MARYLAND GEOLOGICAL SURVEY
REPORT OF INVESTIGATIONS NO. 1

RUBIDIUM **Rb** BORON **B**

COPPER **Cu** BARIUM **Ba**

CHEMICAL QUALITY OF WATER AND TRACE ELEMENTS IN THE PATUXENT RIVER BASIN

COBALT **Co** MOLYBDENUM **Mo**

VANADIUM **V** SODIUM **Na**

By
S.G. Heidel
W.W. Frenier

POTASSIUM **K**

ZIRCONIUM **Zr**

IRON **Fe** CHROMIUM **Cr**

prepared in cooperation with the

GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

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Kenneth N. Weaver, *Director*

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United States Department of the Interior

1965

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Preface

This "Report of Investigations" is the first of a new series to be published by the Maryland Geological Survey and will supplement the existing Bulletin and County Report series.

The larger page format of the Report of Investigations series is better suited to certain types of reports, especially those containing a relatively large number of illustrations and tables.

"Chemical Quality of Water and Trace Elements in the Patuxent River Basin" reports the results of an investigation accomplished under the continuing cooperative program of water resources investigations with the Water Resources Division of the U. S. Geological Survey. Other Maryland agencies including the Natural Resources Institute, Department of Water Resources, and Chesapeake Bay Institute participated in this study and their support is gratefully acknowledged.

KENNETH N. WEAVER
Director

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CHEMICAL QUALITY OF WATER AND TRACE ELEMENTS IN THE PATUXENT RIVER BASIN

By S. G. Heidel *and* W. W. Frenier

Abstract

A one-year investigation of the chemical quality of the river, including spectrographic analysis for trace elements, was begun in July 1963. The salt front, characterized by a section of abrupt increases in salinity, shifted about five miles upstream with high tide. The extent of salt-water intrusion in late summer was as much as 20 miles upstream from the salt front that occurred in late spring. The fresh water of the Patuxent River is low in dissolved solids (less than 100 parts per million); therefore, percentage composition of chemical constituents of the diluted water in the lower estuary was practically the same as sea water.

Trends of concentrations of trace elements in the estuary are similar to the trends of major constituents. Concentrations of boron, lithium, and strontium in the saline water are higher than in the fresh-water inflow, but lower than in sea water. In the fresh water of the Patuxent River, the median concentrations of manganese, boron, and rubidium are higher than those determined for major rivers of North America. Most of 23 other trace elements checked for in fresh waters of the Patuxent River were found in concentrations close to or somewhat less than the median concentrations determined for major North American rivers.

Introduction

The Patuxent River basin is the largest basin completely within the State of Maryland. From its headwaters near U. S. Highway 40 to its mouth at Chesapeake Bay, the Patuxent River flows about 110 miles and drains an area of about 930 square miles. The stage of the river is affected by tides for about half its length, or as far upstream as Hardesty, and during some dry periods of low runoff, brackish water moves upstream nearly 50 miles, or at least as far as Maryland Highway 4 near Upper Marlboro. The Patuxent River basin includes an area that is relatively undeveloped as compared to adjacent metropolitan centers of Baltimore and Washington. The largest city in the basin is the rapidly growing city of Laurel.

Several agencies including the Natural Resources Institute, the Chesapeake Bay Institute, and the Maryland Department of Water Resources have participated in a cooperative program to determine the chemical, physical, and biological characteristics of the Patuxent River prior to expected domestic and industrial developments. As a part of this program, the Geological Survey in cooperation with the Maryland Department of Geology, Mines and Water Resources (Maryland Geological Survey since July 1964) conducted a trace element study in the Patuxent River basin during the 1964 fiscal year.

Purpose and scope of investigation

The purpose of this investigation was to determine the chemical characteristics of surface waters in the basin, including concentrations of trace elements, as a basis for evaluating any possible effects of anticipated industrial and urban developments.

The sampling program was designed to yield the maximum possible information within a one-year period. Samples were obtained at approximately ten-day intervals from six regular stations and analyzed for common constituents. In addition, thirty-three samples were analyzed spectrographically during the year; these samples included one set from 15 locations in the basin and the other sets, collected approximately quarterly, from the six regular sampling locations (fig. 1).

Acknowledgements

Personnel of the Chesapeake Biological Laboratory provided valuable assistance and equipment for sample collection in the estuary.

Chemists under the direction of H. R. Feltz of the U. S. Geological Survey laboratory in Washington, D. C. analyzed the samples by standard chemical methods.

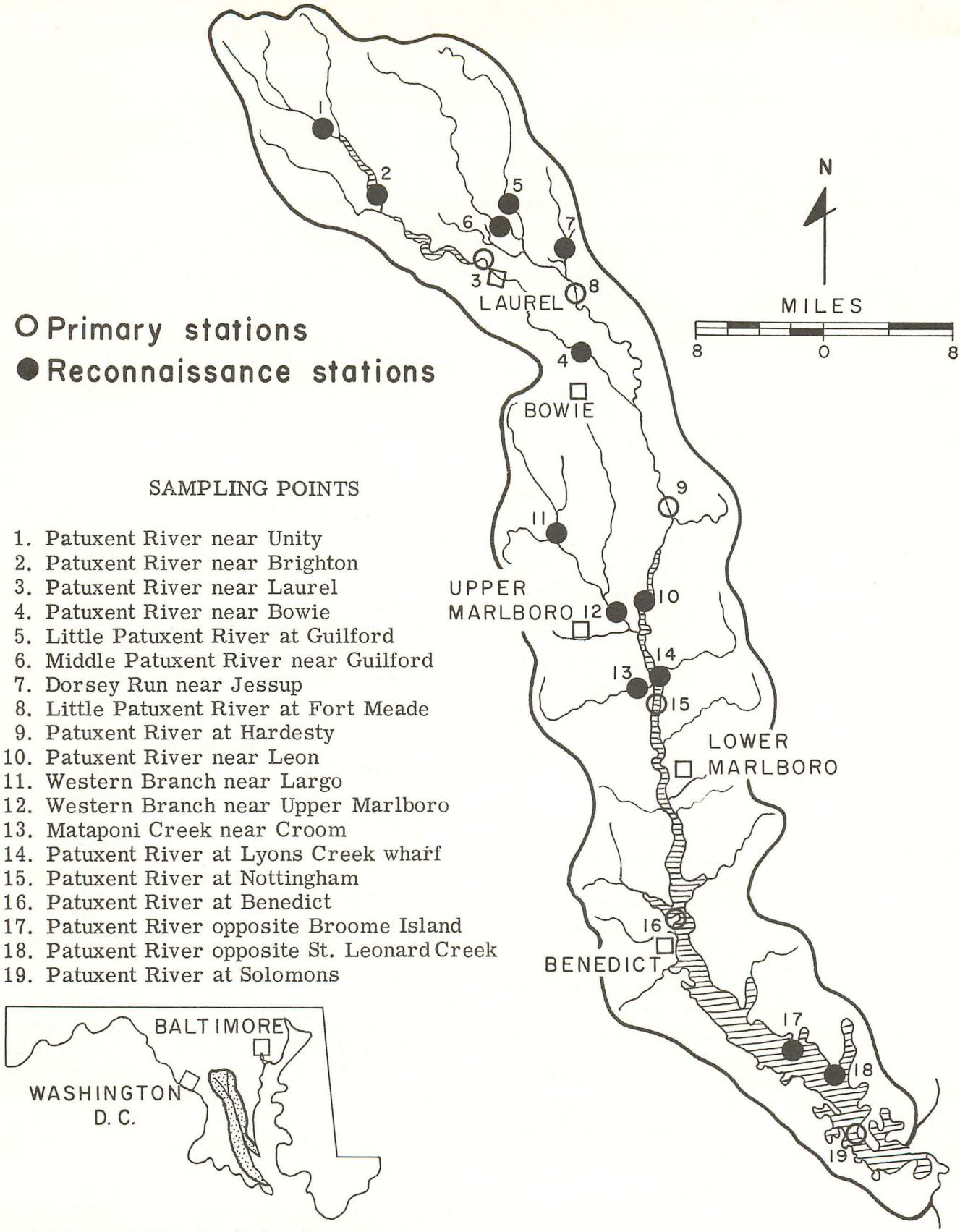
Samples were analyzed for trace elements by Joseph Haffty and P. R. Barnett in the U. S. Geological Survey laboratory in Denver, Colorado and by W. D. Silvey and V. A. Stone in the U. S. Geological Survey laboratory in Sacramento, California.

Methods of investigation

Suitable techniques for determining trace elements in natural waters have been available only in very recent years. The residue method for spectrographic analysis has been used by the Water Resources Division of the Geological Survey (Haffty, 1960) since about 1958. A characteristic of the residue method is that the minimum detectable concentration of any element increases in direct proportion to the concentration of total dissolved solids in the sample. Therefore, concentrations of many trace elements in brackish estuary waters are too low to be detected by the residue method. The Geological Survey laboratory in California has used a chemical enrichment or concentration method in preparing samples for spectrographic analysis (Silvey and Brennan, 1962) and this method was used for most samples obtained in the Patuxent estuary. Results of all the spectrographic analyses are given in Table 1.

The analytical methods are described in detail because, as with all new methods, procedures will be changed with experience, and future evaluation of the analyses presented will depend to some extent on the details of the procedures used for this study.

The complete picture on chemical characteristics of water in a river basin requires knowledge of the concentrations of major constituents; the Geological Survey's standard methods of water analysis (Rainwater and Thatcher, 1960) were used to determine these constituents in the Patuxent River basin. The changes in common constituents in water in response to variation of water discharge are usually more definite than with trace elements. Direct surface runoff dilutes the solutions of mineral matter that occur at base flows, and although simple relationships between water quality and water quantity do not always exist, the concentration of dissolved solids, including the principal constituents, is frequently inversely proportional to discharge. The chemical analyses results are given in tables 2 to 8.



SAMPLING POINTS

1. Patuxent River near Unity
2. Patuxent River near Brighton
3. Patuxent River near Laurel
4. Patuxent River near Bowie
5. Little Patuxent River at Guilford
6. Middle Patuxent River near Guilford
7. Dorsey Run near Jessup
8. Little Patuxent River at Fort Meade
9. Patuxent River at Hardesty
10. Patuxent River near Leon
11. Western Branch near Largo
12. Western Branch near Upper Marlboro
13. Mataponi Creek near Croom
14. Patuxent River at Lyons Creek wharf
15. Patuxent River at Nottingham
16. Patuxent River at Benedict
17. Patuxent River opposite Broome Island
18. Patuxent River opposite St. Leonard Creek
19. Patuxent River at Solomons

Index map of Maryland showing area covered by this report.

Figure 1—Map of the Patuxent River basin showing sampling points and principal cities and towns

Sample collection

Each sample obtained for spectrographic analysis was filtered immediately after collection through a glass-fiber filter paper, capable of retaining all but the very finest particles which may be suspended in the water. After filtration, each sample to be analyzed by the residue method was acidified with 6 milliliters of diluted (1:1) analytical reagent grade nitric acid which was double distilled and contained in a sealed glass ampoule accompanying a 2-liter polyethylene sample bottle. Samples for spectrographic analysis that were analyzed by the concentration method were shipped to the laboratory immediately after filtration.

Samples that were collected for processing by chemical analysis for major constituents were untreated at the time of sampling except that a small extra bottle of water was usually obtained and acidified with a few drops of concentrated hydrochloric acid. The extra bottles thus acidified were analyzed for iron, manganese, and occasionally for aluminum, copper, and zinc by standard wet chemical methods.

Limitations of analytical methods

The spectrographic methods used to determine trace elements in this program provide a relatively rapid means of simultaneous determination of several elements at very low concentrations. Concentrations of most of these elements can be determined to 1 microgram per liter ($\mu g/l$) and for some samples and elements, notably silver, beryllium, copper, and lithium, results may be determined to 0.01 micrograms per liter or hundredths of a part per billion. Nevertheless, the concentrations of the elements determined are so low in most natural waters that they are near the limits of sensitivity or frequently below the limits of detection. With such a low order of occurrence, the method of collection and sample treatment is of paramount importance in the analytical determination. Each of the approved procedures has been standardized for the particular results desired, but because field treatment of these samples is quite different for chemical and spectrographic methods, direct comparison of the results by the separate methods should not be made. The order of magnitude of concentration of any given constituent is approximately the same by any method used, but comparison of the determination of aluminum, iron, manganese, zinc, copper, and boron by spectrographic methods with chemical methods can be made only in a very general way.

Chemical characteristics of the Patuxent River

Chemical composition of fresh-water discharge

The fresh-water portion of the Patuxent River basin contains water of good chemical quality and usually concentrations of dissolved solids are less than 100 parts per million (ppm). The headwaters of the river drain resistant rock consisting of schists, granite, and small amounts of limestone and marble. Southeast of a line connecting Washington, D. C. and Baltimore, Md., the river drains coastal-plain sands and clays which yield water of good chemical quality unless subject to salt-water intrusion.

Two dams built by the Washington Suburban Sanitary Commission at Laurel and at Brighton provide a water supply for the domestic needs of the citizens of the Sanitary District. Two effects of this impoundment are obvious: First, the flow is regulated and the water from the reservoirs reflects the smoothing out of quality and elimination of sharp variations in concentrations of dissolved minerals that occur in unregulated streams; secondly, since the water is used for domestic supply, the reservoirs are protected from outside contamination and thus the water more closely reflects natural conditions than other parts of the basin. At Laurel, the dissolved solids concentrations are very low and average 50 ppm with a range of 41 to 60 ppm for the 18 samples collected. As fig. 2 shows, the water is a calcium-magnesium-bicarbonate type with smaller amounts of chloride, sulfate, and nitrate present.

The confluence of the Patuxent and the Little Patuxent Rivers is a mile downstream from Bowie. The Little Patuxent River and its tributary, the Middle Patuxent River, drain an area with geologic conditions similar to that drained by the Patuxent River at Laurel. However, the flow of the Little Patuxent River is not regulated, and sewage treatment plants operated by the Howard County Metropolitan Commission, Ft. Meade, and the Maryland House of Correction, discharge treated wastes into the stream above and near the sampling station at Simonds Bridge on the Ft. George G. Meade military reservation. The chemical quality reflects both the geologic conditions and the use of the stream by man. The comparatively low dissolved-solids concentration of 85 ppm is nevertheless significantly higher than at Laurel. The water is of a calcium-magnesium-bicarbonate type, but sulfates, chlorides, and nitrates comprise almost one-half of the anions in the Little Patuxent River. The sodium concentration is also higher than at Laurel. This quality reflects the use of the stream for treated sewage effluents.

The water of the Patuxent River upstream from Hardesty (Queen Anne Bridge) is considered to be representative of the entire nontidal portion of the basin, and the concentration of dissolved solids at Hardesty is representative of most water flowing into the estuary. The total dissolved-solids concentration is low (ranging from 49 to 99 ppm during 1963-64), and is characteristic of the geologic conditions of the basin. At this station, bicarbonate comprises less than one-half of the anions, and chlorides, nitrates, and sulfates predominate. Magnesium and calcium are the major cations, but the concentration of sodium is also significant.

Salinity in the estuary

Salinity, a widely used term in oceanography, is a defined quantity that approximates the total salt concentration of the water: S (ppm) = 30 + 1.805 x chlorinity (ppm). Chlorinity is also a defined quantity that originally referred to the total quantity of halogens (chlorine, bromine, and iodine) in grams in 1 kilogram of sea water assuming the bromine and iodine had been replaced by chlorine. However, changes in definition of atomic weights required a redefinition of chlorinity in order to keep the above relationship. Chlorinity is now defined as 0.3285233 times the weight of silver required to precipitate the halides from a kilogram of sea water. The actual difference between chloride content and chlorinity is not large. Using the 1961 atomic weights, the ratio of chloride equivalent to chlorinity is 1.00043.

The salinity of the Patuxent River estuary varies with the depth, the distance upstream from the mouth, the position on the tidal cycle, the season, and with changes in streamflow. Where a river flows to the sea or bay, two aqueous fluids of different density are in contact with each other. Such systems tend to stratify horizontally with the heavier saline water flowing upstream under the lighter river water. Complete stratification does not occur because the fresh water erodes away the salt wedge; thus, an increase in the salinity from top to bottom is expected. No systematic study was made of the stratification of the Patuxent estuary, but samples taken at the surface and the bottom during the present study at Benedict and Solomons showed increases of about 500 ppm in chlorinity. Observa-

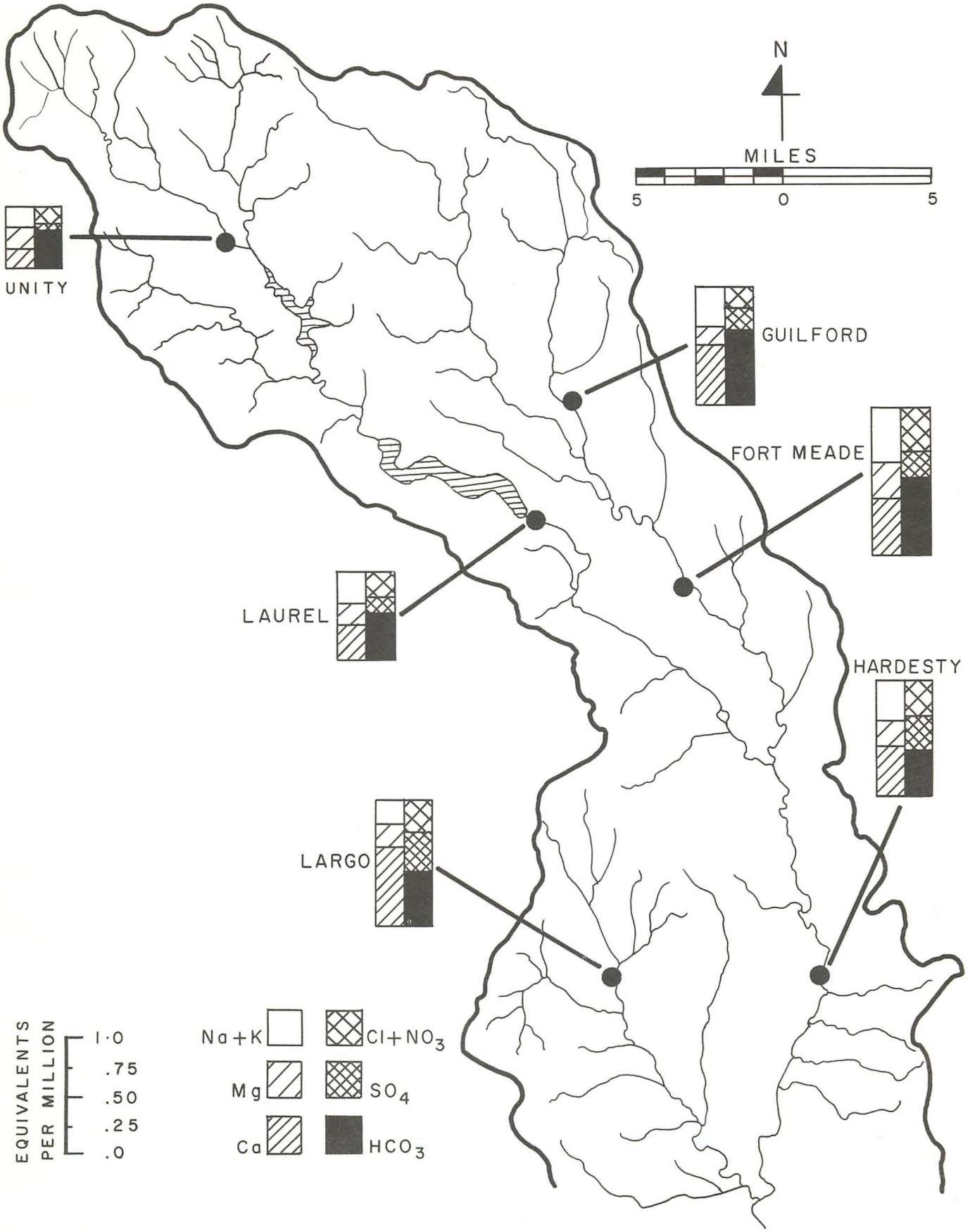


Figure 2—Chemical characteristics of fresh water of the Patuxent River basin.

tions in Data Reports 19, 21 and 23, Patuxent River Cruises of 1952 by the Chesapeake Bay Institute of The Johns Hopkins University indicate a similar trend of increasing salinity from top to bottom that would correspond to chlorinity increases of 1000 ppm or more.

