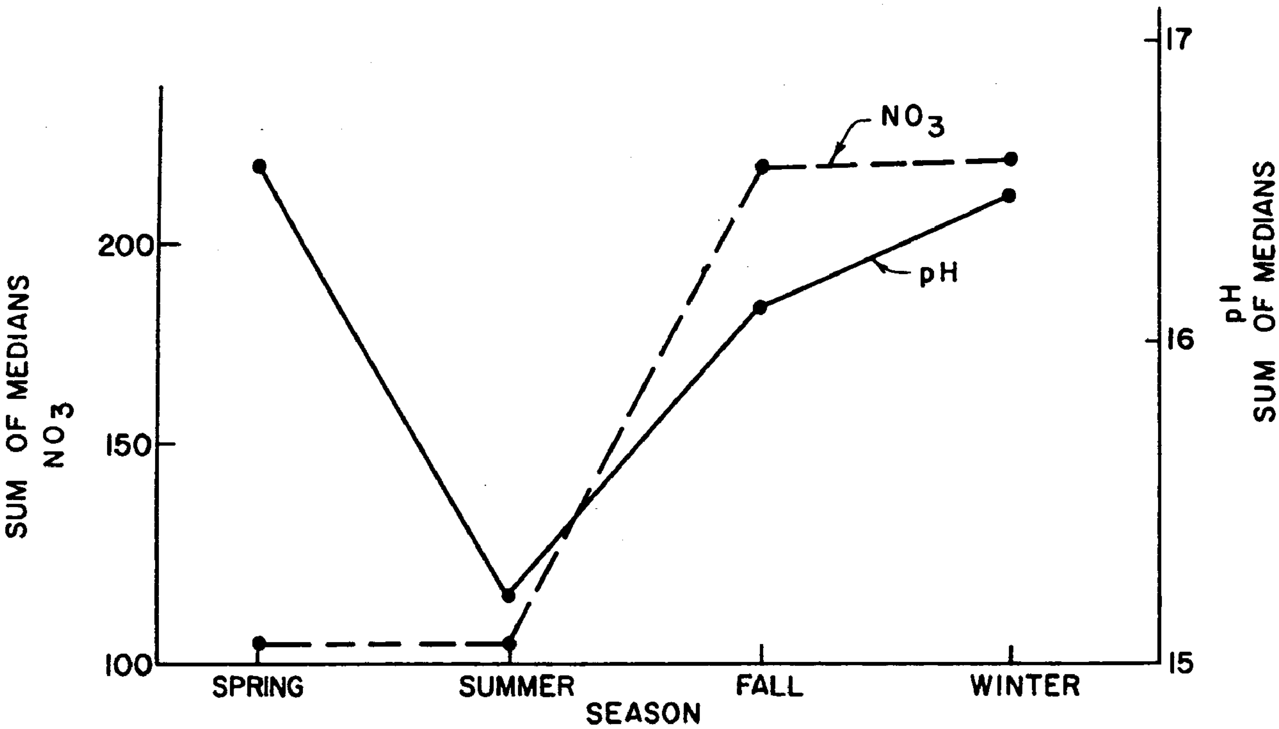

FIGURE 27. SUM OF CELL MEDIANS FOR A TWO-YEAR PERIOD BY SEASON AT STATION 7 FOR pH AND NITRATE.

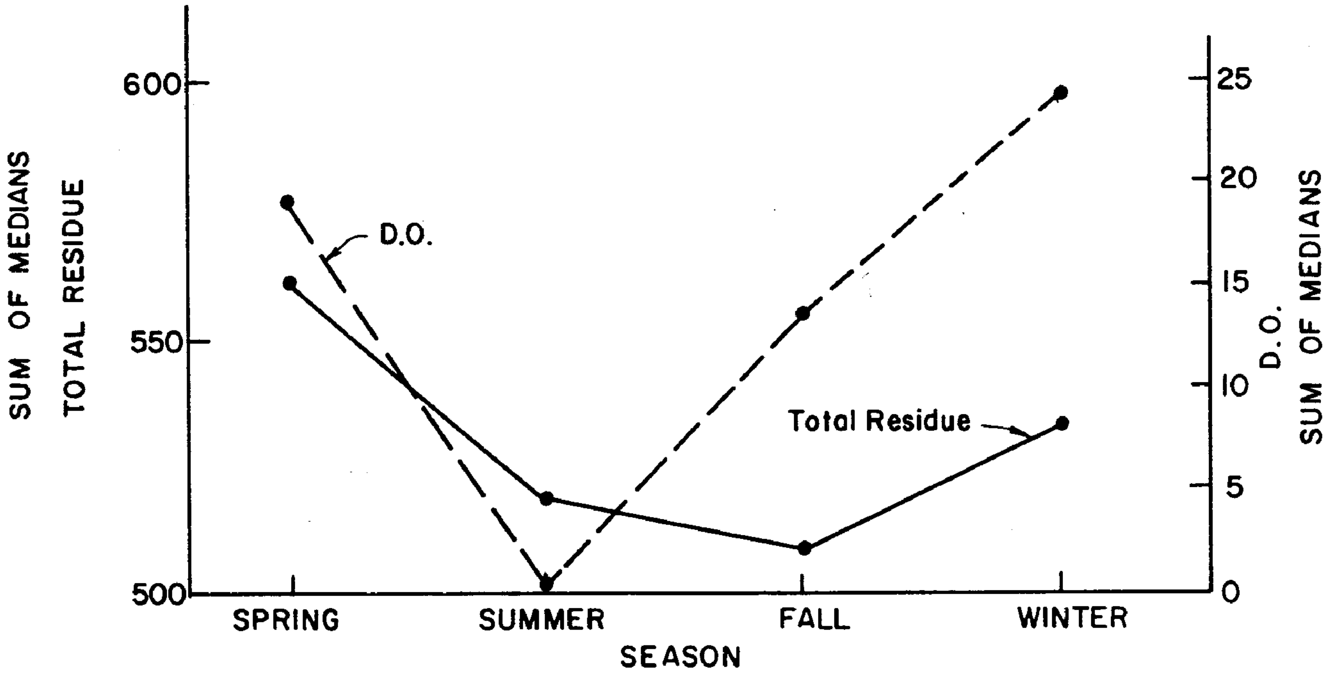

FIGURE 28. SUM OF CELL MEDIANS FOR A TWO-YEAR PERIOD BY SEASON AT STATION 7 FOR DISSOLVED OXYGEN AND TOTAL RESIDUE.

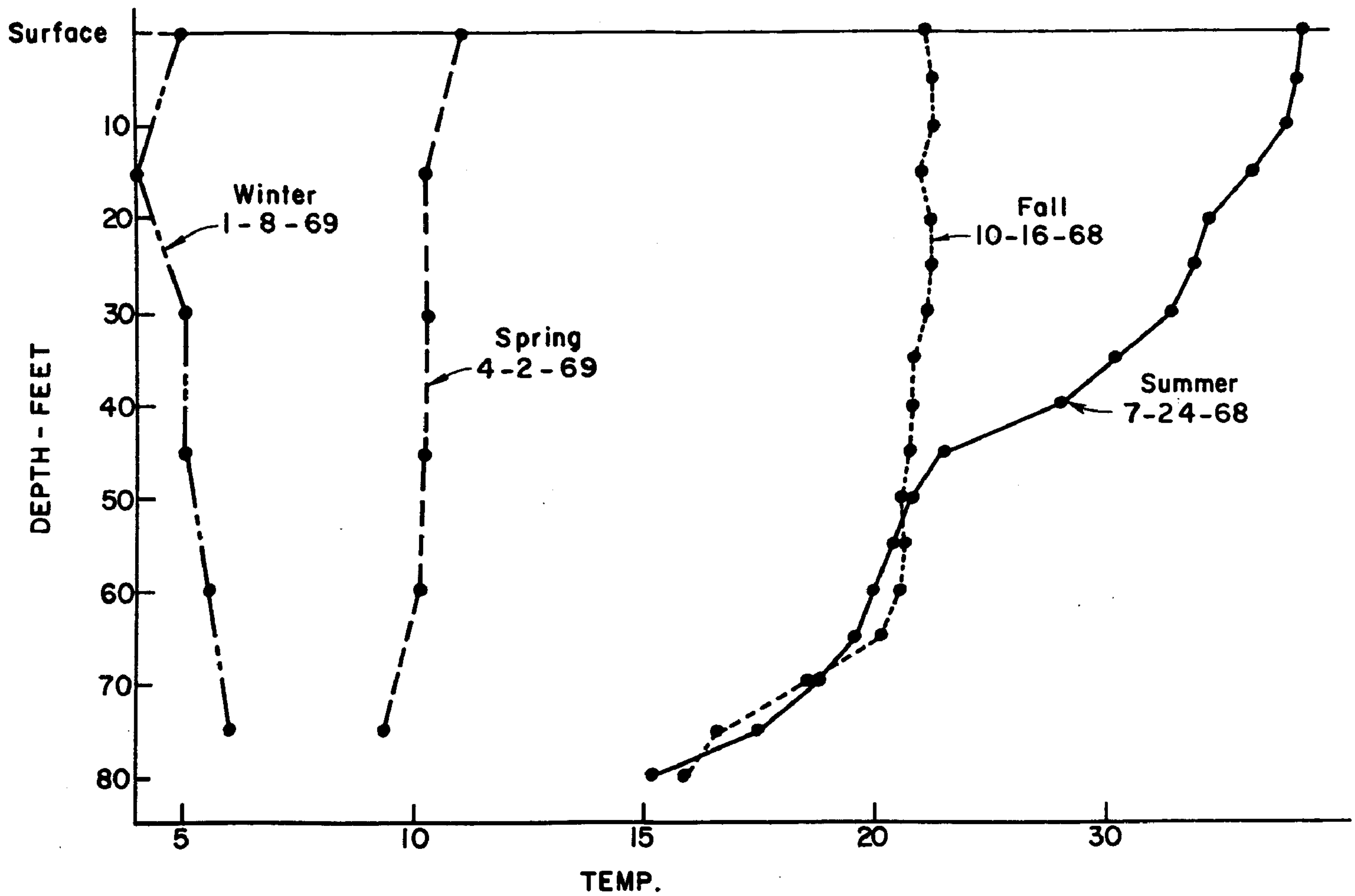

FIGURE 29. VERTICAL PROFILES OF WATER TEMPERATURE AT STATION 7 FOR SELECTED DATES DURING 1968-69.

