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TECHNICAL PAPERS

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INTRODUCTION

At the request of Congressman Clarence D. Long by letter to the Secretary of Health, Education, and Welfare on October 24, 1963, the Public Health Service has conducted a special study of pollution problems in the Back River Basin in Baltimore City and Baltimore County, Maryland. This summary report was prepared in cooperation with State and local agencies to present and evaluate all available information relating to the water quality conditions of Back River.

Agencies cooperating in and providing information for this special study are:

Baltimore City Department of Health

Baltimore City Department of Public Works

Baltimore County Department of Health

Baltimore County Department of Public Works

Maryland State Department of Health

Maryland Water Pollution Control Commission

Maryland State Planning Department

Chesapeake Bay Institute, The Johns Hopkins University

CONCLUSIONS

Evaluation of existing pollution sources and analysis of bacteriological data indicates that Back River is potentially unsafe for bodily contact upstream from Lynch Point. Early improvement of water quality in this area will be exceedingly difficult because of the problems involved in controlling and/or eliminating overflows from hundreds of septic tanks, periodic overflows from several sewage pumping stations, drainage from refuse dumps, and waste discharge from marine craft. No one source of pollution may be implicated as the major contributor to poor water quality primarily because of the present lack of information on water movement within the estuary. Control of waste discharges would effect improvement of the water quality in the Basin. Several benefits may be realized from this improved water quality. These are enhanced recreational use and aesthetic conditions, relief of pollution-caused nuisance conditions, and a probable increase in property values.

In any pollution control program, the effects of surface water drainage from densely populated areas, plus the possibility of failure of waste-water transport and treatment systems, must be recognized.

After control of pollution sources, water quality in the River could possibly be improved to a degree that use of the waters for swimming and other bodily contact activities may be possible in

certain limited areas. Delineation of areas where bodily contact may be permitted would be made after analyzing the data on water movement and bacteriological quality in the estuary.

An effective water quality program to alleviate or control present and future pollution of Back River must be based upon comprehensive watershed planning. In developing such a program, consideration should be given to the following methods for preventing development of additional pollution sources.

1. Adopt more adequate controls regulating the discharges of wastes from marine craft.

2. Provide more rigid control of solid wastes disposal areas and prohibit unregulated dumping of refuse in the area.

3. Develop land-use regulations to control housing developments in areas with no public sewerage.

The complex nature of the problem requires that additional studies be undertaken before finalizing a Basin water quality control program. In planning and guiding specific studies in the area, the formation of a committee representing State and local governmental agencies could be most effective. Examples of studies that could be instituted are listed below.

1. Determination of water movement and circulation in the estuary by dyes or other methods.

2. Locate and identify various sources of surface drainage pollution and measure volumes and periods of sewage pumping station overflow.

3. Establish a network to monitor the streams and the estuary under various hydrologic conditions. This is especially useful in detecting unusual amounts or new contributions of pollution.

4. Review laws and regulations governing formulation of sanitary districts and/or a Back River commission. This review should also investigate the effects of these laws and regulations on administration and financing of pollution control programs and facilities.

Information from these studies is necessary in programing further remedial actions to improve water quality in the Back River Basin.

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PHYSICAL DESCRIPTION

Back River is a tidal estuary of the Chesapeake Bay in Baltimore County, Maryland. The River is 9.2 miles long[1] and drains an area of 62.4 square miles; the drainage area above the head of the estuary is 26.8 square miles. Width of the estuary averages about three-fourths of a mile extending to about a mile and a half near the mouth. At mean low water, depths along the center line of the estuary range from two feet at the headwaters to 31 feet near the mouth, averaging about five feet in the upper half of the estuary and nine feet in the lower half.[3] Tides in the estuary average about 1.2 feet but may rise up to eight feet with strong winds from the northeast. The volume of the estuary is about one billion cubic feet, and the water is exchanged with the Chesapeake Bay at a rate of approximately 100 million cubic feet per day.[4] By comparison, the fresh water run-off to the estuary is about two million cubic feet or more per day 95 per cent of the time.[a] This surface run-off carries large quantities of silt which are deposited in the estuary, especially in the upper reaches. Estuary salinity ranges from an average of about 1.0 part per thousand during spring run-off to about 5.0 parts per thousand during the dry part of the summer.[b]

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a/ Estimated by comparing to the Little Gunpowder Falls in the same vicinity, i.e., 0.36 cubic feet per second per square mile.[2]

b/ The salinity of seawater is about 35 parts per thousand.

The tributaries of Back River are several small creeks which are formed at elevations between 100 and 200 feet and flow through heavily populated sections of eastern Baltimore City and Baltimore County. Soil throughout the basin consists largely of tight gray clay with sand occurring sporadically. Standard water seepage tests average over 40 minutes per inch in the clay and range from one to 14 minutes per inch in the sand, depending on clay content. Significant physical characteristics of the basin are shown in Figure 1.

WATER USES

Principal water uses in the Back River Basin include boating, fishing, aesthetic enjoyment, plus waste-water assimilation and transport. The Back River area has developed as a residential and a major recreational area because of its proximity to metropolitan Baltimore. Much of the estuary shore is lined with residences or summer cottages. In addition to permanent residents of the area, several thousand persons utilize the Back River Neck (NE shore) during the summers. Boating is very popular in the Back River area, as a total of 837 craft with motors of 7 1/2 horsepower or more were registered in 1963.[6/] These craft were harbored at five marinas and many private docks scattered along the shoreline.

SOURCES OF WASTES

Public Sewerage Facilities

The portion of the Back River drainage area located within Baltimore City is essentially completely sewered, as is the portion in Baltimore County to the north of the City. Public sewerage facilities in the areas immediately surrounding the estuary are scattered but serve the important areas of Essex and Middle River to the northeast of Back River, Edgemere to the southwest, and parts of Rosedale and Colgate to the northwest. A portion of the Fullerton area to the northwest is also sewered. All sewage from these areas flows to Baltimore City's Back River Sewage Treatment Plant, by gravity from the extreme northern and western portions of the drainage area and by means of pumps from other areas. Sewered areas, areas where sewers are under construction or design, and pumping stations are shown in Figure 1, with pumping stations listed in Appendix I. The estimated population of the sewered area in the basin was about 105,700 in Baltimore County and 175,400 in Baltimore City at the time of the 1960 census.

Baltimore City's Back River Sewage Treatment Plant is located 7.0 miles upstream from the mouth of the River and serves an estimated 1.17 million persons plus several hundred commercial and industrial establishments. A large portion of the effluent from the secondary units of the plant is utilized by Bethlehem Steel Company's Sparrows Point Plant, while the remainder is discharged to Back River.[1/]

Ultimate disposal of the effluent used by Bethlehem Steel Company is to Bear Creek of the Patapsco River Basin, thus removing this waste from Back River. The trend of effluent use by the Sparrows Point Plant has been to utilize greater quantities, as shown in the following Table.

Year	Total Effluent (MGD)	Effluent Sold to Bethlehem Steel Co.	Effluent to Back River (MGD)
1948	104	32	72
1953	109	53	56
1958	131	85	46
1962	170	110	60
1963	153	113	40

It is anticipated that the Bethlehem Steel Company Plant will continue to use greater quantities of the sewage treatment plant effluent, which may result in decreased discharges to Back River.

The five-day biochemical oxygen demand of the effluent averages about 20 parts per million, with a total suspended solids content of 20 parts per million.[7] Also, the sewage effluent still contains nutrients which could stimulate the growth of algae. Effluent discharged to the river is chlorinated during the recreation season, April through September, to reduce bacterial counts.

Programmed improvements in the Back River Sewage Treatment Plant over the past several years have resulted in improved effluent quality. The plant is presently operating within its capacity of 170 million gallons per day. Planned future development of the treatment facilities will handle the increased load from Baltimore County. The County will share the costs of these developments.

Individual Sewage Disposal Systems

The shores of Back River are lined with private residences, many of which were apparently designed as weekend and summer cottages; however, almost all are inhabited year-round at present. Most of these residences are not served by public sewerage; they utilize septic tanks with seepage pits or drain fields, even though the soil in the area is generally unsuitable for absorption. While these sewage disposal facilities may have been adequate for short-term usage each year, the continuous loading from year-round occupancy has resulted in sewage being discharged to the river by way of ditches, gullies, and storm drains. In addition, waste waters from many residences and several commercial establishments more distant from the river also reach tributaries of Back River after discharge from inadequate septic tank systems.

The number of households with private sewage disposal facilities was about 4,900 at the time of the 1960 census. When in session, the Back River Elementary School discharges about 12,000 gallons per day to a ditch leading to the River from a septic tank and inadequate seepage pit. Also, four large trailer parks discharge sewage to tributary streams, three from septic tanks and inadequate sub-surface disposal, one from a septic tank and sand filter followed by chlorination.

To illustrate difficulties in providing sewage facilities, a major factor is: all sewage projects in Baltimore County must be

self-supporting. The costs for sewerage are apportioned to land owners on a basis of front-footage. Any deficit may be paid over a period of 10 years with interest. Plumbers' fees for sewer connections may also be financed for the owner by the County over a period of 10 years with interest. Within a metropolitan district or a danger-to-health area, designated by a County committee made up of the Chief Sanitary Engineer, The Director of Finance, and the Director of the Section of Environmental Health, all costs may be financed over a period of 40 years with interest. According to preliminary studies by the Baltimore County Department of Public Works, the cost of sewerage to average home owners in now unsewered areas along the shores of Back River may be considerable. Because of present low population densities, the cost of providing sewerage for households in the unsewered areas would probably be prohibitive, unless new methods of financing are developed.

Marinas and Marine Craft

Many of the 837 craft (7½ or more horsepower) registered as having home ports in the Back River area are equipped with flush toilets. Section 402 of the Maryland State Board of Health and Mental Hygiene Regulations (Appendix II) prohibits discharge of domestic sewage into any watercourse in such a manner to cause pollution or create nuisance. Control of waste discharges from craft docked at marinas is achieved through marine-clientele contracts which prohibit waste discharges at the facility. However, waste discharges

from craft cruising in the River or docked at private docks are presently uncontrolled. Marina locations are indicated on Figure 1.

Industrial Waste-Water

The Eastern Stainless Steel Company discharges an average of about 700,000 gallons per day (1.4 million gallons per day maximum) of waste water to Bacon Creek just above its confluence with Back River, 8.5 miles upstream from the mouth. The plant's sanitary sewage and acid process waters are neutralized with lime (automatically fed) in a baffled lagoon with an average retention time of 4.5 hours. The lagoon allows time for neutralization and for settling of iron oxide and other sediment. Cooling water is also discharged to this lagoon and oil is removed by means of an Earle Surface-Separator System. The Maryland Water Pollution Control Commission frequently inspects this operation and has observed effluent pH values as low as 2.8 for short periods of time, generally attributable to equipment failure. It is significant to note that no appreciable effect has been noted on Back River water quality after the pH dropped below the Commission's established limits of 5.5-8.5, even in proximity to the discharge.

Armco Steel Company discharges its sanitary waste to Baltimore City sanitary sewers, with its waste process and cooling water being discharged through City storm sewers to Herring Run, 3.8 miles above the head of the estuary. The rate of waste-water discharge is not metered; however, average water intake to the plant is about 1.5

million gallons per day (3.0 million gallons per day maximum), and the waste-water discharge would probably be in the same range. The acid waste is neutralized, then diluted with cooling water from which waste oil has been skimmed manually and mill scale settled in two settling ponds.

Other industries, which use smaller quantities of water, are located on tributary streams. In addition to the industries which normally discharge waste-water directly to the basin, the many other establishments located on tributaries may influence water quality as a result of spills and other accidents. All sizable industries discharging waste water directly to the Back River Basin are listed in Appendix III.

EFFECTS OF WASTES ON WATER QUALITY AND WATER USE

Studies by Baltimore County Department of Health

Based upon field observations and occasional bacteriological examinations, the Baltimore County Department of Health has considered Back River north of Eastern Airport to be polluted and unsafe for swimming for about the past 20 years. On July 19, 1963, the Section of Environmental Health of that Department surveyed the bacteriological quality of the Back River estuary at 16 key stations. At each station bacteriological samples were taken above, opposite, and below potential sources of pollution, and one pH analysis was made, except for samples taken at the Back River Sewage Treatment Plant outfall where twice as many samples were taken. The results of the survey, presented in Appendix IV, indicate a "high degree of bacteriological pollution" in the River except for the areas below Evergreen Park and Edgemere. Areas below Evergreen Park and Edgemere also had low bacterial counts in a survey on June 25, 1963.

At each station, the most probable number of coliform bacteria in at least one sample exceeded the Maryland State Department of Health Standards governing water quality for bathing beaches. (Appendix V). The survey report states that the high bacterial counts were caused by "Literally hundreds of over-flowing or malfunctioning septic tanks systems situated primarily along the beach and shore fronts" by "over-flowing septic tanks from inland sources," and by marine craft. This report contains a conclusion that the "only means

by which this situation can be solved is the extension of sewers." The survey also indicated that bacterial counts in the vicinity of the Back River Sewage Treatment Plant outfall were relatively low, as compared with other areas in the river (except for the lower reaches).

Studies by the Baltimore City Department of Public Works

The Baltimore City Department of Public Works has sampled the waters of Back River and the adjacent waters of Chesapeake Bay at 14 stations several times a year for the past several years. Analytical results from the most recent samples taken at seven mid-stream stations are presented in Appendix VI. The results from the most recent sampling of five shoreline stations in the vicinity of the outfall and of the effluent, before and after chlorination, are presented in Appendix VII. The bacteriological analyses at all 14 stations obtained during the past two years are presented in Appendix VIII. The surveys showed the bacterial counts (coliform) to be generally high both at mid-stream and at the shorelines upstream of Muddy Gut, while at Muddy Gut and downstream the counts at mid-stream were generally low. The bacterial counts of the Back River at the sewage treatment plant outfall were generally low, reflecting the effects of chlorination. Shoreline samples usually had higher bacterial counts than mid-stream samples; however, during a few of the surveys, conditions were reversed. The bacterial data are very difficult to interpret because of a lack of knowledge about water

movement in the estuary. The five-day biochemical oxygen demand (20°C.) at the outfall averages about 20 parts per million and decreases to about two parts per million near the Chesapeake Bay. The dissolved oxygen concentrations were high, probably due in part to photosynthesis by algae; however, sampling has not been conducted at night to investigate the possibility of diurnal fluctuations.

For some years the Department has also sampled the various streams as they enter and leave the City. At times increases in biochemical oxygen demand and suspended solids have occurred in Moores Run and Herring Run between entry to and exit from the City, with corresponding decreases in dissolved oxygen; however, the concentrations are not generally severe. The results of the two most recent samplings are presented in Appendix IX.

Studies by the Maryland Water Pollution Control Commission

The Maryland Water Pollution Control Commission has sampled the Back River and Bacon Creek in the vicinity of the Eastern Stainless Steel Company periodically. No adverse conditions caused by industrial waste water have been detected in the past few years. Occasional samples have been taken at various points in the basin in past years in reference to specific complaints, principally concerning oil pollution. A listing of the various pollution conditions observed and investigated by the Commission are reproduced in Appendix X.

Studies by Eastern Stainless Steel Company

The Eastern Stainless Steel Company secured the services of Strassburger & Siegel, Inc., Analytical and Consulting Chemists, to assist in a survey of pH and bacterial counts in Bacon Creek and Back River in the vicinity of their plant. The survey was carried out on November 5, 1963, and the most probable numbers of coliform bacteria per 100 milliliters observed in the waste effluent were 2,800 and 3,500 in two samples. After flowing perhaps 25 yards through a ditch, the number dropped to 210; in Bacon Creek the number was 130; and several yards downstream on Bacon Creek, the number was 79. Counts in Bacon Creek upstream of the plant outfall were high, as were the counts in Back River just upstream of Bacon Creek. These data are summarized in Appendix XI.

REGULATORY AND CO-OPERATING AGENCIES IN WATER QUALITY CONTROL

Cooperation at all levels of government is a matter of necessity in developing optimum water quality control programs for the Back River Basin. This need for cooperation has been recognized, and, over a period of time, legislative actions and administrative agreements have defined the following responsibilities in these programs.

State Board of Health and Mental Hygiene

The State Board of Health exercises primary responsibility with respect to water pollution resulting from untreated or inadequately treated sewage. The Board has jurisdiction over the construction and operation of public sewerage systems, plus private sewage disposal systems and sanitary wastes from industries, which discharge to watercourses or tidewater.

Water Pollution Control Commission

The Commission studies, investigates, and recommends means of preventing pollution of State waters. The Commission exercises primary responsibility with respect to water pollution resulting from discharge of industrial waste, and has established certain standards for industrial waste water discharges and the receiving waters. The above standards are reproduced in Appendix XII.

Baltimore County Board of Health

The County Board of Health has jurisdiction over private sewage disposal systems which do not by design discharge to streams. Since the County Health Officer is also a Deputy State Health Officer, at times the County Board may assist the State Board of Health in its functions, such as the sampling of public water supplies and public or industrial sanitary sewage discharges.

Baltimore County Department of Public Works

This Department is active in the planning, design, inspection, and maintenance of public sewerage as a part of its broad program in public works. The County Department of Public Works cooperates with the State and Federal Government in the inspection and approval of those major interceptor projects which are jointly financed with Federal and State grants for sewage works construction.

Baltimore City Department of Health

Within Baltimore City, the City Department of Health supervises soil percolation tests in the few instances where sanitary sewers do not exist, chiefly for industrial and commercial property. Based on the results of the data, recommendations on the type and size of individual disposal systems are submitted to the Bureau of Building Inspectors and are used as a basis for approval.

Baltimore City Department of Public Works

This Department is responsible for public sewerage in the City and operates the City's Back River Sewage treatment plant, as discussed previously. The plant serves all of the sewered areas in the Back River Basin in addition to areas in metropolitan Baltimore.

Maryland State Planning Department

In addition to its normal responsibility in coordinating long-range planning programs which affect the State, the Planning Department is sponsoring the Maryland Water Supply and Requirements Study. Through cooperation with several Federal and State agencies, the staff and several consultants are preparing a complete inventory of water resources and water uses, and are making projections of future needs.

Chesapeake Bay Institute, The Johns Hopkins University

The Institute at Johns Hopkins University studies the chemical, physical, and biological characteristics of the Chesapeake Bay and its estuaries. As a part of its over-all program, salinity, tides, and other factors have been studied in Back River. The rates of exchange for several tributary estuaries of the upper Bay are being determined under a contract with the State Department of Health. To date, the Severn, Magothy, Gunpowder and Susquehanna Rivers, as well as the Baltimore Harbor system, have been examined with tracer releases.

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APPENDIX I

Sewage Pumping Stations in the Back River Basin

Name of Pumping Station	Location of Pumping Station	Stream Receiving Overflow	Capacity (gallons per min.)	Number of Dwellings Served
I. Baltimore City				
Panitz #1	Bowley's Lane	Moores Run	1800	600
Panitz #2	Radecke Avenue	Moores Run	1450	1800
Frankford Gardens	Force Road	Moores Run	2000	1000
Dobson	Seward Avenue	Moores Run	66	74
Welsh	Denview Way	Moores Run	1800	2500
II. Baltimore County				
East Point	Oak Avenue	Bacon Creek		
Essex	Riverside Drive	Back River		
S. Marylyn Avenue	S. Marylyn Avenue	Back River		
Duck Cove	Riverside Drive	Duck Creek		
N. Point Drive	N. Point Blvd.	Bread and Cheese Creek		
Rosedale	Philadelphia Rd.	Moores Run		
Stemmers Run	Mace Avenue	Stemmers Run		
Edgemere	Lynch Point	Back River		

APPENDIX II

Maryland State Board of Health and Mental Hygiene Regulations on Discharge of Domestic Sewage in a Watercourse, Section 4.02

By authority conferred by Section 2 of Article 43 of the Annotated Code of Maryland ..."All domestic sewage shall be disposed of by an approved method of collection, treatment and effluent discharge. Domestic sewage or sewage effluent shall not be disposed of in any manner that will cause pollution of the ground surface, ground water, bathing area, lake, pond, watercourse, or tidewater, or create a nuisance. It shall not be discharged into any abandoned or unused well, or into any crevice, sink hole, or other opening either natural or artificial in a rock formation. Specific approval may be obtained from the approving authority, under unusual conditions, to discharge sand filter chlorinated effluent into a watercourse."

APPENDIX III

Industries Discharging Waste Water Directly to the Back River Basin

Name of Industry	Waste-Water Discharge (million gallons per day)	Receiving Stream	Miles Above Mouth of Stream Listed	Miles Above Mouth of Back River
Friez Instrument Div., Bendix Corp.	Unknown	Herring Run	9.9	19.1
American Totalisator Company, Division of Universal Controls, Inc.		Herring Run	9.9	19.1
Continental Can Co., Plant #16		Trib. of Herring Run	1.1	13.2
Continental Can Co., Plant #79		Trib. of Herring Run	1.0	13.1
Armco Steel Co.	Unknown	Trib. of Herring Run	0.9	13.0
Trailmobile, Inc.		Moores Run	0.5	10.7
Kennedy Mfg. Co.		Redhouse Creek	0.8	10.1
Champion Brick Co.		Redhouse Creek	0.4	9.7
Perfection Laundry		Stemmers Run	1.0	10.3
Eastern Stainless Steel Co.	0.70	Bacon Creek	0.1	8.5
Essex Hy-Grade Laundry I		Trib. of Deep Creek	1.5	8.0

APPENDIX IV

Bacteriological and pH Study of Back River by the Baltimore County Department of Health, July 19, 1963

SAMPLING STATION	COLIFORM CONTENT	ESCHERICHA COLI	pH
Denbows	4,600	3.6	8 plus
	930	21	
	24,000	23	
Easton Boat Yard	11,000	9.1	8 plus
	2,400	9.1	
	930	15	
Lynhurst	230	43	8
	4,600	430	
	24,000 plus	930	
Bletzer Road	24,000 plus	2,400	8
	24,000 plus	11,000	
	4,600	930	
Sewage Plant At Outfall	4,600	150	8 plus
	390	230	
	4,600	390	
Sewage Plant At Outfall	930	430	8 plus
	1,500	230	
	430	43	
North of Eastern Stainless Steel	24,000 plus	24,000 plus	7
	24,000 plus	24,000 plus	
	24,000 plus	24,000 plus	
Near Balto. County Pumping Station	4,600	430	8 plus
	24,000	430	
	11,000	150	
Ken's Marina	4,600	930	8 plus
	24,000	2,400	
	4,600	930	
Cox Point Near Marylyn Avenue	11,000	11,000	8 plus
	11,000	930	
	4,600	930	

APPENDIX IV (Cont'd)

Cox Point	11,000	430	7 plus
	11,000	430	
	11,000	430	
Hyde Park	24,000	4,600	8 plus
	4,600	930	
	2,400	930	
Eastern Airport	4,600	2,400	8 plus
	4,600	4,600	
	2,400	2,400	
Evergreen Park	2,400	93	8 plus
	430	23	
	230	93	
Wildwood	230	43	8
	930	9.1	
	93	23	
Cedar Point	230	43	8 plus
	930	230	
	930	230	

APPENDIX V

Regulations Governing Public Swimming Pools and Bathing Beaches, State Board of Health of Maryland, Regulation 7, Sanitary Quality of Water, etc. (part)

Under authority conferred by Section 2 of Article 43 of the Annotated Code of Maryland . . .

The bacterial quality of water of natural bathing beaches is acceptable when the water shows an average "most probable number" (MPN) of coliform bacteria not in excess of 1,000 per 100 milliliters in any one month during the bathing season, provided a sanitary survey discloses no immediate danger from harmful pollution. The presence of such pollution shall be determined from the findings of sanitary surveys made by the State Board of Health.

The right is reserved to close any swimming pool or bathing beach because of continued failure to meet the above standards.

APPENDIX VI

Analyses of Back River and Chesapeake Bay Waters
Baltimore City Department of Public Works, August 22, 1963

Station Number	Location	Coliform Bacteria (MPN/100 ml)	B.O.D. 5-day, 20°C. (p.p.m.)	Dissolved Oxygen (p.p.m.)	Chlorides (p.p.m.)	pH
1	Island Point	23,000	7	9.7	450	7.24
1A	At Discharge	7.2	20	5.7	730	7.10
1B	Deep Creek	23,000	9	13.3	1270	8.83
2	Muddy Gut	930	4	14.9	1940	9.19
3	Porter's Bar	43	5	13.9	2460	9.11
4	Clay Bank	23	4	9.8	3540	8.37
5	Rocky Point	-3	4	9.7	3660	7.64
6	Brown's Thorofare	3	2	8.8	3370	7.53
7	Miller's Island	3.6	4	8.8	3450	7.23

(All samples were taken at high tide)

APPENDIX VII

Analyses of Shoreline Waters of Back River in the Vicinity of Back River Sewage Treatment Plant, Baltimore City Department of Public Works, September 18, 1963

Station Number	Location	Coliform Bacteria (MPN/100 ml)	B.O.D. 5-day 20°C. (P.P.M.)	Dissolved Oxygen (P.P.M.)	Turbidity (P.P.M.)	pH
1	Island Point Shoreline	43,000	12	13.0	230	8.66
2	South of West End of Bridge	23,000	4	11.2	185	8.81
4	South of East End of Bridge	93,000	5	9.6	220	8.47
5	East Shore - 1 mile South of Bridge	2,300	3	9.9	200	8.89
7	East Shore - North of Deep Creek	2,300	4	11.7	205	8.89
Effluent	Spillway (before chlorination)	9,300,000	29	2.7	---	---
Effluent	Terminal Chamber (after chlorination)*	24,000	43	8.9	---	---

* Some additional contact time exists after this point for chlorine reaction.

APPENDIX VIII

Bacteriological Analyses of Back River, Chesapeake Bay, and Back River Sewage Treatment Plant Effluent, Baltimore City Department of Public Works

Designation for this Report	Station Number	Location	Coliform Bacteria (MPN/100 ml)	
			May 7, 1962 May 14, 1962 May 21, 1962	May 28, 1962 June 4, 1962 June 7, 1963
a	2	South of West End of Bridge	15,000 23,000 1,500	93,000 9,300 --
b	4	South of East End of Bridge	9,300 9,300 150,000	4,300 23,000 --
c	1	Island Point (Mid-stream)	-- -- --	-- -- 430
d	1	Island Point Shoreline	24,000 150,000 93,000	4,300 2,300 --
e	5	East Shore - 1 mile South of Bridge	1,500 43,000 43,000	23,000 23,000 --
f	Effluent	Spillway	4,300,000 430,000 9,300,000	2,300,000 930,000 --
g	Effluent	Terminal Chamber	430,000 930,000 93	43 4,300 --
h	Effluent	Terminal Chamber	2,300,000 4,300,000 4,300	93,000 93,000 --
i	1A	Back River at Effluent Discharge	-- -- --	-- -- 230
j	7	East Shore North of Deep Creek	43,000 7,500 43,000	23,000 43,000 --

APPENDIX VIII (Con't.)

Designation for this Report	Coliform Bacteria (MPN/100 ml)			
	June 11, 1962 June 18, 1962 June 25, 1962	July 2, 1962 July 9, 1962 July 16, 1962	July 23, 1962 July 30, 1962 Aug. 6, 1962	Aug.13, 1962 Aug.16, 1962 Aug.21, 1962
a	2,300 430 23,000	2,300 230 430	2,300 230 4,300	2,300 -- 430
b	23,000 9,300 43,000	9,300 930 23,000	4,300 4,300 2,300	2,300 -- 430
c	-- -- --	-- -- --	-- -- --	-- 430 --
d	2,300 4,300 23,000	4,300 430 4,300	2,300 230 23,000	2,300 -- 360
e	2,300 430 930	930 430 4,300	230 4,300 430	2,300 -- 230
f	2,300,000 2,300,000 430,000	230,000 2,300,000 4,300,000	4,300,000 2,300,000 2,300,000	430,000 -- 2,300,000
g	930 43 23,000	23 23 0	43 23 2,300	9,300 -- 0
h	4,300 4,300 230,000	430 920 930	4,300 9,300 4,300	230 -- 430
i	-- -- --	-- -- --	-- -- --	-- -- --
j	2,300 9,300 23,000	4,000 230 23,000	430 9,300 4,300	4,300 -- 4,300

APPENDIX VIII (Con't.)

Designation for this Report	Coliform Bacteria (MPN/100 ml)			
	Aug. 27, 1962	Sept. 18, 1962	May 27,1963	June 24, 1963
	Sept. 4, 1962	Sept. 21, 1962	June 17,1963	July 1, 1963
	Sept.10, 1962	May 20, 1963	June 20,1963	July 8, 1963
a	62	23,000	230	930
	24,000	—	430	46,000
	230	93	—	4,300
b	430	93,000	430	230
	430	—	430	2,300
	430	93	—	9,300
c	—	—	—	—
	9,300	4,300	—	—
	—	—	430	—
d	2,300	43,000	2,300	9,300
	9,300	—	930	430
	4,300	43	—	46,000
e	230	2,300	430	930
	930	—	430	4,300
	2,300	43	—	24,000
f	23,000,000	9,300,000	2,300,000	2,300,000
	23,000,000	—	2,300,000	9,300,000
	24,000,000	11,000,000	—	9,300,000
g	430	24,000	120	30
	93	—	110,000	23
	430	2,400	—	23
h	2,300	—	930	930
	430	—	110,000	4,300
	—	11,000	—	750
i	—	—	—	—
	—	4,300	—	—
	—	—	230	—
j	2,300	2,300	930	15,000
	930	—	2,300	2,300
	4,300	150	—	24,000

APPENDIX VIII (Con't.)