Depth profiles were determined for one-half of a tidal cycle at Benedict on May 9 and June 9, 1964 and profiles of the full tidal cycle for July 9 were determined by R. L. Cory (written communication, 1964) (figs. 3, 4, and 5). When the concentration of chloride is low (high river discharge—fig. 3), the incoming tide produces a large concentration variation from top to bottom, and changes of 600 to 700 ppm over a span of one-half hour. However, when the flow of the river decreases (June and July—figs. 4 and 5), saline water from the Chesapeake Bay dominates the chemical quality and the average chloride concentration increases; however, the concentration gradients become much less, the isopleths become more vertical, and changes with time become less abrupt. During a prolonged drought, mixing at Benedict is nearly complete and the water approaches homogeneity. However, the percentage composition of the major elements does not change from top to bottom, or during the changes in the tidal cycle, even when large concentration gradients are present. The unchanging percentage compositions demonstrates the strong influence of the Chesapeake Bay water on the gross chemical quality in the Patuxent estuary.

In the upstream portion of the river, the water is low in dissolved solids, but near the mouth, the water will approach the salinity of the Chesapeake Bay. In one small intermediate region of the river, the salinity increases very rapidly. This region, designated as the critical salt front, can be located by plotting the chloride concentration at a number of stations longitudinally distributed along the river. The salt front is defined by the region where the slope of the salinity profile is the largest. The changes in this parameter reflect changes in the salt-water encroachment in the river.

Figure 6 shows several salinity profiles for the Patuxent estuary at different times of the year. During times of maximum encroachment (late summer) the salt front extends 40 to 50 miles from the mouth, or about to Upper Marlboro. In times of minimum salt encroachment (spring) the salt front extends only 20 to 25 miles from the mouth or a few miles upstream from Benedict, indicating a seasonal shift of about 20 miles.

The tide greatly affects the extent of the salt-water intrusion. Keighton (1954) states that the maximum penetration should take place at high-water slack (the momentary zero velocity when the current changes from flood to ebb tide), and the minimum penetration at low-water slack.

Salinity data collected on September 13, 1963 confirms the changes in penetration on the Patuxent River and indicates a shift of the salt front of about 5 miles between high and low tide. Measurements throughout the tidal reach were not obtained just at high-water slack and low-water slack or at maximum and minimum salinities, so the actual shift, which could be as much as 10 miles, is not known.

The seasonal variation of the salinity is also demonstrated by figure 7, a plot of dissolved-solids concentrations during the year at six principal stations. The upper portion of the estuary (Nottingham) shows extreme seasonal changes and for 4 to 5 months of the year the water at this station is non-saline (less than 50 ppm of chloride). The downstream stations also show seasonal variations, but the magnitude of these changes is much less.

The seasonal changes are attributed to changes in runoff. During dry periods of the year the amount of fresh water reaching the estuary decreases and the salt front moves upstream while during the months of high precipitation and evapo-transpiration, the salt front retreats 10 to 15 miles below Nottingham. Nash (1947) has shown the inverse relationship of the surface salinity at Solomons to the streamflow of the Patuxent at a station 5 miles above Laurel. However, a lag of 1 to 2 months occurs between seasonal changes in streamflow and in salinity. The lag was reported to decrease in the upstream reaches where the chemical quality of the water is more directly dependent upon the streamflow.

A similar relationship was noted during the present sampling program. The streamflow data collected at Hardesty and salinity data from Nottingham plotted on figure 8 indicates that the salinity varied inversely with the streamflow with a lag of a month or less. However, the data are not sufficiently detailed to accurately define the lag-time.

The water flowing from the Patuxent River into the estuary is low in dissolved solids, seldom exceeding 100 ppm in concentration; thus, a plot of chloride concentration vs. specific conductivity (fig. 9) shows a higher ratio of chloride to conductance for the Patuxent than for the Potomac

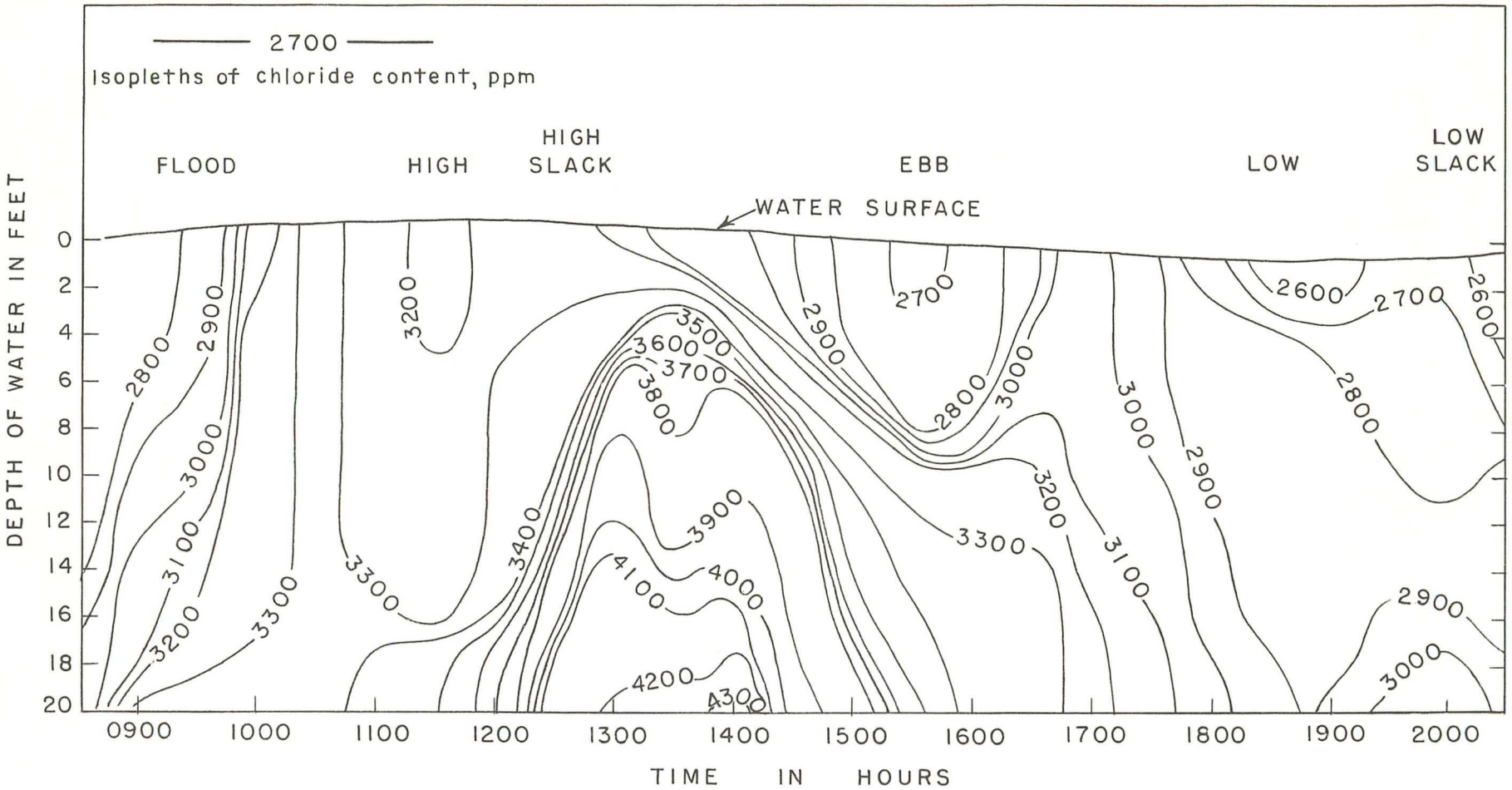


Figure 3—Isopleths of chloride of Patuxent River at Benedict, May 9, 1964.

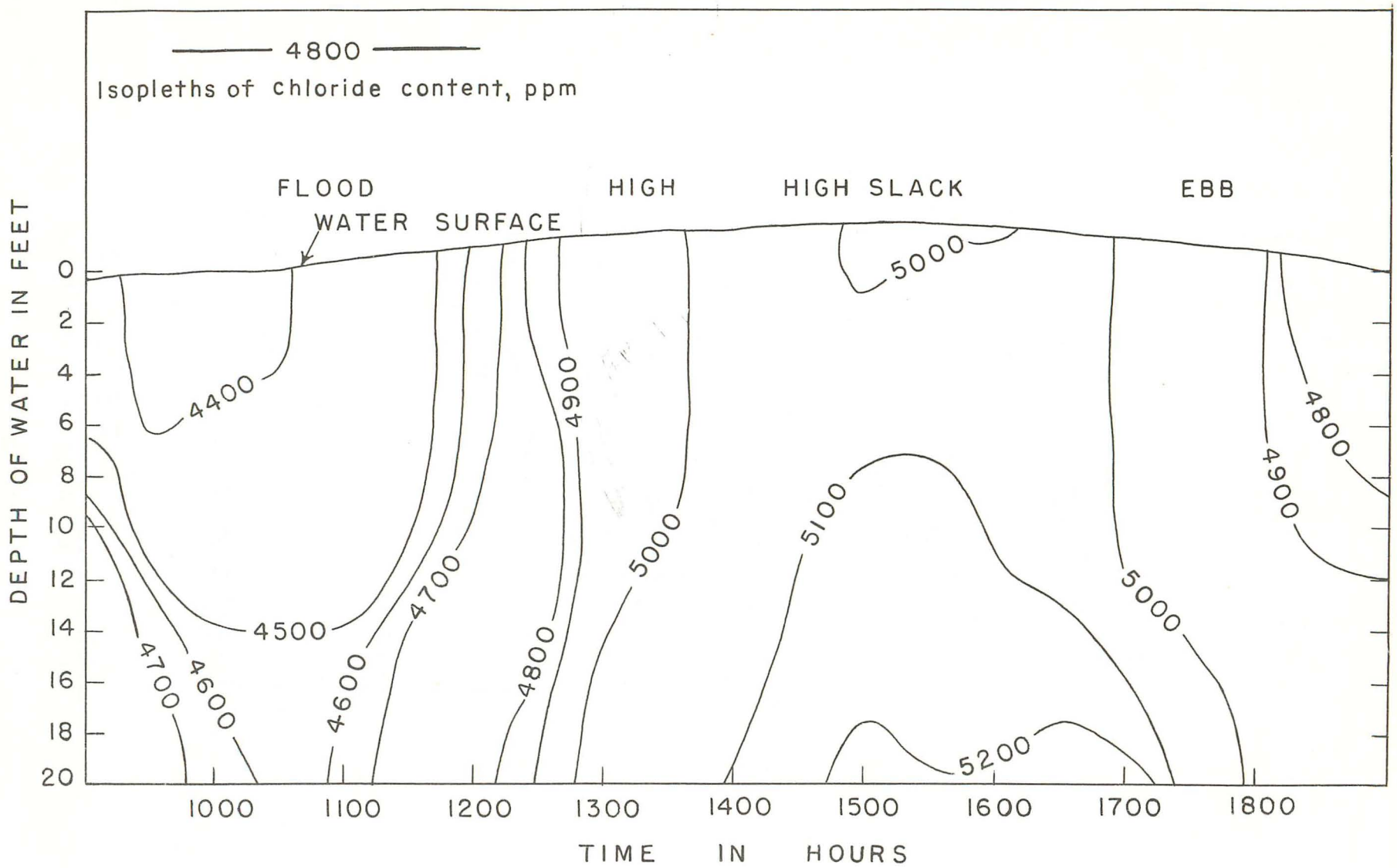


Figure 4—Isopleths of chloride of Patuxent River at Benedict, June 9, 1964.

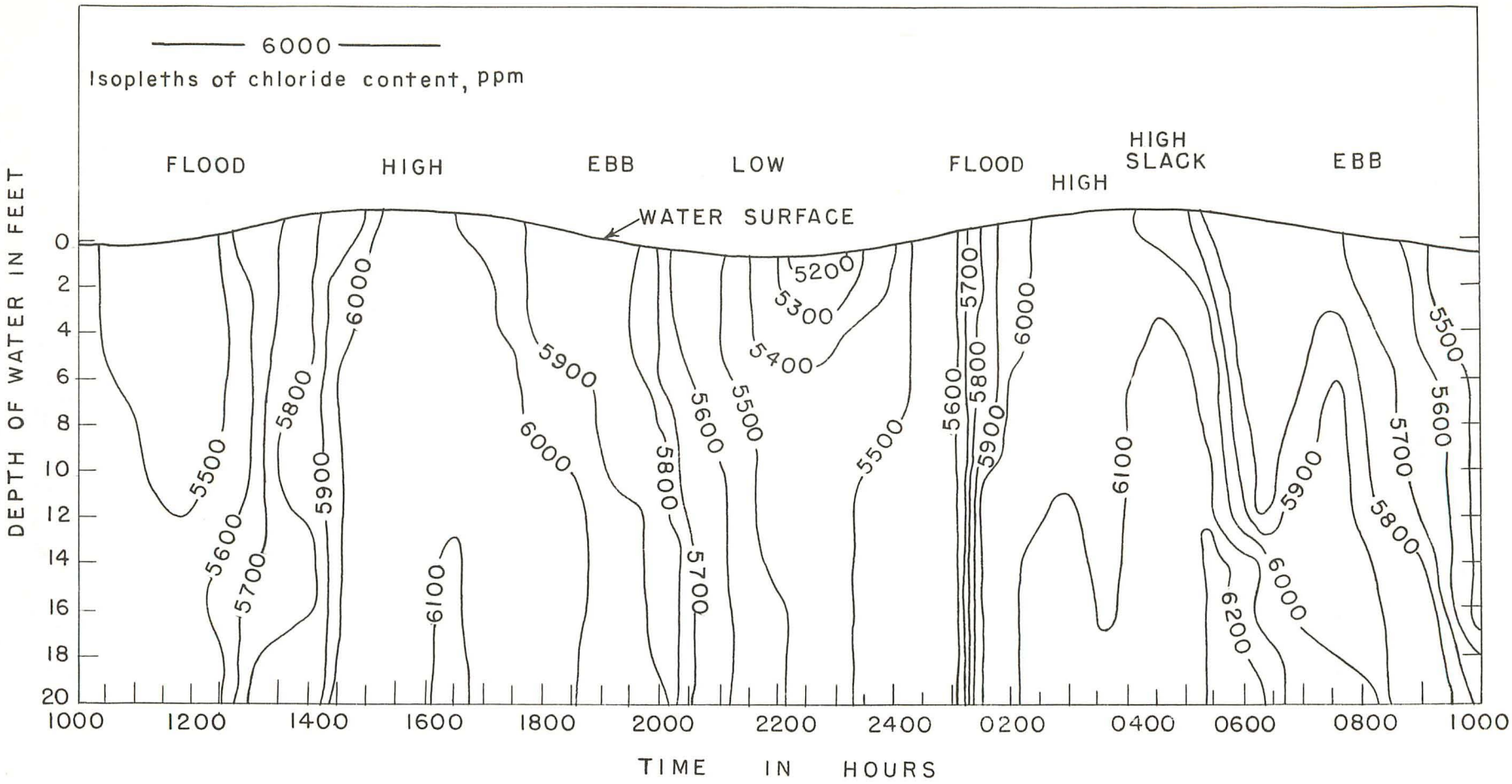


Figure 5—Isopleths of chloride of Patuxent River at Benedict, July 9-10, 1964.