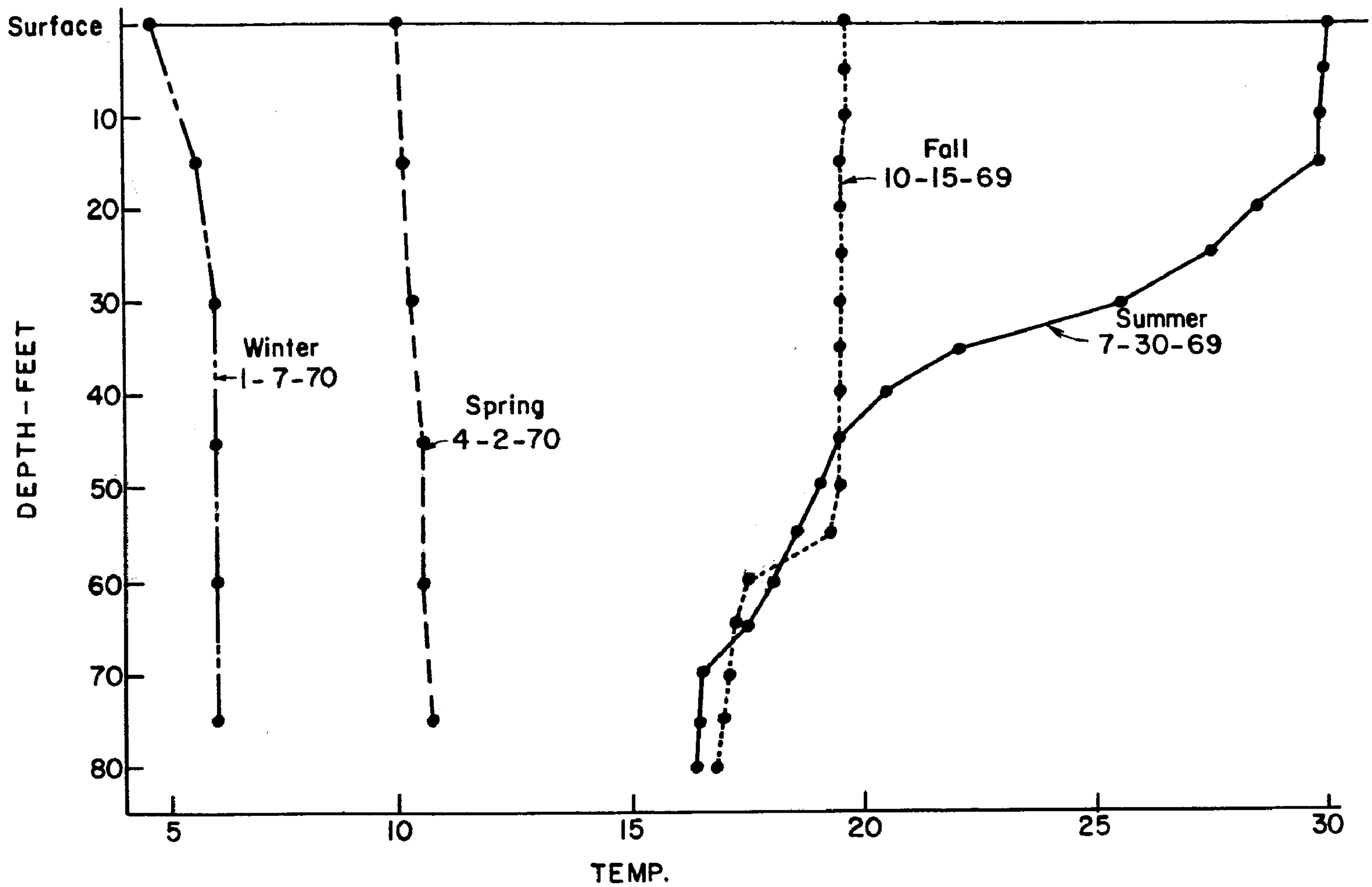

FIGURE 30. VERTICAL PROFILES OF WATER TEMPERATURE AT STATION 7 FOR SELECTED DATES DURING 1969-70.

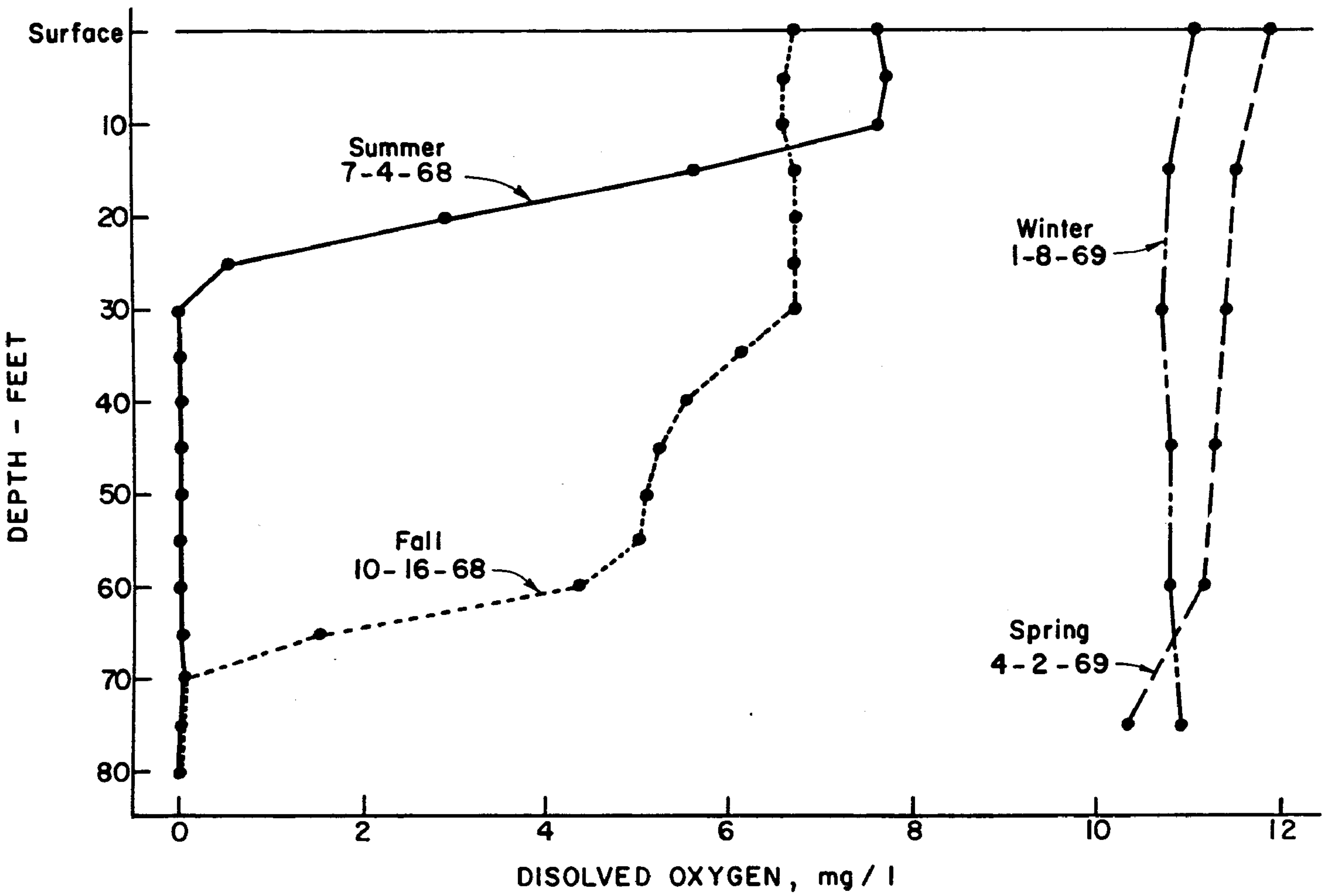

FIGURE 31. VERTICAL PROFILES OF DISSOLVED OXYGEN AT STATION 7 FOR SELECTED DATES DURING 1968-69.

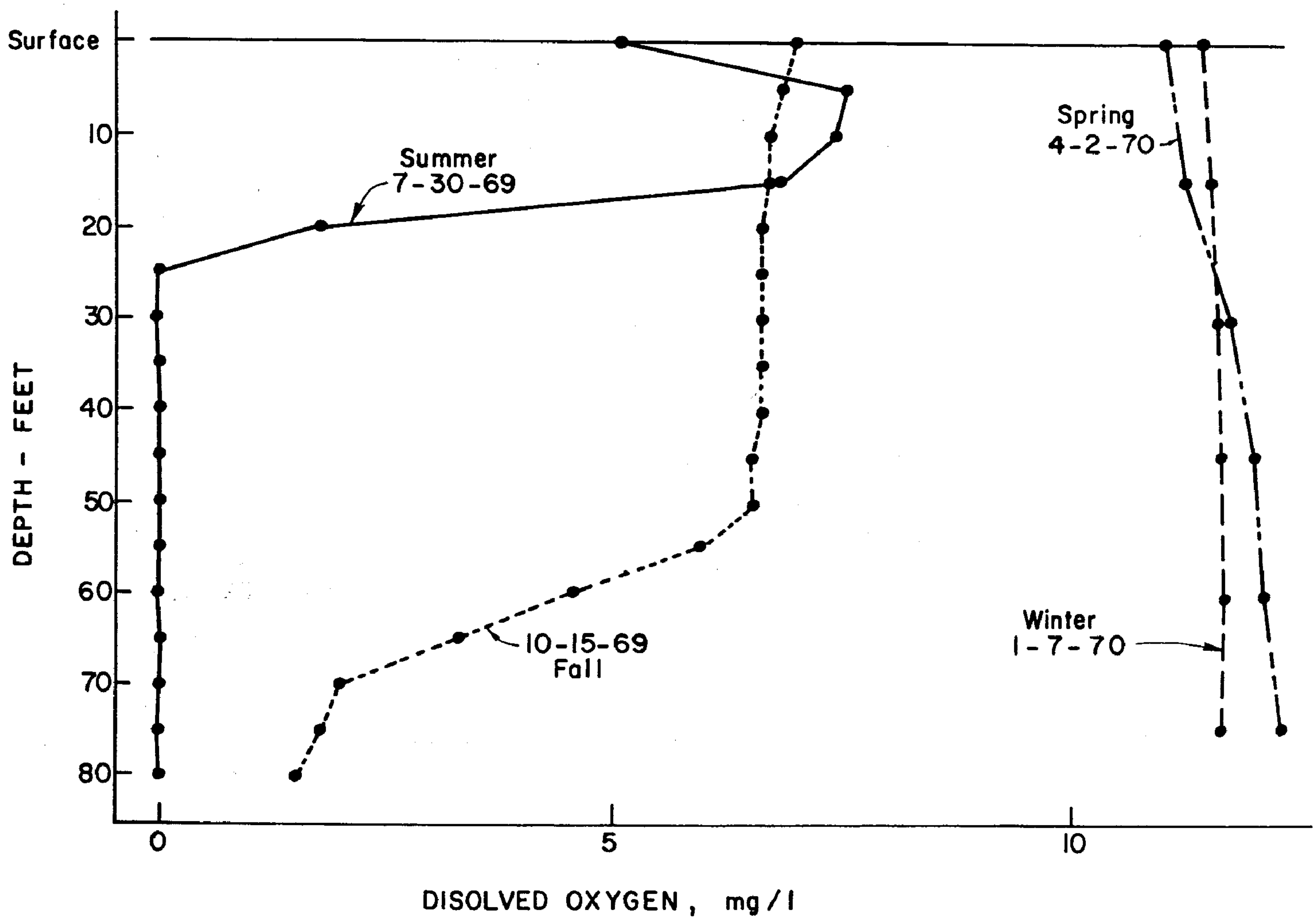

FIGURE 32. VERTICAL PROFILES OF DISSOLVED OXYGEN AT STATION 7 FOR SELECTED DATES DURING 1969-70.

SECTION VI

DISCUSSION

It is interesting that there was no significant reduction in total or fecal coliform concentrations below Arbuckle Dam. Churchill reports a notable reduction in coliform concentrations in the raw water of a municipal supply immediately following closure of a TVA dam which was located approximately 12 miles upstream from the supply intake.(13) However, total coliform reduction below the TVA dam was to an average level slightly above mean levels either prior to or following closure of Arbuckle Dam.

Diversion of sewage effluents, during the period of filling, contributed to a reduction of ammonia, organic nitrogen, and chloride at Station 3 below the municipal waste discharge and in chloride at Station 2 below Arbuckle Dam. Both total phosphate and ortho-phosphate concentrations decreased significantly at Stations 2 and 3 due to diversion of waste effluents. Following filling of the impoundment, total phosphorus values at all stations are similar to the value which Martin and Weinberger list as typical of relatively undisturbed stream areas.(14)

Changes in study parameters are based upon concentrations and do not take into account stream discharges. Flow was a major influence at stream stations, particularly in view of the variation from the average annual discharge observed in the system during the period of study (Table IV). Since there is no accural from tributaries between Arbuckle Dam and Station 2 downstream, reservoir releases can be considered approximately the same as discharge at stream Station 2. During that protion of the study period, prior to closure, stream discharge at Station 2 was approximately one-fifth the annual average for a 9-year period. Following filling of Arbuckle Reservoir, discharge at Station 2 was approximately 1.6 times the average annual discharge.

Stream discharges and median concentrations for the period were used to estimate the amount of chloride, nutrients, and BOD_5 at Station 2 (Table V). While concentrations decreased following impoundment for all 6 parameters considered, average annual amounts decreased only for total and ortho-phosphate and chlorides. Following impoundment, there was a slight increase in average annual amount of ammonia and rather large increases in average annual amounts of nitrate, organic nitrogen, and BOD_5. Since municipal sewage effluents were diverted prior to filling of the impoundment, the large increase in average annual discharge was responsible for increases in amounts of nitrogen and BOD_5.

TABLE IV

STREAM DISCHARGE AND RESERVOIR WATER BALANCE

Location & Period	Volume (Acre-Feet)				
	Total Inflow	Total Discharge	Average Annual Discharge	Municipal and Industrial Use	Evaporation
Rock Creek Sta. #2					
March 1956 thru Sept. 1965[d] (9 years)	--	--	51,100	--	--
[a]Jan. 1966 thru Dec. 1966[e,f]	--	9,790	9,790	--	--
Arbuckle Reservoir					
[b]Jan. 1967 thru April 1968[g] (16 months)	75,110	601	451	974	5,525
[c]May 1968 thru April 1970[g] (2 years)	190,143	159,263	79,632	4,341	22,140

[a]Sampling period prior to closure of Arbuckle Dam

[b]Sampling period during filling to the active conservation elevation

[c]Sampling period following filling with the surface maintained near the top of the active conservation elevation.