Designation for this Report	Coliform Bacteria (MPN/100 ml)			
	July 15, 1963 July 18, 1963 July 22, 1963	July 29, 1963 Aug. 5, 1963 Aug. 12, 1963	Aug. 19, 1963 Aug. 22, 1963 Sept. 3, 1963	Sept. 9, 1963 Sept. 16, 1963
a	110,000 --- 150	230 9,300 2,300	930 --- 930	3,900 24,000
b	110,000 --- 4,300	4,300 24,000 930	2,300 --- 4,300	430 110,000
c	--- 2,000 ---	--- --- ---	--- 23,000 ---	--- ---
d	24,000 --- 4,300	4,300 24,000 4,300	930 --- ---	--- ---
e	430 --- 2,300	2,300 2,300 930	750 --- ---	930 46,000
f	1,500,000 --- 1,500,000	9,300,000 24,000,000 24,000,000	24,000,000 --- ---	24,000,000 110,000,000
g	230 --- 23	-3 430 -3	3.6 --- ---	9,300 23
h	46,000 --- 4,300	230 15,000 150	--- 9,300 ---	4,300 230
i	--- 110,000 ---	--- --- ---	--- --- 7.2	--- ---
j	4,300 --- 24,000	9,300 43,000 430	4,300 --- 2,300	930 24,000

APPENDIX VIII (Con't.)

Designation for this Report	Station Number	Location	Coliform Bacteria (MPN/100 ml)	
			June 7, 1963 Aug. 16, 1963 Sept.21, 1963	June 20, 1963 July 18, 1963 Aug. 22, 1963
k	1B	At Deep Ck. (Mid-stream of Back River)	230 2,300 4,300	4,300 110,000 23,000
l	2	Muddy Gut (Mid-stream of Back River)	230 15 230	230 230 950
m	3	Porter's Bar (Mid-stream of Back River)	43 23 230	23 43 43
n	4	Clay Bank (Mid-stream of Back River)	43 150 43	230 23 23
o	5	Rocky Point (Mid-stream of Back River)	93 23 93	2,100 930 -3
p	6	Brown's Thorofare (Mid-stream of Back River)	23 3.6 43	430 430 3
q	7	Miller's Island Chesapeake Bay	23 20 --	43 93 3.6

APPENDIX IX

Stream Sampling Results by Baltimore City Department of Public Works for Herring Run and Moores Run

Stream	Sampling Station Location	5-Day B.O.D. (p.p.m.)	Dissolved Oxygen (p.p.m.)	Suspended Solids (p.p.m.)	pH	Water Temp. (°F.)
			July 25, 1963			
Moores Run	Entry to City	8	8.3	10	7.44	79
Moores Run	Exit from City	16	5.5	19	7.44	75
W. Br. Herring Run	Entry to City	10	10.7	11	7.90	79
E. Br. Herring Run	Entry to City	12	10.8	14	7.88	79
*Chinquapin Run	Entry to City	10	9.6	11	8.21	72
Herring Run	Exit from City	20	7.0	23	7.16	79
			October 10, 1963			
Moores Run	Entry to City	4	7.1	6	7.26	66
Moores Run	Exit from City	21	1.8	14	6.78	68
W. Br. Herring Run	Entry to City	5	10.9	7	7.62	61
E. Br. Herring Run	Entry to City	6	13.2	8	7.79	57
*Chinquapin Run	Entry to City	3	10.7	4	7.28	54
Herring	Exit from City	17	4.7	13	6.98	61

* Tributary of Herring Run

APPENDIX X

OBSERVATIONS OF WATER POLLUTION CONDITIONS IN THE BACK RIVER DRAINAGE BASIN.*

(Report by the Maryland Water Pollution Control Commission)

These may be listed and described briefly as follows:

(1) Oil

(2) Petroleum Products Other Than Oil

(3) Trash and Debris

(4) Fish Mortalities

(5) Algal Blooms

(6) Pollen Grain Slicks

1. Oil: This pollutant, not infrequently involving heavy black fuel oil, has been observed and traced to a variety of sources. Oil pollution in the Back River Drainage Basin has resulted from spillages during delivery of clean fuel oil, accidental rupturing of pipelines, the flushing down of roadways by fire department personnel following vehicular accidents, improper disposal of waste oil by scavengers, losses from gasoline service stations, leakages from waste oil disposal areas, and losses and spills from industrial operation. Generally, it has been possible--through stern action and continued surveillance--to control oil pollution resulting from fixed sources. There is no way,

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* Since the Maryland Water Pollution Control Commission has jurisdiction only over other-than-health aspects of pollution, and therefore deals in the main with industrial wastes, this description does not include references to water pollution involving sanitary sewage effect on swimming, the public health, or the sanitary quality of the water.

of course, of guaranteeing that oil pollution can be controlled when caused by transient sources entering the storm water drainage system of the Back River Drainage Area.

2. Petroleum Products Other Than Oil: There have been several instances where gasoline and kerosene have spilled into tributaries of Back River. Except where such pollution results from transient sources, the operations responsible can be--and have been--controlled.

3. Trash and Debris: These contaminating materials are derived from two principal sources: Deposits into streams and storm drains throughout the entire drainage basin, and improper operation of dumps and refuse disposal areas. Removal of the objectionable matter and adequate control procedures are required by the Commission wherever the source of the problem can be identified.

4. Fish Mortalities: Years ago, complaints about fish mortalities and observation of fish mortalities were not uncommon during the summer months. These occurrences were attributed to a combination of elevated temperatures and the depletion of dissolved oxygen caused by heavy algal blooms and the consequent diurnal oxygen-carbon dioxide fluctuations. More recently, since the majority of treated sewage from the Back River Sewage Treatment Plant has been transported outside the Back River estuary, the oxygen-carbon dioxide stresses have not occurred, and there have not been any significant fish mortalities in these waters.

5. Algal Blooms: These are natural conditions, growths of aquatic life, which occur in Back River and in other waters of the State depending upon ambient temperatures and the concentration of nutrients in the water. There is no evidence that algal blooms in Maryland are toxic per se, though it is possible that heavy blooms can produce oxygen-carbon dioxide stresses which may kill fish.

6. Pollen Grain Slicks: Periodically, in the Back River estuary, as in other waters of the State, observations are made of (and complaints received on) slicks or scums of fine, yellow matter often referred to by the public as "sulfur on the water." Under microscopic examination, the accumulation and concentration of yellow matter has been identified as pollen grains. Although these slicks are unsightly, they are entirely natural in origin and not harmful.

APPENDIX XI

Survey of Bacon Creek by Eastern Stainless Steel Company, November 5, 1963

Sampling Station Number	Sampling Station Location	Coliform Bacteria (MPN/100 ml)	E Coli (MPN/100 ml)	Standard Plate Count	pH
1	Plant Effluent	2,800	2,800	42	5.0
1	Plant Effluent	3,500	3,500	135	5.0
2	Effluent Ditch	210	31	1,400	4.8
3	Middle, Bacon Creek opp. plant effluent	130	13	650	5.8
4	E. Bank, Bacon Creek opp. plant effluent	70	70	500	4.5
5	Bacon Creek, 25 yds. upstream of effluent	110	110	4,000	8.0
6	Bacon Creek, 40 yds. upstream of effluent	1,100	700	2,000	7.6
7	Bacon Creek, 65 yds. upstream of effluent	240	240	2,600	7.7
8	Bacon Creek, near headwaters	2,400	2,400	3,200	7.5
9	Bacon Creek, 25 yds. downstream from effluent	79	17	2,000	6.3
10	Bacon Creek at Back River	170	49	1,300	6.8
11	Back River, 75 yds. upstream of Bacon Creek	9,200	1,400	4,500	4.8

Bacon Creek flows north to Back River and is influenced by tides in its lower reaches.

APPENDIX XII

Regulations IV, Treatment and Disposal of Industrial Wastes, of the Maryland Water Pollution Control Commission

No industrial wastes shall be placed or permitted to be placed or discharged or permitted to flow into any of the waters of the State in any manner by any person unless the industrial wastes after treatment or untreated shall meet with the nine industrial waste requirements established by the Water Pollution Control Commission before being discharged into any waters of the State. These nine industrial waste requirements are as follows:

1. Solids:

   A. Solids in the effluent -- Must not exceed particle size that can pass Tyler designation 20 mesh screen. Grinding, maceration or any other waste treatment or handling operation intended to reduce the size of oversize solids in the effluent to pass Tyler designation 20 mesh screen, will not be permitted or approved.
   B. Total suspended solids -- Must not exceed 400 ppm.
   C. Dissolved solids -- Must not exceed 1500 ppm.
   D. Total solids -- Must not exceed 1900 ppm.

2. Turbidity -- Must transmit 10% of light through 12 inches of sample in a 3 inch column or not to exceed 300 ppm., as determined by the Jackson candle turbidimeter.

3. Biochemical Oxygen Demand:

   A. The Biochemical Oxygen Demand -- The 5-day, 20°C. Biochemical Oxygen Demand in the effluent must not exceed 100 ppm.
   B. The Dissolved Oxygen in the waste receiving waters must not be depleted beyond 50% of normal saturation.

4. Toxicity or Toxic compounds -- Eliminate, or reduce to limits of tolerance, substances toxic to humans, livestock, fish, aquatic and wildlife.

APPENDIX XII (Con't.)

5. Color — Color intensity regardless of light frequency must not exceed 400 ppm. on the chloroplatinate scale.

6. pH — Must not range below 5.5 or above 8.5.

7. Temperature — Must be below 100°F. in the stream within 50 feet from waste outlet.

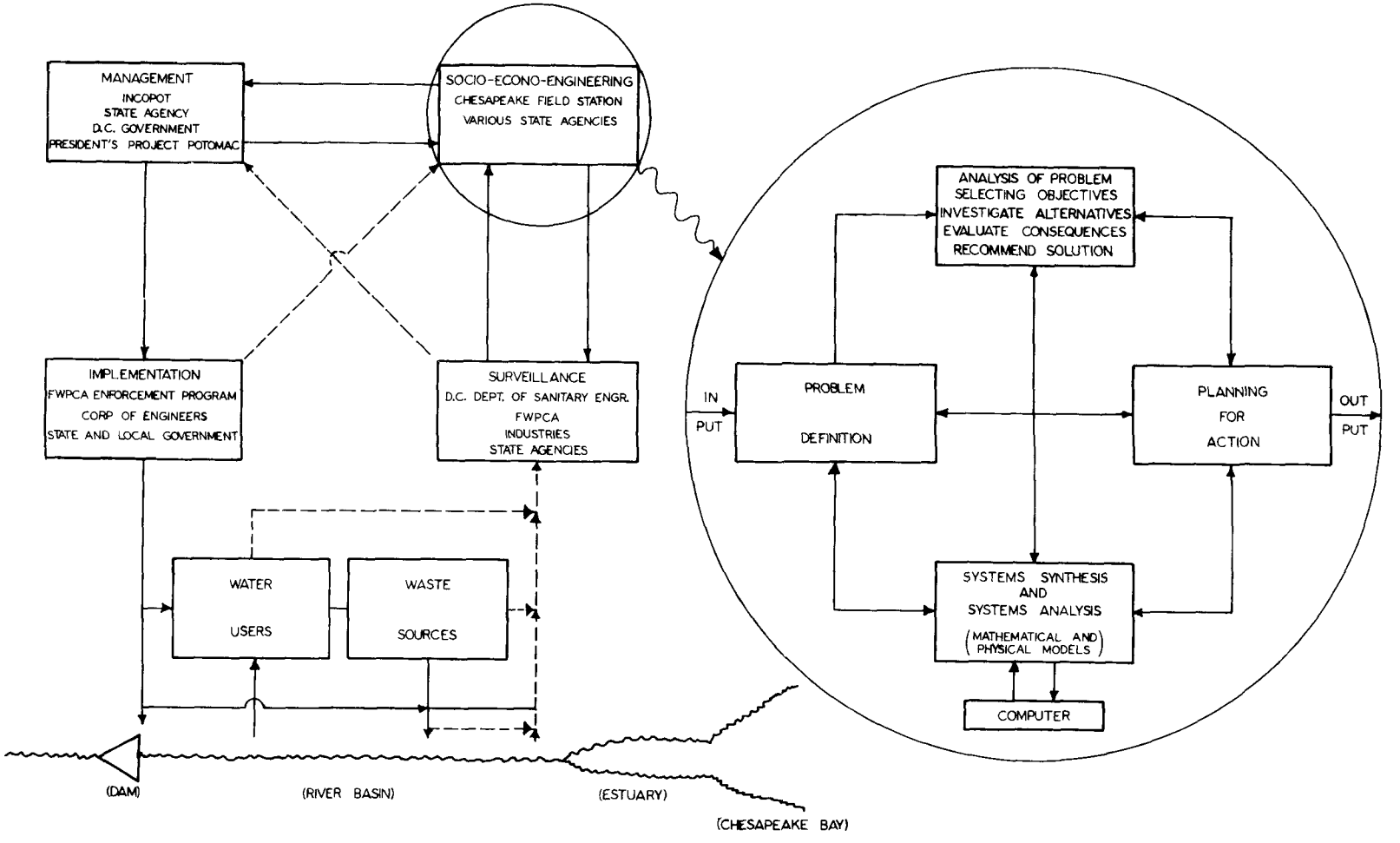
8. Oils and grease in the effluent — Must not exceed 30 ppm.

9. Taste and odor — Effluent must not exceed threshold odor number of 1000. Mixture of the waste and receiving waters shall have a threshold odor number not in excess of 80.

All analyses to be conducted in accordance with the American Public Health Association Standard Methods.

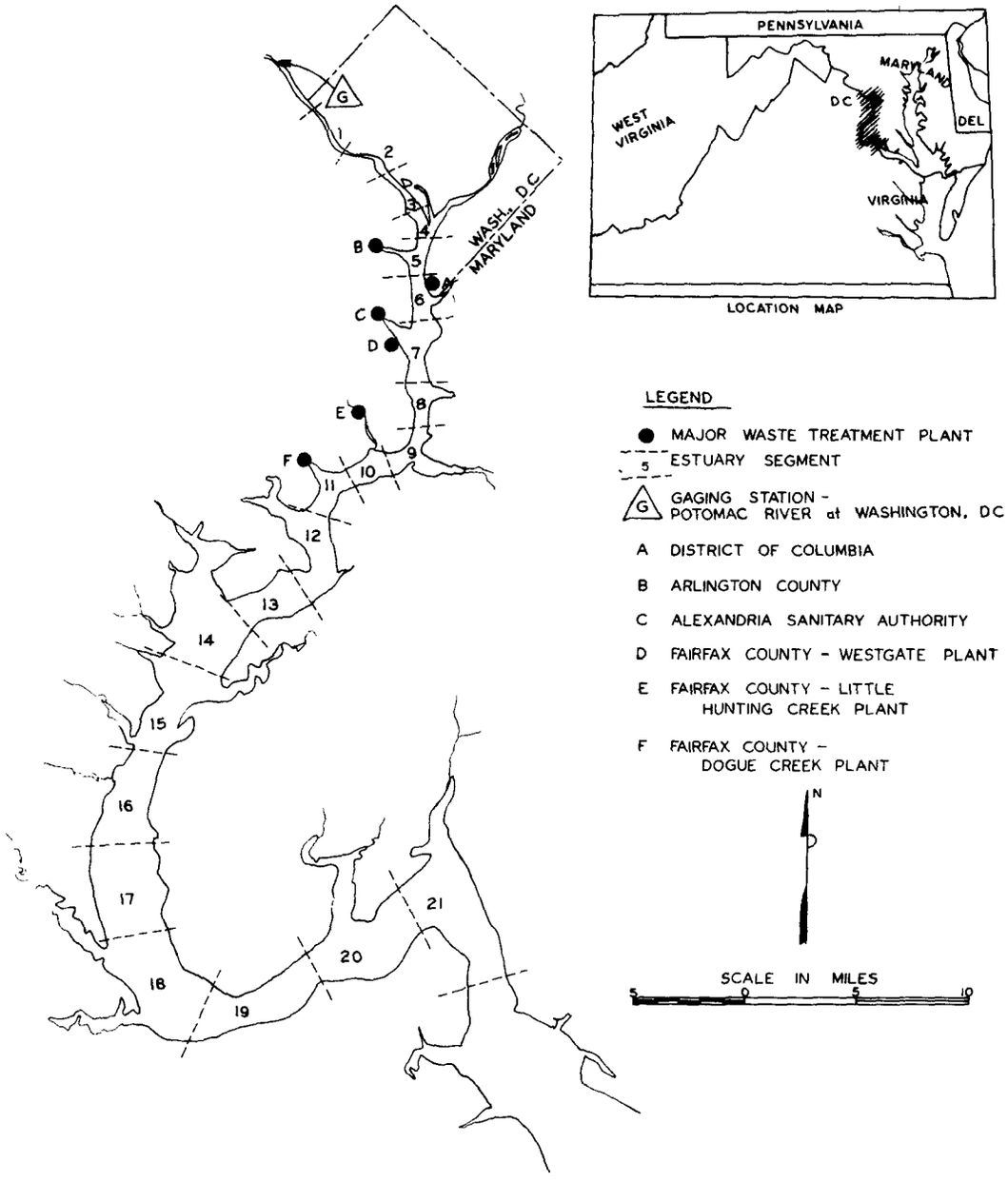
These nine industrial waste requirements are generally applicable values, but are not absolutely fixed values. They can be made more stringent if a survey of the waste receiving waters indicates they are still polluted or are continuing to be degraded, or in any instance where the Water Pollution Control Commission, after due study and deliberation, deems that more stringent requirements are necessary. They can be made more liberal only by formal action of the Commission on the basis of satisfactory evidence and proof that waste receiving waters are sufficient in quantity and quality to not be affected adversely by a particular industrial waste effluent having values in excess of those stated above.

Any industrial wastes, after treatment or untreated, which do not meet with the above requirements shall be deemed and considered in violation of this Regulation based on the Water Pollution Control



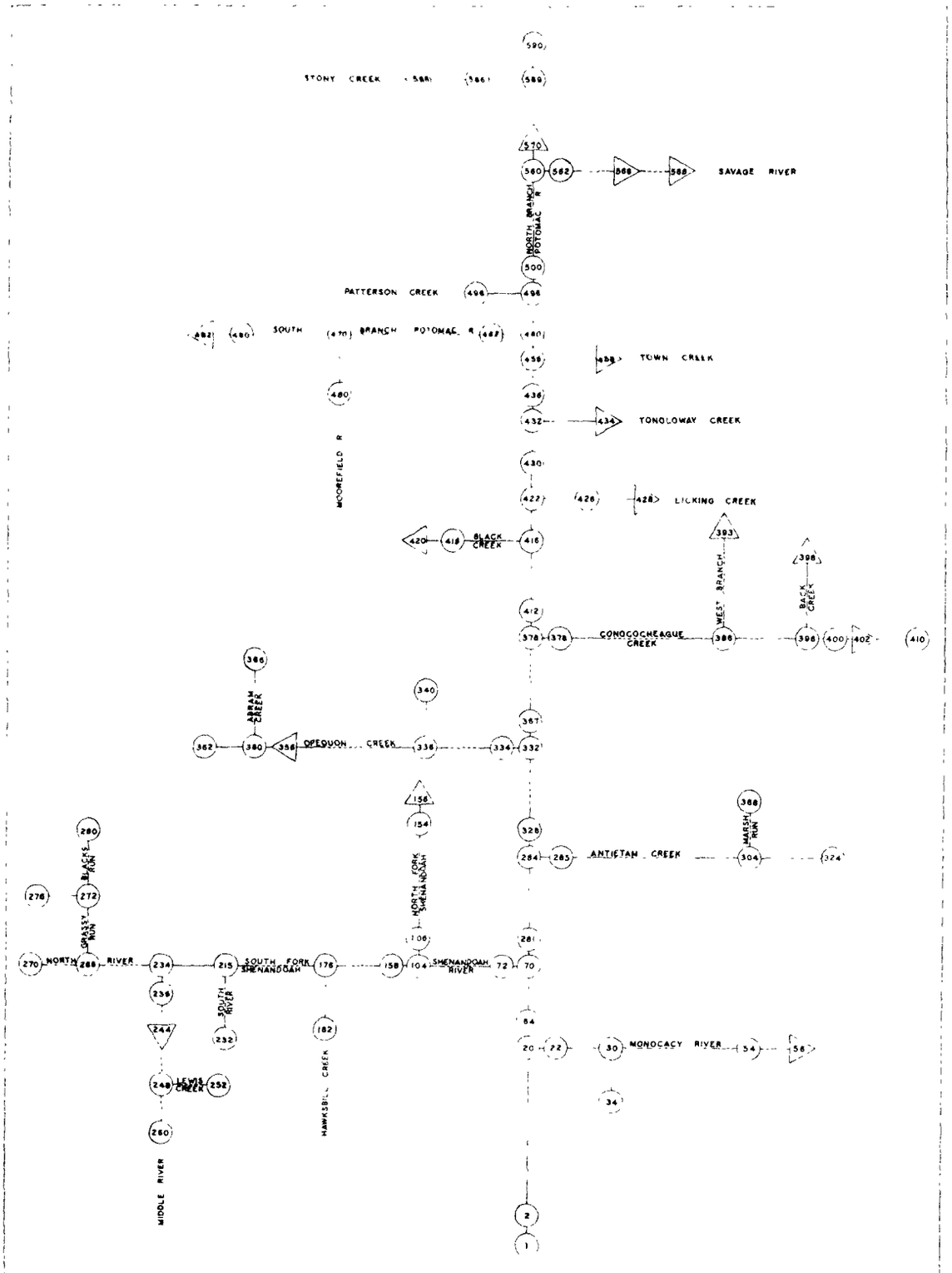
PRESENT USE OF MATHEMATICAL MODELS IN THE POTOMAC WATER QUALITY MANAGEMENT SYSTEM

FIGURE 2



POTOMAC RIVER STUDY AREA

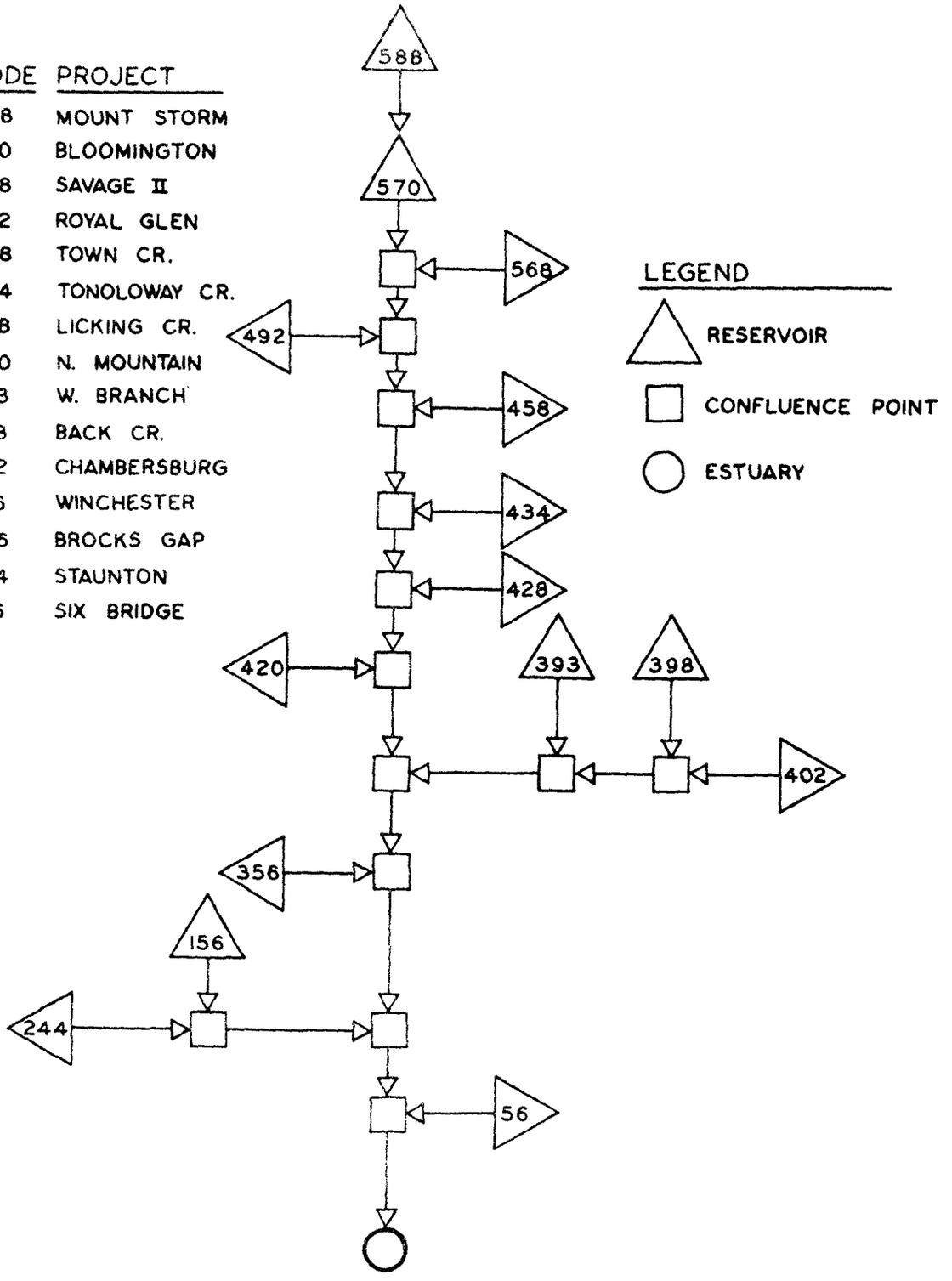
FIGURE 3



OVERALL POTOMAC RIVER BASIN SYSTEM

FIGURE 4

NODE	PROJECT
588	MOUNT STORM
570	BLOOMINGTON
568	SAVAGE II
492	ROYAL GLEN
458	TOWN CR.
434	TONOLOWAY CR.
428	LICKING CR.
420	N. MOUNTAIN
393	W. BRANCH
398	BACK CR.
402	CHAMBERSBURG
356	WINCHESTER
156	BROCKS GAP
244	STAUNTON
56	SIX BRIDGE



A SCHEMATIC REPRESENTATION
OF
PROPOSED RESERVOIR SYSTEM – POTOMAC RIVER BASIN

FIGURE 5

Law (Sections 34-45, Article 66C, Annotated Code of Maryland (1957 Edition)), and shall be subjected to penalties imposed thereby. Each day upon which a violation occurs under this Regulation shall be deemed a separate and additional violation.

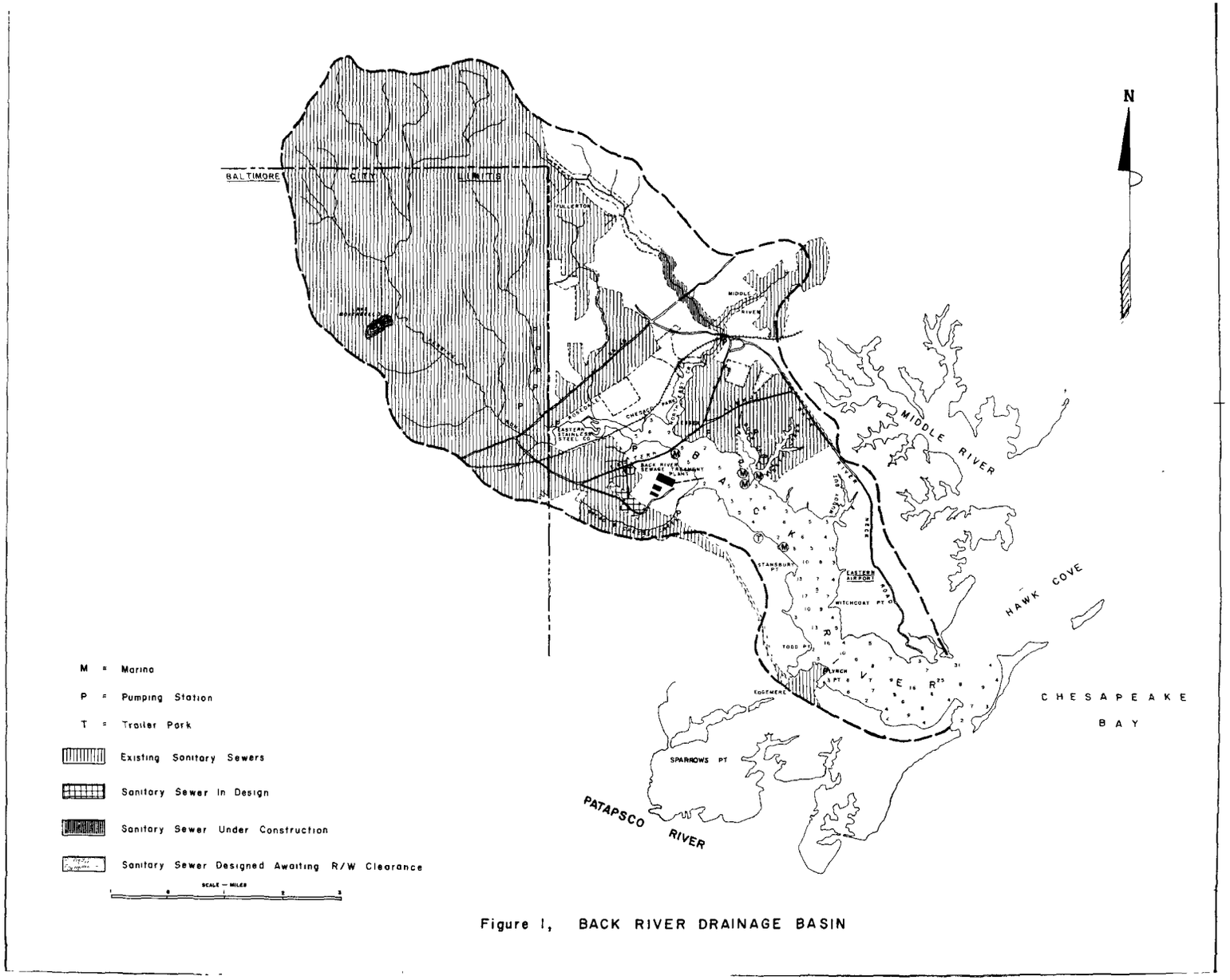


Figure 1, BACK RIVER DRAINAGE BASIN

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INTRODUCTION

In 1962 the Maryland State Planning Department initiated the Maryland Water Supply and Requirements Study. The purpose of the Study is to provide information to assist in planning for the development of the State's water resources to insure meeting future demands. This Study was divided into two principal phases: (1) determination of the existing characteristics of supply and demand, and (2) projections of demand on a multiple-use basis of ten-year intervals to the year 2020. The areal unit of investigations is by major drainage area and includes both surface and ground waters.