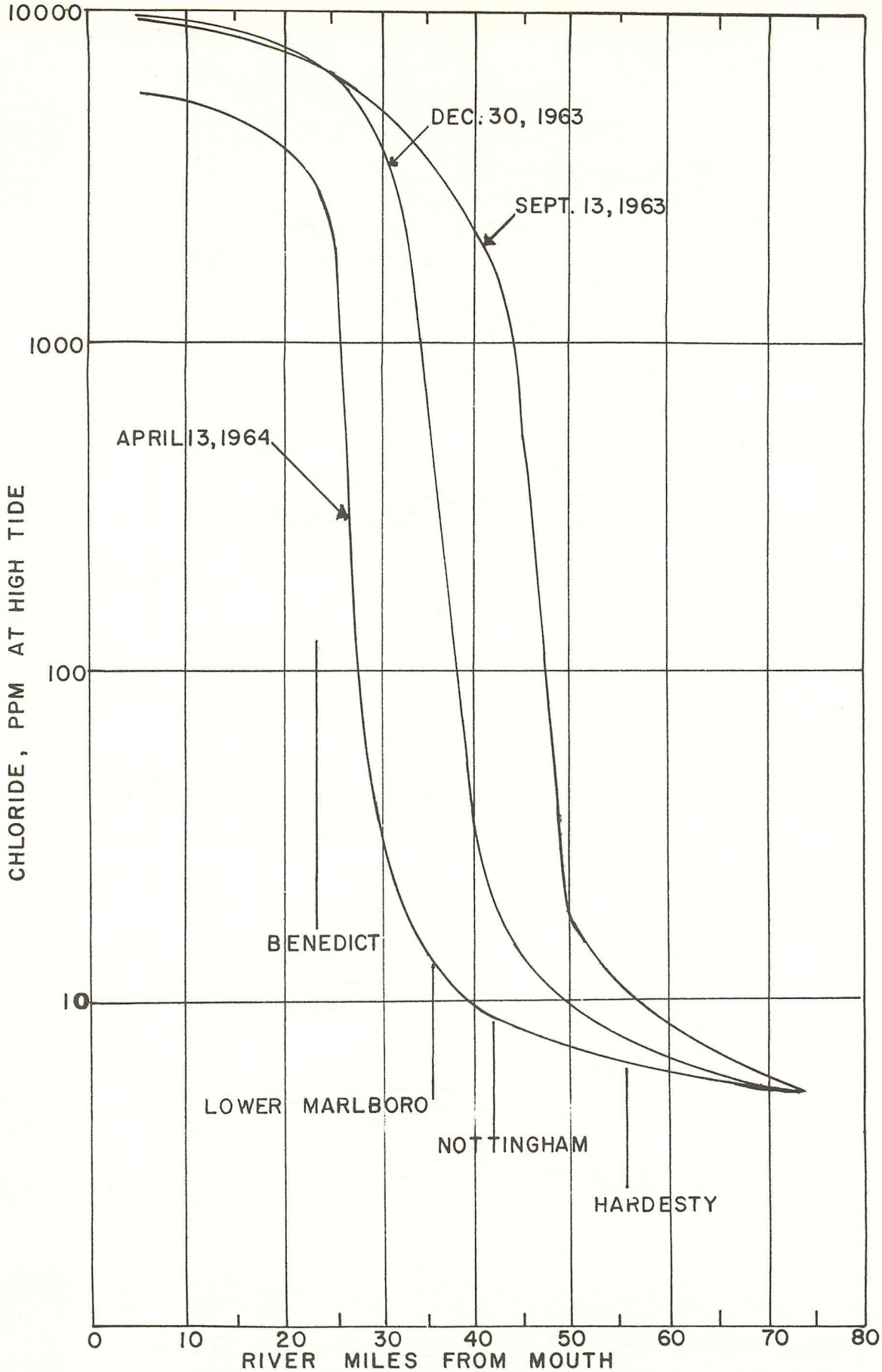


Figure 6.—Patuxent River profile showing average salinity as chloride: Curves defined by measurements at approximately 0.3 mile intervals on Sept. 13, 1963 and by sample analyses at regular stations Dec. 30, 1963 and April 13, 1964.

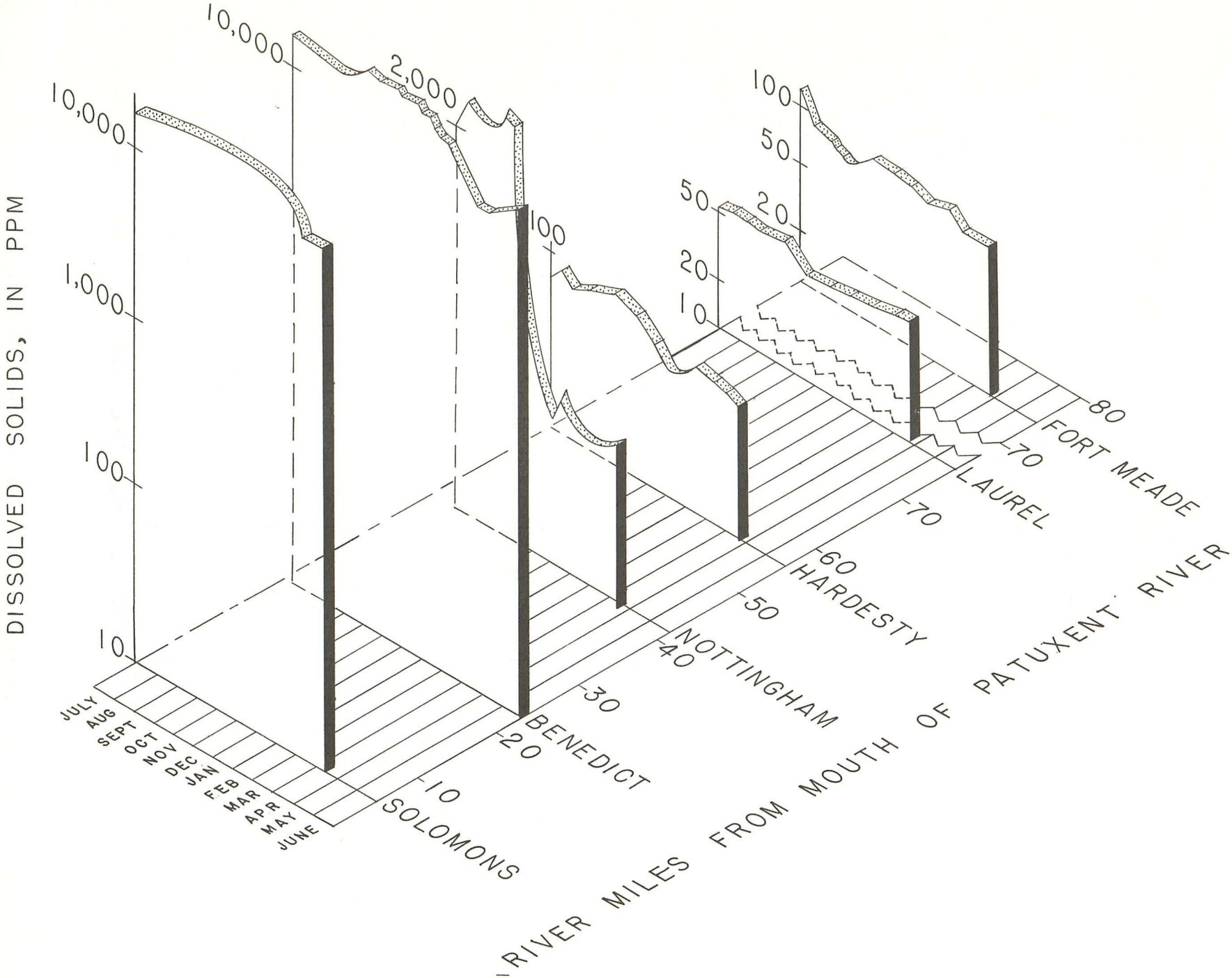


Figure 7—Comparison of dissolved-solids concentrations for several stations during 1963-64.

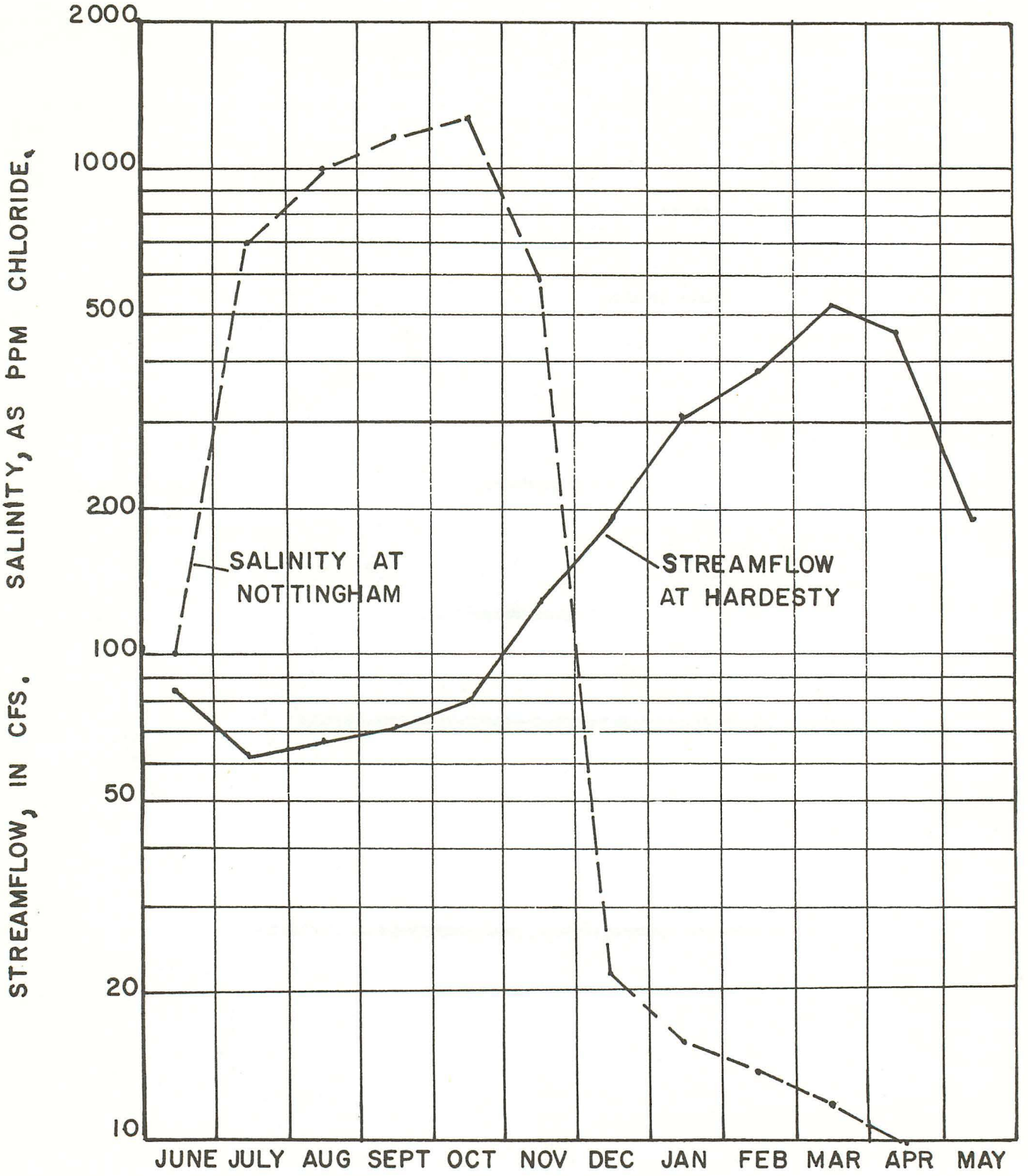


Figure 8—Seasonal variation of streamflow and salinity in the upper Patuxent River Estuary.

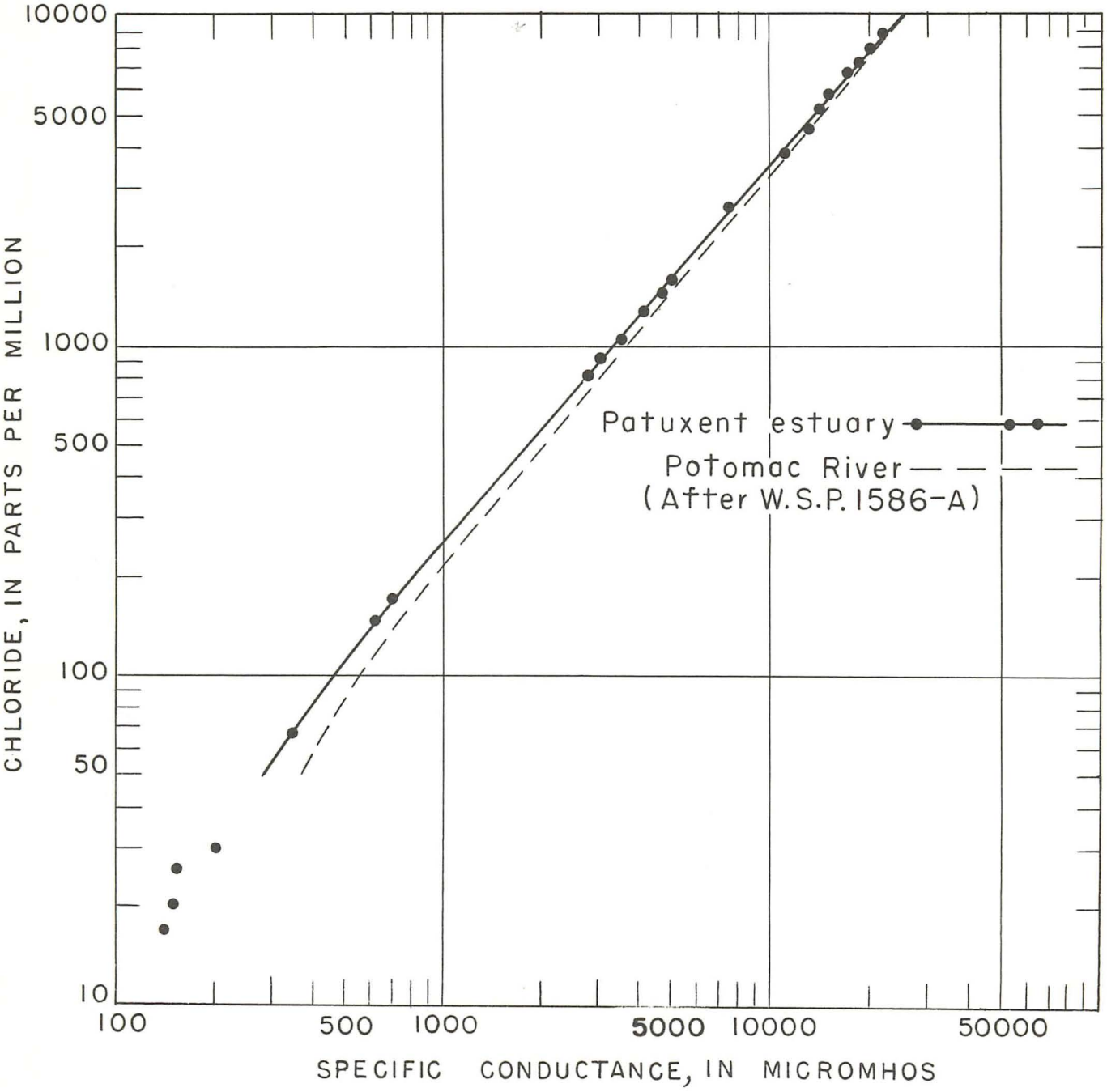


Figure 9—Relation between specific conductance and chloride concentration.

River which has a higher concentration of dissolved solids. This trend is accentuated as the salinity decreases because the percentage of chloride in the Patuxent River is higher than in the Potomac River.

Chemical composition of the estuary

The chemical character of the fresh water of the Patuxent River is determined principally by the natural conditions such as the runoff and geology, and to a lesser extent by man's activity. The chemical quality of sea water in the tidal reaches of the river becomes a dominant factor controlling the quality of water in the estuary.

The station at Nottingham is near the critical salt front during periods of low runoff and about 10 miles upstream from the salt front during the seasons of maximum runoff. During the wet months (about 5) the dissolved-solids concentration (average, 90 ppm) is representative of the river, but the section is still affected by the tide and the concentrations of chloride and sulfate are above the average freshwater inflow. On the average, and especially during the dry months of the year, the percentage composition of the major elements in the estuary at Nottingham strongly reflects the composition of sea water. The average dissolved-solids concentration of 960 ppm for the period sampled shows the strong diluting effect of the river. The chemical composition of the water at Nottingham is shown in figure 10 for the period August to November only. The sum of measured ions of 2.4 equivalents per million (epm) at Nottingham for the period December to April is too low to show on this figure at the scale used of 100 epm per inch.

At Benedict, the diluting effect of the river is also apparent but the freshwater inflow contributes only slightly to the percentage composition of the major elements. The percentage composition is very close to that of sea water. The relative composition remains the same at high and low tide and from top to bottom. The absolute concentrations of the major elements change with season, tide, and depth, but the percentage composition remains very constant. The trend at Solomons is similar to that at Benedict. The river dilutes the sea water but adds little to the total chemical content. The percentage composition of the water at the various stations and the average composition of sea water are shown in Table 9.

Trace elements

The study of trace elements in natural waters has been advanced in recent years by the growing realization that these elements may have an importance to hydrology and ecology out of proportion to their relative abundance. Trace elements discussed in this report are those dissolved cations that generally do not exceed one milligram per liter in natural fresh water. This classification generally includes radioactive elements such as uranium and radium but analysis for these elements is usually by different methods than applied in this investigation and these elements are not included in this study.

More than 60 elements were sought in the spectrographic analysis of the first reconnaissance samples from the Patuxent River basin. However, most of these elements were not detected and 25 elements were sought in the subsequent routine spectrographic analyses. Concentrations above the limit of detection for 11 elements were measured for every sample of fresh water as noted in Table 1. Concentrations of bismuth, gallium, germanium, tin, zinc, and zirconium were below the limit of detection in all samples. Of the remaining eight elements sought in all samples, concentrations of chromium, cobalt, lead and silver were above the limit of detection in most samples and measurable quantities of beryllium, and vanadium occurred in less than half the samples. Cadmium was detected only in samples of brackish water analyzed by the chemical concentration method.

These results are comparable to those obtained in a study (Durum and Haffty, 1963) of major streams of the world in which the 15 largest rivers in North America were included. The median values of the trace elements in the major rivers form a good basis for comparison with the median concentration in the Patuxent River (See fig. 11).

The discussion in this report on the trace elements determined in the Patuxent River refers to the results by spectrographic analysis of filtered samples unless specifically stated otherwise. Results shown on Figure 11 are those from the fresh water in the Patuxent River only. With the exception of boron, lithium, rubidium, and strontium, most trace elements are no more abundant in ocean water than they are in natural fresh water, and of the few that are relatively abundant in sea water, only boron and strontium are found in concentrations exceeding one ppm.

The reconnaissance sampling at thirteen locations in the Patuxent River basin showed no significant difference in quantity of trace elements in water from one part of the drainage basin to another.