[d]U. S. Geological Survey, "Surface Water Supply of the United States 1961-65, Part 7." Geological Survey Water-Supply Paper 1920, Vol. 1, pp. 583-585, 1969.

[e]U. S. Geological Survey, Water Resources Data for Oklahoma, 1966 Surface Water Records. Part 1, p. 166, 1967.

[f]U. S. Geological Survey, Water Resources Data for Oklahoma, 1967 Surface Water Records. Part 1, p. 168, 1968.

[g]Arbuckle Master Conservancy District, Monthly Water Supply Reports. April, 1968 through April, 1970.

TABLE V

ANNUAL AMOUNTS OF NUTRIENTS, BOD_5, AND CHLORIDE AT STATION 2 PRIOR TO CLOSURE AND FOLLOWING FILLING OF ARBUCKLE RESERVOIR

Constituent	Prior to Closure (tons)	Following Filling (tons)
BOD_5	39.26	129.91
Ammonia	4.66	5.30
Nitrate	6.85	11.91
Organic Nitrogen	6.66	32.48
Ortho Phosphate	34.60	5.74
Total Phosphate	37.27	11.26
Chloride	4,765	3,681

In order to determine the influence of diversion of municipal sewage effluents from the system, relative amounts of nutrients and BOD_5 were calculated using median values for parameters considered and discharge estimates at upstream Stations 1, 3, and 4 (Table VI). The total amount of chloride contributed by upstream discharge was calculated for comparison with amount contributed by downstream discharge at Station 2. Since the amount of chloride should remain constant through the system, this method was used to check upstream discharge estimates, which were based on less frequent flow measurements than the daily flow record at the downstream station. Annual chloride amounts contributed by discharge at upstream stations and discharge at downstream Station 2, prior to closure, are in suprisingly close agreement (compare Tables V and VI).

Reductions in the annual amounts of all nutrients and BOD_5 due to the diversion of municipal sewage effluents are not unexpected. However, a very large proportion of the total contribution by upstream discharge for annual amounts of total phosphate, ortho phosphate, ammonia and BOD_5 resulted from treated municipal sewage effluents.

A comparison of annual amounts of nutrients and BOD_5 for the period prior to closure shows some important stream relationships as well as the influence of treated municipal sewage effluents. The annual amount of BOD_5 decreased from 57.30 to 39.26 tons, and the annual amount of ammonia decreased from 17.44 to 4.66 tons with passage from upstream station to the downstream station. Annual amounts of organic nitrogen decreased and nitrate increased with passage downstream. However, amounts of ortho and total phosphate are essentially unchanged with passage downstream.

TABLE VI

RELATIVE ANNUAL AMOUNTS OF NUTRIENTS, CHLORIDE AND BOD_5 CONTRIBUTED BY UPSTREAM DISCHARGE AND SEWAGE EFFLUENTS PRIOR TO CLOSURE

Constituent	Sewage Effluent (tons)	All Other Sources (tons)	Total (tons)
BOD_5	36.0	21.3	57.30
Ammonia	14.32	3.12	17.44
Nitrate	0.80	3.72	4.52
Organic Nitrogen	3.36	6.63	9.99
Ortho Phosphate	33.60	1.33	34.93
Total Phosphate	40.80	1.33	42.13
Chloride	--	--	4,653

Following filling of Arbuckle Reservoir to the active conservation elevation, annual amounts of BOD_5 actually increased with passage downstream. The annual amount of BOD_5 contributed by upstream discharge was 114.72 tons, while the annual amount at Station 2 was 129.91 tons. An increase in the amount of BOD_5 with passage downstream, following filling of Arbuckle Reservoir, is suprising in light of the change prior to filling--a reduction of about 30 percent of the annual amount of BOD_5 with downstream passage.

Values of 5-day BOD reported by Churchill for inflows to two TVA reservoirs are similar to those observed for Arbuckle Reservoir. Reductions of about 50 percent in 5-day BOD occurred in samples collected at frequent intervals during the period of one year in outflows from both TVA dams. Differences between the TVA systems and Arbuckle Reservoir in 5-day BOD reductions are probably due to the "aging effect" common to new reservoirs. Comparisons for each TVA reservoir were made using data that were collected approximately three years following closure, while those for Arbuckle Reservoir were made using data that were collected immediately following filling to the active conservation elevation. Arbuckle Reservoir was cleared only at the conservation pool elevation and decomposition of organic debris produced a higher oxygen demand. Sylvester and Seabloom performed laboratory leaching and ion exchange experiments to relate the physical and chemical characteristics of the overlying water to the type of soil and vegetation on the reservoir floor.[15] They concluded that plant debris would produce a much higher BOD in a new reservoir than would soils having a high organic content and that the natural environment in an impoundment may produce a BOD in water that is as significant as that from traditional sources of wastewaters.

Rates of oxidative metabolism in the hypolimnion of Arbuckle Reservoir provide additional support for the influence of decomposition of organic debris on the production of a high oxygen demand. As shown in Figures 31 and 32, Arbuckle Reservoir is one in which an extreme clinograde oxygen curve develops. The relative oxygen deficit is large and can be used as a basis for classifying the productivity of the reservoir. The hypolimnetic areal relative deficit at Station 7 during the summer stagnation periods was 0.270 and 0.259 mg cm^{-2} day^{-1} for 1968 and 1969, respectively. The mean deficit below one cm^2 of hypolimnion surface was obtained by considering the change in oxygen concentration between dates in relation to the volume of water present in each depth interval of measurement. Hypolimnetic oxidative metabolism rates for Arbuckle Reservoir greatly exceed the rates given by Hutchinson for eutrophic lakes (Table V).(16) Further, the rates for Arbuckle Reservoir are conservative since they represent only the respiratory rates of hypolimnion water and do not account for any passage of oxygen across the surface of the hypolimnetic plane.

Assuming that the rate of oxidative metabolism in Arbuckle Reservoir is about the same at all depths up to the surface, the respiratory rate of the hypolimnion can be used to estimate the over-all metabolic rate of the reservoir. The over-all metabolic rate for the reservoir would be given by $R_t = R_h \times \frac{A_h}{A_t} \times \frac{V_t}{V_h}$. Where R_h is the respiratory rate of the hypolimnion water, A_h the area of the plane at the surface of the hypolimnion, A_t the area of the plane at the surface of the epilimnion, V_h the volume of water in the hypolimnion, and V_t the total volume of water in the reservoir. The over-all metabolic rate (R_t) for Arbuckle Reservoir based on the 1968 areal relative deficit of the hypolimnion during period of stagnation may be computed by $R_t = 0.231 \times \frac{1,380 \text{ acres}}{2,290 \text{ acres}} \times \frac{69,705 \text{ acre-ft.}}{31,830 \text{ acre-ft.}} = 0.304 \text{ mg cm}^{-2} \text{ day}^{-1}$. The over-all metabolic rate for Arbuckle Reservoir, based on the 1968 areal relative deficit of the hypolimnion during the period of stagnation and computed in the same manner as that of the previous year, is 0.315 mg cm^{-2} day^{-1}.

Values for the two years are in close agreement and indicate a very high over-all metabolic rate for Arbuckle Reservoir. Hutchinson estimated the over-all metabolic rate of Mendota Lake to be 0.118 mg cm^{-2} day^{-1} using the oxygen uptake data of Birge and Juday for the years 1906 and 1907. An areal comparison of overall-metabolic rates of Mendota Lake and Arbuckle Reservoir is meaningful since both have about the same maximum depth. It is interesting that Mendota Lake, an old and highly productive system, has an over-all metabolic rate of only about one-third that of newly constructed Arbuckle Reservoir.

TABLE VII

AREAL RELATIVE OXYGEN OF THE HYPOLIMNION DEFICITS IN RELATION TO PRODUCTIVITY

Lake or Reservoir	Maximum Depth m.	Hypolimnetic Oxygen Deficit mg cm^{-2} day^{-1}	Reference
Arbuckle Reservoir			
Summer, 1968	26	0.231	Present Study
Summer, 1969	26	0.239	Present Study
Green Lake	72.2	0.14	Hutchinson[20]
Mendota Lake	25.6	0.109	"
Geneva Lake	43.3	0.090	"
Okauchee Lake	28.6	0.097	"
Oligotrophic Lakes	20-75	0.004-0.033	"
Eutrophic Lakes	20-75	0.05-0.14	"

SECTION VII

ACKNOWLEDGMENTS

We wish to thank Mr. Bob Peters and Mr. Jack Stark, National Park Service, Arbuckle Recreation Area, for their assistance in establishing reservoir sampling stations. The aid of Mr. Wallace Barrett, Manager, Arbuckle Master Conservancy District, in making Arbuckle Reservoir flow release records available to us is appreciated. Initial project planning and early stream monitoring was directed by Mr. Jack Keeley and was most helpful to us. We are grateful for suggestions on statistical procedures and help provided in analyzing data by Dr. Ralph Harkins and Mr. Jim Kingery, Robert S. Kerr Water Research Center, Ada, Oklahoma.

SECTION VIII

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APPENDIX

TABLE I

COMPARISON OF STUDY PARAMETERS AT STREAM STATIONS IN ARBUCKLE SYSTEM BEFORE AND AFTER CLOSURE[1] OF THE DAM

Water Constituent or Characteristic	Station 2	Station 3	Station 4	Station 1
Total Coliform/100 ml[2]				
A	430.5	30910.	1489.	1560.
B	492.0	19360.	1274.	3508.
Total Coliform/100 ml (log transformation)				
A	2.634	4.490	3.173	3.193
B	2.692	4.287	3.105	3.545
C	N	N	N	S
Fecal Coliform/100 ml[2]				
A	54.20	4477.	107.2	628.1
B	67.30	3459.	249.5	1035.
Fecal Coliform/100 ml (log transformation)				
A	1.734	3.651	2.030	2.798
B	1.828	3.539	2.397	3.015
C	N	N	N	N
Fecal Streptococci/100 ml[2]				
A	351.6	2301.	796.2	2427.
B	235.0	1315.	514.0	1069.
Fecal Streptococci/100 ml (log transformation)				
A	2.546	3.362	2.901	3.385
B	2.371	3.119	2.711	3.029
C	N	N	N	S
Total Plate Count/ml 35°C[2]				
A	6966.	22590.	3741.	4508.
B	1637.	19630.	2466.	2972.

TABLE I--Continued

Water Constituent or Characteristic	Station 2	Station 3	Station 4	Station 1
Total Plate Count/ml 35°C (log transformation)				
A	3.843	4.353	3.573	3.654
B	3.214	4.293	3.392	3.473
C	S	N	N	N
Total Plate Count/ml 20°C[2]				
A	5105.	24830.	5023.	4797.
B	959.4	10380.	946.2	1005.
Total Plate Count/ml 20°C (log transformation)				
A	3.708	4.395	3.701	3.681
B	2.982	4.016	2.976	3.002
C	S	N	S	S
BOD, mg/l				
A	3.132	7.314	1.926	1.618
B	2.230	5.544	1.912	1.840
C	N	N	N	N
BOD, mg/l (log transformation)				
A	0.415	0.743	0.225	0.140
B	0.306	0.608	0.243	0.199
C	N	N	N	N
COD, mg/l				
A	27.048	24.700	12.714	8.789
B	20.481	28.366	19.358	11.492
C	N	N	S	N
pH				
A	8.375	8.117	8.342	7.850
B	7.862	7.926	8.253	8.142
C	S	N	N	N

TABLE I--Continued

Water Constituent or Characteristic	Station 2	Station 3	Station 4	Station 1
Alkalinity - HCO_3, mg/l				
A	209.2	230.7	208.9	245.6
B	243.6	224.4	216.8	265.9
C	S	N	N	S
Alkalinity - CO_3, mg/l				
A	46.4	28.4	31.3	33.2
B	24.7	25.3	30.8	20.7
C	S	N	N	S
Hardness as $CaCO_3$, mg/l				
A	322.2	360.4	362.7	290.4
B	304.0	308.8	308.3	296.7
C	N	S	S	N
Conductivity-micromhos/cm @ 25°C				
A	1442.6	2241.2	2340.2	543.7
B	865.4	1491.4	1725.6	560.6
C	S	N	N	N
Magnesium, mg/l				
A	36.4	38.3	42.6	38.4
B	23.8	27.1	29.5	34.3
C	S	S	S	N
Calcium, mg/l				
A	71.7	83.3	76.3	53.3
B	68.4	79.2	72.7	62.6
C	N	N	N	S
Chlorides, mg/l				
A	330.0	556.0	885.8	13.1
B	136.2	328.8	372.2	12.4
C	S	S	N	N