The Chesapeake Bay-Susquehanna River Basins Project, Public Health Service, agreed to prepare a report delineating the present surface water quality of the Potomac River Basin in Maryland. This summary, prepared in the format established by the State Planning Department, is to be included as one section of the Phase 1 report for the Potomac River Basin being prepared by the U. S. Geological Survey under a contract with the State Planning Department. The Geological Survey report will include information on drainage areas, hydrology, water uses, flow regulation, and the availability and quality of ground water.

The primary purpose of this summary is to present recent Potomac River Basin surface water quality data and to draw from these data general conclusions regarding the suitability of these surface waters for various uses within the framework of the water quality criteria promulgated by the Interstate Commission on the Potomac River Basin and the Maryland Department of Water Resources. Only the present quality of surface waters of the Potomac Basin within the State of Maryland and of surface waters from outside the State which have a significant effect on Maryland waters are included in this evaluation.

WATER QUALITY CRITERIA

The Interstate Commission on the Potomac River Basin (INCOPOT) has developed minimum water quality criteria for each of several classes of water use (Table I) which are applicable to all tributary streams and to the main stem of the Potomac River upstream from the confluence of the Monocacy River. These criteria have not been officially assigned as quality objectives for the above specified streams or any specific portion thereof. They are used only to delineate concentrations of the various water quality indicators to serve as guides for evaluating the suitability of the quality of the surface waters for some present or expected use. However, the Commission has adopted specific water quality objectives and criteria for five sections of the Potomac River within the Washington Metropolitan Area from the confluence of the Monocacy River downstream to Hallowing Point (Appendix I).

In addition to these objectives and criteria, the States of Maryland and Virginia have established requirements to regulate sewage discharges for the section of the Potomac River watershed from Monocacy River to Little Falls. These requirements were adopted for the purpose of protection and preservation of water quality in this reach serving as the source of water supply for the District of Columbia and adjacent political subdivisions in Maryland and Virginia. The requirements established by these two States are sympathetic to the "no effluent concept" adopted in 1960 by the Washington Metropolitan Regional Conference (now Washington Metropolitan Council of Governments); upon completion of the Potomac River Interceptor, both existing and future discharges will be eliminated from this reach and will be handled by the Interceptor.

The Maryland Department of Water Resources (MDWR) employs water quality criteria for each of several classes of water use developed in 1949 by the former Water Pollution Control Commission (Table II). These criteria, which are applicable to all surface water streams within the State of Maryland, are used as guides similar to the INCOPOT criteria previously discussed. They have not been officially assigned as water quality objectives for the surface water streams within the State.

Based on a comparison of existing water quality with the criteria contained in Tables I and II, judgments were made by stream reaches as to which water use classes best describe the present quality of the Potomac River and its tributaries in Maryland. These judgments do not have any official standing

and were made only to provide the basis for general conclusions regarding the suitability of these waters for various water uses

In the five sections of the Potomac River within the Washington Metropolitan Area, the existing water quality was compared with the specific objectives for these segments as presented in Appendix I. As before, this was done to provide the basis for evaluating the suitability of these waters for the designated water uses.

TABLE I - MINIMUM WATER QUALITY CRITERIA FOR STREAMS IN THE POTOMAC RIVER BASIN

by
Interstate Commission on the Potomac River Basin
(Approved 8 August 1946)

	CLASS A Drinking Water (No treatment except Chlorination)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria	0 - 50	Mo. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	----------			
Monthly av., ppm	----------	1.5	2.0	3.0
Max. observation, ppm	----------	3.0	4.0	5.0
Dissolved Oxygen, ppm				
Monthly av., ppm	7.5	6.5	6.5	4.0
Min. observation, ppm	6.5	5.0	5.0	Min. daily ave. 3.0 Absolute min. 2.0
Other Conditions	No toxic substances, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor-producing substances	Same as A	Same as A	No toxic substances. oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

TABLE II - CRITERIA FOR THE CLASSIFICATION OF MARYLAND STREAMS

by
Maryland Department of Water Resources

DETERMINATIONS		CLASS AA	CLASS A	CLASS B	CLASS C
		Excellent source of water supply; excellent fish habitat, recreational and industrial water	Good source of water supply; good fish habitat, recreational and industrial water	Serve as source of water supply with complete and auxiliary treatment, poor fish habitat, recreational and industrial water.	Unsatisfactory source of water supply; unsuitable as fish habitat and recreational water
NAME Zoning (Symbol)	Period Covered				
Most probable number Coliform Bacteria per 100 ml--- (C)	Average any month	Not over 100	Not over 2,000	Not over 10,000	Over 10,000
Dissolved oxygen p.p.m.----- (D)	Average any month	Not less than 7.5	Not less than 6.0	Not less than 4.0	Less than 4.0
	Minimum any day	Not less than 6.5	Not less than 5.0	Not less than 3.0	Less than 3.0
5-Day B.O.D. at 20°C.p.p.m.- (B)	Average any month	Not over 0.75	Not over 2.5	Not over 6.0	Over 6.0
	Maximum any day	Not over 1.0	Not over 3.5	Not over 7.0	Over 7.0
pH-------(O1)----------	Average any month	6.2-8.4	5.8-9.0	Between 3.8-5.8 or 9.0-10.5	Less than 3.8 or over 10.5
Fluorides p.p.m.---------- (O_2)	Maximum	Not over 1.0	Not over 1.0	Not over 1.0	Over 1.0
Chlorides p.p.m.---------- (O_3)	Maximum any day	Not over 50	Not over 250	Not over 500	Over 500
Phenolic Compounds p.p.b.--- (O_4)	Maximum	None	Not over 5.0	Not over 25	Over 25
Iron and Manganese p.p.m.--- (O_5)	Maximum	Not over 0.3	Not over 1.0	Not over 15	Over 15
Color p.p.m.---------- (O_6)	Maximum	Not over 20	Not over 75	Not over 150	Over 150
Turbidity p.p.m.---------- (O_7)	Maximum	Not over 10 except as result heavy rain	Not over 250 except as result heavy rain		
Industrial or Domestic Sludge Deposits---------- (O_8)		No deposits present	No deposits present	Slight to moderate localized	Moderate to heavy --general
Other Conditions---------- (O_9)		No toxic substances, oils, tars, or free mineral acid at any time; no floating solids or debris, except from natural sources, only slight amounts of taste and odor producing substances occasionally present.			Toxic substances, oil or tars present frequently; taste and odor producting substances often

SOURCES OF WATER QUALITY DATA*

Each year the Interstate Commission on the Potomac River Basin publishes a report entitled, Potomac River Water Quality Network--Compilation of Data. These annual reports have been published beginning with the water year 1960; a biennial report was published for water years 1958 and 1959; and one report summarized water years 1950 - 1957. Included for each network station are monthly averages of up to four samples for temperature, turbidity, alkalinity, pH, dissolved oxygen, biochemical oxygen demand, total and coliform bacteria, suspended and total solids, together with the corresponding stream discharges. Samples are collected and analyzed by several industries and governmental agencies located throughout the Basin. The total number of stations reported in 1964 was 77, of which 56 were in Maryland waters. The Commission, in cooperation with the Washington Aqueduct Division, U. S. Army Engineer District, Baltimore, and the District of Columbia Department of Public Health, is conducting a special bacteriological study of the major watersheds of the Basin to define possible contributions to high bacterial counts which occur during high flows at Great Falls; however, since insufficient data have been collected to date, an evaluation cannot be made at this time.

In addition to contributing data to the Commission's network, several industries and governmental jurisdictions obtain more detailed water quality data, especially at water supply intakes. Of special significance are daily samples at three locations on the North Branch Potomac River by the West Virginia Pulp and Paper Company at Luke, Maryland, and on the Potomac River at Great Falls, Maryland, by the Washington Aqueduct Division of the U. S. Army Engineer District, Baltimore. Other jurisdictions not participating in the network also routinely maintain water quality records for water supplies.

The U. S. Department of Health, Education, and Welfare, Public Health Service, maintains four stations of the nation-wide Water Pollution Surveillance System in the Potomac River Basin, three of which are located in Maryland. The stations at Williamsport and Great Falls, Maryland, were activated in October 1957, and the station at Memorial Bridge, Washington, D. C., was

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* While much related historical information is available, only data pertinent to present water quality are included.

activated in July 1963. The data on chemical, physical, and bacteriological analyses and radiological determinations are generally determined weekly; plankton counts are made twice a month; organic chemicals by carbon filter technique are determined monthly; three-month composite samples are analyzed twice annually for metallic elements and Strontium 90 activity; and occasional determinations of alkyl benzene sulfonate are made. These data are published in annual compilations. The Public Health Service performed water quality field surveys during the period 1956 - 1960 in the Potomac River Basin with emphasis given to problem areas. The resulting data are published in Potomac River Basin Report, Volume V, Appendix E, U. S. Army Engineer District, Baltimore, Maryland, February 1963. Data on the Potomac River estuary from those surveys are presented in Technical Appendix to Part VII of the Report on the Potomac River Basin Studies, Report on Needs for Water Supply and Flow Regulation for Quality Control in the Washington Standard Metropolitan Area, August 1962, by the Public Health Service. The Public Health Service performed special studies on the bottom and plankton conditions of the Potomac River in the Washington Metropolitan Area for the Interstate Commission on the Potomac River Basin in 1952, and the results are presented in A Report on Water Pollution in the Washington Metropolitan Area, Section III - Appendices, "Appendix A - Bottom and Plankton Conditions in the Potomac River in the Washington Metropolitan Area," Interstate Commission on the Potomac River Basin, Washington, D. C., February 1954.

The Maryland Department of Water Resources initiated a Western Maryland Mine Drainage Survey in 1962 to define reaches of streams receiving acid mine drainage and to assist in locating sources of the mine drainage. Interim Report #1 on the Western Maryland pH Survey, published in June 1963, presents pH data for 1962 and 1963 from the North Branch drainage area. Based upon those data, more detailed studies of acid mine drainage have continued during 1964 and 1965, but these findings have not been published to date. That Department (under the former name of Maryland Water Pollution Control Commission) has also prepared the following: Final Data Report for Zekiah Swamp 3/9/61 - 2/28/62, August 1962; Carroll Creek Survey - 1961; and St. Mary's River Water Quality Survey - 1962; presenting data from water quality surveys on these three streams of the Potomac River Basin. Under contract to the Maryland Department of Water Resources, the Department of Sanitary Engineering and Water Resources of The Johns Hopkins University made a study in 1962-63 resulting in a report entitled Anionic Detergents in Maryland Waters and Wastes, with Dr. Charles E. Renn as Responsible Investigator. Subsequent to that study, the Nation's detergent industry has converted to the production of bio-degradable or "soft" detergents, which are

more easily broken down in waste treatment plants and in streams. As a result, the 1962-63 data would be of limited value in describing present water quality.

The Maryland State Department of Health conducted a water quality survey of the Monocacy River in September 1964. The data are presented in Report on Basic Sewerage System, Frederick County Western Suburban Area, to the Frederick County Metropolitan District and Sanitary Commission, Benjamin E. Beavin Company, Baltimore, Maryland, 1964. The State Department of Health has made studies of shellfish harvesting areas in the Potomac River estuary for many years. An intensive study of the bacteriological quality of these areas was made during the fall of 1964 in cooperation with the Maryland Department of Water Resources and the Maryland Department of Chesapeake Bay Affairs, but these data have not been published. Occasional analyses of community water supplies drawn from surface waters of the Potomac River Basin are also made by the State Department of Health.

The U. S. Department of the Interior, Geological Survey, is maintaining, as of January 1965, four stations in the Potomac River Basin to determine daily suspended-sediment discharge. Two of these stations, near Cumberland and at Point-of-Rocks, are on the Potomac River, and the other two on tributaries, i.e., the Monocacy River near Frederick and the Northwest Branch Anacostia River near Colesville. At three of these stations, Cumberland, Point-of-Rocks, and Frederick, samples are obtained monthly for chemical analysis of the common constituents. The data resulting from these analyses and from studies begun in 1959 of the suspended sediment in the Potomac River Basin are published in annual reports entitled Quality of Surface Waters of the United States. Daily temperature records are also published in these reports and four thermographs are now (1965) installed at selected gaging stations in the Potomac River Basin. The longest period of record of these thermographs, that of the Potomac River at Hancock, has been continuously operated since July 1952. Miscellaneous chemical analyses at other stations in the Basin are also included in the annual surface water quality reports. Sediment data through April 1961 are summarized and discussed in Potomac River Basin Report, Volume VII, Appendix H, Sediment Studies, U. S. Army Engineer District, Baltimore, Maryland, 1962. The Geological Survey summarizes and discusses suspended sediment data collected through April 1962 in Preliminary Study of Sediment Sources and Transport in the Potomac River Basin, Technical Bulletin 1963-11, Interstate Commission on the Potomac River Basin, Washington, D. C., June 1963. The Geological Survey has also published (1961) a report entitled, Water Quality and Hydrology in the Fort Belvoir Area, Virginia, 1954 - 1955,

which considers the quality of the Potomac River estuary in Maryland. The Potomac River at Point-of-Rocks is also one of the sampling stations in the Geological Survey tritium network, and composite samples are analyzed monthly for this radioisotope.

The Chesapeake Bay Institute of The Johns Hopkins University has published Atlas of Salinity and Temperature Distributions in Chesapeake Bay, 1952 - 1961, and Seasonal Averages, 1949 - 1961 by E. D. Stroup and R. J. Lynn, February 1963, and Atlas of the Distribution of Dissolved Oxygen and pH in Chesapeake Bay 1949 - 1961 by R. I. Hires, E. D. Stroup, and R. C. Seitz, December 1963, under contract to the Public Health Service. Those atlases display the results obtained during cruises of the Institute and include the Potomac River estuary from Chesapeake Bay to U. S. Highway 301.

The Virginia Department of Conservation and Economic Development, Division of Water Resources, has periodically published reports entitled, Chemical Character of Surface Waters of Virginia. Chemical analyses of Potomac River tributary streams are generally available since 1948, with some miscellaneous analyses available in earlier years.

The Virginia State Department of Health determines the bacteriological quality of the bays and coves of the Potomac River estuary in Virginia which are active or potential shellfish harvesting areas.

The Potomac Electric Power Company has studied the effects of raised temperature on the Potomac River in the vicinity of its thermo-electric power plant at Dickerson, Maryland. Temperature data are summarized graphically in several reports of the Company, and studies of biological flora before and after the plant began operation were performed for the Company by the Academy of Natural Sciences of Philadelphia and published in three reports on the surveys of 1956, 1960, and 1961.

The Possum Point steam generating plant of the Virginia Electric and Power Company, located on the Potomac River estuary at the mouth of Quantico Creek in Virginia, has sampled the Potomac estuary waters daily for many years. Analyses are performed for temperature, ammonia, hardness, chlorides, and other quality indicators.

The Chesapeake Biological Laboratory of the Natural Resources Institute, University of Maryland, Solomons, Maryland, in a study under R. D. Van Deusen, classified Maryland freshwater streams as to type of fish population which could be supported. The classifications are shown on maps of the State in

Maryland Freshwater Stream Classification by Watershed, Contribution No. 106, Chesapeake Biological Laboratory, Solomons, Maryland, 1954. Using the classification techniques of Van Deusen, the U. S. Department of the Interior, Fish and Wildlife Service, brought the classifications for the Potomac River Basin above Great Falls up to date in 1960, and the results are presented in Potomac River Basin Report, Volume VIII, Appendix J, Fish and Wildlife, U. S. Army Engineer District, Baltimore, 1962. These classifications are presented by sub-reach for the Potomac River Basin in Maryland in Appendix VI of the present report. The classifications indicate only the types of fishlife which could be supported in the absence of pollution and do not describe the present fish population.

The West Virginia Department of Natural Resources, Division of Water Resources, maintains a network of stations in the Potomac River Basin of West Virginia where water quality is determined monthly. While the station at Shepherdstown is on the main stem of the Potomac River, several other stations indicate the quality of West Virginia tributaries entering the main stem.

WATER QUALITY PROBLEMS

The Potomac River Basin in Maryland is composed of several major areas which present a logical sub-division for discussion of water quality. The various areas are different either in types of water quality problems or in physical characteristics. The major areas chosen for consideration of water quality problems in this report are as follows:

	Tributary or Reach	River Miles from Mouth of Potomac River
I.	North Branch Potomac River	381.6 - 285.1
II.	Potomac River, South Branch to Conococheague Creek	285.1 - 210.7
III.	Potomac River, Conococheague Creek to Little Falls	210.7 - 116.1
IV.	Potomac River Estuary	116.1 - 0.0

Tributaries entering these major reaches from States other than Maryland are considered on the basis of their effect upon the quality of water in Maryland streams. A map of each of the major reaches is included in Appendix VIII.

A summary of the water quality of the Potomac River Basin in Maryland is presented in the final chapter of this report. Figures 16 and 17, summarizing areas of water quality problems in the entire Basin in Maryland, are also located in Appendix VIII.

I. NORTH BRANCH POTOMAC RIVER

Length of North Branch Potomac River . . . 96.5 miles

Area Draining to the North Branch . . . . 1,384 square miles

North Branch and South Branch Join to Form the Potomac River at River Mile . . 285.1

Summary

The presence of mine drainage originating in both active and abandoned coal mining operations is detrimental to water quality throughout large portions of the North Branch Potomac drainage area. In addition, industrial and community wastewater discharges further degrade the water quality of the North Branch and of some tributaries. Water quality is discussed below by sub-reaches of the North Branch, and a map of the area is presented in Figure 12.

Headwaters to Savage River (43.0 miles)

The North Branch Potomac River and most of the tributary streams from the headwaters to Savage River possess undesirable characteristics attributable to mine drainage. These streams are strongly acid (pH values as low as 3.0) and contain iron salts which precipitate from the water through natural oxidation and hydrolysis, coating long stretches of the stream bed with bright reddish-brown iron hydroxides. High manganese concentrations, which are generally characteristic of waters receiving mine drainage, are also present. Practically no aquatic life can survive such conditions, and little vegetation can grow in or close to the water's edge. (Algae attached to rocks may be observed at some locations, and one species of Diptera has been observed to inhabit a highly acid reach of the Youghiogheny River of the Ohio River Basin.*) The acid water is costly to treat for municipal or industrial purposes but would be more costly

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* Reppart, R. T., "Aquatic Life and the Acid Reaction," Proceedings, Fifth Annual Symposium on Industrial Waste Control, sponsored jointly by Frostburg State College and the Maryland Water Pollution Control Commission, May 7 and 8, 1964, Frostburg, Maryland.

to use without treatment because of its corrosiveness. The acidity concentration of waters receiving mine drainage varies inversely with flow, generally being higher at the lower stream flows. Limestone which is soluble in acid is reported to be a dominant mineral in the area. However, the geologic formations near the surface through which the drainage seeps are evidently insoluble, since the dissolved solids content of these waters is generally less than 200 mg/l (milligrams per liter).

The sources of mine drainage are the active and abandoned coal mines that are prevalent throughout the Western Maryland region. The Maryland Department of Water Resources is undertaking an exhaustive search for sources of mine drainage through stream sampling and field inspection. Also, the Public Health Service is studying the possibility of establishing an Acid Mine Drainage Demonstration Project in the North Branch Potomac River drainage area to test and evaluate methods of control. Such studies will ultimately lead to effective methods for controlling mine drainage at the source.

The only industrial waste discharges in the sub-reach from the headwaters to Savage River are from two coal washeries of the Alpine Coal Company at Henry, West Virginia, and the North Branch Coal Company at Bayard, West Virginia. The plant at Henry washes about 60,000 tons of coal per month, and that at Bayard will wash about 400,000 tons per month when completed, but is currently operating at less than one-fourth of this capacity. Coal dust and other finely divided solids are removed from freshly mined coal by water sprays. Some of the fines are discharged to the atmosphere, resulting in the surrounding countryside being covered with black dust which may be washed into streams during heavy rainfall. Large lagoons have been constructed to receive waste wash water at the collieries, which are apparently successful in settling out coal fines from wash waters. Only one recent severe incident of stream pollution by coal fines has been reported by local residents, and on that occasion the effects extended down the North Branch for about 40 miles to Luke, Maryland.

Water seeping through the bottom and walls of the lagoons constructed of spoil and fines from coal washing frequently produces an effluent equivalent to mine drainage. The seepage at Henry discharges principally to Elk Run about one mile upstream from its confluence with the North Branch Potomac River at River Mile 91.6 (miles above the mouth of the North Branch) and also to Deakin Run, a small tributary entering the North Branch at River Mile 92.0. The seepage at Bayard discharges to Buffalo Creek about one and one-half miles above its confluence with the

North Branch at River Mile 86.4 and to an abandoned mine shaft. It is likely that the abandoned mine shaft could overflow during periods of high rainfall.

The major tributary to the North Branch in this sub-reach is Stony River in West Virginia. Stony River, as it enters the North Branch at River Mile 78.3, contains high concentrations of iron and manganese. These concentrations have little effect on the North Branch because of the presence of mine drainage in this sub-reach. Two reservoirs on Stony River augment low flows and provide some dilution of the acid concentrations in the North Branch.

The only surface water supply in this sub-reach is taken from Wolfden Run for the unincorporated community of Shallmar, Maryland (population 100), which provides no treatment. Water quality data on Wolfden Run, which joins the North Branch at River Mile 70.4, indicate that the stream receives some mine drainage.

No community sewerage systems exist in this sub-reach. However, sewage discharges from individual homes have been observed entering Buffalo Creek from the town of Bayard, West Virginia, just above its confluence with the North Branch. Discharges of untreated or partially treated sewage from individual households are reported to be common for many small communities in the North Branch drainage area.

The average annual sediment discharge near the lower end of this reach (at Kitzmiller, Maryland, River Mile 68.9) is 94 tons per square mile, or 21,200 tons per year. Abram Creek in West Virginia, entering the North Branch at River Mile 71.3, contributes 21 tons per square mile on the average, or 1,100 tons per year. For comparison, the annual average sediment discharge for the entire Potomac River Basin above Washington, D. C. (at Point-of-Rocks, River Mile 159.5), is 113 tons per square mile, or 1,090,000 tons per year.

This reach of the North Branch and most of the tributaries in Maryland do not meet the minimum criteria for INCOPOT Class D (Table I) because of the presence of free acid, iron precipitates, and pH values below 6.0. The waters generally fall into the MDWR Class C (Table II) because of pH values below 3.8 and the presence of iron precipitates.

Savage River to New Creek (7.8 miles)

The Savage River is of good quality and suitable for most uses. However, manganese removal may be required at times to reduce concentrations to satisfy some uses. Frostburg, Maryland, obtains part of its water supply for 11,000 persons from the Savage River near its headwaters but does not remove manganese. Westernport, Maryland, obtains water from Savage Reservoir at the dam and supplies a population of 3,900 without practicing manganese removal. Piedmont, West Virginia, also receives its water supply for 2,700 persons from Savage River. Most of the Savage River drainage area is covered by forests and contains no sources of municipal or industrial pollution. Mine drainage enters Savage River only from Aaron Run (River Mile 1.1) and a smaller tributary (about River Mile 2.0). During drought periods, releases from the Savage Reservoir provide sufficient alkalinity to neutralize the small quantities of acid entering from these two streams. The mean discharge of the Savage River (164 cfs for a 15-year period of record) at its confluence with the North Branch Potomac River at River Mile 53.5 is about 40 per cent of that of the North Branch immediately upstream (437 cfs over 14 years) and thus provides significant neutralization of the acid in the North Branch.

The water temperature of the North Branch Potomac River just downstream (River Mile 53.3) from the Savage River ranges from 32°F. for long periods during the winter to a peak of 84° to 86°F. in the summer, occurring sometime between mid-June and mid-August. The difference between daily minimum and maximum temperatures during the winter is generally only 1° or 2°F., while in the summer, the average daily range is 6° to 8°F., and on some days may reach 14°F.

The West Virginia Pulp and Paper Company withdraws 40 mgd (million gallons per day) from the North Branch at River Mile 52.7. Part of the water is treated chemically and filtered for process and sanitary purposes. The town of Luke is also supplied with this treated water. Most of the water withdrawal at West Virginia Pulp and Paper Company is utilized for cooling and is neutralized to prevent corrosion. During periods of high water temperatures and low stream flows, a portion of the used cooling water is recycled to the River upstream over a reach of about 0.2 mile through spray nozzles. The North Branch at the plant intake is a mixture of water containing acid mine drainage from upstream areas and high quality water from Savage River. The flow ratio of Savage River to North Branch increases during periods of drought, because the regulated flow from Savage Reservoir is higher than that from the reservoirs on Stony River.

Several waste effluents from the paper mill discharge directly to the North Branch without treatment, their most significant characteristics being high alkalinity, B.O.D.* (biochemical oxygen demand), and temperature. The rocks on the bed of the River below the mill are coated with greenish-white lime wastes, in contrast to the reddish-brown rocks upstream. Lime waste discharges from the mill are such that most of the time the North Branch below the mill is highly alkaline and is acid at other times. The West Virginia Pulp and Paper Company has a program underway to reduce discharges of lime wastes. Lime recovery units, which are under construction, will be in operation early in 1966. The large volume of water used by the mill will continue to be neutralized to prevent corrosion; therefore, the return flows are expected to continue to provide some reduction in the acid concentrations of the North Branch following completion of the lime recovery process. Most of the wastes from the plant (other than cooling water and lime wastes) and the domestic wastes from Luke are transported through a rectangular conduit constructed along the side of the River from the plant to the Upper Potomac River Commission Waste Treatment Facility at Westernport, Maryland. Wastes from the City of Westernport are also treated at the facility, which provides secondary treatment by an activated sludge process (outfall at River Mile 51.0).

The West Virginia Pulp and Paper Company samples the North Branch Potomac River on week days above the plant (River Mile 53.1), below the plant (River Mile 52.4), and at River Mile 45.9, 5.1 miles below the Upper Potomac River Commission Waste Treatment Facility. Daily data on several water quality indicators at the three stations from January 1962 through February 1965, and for the effluent of the Waste Treatment Facility from December 1961 through March 1965, have been analyzed statistically for this summary. A summary of the results of this analysis is presented in Appendix II.

Georges Creek joins the North Branch Potomac River at Westernport (River Mile 51.4), 0.4 mile upstream from the Upper Potomac River Commission Waste Treatment Facility. Georges Creek, an alkaline stream at the headwaters, receives direct mine drainage discharges along its banks and from tributaries throughout its 17-mile length. Untreated sewage is discharged to the Creek from Frostburg, sewered population of 4,000 persons (River Mile 15.7); Lonaconing, 1500 persons (River Mile 8.1); Barton, 600

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* All values of B.O.D. presented in this report are for measurements at 20°C. for five days.

persons (River Mile 4.9); and from individual or small collection systems in several other communities. An interceptor is under construction to transport sewage from Frostburg to Cumberland, Maryland. While the interceptor will remove a major source of organic waste, the corresponding loss of this source of alkalinity is expected to result in some increase in acid concentrations in Georges Creek. The Lotz Wholesale Meats Company discharges an estimated 1,000 gpd (gallons per day) of settled slaughterhouse waste, with a B.O.D. of 175 mg/l, to Sandy Spring Run, 3.4 miles upstream from Georges Creek (confluence at River Mile 15.5). The Dashiell Dairy discharges its wastes to Georges Creek at River Mile 11.2. Even though the B.O.D. concentrations in the Creek near its mouth normally range between 10 and 20 mg/l, the dissolved oxygen levels seldom fall below 80 per cent of saturation, possibly because the stream acidity inhibits bacterial decomposition of the organic material present. Also, coliform bacteria concentrations* generally fall below 2,000/100 ml because of the bactericidal effects of the acid. Several small communities, serving a total population of about 6,500, obtain water supplies from tributaries of Georges Creek and provide only chlorination for treatment. The acidity from Georges Creek is neutralized much of the time by the alkaline waters of the North Branch (as a result of lime waste discharges from the West Virginia Pulp and Paper Company, to be discontinued by 1966). The average annual sediment load from the Georges Creek drainage area is quite high; i.e., 207 tons per square mile, or 15,000 tons per year.

The town of Piedmont, West Virginia, discharges untreated sewage from 2,400 persons at River Mile 51.2. The flow of that discharge is estimated to be about 190,000 gpd.

The effluent from the Upper Potomac River Commission Waste Treatment Facility serving the West Virginia Pulp and Paper Company, Luke and Westernport, is distributed through subsurface nozzles across the center section of the North Branch at River Mile 51.0. Analyses of quality indicators of the waste effluent and the calculated water quality of the North Branch immediately downstream from the facility are summarized in Appendix II.

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* All coliform bacteria counts (or concentrations) in this summary are given as determined at 35°C. and are expressed as monthly geometric means.

Until recently, Keyser, West Virginia, discharged an estimated 360,000 gpd of untreated sewage from 4,500 persons. Since August 1965, a primary treatment plant which discharges to the North Branch at River Mile 45.4 has been in operation.

A quality station on the North Branch at River Mile 45.9, just downstream from an old outfall, is sampled daily by the West Virginia Pulp and Paper Company. Prior to completion of the treatment plant, this outfall discharged a portion of Keyser's sewage. Since the sewage discharged appeared to flow along the bank of the River opposite the sampling station, analyses of the results, summarized in Appendix II, were interpreted on the assumption that none of the sewage flow from Keyser was mixed with the River at that sampling point. Even though the acid of the North Branch is neutralized by the alkaline wastes of West Virginia Pulp and Paper Company much of the time, high iron and manganese concentrations persist beyond this point.

Savage River meets the requirements for INCOPOT Class A and MDWR Class AA. Georges Creek does not meet the minimum standards for INCOPOT Class D because of pH values below 6.0 and B.O.D. values above 5.0 mg/l, and falls into MDWR Class C because of B.O.D. values over 7.0 mg/l. The main stem of the North Branch in this sub-reach does not meet minimum standards for INCOPOT Class D because of pH values in excess of 8.5, B.O.D. values over 5.0 mg/l, high color, and offensive odors, and falls into MDWR Class C because of B.O.D. values over 7.0 mg/l, pH values over 10.5, and the presence of taste and odor producing substances.