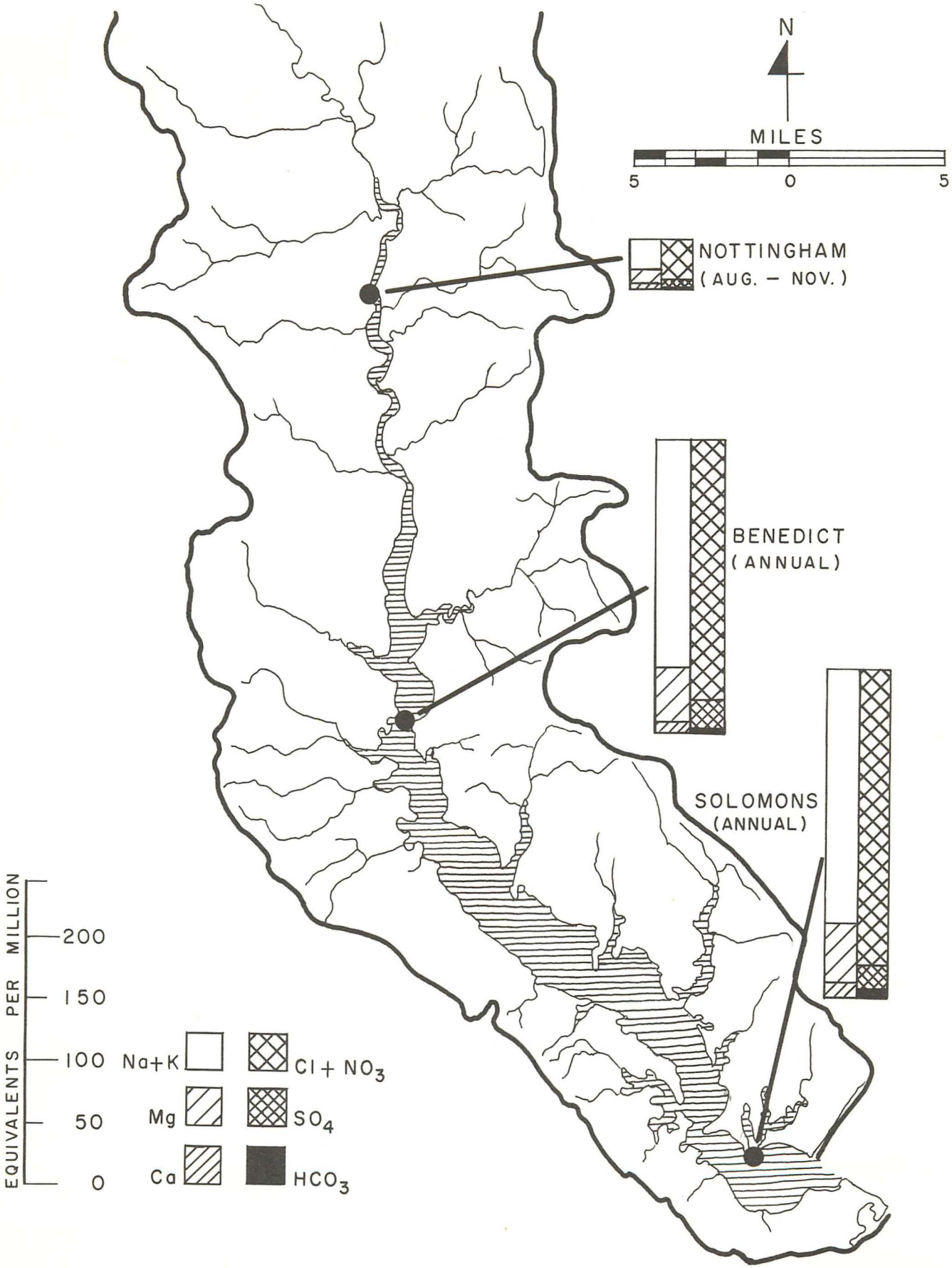


Figure 10—Chemical characteristics of saline water in the Patuxent estuary.

Table 9—Average percentage compositions calculated from parts per million and equivalents per million of dissolved constituents.

Station		*Silica* (SiO_2)	*Aluminum* (*Al*)	*Iron* (*Fe*)	*Manganese* (*Mn*)	*Calcium* (*Ca*)	*Magnesium* (*Mg*)	*Sodium* (*Na*)	*Potassium* (*K*)	*Bicarbonate* (HCO_3)	*Sulfate* (SO_4)	*Chloride* (C_1)	*Fluoride* (*F*)	*Nitrate* (NO_3)
Ft. Meade	ppm	12	.....	.7	.1	9.9	2.9	10		38	12	10	.1	4.0
	epm	8.8	.....	.1	.....	20.6	10.1	4.2		26	11	12	.04	2.9
Laurel	ppm	9.1	.....	2.1	.8	10.8	3.5	9.0		42	10	7.8	.2	4.0
	epm	5.6	.....	5.6	.....	20.0	10.6	13.7		25	7.5	8.1	.....	2.5
Hardesty	ppm	15	1.3	1.2	.....	10.6	2.8	7.2	2.9	29	17	10	.1	3.8
	epm	2.0	.....	2.6	.....	19.6	8.5	11.5	2.6	18	14	11	.....	2.6
Nottingham	ppm	.7	.....	.17	.....	2.2	3.7	28		2.4	8.9	54	.....	.1
	epm	.3	.....	.26	.....	3.0	8.7	37.8		1.0	5.2	42.9	.....	.05
Benedict	ppm	.02	.....	.....	.....	1.2	2.7	31		.5	8.6	55	.....	.....
	epm	.02	.....	.....	.....	1.8	9.2	36.4		.2	5.0	44.8	.....	.....
Solomons	ppm	.01	.....	.....	.....	1.3	3.7	32		.5	7.7	55	.....	.....
	epm	.....	.....	.....	.....	1.9	9.0	38.9		.2	4.7	44.9	.....	.....
Sea Water	ppm	.....	.....	.....	.....	1.1	3.7	30.5	1.1	.5	7.7	55	.....	.....
	epm	.....	.....	.....	.....	1.7	8.6	38.0	.8	.2	5.7	44.5	.....	.....

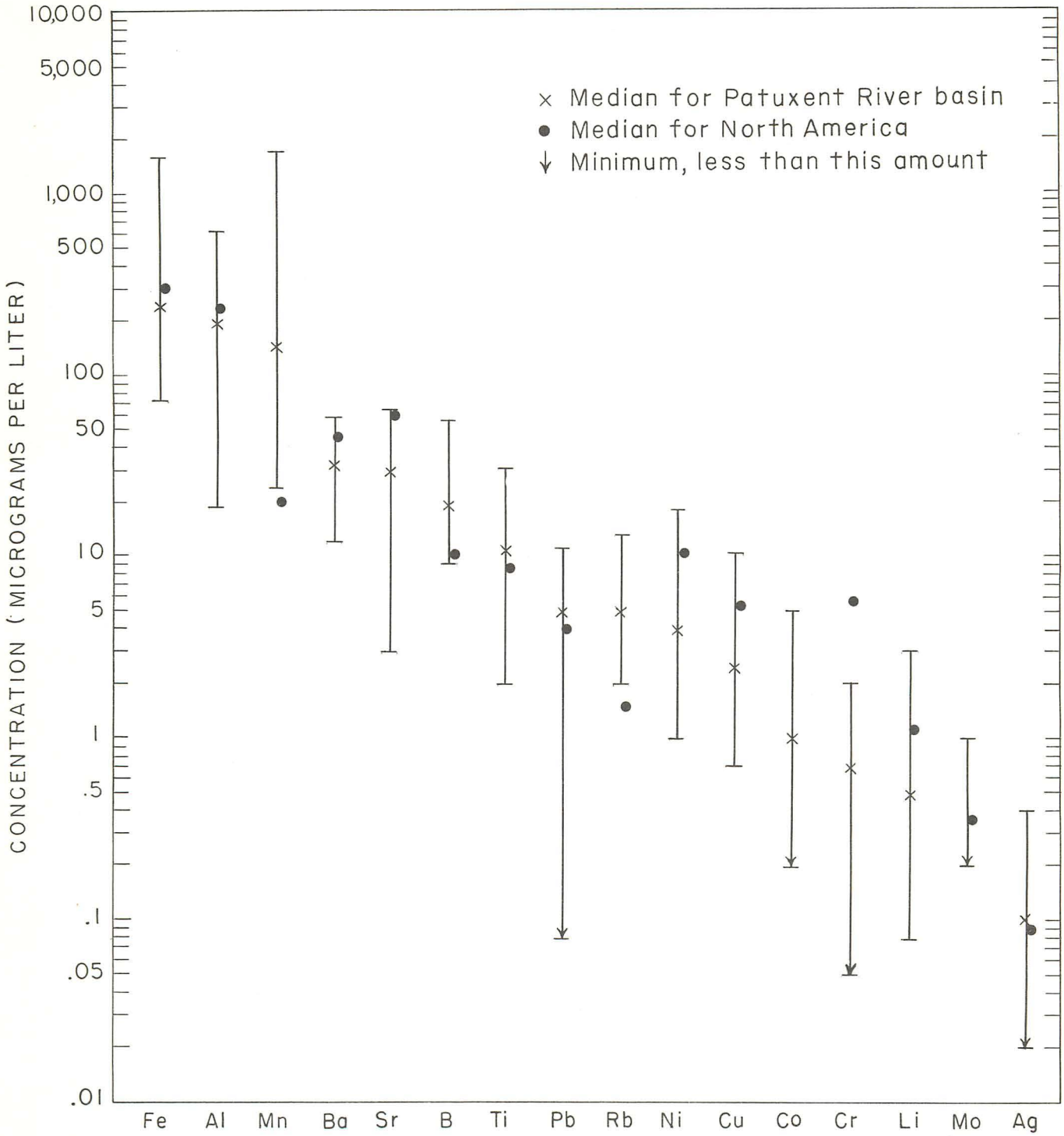


Figure 11—Range in observed concentration of trace elements in the Patuxent River basin.

However, pollution in Dorsey Run probably produced the concentrations of barium, cobalt, copper, nickel, and strontium, which are the maximum or near the maximum concentrations for any location. (See Table 1).

Water quality standards for trace elements

The physical, chemical, and bacterial qualities of drinking water in the United States are judged in relation to the U. S. Public Health Service, Drinking water standards, 1962, and although these standards are for treated water they provide one basis for evaluating the quality of water from the Patuxent River. As shown in Table 10, concentrations of none of the trace elements determined exceeds the maximum allowable limit.

Table 10. Summary of trace elements detected in fresh water of the Patuxent River basin and established limits for drinking water standards.

(Concentration in micrograms per liter)

Chemical constituent	Drinking water standards 1962		Concentration		
			Range		Median
	Recommended limit	Maximum allowable	Max.	Min.	
Aluminum	None	None	620	19	190
Barium	——	1,000	59	12	32
Boron	None	None	55	9	19
Chromium		(Cr^{+6}) 50	2	.05	.7
Cobalt	None	None	5	.2	1
Copper	1,000	——	10	.7	2.5
Iron	300	——	1,600	73	240
Lead	——	50	11	.9	5
Lithium	None	None	3	.08	.5
Manganese	50	——	1,700	24	140
Nickel	None	None	18	1	4
Rubidium	None	None	13	2	5
Silver	——	50	.4	.02	.1
Strontium	None*	None	64	3	29
Titanium	None	None	30	2	11
Zinc	5,000	——	Not detected but less than 180 in any sample analyzed spectrographically.		

* The recommended limit for Sr90, one of strontium's radioactive isotopes, is 10 micromicrocuries per day.

Only the concentrations of iron and manganese in some of the samples exceeded the recommended limits. The concentration of manganese determined from most of the samples exceeded the recommended limit. Limits on manganese and iron, however, are based on economic, esthetic, or taste considerations rather than hazard to health, because these elements can stain or color laundered goods and are objectionable in many industries' plumbing fixtures.

Although abundant in rocks and soils, iron is quite insoluble under oxidizing conditions and usually does not occur in surface water in concentrations higher than 1,000 $\mu g/l$. Many ground waters including those in Southern Maryland, contain much higher iron concentrations and the amount in the Patuxent River is considered normal.

Manganese is seldom present in natural surface waters in concentrations above 1,000 $\mu g/l$ (McKee and Wolf, 1963) but maximum permissable concentration limits ranging from 0 to 1,000 $\mu g/l$ have been recommended for many industries because of undesirable effects in many processes. Special treatment can be used to successfully remove objectionable quantities of manganese.

The concentrations of other individual trace elements vary widely and the implications of their occurrence are so diverse that some discussion of each element is justified. Unless otherwise specified, the ranges and median concentrations of trace elements discussed in this section refer only to the fresh water of the Patuxent River basin and not to the part of the estuary containing saline water from the Chesapeake Bay. The high concentrations of major constituents in the brackish water requires that a special interpretation be made because a different method of analysis was used.

The stations in Table 1 are listed in downstream order and all samples from Lyons Creek downstream contained brackish water except the January 10 and April 2, 1964 samples at Nottingham. As noted in Table 6, the Patuxent River at Nottingham was affected by tide at all times but from December 7, 1963 to April 13, 1964 the river at that section was not significantly affected by salt water encroachment.

Aluminum

Aluminum is the most abundant metal on earth, but the concentration in natural water is usually less than 1 ppm. The disassociated aluminum ion Al^{+++} can be present in large amounts only in acid waters with a pH below five. Therefore, the concentrations of aluminum determined in the Patuxent River ranging from 0.019 to 0.620 ppm with a median concentration of 0.190 ppm are quite normal or a little below average for most rivers. Although the concentrations of aluminum are not a public health problem, aluminum contributes to hardness in water and may be deposited as a scale in boiler

tubes. The following concentrations of aluminum oxide have been suggested (Moore, 1940) as allowable limits for boiler feed water:

pressure (lb. per sq. in.)	0–150	150–250	250–400	over 400
Al_2O_3 (ppm)	5	.5	.05	.01
equivalent Al (ppm)	2.6	.26	.026	.005

Barium

Barite ($BaSO_4$) is a common mineral, but it is not very soluble in water; therefore, significant concentrations of barium are not usually present in natural water. The element can have severe toxic effects upon the heart muscle and the U. S. Public Health Service Standards (1962) state that concentrations of barium in excess of 1,000 $\mu g/l$ are grounds for rejections of the supply. The median concentration of barium of 32 $\mu g/l$ is slightly below the median value of 45 $\mu g/l$ observed by Durum and Haffty for North America and is in agreement with their finding that Atlantic coastal waters tend to be slightly deficient in barium.

Beryllium

Beryllium has been observed in measurable quantities only infrequently in natural rivers. No measurable amount occurred in rivers sampled in the program on the world-wide runoff of dissolved solids (Durum, Heidel, and Tison, 1960) although the presence of minute amounts was detected in the Atchafalaya and Apalachicola Rivers. In a recent study of the public supplies of the largest cities in the United States, (Dufor and Becker, 1964). 0.75 $\mu g/l$ was detected in the Gunpowder River; part of the Baltimore water supply is obtained from this source. In our study 0.2 $\mu g/l$ beryllium was measured from the Patuxent Rover near Bowie, but no other samples contained measurable quantity.

Boron

The concentration of boron in water is particularly important to agriculturalists because of the relation of boron to plant growth. Concentrations of boron that exceed 1 ppm are toxic to some crops and occurrence of boron must be considered in water to be used for irrigation. The concentration of boron in sea water has been reported (Sverdup, 1942) as 4.6 ppm and concentrations of boron in the Patuxent estuary at Benedict and Solomons were .7 and .8 ppm respectively at salinities of about 1/3 and 2/5 the salinity of sea water. The median concentration of boron in the Patuxent River was 0.019 ppm, which is almost twice the median concentration in large rivers of North America. This difference is probably not statistically significant when the relatively low number of total samples is considered.

Chromium

The median concentration of .7 $\mu g/l$ of chromium in the Patuxent River basin is less than that observed for the large rivers of North America (Durum and Haffty, 1963), and in about half the samples the concentration of chromium was below the limit of detection. The only location where the concentration exceeded 2 $\mu g/l$ was at Dorsey Run where 5 $\mu g/l$ was determined. This quantity is far below the limit of 50 $\mu g/l$ that has been set as a basis of rejection for a supply according to the standards of the U. S. Public Health Service (1962). Very little chromium is expected in water from natural sources and there is no evidence of any significant contamination by introduction of chromium into the Patuxent River at the time of this study.

Cobalt

Most major rivers in North America (Durum and Haffty, 1963) have contained no detectable cobalt, but the concentration of cobalt was above the minimum limit of detection in more than half the samples from the fresh water of the Patuxent River. The concentration was low (1 or 2 $\mu g/l$ in most samples) and the quantity carried by the Patuxent River to the estuary is probably not as important in the geochemistry of the estuary as several other trace elements. Trace amounts of cobalt have been reported (McKee and Wolf, 1963) as probably essential to animal diet, but higher concentrations have been injurious to plants as well as toxic to animals. For example, concentrations of 100 and 270 $\mu g/l$ cobalt in culture solutions injured tomato plants.

Copper

Although a measurable amount of copper was determined in all samples of fresh water from the Patuxent River, the median concentration of 2.5 $\mu g/l$ is less than the mean concentrations detected in most studies of natural water. The median concentration of 70 $\mu g/l$ of copper determined from 18 samples from the Patuxent River at Hardesty that were analyzed by standard chemical analysis (see Table 5) emphasizes the difference that may be expected in analysis by different methods. The filtration and immediate acidification in the field with nitric acid on the samples to be analyzed by spectrographic methods accounts for the variation. The standard sample preparation by field acidification with hydrochloric acid without filtration prior

to laboratory analysis by chemical procedures probably allows inclusion of minute quantities that would be separated otherwise by immediate filtration. In determinations identified as "In solution when analyzed" samples were not acidified in the field prior to analysis for metallic ions and some precipitation probably occurred on standing and prior to analysis. The median concentration of copper determined in this type analysis was about 25 μg/l.

Lead

Lead is a cumulative poison in the body and the U. S. Public Health Service, Drinking water standards of 1962 lowered the mandatory limit from 100 μg/l to 50 μg/l. The median concentration of 5 μg/l in the Patuxent River is close to the median of 4 μg/l (Durum and Haffty, 1963) determined for major North America's rivers and concentrations ranging from 0.9 to 11 μg/l including all samples except one, show that some lead is present throughout the waters of the basin.