TABLE I--Continued

Water Constituent or Characteristic	Station 2	Station 3	Station 4	Station 1
Sulphate, mg/l				
A	65.8	75.2	81.8	14.5
B	74.1	50.8	52.5	16.0
C	N	S	S	N
Total Residue, mg/l				
A	1152.8	1322.0	2110.8	348.2
B	512.2	808.6	822.1	341.9
C	S	S	S	N
Filterable Residue, mg/l				
A	859.7	1285.3	1446.0	338.2
B	461.7	817.9	868.0	335.0
C	S	S	S	N
Ammonia, mg/l				
A	0.432	2.178	0.511	0.244
B	0.334	0.937	0.128	0.160
C	N	S	N	N
Organic Nitrogen, mg/l				
A	0.786	1.162	2.471	0.422
B	0.361	0.491	0.183	0.476
C	S	S	N	N
Nitrite, mg/l				
A	0.024	1.158	0.014	0.007
B	0.011	0.148	0.006	0.004
C	N	N	S	S
Nitrate, mg/l				
A	0.674	0.360	0.246	0.512
B	0.100	0.242	0.181	0.602
C	S	N	N	N

TABLE I--Continued

Water Constituent or Characteristic	Station 2	Station 3	Station 4	Station 1
Total Phosphate, mg/l				
A	2.643	4.900	0.300	0.212
B	0.565	1.648	0.181	0.077
C	S	S	N	S
Ortho Phosphate, mg/l				
A	2.285	4.428	0.400	0.220
B	0.405	1.355	0.122	0.040
C	S	S	S	S

[1]A represents mean values prior to closure; B represents mean values following closure; C represents a *t* test at the .05 level for difference between mean values and listings are either as significant (S) or non-significant (N).

[2]No test performed.

TABLE II

DIFFERENCES IN WATER QUALITY PARAMETERS AT STREAM STATIONS IN ARBUCKLE SYSTEM FOR THREE DISCRETE TIME PERIODS[a]

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[b] Inference	Cell Medians A	B	C	Overall Median
Total Coliform /100 ml							2000
Stations	3	29.98	S				
1				1650	2700	3400	
2				450	405	1500	
3				28000	29500	1700	
4				1550	1100	1700	
Periods	2	.09	N				
Interaction	6	11.16	N				
Total	11	41.23					
Fecal Coliform /100 ml							320
Stations	3	76.33	S				
1				560	640	820	
2				65	93	80	
3				3600	4800	175	
4				85	228	168	
Periods	2	.90	N				
Interaction	6	9.74	N				
Total	11	86.97					
Fecal Streptococci /100 ml							580
Stations	3	48.75	S				
1				2150	1150	1000	
2				425	295	140	
3				1550	1800	255	
4				515	385	290	
Periods	2	15.48	S				
Interaction	6	10.15	N				
Total	11	74.37					
Total Plate Count /ml @ 35°C							1450
Stations	3	12.20	S				
1				4150	940	610	
2				2800	1250	1000	
3				26500	13000	825	
4				5800	870	535	
Periods	2	32.26	S				
Interaction	6	4.76	N				
Total	11	49.22					

TABLE II--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[b]	Cell Medians A	B	C	Overall Median
Total Plate Count /ml @ 20°C							3400
Stations	3	7.08	N				
1				4650	3100	3800	
2				4650	1450	3400	
3				24000	20000	2600	
4				4150	2300	2650	
Periods	2	11.63	S				
Interaction	6	11.91	N				
Total	11	30.62					
5-Day BOD, mg/l							1.80
Stations	3	21.69	S				
1				1.60	1.50	1.00	
2				2.95	2.30	1.20	
3				6.10	4.06	1.10	
4				1.60	1.80	1.50	
Periods	2	17.52	S				
Interaction	6	8.88	N				
Total	11	48.09					
COD, mg/l							16
Stations	3	39.04	S				
1				8.00	5.55	14.00	
2				16.00	19.30	22.20	
3				22.00	30.85	15.00	
4				13.00	21.45	13.00	
Periods	2	1.76	N				
Interaction	6	10.14	N				
Total	11	50.94					
pH							8.20
Stations	3	16.21	S				
1				8.35	8.20	8.20	
2				8.45	7.95	8.10	
3				8.10	8.15	8.20	
4				8.35	8.30	8.20	
Periods	2	6.40	S				
Interaction	6	16.63	S				
Total	11	39.24					

TABLE II--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[b] Inference	Cell Medians A	B	C	Overall Median
Bicarbonate Alkalinity, mg/l							236
Stations	3	25.97	S				
1				240	266	287	
2				222	260	177	
3				234	232	239	
4				212	225	245	
Periods	2	7.74	S				
Interaction	6	19.13	S				
Total	11	52.84					
Carbonate Alkalinity, mg/l							28
Stations	3	1.54	N				
1				40	14	14	
2				48	20	24	
3				28	32	20	
4				32	24	10	
Periods	2	9.26	S				
Interaction	6	1.59	N				
Total	11	12.39					
Hardness as $CaCO_3$ mg/l							315
Stations	3	17.73	S				
1				284	300	292	
2				331	306	219	
3				366	330	270	
4				370	311	275	
Periods	2	24.78	S				
Interaction	6	10.35	N				
Total	11	52.87					
Conductivity-micromhos/cm @ 25°C							975
Stations	3	96.35	S				
1				540	555	605	
2				1600	725	490	
3				2200	1700	850	
4				2500	1850	793	
Periods	2	38.58	S				
Interaction	6	18.20	S				
Total	11	153.13					

TABLE II--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[b]	Cell Medians A	B	C	Overall Median
Magnesium, mg/l							33
Stations	3	6.36	N				
1				35	36	31	
2				37	16	20	
3				37	29	30	
4				42	28	26	
Periods	2	39.49	S				
Interaction	6	4.79	N				
Total	11	50.64					
Calcium, mg/l							75
Stations	3	39.58	S				
1				55	63	60	
2				75	81	60	
3				83	82	62	
4				78	80	66	
Periods	2	7.97	S				
Interaction	6	2.49	N				
Total	11	50.04					
Chloride, mg/l							136
Stations	3	96.35	S				
1				13	12	13	
2				358	58	34	
3				573	368	103	
4				640	400	89	
Periods	2	40.34	S				
Interaction	6	21.39	S				
Total	11	158.08					
Sulphate, mg/l							45
Stations	3	75.01	S				
1				13	16	17	
2				68	76	21	
3				80	54	30	
4				79	54	30	
Periods	2	65.58	S				
Interaction	6	22.64	S				
Total	11	163.23					

TABLE II--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[b] Inference	Cell Medians A	B	C	Overall Median
Residue on Evaporation, mg/l							606
Stations	3	86.99	S				
1				347	337	368	
2				995	564	311	
3				1338	1038	483	
4				2200	1055	447	
Periods	2	45.58	S				
Interaction	6	18.11	S				
Total	11	150.68					
Filterable Residue on Evaporation, mg/l							13
Stations	3	71.06	S				
1				277	5	7	
2				383	20	22	
3				458	11	16	
4				344	7	10	
Periods	2	40.27	S				
Interaction	6	16.32	S				
Total	11	127.66					
Ammonia, mg/l							.100
Stations	3	9.43	S				
1				.195	.130	.030	
2				.350	.160	.049	
3				2.050	.450	.028	
4				.260	.095	.030	
Periods	2	54.21	S				
Interaction	6	1.93	N				
Total	11	65.58					
Organic Nitrogen, mg/l							.240
Stations	3	11.41	S				
1				.300	.200	.200	
2				.500	.315	.300	
3				1.050	.300	.200	
4				.400	.155	.200	
Periods	2	22.28	S				
Interaction	6	6.24	N				
Total	11	39.93					

TABLE II--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[b]	Cell Medians A	B	C	Overall Median
Total Phosphate, mg/l							.100
Stations	3	8.21	S				
1				.100	.060	.042	
2				2.800	.100	.104	
3				5.200	.250	.039	
4				.100	.060	.034	
Periods	2	86.09	S				
Interaction	6	11.35	N				
Total	11	105.66					
Ortho Phosphate, mg/l							.100
Stations	3	3.93	N				
1				.100	.030	.015	
2				2.600	.062	.053	
3				4.300	.275	.013	
4				.100	.040	.029	
Periods	2	119.09	S				
Interaction	6	6.70	N				
Total	11	129.71					
Nitrite, mg/l							.010
Stations	3	9.28	S				
1				.006	.003	.038	
2				.010	.005	.030	
3				.050	.007	.010	
4				.014	.005	.004	
Periods	2	32.58	S				
Interaction	6	6.20	N				
Total	11	48.07					
Nitrate, mg/l							.230
Stations	3	34.16	S				
1				.400	.380	.645	
2				.515	.085	.110	
3				.300	.030	.100	
4				.200	.080	.100	
Periods	2	13.71	S				
Interaction	6	16.80	S				
Total	11	64.68					

[a]Cell medians include the period prior to filling (A), the period during filling of the active conservation pool (B), and the period following filling with the surface maintained near the top of the active conservation elevation (C).

[b]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE III

CHI-SQUARES ANALYSIS OF STATION AND SEASON GROUPINGS
FOR MEASUREMENTS AT THE ONE FOOT DEPTH AT ALL IMPOUNDMENT STATIONS

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Stations 8	7	6	5	Overall Median
Total Phosphate, μg/l								34
Seasons	3	3.54	N					
Spring				50	35	50	50	
Summer				40	30	32	35	
Fall				23	45	30	34	
Winter				17	27	24	32	
Station	3	0.68	N					
Interaction	9	3.75	N					
Total	15	7.97						
Temperature °C								17.05
Seasons	3	57.14	S					
Spring				18.0	18.0	17.3	17.5	
Summer				30.0	28.9	27.5	28.0	
Fall				16.6	16.4	16.3	16.8	
Winter				7.0	7.0	7.0	7.2	
Station	3	0.00	N					
Interaction	9	0.00	N					
Total	15	57.14						
Ortho-Phosphate, μg/l								10.5
Seasons	3	18.0	S					
Spring				35	20	40	20	
Summer				7	5	5	6	
Fall				8	10	12	9	
Winter				16	12	15	9	
Station	3	4.28	N					
Interaction	9	5.14	N					
Total	15	27.42						

TABLE III--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Stations 8	7	6	5	Overall Median
pH.								8.20
Seasons	3	3.62	N					
Spring				8.20	8.25	8.25	8.20	
Summer				8.00	8.10	8.20	8.10	
Fall				8.20	8.20	8.10	8.20	
Winter				8.20	8.30	8.10	8.30	
Station	3	0.92	N					
Interaction	9	3.62	N					
Total	15	9.57						
Organic Nitrogen, mg/l								0.30
Seasons	3	27.53	S					
Spring				0.50	0.30	0.30	0.30	
Summer				0.30	0.30	0.30	0.30	
Fall				0.20	0.20	0.20	0.20	
Winter				0.30	0.20	0.20	0.25	
Station	3	1.79	N					
Interaction	9	3.20	N					
Total	15	32.52						
Dissolved Oxygen, mg/l								9.30
Seasons	3	58.79	S					
Spring				9.70	9.30	9.60	9.40	
Summer				7.20	6.70	6.20	7.10	
Fall				9.30	8.50	8.50	8.60	
Winter				11.90	11.70	11.60	11.70	
Station	3	0.14	N					
Interaction	9	1.57	N					
Total	15	60.50						

TABLE III--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Stations 8	7	6	5	Overall Median
Filterable Residue, mg/l								258
Seasons	3	7.57	N					
Spring				258	265	259	279	
Summer				253	249	249	267	
Fall				258	236	253	283	
Winter				254	244	259	277	
Station	3	9.98	S					
Interaction	9	4.80	N					
Total	15	22.37						
Total Residue, mg/l								267
Seasons	3	4.15	N					
Spring				271	268	267	287	
Summer				260	257	257	273	
Fall				266	251	261	287	
Winter				264	263	266	301	
Station	3	17.59	S					
Interaction	9	4.43	N					
Total	15	26.18						
Chloride, mg/l								35
Seasons	3	17.61	S					
Spring				37	35	34	36	
Summer				32	31	32	38	
Fall				35	35	35	37	
Winter				35	36	36	41	
Station	3	5.36	N					
Interaction	9	16.17	N					
Total	15	39.15						