New Creek to Wills Creek (24.0 miles)

The North Branch Potomac River flowing into this sub-reach (beginning at River Mile 45.7) contains high concentrations of B.O.D. (a range of monthly means of 12.7 mg/l to 23.7 mg/l), and yet, the dissolved oxygen content remains high (a range of monthly means from 6.1 mg/l to 13.1 mg/l) and remains essentially constant for the next five miles to River Mile 40 (where the monthly mean range is 5.7 mg/l to 13.3 mg/l). Downstream from that point, the dissolved oxygen concentration begins to drop (to about 5.0 mg/l at River Mile 28.9 during hot weather). There are three possible explanations for the somewhat unusual dissolved oxygen profile. First, the fall in the River between the Piedmont-Westernport area (River Mile 51), where organic wastes enter the River, and River Mile 40 is about 16 feet per mile, indicating the likelihood of a very high degree of aeration; whereas, the fall for the 10 miles below River Mile 40 is only

about 8 feet per mile. Second, the stream waters approaching the region in which organic wastes are discharged (Luke-Piedmont-Westernport area) are highly acid and are almost biologically sterile. Even though the acid is neutralized at Luke much of the time by wastes from the West Virginia Pulp and Paper Company, a certain amount of time is required before the River can establish a biological flora which can decompose the organic wastes and thus reduce dissolved oxygen concentrations. Also, until recently, the untreated sewage from Keyser, West Virginia, entered the River at River Mile 46.2 and from New Creek (River Mile 45.7) and contained large numbers of microorganisms which acted to "seed" the River. Third, wastes from Keyser, Bel Air (River Mile 32.7), Barton's Dairy (River Mile 32.6), the Allegany Ballistics Laboratory (River Mile 32.5), Mason's Dairy (River Mile 29.7), and Cresaptown (River Mile 29.5) add to the biological population and the organic loading in the 10-mile reach of the River in which the dissolved oxygen concentration drops.

The community of Rawlings Heights obtains its water supply from an unnamed tributary of Mill Run, which enters the North Branch at River Mile 35.0.

The community of Bel Air, with an estimated sewered population of 400, discharges its waste effluent after treatment by lagoon to the North Branch at River Mile 32.7. The loading from the town is estimated to be about 10 pounds of B.O.D. per day in a flow of 30,000 gpd.

Barton's Dairy at Pinto, Maryland, discharges an unknown quantity of milk processing wastes at River Mile 32.6.

The average annual sediment discharge measured at Pinto, Maryland (River Mile 32.6) is 130 tons per square mile, or 78,000 tons per year.

The Allegany Ballistics Laboratory of Hercules Powder Company at Rocket Center, West Virginia, discharges approximately 100,000 gpd of sanitary wastes from about 2,000 persons to the North Branch at River Mile 32.5 after secondary treatment. No significant quantities of industrial wastes are discharged to the River from this plant. The total waste loading to the River is estimated to be 50 pounds of B.O.D. per day.

Mason's Dairy at Cresaptown, Maryland, discharges about 35,000 gpd of milk processing wastes at River Mile 29.7. The loading is about 20 pounds of B.O.D. per day.

Cresaptown discharges an estimated 280,000 gpd of sewage effluent, after primary treatment, to the North Branch at River Mile 29.5. The waste loading is estimated to be about 390 pounds of B.O.D. per day.

The Celanese Fibers Company at Amcelle, Maryland, withdraws an average of 40 mgd of cooling water from the North Branch at River Mile 28.9, and up to 53 mgd during periods of high water temperatures. An additional 2.0 mgd are obtained for process and sanitary purposes from the City of Cumberland. The plant has about 3,000 employees. Fly ash is settled and sanitary wastes undergo decomposition in a large lagoon; whereas, process wastes receive treatment in another lagoon. The plant produces acetate fibers, polymers of cellulose acetate, and cellulose proprionate. The total average waste loading to the River is about 15,000 pounds of B.O.D. per day from this plant. A larger lagoon system, which is expected to provide a higher degree of treatment for organic wastes, is under design.

The dissolved oxygen concentrations seldom fall below 50 per cent of saturation above the Celanese plant, even during periods of high water temperatures. The water temperatures at that point range from 32°F. in the winter to 89°F. at times during the summer. Based on five years of record, during the warmest ten-week period of the year, the temperature averaged 78°F., and 84°F. during the warmest week. The mean water temperature for the month of July is 78°F., as compared to 74°F. at Keyes (the last sampling station upstream), showing an average rise in mean temperatures of 4°F. between the two points. Coliform bacteria, which were generally present in the order of magnitude of 100,000 to 1,000,000/100 ml about 10 miles below Keyser before completion of the Keyser sewage treatment plant, were reduced to about 1,000 to 100,000/100 ml at the Celanese plant, even with some additional bacterial loadings immediately upstream. Color and odor from the paper-mill waste are still detectable above the Celanese plant.

Immediately below the Celanese plant, the coliform bacteria counts increase by about 10,000 to 100,000/100 ml. During the warmer months of the year, the dissolved oxygen content below the plant is much less (near zero at times) than above the plant, while during the colder months, there is little change. Water temperatures below the plant are increased about 1°F. during periods of high river discharge and up to 9°F. during periods of low river discharge.

Bowling Green, Maryland, discharges an estimated 180,000 gpd of sewage effluent, after primary treatment, to the North

Branch at about River Mile 25.0. The loading after treatment from the 2,250 persons served is estimated to be 250 pounds of B.O.D. per day. The treatment plant was constructed in 1964 by the Bowling Green Sanitary District.

The Kelly-Springfield Tire Company obtains 2.9 mgd from the North Branch for cooling purposes at River Mile 23.4 and discharges the heated water just downstream. Water for sanitary and boiler use is obtained from Cumberland at an average rate of 1.9 mgd, and the sanitary wastes are discharged to Cumberland sewers. No process wastes are generated at this plant.

The Potomac Edison Company obtains 675 gpd from the North Branch for cooling purposes at River Mile 22.6 and discharges the heated water just downstream. An average of 32,000 gpd are obtained for sanitary and boiler uses from the City of Cumberland. Sanitary wastes are discharged to Cumberland sewers. The effect of the cooling water discharges of the two adjacent plants (Kelly-Springfield and Potomac Edison) is to raise the temperature of the River about 2°F. during high stream flows and up to 6°F. during low stream flows, reaching 88°F. at times.

A pool created by a low dam on the North Branch at River Mile 21.9 provides an adequate depth for the cooling water intakes of the Kelly-Springfield Tire Company and the Potomac Edison Company. The velocity of the River decreases in this pool, permitting suspended solids, including organic matter from the numerous waste-water discharges upstream, to settle out at this point. Conditions are created which permit organic solids to accumulate on the bottom of the pool and decompose at a high rate. Numerous bubbles may be seen breaking at the surface as a result of anaerobic decomposition taking place at the bottom.

The entire sub-reach from New Creek to Wills Creek does not meet the minimum requirements for INCOPOT Class D because of B.O.D. values over 5.0 mg/l, and offensive odors which occur most of the time. The entire sub-reach falls into MDWR Class C because of coliform bacteria concentrations over 10,000/100 ml, B.O.D. values over 7.0 mg/l, and the presence of taste and odor producing substances.

Wills Creek to South Branch (21.7 miles)

Wills Creek, as it enters Maryland from Pennsylvania, carries the untreated domestic wastes from Hyndman, Pennsylvania, a town of 1,124 persons. Hyndman is located approximately 8 river miles above the Maryland State line. The average annual

sediment discharge below Hyndman is 127 tons per square mile, or 18,500 tons per year. Untreated sewage from a portion of Frostburg, Maryland, is discharged into Jennings Run, which enters Wills Creek at River Mile 4.4. The Appalachian Stone Division of the Martin-Marietta Corporation obtains water from Wills Creek at River Mile 4.1 for washing sand and gravel and returns the water to the stream after settling. The Manley Sand Division of the Martin-Marietta Corporation also maintains a similar operation on Wills Creek at River Mile 3.1. La Vale, Maryland, population of 4,031, discharges untreated sewage to Braddock Run, which joins Wills Creek at River Mile 2.3. An interceptor sewer is under construction to transport sewage from Frostburg and La Vale to Cumberland for treatment. Wills Creek has a high capacity for assimilating organic wastes, and the dissolved oxygen concentration near its mouth has been found to be high. Both Jennings and Braddock Runs occasionally show signs of acid mine drainage; however, Wills Creek contains sufficient alkalinity to neutralize considerable amounts of acid. At least part of the time more than trace concentrations of manganese can be found in Wills Creek near the mouth. Wills Creek joins the North Branch Potomac River at River Mile 21.7 within the City of Cumberland, and below the low dam on the North Branch mentioned above.

Ridgeley, West Virginia, discharges untreated sewage from 1,000 persons to the North Branch at about River Mile 21.5. The loading is estimated to be about 170 pounds of B.O.D. per day.

Cumberland, Maryland, discharges sewage effluent from 33,000 persons to the North Branch at River Mile 18.2 after primary treatment. The wastes from several industries, including Cumberland Brewing Company, Cumberland Coca-Cola Bottling Company, Kelly-Springfield Tire Company (sanitary waste only), Liberty Milk Company, Potomac Edison Power Company (sanitary waste only), Potomac Farms Quality Dairy Products, Queen City Brewing Company, and Queen City Cooperative Dairy, Inc., account for the high total waste effluent discharge of 5 0 mgd from the Cumberland sewage treatment plant.

Evitts Creek enters the North Branch at River Mile 17.5. Cumberland obtains its water supply from two reservoirs on Evitts Creek in Pennsylvania at River Miles 14.3 and 13.0. The community of Growdenvale, Maryland, discharges sewage effluent to Evitts Creek from about 65 persons after primary treatment at River Mile 2.0. Evitts Creek is alkaline and has no known water quality problems.

The Pittsburgh Plate Glass Company discharges about 2.0 mgd of industrial wastes to the North Branch at River Mile 11.3

and about 400,000 gpd of sanitary wastes from about 1,200 employees, after primary treatment, at River Mile 11.1. The industrial wastes containing iron oxide and silica oxide are treated with acid to reduce the pH and are settled before discharge.

Past data have shown that the high iron and manganese contents from upstream acid mine drainage and taste, odor, and color from paper-mill wastes persist in the North Branch downstream below Cumberland.

Patterson Creek enters the North Branch from West Virginia at River Mile 9.0. The average annual sediment discharge from Patterson Creek, as measured at Headsville, West Virginia, is 84 tons per square mile, or 18,400 tons per year.

Because of a lack of current water quality data for the North Branch and the Potomac River between Cumberland, Maryland, and Hancock, Maryland (River Mile 237.5), a special study of that reach was made by the Chesapeake Bay-Susquehanna River Basins Project of the Public Health Service in July 1965. At each of the five stations established during the study, four sampling runs were made. Three runs were performed during the daylight hours, and one was performed prior to sunrise to evaluate possible algal activity. The results of that survey are presented in Appendix III. Above the Cumberland sewage treatment plant effluent outfall, at River Mile 19.6, the B.O.D. averaged 1.8 mg/l; dissolved oxygen, 3.6 mg/l; coliform bacteria, 9,900/100 ml (geometric mean); and hardness, 230 mg/l. The dissolved oxygen at 3:00 a.m. (3.2 mg/l) was slightly lower than at 2:30 p.m. of the same day (3.9 mg/l). The water temperature and total dissolved solids averaged 82.8°F. and 450 mg/l, respectively. Average stream flow during the survey was 168 cfs.

Downstream of the Cumberland sewage treatment plant and the Pittsburgh Plate Glass Company industrial waste outfalls, the average total dissolved solids during the special survey increased to 490 mg/l and the total hardness to 250 mg/l, while coliform bacteria count decreased to 2,300/100 ml. Factors explaining the reduced bacterial counts would be the natural die-off in the seven miles of stream between the sampling points, especially in the pool behind a low dam on the North Branch at the Pittsburgh Plate Glass Company, and the diluting effects of stream flows from Evitts Creek and other small tributaries. The B.O.D. dropped slightly to an average of 1.1 mg/l, even though on two sampling runs the change was not significant. There was no change in the average dissolved oxygen concentration (3.6 mg/l) between the two stations. The water temperature dropped an average of 3.6°F. to 79.2°F.; this would be expected because of

artificially elevated water temperatures at the upstream station from industrial cooling water discharges.

A third sampling station in the special survey of July 1965 was located at Oldtown, Maryland, 2.2 miles upstream from the mouth of the North Branch. The coliform bacteria count (2,300/100 ml) was the same as that for the last station upstream (a distance of 9.0 miles). The average B.O.D. increased to 1.7 mg/l, and the average dissolved oxygen concentration increased to 6.2 mg/l. The dissolved oxygen concentration in the middle of the night (5.1 mg/l) was 2.2 mg/l lower than on the same day in the late afternoon (7.3 mg/l), indicating the possible presence of photosynthetic plants. The total dissolved solids averaged 510 mg/l, the total hardness averaged 230 mg/l, and the average water temperature was 80.6°F.

Wills Creek does not meet the minimum requirements for INCOPOT Class D because of B.O.D. concentrations higher than 5.0 mg/l and falls into MDWR Class C because of B.O.D. concentrations above 7.0 mg/l and coliform bacteria counts over 10,000/100 ml. Braddock Run and Jennings Run of Wills Creek have these same classifications because of mine drainage conditions in addition to untreated sewage discharges. Evitts Creek in Maryland, except possibly immediately below the sewage effluent outfall of Growdenvale, may be classified as INCOPOT Class B and MDWR Class A. The North Branch in this sub-reach does not meet the minimum requirements for INCOPOT Class D because of average dissolved oxygen concentrations below 4.0 mg/l in the upper portion and the presence of odors throughout, and falls into MDWR Class C because of the same reasons plus coliform bacteria concentrations over 10,000/100 ml in the upper portion.

II. POTOMAC RIVER, SOUTH BRANCH TO CONOCOCHEAGUE CREEK

Upstream River Mile	285.1	
Downstream River Mile	210.7	
Length of Reach	74.4	miles
Area Draining Directly to Reach	4,782	square miles
Total Drainage Area to Downstream Limit of Reach	6,110	square miles

Summary

The Potomac River is formed 285.1 miles above its mouth by the confluence of the North Branch from Maryland and the South Branch from West Virginia. The North Branch, as it enters the Potomac River, contains iron, manganese, and taste and odor producing substances in greater than trace concentrations. Water of higher quality from large tributaries in West Virginia, including the South Branch and the Cacapon River, provide dilution of these undesirable constituents from the North Branch. At the lower end of the reach, after receiving dilution flows and undergoing self-purification, the quality is good, except that some taste and odor producing substances are still present. Surface run-off and several small communities constitute the only waste sources within this reach. A map of this reach is presented in Figure 13.

South Branch to Tonoloway Creek (47.6 miles)

The South Branch Potomac River, as it joins the North Branch to form the Potomac River at River Mile 285.1, is of a quality suitable for most uses. Normally, the dissolved oxygen content is 80 per cent of saturation or higher, and the B.O.D. is less than 3.0 mg/l. Manganese removal, however, may be necessary to reduce concentrations to satisfy some water uses. The South Branch contains some taste and odor producing substances, but to a lower degree than the North Branch. The average stream discharge of the South Branch (1,253 cfs for a 39-year period of record as measured 13 miles upstream from its mouth) is about 67 per cent of the average discharge of the North Branch (1,867 cfs for a 25-year period), and, therefore, provides considerable

dilution of some constituents in the North Branch, such as iron, color, tastes and odors. The alkalinity of the South Branch normally ranges from 50 to 100 mg/l. The coliform bacteria concentrations of the South Branch usually fall below 2,000/100 ml. The average annual sediment discharge from the South Branch is 107 tons per square mile, or 157,000 tons per year. Comparable sediment figures for the North Branch are 138 tons per square mile, or 225,000 tons per year. While the North Branch contributes more sediment per square mile of tributary area, it also contributes more water in about the same proportion, and thus the suspended solids content of these two rivers is quite comparable.

The town of Paw Paw, West Virginia (River Mile 276.8), discharges about 50,000 gpd of untreated wastes from 750 persons to the Potomac River. A waste stabilization lagoon is under construction, and, after completion, the waste loading discharged to the River is estimated to be about 15 pounds of B.O.D. per day. A reduction in coliform bacteria of about 90 per cent can also be expected.

The average annual sediment discharge of the Potomac River at Paw Paw, West Virginia, is 123 tons per square mile, or 383,000 tons per year.

A previously mentioned survey by the Chesapeake Bay-Susquehanna River Basins Project of the Public Health Service in July 1965, indicated that the dissolved oxygen concentration of the Potomac River at Paw Paw, West Virginia (River Mile 276.5), averaged 6.9 mg/l; the B.O.D., 1.3 mg/l; the total dissolved solids, 320 mg/l; the total hardness, 150 mg/l; and the coliform bacteria concentration, 9,500/100 ml. The sewage outfall at Paw Paw, located 0.3 mile upstream of the sampling station, may have some influence on the coliform concentrations. The average stream flow at Paw Paw during the survey was 597 cfs, as compared to a long-term average of 3,120 cfs (25 years of record).

Most of the drainage area of the Potomac River within this sub-reach is covered by forests. Farm land occurs intermittently.

The Cacapon River joins the Potomac River from West Virginia at River Mile 247.9. Available data indicate that the water quality of the Cacapon River is excellent for most uses. The average stream discharge of the Cacapon River (564 cfs for a 40-year period of record, measured 6.5 miles from the mouth) is only about 16 per cent of the annual average stream discharge of the Potomac River (3,435 cfs for a 31-year period) just upstream from their confluence; thus, in general, a slight

improvement of water quality in the Potomac River by the dilution could be expected. The dissolved oxygen concentration in the Cacapon River seldom falls below 90 per cent of saturation, and the B.O.D. is normally below 3.0 mg/l. Coliform bacteria are generally below 1,000/100 ml, and the suspended solids concentrations generally are less than 50 mg/l. Total solids are normally less than 150 mg/l, and turbidity is less than 10 standard scale units. The average annual sediment discharge of the Cacapon River is 64 tons per square mile, or 43,600 tons per year, about one-half of the areal rate in the Potomac River Basin above Paw Paw.

The most downstream station of the special Public Health Service survey of July 1965 was at Hancock, Maryland (River Mile 239.1). The Potomac River at that point (37.4 miles from the next upstream station) had an average dissolved oxygen concentration of 7.6 mg/l. The dissolved oxygen concentration of 6.8 mg/l at 7:00 a.m. was 2.0 mg/l lower than the 8.8 mg/l found at 5:00 p.m. on the same day, indicating the possible presence of photosynthetic aquatic plants. The B.O.D. averaged 1.0 mg/l; total dissolved solids, 300 mg/l; the total hardness, 140 mg/l; and the mean coliform bacteria count was 2,300/100 ml. The stream flow at Hancock during the survey averaged 907 cfs and at Paw Paw was 597 cfs. The U. S. Geological Survey has determined the travel time between Paw Paw and Hancock at 1,010 cfs (measured at Paw Paw) to be 48.6 hours, a velocity of 0.78 miles per hour. The average stream flow of the Potomac River at Hancock is 3,999 cfs (31 years of record).

Hancock, Maryland, a city of 2,000 persons, obtains its water supply (200,000 gpd) from Little Tonoloway Creek about one mile above its confluence with the Potomac River at River Mile 238.8 and maintains an emergency pump on the Potomac River at River Mile 239.0. No recent samples of the Potomac River supply at Hancock have been taken, although the Little Tonoloway Creek supply is reported to contain about 200 mg/l of hardness and about 180 mg/l of alkalinity.

Warm Springs Run, as it enters the Potomac River from West Virginia at River Mile 238.3, receives untreated sewage from over 700 persons at Berkeley Springs, West Virginia, 7.0 miles upstream, and industrial and sanitary wastes from the Pennsylvania Glass Sand Company, 4.0 miles upstream. The Pennsylvania Glass Sand Company employs about 225 persons. These industrial wastes of about 180,000 gpd, with high concentrations of suspended solids, are treated by settling. Before the recent construction of a settling basin at the plant, suspended solids concentrations of about 10,000 mg/l were found in Warm Springs

Run. The degree of reduction of suspended solids by the present treatment has not been established.

The Potomac River in the upper portion of this sub-reach may be classified as INCOPOT Class D because of mean coliform bacteria counts over 5,000/100 ml and the presence of taste and odor producing substances, and MDWR Class C because of the presence of taste and odor producing substances. After self-purification and dilution, the lower portion of the sub-reach may be classified as INCOPOT Class C because of mean coliform bacteria counts between 500 and 5,000/100 ml, and MDWR Class B because of mean coliform bacteria counts between 2,000 and 10,000/100 ml (assuming for both classifications that taste and odor producing substances are present only occasionally). Little Tonoloway Creek may be classified as INCOPOT Class B and MDWR Class A.

Tonoloway Creek to Conococheague Creek (26.8 miles)

Tonoloway Creek enters the Potomac River at River Mile 237.5. The City of Hancock discharges about 150,000 gpd of sewage effluent from 2,000 persons, after treatment by waste stabilization lagoon, to Tonoloway Creek at about River Mile 0.8. An additional 200 persons at Hancock discharge untreated sewage to the Creek. The estimated total organic loading to the Creek is about 80 pounds of B.O.D. per day.

Back Creek, which enters the Potomac River at River Mile 225.9, from West Virginia, has an average annual sediment discharge of 51 tons per square mile, or 12,400 tons per year. Back Creek receives untreated sewage from about 500 persons throughout its drainage area, but these wastes are stabilized to negligible levels before the Creek reaches the Potomac River. A sand and gravel operation on Back Creek does not appear to impair water quality.

Much of the drainage area to this sub-reach is covered by forests with intermittent farm land.

This sub-reach down to Back Creek has been clouded and covered with silt fines from Warm Springs Run (River Mile 238.3). Since the construction of the settling basin at the glass-sand plant on Warm Springs Run, the present concentration of suspended solids is unknown.

The City of Hagerstown, Maryland, obtains most of its water supply from the Potomac River at River Mile 212.0. This source serves 57,000 persons, while mountain springs serve an

additional 28,000 persons. The Potomac source is treated to control tastes and odors.

The only current water quality data available for this sub-reach are those obtained for the Public Health Service Water Pollution Surveillance System at Williamsport, Maryland, in cooperation with the Hagerstown Water Department. Periodic samples are taken above the water supply intake at River Mile 212.5. Five years of data (1960 - 1965) from that station have been analyzed, and a summary of the results is presented in Appendix IV. These analyses include 35 observations for dissolved oxygen, 36 for B.O.D., 180 for coliform bacteria, 197 for pH, intermediate numbers for other indicators, and 8 observations for C.O.D. (chemical oxygen demand). The summary shows that the monthly average dissolved oxygen concentration reached a minimum of 7.5 mg/l in August, with the minimum individual observation of 6.0 mg/l also occurring in August. The monthly average B.O.D. reached a maximum concentration of 1.3 mg/l in September and November, with a maximum individual value of 2.6 mg/l occurring in November. The maximum monthly mean coliform bacteria concentration was reported as 590/100 ml.

The monthly average water temperatures of the Potomac River at Williamsport range from 35.2°F. in January to 77.2°F. in July, with the maximum individual value of 82.0°F. having occurred in July. The maximum individual determination of gross beta radioactivity of 141 pc/l (picocuries per liter, a picocurie being one-millionth of a microcurie, or commonly called a micro-microcurie), the maximum monthly (February) average of 43 pc/l, and the annual average of 19 pc/l, are all well under the maximum permissible concentration of 1,000 pc/l for mixtures of unknown radionuclides.

As noted in the preceding discussion, current water quality data for this sub-reach are minimal; however, based upon the known quality of water at Williamsport, Maryland (River Mile 212.5), the sub-reach may be classified as INCOPOT Class C because of monthly mean coliform bacteria counts between 500 and 5,000/100 ml, and MDWR Class A because of monthly mean coliform bacteria counts between 100 and 2,000/100 ml. Taste and odor producing substances occur only occasionally.

III. POTOMAC RIVER, CONOCOCHEAGUE CREEK TO LITTLE FALLS

Upstream River Mile	210.7	
Downstream River Mile	116.1	
Length of Reach	94.6	miles
Area Draining Directly to Reach	5,470	square miles
Total Drainage Area to Downstream Limit of Reach	11,580	square miles

Summary

The waters of the Potomac River from Conococheague Creek to Little Falls are moderately hard (annual averages between 100 mg/l and 125 mg/l). Monthly mean coliform bacteria concentrations generally exceed 2,000/100 ml immediately below major tributaries, and die-off to lower values between these tributaries. Maximum monthly mean coliform bacteria concentrations of 9,000/100 ml occur at Point-of-Rocks, Maryland, and then decrease to 3,900/100 ml at Great Falls, Maryland. These maximum values commonly occur at high stream flows, indicating that surface drainage may be a principal source of the bacteria. Average monthly dissolved oxygen concentrations in the Potomac River are generally above 6.0 mg/l, but fall to about 3.0 mg/l at times. Two thermo-electric generating stations (at Williamsport, Maryland, and just downstream from the Monocacy River) raise the temperature of the Potomac River by several degrees (F.), but there appears to be no serious effect on water quality. Manganese is present in concentrations which may require removal for some uses in upstream portions of this reach, but is diluted to insignificant levels downstream. Tastes and odors are present at times in municipal water supplies drawn from this reach. Several tributaries of the Potomac River in this reach have degraded water quality because of municipal and/or industrial waste discharges. Conococheague Creek contains taste and odor producing substances and hardness concentrations of about 180 mg/l. Antietam Creek contains moderate concentrations of coliform bacteria, is low in dissolved oxygen below Hagerstown (1.0 mg/l at times), and has a hardness from 190 mg/l upstream to 225 mg/l downstream. The Monocacy River has been found to have low concentrations of dissolved oxygen just below the Pennsylvania State line and below Frederick, Maryland, and at times to contain taste

and odor producing substances. A map of this reach of the Potomac River is presented in Figure 14.

Conococheague Creek to Antietam Creek (30.5 miles)

Conococheague Creek, upstream of the Maryland-Pennsylvania State line, receives, following secondary treatment, 100,000 gpd from 850 persons at the Scotland Orphanage and 300,000 gpd from 2,700 persons at the Dixon TB Hospital in Pennsylvania; 3,000,000 gpd of secondary sewage plant effluent from 22,000 persons at Chambersburg, Pennsylvania; 500,000 gpd of canning wastes from the H. J. Heinz Company, and 25,000 gpd from Path Valley Esso at Chambersburg, both after secondary treatment; 220,000 gpd of secondary effluent from 2,300 persons at Mercersburg, Pennsylvania; 220,000 gpd of tannery wastes from Lowengart and Company at Mercersburg, after primary treatment; 125,000 gpd of secondary effluent from 4,000 persons at Greencastle, Pennsylvania; and 12,000 gpd of meat packing wastes from the Greencastle Packing Company at Greencastle, after secondary treatment. Although data are limited, Conococheague Creek appears to be of good quality with respect to dissolved oxygen (greater than 6.5 mg/l) and B.O.D. content (less than 1.5 mg/l) as it enters Maryland. However, substances producing tastes and odors are present, hardness is about 180 mg/l, and the alkalinity is about 160 mg/l. The W. D. Byron and Sons Tannery at Williamsport, Maryland, obtains 210,000 gpd of water from Conococheague Creek at River Mile 0.4, 84,000 gpd from a spring, and 66,000 gpd from Williamsport, and discharges 300,000 gpd of process wastes to the Creek at River Mile 0.3 after screening, neutralization, aeration, and settling. Conococheague Creek, as it enters the Potomac River at River Mile 210.7, has a hardness of about 150 mg/l, alkalinity of about 130 mg/l, and taste and odor producing substances. Conococheague Creek, as measured at Fairview, Maryland, 18 miles upstream of its mouth, discharges a relatively high average annual sediment load of 217 tons per square mile, or 107,000 tons per year.

The Potomac Edison Company, R. Paul Smith Station, obtains an average of 72.0 mgd of cooling water plus 42,000 gpd for boiler and other uses from a low dam on the Potomac River at River Mile 210.6, just below the entry of Conococheague Creek, and returns the used waters to the Potomac River just downstream. The maximum usages during hot weather are 192.0 mgd for cooling and 641,000 gpd for boiler and other uses. Fly ash is removed from wash waters by settling before discharge. The rise in temperature of the Potomac River is not pronounced, usually being no more than 3.0°F.

Williamsport, Maryland, discharges 30,000 gpd of sewage effluent from 1,900 persons, after primary treatment, to the Potomac River at River Mile 210.3. The organic waste loading is about 210 pounds of B.O.D. per day.

The water quality of the Potomac River is affected by the Conococheague Creek waters and the sewage effluent discharge from Williamsport, but not to a point causing nuisance conditions because of the large amounts of dilution afforded by the Potomac. The stream flow of Conococheague Creek at Fairview, Maryland, 18.0 miles upstream of its mouth, averaged 561 cfs over 35 years, as compared to 3,999 cfs over 31 years for the Potomac River at Hancock, Maryland. Generally, the maximum B.O.D. in the Potomac River increases from 1.0 mg/l upstream of Conococheague Creek to about 1.5 mg/l downstream of the Creek and Williamsport; the annual average alkalinity increases from about 50 mg/l upstream to about 100 mg/l downstream; and the maximum monthly coliform bacteria counts increase from about 600 to about 2,000/100 ml. Limited data are available on dissolved oxygen concentration; however, it appears that the dissolved oxygen concentration decreases slightly from 85 per cent saturation upstream to about 80 per cent saturation downstream much of the time during warm weather. Dissolved oxygen concentrations are near saturation during some days downstream to Conococheague Creek and Williamsport. This may be the result of photosynthesis by growths of plant life stimulated by nutrients in the tannery wastes (typically high in nitrogen content), and in the Williamsport sewage effluent. Night-time sampling would be necessary to determine daily minimum concentrations of dissolved oxygen. The Potomac River below Conococheague Creek and Williamsport has a hardness of approximately 125 mg/l, and contains some taste and odor producing substances.

The E. I. DuPont de Nemours and Company explosives plant at Falling Waters, West Virginia, discharges 10,000 gpd of sanitary wastes from 420 persons, after intermediate (approximately 50 per cent B.O.D. removal) treatment, and 500,000 gpd of industrial wastes to the Potomac River at River Mile 205.4. The industrial waste loading is unknown. Nitrogenous substances are typical of this type of industrial waste.