Lithium

Lithium is a comparatively rare element, but most simple compounds of lithium are very soluble and measurable amounts have been determined in many waters. The median concentration of 0.5 μg/l from the Patuxent River basin and the range from .08 to 3 μg/l compare favorably with results compiled by Livingstone (1963, p. G43) for a number of lakes and rivers. Lithium has been identified as poisonous to some citrus fruits (McKee and Wolf, 1963) and the presence of the element may be of concern in waters that are considered for irrigation.

Nickel

Concentrations of nickel ranged from 1 to 18 μg/l in the Patuxent River basin. The median concentration was 4 μg/l and these concentrations are in the same range that Hutchinson (1957, p. 824-825) has suggested as normal. Altough the U. S. Public Health Service, Drinking water standards, 1962, do not place any limit on nickel, the toxicity of the element to plants, including citrus fruits and flax has been noted by McKee and Wolf (1963). Specific concentrations reported at which toxicity has been determined have been 0.5 milligram per liter and higher which is many times the concentrations determined in this investigation.

Rubidium

The alkali metal, rubidium, has been detected in most waters in which it has been sought, but the mean concentrations have generally been less than 2 μg/l. The concentration of rubidium in the Patuxent River is higher than the average for other rivers, and ranged from 2 to 13 μg/l with a median (and average) concentration of 5μg/l. Rubidium resembles potassium in its behavior in the weathering process and Livingstone (1963) notes a K/Rb ratio of slightly over 1,000 has been determined by some observers. The K/Rb ratio in the Patuxent River of about 400 therefore shows an unusually high concentration of rubidium in this basin. Observers (McKee and Wolf, 1963) have not noted any toxicity of rubidium toward human beings and it is fairly abundant in some food elements.

Silver

Almost half the samples from the Patuxent River (12 samples of 25) contained less silver than could be detected by the spectrographic method used. The maximum concentration determined (0.4 μg/l at Dorsey Run) and median concentrations of 0.1 μg/l were far below the mandatory maximum limit of 50 μg/l set by the U. S. Public Health Service Drinking water standards of 1962. This limit was set to prevent intentional addition of excessive amounts to water for disinfection; most concentrations of silver determined in natural water have been less than 30 μg/l. The concentration of silver in the Patuxent River is about the same as the concentration in many surface waters.

Strontium

Strontium, an alkaline earth element, is one of the most abundant minor constituents of rocks, and trace quantities are found in all natural water. Numerous samples analyzed from major rivers in the United States showed concentrations that ranged from 7 to 15,000 μg/l (Skougstad and Hoor, 1963). Their results showed that streams in the Atlantic coastal plain usually contained less than 500 μg/l and frequently less than 10 μg/l. The concentrations in the Patuxent River are consistent with these other results and ranged from 3 to 64 μg/l with a median concentration of 29 μg/l. Similar to major constituent trends, strontium concentrations tend to decrease with increasing discharge. At Hardesty, the minimum concentration of 26 μg/l occurred at the maximum measured discharge of 2,180 cfs.

Titanium

In rocks, titanium is more abundant than any of the trace elements except iron and aluminum. Titanium and titanium dioxide are insoluble in

water and probably very little titanium goes into solution. However, waters containing titanium are common and Durum and Haffty (1963) reported the median concentration of 8.6 μg/l in major North American Rivers. Titanium was detected in all samples from the Patuxent River and the median concentration of 11 μg/l indicates that the Patuxent River is about average in titanium content.

Vanadium

Minute concentrations of vanadium (less than 1 μg/l) are probably contained in most river and lake waters. Vanadium concentrations above the minimum limit of detection were determined in more than 60% of the surface waters sampled in California during 1960-62 (W. P. Silvey, written communication, 1964), and the median concentration of vanadium in 61 samples in California in 1961 was 1.4 μg/l. The concentration of vanadium was less than the limit of detection in more than half the samples obtained in the program of sampling 75% of the world's largest rivers (Durum, Heidel, and Tison, 1960). In the Patuxent River basin, concentrations of vanadium ranged from 0.6 to 3 μg/l in the 9 samples in which vanadium was above the limit of detection. Any conclusions on seasonal variations or variations with discharge would be speculative as the concentration of vanadium was below the limit of detection in more than half the samples collected in this study.

Trace elements not detected

Bismuth, gallium, and germanium were not expected or detected in any samples from the Patuxent River basin. Apparently few if any quantitative data have been obtained on the occurrence of these elements in natural water. Concentrations of germaniun of 14 to 50 μg/l have been measured in some springs of California (W. D. Silvey, written communication, 1964).

Concentrations of tin, zinc, and zirconium were also below the limit of detection in all samples analyzed spectrographically, but the maximums that could have occurred were 1 μg/l of tin, 180 μg/l of zinc and 1 μg/l of zirconium. Unfortunately, the spectrographic method used is not sufficiently sensitive to determine zinc in concentrations that could under some conditions be toxic toward some organisms. McKee and Wolf (1963) state concentrations of zinc from 100 to 1,000 μg/l have been reported as lethal (toward fish and aquatic organisms), but zinc is not known to have adverse physiological effects on man in concentrations below the taste threshold. In the unfiltered samples from the Patuxent River basin analyzed by chemical methods zinc concentrations as high as 1,100 ppb were measured (Patuxent River at Laurel) and the median concentration of 100 ppb was determined for the sampling station at Hardesty as shown in table 5. Concentrations of zinc in the Patuxent River basin that range from 15 to 60 ppb (O'Connor, Renn, and Wintner, 1964) probably are the best data on zinc available for the Patuxent River, but the methods of sample collection in their study were not published.

Ratios of trace elements and correlation with streamflow

Study of the relative distribution of trace elements is facilitated by comparison of ratios of several of the ions, particularly those which are similar chemically. In the Patuxent River, barium to chloride and nickel to copper ratios agree closely with values determined for major rivers, (table 11). Strontium and chromium seem to be somewhat deficient compared to the average reported for larger rivers, but all concentrations reported are of the right order of magnitude. The median concentrations of trace elements measured in the Patuxent River are less than the median concentrations measured for North America for nickel, copper, and the more abundant trace elements such as iron, aluminum, and manganese (fig. 2) but considering the lower concentration of all constituents present in the Patuxent River, these lower values of trace elements are not unusual.

Concentrations of trace elements in the estuary and ratios of these elements show the same increasing influence of brackish water that is noted in the major constituents. The station at Benedict (table 11) was chosen as near average for the estuary, but the increasing chloride and strontium concentrations throughout the estuary from Nottingham to Solomons are noted. Concentrations of boron and lithium are also higher in sea water than in natural fresh water and the increasing concentration in the estuary is noted. Rubidium concentration in sea water has been reported as 0.2 milligrams per liter (Sverdup, 1950) but the concentration in the estuary was too low to detect by the spectrographic determination on the residue.

The concentrations of most of the trace elements could not be correlated consistently with streamflow. The concentration of the most abundant trace elements tended to decrease with increasing discharge at Hardesty as noted on figure 12; the most consistent relationship was that for iron.

Table 11. Ratios of elements in large North American Rivers, the Patuxent River and the ocean.
(Median value of wt/wt)

Ratio	Large rivers of North America		Patuxent River basin		Ocean*
	All	*Atlantic*	*Fresh water*	*Estuary at Benedict*	
$\frac{Ba}{Cl} \times 10^3$	5.4	3.8	4.0†	0.04	0.00033
$\frac{Sr}{Cl} \times 10^3$	5.9	5.0	3.6†	0.53	0.42
$\frac{Ba}{Sr}$	0.87	0.55	1.07	0.08	0.00078
$\frac{Ni}{Cr}$	1.8	1.1	5.7	> 2	10
$\frac{Ni}{Cu}$	2.1	1.6	1.6	> 2	0.17

*—Durum, W. H., and Haffty, Joseph (1963).
†—Based on weighted mean chloride concentration at Hardesty.

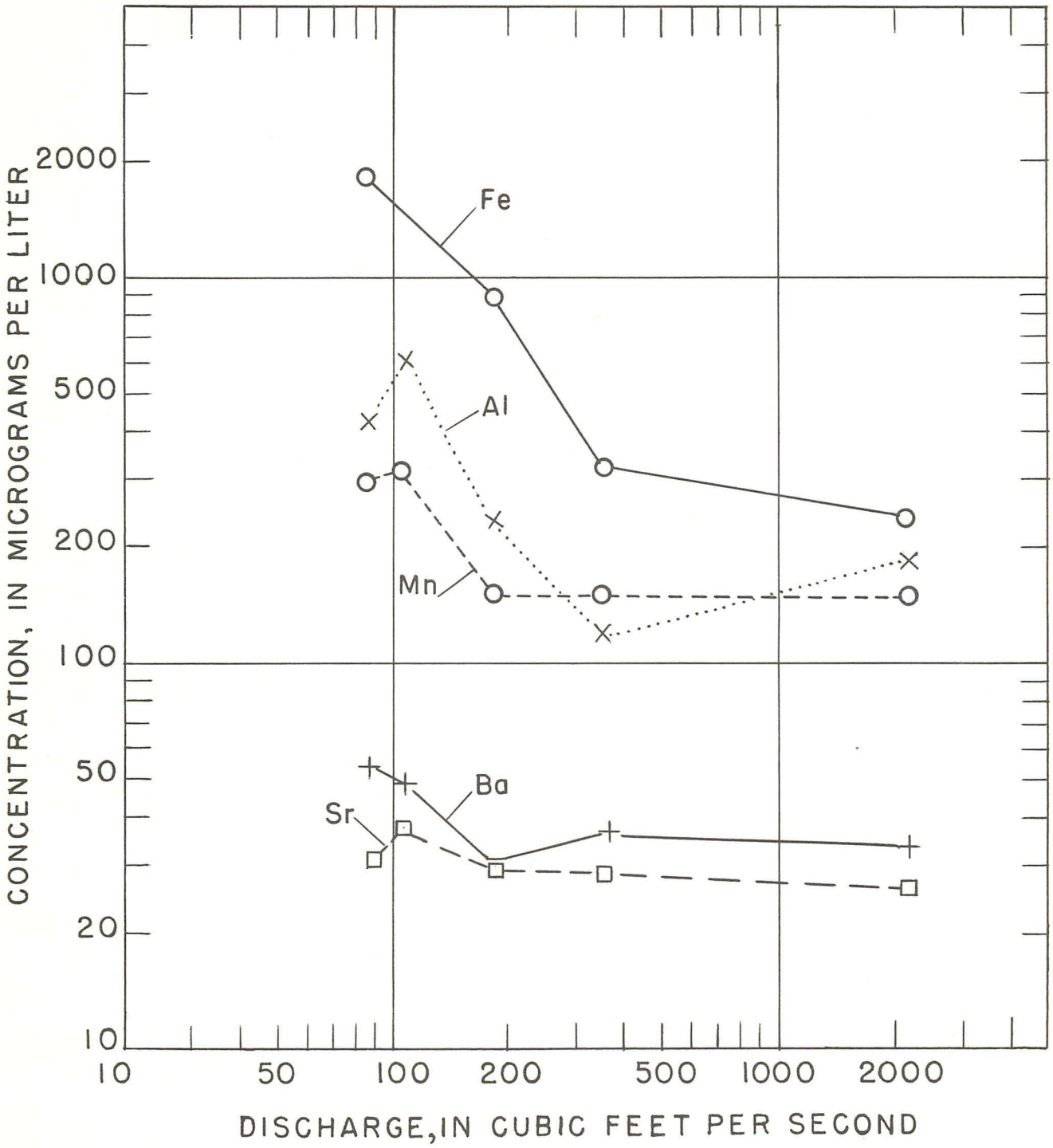


Figure 12—Relation of streamflow of Patuxent River at Hardesty to concentration of trace elements.

Quantity of dissolved constituents in the Patuxent River

The discharge per square mile at Laurel is lower than the discharge from the rest of the Patuxent River basin because part of the flow is diverted for public supply. From 1954 through 1962, the average flow was 45 cubic feet per second (cfs) or 0.34 cfs per square mile, which is much lower than the average for the rest of the basin. Since the discharge of the Patuxent River at Laurel and dissolved-solids concentrations are low, the total quantity of dissolved material is also low. The average dissolved-solids load at Laurel was computed as 6 tons per day, or about 2100 tons per year.

The average flow of the Little Patuxent River at Ft. Meade is estimated as about 130 cfs or 1.05 cfs per square mile and is characteristic of the natural streams in the basin. From this flow and a dissolved-solids concentration of 85 ppm, the average dissolved-solids load at Ft. Meade was computed as 31 tons per day or 12,000 tons per year.

Based on discharge measurements, the drainage area, and average flows for most streams in the area, a flow-duration curve was constructed for the Patuxent River at Hardesty and an average flow of 400 cfs was computed. An average weighted dissolved-solids concentration for this station was computed at 70 ppm and the average load of dissolved-solids carried past Hardesty on this basis is 73 tons per day or about 27,000 tons per year. The drainage area at Hardesty is 371 square miles and the combined area above the Laurel and Ft. Meade stations is 260 square miles; thus considering the total load at these two stations and the load at Hardesty, 30% of the area (i.e. below the two upstream stations) provides almost 50% of the total load of dissolved solids. Also, 64% of the area (that which is downstream from the Laurel station only) provides more than 90% of the load passing the Hardesty station.

Similar to many other streams, the concentration of dissolved solids decreases with increasing discharge. The relationship of dissolved-solids concentration to discharge is shown in figure 13 for the Patuxent River at Hardesty. The scatter of the points is rather large and lack of data precludes any precise correlation at high discharge.

The quantity of trace elements dissolved in the river is very small when compared to the total load of dissolved solids. In contrast to the total dissolved-solids content, the sum of the three most abundant trace elements (iron, aluminum, and manganese) was 1.4 ppm at Hardesty and the sum of the 12 other trace elements detected in most samples was about .15 ppm; therefore, on the same basis, the quantity of iron, manganese, and aluminum discharged past Hardesty is about 1.6 tons per day or 1.5 tons per square mile per year. The quantity of all 12 other trace elements usually detected is about .18 tons per day or less than 0.2 tons per square mile per year. Moreover, the relatively common four elements (barium, boron, strontium, and titanium) comprise over 80% of the .18 tons per day computed for the 12 trace elements.

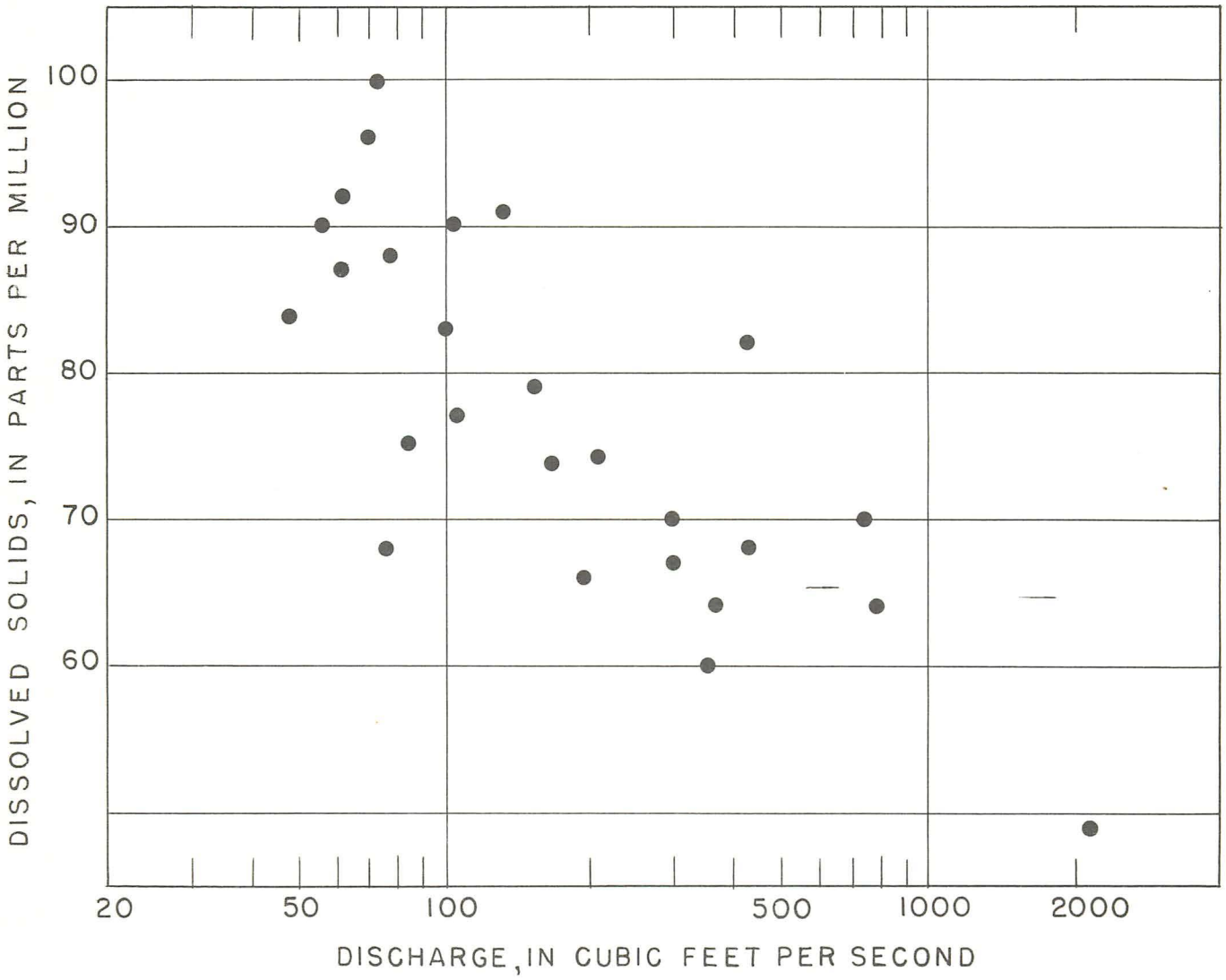


Figure 13—Relation of dissolved solids to discharge, Patuxent River at Hardesty.

Summary

The Patuxent River drains an area that is relatively unaffected by industrial and municipal development when compared to adjacent metropolitan areas. The impending pressure from such development indicates potential changes in the quality of the surface waters of the basin. A one-year program of sampling and analysis of the water was carried out beginning in July 1963, and 33 samples were analyzed spectrographically to determine the concentration of trace elements. Most samples were obtained at approximately 10-day intervals from six regular sampling stations to determine the concentration of common constituents in the water by regular chemical laboratory methods and to measure the change in flow and trends in chemical quality throughout the year. Samples were obtained at 19 reconnaissance sampling stations extending from Unity, less than 15 miles from the headwater, to Solomons in the estuary where the water quality is most similar to Chesapeake Bay.