TABLE III--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Stations 8	7	6	5	Overall Median
Sulfate, mg/l								16
Seasons	3	24.61	S					
Spring				19	19	19	21	
Summer				14	15	15	17	
Fall				15	15	16	16	
Winter				18	17	18	20	
Station	3	5.4	N					
Interaction	9	8.46	N					
Total	15	38.47						
Ammonia, µg/l								41
Seasons	3	12.21	S					
Spring				30	50	40	50	
Summer				42	20	30	30	
Fall				50	60	70	51	
Winter				50	52	40	44	
Station	3	3.99	N					
Interaction	9	7.49	N					
Total	15	23.71						
Nitrate, µg/l								60
Seasons	3	53.78	S					
Spring				50	50	60	50	
Summer				50	50	50	50	
Fall				76	130	130	86	
Winter				120	120	120	110	
Station	3	0.71	N					
Interaction	9	0.97	N					
Total	15	55.46						

TABLE III--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Stations 8	7	6	5	Overall Median
Conductivity, micromhos/cm								440
Seasons	3	12.25	S					
Spring				455	455	440	500	
Summer				420	420	420	440	
Fall				430	440	440	440	
Winter				460	450	440	500	
Station	3	2.51	N					
Interaction	9	3.98	N					
Total	15	18.74						
Bicarbonate Alkalinity, mg/1								160
Seasons	3	11.96	S					
Spring				164	160	164	168	
Summer				156	156	158	162	
Fall				156	162	158	166	
Winter				160	160	168	176	
Station	3	5.54	N					
Interaction	9	5.83	N					
Total	15	23.33						
Phytoplankton								7.03
Seasons	3	9.43	S					
Spring				10.27	6.11	9.17	8.14	
Summer				13.30	4.91	9.70	13.14	
Fall				3.49	1.33	6.82	3.62	
Winter				11.71	1.38	6.05	5.83	
Station	3	5.45	N					
Interaction	9	5.51	N					
Total	15	20.40						

TABLE III--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Stations 8	7	6	5	Overall Median
Macroinvertebrate								6.84
Seasons	2	8.71	S					
Spring								
Summer				5.68	10.02	2.41	4.23	
Fall				5.68	10.02	2.41	4.23	
Winter				6.90	21.02	8.46	13.60	
Station	3	1.53	N					
Interaction	6	3.07	N					
Total	11	13.32						

[a]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE IV

CHI-SQUARES ANALYSIS OF STATION AND YEAR GROUPINGS FOR MEASUREMENTS AT THE ONE FOOT DEPTH AT ALL IMPOUNDMENT STATIONS

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Macroinvertebrates						6.83
Stations	3	1.53	N			
7				5.63	16.54	
5				0.84	12.08	
6				1.48	7.28	
8				2.44	8.45	
Year	1	9.80	S			
Interaction	3	-0.13	N			
Total	7	11.18				
Phytoplankton						7.03
Stations	3	5.45	N			
7				1.27	9.11	
5				5.83	5.68	
6				7.92	10.27	
8				8.27	11.17	
Year	1	2.91	S			
Interaction	3	2.54	N			
Total	7	10.91				
Total Phosphate, μg/1						34
Stations	3	0.68	N			
7				46	34	
5				41	31	
6				24	36	
8				28	40	
Year	1	0.04	N			
Interaction	3	2.12	N			
Total	7	2.84				
Ortho-Phosphate, μg/1						10.50
Stations	3	4.28	N			
7				14.00	11.00	
5				9.00	8.00	
6				14.00	15.00	
8				8.00	10.00	
Year	1	0.0	N			
Interaction	3	1.04	N			
Total	7	5.33				

TABLE IV--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
pH						8.20
Stations	3	.92	N			
7				8.10	8.20	
5				8.10	8.20	
6				8.10	8.20	
8				8.05	8.20	
Year	1	15.93	S			
Interaction	3	2.68	N			
Total	7	19.53				
Bicarbonate Alkalinity, mg/1						160.00
Stations	3	5.54	N			
7				160.00	156.00	
5				170.00	162.00	
6				164.00	158.00	
8				164.00	156.00	
Year	1	6.60	S			
Interaction	3	.97	N			
Total	7	13.12				
Conductivity						440.00
Stations	3	2.50	N			
7				460.00	420.00	
5				480.00	430.00	
6				465.00	420.00	
8				460.00	420.00	
Year	1	41.08	S			
Interaction	3	.90	N			
Total	7	44.49				
Nitrate, μg/1						60.00
Stations	3	.70	N			
7				100.00	50.00	
5				80.00	50.00	
6				100.00	60.00	
8				85.00	50.00	
Year	1	2.94	N			
Interaction	3	.43	N			
Total	7	4.07				

TABLE IV--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Year 1968-69	Year 1969-70	Overall Median
Sulfate, mg/l						16.00
Stations	3	5.40	N			
7				16.50	16.00	
5				19.50	16.00	
6				17.50	15.00	
8				18.00	16.00	
Year	1	.48	N			
Interaction	3	.92	N			
Total	7	6.80				
Chlorine, mg/l						35.00
Stations	3	6.79	N			
7				35.50	33.00	
5				39.00	36.00	
6				35.50	33.00	
8				35.50	33.00	
Year	1	6.76	S			
Interaction	3	.23	N			
Total	7	13.79				
Total Residue, mg/l						267.00
Stations	3	17.59	S			
7				264.00	252.00	
5				291.00	273.00	
6				279.00	258.00	
8				271.00	262.00	
Year	1	9.03	S			
Interaction	3	3.09	N			
Total	7	29.72				
Filterable Residue, mg/l						258.00
Stations	3	9.98	S			
7				263.50	248.00	
5				288.00	263.00	
6				267.50	251.00	
8				265.50	254.00	
Year	1	9.39	S			
Interaction	3	.78	N			
Total	7	20.16				

TABLE IV--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Temperature						17.05
Stations	3	.00	N			
7				14.50	18.00	
5				14.00	17.50	
6				14.50	17.30	
8				13.80	18.00	
Year	1	.57	N			
Interaction	3	.00	N			
Total	7	.57				
Dissolved Oxygen, mg/l						9.30
Stations	3	.14	N			
7				9.00	9.30	
5				9.40	9.60	
6				9.60	9.00	
8				9.30	9.70	
Year	1	.00	N			
Interaction	3	.29	N			
Total	7	.43				
Organic Nitrogen, mg/l						.30
Stations	3	1.78	N			
7				.30	.30	
5				.30	.30	
6				.30	.30	
8				.35	.30	
Year	1	.27	N			
Interaction	3	1.25	N			
Total	7	3.31				
Ammonia, μg/l						41.00
Stations	3	3.99	N			
7				50.00	40.00	
5				40.00	30.00	
6				45.00	30.00	
8				50.00	30.00	
Year	1	3.71	N			
Interaction	3	1.06	N			
Total	7	8.76				

[a]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE V

CHI-SQUARES ANALYSIS OF SEASON AND YEAR GROUPINGS
FOR MEASUREMENTS AT THE ONE FOOT DEPTH AT ALL IMPOUNDMENT STATIONS

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Total Phosphate, μg/l						34
Seasons	3	3.54	N			
Spring				50.0	32.5	
Summer				35.0	33.5	
Fall				27.5	34.5	
Winter				25.0	39.5	
Year	1	0.04	N			
Interaction	3	3.22	N			
Total	7	6.80				
Ortho-Phosphate, μg/l						10.50
Seasons	3	18.00	S			
Spring				45.00	12.50	
Summer				7.00	6.00	
Fall				7.50	18.00	
Winter				12.50	13.50	
Year	1	.00	N			
Interaction	3	16.25	S			
Total	7	34.25				
pH						8.20
Seasons	3	5.04	N			
Spring				8.14	8.25	
Summer				7.85	8.20	
Fall				8.05	8.20	
Winter				8.30	8.20	
Year	1	15.93	S			
Interaction	3	2.97	N			
Total	7	23.95				
Bicarbonate Alkalinity, mg/l						160.00
Seasons	3	11.95	S			
Spring				162.00	164.00	
Summer				157.00	157.00	
Fall				166.00	155.00	
Winter				173.00	158.00	
Year	1	6.60	S			
Interaction	3	16.53	S			
Total	7	35.09				

TABLE V--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Conductivity						440.00
Seasons	3	12.24	S			
Spring				472.50	420.00	
Summer				430.00	420.00	
Fall				460.00	420.00	
Winter				472.50	435.00	
Year	1	41.08	S			
Interaction	3	.12	N			
Total	7	53.20				
Nitrate, μg/1						60.00
Seasons	3	55.78	S			
Spring				100.00	50.00	
Summer				50.00	50.00	
Fall				130.00	93.00	
Winter				120.00	120.00	
Year	1	2.93	N			
Interaction	3	1.79	N			
Total	7	58.51				
Ammonia, μg/1						41.00
Seasons	3	12.21	S			
Spring				100.00	30.00	
Summer				40.00	30.00	
Fall				30.00	70.00	
Winter				50.00	30.00	
Year	1	3.70	N			
Interaction	3	18.91	S			
Total	7	34.83				
Sulfate, mg/1						16.00
Seasons	3	24.60	S			
Spring				19.50	18.00	
Summer				14.00	15.00	
Fall				15.00	16.00	
Winter				20.50	16.00	
Year	1	.48	N			
Interaction	3	6.70	N			
Total	7	31.79				

TABLE V--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Chlorine, mg/l						35.00
Seasons	3	17.61	S			
Spring				40.00	29.50	
Summer				33.00	33.00	
Fall				37.00	33.00	
Winter				36.00	37.00	
Year	1	6.76	S			
Interaction	3	12.47	S			
Total	7	36.85				
Total Residue, mg/l						267.00
Seasons	3	4.14	N			
Spring				287.50	266.50	
Summer				266.00	257.50	
Fall				273.00	257.00	
Winter				291.00	259.50	
Year	1	9.03	S			
Interaction	3	.77	N			
Total	7	13.95				
Filterable Residue, mg/l						258.00
Seasons	3	7.57	N			
Spring				284.00	258.00	
Summer				252.00	252.00	
Fall				264.00	250.00	
Winter				279.50	248.00	
Year	1	9.39	S			
Interaction	3	5.42	N			
Total	7	22.39				
Temperature						12.05
Seasons	3	57.14	S			
Spring				16.25	17.75	
Summer				28.50	28.00	
Fall				17.75	16.50	
Winter				7.10	6.75	
Year	1	.57	N			
Interaction	3	.94	N			
Total	7	58.66				

TABLE V--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Dissolved Oxygen, mg/l						9.30
Seasons	3	58.78	S			
Spring				9.50	9.45	
Summer				7.05	6.75	
Fall				8.15	9.90	
Winter				11.60	12.00	
Year	1	.00	N			
Interaction	3	2.06	N			
Total	7	60.85				
Organic Nitrogen, mg/l						.30
Seasons	3	27.53	S			
Spring				.40	.30	
Summer				.40	.30	
Fall				.20	.20	
Winter				.20	.25	
Year	1	.27	N			
Interaction	3	1.81	N			
Total	7	29.61				
Macroinvertebrates						6.83
Seasons	2	8.71	S			
Spring						
Summer				.62	8.41	
Fall				1.61	9.78	
Winter				12.03	12.02	
Year	1	9.78	S			
Interaction	2	4.72	N			
Total	5	23.22				
Phytoplankton						7.03
Seasons	3	9.43	S			
Spring				8.03	10.09	
Summer				5.54	19.87	
Fall				.79	6.82	
Winter				11.27	2.15	
Year	1	2.90	S			
Interaction	3	11.32	S			
Total	7	23.66				