Opequon Creek enters the Potomac River from West Virginia at River Mile 202.0. Opequon Creek and its tributaries receive 2.5 mgd of sewage effluent from Winchester, Virginia, after secondary treatment; 300,000 gpd of canning wastes from the Musselman Canning Company in Inwood, West Virginia, after intermediate (approximately 60 per cent B.O.D. reduction) treatment; 2.5 mgd of sewage effluent from 12,000 persons at Martinsburg, West Virginia,

after secondary treatment; and a total of about 750,000 gpd of industrial wastes from the National Fruit Company, Interwoven Company, Standard Lime and Stone Company, and Blair Limestone Company at Martinsburg, none of whose waste loadings are known. Below Martinsburg, Opequon Creek has a B.O.D. of approximately 3.0 mg/l, with values at times greater than 5.0 mg/l. The hardness is about 250 mg/l, alkalinity about 225 mg/l, and coliform bacteria frequently exceed 10,000/100 ml. Dissolved oxygen concentrations fall to 3.5 mg/l at Martinsburg during warmest periods with corresponding low stream discharges, but lower D.O. values may occur between this point and the confluence with the Potomac, 8.3 miles downstream. Opequon Creek, near Martinsburg, has a moderate average annual sediment discharge of 97 tons per square mile, or 26,400 tons per year. The stream flow added to the Potomac River by the Opequon is relatively small (204 cfs average over 16 years at Martinsburg, as compared to a 3,999 cfs average over 31 years on the Potomac River at Hancock), so that the water quality of the Potomac River is not seriously affected by the lower quality water from Opequon Creek.

Shepherdstown, West Virginia, obtains its water supply from the Potomac River at River Mile 183.6 and provides spray aeration to remove tastes and odors during the treatment process. The Potomac River at Shepherdstown has a hardness of about 125 mg/l and an alkalinity of about 100 mg/l. Coliform bacteria concentrations are generally less than 2,000/100 ml. Dissolved oxygen concentrations are normally greater than 6.5 mg/l and fall below 5.0 mg/l only rarely during the warmest weather. B.O.D. levels average about 1.5 to 2.0 mg/l at this point.

Shepherdstown discharges 150,000 gpd of untreated sewage from 2,000 persons at about River Mile 183.0. The loading is estimated to be 340 pounds of B.O.D. per day.

Conococheague Creek may be classified as INCOPOT Class D and MDWR Class C because of taste and odor producing substances. The taste and odor problem is moderate above Williamsport but great below Williamsport. The Potomac River in this sub-reach may be classified as INCOPOT Class D because of dissolved oxygen concentrations below 5.0 mg/l and the presence of taste and odor producing substances, and MDWR Class B because of dissolved oxygen concentrations between 3.0 and 5.0 mg/l, with an average of about 4.0 mg/l.

Antietam Creek to Monocacy River (26.7 miles)

Antietam Creek, as it enters Maryland from Pennsylvania at River Mile 37.0, contains 1.2 mgd of secondary sewage effluent

from 11,000 persons at Waynesboro, Pennsylvania; 21,000 gpd of secondary sewage effluent from 350 persons at the E. U. B. Orphanage in Pennsylvania; and 140,000 gpd of secondary sewage effluent from 1,500 military residents plus 280 civilian employees at Fort Ritchie (National Guard), Maryland. The average of six samples taken in September and October of 1958 just below the State line showed that the water quality was good with respect to dissolved oxygen concentration (7.8 mg/l) and B.O.D. (1.5 mg/l). Antietam Creek at that point had a hardness and an alkalinity of 186 mg/l and 162 mg/l, respectively, and a coliform count of 8,100/100 ml. Hagerstown obtains part of its water supply from mountain springs of high quality in the headwaters of Little Antietam Creek (the more northernly of the two Little Antietam Creeks). Marquette Cement Manufacturing Company at Security, Maryland, obtains 8.1 mgd of water from Antietam Creek at River Mile 27.0 and discharges 7.8 mgd of cooling water at River Mile 26.8. The Fairchild Stratos Corporation discharges about 30,000 gpd of sanitary wastes from 4,600 employees, after secondary treatment, and 50,000 gpd of cooling water to the West Branch of Marsh Run, about 5.0 miles upstream from the confluence of Marsh Run with Antietam Creek at River Mile 26.4. The Municipal Electric Light Plant obtains an average of 33.4 mgd of cooling water and a maximum of 62.2 mgd from a low dam impoundment on Antietam Creek at River Mile 23.8 and discharges the used cooling water just downstream. The Western Maryland Railway Company discharges 150,000 gpd of engine and railroad car cleaning wastes, after settling and oil removal, to a small tributary at Hagerstown, Maryland, which enters Antietam Creek at River Mile 23.7. Potomac Creamery Company discharges an unknown quantity of cooling water to a branch of that same small tributary. Hagerstown discharges about 3.8 mgd of secondary sewage effluent from 36,000 persons to Antietam Creek at River Mile 22.6. Sampling upstream and downstream of the effluent outfall shows that under average stream flow conditions (265 cfs average over 40 years at Sharpsburg, Maryland), the B.O.D. increases from about 1.0 mg/l above the outfall to about 2.5 mg/l below the outfall; the dissolved oxygen concentration decreases from about 98 per cent to about 30 per cent of saturation in hot weather. Coliform bacteria concentrations increase from 500 to 3,000/100 ml. The alkalinity below the Hagerstown outfall ranges from 150 to 200 mg/l. Funkstown, Maryland, discharges to Antietam Creek at River Mile 21.4 about 75,000 gpd of wastes from 970 persons, after treatment by a stabilization lagoon. The Maryland State Reformatory for Males at Breathedsville, Maryland, discharges 125,000 gpd of secondary sewage effluent from 1,250 persons to Antietam Creek at River Mile 12.4. Boonsboro, Maryland, discharges 120,000 gpd of sewage effluent from 1,200 persons after treatment by a waste stabilization lagoon, to a tributary of Little Antietam Creek (southern). Boonsboro obtains

its water supply from Gilardi Run of Little Antietam Creek (southern) and from several springs. Keedysville, Maryland, does not have a municipal sewerage system but is estimated to discharge about 47,000 gpd of untreated sewage from 320 persons through individual and small sewerage systems to Little Antietam Creek (southern) about 1.0 mile above its confluence with Antietam Creek. The total organic loading from these four discharges is about 140 pounds of B.O.D. per day. Untreated sewage from small collection systems in a portion of Sharpsburg, Maryland, discharges to Antietam Creek. Antietam Creek near Sharpsburg, Maryland, has a high average annual sediment discharge of 193 tons per square mile, or 54,200 tons per year. Although no recent water quality data are available on Antietam Creek except at Hagerstown, the results of six samples taken in September and October of 1958 showed that dissolved oxygen concentrations remained high throughout Antietam Creek, even with B.O.D. loadings higher than at present. The hardness near the mouth was about 225 mg/l, and the alkalinity about 175 mg/l.

Harpers Ferry, West Virginia, discharges untreated sewage from 250 persons to the Potomac River and the Shenandoah River at their confluence.

The Shenandoah River enters the Potomac River from West Virginia at River Mile 171.5 and transports the residual of municipal wastes and industrial wastes of a wide variety from Virginia and West Virginia. The Shenandoah River at Millville, West Virginia, has a moderate average annual sediment discharge of 120 tons per square mile, or 365,000 tons per year. The Public Health Service has maintained a station of the National Water Pollution Surveillance System at Berryville, Virginia, since June 1961, in cooperation with the U. S. Army Corps of Engineers. Mineral analyses were performed weekly for a total of about 150 observations through February 1965, while smaller numbers of observations were made for dissolved oxygen (73), B.O.D. (39), and certain other indicators. This station is about 25 miles upstream of the mouth of the Shenandoah River and, therefore, does not show the effects of several downstream waste discharges in West Virginia. However, by considering the sampling results at Berryville along with the results of samples obtained in September and October of 1958 at the mouth of the Shenandoah River, a reasonable description of the water quality of the Shenandoah River entering the Potomac River may be given. The 48-year average stream flow of the Shenandoah River at Millville, West Virginia, 5.0 miles upstream from its mouth, is 2,677 cfs, as compared with an average flow (including the Shenandoah River) of the Potomac River at Point-of-Rocks, Maryland, of 9,215 cfs over 68 years of record. The results from the analysis of approximately three and one-half

years of sampling at Berryville are briefly summarized in Appendix IV. This analysis indicates that the monthly average dissolved oxygen concentrations reached a minimum of 7.2 mg/l in July, with the lowest observed concentration of 5.1 mg/l occurring in August. In the month of August, the monthly average B.O.D. reached a maximum concentration of 5.1 mg/l, and a maximum individual value of 6.7 mg/l was observed. The maximum monthly mean coliform bacteria concentration of 300/100 ml occurred in October. Recent results of sampling by the Interstate Commission on the Potomac River Basin at West Virginia Highway 9, about six miles from the mouth of the Shenandoah River, showed that the mean coliform counts for individual months reached as high as 6,300/100 ml.

The monthly average water temperatures of the Shenandoah River at Berryville ranged from 35.7°F. in January to 77.7°F. in July, with the maximum individual value of 82.4°F. occurring in July. The maximum monthly average hardness of 181 mg/l occurred in October (at lowest flows) as did the maximum individual value of 240 mg/l; the annual average hardness concentration appears to be approximately 146 mg/l. The maximum individual determination of gross beta radioactivity of 136 pc/l (picocuries per liter), the maximum monthly (March) average of 70 pc/l, and the annual average of 37 pc/l, are all well under the maximum permissible concentration of 1,000 pc/l for mixtures of unknown radionuclides. Other constituents measured were well within acceptable limits. Samples obtained in 1958 at the mouth indicate that iron, manganese, and taste and odor producing substances were present in concentrations which may require treatment prior to satisfying some water uses. Monthly sampling of the Shenandoah River at River Mile 7.4 in 1963 by the West Virginia Department of Natural Resources, indicated that the quality was essentially the same as at Berryville, except that higher B.O.D. concentrations (up to 6.9 mg/l in June) were found.

The Baltimore and Ohio Railroad locomotive maintenance shop at Brunswick obtains its water supply from the Potomac River at River Mile 165.5 and discharges the waste cleaning waters, after settling and oil removal, at River Mile 165.3.

Brunswick, Maryland, discharges about 250,000 gpd of sewage effluent from 3,700 persons, after primary treatment, to the Potomac River at River Mile 165.2. This loading amounts to about 410 pounds of B.O.D. per day when the treatment plant is operating efficiently. The Maryland State Department of Health has recommended replacement of the treatment plant.

Catoctin Creek, Maryland (Catoctin Creek of Virginia is discussed in the following section), enters the Potomac River at River Mile 162.4. Myersville, Maryland, discharges 25,000 gpd of sewage effluent from 450 persons, after primary treatment, to Catoctin Creek at about River Mile 24.7. The loading from Myersville is about 50 pounds of B.O.D. per day. Myersville obtains its water supply from springs along Broad Run, which enters Catoctin Creek at River Mile 5.8, and provides only chlorination. Middletown, Maryland, discharges 60,000 gpd of sewage effluent from 1,100 persons, after primary treatment, to Catoctin Creek at about River Mile 15.4. The loading from Middletown is about 120 pounds of B.O.D. per day. Catoctin Creek near Middletown has a low average annual sediment discharge of 47 tons per square mile, or 31,200 tons per year. While no recent water quality data are available for Catoctin Creek, the results from six samples taken in September and October of 1958 indicated that the hardness and alkalinity were quite low, being 55 and 50 mg/l, respectively.

Catoctin Creek, Virginia, enters the Potomac River at River Mile 159.8. Catoctin Creek receives about 105,000 gpd of sewage effluent from 850 persons, after primary treatment, at Purcellville, Virginia, about 110,000 gpd of meat packing wastes from J. Lynn Cornwell, Inc., at Purcellville, and untreated sewage from individual or small collection systems at Lovettsville, Virginia.

At Point-of-Rocks, Maryland (River Mile 159.5), the Potomac River has an average stream discharge of 9,215 cfs (68 years of record); however, the range of stream discharges is great, with fluctuations often occurring rapidly. During lower stream discharges, the Potomac River at Point-of-Rocks is moderately hard (150 mg/l at 2,000 cfs), while at high stream discharges, hardness is low (60 mg/l at 50,000 cfs and higher). The average annual sediment discharge is 113 tons per square mile, or 1,090,000 tons per year. The sediment discharge varies greatly throughout the year here, as at most locations in the Basin. In 1962, the monthly sediment discharge ranged from 295 tons in September to 601,653 tons in March. Even during low stream discharges (about 1,500 cfs), and at highest temperatures, the monthly average dissolved oxygen concentrations do not fall below about 6.0 mg/l. Monthly average B.O.D. concentrations range between 1.0 and 6.1 mg/l, with an annual average concentration of 2.5 mg/l. Generally, the higher B.O.D. concentrations occur at higher flows during the winter and early spring, while lower concentrations occur at lower flows during the summer. The highest coliform bacteria concentrations at Point-of-Rocks occur during the high flows of winter and spring (mean of 9,000/100 ml for January - June for

three years), while the lowest coliform bacteria concentrations occur during the low flows of summer and early fall (mean of 2,300/100 ml for July - October for three years). This relationship between coliform bacteria concentration and stream discharge is under special study by the Interstate Commission on the Potomac River Basin. The washing of pastures and barnyards by heavy rainfall is suspected as a source of the high concentrations.

Antietam Creek, upstream from Hagerstown, may be classified as INCOPOT Class C and MDWR Class B because of monthly mean coliform bacteria concentrations above 5,000/100 ml. Antietam Creek downstream from Hagerstown may be classified as INCOPOT Class D and MDWR Class C because of average dissolved oxygen concentrations below 4.0 mg/l. Even though current water quality data are not available for the Potomac River between Antietam Creek and the Shenandoah River, the classifications may be assumed to be the same as those for the sub-reach immediately upstream (discussed in the previous section); i.e., INCOPOT Class D and MDWR Class B. The Potomac River between the Shenandoah River and the Monocacy River may be classified as INCOPOT Class D because of average B.O.D. concentrations above 3.0 mg/l, coliform bacteria concentrations greater than 5,000/100 ml, and the presence of taste and odor producing substances, and MDWR Class C because of monthly average B.O.D. concentrations over 6.0 mg/l, coliform bacteria concentrations over 10,000/100 ml, and the presence of taste and odor producing substances. In the absence of current water quality data for Catoctin Creek, it can be classified as INCOPOT Class D and MDWR Class B because of coliform bacteria concentrations over 5,000/100 ml found in 1958.

Monocacy River to Little Falls (37.4 miles)

The Monocacy River enters the Potomac River at River Mile 153.5 and has an average stream discharge (886 cfs over 34 years, as measured near Frederick, Maryland) of about 10 per cent of that of the Potomac River upstream (9,215 cfs over 68 years at Point-of-Rocks, Maryland). Rock Creek joins Marsh Creek at the Pennsylvania State line to form the Monocacy River at River Mile 52.5. Results of six samples from Rock Creek, taken in September and October of 1958, indicate an average B.O.D. of 4.6 mg/l, an average alkalinity of 122 mg/l, hardness of about 125 mg/l, and a mean coliform bacteria concentration of 2,900/100 ml. Dissolved oxygen concentrations averaged 4.5 mg/l, with a minimum of 1.5 mg/l found on one occasion. Waste effluents discharged to the Monocacy River drainage area in Pennsylvania are 750,000 gpd from 10,000 persons, after secondary treatment, at Gettysburg; 160,000 gpd from 2,800 persons, after secondary treatment, at Littlestown;

and 108,000 gpd of inorganic wastes from the Funkhouser Company, after settling in lagoons. The results from other sampling in the Monocacy River drainage area in 1958 are generally not applicable at present because of changes in waste treatment and populations, except for hardness, which was about 100 mg/l in stream reaches downstream from the State line, and alkalinity was 80 mg/l. The headwaters of several tributaries of the Monocacy River serve as water supplies for several communities and receive only chlorination. Piney Creek, which enters the Monocacy River at River Mile 45.3, receives about 150,000 gpd of sewage effluent from 1,500 persons, after secondary treatment, from Taneytown, Maryland; 22,000 gpd of cooling water from Cambridge Rubber Company; and 10,000 gpd of cooling water from A. W. Feeser and Company, both at Taneytown. The loading from the City of Taneytown is estimated to be 38 pounds of B.O.D. per day. The Toms Creek drainage basin, which drains to the Monocacy River at River Mile 43.9, receives 35,000 gpd of sewage effluent from 200 persons, after secondary treatment, at the Victor Cullen State Hospital, Sabillasville, Maryland; 250,000 gpd from 2,600 persons, after secondary treatment, at Emmitsburg, Maryland; 50,000 gpd from 600 persons, after treatment by waste stabilization lagoon following primary treatment, at Mount St. Mary's College at Emmitsburg; and 70,000 gpd from 900 persons, after primary treatment, at Mount St. Joseph's Academy at Emmitsburg. The total organic waste discharge to the Toms Creek drainage area is estimated to be about 200 pounds of B.O.D. per day. The Double Pipe Creek drainage basin, which enters the Monocacy River at River Mile 38.3, receives 40,000 gpd of milk-processing wastes from the Willow Farms Dairy; about 750,000 gpd of sewage effluent from 8,000 persons, after secondary treatment, at Westminster, Maryland; 20,000 gpd of steam condensate from the distillation of wormseed oil at the George W. Magin Company; 55,000 gpd of sewage effluent from 700 persons, after secondary treatment, at New Windsor, Maryland; and 65,000 gpd from 800 persons, after treatment by waste stabilization lagoon, at Union Bridge, Maryland. The total organic waste loading to the Double Pipe Creek drainage area is estimated to be about 250 pounds of B.O.D. per day.

The Maryland State Department of Health sampled the Monocacy River for four days in September 1964. At River Mile 32.9, which is 5.4 miles downstream from Double Pipe Creek, the B.O.D. averaged 1.4 mg/l. The dissolved oxygen concentration averaged 8.6 mg/l, with a minimum of 8.0 mg/l, and the mean coliform bacteria concentration was 850/100 ml. Hunting Creek, which enters the Monocacy River at River Mile 31.6, or its tributaries, receive 55,000 gpd of sewage effluent from 675 persons, after secondary treatment, at Thurmont, Maryland; 18,000 gpd of meat-

packing wastes, after primary treatment, from Howard Late and Company at Thurmont; and 9,000 gpd of meat-packing wastes, after treatment by waste stabilization lagoon, from Fraley's Meats at Catoctin Furnace, Maryland. The total waste loading to the Hunting Creek drainage area is estimated to be 150 pounds of B.O.D. per day. The results of four samples taken in September 1964, by the Maryland State Department of Health, from the Monocacy River at River Mile 28.2 (3.4 miles downstream from Hunting Creek) indicated an average B.O.D. of 1.0 mg/l, an average dissolved oxygen concentration of 8.8 mg/l, and a mean coliform bacteria concentration of 750/100 ml. Thus, even with the added waste loading from Hunting Creek, the dissolved oxygen concentration remained high, and the B.O.D. and coliform bacteria concentrations decreased from values found at the upstream sampling station. A slope of about 4.0 feet per mile aids in the self-purification of this stream. The slope downstream from this point decreases to 2.2 feet per mile. During the same survey, the dissolved oxygen content of the Monocacy River increased to an average of 8.9 mg/l at River Mile 25.2 and to an average of 10.2 mg/l at River Mile 22.4, while the B.O.D. concentration increased to an average of about 1.3 mg/l at these two stations. The mean coliform bacteria concentration decreased to 340/100 ml at River Mile 25.2 and increased to 880/100 ml at River Mile 22.4. The increase in coliform concentration at River Mile 22.4 is attributed to waste discharges from individual and small sewerage systems at Walkersville, Maryland (estimated to be 85,000 gpd from 680 persons), and other small communities in the vicinity.

Frederick, Maryland, and Fort Detrick, Maryland, obtain water supplies from the Monocacy River at River Mile 20.4. Taste and odor control are practiced at each treatment facility. A sample of raw water from the Frederick supply, taken by the Maryland State Department of Health in July 1962, contained 88 mg/l hardness, 73 mg/l alkalinity, 144 mg/l total dissolved solids, 9.3 mg/l chlorides, 2.0 mg/l nitrates, 0.2 mg/l iron, and had a turbidity of 10 units, color of 18 units, and a pH of 8.2. Ideal Farms Dairy discharges 4,000 gpd of cooling water to Detrick Creek, which enters the Monocacy River at River Mile 20.1. Fort Detrick discharges 650,000 gpd of sewage effluent after secondary treatment to the Monocacy River at River Mile 19.7. Waste discharges from Fort Detrick average 15 pounds of B.O.D. per day, indicating a high degree of treatment (about 95 per cent removal).

Carroll Creek, which flows through the City of Frederick and enters the Monocacy River at River Mile 18.8, receives 94,000 gpd of neutralized plating wastes from the Everedy Company; an unknown quantity of cooling waters from Jenkins Brothers; unknown

quantities of cooling water from the Corning Packaging Company; and an unknown quantity of condenser cooling water from Fort Detrick. A survey of Carroll Creek in 1961 by the Maryland Water Pollution Control Commission indicated the dissolved oxygen content to be high both in the winter (range of 10.1 to 12.3 mg/l) and in the summer (range of 8.6 to 14.0 mg/l). Obviously, photosynthesis brought about supersaturated dissolved oxygen conditions at times during the summer. The B.O.D. ranged from 0.6 to 5.4 mg/l. Large quantities of trash and refuse in the Creek were reported. The Monocacy River at Jug Bridge near Frederick has a very high average annual sediment discharge of 327 tons per square mile, or 267,000 tons per year.

The City of Frederick discharges 3.8 mgd of secondary sewage effluent from 24,500 persons to the Monocacy River at River Mile 18.7. The wastes treated at the sewage treatment plant include dairy, poultry, meat-packing, and cannery wastes. Even with a high degree of treatment (average of about 90 per cent), the waste loading after treatment during the canning season in September 1964, was found to be 1,200 pounds of B.O.D. per day. The Maryland Cooperative Milk Producers discharges 2,000 gpd of wastes from its milk receiving station at Unionville, Maryland, to the North Fork of Linganore Creek. Linganore Creek enters the Monocacy River at River Mile 16.3. The Maryland State Department of Health survey in September 1964 found the following average concentrations in the Monocacy River at River Mile 15.6 (3.1 miles downstream of the Frederick effluent outfall): dissolved oxygen of 1.0 mg/l (minimum of 0.1 mg/l), B.O.D. of 3.4 mg/l (maximum of 4.5 mg/l), and coliform bacteria of 2,400,000/100 ml. The average dissolved oxygen concentration increased rapidly to 6.8 mg/l at River Mile 12.9 and was found to be 8.5 mg/l at River Mile 1.8. The B.O.D. decreased to an average of 2.2 mg/l at River Mile 1.8, and the coliform bacteria decreased to 830/100 ml at that point. Examination of three years of data from the Interstate Commission on the Potomac River Basin network station near the mouth of the Monocacy River shows that the monthly average dissolved oxygen content at that point ranged from 6.4 mg/l in August to 12.3 mg/l in February. The average B.O.D. concentration ranged from 1.2 mg/l in September to 4.6 mg/l in February, and the mean coliform bacteria concentration ranged from 1,300/100 ml in September to 36,000/100 ml in March.

The Potomac Electric Power Company obtains an average of 355 mgd and a maximum of 415 mgd from the Potomac River at River Mile 152.4 for the Dickerson Generating Station in Maryland, and discharges the heated waters after use at River Mile 152.1.

Sanitary wastes from 81 employees are given secondary treatment before discharge at the same point. The Academy of Natural Sciences of Philadelphia (Pennsylvania) performed extensive biological and chemical surveys of the Potomac River upstream and downstream of the Station in 1956, 1960, and 1961 to determine the effects of the heated waste discharges on the River. These surveys were performed both before and after initial operation (1958) and expansion (1960) of the Station. The 1961 report concludes, "These surveys were carried out in June (High Water) and August (Low Water) and indicated that overall there were no major changes in the aquatic biota that might have been caused by the PEPCO operations." The Potomac River was rated as "healthy" with respect to all biological types at all sampling stations during each of the three survey periods. Examination of the temperature data reveals that the warmer waters of the Shenandoah River do not mix readily with the cooler waters of the Potomac River during higher stream discharges. At 6:00 a.m. in June, at Point-of-Rocks, Maryland (River Mile 159.5), the water temperature on the right (Virginia) bank was 1.8° to 5.6°F. higher than on the left (Maryland) bank, though this differential decreased to 0.7° to 1.8°F. by 6:00 p.m. During low stream discharges, the difference in temperatures between banks at Point-of-Rocks was insignificant. Immediately below the Generating Station, the water temperature on the left bank at 6:00 a.m. averaged 80.8°F. for the four sampling days in June (high stream discharges), while the corresponding temperatures on the right bank averaged 75.4°F., the differential of 5.4°F. being caused by the Station's discharge. The maximum water temperatures in June at the Station were reached at 3:00 p.m., being 82.0°F. on the left bank (Station side) and 77.4°F. on the right bank, a differential of 4.6°F. In August (low stream discharge), the 6:00 a.m. temperatures immediately below the Station averaged 85.8°F. on the left bank and 78.4°F. on the right bank, a differential of 7.4°F., while the 3:00 p.m. temperatures averaged 92.1°F. on the left bank and 83.1°F. on the right bank, a differential of 9.0°F. Dissolved oxygen concentrations were decreased by the elevated temperatures, but no dissolved oxygen concentrations below 6.0 mg/l were found. Total hardness measured at the Generating Station in 1961 averaged 115 mg/l in June and 137 mg/l in August; the alkalinity averaged 79 mg/l in June and 99 mg/l in August; the B.O.D. of one sample in June was 2.5 mg/l and of one sample in August was 6.0 mg/l; and the mean coliform bacteria concentration was 540/100 ml in June and 120/100 ml in August. Dissolved iron content was insignificant, phosphate averaged 0.06 mg/l in June and 0.10 mg/l in August; nitrate nitrogen averaged 0.59 mg/l in June and 0.31 mg/l in August; and total of nitrite, nitrate, and ammonia nitrogen averaged 0.69 mg/l in June and 0.39 mg/l in August. The Academy found the water quality of the Potomac River 5.5 miles downstream of the Generating Station

(i.e., River Mile 146.6) to be essentially the same as that immediately below the Station, except that the temperatures were lower (roughly 5.0° to 9.0°F. on the left bank) and the dissolved oxygen concentrations were higher by about 0.5 to 4.0 mg/l, with evidence of photosynthetic plants being present at the lower sampling station.

Goose Creek, which enters the Potomac River from Virginia at River Mile 142.1, receives a total of about 240,000 gpd of sewage effluent from about 3,000 persons from Middlesburg, Leesburg, Goose Creek Country Club, and Foxcroft School, all after secondary treatment. Goose Creek has a very high average annual sediment discharge of 290 tons per square mile, or 98,000 tons per year, as measured near Leesburg, Virginia.

Sugarland Creek, which enters the Potomac River from Virginia at River Mile 135.3, receives about 155,000 gpd of sewage effluent from 1,960 persons, after secondary treatment, from Herndon, Virginia. Three years of data from the Interstate Commission network show that the maximum monthly average B.O.D. concentration was 3.2 mg/l in January, the minimum monthly mean dissolved oxygen concentration was 4.3 mg/l in September, and the maximum mean monthly coliform bacteria concentration was 89,000/100 ml in August.

Seneca Creek, which enters the Potomac River at River Mile 133.9, or its tributaries, receive about 1,200 gpd of plating wastes after neutralization, oxidation, and settling from Weinschel Engineering Company; 15,000 gpd of milk processing wastes and 10,000 gpd of cooling water from Hadley Farms Dairy at Laytonsville, Maryland. The maximum monthly average B.O.D. concentration of Seneca Creek for three years was 3.3 mg/l in February, the minimum monthly average dissolved oxygen concentration was 7.4 mg/l in June, and the maximum monthly mean coliform bacteria concentration was 9,900/100 ml in June. Seneca Creek has a very high average annual sediment discharge of 320 tons per square mile, or 32,300 tons per year, as measured at Dawsonville, Maryland.

Watts Branch, which enters the Potomac River at River Mile 129.2 has an unusually high average annual sediment discharge of 516 tons per square mile, or 1,910 tons per year.

Difficult Run, which enters the Potomac River from Virginia at River Mile 124.1, also has a high average annual sediment discharge of 290 tons per square mile, or 16,200 tons per year.

The Washington Suburban Sanitary Commission obtains an average of 5.5 mgd from the Potomac River at about River Mile 127.0. The Washington Aqueduct Division, U. S. Army Engineer District, Baltimore, obtains an average of 167 mgd from the Potomac River at Great Falls, Maryland (River Mile 126.5), to supply Washington, D. C. Treatment practices, at times, include taste and odor control.

The Public Health Service maintains a station of the National Water Pollution Surveillance System at Great Falls in cooperation with the Washington Aqueduct Division. The results from five years of weekly sampling have been analyzed and are summarized in Appendix IV. That analysis shows that the monthly average dissolved oxygen concentration reached a minimum of 5.9 mg/l in July, when a minimum individual value of 3.0 mg/l occurred. The monthly average B.O.D. reached a maximum concentration (3.3 mg/l) in February, with a maximum individual concentration value of 8.6 mg/l. The maximum monthly mean coliform bacteria concentration of 3,900/100 ml occurred in March. While this coliform concentration was determined from weekly sampling for a period of five years, daily sampling for four years (within the above five-year period) by the Washington Aqueduct Division resulted in a monthly mean of 8,200/100 ml for March. That Division attributes the difference in results to the "flashy" nature of the Potomac River, so that weekly sampling may miss many high bacterial counts at high stream flows of short duration. The fact that the highest concentrations of B.O.D. and coliform bacteria occur at times of highest stream discharge suggests that surface drainage is a principal source. Calculations of the Interstate Commission on the Potomac River Basin show that the coliform bacteria counts exceed 2,000/100 ml at least some portion of every month and up to about 95 per cent of the time during some months, the high values occurring principally in the winter (high stream flow) months. The monthly average water temperatures at Great Falls ranged from 34.7°F. in January to 78.6°F. in July, with a maximum individual value of 91.9°F. (occurring in July). The maximum monthly average hardness of 141 mg/l occurred in October (at lowest flows) with a maximum individual value of 188 mg/l occurring in August; the annual average hardness was 105 mg/l. The maximum individual determination of gross beta radioactivity of 213 pc/l (picocuries per liter), the maximum monthly average of 55 pc/l (November), and the annual average of 23 pc/l, are well under the maximum permissible concentration of 1,000 pc/l for mixtures of unknown radionuclides in the absence of alpha emitters and Strontium 90. The maximum soluble phosphate phosphorus concentration of 0.3 mg/l occurred in April. A special study of chlorinated hydrocarbon pesticides was made on September 23, 1964, as part of the National Water

Pollution Surveillance System. At Great Falls, the Potomac River had a concentration of Dieldrin between 0.040 µg/l (micrograms per liter) and 0.08 µg/l and a concentration of Endrin between 0.094 µg/l and 0.188 µg/l, the latter being the highest concentration found at any of the stations located throughout the Nation. (These values are similar in magnitude to those found in the lower Mississippi River during the major fish kill of 1964, except that the concentrations in the Potomac River were apparently of short duration.) Water of the Potomac River at Great Falls is generally moderately hard, and at times contains tastes and odors.