The estuary extends for almost half the length of the Patuxent River and is subject to tides and invasion of saline water from Chesapeake Bay. The extremely high concentrations of salts common to sea water dominate the quality of the estuarine water and the effect of the fresh-water inflow is to dilute the sea water and to contribute only amounts of elements not found in sea water. As a result, the percentage composition of dissolved materials in the estuary is approximately the same as for sea water.

The analyses show that concentrations of the trace elements are of the same order of magnitude as in most major rivers of North America. Large rivers such as the Mississippi, Susquehanna, Sacramento, and the Columbia contain higher concentrations of the major constituents, (sodium, calcium, magnesium, bicarbonate, chloride, and sulfate) than the Patuxent River. Most large rivers have a much higher hardness than occurs in the Patuxent River; for example, the waters of this river are softer than those of the Potomac River by a factor of about 5. Similar to most rivers, the concentration of dissolved mineral constituents in the Patuxent River decreases with increasing flow. This correlation is not as valid for less abundant constituents such as iron and aluminum. No apparent correlation with streamflow exists for trace elements that occur just above the limit of detection.

The concentrations of manganese, boron, and rubidium in the Patuxent River are substantially higher than for the major rivers of North America. Conversely, the Patuxent River contains less chromium, copper, lithium, nickel, and strontium than most major rivers. The concentration of most other trace elements in the Patuxent River is about the same as in other river basins.

References

DURFOR, C. N., 1961, *Water quality and hydrology in the Fort Belvoir area Virginia, 1954-55: U.S. Geol. Survey Water Supply Paper 1586-A, 57 p.*

DURFOR, C. N. and BECKER, EDITH C., *Public Water Supplies of the 100 Largest Cities in the United States, 1962: U. S. Geol. Survey Water Supply Paper 1812, 364 p.*

DURUM, W. H. and HAFFTY, JOSEPH, *1963, Implication of the minor element content of some major streams of the world: Geochimica at Cosmochimica Acta, V 27, pp. 1-11.*

DURUM, W. H., HEIDEL, S. G., and TISON, L. J., *1960, world-wide runoff of dissolved solids: Internat. Assoc. Sci. Hydrology, Pub. no. 15, General Assembly of Helsinki, p. 618 - 628.*

HAFFTY, JOSEPH, *1960, Residue methods for common minor elements: U. S. Geol. Survey Water Supply Paper 1540-A, 9 p.*

HUTCHINSON, C.E., *1937, A treatise on limnology, V. I. Geography, physics and chemistry: New York, John Wiley and Sons, 1015 p.*

KEIGHTON, W. B., *1954, The investigation of chemical quality of water in tidal rivers: U. S. Geol. Survey open-file report.*

LIVINGSTONE, D. G., *1963, Chapter G. Chemical composition of rivers and lakes, Data of Geochemistry: U. S. Geol. Survey Prof. Paper 440-G, 64 p.*

MCKEE, J. E., and WOLF, H. W., *1963, Water quality criteria: California State Water Quality Control Board, 548 p.*

MOORE, E. W., *1940, Progress report of the committee on quality tolerances of water for industrial uses: Jour. New England Water Works Assoc., Vol. 54, p. 263.*

NASH, C. B., *1947, Environmental characteristics of a river estuary: Chesapeake Biological Laboratory, State of Maryland Board of Natural Resources Department of Research and Education, Publication No. 64, 174 p.*

O'CONNOR, J. T., RENN, C. E., and WINTNER, I., *1964, Zinc concentrations in rivers of the Chesapeake Bay region: Am. Waterworks Assoc. Jour. V 56, p. 280-286.*

RAINWATER, F. H., and THATCHER, *1960, Methods for collection and analysis of water samples: U. S. Geol. Survey Water Supply Paper 1454, 301 p.*

SILVEY, W. D. and BRENNAN, ROBERT, *1962, Concentration method for the spectrochemical determination of seventeen minor elements in natural water: Analytical Chemistry, Vol. 341, June 1962, pp. 784-6.*

SKOUGSTAD, M. W. and HORR, C. A., *1963, Occurrence and distribution of strontium in natural waters: U. S. Geol. Survey Water Supply Paper 1496-D, 97 p.*

SVERDRUP, H. V., JOHNSON, M. W., and FLEMMING, R. H., *1962, The oceans, their physics, chemistry, and general biology; Englewood Cliffs, N. J. Prentice-Hall, Inc., 1087 p.*

U. S. Public Health Service, 1962, Drinking water standards, 1962: U. S. Public Health Service Publication No. 956, 61 p.

TABLE 1. SPECTROGRAPHIC ANALYSES FOR TRACE ELEMENTS IN THE PATUXENT RIVER BASIN

(Spectrographic analysis in micrograms per liter except as indicated)

Date of collection	Discharge (cfs)	Aluminum (Al)	Barium (Ba)	Beryllium (Be)	Boron (B)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Rubidium (Rb)	Silver (Ag)	Strontium (Sr)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
Patuxent River near Unity, Md.																						
July 1, 1963	14	52	16	*0.06	9	*0.06	*0.6	1	100	1	0.6	26	0.2	2	7	*0.06	8	*0.6	5	*2	* 63	*0.3
Patuxent River below Tridelphia Reservoir near Brighton, Md.																						
July 1, 1963	43	320	33	0.08	24	2	*0.8	2	75	4	.3	54	3	4	6	*0.08	28	*0.8	5	*2	* 77	*0.4
Patuxent River near Laurel, Md.																						
July 1, 1963	14	38	28	*0.06	17	*0.06	2	1	120	2	0.1	1,700	*0.2	2	7	0.1	7	*0.5	8	*2	* 60	*0.3
Oct. 2, ...	11	27	36	* .2	10	* .2	1	.9	>1,000	2	.08	590	* .7	2	7	.07	4	*1	2	*1	* 50	*1
Jan. 10, 1964	13	230	22	* .1	17	.5	.9	2	250	2	.2	140	* .2	2	4	* .03	27	* .5	9	.8	* 16	* .5
Apr. 2, ...	107	150	19	* .1	14	* .8	* .6	4	170	11	.2	60	* .3	3	2	* .02	11	* .6	13	.6	* 11	* .6
Patuxent River at Penna. R.R. bridge near Bowie, Md.																						
July 2, 1963	22	530	26	0.2	19	0.6	*0.8	2	470	3	0.4	250	*0.2	4	6	0.1	7	*0.8	25	*2	* 82	0.0X
Little Patuxent River at Guilford, Md.																						
June 27, 1963	11	80	32	*0.1	17	*0.1	*0.1	1	160	1	0.5	86	*0.3	3	4	0.1	27	*1	6	*3	* 99	*0.5
Middle Patuxent River near Guilford, Md.																						
June 27, 1963	--	19	13	*0.09	9	*0.09	*0.9	0.8	22	*0.9	0.2	24	*0.3	1	2	0.2	3	*0.9	2	*3	* 90	*0.4
Dorsey Run near Jessup, Md.																						
July 2, 1963	5	530	57	*0.1	30	0.8	5	10	700	6	2	230	1	18	9	0.4	58	*1	20	*4	*140	*0.7
Little Patuxent River at Ft. George G. Meade, Md.																						
June 27, 1963	41	300	41	*0.2	18	*0.2	*2	3	290	2	0.4	86	*0.5	6	7	0.3	64	*2	11	*5	*180	*0.9
Oct. 2, ...	30	38	12	* .2	19	.2	* .8	2	73	2	.2	100	* .8	2	5	* .04	7	*1	3	*1	* 58	*1
Jan. 10, 1964	474	250	45	* .2	15	2	1	3	240	5	.5	74	.5	4	3	.09	35	* .8	13	2	* 25	* .8
Apr. 2, ...	131	100	32	* .2	16	2	1	4	290	9	.5	62	* .5	3	2	.09	39	* .9	9	.9	* 18	* .9
Patuxent River at Hardesty, Md.																						
June 27, 1963	85	430	54	*0.1	55	0.7	2	5	1,800	4	0.7	290	*0.4	7	6	0.1	31	*1	21	*4	*120	*0.6
Oct. 2, ...	104	620	48	* .2	34	.9	2	6	>1,000	4	1	310	* .7	14	9	.1	38	*1	26	3	* 56	*1
Jan. 10, 1964	2,180	190	34	* .2	26	.9	2	4	240	2	.7	150	* .3	5	5	* .04	26	*.7	7	1	* 20	* .7
Apr. 2, ...	354	120	37	* .2	29	*1	2	3	320	6	.6	150	* .4	5	3	.03	29	*.9	13	* .7	* 18	* .9
May 12, ...	181	230	30	* .2	30	* .9	1	6	900	8	.7	150	* .3	10	6	.1	30	*1	30	1	* 30	*1
Western Branch near Largo, Md.																						
June 27, 1963	3.7	420	59	*0.1	41	1	2	5	1,600	5	3	210	0.4	10	13	*0.1	39	*1	24	*4	*130	*0.7

X Semiquantitative estimate in the digit order shown
> Larger than figure indicated
* Less than figure indicated

TABLE 1. SPECTROGRAPHIC ANALYSES FOR TRACE ELEMENTS IN THE PATUXENT RIVER BASIN -- Continued

(Spectrographic analysis in micrograms per liter except as indicated)

Date of collection	Discharge (cfs)	Aluminum (Al)	Barium (Ba)	Beryllium (Be)	Boron (B)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Rubidium (Rb)	Silver (Ag)	Strontium (sr)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
Western Branch at U. S. Highway 301 near Upper Marlborough																						
July 3, 1963	44	71	38	*0.1	32	*0.1	1	0.7	190	2	0.8	140	*0.4	5	7	*0.1	12	*1	17	*4	*130	0.X
Mataponi Creek near Croom, Md.																						
July 3, 1963	4.7	30	14	*0.05	18	*0.05	*0.5	0.7	120	0.9	0.3	27	*0.1	2	2	*0.05	6	*0.5	4	*1	* 49	0.0X
Patuxent River at Lyons Creek Wharf, Md.																						
June 28, 1963	--	390	39	*0.2	30	*0.2	*2	5	430	3	2	150	2	5	8	*0.2	82	*2	6	*7	*220	*1
Patuxent River at Nottingham, Md.																						
Nov. 14, 1963 a/	--	460	--	*0.57	--	*1.4	*1.4	*1.4	69	*1.4	--	40	*0.29	2.8	--	--	--	--	* 0.57	12	* 5.7	--
Jan. 10, 1964	--	310	32	* .2	19	1	1	3	300	3	1	160	.4	4	3	* .04	34	* .8	18	1	* 25	* .8
Apr. 2, 1964	--	210	28	* .2	37	2	.8	4	390	6	.7	70	.5	4	2	.2	20	* .8	19	.1	* 16	* .8
Patuxent River at Benedict, Md.																						
June 28, 1963 a/	--	150	240	*12	700	*12	*120	61	*120	*120	51	*120	*36	*120	*120	*12	2,900	*120	*120	*360	--	*60
Nov. 14, ... a/	--	106	--	* .57	--	* 1.4	* 1.4	* 1.4	11	* 1.4	--	40	8.0	3.7	--	--	--	--	* .57	.91	* 5.7	--
Jan. 15, 1964 a/ b/	--	38	--	* .57	--	6.4	* 1.4	* 1.4	16	* 1.4	--	4.3	2.0	8.0	--	--	--	--	* .57	.29	* 5.7	--
Apr. 13, ... a/	--	98	--	* .33	--	* .83	* .83	1.8	.4	.83	--	1.1	1.6	2.5	--	--	--	--	3.3	.32	* 3.3	--
Patuxent River at Solomons, Md.																						
June 28, 1963 a/ c/	--	130	*150	*15	880	*15	*150	64	*150	*150	72	*150	*44	*150	*150	15	5,400	*150	*150	*440	--	*73
Jan. 15, 1964 a/	--	46	--	.57	--	* 1.4	* 1.4	* 1.4	13	* 1.4	--	6.3	2.6	9.6	--	--	--	--	.57	* .29	5.7	--
Apr. 13, ... a/	--	64	--	* .33	--	* .83	.83	2.0	8.8	* .83	--	13	3.0	5.5	--	--	--	--	2.8	* .17	* 3.3	--

* Less than figure indicated
X Semiquantitative estimate in the digit order shown
a/ Chemical concentration method used prior to spectrographic analysis
b/ 6 micrograms per liter cadmium determined
c/ 5.6 micrograms per liter cadmium determined

TABLE 2. MISCELLANEOUS ANALYSES OF WATER FROM THE PATUXENT RIVER BASIN IN MARYLAND

(Chemical analyses, in parts per million)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
Patuxent River near Unity																									
May 22, 1963 b/	14	--	--	--	--	--	--	--	--	--	16	--	--	--	--	--	--	--	--	58	7.4	--	58	--	--
July 1, 1963	14	7.7	0.0 a/	0.0 a/	0.00 a/	3.8	2.1	2.7	1.0	0.00	20	1.6	3.4	0.1	3.3	0.01	41	18	2	55	6.5	3	71	0.02 a/	0.00 a/
Oct. 22, 1963 b/	5.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	63	6.4	--	55	--	--
Patuxent River below Tridelphia Reservoir near Brighton																									
May 22, 1963 b/	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	73	--	--	66	--	--
July 1, 1963	43	4.0	0.0 a/	0.00 a/	0.00 a/	6.0	1.7	2.8	2.1	0.00	17	6.8	4.3	0.2	3.5	0.02	43	22	8	71	--	5	69	0.01 a/	0.00 a/
Patuxent River at Penna. Railroad Bridge near Bowie																									
July 2, 1963	22	5.5	0.1 a/	0.03 a/	0.00 a/	6.0	2.2	4.7	2.5	0.00	16	11	6.5	0.2	3.6	0.21	59	24	11	85	6.0	5	74	0.01 a/	0.00 a/
Little Patuxent River at Guilford																									
May 22, 1963 b/	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	108	7.4	--	65	--	--
June 27, 1963	11	19	0.0 a/	0.04 a/	0.00 a/	11	1.6	6.2	1.7	0.00	40	8.0	5.0	0.2	3.2	0.06	75	76	1	110	6.5	5	68	0.01 a/	0.00
Oct. 22, 1963 b/	7.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	118	6.4	--	56	--	--
Middle Patuxent River near Guilford																									
June 27, 1963	12 e/	15	0.02 a/	0.02 a/	0.00	11	1.6	4.7	1.6	0.00	40	5.2	5.0	0.1	1.9	0.05	69	34	1	101	6.6	2	72	0.08 a/	0.00 a/
Oct. 22, 1963 b/	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	117	6.5	--	55	--	--
Dorsey Run near Jessup																									
May 22, 1963	5 e/	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	205	--	--	66	--	--
July 2, 1963	5.2	8.8	0.0 a/	0.01 a/	0.00 a/	9.5	3.0	12	3.5	0.00	26	15	15	0.3	9.7	0.41	97	36	14	139	6.3	5	--	0.02 a/	0.00 a/
Patuxent River near Leon																									
Sept. 13, 1963	--	6.2	--	0.00 a/	0.00 a/	20	10	8	3	--	46	32	143	0.1	0.4	--	346	92	55	638	6.8	5	72	--	--
Western Branch near Largo																									
June 27, 1963	3.7	14	0.1 a/	0.02 a/	0.00 a/	14	1.7	3.7	2.0	0.00	28	15	9.6	0.4	0.8	0.06	85	42	19	120	6.4	3	--	0.01 a/	0.00 a/
Western Branch at Highway U. S. 301 near Upper Marlboro																									
July 3, 1963	44	15	0.1 a/	0.00 a/	0.00 a/	17	2.3	3.5	3.5	0.00	40	18	7.4	0.3	0.9	0.05	99	52	19	99	6.5	7	--	0.02 a/	0.00 a/

a/ In solution when analyzed
b/ Field determination
c/ Sample 5 ft. below surface
d/ Near bottom
e/ Estimated

TABLE 2. MISCELLANEOUS ANALYSES OF WATER FROM THE PATUXENT RIVER BASIN IN MARYLAND (Continued)

(Chemical analyses in parts per million)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
Mataponi Creek near Croom																									
July 3, 1963	4.7	21	0.1 a/	0.00 a/	0.00 a/	6.8	1.7	2.7	1.2	--	14	13	4.4	0.2	0.2	0.07	69	24	13	68	6.0	7	73	0.02 a/	0.00 a/
Patuxent River at Lyon's Creek Wharf																									
June 28, 1963	--	3.3	0.0 a/	3.0 a/	--	11	4.0	35	3.2	--	26	22	56	0.3	0.8	0.26	173	44	23	287	6.1	5	80	0.03 a/	0.0 a/
Patuxent River opposite Broome Island																									
June 28, 1963	--	2.9	0.8 a/	0.02 a/	0.00 a/	199	417	3,730	107	--	66	950	6,890	0.8	0.06	0.06	13,900	2,220	2,160	19,300	6.7	2	--	0.03 a/	0.1 a/
Oct. 4, ... c/	--	1.9	--	.00 a/	.02 a/	187	589	4,890		--	70	1,210	8,650	.7	.0	--	16,100	2,890	2,890	22,300	6.8	--	66	--	--
Jan. 20, 1964 c/	--	2.0	--	.00 a/	.00 a/	212	590	4,990		--	73	1,230	8,830	.8	3.2	--	17,100	2,960	2,900	24,900	7.1	--	--	--	--
Jan. 20, ... d/	--	1.2	--	.00 a/	.00 a/	246	640	5,450		--	69	1,360	9,650	.9	.0	--	19,000	3,250	3,190	26,800	6.9	--	--	--	--
Apr. 13, ... c/	--	--	--	--	--	--	--	--		--	--	--	5,270	--	--	--	--	--	--	14,300	--	--	52	--	--
Apr. 13, ... d/	--	--	--	--	--	--	--	--		--	--	--	5,440	--	--	--	--	--	--	15,100	--	--	--	--	--
Patuxent River opposite St. Leonard Creek																									
June 28, 1963	--	2.9	0.9 a/	0.02 a/	0.00 a/	219	425	3,740	107	--	66	984	6,960	0.8	0.9	0.12	14,100	2,300	2,240	19,700	6.6	3	--	0.09 a/	0.1 a/
Oct. 4, ... c/	--	1.9	--	.00 a/	.02	192	605	5,020		--	73	1,240	8,880	.8	.0	--	16,100	2,970	2,910	22,800	--	--	--	--	--
Jan. 20, 1964 c/	--	1.5	--	.00 a/	.00	234	623	5,440		--	74	1,320	9,600	.8	.0	--	18,300	3,150	3,090	26,800	--	--	--	--	--
Apr. 13, ...	--	3.7	--	.03	.04	144	394	3,110		--	58	804	5,560	.4	.4	--	10,900	1,980	1,930	16,500	--	--	--	--	--
Apr. 13, ... c/	--	--	--	--	--	--	--	--		--	--	--	5,450	--	--	--	--	--	--	14,900	--	--	--	--	--
Apr. 13, ... d/	--	--	--	--	--	--	--	--		--	--	--	5,550	--	--	--	--	--	--	14,900	--	--	--	--	--

a/ In solution when analyzed.

c/ Sample 5 ft. below surface.
d/ Near bottom.