[a]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE VI

CHI-SQUARES ANALYSIS OF DEPTH AND SEASON GROUPINGS FOR VERTICAL PROFILE MEASUREMENTS AT STATION 7

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Season: Spring	Summer	Fall	Winter	Overall Median
Phytoplankton								5.83
Depth	5	4.82	N					
75'				6.41	11.67	5.83	4.63	
60'				5.11	10.49	0.64	8.54	
45'				6.52	5.94	1.05	4.99	
30'				9.24	8.78	4.71	7.81	
15'				14.07	13.38	2.54	9.51	
1'				6.73	5.40	1.45	2.56	
Season	3	5.61	N					
Interaction	15	8.50	N					
Total	23	18.93						
Total Phosphate, μg/1								35
Depth	5	16.86	S					
75'				6.75	148.0	197.0	28.0	
60'				32.5	100.0	36.0	24.5	
45'				43.0	65.0	46.0	28.5	
30'				29.5	26.0	36.0	20.0	
15'				26.0	31.0	39.0	18.0	
1'				35.0	30.0	45.0	27.0	
Season	3	14.42	S					
Interaction	15	14.03	N					
Total	23	45.31						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Season: Spring	Summer	Fall	Winter	Overall Median
Conductivity, micromhos/cm								440
Depth	5	3.99	N					
75'				435	490	450	455	
60'				430	440	440	455	
45'				430	450	460	455	
30'				430	420	460	440	
15'				435	420	450	450	
1'				455	420	440	450	
Season	3	5.92	N					
Interaction	15	6.67	N					
Total	23	16.58						
pH.								8.1
Depth	5	13.99	S					
75'				8.1	7.4	8.0	8.2	
60'				8.1	7.4	8.0	8.2	
45'				8.1	7.7	8.1	8.2	
30'				8.2	7.6	8.1	8.3	
15'				8.3	8.0	8.2	8.3	
1'				8.2	8.1	8.2	8.3	
Season	3	39.73	S					
Interaction	15	7.28	N					
Total	23	61.0						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Season: Spring	Summer	Fall	Winter	Overall Median
Bicarbonate Alkalinity, mg/l								164
Depth	5	8.75	N					
75'				166	176	166	166	
60'				163	168	156	164	
45'				163	168	160	162	
30'				163	164	164	162	
15'				163	160	164	160	
1'				160	156	162	160	
Season	3	5.16	N					
Interaction	15	21.53	N					
Total	23	35.44						
Chloride, mg/l								34
Depth	5	2.95	N					
75'				32	27	34	37	
60'				32	26	35	37	
45'				32	26	35	37	
30'				32	31	35	37	
15'				32	32	35	36	
1'				35	33	35	36	
Season	3	69.68	S					
Interaction	15	3.49	N					
Total	23	76.12						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Season				Overall Median
				Spring	Summer	Fall	Winter	
Sulfate, mg/l								16
Depth	5	1.18	N					
75'				20	13	14	18	
60'				19	14	16	18	
45'				20	14	16	17	
30'				20	15	16	18	
15'				19	15	13	17	
1'				17	15	15	17	
Season	3	41.99	S					
Interaction	15	5.92	N					
Total	23	49.10						
Temperature ^{o}C								15.6
Depth	5	2.07	N					
75'				10.7	16.5	15.6	6.2	
60'				12.3	19.0	15.9	6.4	
45'				13.1	20.5	16.0	6.5	
30'				13.4	25.5	16.2	7.0	
15'				13.5	28.0	16.2	7.0	
1'				18.2	28.9	16.4	7.0	
Season	3	74.85	S					
Interaction	15	4.88	N					
Total	23	81.81						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Season: Spring	Summer	Fall	Winter	Overall Median
Dissolved Oxygen, mg/l								8.1
Depth	5	4.80	N					
75'				6.3	0.00	6.1	12.3	
60'				8.3	0.00	7.7	12.2	
45'				9.1	0.00	7.9	12.2	
30'				9.7	0.00	7.9	12.3	
15'				10.2	6.1	8.1	12.0	
1'				9.3	6.7	8.5	11.7	
Season	3	86.32	S					
Interaction	15	4.00	N					
Total	23	95.13						
Total Residue, mg/l								265
Depth	5	9.60	N					
75'				278	288	277	270	
60'				275	267	267	265	
45'				273	264	261	265	
30'				270	260	260	269	
15'				274	256	264	260	
1'				268	257	251	263	
Season	3	5.24	N					
Interaction	15	7.90	N					
Total	23	22.75						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Season: Spring	Summer	Fall	Winter	Overall Median
Filterable Residue, mg/l								258
Depth	5	4.63	N					
75'				269	279	256	263	
60'				265	257	259	263	
45'				274	252	236	262	
30'				260	248	242	262	
15'				268	247	258	254	
1'				265	249	236	244	
Season	3	12.99	S					
Interaction	15	11.47	N					
Total	23	29.10						
Organic Nitrogen, mg/l								0.30
Depth	5	5.66	N					
75'				0.40	0.40	0.30	0.20	
60'				0.30	0.20	0.20	0.20	
45'				0.30	0.30	0.20	0.25	
30'				0.30	0.30	0.20	0.25	
15'				0.30	0.30	0.30	0.25	
1'				0.30	0.30	0.20	0.20	
Season	3	11.91	S					
Interaction	15	11.60	N					
Total	23	29.17						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Season: Spring	Summer	Fall	Winter	Overall Median
Nitrate, μg/l								86
Depth	5	1.03	N					
75'				60	50	130	125	
60'				50	50	160	130	
45'				50	50	150	120	
30'				55	50	140	120	
15'				50	50	130	135	
1'				50	50	130	120	
Season	3	63.49	S					
Interaction	15	2.47	N					
Total	23	66.99						
Ammonia, μg/l								50
Depth	5	11.52	S					
75'				50	800	160	52	
60'				45	400	80	50	
45'				50	300	70	50	
30'				45	48	50	50	
15'				40	40	60	45	
1'				50	20	60	52	
Season	3	2.23	N					
Interaction	15	20.37	N					
Total	23	34.12						

TABLE VI--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Season				Overall Median
				Spring	Summer	Fall	Winter	
Ortho-Phosphate, μg/l								13
Depth	5	23.73	S					
75'				30	124	32	19	
60'				17	64	24	9	
45'				17	39	12	10	
30'				14	7	8	10	
15'				7	6	12	10	
1'				20	5	10	12	
Season	3	11.04	S					
Interaction	15	13.00	N					
Total	23	47.78						

[a]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE VII

CHI-SQUARES ANALYSIS OF DEPTH AND YEAR GROUPINGS
FOR VERTICAL PROFILE MEASUREMENTS AT STATION 7

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Phytoplankton						5.83
Depth	5	4.82	N			
75'				3.42	9.68	
60'				5.11	8.90	
45'				4.39	6.52	
30'				6.32	10.68	
15'				3.38	14.43	
1'				1.99	9.54	
Year	1	8.94	S			
Interaction	5	1.63	N			
Total	11	15.40				
Total Phosphate, μg/1						35
Depth	5	16.86	S			
75'				166.0	64.0	
60'				35.0	36.0	
45'				36.0	46.0	
30'				27.0	31.0	
15'				27.5	31.0	
1'				46.0	34.0	
Year	1	0.02	N			
Interaction	5	3.37	N			
Total	11	20.26				
Organic Nitrogen, mg/1						0.30
Depth	5	5.66	N			
75'				0.30	0.30	
60'				0.20	0.20	
45'				0.30	0.20	
30'				0.40	0.20	
15'				0.30	0.30	
1'				0.30	0.30	
Year	1	0.00	N			
Interaction	5	3.25	N			
Total	11	8.91				

TABLE VII--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Dissolved Oxygen, mg/l						8.1
Depth	5	4.35	N			
75'				7.7	2.3	
60'				7.9	5.4	
45'				7.9	6.9	
30'				9.3	8.0	
15'				9.4	9.1	
1'				8.7	9.3	
Year	1	0.17	N			
Interaction	5	0.14	N			
Total	11	4.66				
Temperature °C						15.6
Depth	5	2.07	N			
75'				14.0	12.0	
60'				14.2	15.9	
45'				14.2	16.0	
30'				12.2	15.5	
15'				12.3	16.8	
1'				16.5	18.0	
Year	1	1.50	N			
Interaction	5	2.12	N			
Total	11	5.70				
Filterable Residue, mg/l						258
Depth	5	4.63	N			
75'				270	259	
60'				261	254	
45'				261	252	
30'				264	254	
15'				265	251	
1'				263	248	
Year	1	12.17	S			
Interaction	5	4.02	N			
Total	11	20.82				
Total Residue, mg/l						265
Depth	5	10.20	N			
75'				283	266	
60'				273	259	
45'				266	258	
30'				269	260	
15'				269	257	
1'				264	252	
Year	1	13.78	S			
Interaction	5	3.10	N			
Total	11	27.05				

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Year 1968-69	Year 1969-70	Overall Median
Chloride mg/1						34
Depth	5	2.95	N			
75'				35	31	
60'				35	31	
45'				34	31	
30'				35	33	
15'				35	33	
1'				35	33	
Year	1	19.22	S			
Interaction	5	0.92	N			
Total	11	23.10				
Sulfate, mg/1						6
Depth	5	1.38	N			
75'				15	15	
60'				18	15	
45'				18	16	
30'				18	15	
15'				15	16	
1'				16	16	
Year	1	0.62	N			
Interaction	5	1.69	N			
Total	11	3.70				
Ammonia, μg/1						50
Depth	5	11.52	S			
75'				350	130	
60'				60	80	
45'				50	70	
30'				46	60	
15'				40	40	
1'				50	40	
Year	1	0.06	N			
Interaction	5	3.27	N			
Total	11	14.86				
Nitrate, μg/1						86
Depth	5	1.03	N			
75'				50	110	
60'				120	94	
45'				100	74	
30'				100	90	
15'				90	50	
1'				100	50	
Year	1	1.16	N			
Interaction	5	2.32	N			
Total	11	4.51				

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical Inference[a]	Year 1968-69	Year 1969-70	Overall Median
Bicarbonate Alkalinity, mg/l						164
Depth	5	8.75	N			
75'				180	164	
60'				164	162	
45'				164	162	
30'				164	160	
15'				164	158	
1'				160	156	
Year	1	10.77	S			
Interaction	5	3.48	N			
Total	11	23.01				
Conductivity, micromhos/cm						440
Depth	5	3.99	N			
75'				490	420	
60'				470	420	
45'				460	430	
30'				460	420	
15'				460	420	
1'				460	420	
Year	1	36.49	S			
Interaction	5	2.42	N			
Total	11	42.91				
pH.						8.1
Depth	5	13.99	S			
75'				7.8	8.0	
60'				7.9	8.0	
45'				7.9	8.1	
30'				8.0	8.2	
15'				8.2	8.2	
1'				8.1	8.2	
Year	1	6.99	S			
Interaction	5	5.32	N			
Total	11	26.31				
Ortho-Phosphate, μg/l						13
Depth	5	23.73	S			
75'				43	57	
60'				13	27	
45'				10	24	
30'				6	10	
15'				9	11	
1'				14	11	
Year	1	0.41	N			
Interaction	5	6.14	N			
Total	11	30.28				

[a]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE VIII

CHI-SQUARES ANALYSIS OF SEASON AND YEAR GROUPINGS FOR VERTICAL PROFILE MEASUREMENTS AT STATION 7

Water Constituent to Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Total Phosphate, μg/l						31.0
Seasons	3	9.24	S			
Spring				99.0	33.5	
Summer				36.5	50.0	
Fall				31.0	37.5	
Winter				25.5	22.5	
Year	1	1.50	N			
Interaction	3	0.27	N			
Total	7	11.01				
Phytoplankton						5.81
Seasons	3	5.63	N			
Spring				6.06	7.70	
Summer				4.54	14.61	
Fall				0.26	11.58	
Winter				9.70	2.87	
Year	1	6.92	S			
Interaction	3	28.48	S			
Total	7	41.03				
Organic Nitrogen, mg/l						0.30
Seasons	3	11.88	S			
Spring				0.30	0.30	
Summer				0.35	0.30	
Fall				0.30	0.20	
Winter				0.20	0.30	
Year	1	0.02	N			
Interaction	3	8.71	S			
Total	7	20.62				
Dissolved Oxygen, mg/l						7.7
Seasons	3	83.72	S			
Spring				11.2	8.1	
Summer				0.0	0.0	
Fall				6.7	6.8	
Winter				12.3	12.0	
Year	1	0.00	N			
Interaction	3	3.74	N			
Total	7	87.46				