The U. S. Navy Bureau of Ships discharges about 130,000 gpd of secondary sewage effluent from about 1,600 persons at the David Taylor Model Basin, Carderock, Maryland, to the Potomac River at River Mile 121.7.

Downstream from the vicinity of Cabin John Creek (River Mile 119.0), the sewerage system draining to the District of Columbia Blue Plains Sewage Treatment Plant (now called the District of Columbia Water Pollution Control Plant) contains combined sewers which transport both sanitary sewage and storm drainage. These sewers overflow during intensive rain storms, thus allowing untreated sewage to enter the Potomac River. An extensive program is underway to provide separate sewers throughout the entire sewerage system.

Little Falls Branch, which enters the Potomac River at River Mile 116.3 just upstream of the District of Columbia boundary line, receives about 10,000 gpd of settled concrete truck washing wastes from Maloney Concrete Company and occasional discharges of oil-drum cleaning and oil spillage wastes from the Washington Petroleum Company, both in the Chevy Chase area of Maryland. Little Falls Branch has an extremely high average annual sediment discharge of 2,320 tons per square mile, or 9,530 tons per year, as measured near Bethesda, Maryland.

During low stream discharge periods, the Washington Aqueduct Division obtains a portion of the water supply for Washington, D. C., just above Little Falls at River Mile 116.3. The Dalecarlia Water Filtration Plant of the Washington Aqueduct Division discharges an average of 1.8 mgd of filter wash water plus wastes from washing settling basins (discharged at high stream flows) to the Potomac River below Little Falls. These wastes contain all of the silt removed from the raw water, plus coagulating chemicals, principally alum. The maximum wash water use occurs during the summer, with the peak usage occurring in August. The average wash water use over the past five years was 2.2 mgd, or about 1.3 per cent of the total raw water intake volume (for two filtration plants).

The head of tide on the Potomac River begins just below the lower end of Little Falls (River Mile 116.1). The average Potomac River discharge to the estuary is 11,040 cfs (33 years of record, measured two miles upstream of the District of Columbia boundary).

The Monocacy River, in the approximately 15-mile reach upstream of Frederick, may be classified as INCOPOT Class C because of mean coliform bacteria counts between 500 and 5,000/100 ml, and MDWR Class A because of average B.O.D. concentrations between 1.0 and 2.5 mg/l. In a reach just below the Pennsylvania State line, about five miles in length, the Monocacy River does not meet the minimum criteria for INCOPOT Class D and must be classified as MDWR Class C because of dissolved oxygen concentrations less than 2.0 mg/l. In between these two reaches, the remaining 12 miles probably falls within INCOPOT Class D and MDWR Class B, since monthly coliform bacteria concentrations are estimated to range from 2,000 to 10,000/100 ml. The Monocacy River below Frederick must be classified as not meeting INCOPOT Class D minimum criteria, and as MDWR Class C, because mean monthly coliform bacteria concentrations exceed 10,000/100 ml, and dissolved oxygen concentrations fall to 1.0 mg/l. Carroll Creek of the Monocacy River must also be classified as not meeting INCOPOT Class D, and as MDWR Class C because of large quantities of floating solids and debris. Even though coliform bacteria counts were not obtained in the survey of Carroll Creek in 1961, high counts would be suspected in this small stream which traverses densely populated areas. Low dissolved oxygen concentrations could also be suspected, since B.O.D. concentrations over 4.0 mg/l were found.

The Interstate Commission on the Potomac River has established specific objectives and criteria for the main stem Potomac River from the Monocacy River to Little Falls which are presented in Appendix I. The classification system used upstream is, therefore, not utilized for the main stem Potomac River in this sub-reach and below. The Potomac River is well within the criteria set by the Interstate Commission for this sub-reach during most of the year. However, during the high stream flow periods of March through May, the monthly median coliform bacteria concentrations are greater than 2,000/100 ml, at times taste and odor producing substances are present, and occasionally individual pH values exceed 8.5. On very rare occasions, the dissolved oxygen concentration has been below 4.0 mg/l. The Potomac River in this sub-reach would be MDWR Class B, since monthly mean coliform bacteria concentrations lie between 2,000 and 10,000/100 ml, monthly mean dissolved oxygen concentrations lie between 4.0 and 6.0 mg/l with no value falling below 3.0 mg/l, and monthly average

B.O.D. concentrations fall between 2.5 and 6.0 mg/l. Seneca Creek may be classified as INCOPOT Class D and MDWR Class B, because of monthly geometric mean coliform bacteria concentrations between 2,000 and 10,000/100 ml and monthly average B.O.D. concentrations between 2.5 and 6.0 mg/l. Muddy Branch, which enters the Potomac River at River Mile 131.4, may be classified as INCOPOT Class D and MDWR Class B, because of monthly mean coliform bacteria concentrations between 2,000 and 10,000/100 ml.

IV. POTOMAC RIVER ESTUARY

Upstream River Mile	116.1	
Downstream River Mile	0.0	
Length of Estuary	116.1	miles
Area Draining Directly to Estuary	3,090	square miles
Total Drainage Area to Potomac River Basin	14,670	square miles

Summary

Waste effluents discharged in the metropolitan area of the District of Columbia significantly reduce water quality in the upper Potomac River estuary over a distance of approximately 40 miles from the vicinity of the 14th Street Bridge in the District of Columbia to Sandy Point. Deleterious effects attributable to these wastes include very high bacterial levels, high concentrations of organic materials, a low and sometimes depleted dissolved oxygen content, and high nutrient concentrations which bring about massive algal blooms. The algal blooms discolor the water, reduce its clarity, and in general create a displeasing aesthetic appearance. The subsequent death, sedimentation, and decay of these organisms may contribute further to the unsatisfactory oxygen conditions in the upper estuary. Low dissolved oxygen levels may be a predisposing, if not primary, factor in some of the fish kills which are repeatedly observed in the Potomac. Suspended sediment entering at the head of the estuary from the Potomac River, from surface runoff in the D. C. metropolitan area, and from sand and gravel operations, contribute to the turbidity of the upper estuary.

In the lower estuary from U. S. Highway 301 Bridge to the mouth, water quality is generally satisfactory for most uses; however, occasional algal blooms and fish kills do occur. In addition, there are a few small isolated areas below waste outfalls where coliform bacteria concentrations are such as to prevent the commercial harvesting of shellfish. Depleted oxygen conditions in the deep waters near the mouth of the Potomac are observed annually during the warmest months of the year. This condition is common to all deep waters of the Chesapeake Bay and its tributary estuaries.

The water quality objectives set for the estuary from Little Falls to Hallowing Point by the Interstate Commission on the Potomac River Basin are not being met in all respects at the present time (1965).

A map of the Potomac River estuary is presented in Figure 15.

Little Falls to U. S. Highway 301 Bridge (67.3 miles)

The quality of estuarial waters is predominantly influenced by the quality of the fresh water inflow at its head and the brackish or salt water body at its mouth. In addition, tributary streams, ground water, and waste water discharges entering the estuary along its length affect the water quality.

The principal fresh water inflow to the Potomac estuary is provided by the Potomac River. The River, upon entering the area of tidal influence just below Little Falls, 116.1 miles above Chesapeake Bay, has drained about 11,500 square miles, or about 80 per cent of the total area draining to the tidal estuary. The River provides roughly 80 per cent of the total fresh water inflow, since ground-water accretions to the estuary are not considered to be significant.

Minor tributary streams having relatively small drainage basins enter the estuary all along its length. Two of these, Rock Creek and Anacostia River, enter near the head of the estuary and drain major portions of the District of Columbia Metropolitan Area. All of these tributaries are important to the estuary, but more from the standpoint of quality than quantity.

Rock Creek, which enters the Potomac River estuary in the District of Columbia at River Mile 111.9, receives untreated sewage when combined sewers overflow during storms. Also, the District of Columbia West Heating Plant discharges 225,000 gpd of cooling water and 225,000 gpd of boiler blowdown and water softener backwash to Rock Creek. Minor quantities of oil from spillage at two establishments are discharged to tributaries. Because of the storm-water overflows, the water quality in Rock Creek is highly variable. Monthly mean B.O.D. values at the mouth average 4.4 mg/l during December through May, and 2.8 mg/l during June through November, reflecting high storm-water flows in the winter and spring. Monthly mean coliform bacteria counts at the mouth vary from 110 to 130,000/100 ml, showing no distinct seasonal pattern. Monthly mean dissolved oxygen concentrations at the mouth average 8.9 mg/l during June through November, with

no monthly mean below 7.0 mg/l. The quality of water upstream in Rock Creek for nine miles is essentially the same as at the mouth, although B.O.D. and coliform concentrations are slightly lower upstream. The quality of the Potomac River estuary adjacent to the confluence with Rock Creek is generally better than that in Rock Creek, indicating that the lower water quality in Rock Creek is the result of the storm-water overflows from combined sewers in the drainage area, and not due to tidal exchange with the Potomac estuary. The average annual sediment discharge of Rock Creek at Sherrill Drive, Washington, D. C., is 1,600 tons per square mile, or 99,500 tons per year.

The Anacostia River, which enters the Potomac River estuary in the District of Columbia at River Mile 107.8, is influenced for about four miles by tidal exchange with the main estuary. Significant concentrations of sewage effluent from the District of Columbia Blue Plains Sewage Treatment Plant have been traced by dye throughout the lower four miles of the Anacostia River. Untreated sewage from combined sewers overflowing during storms discharges directly to the Anacostia River. Other discharges to the River or its tributaries include 264 mgd of cooling water from two electric generating stations, wash water from sand and gravel washing operations, 110,000 gpd of sanitary waste effluent, after primary treatment, and 160,000 gpd of cooling water from the Naval Ordnance Laboratory, and other wastes of lesser significance. The quality of water in the Anacostia River is highly variable. Monthly mean coliform counts in the lower seven miles have ranged from 500 to 4,880,000/100 ml, the higher values generally occurring December through May, but with high and low values being found throughout the year. Monthly mean B.O.D. values range from 0.9 to 17.2 mg/l, being generally higher upstream during December through May, and generally higher downstream from June through November. Monthly mean dissolved oxygen concentrations near zero may be found at times beginning two miles above the mouth and extending upstream for two or more miles, but concentrations are generally above 5.0 mg/l near the mouth throughout the year. The average annual sediment discharge of the Northeast Branch Anacostia River at Riverdale, Maryland, is 1,060 tons per square mile, or 77,400 tons per year; of the Northwest Branch Anacostia River near Colesville, Maryland, is 470 tons per square mile, or 10,000 tons per year; of the Northwest Branch Anacostia River near Hyattsville, Maryland, is 1,850 tons per square mile, or 91,300 tons per year.

The quality of the Potomac River at Great Falls, summarized in Appendix IV, may be considered representative of the fresh water contribution to the estuary. By considering its chloride content, which is quite low as compared to that found

at the mouth in Chesapeake Bay, some idea may be gained of the distribution along the estuary of the soluble constituents contributed by both sources.

Mineral Salts. It is generally recognized that the chloride content of the estuary will gradually increase from a minimum value at the head to a maximum value at the mouth. This is also true of other constituents such as alkalinity, sodium, potassium, and others which are present in much higher concentrations in the sea than in rivers. Chlorides, however, are usually of greater significance to most water uses.

The chloride content of the Potomac River at Great Falls varies from 3.0 to 30 mg/l, while that of the Chesapeake Bay at the mouth of the Potomac River varies from about 5,000 to 10,000 mg/l. The chloride content within the estuary will lie between these extremes, the actual value being dependent upon location in the estuary and seasonal differences in fresh water inflow rates. The chlorides of the Bay waters move up the estuary by a process usually referred to as turbulent diffusion, which is brought about by the action of reversing tidal currents. The chlorides contributed by the Potomac River move downstream by the same process and, in addition, are displaced seaward by the river discharge which flows through the estuary to the Bay. This latter process is referred to as advection.

As would be expected, the chloride concentration in the upper estuary varies inversely with the river inflow. At the Public Health Service automatic water quality monitor on Memorial Bridge at Washington, D. C., the chloride concentration between July 1963 and December 1964 varied from a low of 5.0 mg/l during the winter, to a high of 50 mg/l during the late autumn of 1964. This latter value is almost twice the maximum chloride concentration found at Great Falls and reflects the presence of sea salts which have diffused upward from the Bay. At the U. S. Highway 301 Bridge (River Mile 40.3), the low spring chloride content is usually greater than 1,500 mg/l, while the late fall maximum concentration will generally reach 6,000 mg/l.

During the four-year period of 1961 - 1964, chloride concentrations of 250 mg/l reached approximately 86, 90, 98, and 90 miles above the River mouth in successive years, the maximum upward intrusion taking place in the late fall. The maximum intrusion occurred in November of 1963, when chlorides of 192 and 359 mg/l were observed at Fort Foote (River Mile 101.7) and Fort Washington (River Mile 97.8), respectively. This extensive upstream intrusion of sea salts can be attributed to the very low Potomac River flows experienced during that year and was comparable

to the intrusion found during the 1930 drought. In that year, the chloride level at Indian Head (River Mile 86.3) reached a maximum value of just over 3,000 mg/l, while in 1963, a maximum of 2,650 mg/l was observed at Possum Point (River Mile 78.5). The total Potomac River flow (at Point-of-Rocks, Maryland) in 1930 was 4.7 million acre-feet, while in 1963, 5.1 million acre-feet were discharged at this Potomac River gage. It is doubtful that chloride concentrations in excess of 250 mg/l would ever be found very far upstream of Fort Foote, unless droughts were more severe than those experienced over the last 70 years. The 250 mg/l chloride level is significant, since this is the recommended maximum concentration for drinking water supplies (Public Health Service Drinking Water Standards).

Should the Potomac River Basin flows above the estuary become more regulated as the result of dam construction, minimum drought flows to the estuary will be increased, and the upstream intrusion of sea salts will be inhibited. On the other hand, if any significant quantity of Potomac River water is not returned to the upper estuary after use, a further intrusion of salts would be expected.

The variations in chlorides described above apply also to total dissolved solids, hardness, and sulfates. During periods of low fresh water inflow, the total dissolved solids content of the Potomac River at Memorial Bridge falls between 200 to 300 mg/l, the hardness between 150 to 200 mg/l, and sulfates in the range from 75 to 100 mg/l. When the Potomac River flows are high, these concentrations drop to ranges of 140 to 200 mg/l for total dissolved solids, 80 to 135 mg/l for hardness, and 25 to 50 mg/l for sulfates. The lowest concentrations cited are comparable to those found in the Potomac River at Great Falls at times of maximum flow, while the highest values are all higher than those encountered at Great Falls and reflect the presence of sea salts just as in the case of chlorides. As one moves down the estuary, each of these quality indicators increases in a manner similar to the increases described for chlorides.

Temperature. Water temperatures in the upper estuary reflect ambient conditions, being highest in July and lowest in January. The five-year mean (1960 - 1964) surface temperatures at Memorial Bridge for the above months were 82° and 36°F., respectively. Maximum values in the mid-nineties may be found in shallow waters at sunset during the summer. These temperatures are typical of the entire upper estuary down to the U. S. Highway 301 Bridge. At depths below 30 feet in the saline portions of the upper estuary, water temperatures are usually 2.0° to 3.0°F. cooler.

Sediment and Water Transparency. A considerable sediment load, estimated to be approximately 2.5 million tons annually, is transported to the estuary by tributary streams. Much of this load is delivered to the head of tide by the Potomac River; however, significant amounts also enter from the smaller tributaries which drain the Washington Metropolitan Area. This silt contributes to the turbidity of the tidal estuary before settling to the bottom. Since 90 per cent of the upstream load enters during that 10 per cent of the time when stream flows are highest, maximum turbidity levels would be expected during the same period of the year; i.e., late winter and spring. Any intense local rainstorm in the Washington Metropolitan Area will produce a heavy silt load which causes very high turbidities in the estuary at and near Washington. This silt gives the water an obvious brown color, which rapidly dissipates as the suspended material settles out.

The average turbidity of the Potomac River during the four-year period from 1961 - 1964 is shown in Figure 1. The average turbidity in the upper five miles of the estuary and that observed near Maryland Point, 50 miles downstream, are both relatively low, being less than 40 J.C.U.* Everywhere in the 50-mile reach between these two limits, the turbidity is higher. Two turbidity peaks may be readily identified. A rather sharp peak (51 J.C.U.), occurring near the Blue Plains outfall, is attributed to the discharge of sewage treatment plant effluent containing suspended solids. After the peak at the sewage treatment plant, a more gradual build-up in turbidity is observed, reaching a maximum of 54 J.C.U. at Hallowing Point. This turbidity build-up is similar to the B.O.D. build-up in the estuary (discussed in a later section). Both B.O.D. and turbidity reach a peak at Hallowing Point, 15 miles below the Blue Plains outfall, and are assumed to derive from the same cause; i.e., algal cells. This assumption is supported by recent findings of the Chesapeake Bay Institute, which is carrying out algae and nutrient studies in the Potomac estuary for the Public Health Service. For these studies, maximum chlorophyll levels, indicative of maximum algal density, have been consistently found at stations near Hallowing Point. Thus, while the direct effect of the Blue Plains effluent in increasing turbidity is quite noticeable, the indirect effects caused by the stimulation of algal growths reach even higher levels and affect a much greater section of the estuary.

A large (400 tons per hour) sand and gravel dredging operation is carried out on Greenway Flats just below Hallowing Point.

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* Jackson Candle Units

Studies by the Maryland Department of Water Resources show that a great deal of turbidity is created in the immediate vicinity of the dredging and washing operations. These effects are confined, however, and are not noticeable beyond a distance of about 1,000 feet.

The Potomac River at Great Falls had an average turbidity of 40 J.C.U. for 252 samples collected over a recent five-year period. This is quite comparable to the estuary outside of the area influenced by waste discharges. The Potomac estuary also compares favorably with another heavily populated East Coast estuary, the Delaware at Philadelphia, where the average of 53 readings during the 1962 water year was 80 J.C.U.

Turbidity or resistance to light penetration into the water may also be measured by means of the Secchi disk or photometer cells. Equivalent Secchi disk readings, or the depths at which approximately 16 per cent of the incident light remains, were recorded during the period from March to September of 1965. In the navigation channel of the upper estuary below Giesboro Point, Secchi disk readings varied from 1.5 to 5.0 feet. The lowest values, 1.5 to 2.5 feet, were found between Giesboro Point (River Mile 107.4) and Indian Head (River Mile 86.5); values in this area were usually higher in the spring than in the summer. Between Indian Head and U. S. Highway 301 Bridge, somewhat higher readings were obtained, ranging from 2 to 5 feet. In this reach, however, the higher readings were obtained in August and September. It appears that in the spring the upper estuary is uniformly turbid as a result of spring runoff. In the summer, the lower portion becomes clearer as the silt load is reduced, while algal growths in the upper portion restrict light penetration even further than the light restriction experienced in the spring.

Nutrients. Heavy algal growths which give a bright green color to the water are observed throughout the upper estuary during the warmest months of the year. These growths are known to be stimulated by the fertilizing materials contained in waste effluents, primarily nitrogen and phosphorus. During August and September of 1965, when algal growths were particularly heavy, about 15 tons of inorganic nitrogen were added to the estuary each day in waste effluents, in addition to about 3.0 tons per day which entered in the Potomac River inflow. Most of the nitrogen was in the form of ammonia, with a peak concentration of over 3.0 mg/l being observed near the Blue Plains Sewage Treatment Plant outfall. Much of the ammonia was subsequently converted by bacterial oxidation to the nitrate form, which reached a concentration of over 1.0 mg/l about 10 miles below the Blue Plains outfall. Extremely high phosphorus concentrations were also present, 0.9 mg/l being observed near Fort Washington.

In a study of the Potomac River in the Washington Metropolitan Area (1959), the total phosphorus content of the River just above the tidal reach was found to be 0.23 mg/l, and the content in the tidal area several miles below the municipal sewage effluent outfall was found to be greater than 1.0 mg/l. Based on measurements made in 1965, it is estimated that approximately eight tons per day of phosphorus are discharged to the estuary in waste effluents. These nutrient materials are present in sufficient quantity to support massive algal growths in the estuary. Chlorophyll levels, which are indicative of algal density, were found in 1965 to have reached a maximum of 180 ug/l in the estuary. This level is higher than previously reported anywhere in the Chesapeake Bay tidal system.

Influence of Waste-Water Discharges. The Potomac River estuary and its minor tributaries receive waste-water discharges from the Washington Metropolitan Area, several communities and Federal installations below Washington, power generating stations, and several industries, principally sand and gravel washing operations. The principal organic waste loadings occur in the Washington Metropolitan Area and include the District of Columbia Blue Plains Sewage Treatment Plant (80,300 lbs/day B.O.D.), Arlington County (23,000 lbs/day B.O.D.), and Fairfax County (12,500 lbs/day B.O.D.). A complete listing of waste discharges giving location and treatment provided is presented in Appendix V.

The Blue Plains Sewage Treatment Plant outfall, which is the principal waste source, enters the estuary at River Mile 105.4. Upon leaving the outfall pipe, which lies on the bottom and terminates at the eastern edge of the deep water channel, this waste stream rises to the surface, becoming slightly diluted by the surrounding waters which are entrained in the waste plume. The turbulence of the moving tidal waters bring about favorable mixing conditions, with the wastes being transported over several miles upstream or downstream depending on whether the tide is flooding or ebbing. To a large extent, the water mass containing the waste is returned to the vicinity of the outfall by the reversing tidal current. However, in traversing the distance of the tidal excursion, the waste material is mixed throughout a larger water mass by turbulent diffusion processes, resulting in lower waste concentrations on returning to the point of discharge.

An idealized pattern of dispersion of a waste discharge to a uniform tidal channel having no inflow may be envisioned by considering the incremental discharge at the time of slack water. A plot of waste concentration versus distance longitudinally along the estuary would, at the time of discharge,

show an extremely high concentration at the discharge point, with no waste present at short distances upstream or downstream. After one complete tidal cycle, such a plot would show the peak concentration remaining at the point of discharge, though greatly reduced in magnitude, with a normal distribution of waste both upstream and downstream for a total distance approaching the tidal excursion distance. With succeeding tidal cycles, the normal distribution of waste concentration would remain about the discharge point but with a diminishing peak concentration. From this peak value, the concentration decreases in both upstream and downstream directions for large distances. Ultimately this curve would flatten out to a straight line, indicating uniformly infinitesimal concentrations throughout the system. Under the more practical conditions of the Potomac estuary with stream flow entering at the head, the channel cross-section increasing toward the mouth, and a net outflow to the ocean causing a net outflow displacement seaward through the estuary, the normal distribution mentioned above would be skewed toward the Bay, and the peak concentration, instead of remaining in the vicinity of the outfall, would have a net movement seaward with time.

In the usual case of a steady discharge, such as that from a waste treatment plant, the peak concentration in the estuary would lie downstream from the discharge point at low slack water and above the discharge at high slack water. If averaged over a tidal cycle, the peak concentration would be found at the outfall. Both the magnitude of the peak concentration and the extent of the upstream intrusion of the waste would be limited by the fresh water inflow entering at the head of the estuary. In the case of non-conservative pollutants, increasing stream flows to the estuary would result in an increase in downstream pollutant concentrations.

Oxygen Balance. The presence of organic waste discharges to the Potomac River may be detected by increased B.O.D. concentrations and the resulting depressed dissolved oxygen conditions, which these waste materials bring about in the estuary.

Samples collected at five stations located at about one-mile intervals above the 14th Street Bridge from June to November show the B.O.D. to be quite uniform. The B.O.D. level exceeded 10 per cent of the time in this area is near 3.5 mg/l. Below the 14th Street Bridge, the B.O.D. concentration rises rapidly over the next four miles, reaching a maxumum just below the Blue Plains outfall where the level exceeded 10 per cent of the time is 12.0 mg/l. The B.O.D. concentration drops very slowly and at a distance of 40 miles below the peak concentration has not returned to the levels found above the 14th Street Bridge. The

upper 10 per cent of the concentrations found at Maryland Point (River Mile 61.0) exceed 4.3 mg/l.

An attempt to balance the incoming B.O.D. waste loadings with the total B.O.D. found in the estuary has shown more than ten times the calculated value to be present. This apparent production of secondary B.O.D. in the estuary begins above the Blue Plains outfall and reaches a peak some 15 miles below the outfall, after which it begins to drop off. It may be presumed that this discrepancy is partially attributable to algal cells which are contained in the samples collected in the estuary but are not present in the waste-water effluent samples.

Dissolved oxygen concentrations in the estuary drop steadily from the head of tide to a minimum at the Blue Plains outfall, as shown in Figure 2. In the critical two-month period from July 15 to September 15, the lowest 10 per cent of the values observed over five years were below 6.7 mg/l at River Mile 114.8, dropping to 1.4 mg/l at the Blue Plains outfall. Proceeding downstream, dissolved oxygen concentrations rise steadily, and at Sandy Point (River Mile 75.0), the lower 10 per cent of the values lie below 6.5 mg/l, similar to conditions found some 40 miles upstream. The recovery of the dissolved oxygen curve is impeded by the increasing salinity and resulting decreased solubility of oxygen encountered downstream of the Washington Metropolitan Area.

From the above, it is evident that the estuary oxygen balance is affected by Metropolitan Area waste discharges over a distance of about 40 miles. These effects are most serious in a 10-mile reach extending from Giesboro Point (River Mile 107.4) to Fort Washington (River Mile 97.8) where dissolved oxygen concentrations are less than 4.0 mg/l half of the time during the warm summer months. Concentrations between zero and 1.0 mg/l are not infrequent in this stretch. Furthermore, it should be noted that the concentrations discussed above were found in samples collected near the surface of the navigation channel during daylight hours. Nighttime samples collected near the bottom, especially outside the channel, could be as much as 1.0 to 2.0 mg/l lower. This is due to the uptake of oxygen by both the decomposible, organically rich bottom muds and respiring phytoplankton, which may be found in great numbers in the upper estuary during the warmer months.

The trend in critical dissolved oxygen concentrations at six estuary stations measured over the past 10 years is shown in Figures 3 through 8. Little significant improvement in minimum dissolved oxygen concentrations is apparent during that period.

Bacteriological Quality. The number of coliform organisms present in the estuary is markedly influenced by the waste effluents discharged in the Washington Metropolitan Area, primarily by that discharged at Blue Plains. Figures 9 and 10 show the five-year mean of the average monthly concentrations found in the June through November, and December through May periods, respectively. The highest coliform concentrations are encountered in the winter and spring months, considered to be primarily the result of the cessation of chlorination of the Blue Plains effluent. The high fresh water inflows which carry large numbers of coliforms and, in the case of downstream stations, the lower die-off rates experienced in colder weather, and the advective effects of high stream flows on the peak concentration, also contribute to higher bacterial levels during December through May. During the same period, the mean coliform counts above the estuary were 6,800/100 ml at Point-of-Rocks (River Mile 159.4), Maryland, and 3,100/100 ml at Great Falls (River Mile 126.5). Coliform levels in the upper five miles of the estuary above the Memorial Bridge are lower than those in the River at Point-of-Rocks, and it is not until a half-mile below the 14th Street Bridge that the upper River coliform levels are exceeded in the estuary. The mean coliform counts quickly rise in the 4.5 miles below this point and reach a peak of 260,000/100 ml near the Blue Plains outfall. This high level slowly drops over the next 30 miles, until a relatively stable mean value, less than 200/100 ml, is reached. Thus, in the winter and spring months, the mean coliform level in three overlapping reaches of different lengths in the vicinity of the Blue Plains outfall are as follows: in the upper 30 miles of the estuary, mean coliform counts generally exceed 2,000/100 ml; in the 15-mile reach from Potomac Park (River Mile 109.1) to below Marshall Hall (River Mile 93.8), they exceed 10,000/100 ml; and they exceed 50,000/100 ml in a five-mile reach from just below Giesboro Point (River Mile 107.4) to a point below Fort Foote (River Mile 101.7).

In the summer and fall months of the recreational season on the Potomac estuary, the River contributes less inflow and contains fewer coliform organisms. However, coliform concentrations in the estuary above the Blue Plains outfall are as high, or higher, at this time than during the winter, since further upstream intrusion of wastes is possible. Though the Blue Plains effluent is chlorinated, some regrowth of organisms possibly takes place in the estuary. The mean peak concentration at the outfall is less than half the winter-spring value, or 120,000/100 ml. The drop in bacterial numbers is more rapid than in the winter below the plant, and mean concentrations less than 1,000/100 ml are found at Hallowing Point (River Mile 89.5). In the summer-fall season, then, mean coliform concentrations

in excess of 2,000/100 ml extend over a 20-mile stretch of the upper estuary above Fort Washington, and values greater than 50,000/100 ml are confined to a four-mile stretch from below Giesboro Point to just above Fort Foote.