TABLE 3. CHEMICAL ANALYSES OF WATER OF THE PATUXENT RIVER NEAR LAUREL, MD.

LOCATION.--At gaging station at Rocky Gorge Pumping Station, 600 feet downstream from Rocky Gorge Dam, 0.7 mile upstream from Walker Branch and 1.3 miles northwest of Laurel, Prince Georges' County.
DRAINAGE AREA.--132 square miles.

(Chemical analyses in parts per million)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
May 22, 1963 a/	12	--	--	--	--	--	--	--	--	--	24	--	--	--	--	--	--	--	--	86	7.0	--	55	--	--
July 1, ...	14	7.3	0.1 b/	1.3 b/	0.5 b/	6.0	2.4	3.0	2.4	0.00	24	6.0	4.4	0.2	2.5	0.02	54	25	6	75	6.5	7	58	0.06 b/	1.1 b/
July 23,....	13	7.2	--	.07	.00	5.5	1.9	5.1		--	30	6.4	4.1	.0	2.2	--	51	25	4	77	6.9	3	55	--	--
Aug. 16,....	12	7.0	--	.26	.00	6.5	2.7	4.4		--	27	5.2	4.2	.4	2.3	--	54	27	5	78	6.5	30	58	--	--
Sept. 9,....	10	6.7	--	.15	.00	7.5	2.8	2.8		--	28	4.6	4.4	.0	2.7	--	52	30	7	79	6.3	30	55	--	--
Sept.19,....	11	7.4	--	.28 b/	.01 b/	9.0	.9	5.3		--	30	4.4	4.6	.0	2.5	--	54	26	2	78	6.7	30	56	--	--
Oct. 2, ...	11	7.5	.4	6.9	.00	8.0	1.9	3.0	2.2	--	30	3.4	4.5	.0	4.1	.00	60	28	4	81	6.6	70	55	.25	.8
Oct. 16,....	10	7.8	.4	8.0	3.0	7.2	2.4	3.3	2.4	.00	29	3.4	4.3	.1	3.5	.06	57	28	4	81	6.6	--	56	.27	.02
Oct. 22,.... a/	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	115	6.1	--	56	--	--
Oct. 25,....	10	7.6	--	9.4	3.0	6.5	2.9	7.4		--	34	4.2	4.7	.1	5.3	--	59	28	0	88	6.4	--	50	--	--
Nov. 4, ...	9.7	2.6	--	.99 b/	.01 b/	5.9	2.3	4.1		--	24	6.0	4.6	.1	.9	--	42	24	5	74	6.6	--	57	--	--
Nov. 14,....	11	2.0	--	.66	.61	6.0	1.7	5.3		--	24	6.4	4.5	.0	1.2	--	44	22	3	72	6.7	10	53	--	--
Nov. 25,....	12	5.6	--	.68	.33	6.4	1.7	3.0	2.8	--	22	7.4	4.5	.1	2.1	--	52	23	5	76	7.0	--	49	--	--
Dec. 7, ...	12	3.4	--	.44	.14	5.6	2.2	3.1	2.4	--	23	6.2	4.2	.1	1.6	--	46	23	4	73	6.8	--	47	--	--
Dec. 18,....	12	3.2	--	.20	.04	6.3	1.8	5.5		--	23	6.8	5.5	.0	1.8	--	43	24	4	72	6.7	10	42	--	--
Dec. 30,....	13	3.3	--	.61	.06	6.3	1.9	5.3		--	23	6.2	5.5	.0	2.0	--	42	24	4	71	6.7	10	39	--	--
Jan. 10, 1964	13	3.6	--	.40	.05	6.3	1.8	5.8		--	22	6.8	5.5	.0	2.9	--	41	23	5	72	6.6	10	39	--	--
Jan. 24, ...	90	4.1	.2	.50	.08	6.2	1.8	4.1		--	10	6.8	4.7	.1	1.9	--	46	23	7	71	7.1	--	38	--	--
Feb. 4, ...	52	13	--	.31	.20	6.8	1.5	4.1		--	21	7.2	4.6	.1	.8	--	46	23	6	69	7.5	--	37	--	--
Feb. 14, ...	51	4.4	--	.30	.36	5.6	1.9	3.5	2.2	--	21	7.4	4.9	.0	1.6	--	45	22	5	71	6.6	3	38	--	--
Feb. 26, ...	46	5.5	--	.31	.07	5.6	1.9	2.6	2.2	--	20	7.8	4.0	.0	2.0	--	43	22	6	70	6.9	2	38	--	--
Mar. 5, ...	148	5.7	--	.33	.39	5.6	1.9	3.4	2.2	--	20	7.6	5.1	.1	2.1	--	47	22	6	70	6.8	4	43	--	--
Mar. 16, ...	115	4.1	--	.50	.08	6.2	1.8	4.1		--	10	6.8	4.7	.1	1.9	--	46	23	7	70	7.1	--	44	--	--
Mar. 25, ...	155	6.8	--	.33	.18	8.2	.1	4.8		--	18	7.6	4.6	.1	2.7	--	51	21	6	68	7.3	--	47	--	--
Apr. 2, ...	107	6.8	.1	.22	.00	5.2	1.9	3.2	1.9	.01	18	5.8	4.8	.0	3.0	.00	47	21	6	71	6.7	3	45	.06	.1
Apr. 14, ...	150	6.3	--	.20	.10	6.0	1.7	3.1	2.0	--	16	6.8	4.1	.1	3.6	--	50	22	9	74	6.8	5	47	--	--
Apr. 24, ...	150	--	--	--	--	--	--	--	--	--	--	--	4.4	--	--	--	--	--	--	66	--	--	--	--	--

a/ Field determination
b/ In solution when analyzed

TABLE 4. CHEMICAL ANALYSES OF WATER OF THE LITTLE PATUXENT RIVER AT FORT GEORGE G. MEADE, MD.

LOCATION.--At Simond's Bridge on State Highway 198, on Fort George G. Meade Military Reservation, about 4 miles east of Laurel, Anne Arundel County.
DRAINAGE AREA.--127 square miles.

(Chemical analyses in parts per million)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
June 27, 1963	41	15	0.1	0.57	0.06	12	2.2	24	3.3	0.00	64	26	7.6	0.4	5.1	1.7	137	39	0	204	6.4	8	68	0.02	0.0
July 23, ...	20	10	--	.00	.00	9.5	3.5	11		--	50	9.2	7.1	.1	1.0	--	82	38	0	130	7.2	5	73	--	--
Aug. 2, ...	13	11	--	.00	.00	10	3.6	11		--	48	11	7.2	.1	3.2	--	84	40	1	134	7.0	8	74	--	--
Aug. 16, ...	20 e/	10	--	.02	.00 a/	10	3.2	11		--	40	15	8.0	.1	.9	--	85	38	5	136	6.3	10	66	--	--
Aug. 26, ...	20 e/	11	--	.00 a/	.00 a/	12	2.7	9.2		--	48	8.4	7.8	.1	1.7	--	82	41	2	128	7.0	5	65	--	--
Sept. 9, ...	20	4.8	--	.00 a/	.00 a/	11	2.8	9.2		--	48	7.8	6.9	.1	1.6	--	64	39	0	124	7.3	5	64	--	--
Sept.19, ...	--	10	--	.00 a/	.00 a/	12	3.2	9.9		--	47	9.6	9.4	.1	2.6	--	85	43	5	138	7.4	5	64	--	--
Oct. 2, ...	30	11	.4	.71	.00	9.5	3.0	8.3	4.1	--	40	12	8.6	.0	.3	--	95	36	3	125	6.4	25	54	.09	.1
Oct. 16, ...	21	11	.2	.57	.22	10	3.4	9.0	2.8	.01	50	8.6	7.5	.2	.0	.29	79	39	0	129	6.6	--	54	.12	.0
Oct. 25, ...	23	10	--	.48	.08	12	3.2	12		--	54	12	8.3	.2	.2	--	87	43	0	145	6.6	--	54	--	--
Nov. 4, ...	31	12	--	.59	.01	11	3.3	8.7		--	40	11	9.2	.1	2.3	--	86	41	8	132	6.8	--	42	--	--
Nov. 14, ...	49	15	--	2.6	.14	10	2.9	7.6		--	35	11	7.2	.0	4.3	--	78	37	9	116	6.9	0	44	--	--
Nov. 25, ...	68	13	--	.61	.09	9.5	3.0	6.1	2.9	--	30	13	8.0	.1	3.2	--	76	36	12	115	6.8	--	42	--	--
Dec. 7, ...	69	15	--	.57	.12	9.3	3.2	6.3	2.0	--	34	11	6.6	.1	2.4	--	78	36	8	112	7.0	--	37	--	--
Dec. 18, ...	78	16	--	.51	.04	9.6	3.0	8.3		--	32	13	9.0	.0	3.3	--	75	36	10	110	6.6	5	33	--	--
Dec. 30, ...	68 e/	15	--	.69	.05	9.4	2.7	8.5		--	31	11	9.0	.0	4.4	--	74	34	9	107	6.8	5	32	--	--
Jan. 10, 1964	474	7.5	--	3.1	.10	6.8	1.9	6.2		--	14	15	6.5	.0	2.8	--	60	36	8	112	7.0	10	35	--	--
Jan. 24, ...	65	12	--	.88	.14	6.2	4.0	6.2		--	22	14	7.4	.1	2.3	--	74	32	14	97	7.2	--	36	--	--
Feb. 4, ...	103	15	--	.45	.04	9.8	2.2	6.4		--	26	12	7.1	.1	3.7	--	75	34	12	101	7.4	--	33	--	--
Feb. 14, ...	127	13	--	.67	.10	9.2	2.7	8.5	1.6	--	29	11	14	.0	1.9	--	75	34	10	123	6.8	3	34	--	--
Feb. 26, ...	140 e/	15	--	.47	.30	8.4	2.9	5.4	1.4	--	26	13	8.0	.0	2.9	--	72	33	12	107	6.6	3	34	--	--
Mar. 5, ...	300 e/	10	--	1.6	.70	8.4	2.7	5.9	2.0	--	24	13	8.6	.0	2.7	--	69	32	13	109	7.0	3	45	--	--
Mar. 16, ...	140 e/	12	--	.47	.02	8.8	2.1	8.0		--	29	11	7.4	.2	2.0	--	74	30	7	103	7.3	--	42	--	--
Mar. 25, ...	145 e/	12	--	.62	.04	6.8	3.7	8.5		--	28	14	7.4	.1	2.6	--	71	32	9	101	7.5	--	46	--	--
Apr. 2, ...	131	12	--	.44	.01	7.6	3.2	6.0	1.4	--	32	9.4	7.4	.0	2.4	--	68	32	6	105	6.8	4	38	--	--
Apr. 13, ...	142	11	--	.46	.03	9.3	2.4	5.8	1.6	--	28	11	6.6	.1	1.2	--	74	33	10	110	6.5	--	56	--	--
Apr. 24, ...	164	--	--		--	--	--	--	--	--	--	--	6.4	--	--	--	--	--	--	104	--	--	--	--	--

a/ In solution when analyzed.
e/ Estimated.

TABLE 5. CHEMICAL ANALYSES OF WATER OF THE PATUXENT RIVER AT HARDESTY, MD.

LOCATION.--At Queen Anne Bridge at Hardesty, Prince Georges County, about 0.2 mile below Davidsonville Branch and 0.7 mile south of State Highway 214.
DRAINAGE AREA.--371 square miles.

(Chemical analyses in parts per million)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
June 27, 1963	85	13	0.0	2.0	0.10	10	1.9	7.4	2.5	0.00	30	13	7.3	0.2	5.0	0.26	75	33	1	120	6.4	2	71	0.02	0.0
July 23, ...	56	9.1	--	.0 a/	.0 a/	10	2.7	16		--	40	15	12	.3	5.0	--	90	36	3	143	6.8	5	73	--	--
Aug. 2, ...	48	8.7	--	.02	.00	11	2.8	11		--	40	13	8.8	.3	2.7	--	84	39	6	136	7.0	7	73	--	--
Aug. 16, ...	76	7.5	--	.00 a/	.00 a/	10	1.7	7.4		--	21	18	6.6	.1	3.2	--	68	32	15	109	6.1	10	66	--	--
Aug. 26, ...	77	12	.3	2.1	.10	11	2.6	8.0	3.5	.00	29	18	10	.1	4.[illegible]	.14	88	38	14	135	6.5	5	67	.07	.20
Sept. 9, ...	61	8.6	.2	1.5	.04 a/	11	2.8	10	3.5	.00	36	15	12	.2	5.2	.17	87	39	10	143	6.4	5	64	.04	.0
Sept.19, ...	62	11	--	.01 a/	.00 a/	11	2.3	9.7		--	27	18	10	.1	3.5	--	92	37	15	128	6.4	5	63	--	--
Oct. 2, ...	104	10	.4	2.1	.00	10	1.7	5.9	3.5	--	24	19	7.8	.2	.1	.00	90	32	13	114	6.4	15	56	.12	.3
Oct. 16, ...	69	11	.1	2.1	.00	11	2.6	8.4	3.2	--	36	13	9.4	.2	3.7	.51	96	38	9	133	6.5	5	52	.05	.1
Oct. 25, ...	73	10	.2	1.5	.00	11	3.0	8.6	3.6	--	42	12	9.9	.3	1.0	.00	99	40	6	134	6.4	10	57	.07	.1
Nov. 4, ...	100	11	--	.19 a/	.02 a/	9.5	3.0	9.4		--	31	16	9.2	.2	1.1	--	83	36	11	127	6.5	--	47	--	--
Nov. 14, ...	131	13	.1	1.4	.00	10	3.2	6.6	3.0	--	26	17	8.6	.2	4.2	.28	91	38	17	124	6.5	5	45	.04	.1
Nov. 25, ...	210	11	--	1.4	.25	8.9	2.4	5.8	2.8	--	21	16	6.6	.1	3.6	--	74	32	15	111	6.6	--	46	--	--
Dec. 7, ...	164	13	.1	1.1	.28	9.3	2.7	6.3	2.4	.01	22	16	7.2	.2	4.5	.33	79	34	16	116	7.0	--	39	.07	.0
Dec. 18, ...	169	12	.2	1.0	.08	9.7	2.5	7.2	2.1	.02	20	17	10	.1	5.9	.33	74	34	18	117	6.4	5	33	.07	.2
Dec. 30, ...	107	12	.1	198	.08	9.5	2.3	9.0	2.0	.12	20	15	14	.1	6.0	.33	77	33	16	120	7.3	5	32	.07	.2
Jan. 10, 1964	2,180	6.1	.1	3.2	.09	5.7	1.8	3.6	2.4	.12	8	14	7.0	.0	2.0	.06	49	21	14	74	5.8	10	37	.10	.3
Jan. 24, ...	196	9.0	.7	1.2	.02	7.8	2.1	5.2	2.0	.03	14	17	7.5	.0	1.6	.38	66	28	17	101	6.0	3	37	.11	.1
Feb. 4, ...	300	11	.2	.75	.02	8.2	2.3	5.1	2.0	.02	19	15	6.8	.0	2.6	.11	70	30	15	101	6.6	2	37	.04	.0
Feb. 14, ...	423	9.9	.3	.77	.02	8.4	2.2	8.6	2.2	.02	18	13	14	.0	4.2	.34	82	30	15	122	6.5	2	38	.07	.0
Feb. 26, ...	300	11	.4	.77	.00	8.0	2.4	5.4	1.8	.0	19	15	7.5	.0	1.8	.00	67	30	15	102	6.2	3	38	.05	.0
Mar. 5, ...	741	4.6	.7	1.2	.00	8.0	2.2	6.7	2.0	.03	16	17	9.0	.1	3.2	.01	70	29	16	108	7.1	3	45	.06	.1
Mar. 16, ...	368	9.9	.20	.64	.00	7.4	2.3	5.1	1.8	.02	20	13	6.8	.0	1.7	.14	64	28	12	95	6.7	4	45	.09	.4
Mar. 25, ...	773	9.0	.4	.89	.00	7.6	1.9	5.2	1.9	.01	15	14	7.0	.0	2.9	.00	64	27	15	97	6.4	2	--	.11	.2
Apr. 2, ...	354	9.5	--	.60	.12	6.8	2.7	5.5	1.4	--	20	13	7.7	.0	3.2	--	60	28	12	95	6.5	3	42	--	--
Apr. 13, ...	425	7.8	--	.79	.10	8.1	1.9	4.9	1.9	--	18	13	6.4	.1	3.0	--	68	28	13	101	6.5	--	55	--	--
Apr. 24, ...	440	--	--	--	--	--	--	--	--	--	--	--	6.0	--	--	--	--	--	--	96	--	--	--	--	--
May 12, ...	181	--	--	--	--	--	--	--	--	--	--	--	6.6	--	--	--	--	--	--	104	--	--	65	--	--

a/ In solution when analyzed

TABLE 6. CHEMICAL ANALYSES OF WATER OF THE PATUXENT RIVER AT NOTTINGHAM, MD.

LOCATION.--At wharf on right bank at Nottingham, Prince Georges County, Md., about 0.9 miles upstream from Tanyard Branch and about 2.4 miles east of Naylor.
DRAINAGE AREA.--581 square miles.