TABLE VIII--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Temperature ^{o}C						14.2
Seasons	3	62.85	S			
Spring				10.2	15.0	
Summer				22.0	25.0	
Fall				20.3	12.3	
Winter				7.0	6.0	
Year	1	0.22	N			
Interaction	3	8.43	S			
Total	7	71.50				
Filterable Residue, mg/l						255
Seasons	3	4.96	N			
Spring				290	251	
Summer				250	252	
Fall				265	234	
Winter				258	249	
Year	1	23.02	S			
Interaction	3	5.90	N			
Total	7	33.90				
Total Residue, mg/l						264
Seasons	3	10.29	S			
Spring				295	266	
Summer				262	257	
Fall				264	244	
Winter				276	256	
Year	1	12.02	S			
Interaction	3	6.04	N			
Total	7	28.36				
Chloride, mg/l						34
Seasons	3	64.25	S			
Spring				34	30	
Summer				31	28	
Fall				36	32	
Winter				37	37	
Year	1	10.81	S			
Interaction	3	17.75	S			
Total	7	92.81				

TABLE VIII--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Sulfate, mg/l						16
Seasons	3	46.56	S			
Spring				20	20	
Summer				14	15	
Fall				14	15	
Winter				20	16	
Year	1	0.35	N			
Interaction	3	6.59	N			
Total	7	53.52				
Ammonia, µg/l						50
Seasons	3	4.24	N			
Spring				50	45	
Summer				40	50	
Fall				50	80	
Winter				50	20	
Year	1	0.12	N			
Interaction	3	11.45	S			
Total	7	15.81				
Nitrate, µg/l						60
Seasons	3	68.29	S			
Spring				50	50	
Summer				50	50	
Fall				135	105	
Winter				120	125	
Year	1	0.31	N			
Interaction	3	1.87	N			
Total	7	70.47				
Conductivity, micromhos/cm						440
Seasons	3	8.27	S			
Spring				480	420	
Summer				430	420	
Fall				460	420	
Winter				460	440	
Year	1	27.18	S			
Interaction	3	17.13	S			
Total	7	52.60				

TABLE VIII--Continued

Water Constituent or Characteristic	Degrees of Freedom	Chi-Squares	Statistical[a] Inference	Year 1968-69	Year 1969-70	Overall Median
Bicarbonate Alkalinity, mg/l						16
Seasons	3	5.80	N			
Spring				156	165	
Summer				160	166	
Fall				164	150	
Winter				170	156	
Year	1	6.04	S			
Interaction	3	43.16	S			
Total	7	55.00				
pH.						8.1
Seasons	3	43.27	S			
Spring				8.4	8.2	
Summer				7.3	7.9	
Fall				8.1	8.1	
Winter				8.3	8.2	
Year	1	8.53	S			
Interaction	3	0.20	N			
Total	7	52.00				
Ortho-Phosphate, μg/l						12
Seasons	3	4.00	N			
Spring				20	15	
Summer				20	21	
Fall				7	13	
Winter				7	11	
Year	1	2.48	N			
Interaction	3	3.82	N			
Total	7	10.31				

[a]Differences are tested at the 0.05 level and listings are either as significant (S) or non-significant (N).

TABLE IX

MEASUREMENTS FOR PARAMETERS NOT INCLUDED IN THE CHI-SQUARES ANALYSIS

Total Coliforms/100 ml.

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	–	–	–	–	–	170	210	160	510
	5/1/68	–	–	–	–	–	400	800	10	1000
	5/22/68	–	–	–	–	–	60	200	110	38
	4/2/69	–	–	–	–	–	11	38	10	37
Summer	6/26/68	1600	1200	1400	1700	1600	700	1400	800	1900
	7/24/68	–	–	–	–	–	230	2400	700	900
	8/21/68	–	–	–	–	–	50	30	160	60
Fall	9/18/68	2000	600	1100	500	900	500	400	800	300
	10/16/68	–	–	–	–	–	<100	500	200	200
	11/18/68	–	–	–	–	–	1150	200	40	60
	12/11/68	208	225	220	150	190	220	165	130	130
Winter	1/8/69	–	–	–	–	–	60	50	70	390
	2/5/69	–	–	–	–	–	4	110	6	55
	3/12/69	–	–	–	–	–	–	–	–	–
	3/6/69	–	–	–	16	6	10	32	13	45
Year-1969-70										
Spring	4/30/69	–	–	–	–	–	500	420	380	800
	5/21/69	125	140	560	420	110	130	280	135	2500
	4/1/70	–	–	–	–	–	25	230	25	380
Summer	6/26/69	20	25	75	500	375	600	680	185	1900
	7/30/69	–	–	–	–	–	400	500	500	140
	8/20/69	100	100	100	920	1400	2000	800	1900	700
	9/17/69	–	–	–	–	–	180	280	380	220
Fall	10/15/69	–	–	–	–	–	665	330	940	1260
	11/12/69	2000	1250	1300	1250	90	270	340	590	240
	12/11/69	–	–	–	–	–	170	120	160	160
Winter	1/7/70	–	–	–	–	–	270	120	240	140
	2/7/70	<10	20	<10	30	20	10	200	20	370
	3/5/70	–	–	–	–	–	75	300	800	3300

TABLE IX--Continued

Carbonate Alkalinity
mg/1

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	0	0	0	0
	5/1/68	-	-	-	-	-	32	32	24	40
	5/22/68	-	-	-	-	-	0	4	0	0
	4/2/69	0	28	28	24	24	24	0	16	0
Summer	6/26/68	0	0	0	0	0	0	0	0	0
	7/24/68	0	0	0	0	0	0	0	8	0
	8/21/68	0	0	0	0	0	0	0	0	0
Fall *	9/18/68	0	0	0	0	0	0	0	0	0
	10/16/68	0	0	0	0	0	0	0	0	0
	11/18/68	0	0	0	0	0	0	0	0	0
	12/11/68	0	0	0	0	0	0	0	0	0
Winter	1/9/69	0	0	0	0	0	0	0	0	0
	2/5/69	0	0	0	0	0	0	0	0	0
	3/12/69	0	0	16	16	16	24	20	0	0
	3/6/69	-	-	-	0	0	0	0	0	0
Year-1969-70										
Spring	4/30/69	0	0	0	0	0	0	0	0	0
	5/21/69	0	0	0	0	0	0	0	0	0
	4/1/70	0	0	0	0	0	0	0	24	0
Summer	6/26/69	0	0	0	0	0	0	0	0	0
	7/30/69	0	0	0	0	0	0	0	0	0
	8/20/69	0	0	0	0	0	0	0	0	0
	9/17/69	0	0	0	0	0	0	0	0	0
Fall	10/15/69	0	0	0	0	0	0	0	0	0
	11/12/69	0	0	0	0	0	0	0	0	0
	12/11/69	0	0	0	0	0	0	0	0	0
Winter	1/7/70	0	0	0	0	0	0	0	0	0
	2/7/70	0	0	0	0	0	0	0	0	0
	3/5/70	8	8	8	8	8	8	12	0	0

*Alkalinities measured after samples returned to laboratory.

TABLE IX--Continued

Total Iron
mg/1

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	-	-	-	-
	5/1/68	-	-	-	-	-	-	-	-	-
	5/2/68	-	-	-	-	-	-	-	-	-
	4/2/69	-	-	-	-	-	-	-	-	-
Summer	6/26/68	-	-	-	-	-	-	-	-	-
	7/24/68	.6	.4	.5	.1	<.1	<.1	<.1	<.1	<.1
	8/21/68	1.1	.4	.1	0.1	.2	.2	.1	.1	.2
Fall	9/18/68	-	-	-	-	-	-	-	-	-
	10/16/68	.4	.2	<.2	<.2	<.2	.2	.2	.2	<.2
	11/13/68	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
	12/11/68	-	-	-	-	-	-	-	-	-
Winter	1/8/69	-	-	-	-	-	-	-	-	-
	2/5/69	-	-	-	-	-	-	-	-	-
	3/12/69	-	-	-	-	-	-	-	-	-
	3/6/69	-	-	-	-	-	-	-	-	-
Year-1969-70										
Spring	4/30/69	.19	.20	.19	.13	.10	.12	.20	.13	.30
	5/21/69	-	-	-	-	-	-	-	-	-
	4/1/70	.12	.08	.11	.10	.13	.13	.19	.13	.25
Summer	6/26/69	.40	.43	.35	.30	.37	.27	.36	.31	.45
	7/30/69	.68	.34	.27	.36	.17	.17	.18	.15	.15
	8/20/69	-	-	-	-	-	-	-	-	-
	9/17/69	2.75	.64	.67	.15	.16	.13	.19	.19	.17
Fall	10/15/69	0.70	.43	.30	.33	.28	.18	.23	.31	.33
	11/12/69	-	-	-	-	-	-	-	-	-
	12/11/69	0.13	.13	.24	.16	.14	.16	.16	.15	.15
Winter	1/7/70	0.07	.11	.07	.10	.11	.07	.12	.12	.10
	2/7/70	-	-	-	-	-	-	-	-	-
	3/5/70	0.09	.09	.09	.12	.12	.13	.22	.30	.64

TABLE IX--Continued

Fecal Coliforms/100 ml

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	–	–	–	–	–	12	28	47	155
	5/1/68	–	–	–	–	–	<1	<1	<1	<1
	5/22/68	–	–	–	–	–	2	7	10	21
	4/2/69	–	–	–	–	–	<1	2	<1	1
Summer	6/26/68	11	1	4	6	1	<1	<1	15	40
	7/24/68	–	–	–	–	–	<1	<1	<1	<1
	8/21/68	–	–	–	–	–	<1	1	1	1
Fall	9/18/68	5	12	1	<1	<1	<1	1	1	<1
	10/16/68	–	–	–	–	–	1	6	3	6
	11/13/68	–	–	–	–	–	2	33	2	9
	12/11/68	4	4	3	1	<1	4	2	<1	<1
Winter	1/8/69	–	–	–	–	–	8	5	15	19
	2/5/69	–	–	–	–	–	<1	17	<1	1
	3/12/69	–	–	–	–	–	–	–	–	–
	3/6/69	–	–	–	<1	<1	1	6	2	3
Year-1969-70										
Spring	4/30/69	–	–	–	–	–	13	74	28	124
	5/21/69	6	16	38	26	10	10	11	8	79
	4/1/70	–	–	–	–	–	1	<1	<1	8
Summer	6/26/68	5	1	24	2	1	4	1	<1	<1
	7/30/69	–	–	–	–	–	<1	<1	1	1
	8/20/69	<1	1	<1	<1	<1	1	<1	<1	<1
	9/17/69	–	–	–	–	–	1	<1	<1	<1
Fall	10/15/69	–	–	–	–	–	149	92	226	262
	11/12/69	80	113	21	18	14	8	4	3	1
	12/11/69	–	–	–	–	–	2	<1	4	<1
Winter	1/7/70	–	–	–	–	–	5	1	3	2
	2/7/70	<1	<1	<1	<1	<1	<1	<1	<1	<1
	3/5/70	–	–	–	–	–	22	88	>100	>100

TABLE IX--Continued

Total Manganese
mg/1

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	-	-	-	-
	5/1/68	-	-	-	-	-	-	-	-	-
	5/22/68	-	-	-	-	-	-	-	-	-
	4/2/69	-	-	-	-	-	-	-	-	-
Summer	6/26/68	-	-	-	-	-	-	-	-	-
	7/24/68	.7	.5	.8	<.1	<.1	<.1	<.1	<.1	<.1
	8/21/68	1.8	.2	<.1	<.1	<.1	<.1	.2	<.1	<.1
Fall	9/18/68	-	-	-	-	-	-	-	-	-
	10/16/68	5.2	.1	.1	.1	<.2	.1	.1	.1	.1
	11/13/68	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
	12/11/68	-	-	-	-	-	-	-	-	-
Winter	1/8/69	-	-	-	-	-	-	-	-	-
	2/5/69	-	-	-	-	-	-	-	-	-
	3/12/69	-	-	-	-	-	-	-	-	-
	3/6/69	-	-	-	-	-	-	-	-	-
Year-1969-70										
Spring	4/30/69	.19	.06	.03	<.02	<.02	<.02	.03	.02	.09
	5/21/69	-	-	-	-	-	-	-	-	-
	4/1/70	.10	.12	.10	.10	.10	.08	.11	.10	.03
Summer	6/26/69	.53	.45	.35	.04	.07	.09	.12	.07	.07
	7/30/69	3.64	1.00	.66	.35	.02	.02	.02	.02	.04
	8/20/69	-	-	-	-	-	-	-	-	-
	9/17/69	4.4	1.18	1.68	<.05	<.05	.05	<.05	.08	<.05
Fall	10/15/69	.80	.50	.38	.17	.18	.25	.17	.17	.16
	11/12/69	-	-	-	-	-	-	-	-	-
	12/11/69	.06	<.05	.05	.06	<.05	<.05	<.05	.06	<.05
Winter	1/7/70	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
	2/7/70	-	-	-	-	-	-	-	-	-
	3/5/70	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05