Fish Kills. The Potomac estuary has had a long history of large fish kills. One of the more recent of these (1963) was tentatively attributed to a bacterial infection among the white perch. The large kill which occurred in May 1965, however, affected several different fish species, and in this case, bacterial studies yielded negative results. The extent of this kill is shown in Figure 11. Examination of a few of the more than 500,000 fish estimated to have died showed the presence of pesticides. However, these compounds were also found at similar non-lethal levels in fish that were not affected and was not considered to have caused the mass mortality which was observed. A small number of water samples analyzed for dissolved oxygen at that time showed concentrations much lower than would be expected at that time of year, and this condition may have contributed, directly or indirectly, to the fish kill. A definite correlation may not always be established between man-made pollution and fish kills in the Potomac River; however, this possibility can not be completely ruled out.

Water Quality Criteria. The water quality objectives and criteria established for the upper Potomac estuary in 1958 by the Interstate Commission on the Potomac River Basin are given in Appendix I. The objectives and criteria differ for each of three reaches of the estuary.

In the upper reach, from Little Falls (River Mile 116.1) to Key Bridge (River Mile 112.5), the water use objectives are swimming, boating, shore recreation, and propagation of all fish species. The criteria established to meet these objectives are currently not being met with respect to coliform numbers, since levels in excess of the maximum of 2,000/100 ml specified for "nearly all" of the samples are frequently observed. Criteria established for dissolved oxygen are being met in this reach.

In the middle reach, from Key Bridge (River Mile 112.5) to Fort Washington (River Mile 97.8), the water use objectives are boating, shore recreation, industrial water supply, safe passage of all fish, and propagation of the hardier types of fish. Here the criterion for the coliform group is less than 10,000/100 ml in "most" of the samples. This criterion is not met in the reach except for a two-mile stretch at the upper end. The specified monthly average dissolved oxygen of 5.0 mg/l with a minimum of 4.0 mg/l is not met anywhere in the reach during

the summer months. The turbidity criterion is not met because of storm runoff, and the nutrients in waste effluents could be interpreted as deleterious substances which make the waters unsuitable, through the stimulation of algal growths, for boating and shore recreation. The fish kills observed in this and lower reaches of the estuary are ample evidence that the waters are unsafe for the passage of all species of fish. It is not possible to state conclusively at this time, however, that this condition is brought about by man-made pollution.

In the lowest reach for which objectives and criteria have been established; i.e., Fort Washington (River Mile 97.8) to Hallowing Point (River Mile 89.5), the water uses to be protected are boating, fishing, swimming, and other recreational uses. The coliform criterion of 2,000/100 ml is exceeded in most of the samples collected in this reach during most of the year. The minimum monthly average dissolved oxygen of 5.0 mg/l, with no dissolved oxygen below 4.0 mg/l, is likewise not achieved at all times. The comments on the upstream reaches pertaining to effects of algae and low water transparency on suitability of the water for recreational purposes and to fish kills apply in this reach as well.

U. S. Highway 301 Bridge to Mouth of Potomac (48.8 miles)

In the lower Potomac estuary from the U. S. Highway 301 (Morgantown) Bridge to the River mouth, there is always present a detectable amount of sea salts which diffuse up the estuary from Chesapeake Bay. These concentrations are highest during the later summer and fall months due to the low fresh water inflows to the Potomac estuary and to the entire Bay system which are experienced at this time. During the fall months, salinities* average approximately 9.0 and 11 parts per thousand at the surface and at a 30-foot depth, respectively, near the Highway 301 Bridge. This vertical stratification in the fall is not as pronounced with respect to temperature, which averages near 52°F., through the water column. Surface dissolved oxygen values are generally near 7.0 mg/l, although values up to 11 mg/l may be found in late fall when temperatures have dropped. Little information is available on bottom oxygen conditions in the Highway 301 Bridge area.

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* 1 ppt salinity is approximately equal to 550 mg/l chlorides.

At the mouth of the Potomac during late summer and fall, the salinities are the highest experienced in the Potomac estuary, usually being about 17 ppt at the surface and 18 ppt at the 30-foot depth. Surface water temperatures in the fall are warmer at the mouth than upstream, being near 57°F. at the surface and about two degrees less at a 30-foot depth. Surface dissolved oxygen values are similar to those experienced upstream, 6.0 to 7.0 mg/l during the warmer fall months and rising to 10 and 11 mg/l during late fall. At a 40-foot depth at the mouth, the dissolved oxygen concentrations are generally 1.0 to 3.0 mg/l less than surface values; pH values of 8.0 and 8.4 have been reported at 40 feet and the surface, respectively.

During the winter months, the salinity at Highway 301 Bridge drops to about 5.0 ppt under the influence of increased fresh water inflows. Temperatures are usually near 36°F., and saturated dissolved oxygen concentrations are normally present. A similar effect is felt at the mouth, where salinities are about 13 and 15 ppt at the surface and at a 40-foot depth, respectively. Water temperatures are usually two to four degrees warmer at the mouth than at Highway 301 Bridge. Saturated dissolved oxygen conditions may be found both at the surface and at the deeper waters near the mouth.

During the spring months, salinities are at their lowest values, coinciding with highest fresh water inflows. At the Highway 301 Bridge, salinity is usually near 3.0 ppt at the surface and 4.0 ppt at a 30-foot depth. Surface temperatures average 57°F. at the surface, being two to four degrees cooler in the deeper waters. Dissolved oxygen concentrations are near saturation at the surface and may be significantly less near the bottom at this time, although little data are currently available; pH values near 8.0 are usually found. At the mouth, surface salinity may drop to 10 ppt and is some 2.0 to 3.0 ppt higher in the bottom layers. Water temperatures are similar to those found near the Highway 301 Bridge, and pH values usually lie between 8.0 and 9.0.

During the summer months, salinities in the lower estuary begin their annual upward rise, as fresh water inflows drop off. Vertical stratification is also most pronounced at this time of year, as reflected by salinity, temperature, and dissolved oxygen concentrations. Surface and 30-foot salinities are usually 7.0 and 10 ppt at Highway 301 Bridge and 13 and 16 ppt, respectively, at the mouth of the estuary. Average surface water temperatures are at or above 81°F. throughout the entire lower estuary and are two to four degrees cooler at a depth of 30 feet. Very striking dissolved oxygen conditions are found in the lower

estuary during the warm summer months. Daytime dissolved oxygen concentrations at the surface are generally at or above saturation and, while no nighttime dissolved oxygen values are available, it could be expected that these would be below saturation. In the deeper waters (40 feet and below) at the mouth of the Potomac, complete depletion of oxygen is commonly found from July to September. The pH values in these deep waters are just above 7.0, while at the surface the pH generally exceeds 8.0. These completely deoxygenated conditions are also found below 40 feet throughout the entire central portion of Chesapeake Bay during the summer and can be attributed to oxygen uptake by bottom sediments coupled with a lack of vertical mixing due to a significant degree of vertical density stratification. It is not known how far up the Potomac estuary similar conditions exist, but it may be reasonably assumed that the entire lower estuary is probably devoid of oxygen at water depths greater than 35 to 40 feet during the summer.

Transparency of the water, as measured by Secchi disk readings taken between March and September, varied from 3 to 13 feet. The highest values are found near the Chesapeake Bay in the spring (11-13 feet) and near the Highway 301 Bridge in the summer (7-9 feet). The water is more turbid at the River mouth in summer (7-8 feet) and near the Highway 301 Bridge in the spring (3-5 feet).

The Maryland State Department of Health, as a participant in the certification program of interstate shellfish shippers in cooperation with the Public Health Service and the shellfish industry, has classified the waters of the lower Potomac River estuary and its estuarine tributaries according to Part I of the Manual of Operations of the Cooperative Program for the Certification of Interstate Shellfish Shippers, PHS Publication No. 33. Based upon bacteriological sampling and sanitary surveys, the following areas have been classified as "prohibited:" Neale Sound north of Cobb Island (River Mile 38.1); Breton Bay north of a line drawn from Society Hill to Lovers Point (River Mile 27.2); and St. Mary's River upstream from a line from Portobello Point east to the opposite shore. All other areas are classified as "approved." The upstream limit of shellfish production in the estuary lies between Colonial Beach and Dahlgren, Virginia, on the western shore and just downstream from the Highway 301 Bridge on the eastern shore. The Potomac River produces about 13 per cent of the clams and 10 per cent of the oysters harvested in Maryland.

SUMMARY OF WATER QUALITY IN THE POTOMAC RIVER BASIN IN MARYLAND

Numerous significant water quality problems exist in the Potomac River Basin in Maryland. In the 97-mile length of the North Branch, the wide-spread occurrence of mine drainage inhibits the development of normal biological life in many of the tributary streams as well as in the upper North Branch itself. Water containing mine drainage requires expensive treatment when used for municipal and industrial purposes. Iron and manganese are also present in concentrations which may require removal to satisfy some uses in this sub-basin. High bacterial counts and low dissolved oxygen concentrations are found in the lower third of the North Branch.

The 74-mile reach of the main stem Potomac River downstream from the confluence of the North and South Branches to Conococheague Creek gradually improves in quality over that found in the North Branch, because of dilution by better quality waters entering from West Virginia. However, due to discharges of untreated domestic wastes and run-off from agricultural areas, coliform bacteria are present throughout this reach in concentrations unsatisfactory for some uses when compared with criteria of the Interstate Commission on the Potomac River and Maryland Department of Water Resources.

Several tributaries which enter the Potomac River in the 95-mile reach from Conococheague Creek to the estuary have lowered water quality because of municipal or industrial waste discharges. Great quantities of suspended sediment are contributed by the Monocacy sub-basin, and high coliform bacteria levels occur in streams throughout the area at times of high spring stream flows. Tastes, odors, iron, and manganese are problems at times in surface water supplies in this area. The discharge of some untreated sewage and entry of inferior quality water from tributaries adversely affect dissolved oxygen levels in the upper third of this reach.

The quality of water in a 40-mile reach of the upper Potomac estuary is seriously diminished by pollution from wastewater discharges. Deleterious effects attributable to these wastes include very high bacterial levels, high concentrations of organic materials, a low and sometimes depleted dissolved oxygen content, and high nutrient concentrations which bring about massive algal blooms. The algal blooms discolor the water, reduce its clarity, and, in general, create a displeasing aesthetic appearance. The subsequent death, sedimentation, and decay

of these organisms may contribute further to the unsatisfactory oxygen conditions in the upper estuary. Low dissolved oxygen levels may be a predisposing, if not primary, factor in some of the fish kills which are repeatedly observed in the Potomac. Suspended sediment entering at the head of the estuary from the Potomac River from surface runoff in the Washington Metropolitan Area and from sand and gravel operations also contributes to the excessive turbidity of the upper estuary.

In the lower estuary from U. S. Highway 301 Bridge to the mouth, water quality is generally satisfactory for most uses; however, occasional algal blooms and fish kills do occur. In addition, there are a few small isolated areas below waste outfalls where coliform bacteria concentrations are such as to prevent the commercial harvesting of shellfish. Depleted oxygen conditions in the deep waters near the mouth of the Potomac are observed annually during the warmest months of the year. This condition is common to all deep waters of the Chesapeake Bay.

The present (1965) water quality from Little Falls to Hallowing Point generally does not meet the objectives set for this reach of the estuary by the Interstate Commission on the Potomac River Basin. Results of studies have indicated that for the major portion of this reach, coliform and dissolved oxygen concentrations failed to meet the criteria established for these indicators more than 50 per cent of the time.

Diagrams illustrating the present water quality based on Interstate Commission on the Potomac River Basin criteria (Table I) and the Maryland Department of Water Resources (Table II) are presented in Figures 16 and 17, respectively.

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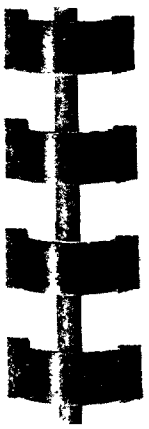


APPENDIX I. WATER QUALITY CRITERIA FOR THE POTOMAC RIVER IN THE WASHINGTON METROPOLITAN AREA

by
Interstate Commission on the Potomac River Basin
(Adopted January 22, 1958)

The ultimate goal of a comprehensive pollution abatement program is to provide that quality of water in the Potomac which will be compatible with the principal uses the people desire to make of them. Many uses are currently being made of the river even though the water quality is far from desirable for many such uses. Other uses are proposed for the future which can be realized only if pollution abatement is achieved. It is believed that the following water quality objectives and criteria for Five Sections of the Potomac River in the Washington Metropolitan Area are capable of achievement and desirable of attainment. Some aspects are admittedly long-range objectives. For example, the complete removal of raw sewage must await elimination of combined sewage and an application of practical methods of disposal of sewage and other wastes from boats. Nevertheless, the objectives are worthy goals and should be sought.

Because of the varying nature of the streams and the situations pertaining to them, no single set of water quality criteria can be made to apply to the entire Metropolitan region. The portion of the Potomac under consideration has been divided into Five Sections.

(1) Mouth of Monocacy to Great Falls

(2) Great Falls to Little Falls

(3) Little Falls to Key Bridge

(4) Key Bridge to Fort Washington

(5) Fort Washington to Hallowing Point

Key Bridge is the present division point between Sections (3) and (4), but this would be moved downstream to the vicinity of 14th Street Bridge in Washington at the proposed "Barrier Dam" if the provision for a water recreation basin is adopted as recommended in the Wolman Report entitled, "A Clean Potomac River in the Washington Metropolitan Area," November 1957.

APPENDIX I. (Continued)

As a basic consideration applying to all Sections, the Commission advocates that all sewage or industrial wastes discharged or permitted to flow into tributaries of the Potomac should be treated to that extent, if any, which may be necessary to maintain such waters in a sanitary and satisfactory condition at least equal to the criteria recommended below for the waters of the Potomac immediately above the confluence of the tributary with the main stream.

The water quality objectives for the Sections indicated above are as follows:

SECTION I

POTOMAC RIVER: MONOCACY RIVER TO GREAT FALLS

Objective: The establishment of conditions suitable for domestic water supplies, fish propagation, and recreational uses, and elimination of excessive soil erosion.

Criteria: The water quality shall be held in the normal natural condition of the stream, with nearly all samples falling within the following limits:

1. Coliform Group: MPN not to exceed 2,000 per 100 ml.

2. pH: Range between 6.5 and 8.5.

3. D. O.: Monthly median not less than 6.5 ppm, with no D. O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the River, turbidity of the stream should not be appreciably changed.

5. Other Conditions: There shall be no floating solids, oil, settleable solids, or sludge deposits attributable to sewage, industrial wastes or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes, or heated liquids, taste or odor producing substances either alone or in combinations sufficient to be injurious to fish life or to make the waters unsafe or unsuitable as a source of municipal water supply or other desirable uses.

APPENDIX I. (Continued)

SECTION II

POTOMAC RIVER: GREAT FALLS TO LITTLE FALLS

Objective: The elimination of sewage and waste effluent and excessive soil erosion so that the water will be suitable for domestic water supplies and fish life.

Criteria: The water quality shall be held in the normal natural condition of the stream, with nearly all samples falling within the following limits:

1. Coliform Group: MPN not to exceed 2,000 per 100 ml.

2. pH: Range between 6.5 and 8.5.

3. D. O.: Monthly median not less than 6.5 ppm, with no D. O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the River, turbidity of the stream should not be appreciably changed.

5. Other Conditions: There shall be no floating solids, oil, settleable solids, or sludge deposits attributable to sewage, industrial wastes or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes, or heated liquids, taste or odor producing substances, either alone or in combinations in sufficient amounts to be injurious to fish life or to make the waters unsafe or unsuitable as a source of municipal water supply or other desirable uses.

SECTION III

POTOMAC RIVER: LITTLE FALLS TO KEY BRIDGE

Objective: The elimination of sewage and waste effluent and excessive soil erosion so that the water will be suitable for swimming, boating, shore recreation, and safe for all species of fish life with favorable conditions prevailing for their propagation.

APPENDIX I. (Continued)

Criteria: The water quality shall be held in the normal natural condition of the stream, with nearly all samples falling within the following limits:

1. Coliform Group: MPN not to exceed 2,000 per 100 ml.

2. pH: Range between 6.5 and 8.5.

3. D. O.: Monthly median not less than 6.5 ppm, with no D. O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the River, turbidity of the stream should not be appreciably changed.

5. Other Conditions: There shall be no oil, floating solids, settleable solids, or sludge deposits attributable to sewage, industrial wastes, or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes or heated liquids, taste or odor producing substances, either alone or in combinations, in sufficient amounts to be injurious to fish life or to make the waters unsafe for swimming or shore recreation.

SECTION IV

POTOMAC RIVER: KEY BRIDGE TO FORT WASHINGTON

Objective: To reduce the quantity of combined sewage discharged, and to control the quality of waste effluents by effective treatment so as to make the water suitable for boating, shore recreation, industrial water supply and safe for the passage of all species of fish, with favorable conditions prevailing for the propagation of the hardier types.

Criteria: The water quality shall be maintained so that the results of most of the samples fall within the following limits:

1. Coliform Group: MPN not to exceed 10,000 per 100 r

2. pH: Range between 6.5 and 8.5.

APPENDIX I. (Continued)

3. D. O.: Monthly average not less than 5.0 ppm, with no D. O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the River, turbidity of the stream should not be appreciably changed.

5. Other Conditions: There shall be no floating solids, oil, settleable solids, or sludge deposits attributable to sewage, industrial wastes or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes or heated liquids, taste or odor producing substances, either alone or in combinations, in sufficient amounts to make the waters unsafe or unsuitable as a source of industrial process water supply, or for boating, shore recreation, passage of all species of fish or propagation of the hardier species of fish.

SECTION V

POTOMAC RIVER: FORT WASHINGTON TO HALLOWING POINT

Objective: To reduce the quality of combined sewage discharged and to control the quality of waste effluents by effective treatment of wastes and disinfection of effluents to make the water suitable for boating, fishing, swimming, and other recreational uses.

Criteria: The water quality shall be maintained so that the results of most of the samples fall within the following limits:

1. Coliform Group: MPN not to exceed 2,000 per 100 ml.

2. pH: Range between 6.5 and 8.5.

3. D. O.: Monthly average not less than 6.5 ppm, with no D. O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the River, turbidity of the stream should not be appreciably changed.

APPENDIX I. (Continued)

5. Other Conditions: There shall be no floating solids, oil, settleable solids, or sludge deposits attributable to sewage, industrial wastes or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes or heated liquids, taste or odor producing substances, either alone or in combinations, in sufficient amounts to be injurious to fish life or to make the waters unsafe or unsuitable for swimming, fishing, or other recreational uses.

INTERPRETIVE NOTES:

In arriving at numerical values included in the foregoing objectives, it is the intent that A.P.H.A. Standard Methods be utilized. It is further intended with a series of samples, that arithmetical averages be used.

The reference "other wastes" under Condition No. 5 of the foregoing objectives shall be interpreted to include trash, garbage, dirt, soil, or any matter causing or aiding pollution.

With reference to disinfection of effluents for safeguarding of recreational areas, it is intended that the recreational season comprise the period of May 1 to September 30.

APPENDIX II. SUMMARY OF ANALYSES OF WATER QUALITY DATA FOR THE NORTH BRANCH POTOMAC RIVER OBTAINED BY THE WEST VIRGINIA PULP AND PAPER COMPANY

A. Above Luke, Maryland (River Mile 53.1)
Critical Concentrations (January 1962 - February 1965)

Item	Units	Critical Month	High (H) or Low (L)	Mean	No. Observations for Critical Month
D. O.	mg/l	July	L	9.0	61
Temperature	°C.	July	H	19.6	61
B.O.D.$_5$	mg/l	July	H	4.5	61
pH	---	August	L	4.7*	65
Color	Platinum	July	H	7	61
Turbidity	Jackson Candle	March	H	45.1	65
Total Alkalinity	mg/l	May	L	4.0	65
Hardness	mg/l	July	H	83.7	61
Total Dissolved Solids	mg/l	July	H	217	61
Suspended Solids	mg/l	March	H	47	65

* Geometric

APPENDIX II. (Continued)

B. Below Luke, Maryland (River Mile 52.4)
Critical Concentrations (January 1962 - February 1965)

Item	Units	Critical Month	High (H) or Low (L)	Mean	No. Observations for Critical Month
D. O.	mg/l	August	L	7.1	65
Temperature	^{o}C.	July	H	24.2	43**
B.O.D.$_5$	mg/l	September	H	20.5	58
pH	---	October	H	9.4*	66
Color	Platinum	October	H	11.	68
Turbidity	Jackson Candle	October	H	67.3	68
Total Alkalinity	mg/l	April	L	9.6	58
Hardness	mg/l	July	H	98.1	63
Total Dissolved Solids	mg/l	July	H	381	63
Suspended Solids	mg/l	October	H	169	68

* Geometric

** Two years only

APPENDIX II. (Continued)

C. At Keyser, West Virginia (River Mile 45.9)
Critical Concentrations (January 1962 - February 1965)

Item	Units	Critical Month	High (H) or Low (L)	Mean	No. Observations for Critical Month
D. O.	mg/l	August	L	6.8	65
Temperature	^{o}C.	July	H	24.0	41**
B.O.D.$_5$	mg/l	December	H	21.2	46
pH	---	September	H	8.2*	60
Color	Platinum	August	H	118	64
Turbidity	Jackson Candle	October	H	115.7	68
Total Alaklinity	mg/l	April	L	13.8	57
Hardness	mg/l	October	H	210	68
Total Dissolved Solids	mg/l	October	H	638	68
Suspended Solids	mg/l	September	H	154	56

* Geometric

** Two years only

APPENDIX II. (Continued)

D. Upper Potomac River Commission Waste Treatment Facility, Westernport, Maryland (River Mile 51.0)
Critical Concentrations (January 1962 - February 1965)

Item	Units	Critical Month	High (H) or Low (L)	Mean	No. Observations for Critical Month
D. O.	mg/l	April	L	2.5	90
$B.O.D._5$	mg/l	January	H	82.0	124
pH	---	May	L	6.8*	93
Color	Platinum	February	H	829	84
Turbidity	Jackson Candle	October	H	420	93
Total Dissolved Solids	mg/l	June	H	1,725	90
Suspended Solids	mg/l	August	H	353	93

* Geometric

APPENDIX III

WATER QUALITY DATA FROM A SPECIAL STUDY OF THE UPPER POTOMAC RIVER BY THE PUBLIC HEALTH SERVICE IN 1965

APPENDIX III. WATER QUALITY DATA FROM A SPECIAL STUDY OF THE UPPER POTOMAC RIVER BY THE PUBLIC HEALTH SERVICE IN 1965

Location	River Miles to Mouth of Potomac	Date	Time	Stream Flow (cfs)	Water Temp. (°C.)	D.O. (mg/l)	B.O.D.$_5$ (mg/l)	Coliform Bacteria (MPN/100 ml)	E. Coli Bacteria (MPN/100 ml)	Total Hardness (mg/l as $CaCO_3$)	Alkalinity (mg/l)	pH	Conductivity (μ mhos 25^{0}C.)	Total Diss. Solids (mg/l)	Susp. Solids (mg/l)
Cumberland, Md.	304.7	7/14	0910	200	27.0	3.8	0.7	43,000	4,600	240	78	7.3	660	465	12
		7/15	0310	166	28.5	3.2	1.1	--	--	220	74	7.8	620	437	10
(Wiley Ford Bridge)		7/15	1430	166	29.5	3.9	2.5	--	--	220	70	8.4	620	431	22
		7/16	1210	138	27.9	3.5	3.0	2,300	3	220	79	7.3	660	476	10
		Average		168	28.2	3.6	1.8	9,900 *	120 *	230	75	7.7 *	635	452	13
Below Cumberland	296.3	7/14	1045	--	26.0	3.0	0.7	2,300	2,300	250	87	7.2	810	547	3
		7/15	0355	--	27.0	3.8	0.9	--	--	280	82	7.2	750	552	--
(Pittsburg Plate-Glass		7/15	1500	--	28.0	4.1	1.0	--	--	240	80	7.3	670	476	12
Company Dam)		7/16	1115	--	26.5	3.8	1.8	2,300	3	210	75	6.7	630	392	22
		Average		--	26.8	3.6	1.1	2,300 *	83 *	250	81	7.1 *	710	491	12
Oldtown, Md.	287.3	7/14	1120	--	27.2	5.6	1.3	230	230	200	90	7.6	800	517	--
		7/15	0450	--	27.0	5.1	2.3	--	--	220	93	7.3	740	491	16
(Greenspring Bridge)		7/15	1540	--	28.0	7.3	1.5	--	--	250	86	7.7	740	524	10
		7/16	1035	--	26.0	7.1	1.8	23,000	3	250	79	7.7	700	511	--
		Average		--	27.0	6.2	1.7	2,300 *	26 *	230	87	7.6 *	745	510	13
Paw Paw, W. Va.	276.5	7/14	1415	748	27.9	7.5	1.1	43,000	43	150	91	8.0	460	300	--
		7/15	0530	574	26.5	6.5	1.5	--	--	150	97	7.9	495	320	2
(Md. Rt. 51 Bridge)		7/15	1625	574	28.5	7.6	1.5	--	--	150	89	8.1	485	331	--
		7/16	0950	468	26.0	6.3	1.1	2,100	3	160	85	7.6	540	321	4
		Average		597	27.2	6.9	1.3	9,500 *	4 *	150	90	7.9 *	495	318	3
Hancock, Md.	239.1	7/14	1405	1,200	29.2	8.5	1.0	2,300	43	150	91	8.5	445	297	0.4
		7/15	0655	870	28.0	6.8	1.2	--	--	140	92	8.5	400	276	--
(U. S. Rt. 522 Bridge)		7/15	1725	870	29.2	8.8	0.9	--	--	140	86	8.7	430	292	0.0
		7/16	0845	650	25.5	6.5	1.0	2,300	3	140	83	8.3	490	322	--
		Average		907	27.9	7.6	1.0	2,300 *	4 *	140	88	8.5 *	441	296	0.2

* Geometric mean

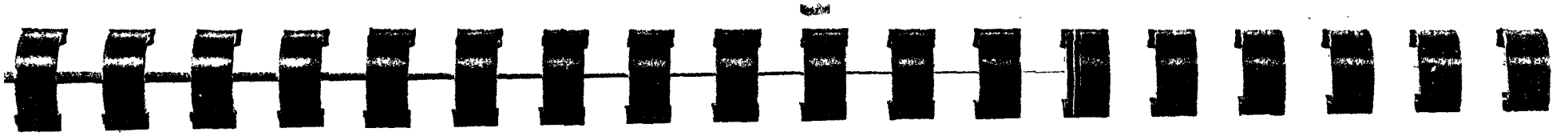
APPENDIX IV. SUMMARY OF ANALYSES OF WATER QUALITY DATA FOR THE POTOMAC RIVER BASIN FROM THE PUBLIC HEALTH SERVICE WATER POLLUTION SURVEILLANCE SYSTEM

A. POTOMAC RIVER AT WILLIAMSPORT, MARYLAND

1. Critical Concentrations

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var. %**	No. Observations for Critical Month
D.O.	mg/l	Aug.	L	6.0	7.5	8.7	13	6
D.O.	% sat.	Oct.	L	69	81	81	9	6
Temp.	^{o}C.	July	H	22.8	25.1	27.8	6	16
B.O.D.$_5$	mg/l	Nov.	H	0.3	1.3	2.6	77	4
C.O.D.	mg/l	Annual	H	9	12	21	36	8
pH	---	Aug.	H	7.6	7.9*	8.6	1*	20
Coliform Bacteria	MF/100 ml	May	H	10	590*	6,200	27*	16
Color	Platinum	Oct.	H	5	13	30	62	14
Turbidity	Jackson Candle	Mar.	H	6	96	1,000	245	17
Total Beta Radio-activity	pc/l	Feb.	H	6	43	85	82	7

* Geometric



APPENDIX IV. (Continued)

A. POTOMAC RIVER AT WILLIAMSPORT, MARYLAND

2. Critical Mass Flow Rates

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
D.O.	lbs/day (1,000's)	Sept.	L	14	24	34	41	3
$B.O.D._5$	lbs/day (1,000's)	Apr.	H	16	41	61	47	4
C.O.D.	lbs/day (1,000's)	Annual	H	64	570	2,200	139	8
Coliform Bacteria	MF/day (10^{12}'s)	Mar.	H	520	9,900*	210,000	6*	14
Total Beta Radio-activity	uc/day (1,000's)	Apr.	H	176	727	1,590	82	7

* Geometric

** Coefficient of Variation equals standard deviation divided by the mean.

APPENDIX IV. (Continued)

B. SHENANDOAH RIVER AT BERRYVILLE, VIRGINIA

1. Critical Concentrations

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
D.O.	mg/l	July	L	6.0	7.2	8.1	12	4
D.O.	% sat.	Oct.	L	62	80	87	9	10
Temp.	$^{o}C.$	July	H	22.5	25.4	28	8	9
$B.O.D._5$	mg/l	Aug.	H	3.7	5.1	6.7	20	6
C.O.D.	mg/l	Annual	H	7	25	49	61	8
pH	---	Dec.	H	7.8	8.4*	9.7	3*	17
Coliform Bacteria	MF/100 ml	Oct.	H	5.0	300*	23,000	61*	8
Color	Platinum	Mar.	H	0	8	20	85	11
Turbidity	Jackson Candle	Mar.	H	25	120	550	134	11
Total Beta Radio-activity	pc/l	Mar.	H	24	70	126	66	6

* Geometric

** Coefficient of Variation equals standard deviation divided by the mean.

APPENDIX IV. (Continued)

B. SHENANDOAH RIVER AT BERRYVILLE, VIRGINIA

1. Critical Concentrations (Continued)

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
Chloride	mg/l	Sept.	H	9	21	35	43	10
Total Alkalinity	mg/l	Mar.	L	64	77	88	12	11
Hardness	mg/l	Oct.	H	112	181	240	17	17
Total Dissolved Solids	mg/l	Oct.	H	144	305	440	31	13
Sulfate	mg/l	Sept.	H	64	133	240	47	10
Phosphate	mg/l	Jan.	H	0	0.1	0.8	265	7

** Coefficient of Variation equals standard deviation divided by the mean.

B. SHENANDOAH RIVER AT BERRYVILLE, VIRGINIA

2. Critical Mass Flow Rates

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
D.O.	lbs/day (1,000's)	Aug.	L	12	22	47	59	7
$B.O.D._5$	lbs/day (1,000's)	Mar.	H	9	140	380	141	3
C.O.D.	lbs/day (1,000's)	Annual	H	39	880	2,200	113	8
Coliform Bacteria	MF/day (10^{-12}'s)	Mar.	H	38	2,600*	26,000	9*	5
Total Beta Radio-activity	uc/day (1,000's)	Mar.	H	177	1,640	4,280	98	5
Chloride	lbs/day (1,000's)	Mar.	H	110	300	610	52	10
Total Alkalinity	lbs/day (1,000's)	July	L	28	41	800	48	8
Hardness	lbs/day (1,000's)	Mar.	H	1,820	5,290	12,600	60	11
Total Dissolved Solids	lbs/day (1,000's)	Mar.	H	3,050	7,040	17,000	60	10
Sulfate	lbs/day (1,000's)	Mar.	H	550	1,200	2,400	59	8
Phosphate	lbs/day (1,000's)	Jan.	H	0	4	25	2[illegible]	7

* Geometric

[illegible] divided by the mean.