(Chemical analyses in parts per million)

Date of collection	Tidal stage	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
Aug. 2, 1963	High	1.5	--	0.01	0.00	32	53	528		--	32	142	900	0.3	0.4	--	1,690	300	274	3,120	6.5	8	84	--	--
Aug. 16, ...	Ebb	1.2	--	.01 a/	.01 a/	44	86	719		--	32	185	1,280	.3	.5	--	2,420	464	438	4,230	6.5	--	75	--	--
Aug. 26, ...	High	3.9	--	.00 a/	.02 a/	29	57	463		--	28	125	820	.2	1.3	--	1,600	306	283	2,860	6.4	--	74	--	--
Sept. 9, ...	High	2.1	--	.00 a/	.02 a/	43	100	815		--	31	210	1,450	.3	.4	--	2,800	520	494	4,810	6.4	--	77	--	--
Sept.19, ...	High-ebb	2.3	--	.05 a/	.00 a/	38	70	600		--	33	158	1,060	.2	1.1	--	2,140	385	358	3,610	6.4	--	67	--	--
Oct. 4, ...	High	1.4	--	1.3	.87	39	88	706		--	33	180	1,260	.3	.7	--	2,420	458	431	4,200	6.5	--	62	--	--
Oct. 16, ...	Low	2.8	0.3	1.2	.10	34	63	530	23	0.3	34	134	925	.1	1.1	0.06	1,660	344	316	3,100	6.7	10	64	0.05	0.3
Oct. 25, ...	Low	2.1	--	.99	.86	46	103	859		--	36	223	1,520	.2	1.3	--	3,020	540	511	5,020	6.4	--	63	--	--
Nov. 4, ...	Lo-flood	4.9	--	5.7	.60	47	96	803		--	35	202	1,430	.2	.5	--	2,560	512	484	4,650	7.0	10	50	--	--
Nov. 14, ...	Hi-flood	10	--	2.9	.24	12	13	104		--	21	43	175	.0	.5	--	390	84	67	702	6.4	20	50	--	--
Nov. 25, ...	Ebb	12	--	1.8	.40	12	6.8	43		--	32	27	68	.1	.9	--	103	58	32	351	6.8	--	51	--	--
Dec. 7, ...	Low	11	.2	2.5	.05	9.2	3.2	12	3.0	.14	18	21	20	.0	1.2	.16	91	36	21	150	7.1	10	43	.09	.2
Dec. 18, ...	Low	12	.4	1.8	.05	11	3.2	11	2.5	.18	26	20	19	.0	.2	.05	92	40	19	147	6.2	20	32	.03	.1
Dec. 30, ...	Low	15	.4	1.8	.07	13	4.2	18	2.7	.13	29	23	20	.0	4.2	.14	121	50	26	201	6.5	5	33	.12	.2
Jan. 10, 1964	Low	8.3	.1	4.3	.08	7.3	1.9	5.5	2.5	.08	10	18	9.5	.0	1.9	.07	62	26	18	93	5.8	10	39	.04	.4
Jan. 24, ...	High	13	--	2.2	.00	9.8	4.0	16		--	18	22	26	.2	.8	--	115	41	26	155	6.8	--	33	--	--
Feb. 4, ...	Flood	13	--	1.4	.34	9.5	2.4	6.9		--	21	18	8.7	.2	.2	--	78	34	17	105	7.2	--	55	--	--
Feb. 14, ...	Hi-flood	12	--	3.1	.77	9.2	2.9	9.9	1.9	--	17	21	17	.0	1.8	--	88	35	21	140	6.5	2	38	--	--
Feb. 26, ...	Lo-flood	12	--	1.8	.46	9.2	2.7	8.0	1.7	--	15	20	14	.1	1.2	--	78	34	22	127	6.8	3	40	--	--
Mar. 5, ...	Ebb	13	--	2.4	.50	8.8	3.4	12	1.8	--	19	22	20	.1	.0	--	90	36	21	149	6.3	--	46	--	--
Mar. 16, ...	Low	12	--	2.5	.00	9.0	2.7	7.4		--	20	18	8.4	.2	2.2	--	78	34	17	108	7.4	--	47	--	--
Mar. 25, ...	High	11	--	2.9	.22	9.0	1.9	6.4		--	17	17	9.0	.2	.0	--	74	30	17	103	6.8	--	50	--	--
Apr. 2, ...	Low-ebb	12	--	1.6	.28	8.4	2.9	4.9	1.8	--	20	18	8.6	.0	1.5	--	69	33	17	108	6.9	3	43	--	--
Apr. 13, ...	Flood	13	--	1.9	.31	9.2	2.4	6.5	2.0	--	14	24	9.4	.1	1.6	--	83	33	22	124	6.2	--	50	--	--
Apr. 24, ...	High	--	--	--	--	--	--	--	--	--	--	--	9.8	--	--	--	--	--	--	120	--	--	--	--	--
May 12, ...	High	--	--	--	--	--	--	--	--	--	--	--	9.6	--	--	--	--	--	--	123	--	--	72	--	--

a/ In solution when analyzed

TABLE 7. CHEMICAL ANALYSES OF WATER OF THE PATUXENT RIVER AT BENEDICT, MD.

LOCATION.--On bridge on State Highway 231 at Benedict, Charles County about 2 miles downstream from Swanson Creek.
DRAINAGE AREA.--742 square miles.

(Chemical analyses in parts per million)

Date of collection	Tidal stage	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
June 28, 1963	High-ebb	3.8	0.8	0.24	0.00 a/	149	383	3,240	118	0.85	60	930	5,880	0.8	1.9	0.13	11,700	1,950	1,900	16,800	6.5	5	79	0.01	0.0
Aug. 16, ...	Low	5.0	--	.36 a/	.01 a/	149	468	3,730		--	63	928	6,650	.6	.4	--	12,600	2,300	2,250	18,300	6.7	--	73	--	--
Aug. 26, ...	High	4.2	--	.04	.00	169	257	4,420		--	65	1,020	7,060	.7	1.8	--	13,800	1,480	1,430	19,900	6.7	5	73	--	--
Oct. 4, ...	Low-flood	2.6	1.0	.84	.05	156	484	3,720	159	.83	58	966	6,940	.7	.4	.18	12,900	2,380	2,330	18,000	6.9	5	65	.00	.1
Oct. 4, ... b/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	6,660	--	--	--	--	--	--	18,400	--	--	--	--	--
Oct. 4, ... c/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	6,860	--	--	--	--	--	--	18,900	--	--	--	--	--
Oct. 16, ...	Low	1.9	.8	.56	.04 a/	181	551	4,450	170	1.2	66	1,120	8,010	.7	.4	.26	14,800	2,720	2,670	20,300	6.9	5	64	.00	.1
Nov. 4, ...	High-flood	2.2	--	.00 a/	.01 a/	196	600	4,950		--	71	1,240	8,770	.7	.0	--	16,700	2,960	2,900	22,800	6.8	--	53	--	--
Nov. 14, ...	Flood	2.3	--	.58	.02	190	587	4,900		--	71	1,220	8,660	.6	.0	--	16,500	2,890	2,830	22,500	6.8	--	51	--	--
Nov. 14, ... b/	Flood	2.7	--	.26	.03	170	519	4,280		--	64	1,050	7,600	.6	.2	--	14,300	2,560	2,510	20,200	6.6	--	--	--	--
Nov. 25, ...	Low	2.5	--	.21	.01	183	581	4,800		--	70	1,180	8,500	.7	.4	--	16,100	2,850	2,790	22,200	7.3	--	54	--	--
Dec. 7, ...	Low-flood	2.7	--	.22	.07	185	549	4,840		--	69	1,150	8,500	.7	1.6	--	15,600	2,720	2,660	21,100	6.9	--	46	--	--
Dec. 7, ... b/	Low-flood	3.7	--	.10	.03	163	513	4,020		--	64	1,040	7,180	.6	.4	--	13,600	2,520	2,470	18,900	7.6	--	45	--	--
Dec. 7, ... c/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	8,880	--	--	--	17,100	--	--	22,600	--	--	--	--	--
Dec. 18, ...	Low-ebb	3.4	--	.53	.07	183	550	4,540		--	68	1,120	8,060	.6	1.6	--	15,000	2,720	2,660	20,400	6.9	--	36	--	--
Dec. 18, ... b/	Low-ebb	3.6	--	.02	.04	168	547	4,390		--	67	1,090	7,810	.5	.0	--	14,400	2,670	2,620	19,700	6.9	--	36	--	--
Dec. 18, ... c/	Low-ebb	2.8	--	.00	.08	178	553	4,460		--	68	1,120	7,930	.6	.0	--	15,000	2,720	2,660	20,200	6.8	--	37	--	--
Dec. 30, ...	Low-flood	3.2	--	.01	.03	183	586	4,720		--	70	1,160	8,410	.9	1.2	--	15,500	2,870	2,810	20,800	7.1	--	33	--	--
Dec. 30, ... b/	Low-flood	3.2	--	.00	.03	193	604	4,580		--	70	1,160	8,260	.7	.4	--	15,500	2,970	2,910	20,800	6.8	--	33	--	--
Dec. 30, ... c/	Low-flood	3.2	1.0	.01	.03	190	545	4,880	178	1.1	72	1,170	8,600	.8	.4	.03	15,800	2,720	2,660	21,200	7.2	5	33	.00	.0
Jan. 15, 1964	High-flood	3.0	.7	.83	.02	203	559	4,530	179	2.1	72	1,130	8,450	.2	4.9	.02	15,100	2,810	2,750	22,800	6.8	10	33	.05	.2
Jan. 15, ... b/	High-flood	--	--	--	--	--	--	--	--	--	--	--	7,910	--	--	--	--	--	--	19,800	--	--	--	--	--
Jan. 15, ... c/	High-flood	--	--	--	--	--	--	--	--	--	--	--	8,150	--	--	--	--	--	--	21,000	--	--	--	--	--
Jan. 24, ...	Ebb	3.1	--	.23	.00	178	512	4,370		--	63	1,080	7,700	.6	.8	--	14,800	2,550	2,500	22,100	6.7	--	37	--	--
Jan. 24, ... b/	Ebb	--	--	--	--	--	--	--	--	--	--	--	4,610	--	--	--	--	--	--	12,800	--	--	--	--	--
Jan. 24, ... c/	Ebb	--	--	--	--	--	--	--	--	--	--	--	7,750	--	--	--	--	--	--	19,400	--	--	--	--	--
Feb. 4, ...	Low-flood	3.5	--	.48	.02	178	492	4,330		--	62	1,050	7,610	.7	.0	--	14,500	2,470	2,420	21,800	6.8	--	37	--	--
Feb. 4, ... b/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	5,270	--	--	--	--	--	--	14,500	--	--	--	--	--
Feb. 4, ... c/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	7,220	--	--	--	--	--	--	19,300	--	--	--	--	--
Feb. 14, ...	High	3.7	--	.91	.03	158	475	3,970		--	61	978	7,020	.6	.0	--	13,300	2,350	2,300	20,200	6.7	--	38	--	--

a/ In solution when analyzed
b/ Sampled near top
c/ Sampled near bottom

TABLE 7. CHEMICAL ANALYSES OF WATER OF THE PATUXENT RIVER AT BENEDICT, MD. -- Continued

(Chemical analyses in parts per million)

Date of collection	Tidal stage	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
Feb. 14, 1964 b/	High	--	--	--	--	--	--	--	--	--	--	--	6,700	--	--	--	--	--	--	17,200	--	--	--	--	--
Feb. 14, ... c/	High	--	--	--	--	--	--	--	--	--	--	--	7,430	--	--	--	--	--	--	18,400	--	--	--	--	--
Feb. 26, ...	High-flood	4.4	--	0.41	0.06	138	378	3,380		--	45	841	5,910	0.5	0.0	--	11,600	1,900	1,860	17,200	6.5	--	58	--	--
Feb. 26, ... b/	High-flood	--	--	--	--	--	--	--	--	--	--	--	5,710	--	--	--	--	--	--	15,500	--	--	--	--	--
Feb. 26, ... c/	High-flood	--	--	--	--	--	--	--	--	--	--	--	6,650	--	--	--	--	--	--	16,800	--	--	--	--	--
Mar. 5, ...	Low-ebb	5.3	--	1.1	.35	124	433	3,040		--	54	780	5,560	.5	.8	--	10,800	2,090	2,050	16,400	--	--	47	--	--
Mar. 5, ... b/	Low-ebb	--	--	--	--	--	--	--	--	--	--	--	5,520	--	--	--	--	--	--	14,900	--	--	--	--	--
Mar. 5, ... c/	Low-ebb	--	--	--	--	--	--	--	--	--	--	--	5,620	--	--	--	--	--	--	14,800	--	--	--	--	--
Mar. 16, ...	Low-ebb	5.7	--	1.1	.03	119	331	2,910		--	51	714	5,100	.5	.0	--	9,650	1,660	1,620	15,200	6.6	--	47	--	--
Mar. 16, ... b/	Low-ebb	--	--	--	--	--	--	--	--	--	--	--	3,890	--	--	--	--	--	--	11,300	--	--	--	--	--
Mar. 16, ... c/	Low-ebb	--	--	--	--	--	--	--	--	--	--	--	4,930	--	--	--	--	--	--	13,600	--	--	--	--	--
Mar. 25, ...	High-ebb	5.4	--	.24	.03	139	363	3,080		--	55	750	5,460	.5	.8	--	10,200	1,840	1,790	15,600	6.7	--	51	--	--
Mar. 25, ... b/	High-ebb	--	--	--	--	--	--	--	--	--	--	--	5,050	--	--	--	--	--	--	13,600	--	--	--	--	--
Mar. 25, ... c/	High-ebb	--	--	--	--	--	--	--	--	--	--	--	5,510	--	--	--	--	--	--	15,400	--	--	--	--	--
Apr. 13, ...	Low-flood	8.0	0.7	.87	.19	90	237	1,680		0.73	43	475	3,100	.3	2.8	0.00	6,060	1,200	1,170	9,900	6.9	2	56	0.12	0.2
Apr. 13, ... b/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	2,920	--	--	--	--	--	--	8,320	--	--	--	--	--
Apr. 13, ... c/	Low-flood	--	--	--	--	--	--	--	--	--	--	--	3,180	--	--	--	--	--	--	8,980	--	--	--	--	--
Apr. 24, ...	High-ebb	--	--	--	--	--	--	--	--	--	--	--	4,050	--	--	--	--	--	--	13,300	--	--	--	--	--

b/ Sampled near top
c/ Sampled near bottom

TABLE 8. CHEMICAL ANALYSES OF WATER OF THE PATUXENT RIVER AT SOLOMONS, MD.

LOCATION.--At buoy in Patuxent River estuary off Sandy Point at Solomons, Calvert County.
DRAINAGE AREA.--909 square miles.

(Chemical analyses in parts per million)

Date of collection	Tidal stage	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Boron (B)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphorus as (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Water temperature (°F)	Copper (Cu)	Zinc (Zn)
June 28, 1963	Low	2.3	1.0	0.11	0.00	209	419	4,270	119	1.0	73	1,040	7,490	1.0	5.9	0.00	15,300	2,250	2,190	21,000	6.6	2	74	0.15	0.0
Oct. 4, ...	Low	1.6	--	.09	.02	211	662	5,360		--	78	1,360	9,510	.8	.2	--	18,500	3,250	3,190	24,700	6.8	--	63	--	--
Oct. 4, ... a/	Low	--	--	--	--	--	--	--	--	--	--	--	9,320	--	--	--	--	--	--	24,500	--	--	--	--	--
Oct. 4, ... b/	Low	--	--	--	--	--	--	--	--	--	--	--	9,800	--	--	--	--	--	--	25,300	--	--	--	--	--
Oct. 11, ... a/	High-flood	1.6	--	.00 c/	.00 c/	222	665	5,600		--	79	1,360	9,910	.6	2.4	--	17,900	3,290	3,220	26,400	6.9	8	--	--	--
Oct. 24, ... a/	Low-flood	1.6	--	.00 c/	.00 c/	220	655	5,470		--	78	1,300	9,720	.6	3.0	--	17,600	3,240	3,180	25,000	7.0	10	--	--	--
Nov. 6, ... a/	Low-flood	1.5	--	.00 c/	.00 c/	234	709	6,110		--	84	1,420	10,800	.7	3.2	--	19,400	3,500	3,430	27,800	6.9	5	--	--	--
Nov. 18, ...	Low-flood	1.1	--	.68	.06	232	746	5,800		--	78	1,460	10,400	.9	.2	--	19,600	3,650	3,590	25,600	7.5	--	--	--	--
Jan. 15, 1964 a/	Flood	--	--	--	--	--	--	--	--	--	--	--	9,430	--	--	--	--	--	--	22,700	--	--	--	--	--
Jan. 15, ... b/	Flood	--	--	--	--	--	--	--	--	--	--	--	9,860	--	--	--	--	--	--	23,500	--	--	--	--	--
Jan. 15, ...	Flood	2.1	.9	.07	.03	210	616	5,680	197	1.3	79	1,360	9,620	.9	1.2	.00	17,900	3,060	3,000	23,600	7.4	5	34	.00	.1
Feb. 3, ... a/	High-flood	1.6	--	.00 c/	.00 c/	202	606	4,940		--	84	1,240	8,770	.7	1.0	--	17,200	3,000	2,930	24,600	7.5	--	--	--	--
Feb. 26, ... a/	High-ebb	1.8	--	.00 c/	.00 c/	187	581	4,520		--	63	1,120	8,130	.7	.0	--	15,600	2,860	2,810	23,100	7.0	--	--	--	--
Mar. 23, ... a/	--	2.3	--	.00 c/	.00 c/	131	353	3,030		--	51	762	5,340	.5	2.0	--	10,300	1,780	1,740	16,000	6.8	--	--	--	--
Apr. 8, ...	Ebb	1.9	--	.00 c/	.00 c/	171	407	3,310		--	58	843	5,930	.6	1.8	--	11,800	2,100	2,050	17,600	6.8	--	--	--	--
Apr. 13, ... a/	Ebb	2.7	.6	2.7	.00	151	414	3,080	121	.62	59	809	5,700	.5	1.6	.00	11,300	2,080	2,030	16,600	7.0	2	49	.06	.1
Apr. 13, ... b/	Ebb	--	--	--	--	--	--	--	--	--	--	--	5,570	--	--	--	--	--	--	15,300	--	--	--	--	--
Apr. 13, ... a/	Ebb	--	--	--	--	--	--	--	--	--	--	--	5,770	--	--	--	--	--	--	15,300	--	--	--	--	--
May 5, ...	--	--	--	--	--	--	--	--	--	--	--	--	3,420	--	--	--	--	--	--	11,400	--	--	--	--	--

a/ 5 ft. depth
b/ Near bottom
c/ In solution when analyzed