TABLE IX--Continued

Fecal Streptococci
/100 ml

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	9	46	55	102
	5/1/68	-	-	-	-	-	1	<1	3	2
	5/22/68	-	-	-	-	-	9	40	28	42
	4/2/69	-	-	-	-	-	<1	1	<1	<1
Summer	6/26/68	24	9	8	9	8	1	6	8	11
	7/24/68	-	-	-	-	-	<1	4	12	1
	8/21/68	-	-	-	-	-	6	12	12	<1
Fall	9/18/68	1	1	1	<1	<1	<1	1	<1	1
	10/16/68	-	-	-	-	-	4	4	2	7
	11/13/68	-	-	-	-	-	10	3	<1	<1
	12/11/68	1	<1	2	1	1	2	2	1	1
Winter	1/8/69	-	-	-	-	-	1	<1	6	9
	2/5/69	-	-	-	-	-	<1	39	<1	3
	3/12/69	-	-	-	-	-	-	-	-	-
	3/6/69	-	-	-	<1	5	3	8	<1	<1
Year-1969-70										
Spring	4/30/69	-	-	-	-	-	23	160	15	99
	5/21/69	<2	2	64	50	6	3	9	3	20
	4/1/70	-	-	-	-	-	1	<1	<1	2
Summer	6/26/69	2	3	9	2	1	7	<1	<1	2
	7/30/69	-	-	-	-	-	<1	<1	1	3
	8/20/69	<1	1	1	<1	1	7	<1	<1	<1
	9/17/69	-	-	-	-	-	<1	2	<1	1
Fall	10/15/69	-	-	-	-	-	232	121	277	226
	11/12/69	77	64	20	4	2	2	3	4	1
	12/11/69	-	-	-	-	-	13	<1	13	<1
Winter	1/7/70	-	-	-	-	-	22	19	36	21
	2/7/70	<1	2	1	<1	<1	<1	1	<1	3
	3/5/70	-	-	-	-	-	20	66	>100	>100

TABLE IX--Continued

Total Plate Count/ml @ 20^{o}C

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	7200	4300	8800	2400
	5/1/68	-	-	-	-	-	460	100	350	700
	5/22/68	-	-	-	-	-	470	660	460	540
	4/2/69	-	-	-	-	-	240	910	900	1070
Summer	6/26/68	800	1500	1200	450	300	140	320	2400	3200
	7/24/68	-	-	-	-	-	490	510	190	640
	8/21/68	-	-	-	-	-	380	630	510	230
Fall	9/18/68	180	470	140	170	150	130	170	230	400
	10/16/68	-	-	-	-	-	410	490	690	420
	11/13/68	-	-	-	-	-	500	250	280	310
	12/11/68	2500	1020	810	820	760	1130	950	480	180
Winter	1/8/69	-	-	-	-	-	450	610	430	1900
	2/5/69	-	-	-	-	-	89	2100	100	420
	3/12/69	-	-	-	-	-	-	-	-	-
	3/6/69	-	-	-	160	160	160	300	320	280
Year-1969-70										
Spring	4/30/69	-	-	-	-	-	1700	3200	1700	3000
	5/21/69	400	460	890	1050	260	290	810	600	1800
	4/1/70	-	-	-	-	-	85	190	157	420
Summer	6/26/69	690	620	560	560	450	180	560	190	540
	7/30/69	-	-	-	-	-	290	440	130	490
	8/20/69	210	120	130	130	100	60	100	40	90
	9/17/69	-	-	-	-	-	90	118	92	117
Fall	10/15/69	-	-	-	-	-	4550	1990	4500	6050
	11/12/69	230	170	170	99	51	80	80	138	153
	12/11/69	-	-	-	-	-	201	64	360	140
Winter	1/7/70	-	-	-	-	-	1130	1100	1860	1130
	2/7/70	760	910	850	130	700	1170	280	1380	270
	3/5/70	-	-	-	-	-	690	2800	10200	>10000

TABLE IX--Continued

Total Plate Count/ml @ 35°C

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	183	550	1600	990
	5/1/68	-	-	-	-	-	70	280	370	260
	5/22/68	-	-	-	-	-	640	190	290	320
	4/2/69	-	-	-	-	-	200	200	210	1200
Summer	6/26/68	350	370	1800	370	250	80	810	180	5700
	7/24/68	-	-	-	-	-	170	500	200	470
	8/21/68	-	-	-	-	-	370	910	580	420
Fall	9/18/68	370	150	200	140	300	130	370	190	370
	10/16/68	-	-	-	-	-	180	260	160	220
	11/13/68	-	-	-	-	-	220	102	163	220
	12/11/68	360	105	270	123	143	210	107	132	131
Winter	1/8/69	-	-	-	-	-	53	65	80	110
	2/5/69	-	-	-	-	-	36	270	40	140
	3/12/69	-	-	-	-	-	-	-	-	-
	3/6/69	-	-	-	79	44	96	150	64	360
Year-1969-70										
Spring	4/30/69	-	-	-	-	-	260	770	250	1800
	5/21/69	170	190	330	370	200	108	230	270	750
	4/1/70	-	-	-	-	-	38	38	33	87
Summer	6/26/69	630	210	330	70	190	490	350	110	660
	7/30/69	-	-	-	-	-	380	150	260	430
	8/20/69	160	160	260	160	120	80	90	80	100
	9/17/69	-	-	-	-	-	27	87	55	170
Fall	10/15/69	-	-	-	-	-	760	1050	1260	1310
	11/12/69	130	106	78	55	47	28	53	88	97
	12/11/69	-	-	-	-	-	130	80	140	64
Winter	1/7/70	-	-	-	-	-	98	96	270	137
	2/7/70	25	9	36	30	25	34	18	37	110
	3/5/70	-	-	-	-	-	149	330	1310	4200

TABLE IX--Continued

Nitrite
µg/l

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	<50	<50	<50	<50
	5/1/68	-	-	-	-	-	<50	<50	<50	<50
	5/22/68	-	-	-	-	-	<50	<50	<50	<50
	4/2/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
Summer	6/26/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
	7/24/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
	8/21/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
Fall	9/18/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
	10/16/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
	11/12/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
	12/11/68	<50	<50	<50	<50	<50	<50	<50	<50	<50
Winter	1/8/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	2/5/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	3/12/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	3/6/69	-	-	-	<50	<50	<50	<50	<50	<50
Year-1969-70										
Spring	4/30/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	5/21/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	4/1/70	<50	<50	<50	<50	<50	<50	<50	<50	<50
Summer	6/26/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	7/30/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	8/20/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	9/17/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
Fall	10/15/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	11/12/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
	12/11/69	<50	<50	<50	<50	<50	<50	<50	<50	<50
Winter	1/7/70	<50	<50	<50	<50	<50	<50	<50	<50	<50
	2/7/70	<50	<50	<50	<50	<50	<50	<50	<50	<50
	3/5/70	<50	<50	<50	<50	<50	<50	<50	<50	<50

TABLE IX--Continued

COD, mg/l

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	26	24	26	24
	5/1/68	-	-	-	-	-	26	28	26	32
	5/22/68	-	-	-	-	-	15	15	13	22
	4/2/69	-	-	-	-	-	-	-	-	-
Summer	6/26/68	13	0	22	13	16	13	13	11	13
	7/24/68	-	-	-	-	-	-	-	-	-
	8/21/68	-	-	-	-	-	-	-	-	-
Fall	9/18/68	25	27	19	17	19	25	17	23	25
	10/16/68	-	-	-	-	-	-	-	-	-
	11/13/68	-	-	-	-	-	-	-	-	-
	12/11/68	26	24	19	12	13	11	15	13	14
Winter	1/8/69	-	-	-	-	-	-	-	-	-
	2/5/69	-	-	-	-	-	-	-	-	-
	3/12/69	21.9	20.8	18.3	18.8	16.4	16.4	18.3	14.6	23.8
	3/6/69	-	-	-	-	-	-	-	-	-
Year-1969-70										
Spring	4/30/69	-	-	-	-	-	-	-	-	-
	5/21/69	21	19	21	26	22	27	23	23	25
	4/1/70	-	-	-	-	-	-	-	-	-
Summer	6/26/69	-	-	-	-	-	-	-	-	-
	7/30/69	-	-	-	-	-	-	-	-	-
	8/20/69	20	15	15	15	46	44	15	43	44
	9/17/69	-	-	-	-	-	-	-	-	-
Fall	10/15/69	-	-	-	-	-	-	-	-	-
	11/12/69	7	7	7	9	5	5	9	16	9
	12/11/69	-	-	-	-	-	-	-	-	-
Winter	1/7/70	-	-	-	-	-	-	-	-	-
	2/7/70	11	11	13	14	15	16	13	14	14
	3/5/70	-	-	-	-	-	-	-	-	-

TABLE IX--Continued

BOD, mg/l

Year-1968-69	Station	7	7	7	7	7	7	8	6	5
	Depth	75'	60'	45'	30'	15'	1'	1'	1'	1'
Season	Date									
Spring	4/2/68	-	-	-	-	-	2	2	2	3
	5/1/68	-	-	-	-	-	2	2	2	2
	5/22/68	-	-	-	-	-	2	2	1.7	2
	4/2/69	-	-	-	-	-	-	-	-	-
Summer	6/26/68	2.9	2.5	1.6	1.4	1.2	1.5	1.5	1.7	1.8
	7/24/68	-	-	-	-	-	-	-	-	-
	8/21/68	-	-	-	-	-	-	-	-	-
Fall	9/18/68	2.0	1.3	2.9	1.1	1.3	1.6	1.8	1.3	2.2
	10/16/68	-	-	-	-	-	-	-	-	-
	11/13/68	-	-	-	-	-	-	-	-	-
	12/11/68	2.7	2.6	2.6	2.4	2.1	2.4	2.5	2.4	2.5
Winter	1/8/69	-	-	-	-	-	-	-	-	-
	2/5/69	-	-	-	-	-	-	-	-	-
	3/12/69	2.0	2.4	1.9	2.7	2.6	2.6	2.5	2.5	2.6
	3/6/69	-	-	-	2.2	2.2	2.2	2.4	2.2	2.1
Year-1969-70										
Spring	4/30/69	-	-	-	-	-	-	-	-	-
	5/21/69	.9	.8	.9	.8	1.0	1.1	2.2	1.5	1.6
	4/1/70	-	-	-	-	-	-	-	-	-
Summer	6/26/69	-	-	-	-	-	-	-	-	-
	7/30/69	-	-	-	-	-	-	-	-	-
	8/20/69	3.1	2.9	1.7	2.6	1.4	1.2	1.5	1.4	1.2
	4/17/69	-	-	-	-	-	-	-	-	-
Fall	10/15/69	-	-	-	-	-	-	-	-	-
	11/12/69	1.2	1.3	1.0	1.0	.7	2.1	2.2	1.4	2.7
	12/11/69	-	-	-	-	-	-	-	-	-
Winter	1/7/70	-	-	-	-	-	-	-	-	-
	2/7/70	2.5	2.3	2.3	2.3	2.4	2.5	2.4	2.3	2.6
	3/5/70	-	-	-	-	-	-	-	-	-

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16. Abstract

Changes in stream water quality, resulting from recent impoundment, are presented and discussed. Extensive data reflecting pre- and post-impoundment conditions were statistically analyzed. The extent to which pollutants influence changes in water quality was minimal, since the drainage basin was relatively undisturbed by the activities of man. Chemical, physical, and microbiological parameters at stream stations were evaluated for three discrete periods of time: prior to closure of the dam, during filling of the active conservation pool, and following filling with the surface maintained near the top of the active conservation elevation. Effects of removing treated municipal waste effluents from a tributary were also evaluated. Water quality changes within the impoundment were compared with respect to season, year, station location, and depth of sampling. Critical factors in the impoundment, which contributed to water quality changes, are identified.

17a. Descriptors

*Reservoirs, *Pre-impoundment, *Post-impoundment, *Water Analysis, Dissolved Oxygen, Thermal Stratification, Nutrients, Biochemical Oxygen Demand, Aquatic Life, Sewage Effluents, Decomposing Organic Matter, Statistical Methods, Water Balance.

17b. Identifiers

*Arbuckle Reservoir, *Rock Creek, Oxidative Metabolism, Hypolimnetic Oxygen Deficit

17c. COWRR Field & Group 04A

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