C. POTOMAC RIVER AT GREAT FALLS, MARYLAND

1. Critical Concentrations

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.,%**	No. Observations for Critical Month
D.O.	mg/l	July	L	3.0	5.9	7.6	18	22
D.O.	% sat.	July	L	34	73	94	21	22
Temp.	°C.	July	H	21	25.9	33.3	14	23
B.O.D.$_5$	mg/l	Feb.	H	1.6	3.3	8.6	59	16
C.O.D.	mg/l	Feb.	H	5	22	67	72	15
pH	---	July	H	7.9	8.4*	9	2*	21
Coliform Bacteria	MF/100 ml	Mar.	H	140	3,900*	55,000	15*	15
NH_3-N	mg/l	Jan.	H	0.1	0.2	0.3	44	20
Color	Platinum	June	H	3	14	100	148	20
Turbidity	Jackson Candle	Jan.	H	9	83	430	155	21

* Geometric

** Coefficient of Variation equals standard deviation divided by the mean.

C. POTOMAC RIVER AT GREAT FALLS, MARYLAND

1. Critical Concentrations (Continued)

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
Total Beta Radioactivity	pc/l	Nov.	H	1	55	137	91	7
Chloride	mg/l	Oct.	H	6	18	30	36	23
Total Alkalinity	mg/l	Mar.	L	34	42	55	16	21
Hardness	mg/l	Oct.	H	116	141	162	8	23
Total Dissolved Solids	mg/l	Oct.	H	156	221	290	16	23
Sulfate	mg/l	Sept.	H	26	61	130	51	21
Phosphate	mg/l	Apr.	H	0	0.3	1.2	138	10

** Coefficient of Variation equals standard deviation divided by the mean.

C. POTOMAC RIVER AT GREAT FALLS, MARYLAND

2. Critical Mass Flow Rates

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
D.O.	lbs/day (1,000's)	Aug.	L	19	55	103	43	17
$B.O.D._5$	lbs/day (1,000's)	Feb.	H	49	530	4,200	203	16
C.O.D.	lbs/day (1,000's)	Feb.	H	120	4,600	33,000	200	15
Coliform Bacteria	MF/day (10^{12}'s)	Mar.	H	140,000	420,000*	3,700,000	3*	12
NH_3-N	lbs/day (1,000's)	Feb.	H	2	17	98	159	16
Total Beta Radioactivity	uc/day (1,000's)	Apr.	H	0	3,380	19,600	196	8
Chloride	lbs/day (1,000's)	Mar.	H	430	1,218	2,180	50	15
Total Alkalinity	lbs/day (1,000's)	Aug.	L	360	690	1,160	44	17
Hardness	lbs/day (1,000's)	Mar.	H	4,050	9,850	15,500	38	17
Total Dissolved Solids	lbs/day (1,000's)	Mar.	H	7,080	17,100	23,500	31	12

C. POTOMAC RIVER AT GREAT FALLS, MARYLAND

2. Critical Mass Flow Rates (Continued)

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
Sulfate	lbs/day (1,000's)	Aug.	H	240	430	570	24	17
Phosphate	lbs/day (1,000's)	Apr.	H	0	36	240	205	10

** Coefficient of Variation equals standard deviation divided by the mean.

D. POTOMAC RIVER ESTUARY AT WASHINGTON, D.C. (MEMORIAL BRIDGE)

1. Critical Concentrations

Item	Units	Critical Month	High (H) or Low (L)	Minimum	Mean	Maximum	Coef. of Var.%**	No. Observations for Critical Month
D.O.	mg/l	July	L	3.6	5.5	7.8	31	6
D.O.	% sat.	July	L	46	70	96	30	6
Temp.	°C.	July	H	26.5	27.8	29.1	4	6
$B.O.D._5$	mg/l	Apr.	H	1	1.6	2.4	39	5
C.O.D.	mg/l	Oct.	H	22	34	67	42	8
pH	---	Nov.	H	7.4	7.9*	9.4	4*	8
Coliform Bacteria	MF/100 ml	July	H	3,500	42,000*	200,000	15*	5
NH_3-N	mg/l	July	H	0	0.5	0.7	59	6
Color	Platinum	Feb.	H	5	12	31	76	8
Turbidity	Jackson Candle	Jan.	H	25	150	490	113	7
Total Beta Radio-activity	pc/l	Aug.	H	9	38	84	75	5

APPENDIX V. TABULATION OF MUNICIPAL AND INDUSTRIAL WASTE DISCHARGES IN THE POTOMAC RIVER BASIN OF MARYLAND

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
POTOMAC RIVER					
North Branch Potomac River	285.1				
Elk Run (W. Va.)	91.6				
Henry, W. Va.	0.1				
Alpine Coal Co.[a]	1.0	Wash Water		Settling	
Buffalo Creek (W. Va.)	86.4				
Bayard, W. Va.[b]	0.1				
North Branch Coal Co.	1.5	Wash Water		Settling	
Stony River (W. Va.)	78.3				
Savage River	53.5				
Luke, Md.[c]	52.5				
W. Va. Pulp & Paper Co.	52.5	Pulp & Paper Cooling & Lime		None[c]	
Georges Creek	51.4				
Frostburg, Md.	15.7	4,000[d]		None	680[d]
Sandspring Run	15.5				
Lotz Wholesale Meats Co.	3.4		1,000	Settling	2
Dashiell Dairy	11.2				

a. Part seepage to Deakin Run entering North Branch at River Mile 92.0.
b. Discharges of untreated or partially treated sewage from individual households.
c. Major portion of waste is treated at the Upper Potomac River Commission Waste Treatment Facility (45.9).
d. Part discharged to Wills Creek drainage area (see below).

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Piedmont, W. Va.	51.2	2,400	190,000	None	410
Westernport, Md.	51.0				
Upper Potomac River Commission	51.0	Pulp and Paper	17,200,000	Secondary	
Keyser, W. Va.	46.2	4,500	360,000	Primary	500
Bel Air, Md.	32.7	400	30,000	Lagoon	10
Pinto, Md.					
Barton's Dairy	32.6	Dairy		None	
Rocket Center, W. Va.	32.5				
Allegany Ballistics Lab., Hercules Powder Co.	32.5	2,000	100,000	Secondary	50
Cresaptown, Md.	29.5	3,500	280,000	Primary	390
Mason's Dairy	29.7	Dairy	35,000	None	20
Amcelle, Md.					
Celanese Fibers Co.	28.8	3,000			
		Processing	1,950,000	Lagoon	
		Cooling	40,000,000	None	15,000
		Sanitary	50,000	Lagoon	
Bowling Green, Md.	25.0	2,250	180,000	Primary	250
Kelly-Springfield Tire Co.	23.4	Cooling	2,900,000	None	
Potomac Edison Co.	22.6	Cooling	675,000	None	

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Wills Creek	21.7				
Hyndman, Pa.		1,124		None	190
Jennings Run	4.4				
Frostburg, Md.				None	
Appalachian Stone Corp.	4.1	Wash-Sand & Gravel		Settling	
Manley Sand Corp.	3.1	Wash-Sand & Gravel		Settling	
Braddock Run	2.3				
La Vale, Md.		4,031		None	680
Ridgeley, W. Va.	21.5	1,000		None	170
Cumberland, Md.	18.2	33,000	5,000,000[e]	Primary	
Evitts Creek	17.5				
Growdenvale, Md.	2.0	65		Primary	10
Pittsburgh Plate Glass Co.	11.3	Industrial	2,300,000	Lagoon	
	11.1	1,200	25,000	Primary	200
POTOMAC RIVER MAIN STEM					
South Branch Potomac River (W. Va.)	285.1	Various			
Paw Paw, W. Va.	276.8	750	50,000	None[f]	110

e. This includes wastes from several industries.
f. Lagoon under construction. Loading will be 15 lbs. B.O.D. (5-day) per day.

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Warm Springs Run (W. Va.)	238.3				
Berkeley Springs, W. Va.	7.0	700		None	120
Pennsylvania Glass Sand Co.	4.0	225	3,500	None	40
		Sand Washing	180,000	Settling	
Tonoloway Creek	237.5				
Hancock, Md.	0.8	2,000	150,000	Lagoon	50
Back Creek (W. Va.)	225.9	500			85
Conococheague Creek	210.7				
Scotland Orphanage, Pa.		850	100,000	Secondary	140
Dixon TB Hospital, Pa.		1,700	300,000	Secondary	240
Chambersburg, Pa.		22,000	3,000,000	Secondary	3,700
H. J. Heinz Co.		Canning	500,000	Secondary	
Path Valley Esso		Industrial	25,000	Secondary	
Mercersburg, Pa.		2,300	220,000	Secondary	390
Lowengart & Co.		Tannery	220,000	Primary	
Greencastle, Pa.		4,000	125,000	Secondary	680
Greencastle Packing Co.		Meat Packing	12,000	Secondary	
Williamsport, Md.					
W. D. Byron & Sons	0.3	Tannery	300,000	Screening, Neutralization, Aeration & Settling	
Potomac Edison Co.	210.6	Boiler	42,000		
		Cooling	72,000,000	Settling	
Williamsport, Md.	210.3	1,900	30,000	Primary	210

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Falling Waters, W. Va.	205.4				
E. I. DuPont de Nemours & Co.	205.4	420	10,000	Intermediate	70
		Industrial	500,000		
Opequon Creek (W. Va.)	202.0				
Winchester, Va.			2,500,000	Secondary	
Middleway, W. Va.			No community system		
Inwood, W. Va.			No community system		
Musselman Canning Co.		Industrial	300,000	Intermediate	
Leetown, W. Va.			No community system		
Kearneysville, W. Va.			No community system		
Martinsburg, W. Va.		Industrial[g]	750,000		
		12,000	2,500,000	Secondary	305
Shepherdstown, W. Va.	183.0	2,000	150,000	None	340
Antietam Creek					
Waynesboro, Pa.		11,000	1,200,000	Secondary	1,900
E. U. B. Orphanage, Pa.		350	21,000	Secondary	60
Camp Ritchie (National Guard), Md.		1,000	50,000	Secondary	170
Security, Md.					
Marquette Cement Co.	26.8	Cooling	7,800,000		
Marsh Run	26.4				
Fairchild Stratos Corp.		Plating	150,000		
		Cooling	50,000		
		Sanitary	30,000	Secondary	
Municipal Electric Light Plant	23.7	Cooling	33,000,000		
Hagerstown, Md.	22.6	36,000	3,800,000	Secondary	6,100

g. This total accounts for the industrial wastes of the following: National Fruit Co., Interwoven Co., Standard Lime & Stone Co., and Blair Lime Stone Co.

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Antietam Creek (Continued)					
Unnamed Tributary					
Western Maryland Rail. Co.		RR Car & Engine Cleaning	150,000	Settling & Oil Removal	
Funkstown, Md.	21.4	970	75,000	Lagoon	25
Breathedsville, Md.					
Maryland State Reformatory for Males	12.4	1,250	450,000	Secondary	30
Little Antietam (southern)		1,200	60,000	Lagoon	30
Boonsboro, Md.			47,000	None	55
Keedysville, Md.	1.0	320			
Shenandoah River (Va.)	171.5	Various			
Brunswick, Md.	165.2	3,700	250,000	Primary	410
Baltimore and Ohio Railroad Yard	165.3	Cleaning		Settling & Oil Removal	
Catoctin Creek	162.4		25,000	Primary	50
Myersville, Md.	24.7	450	60,000	Primary	120
Middletown, Md.	15.4	1,100			
Catoctin Creek (Va.)	159.8		105,000	Primary	140
Purcellville, Va.		850	110,000		
J. Lynn Cornwell, Inc.		Meat Packing	37,000	None	
Lovettsville, Va.					

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Monocacy River	153.5				
Gettysburg, Pa.		10,000	750,000	Secondary	1,700
Littlestown, Pa.		2,800	160,000	Secondary	50
Funkhouser Co.		Inorganic	108,000	Lagoons	
Piney Creek	45.3				
Taneytown, Md.		1,500	150,000	Secondary	40
Toms Creek	43.9				
Sabillasville, Md.		200	35,000	Secondary	5
Victor Cullen State Hospital		2,600	250,000	Secondary	65
Emmitsburg, Md.		600	50,000	Primary & Lagoon	15
St. Mary's College		900	70,000	Primary	100
Mt. St. Joseph's Academy					
Double Pipe Creek	38.3				
Willow Farms Dairy		Milk Processing	40,000		
Westminister, Md.		8,000	750,000	Secondary	210
George W. Magin Co.		Steam Condensate	20,000		
New Windsor, Md.		700	55,000	Secondary	20
Union Bridge, Md.		800	65,000	Lagoon	20
Hunting Creek	31.6				
Thurmont, Md.		675	55,000	Secondary	20
Howard Late & Co.		Meat-Packing	18,000	Primary	
Catoctin Furnace, Md.					
Fraley's Meats		Meat-Packing	9,000	Lagoon	

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Monocacy River (Continued)					
Detrick Creek	20.1				
Ideal Farms Dairy		Cooling	4,000		
Fort Detrick	19.7		650,000	Secondary	15
Carroll Creek	18.8				
Everedy Co.		Plating	94,000	Neutralization	
Jenkins Brothers		Canning			
Corning Packaging Co.		Cooling & Foam Plastic Packaging			
Frederick, Md.	18.7	24,500	3,800,000	Secondary[h]	1,200
Linganore Creek	16.3				
Unionville, Md.					
Maryland Coop. Milk Producers		Industrial	2,000		
PEPCO Dickerson Generating Station, Md.	152.1	81	1,215	Secondary	2
		Cooling	355,077,000	None	
Goose Creek (Va.)	142.1				
Middlesburg, Va.[i]		3,000	240,000	Secondary	80
Sugarland Creek (Va.)	135.3				
Herndon, Va.		1,960	155,000	Secondary	50

h. This includes dairy, poultry, meat packing, and cannery wastes.
i. This includes Leesburg, Goose Creek Country Club, and Foxcroft School, Va.

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Seneca Creek	133.9				
Weinschel Engineering Co.		Plating	1,200	Neutralization & Oxidation	
Carderock, Md.					
David Taylor Model Basin	121.7	1,600	130,000	Secondary	
Little Falls Branch	116.3				
Maloney Concrete Co.		Concrete Truck Washing	10,000	Settling	
Washington Petroleum		Oil-drum Cl.			
Dalecarlia Water Filtration Plant	116.1	Filter Wash	1,800,000	Chlorination	
Rock Creek	111.9				
Tributary					
Rockville, Md.					
H. & D. Metro Ford Tractor Co.	1.7	Tractor Cleaning		Settling & Oil Removal	
Tributary	13.9				
Chevy Chase, Md.					
Contee Sand & Gravel Co.	1.1	Concrete Truck Wash, Asphalt Stack Wash	5,000	Settling & Oil Removal	
District of Columbia West Heating Plant		Cooling Water	225,000	Retention, Dilution	None
		Boiler Blowdown, Softening	225,000	None	None

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Arlington, Va.					
Heating and Sewage Treatment Plants (Pentagon, etc.)		Sanitary	2,000,000	Secondary	1,500
		Cooling Water		None	None
Anacostia River	107.8				
Northeast Branch	8.6				
Indian Creek	3.6				
Muirkirk, Md.					
Mineral Pigments Corp.		Pigments, chrom.	200,000	Oxid., setl.	None
Branchville, Md.					
A. H. Smith Sand & Gravel Co.		Sand & Gravel Wash	1,400,000	Settling	None
Paint Branch	3.6				
Whiteoak, Md.					
U. S. Naval Ordnance Lab.		3,000	110,000	Primary	
		Cooling Water	160,000	None	None
Wm. H. McCeney Co.		Sand & Gravel Wash	460,000	Settling	None
Tributary					
Hyattsville, Md.					
Lustine Chevrolet Co.		Engine Cl.		Oil Seprtn.	
District of Columbia					
PEPCO Benning Generating Station		Cooling Water	154,520,000	None	None
Potomac Sand & Gravel Co.		Sand & Gravel Wash		Settling	None
		Cooling Water	109,169,000	None	None

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Fourmile Run (Va.)	106.9				
Arlington County, Va.	0.7	185,000	17,400,000	Primary	23,000
District of Columbia					
Office of Naval Research	105.4	Cooling Water	184,000	None	None
		Radioactive	6,600	Holding	None
Blue Plains Sewage Treatment Plant (District of Columbia Water Pollution Control Plant)	105.4	1,400,000	215,000,000	Secondary	80,300
Alexandria, Va.					
PEPCO Generating Station		Cooling Water	315,609,000	None	None
Oxon Run	104.6				
Hillside, Md.					
Washington Sand & Gravel Co.		Sand & Gravel Wash		Settling	None
Hunting Creek (Va.)	103.2				
	1.4				
Cameron Run					
Back Lick Run					
Springfield, Va.					
Virginia Sand & Gravel Co.		Sand & Gravel Wash	1,000,000	Settling	None
		138,000	13,200,000	Secondary	4,500
Alexandria, Va.					
Fairfax County Sanitary District #1					
Westgate Plant		90,000	9,600,000	Intermediate	11,700
Broad Creek	100.4				
	3.2				
Henson Creek					
Camp Springs, Md.					
[illegible] Sand & Gravel Co.	6.1	Sand & Gravel	[illegible]	Settling	None

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Piscataway Creek	97.2				
Tinkers Creek	4.4				
Meetinghouse Branch	7.9				
Andrews AFB Plant #1		Sanitary	700,000	Secondary	
Paynes Branch	7.9				
Andrews AFB Plant #4		Sanitary		Secondary	
Clinton, Md.					
Inland Materials, Inc.		Sand & Gravel Wash		Settling	None
Tributary					
Clinton, Md.					
Country Club Cleaners		Laundry & Dry Cleaning		Secondary	
Fort Washington Estates			100,000	Secondary	100
Little Hunting Creek (Va.)	95.8				
Fairfax County Sewage Treatment Plant	1.2	11,000	2,200,000	Secondary	450
Dogue Creek (Va.)	93.5				
Fairfax County Sewage Treatment Plant		8,000	1,100,000	Secondary	340
Fort Belvoir (USAR) Plant #2		Sanitary	1,450,000	Secondary	170
		Cooling Water	7,500,000	None	None
Gunston Cove (Va.)	91.3				
Accotink Creek	2.0				
		12,600	1,400,000	Secondary	350

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Gunston Cove (Va.) (Continued)					
Pohick Creek	1.6				
Pohick Estates			13,000	Secondary	10
Fort Belvoir (USAR) Plant #1		3,700	312,000	Secondary	50
Potomac Sand & Gravel Co. (Mobile Barge)		Sand & Gravel		Settling	None
		Wash		Settling	None
		Dredging			
Pomonkey Creek	89.0				
North Indian Head Estates, Md.		170	13,000	Secondary	4
Potomac Heights, Md.		2,700	120,000	Primary	300
Indian Head, Md.		1,200	96,000	Primary	130
Occoquan Bay (Va.)	83.3				
Occoquan Creek					
Broad Run					
Warrenton, Va.					
Lee-Hi Motel				Secondary	
Gainesville, Va.					
Lakeview Estates				Secondary	
Bristow, Va.					
Linton Hall School		400		Primary	40
Cedar Run					
Camp Upshur (U. S. Marine Corps)		Filter Backwash (summer)	2,000	None	None
		Sanitary (summer)	94,000	Secondary	

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Occoquan Bay (Va.) (Continued)					
Bull Run					
Yorkshire, Va.				Secondary	
Yorkshire Elementary School		3,560	400,000	Secondary	90
Manassas, Va.					
Manassas Regional High School		440	10,000	Secondary	
Occoquan, Va.					
Woodbridge S. D. Plant		Sanitary	100,000	Secondary	
Massey Creek	3.6				
Giles Run					
Lorton Nike Site (USAR)		50	3,000	Secondary	1
Marumsco Creek	1.4				
Woodbridge S. D. Plant		Sanitary	340,000	Secondary	
Farm Creek	0.2				
Woodbridge S. D. Lynwood - Featherstone Plant		Sanitary		Secondary	
Indian Head, Md.					
U. S. Naval Propellant Plant					
- Housing, Jado, and Storage Areas		Sanitary	255,000	Primary	
- Industrial Area			380,000	None	
Neabsco Creek (Va.)	82.4				6
M. G. Garber Trailer Park		240	23,000	Secondary	
Garfield High School		730	15,000	Secondary	

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Mattawoman Creek	81.6				
Waldorf Nike Site (USAR)		Sanitary	2,400	Secondary	
Waldorf, Md.					
Naval Research Lab.		20		Secondary	
Tributary					
Bryans Road, Md.					
Crazy Carryout & Laundromat		Laundry		Carb. Filter, Chlorination	
Indian Head, Md.					
U. S. Naval Propellant Plant - Industrial Area		San. & Chem.	20,000	None	
Quantico U. S. Marine Corps Reservation, Va.		Filter Wash Water	90,000	None	
VEPCO Possum Pt. Generating Station, Va.	78.5	Cooling Water		None	None
Quantico Creek (Va.)	78.2				
Tributary					
Washington Reid Elem. School				Secondary	
Dumfries Triangle, Va. (2 plants)		1,400	140,000	Secondary	35
Dumfries School, Va.		Sanitary		Secondary	
Tributary					
Melrose Gardens Subdivision, Va.		1,200	120,000	Secondary	30
Quantico U. S. Marine Corps Reservation					
- Post Docks		20	400	None	
- Main Sewage Treatment Plant		Sanitary	1,390,000	Secondary	
- Vehicle Wash Racks		Vehicle Wash	10,000	None	

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Chopawamsic Creek (Va.)	76.1				
Quantico U. S. Marine Corps Reservation					
Brown Field (Summer)		Sanitary	86,400	Primary	
Tank Creek (Va.)	74.7				
Quantico U. S. Marine Corps Reservation					
Midway Island (Housing)		Sanitary	62,000	Secondary	
Aquia Creek (Va.)	69.3				
Beaverdam Run					
Quantico U. S. Marine Corps Res.					
- Rifle Range			60,000	Secondary	
Garrisonville, Va.					
Aquia Mobile Park		100	10,000	Lagoon	
Camp Barrett (U. S. Marine Corps)		Sanitary	164,500	Secondary	
		Filter Wash Water	7,500	None	
Potomac Creek (Va.)	66.9				
Accakeek Creek					
Claiborne Creek					
Stafford High School				Secondary	
Port Tobacco River	53.5				
Port Tobacco Creek					
La Plata, Md.		1,400	110,000	Secondary	
Upper Machodoc Creek (Va.)	45.0				
Dahlgren, Va.					
U. S. Naval Weapons Lab.		2,800 day	350,000	Secondary	

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Wicomico River	35.1				
Allens Fresh Run					
Zekiah Swamp					
Waldorf, Md.					
Waldorf Laundry		Laundry	7,000	Settling	
East Coast Radio Trans. Station (USAR)		Sanitary	10,000	Secondary	
Newport Run					
Gilbert Swamp Run					
So. Md. Correctional Camp		130	11,000	Secondary	
Nomini Bay (Va.)	28.7				
Nomini Creek	1.9			Secondary	
Cople-Montross Elem. School					
Breton Bay	27.2				
Town Run	7.0				
Leonardtown, Md.	1.0	670	54,000	Primary	75
Glebe Run					
Leonardtown Sand & Gravel Co.		Sand & Gravel Wash		Settling	None
Piney Point, Md.					
L. P. Steuart		Bulk Oil Stg. (spillage)		Catch pans	
Marina & Residences (Summer)		250		Primary	30
Piney Point Creek					
Piney Point Hotel (Summer)		250		Primary	30

APPENDIX V. (Continued)

Location of Municipality or Industry	River Miles	Population Served or Waste Type	Waste Discharge (gpd)	Type of Treatment	B.O.D. (5) Discharged (lbs/day)
Yeocomico River (Va.)	12.7				
South Yeocomico River	1.1				
Lodge Creek	1.4				
Callao Elementary School				Secondary & Lagoon	
St. Mary's River	11.3				
St. Mary's City, Md.					
St. Mary's Jr. College		180	8,000	Primary	
Naval Air Navigation & Electronics Project (Webster Field)		65 day		Primary (part) Secondary (part)	
Smith Creek	9.9				
Ridge Md.					
G. I. Rupert Lore Seafood Co.		Shellfish Shucking		None	
Coan River (Va.)	8.0				
Lake, Va.					
S. S. Headley Oyster Packer		Shellfish Shucking			

APPENDIX VI. POTENTIAL FISHERY CLASSIFICATIONS OF STREAMS IN THE POTOMAC RIVER BASIN OF MARYLAND

by
U. S. Fish and Wildlife Service

I. NORTH BRANCH POTOMAC RIVER

Headwaters to Savage River (43.0 miles)

The main stem of the North Branch in this sub-reach has been classified as Type 3P (Trout stream with observed pollution condition). This is a potential classification only. One long-time resident of Barnum, West Virginia, the site of the proposed Bloomington Reservoir, stated that no fish had been seen at that site for 35 years. Some of the small tributaries in Maryland are classified as Type 2 (Trout feeder), Type 3 (Trout stream), and Type 4 (Sucker stream).

Savage River to New Creek (7.8 miles)

Savage River in its headwaters and below Savage Reservoir has been classified as Type 2 (Trout feeder) and in other sections as Type 3 (Trout stream). Most tributaries to Savage River are classified as Type 2 (Trout feeder) in their headwaters and Type 3 (Trout stream) in their lower reaches, except that Crabtree Creek is classified as Type 4 (Sucker stream). Georges Creek is classified as Type 2 (Trout feeder) in the headwaters, Type 3 (Trout stream) in the upper reaches below the headwaters, and 2P (Trout feeder with observed pollution condition) in the lower reaches. The main stem of the North Branch Potomac River in this sub-reach is classified as 6P (Bass stream with observed pollution condition).

New Creek to Wills Creek (24.0 miles)

This entire 24-mile sub-reach is classified as 8P (Bullhead stream with observed pollution condition).

APPENDIX VI. (Continued)

Wills Creek to South Branch (21.7 miles)

Wills Creek in Maryland has been classified as Type 6 (Bass stream) upstream and Type 6P (Bass stream with observed pollution condition) downstream. Jennings Run is classified as Type 3P (Trout stream with observed pollution condition). Braddock Run, while not reported, would probably be classified the same as Jennings Run. Evitts Creek has been assigned Type 5 (Bass feeder) classification. The North Branch in the sub-reach from Cumberland to its junction with the South Branch is classified as Type 8 (Bullhead stream).

II. POTOMAC RIVER, SOUTH BRANCH TO CONOCOCHEAGUE CREEK

South Branch to Tonoloway Creek (47.6 miles)

This sub-reach of the Potomac River has been classified as Type 6 (Bass stream). Fifteen Mile Creek (confluence at River Mile 255.4) and Sideling Hill Creek have been classified as Type 5 (Bass feeder). Little Tonoloway Creek has been classified as Type 4 (Sucker stream).

Tonoloway Creek to Conococheague Creek (26.8 miles)

Tonoloway Creek in Maryland has been classified as Type 5P (Bass feeder with observed pollution condition) before the construction of waste treatment facilities at Hancock. It is assumed that the classification would now be Type 5, except perhaps immediately below the effluent outfall. The Potomac River in this sub-reach is classified as Type 6 (Bass stream). Licking Creek is classified as Type 6 (Bass stream). Little Conococheague Creek, which enters the Potomac River at River Mile 216.6, is classified as Type 4 (Sucker stream).

APPENDIX VI. (Continued)

III. POTOMAC RIVER, CONOCOCHEAGUE CREEK TO LITTLE FALLS

Conococheague Creek to Antietam Creek (30.5 miles)

Conococheague Creek in Maryland has been classified as Type 9 (Catfish stream). Rockdale Run, which enters Conococheague Creek at River Mile 17.0, is classified as Type 4 (Sucker stream). The Potomac River in this sub-reach is classified as Type 5 (Bass feeder). Marsh Run, which enters the Potomac River at River Mile 192.4, is classified as Type 4 (Sucker stream).

Antietam Creek to Monocacy River (26.7 miles)

Antietam Creek has been classified as Type 5 (Bass feeder). The upper reaches of the small tributaries of Antietam Creek near the Pennsylvania State line are classified as Type 4 (Sucker stream). The Potomac River between Antietam Creek and the Shenandoah River is classified as Type 6 (Bass stream). The Potomac River between the Shenandoah River and the Monocacy River is classified as Type 9 (Catfish stream). The West Branch of Catoctin Creek, which enters Catoctin Creek (Maryland) at River Mile 28.2, is classified as Type 2 (Trout feeder). The upper-third of Catoctin Creek (Maryland) is classified as Type 3 (Trout stream), the middle-third as Type 5 (Bass feeder), and the lower-third as Type 6 (Bass stream). Little Catoctin Creek, which enters Catoctin Creek at River Mile 17.0, is classified as Type 4 (Sucker stream). Tuscarora Creek, which enters the Potomac River at River Mile 155.7, is classified as Type 4 (Sucker stream).

Monocacy River to Little Falls (37.4 miles)

The Monocacy River has been classified as Type 6 (Catfish stream) except for a short reach of about three miles just below the Pennsylvania State line, which is classified as Type 5 (Bass feeder). The small tributaries of the Monocacy River to the west of the River are generally classified as Type 3 (Trout stream) in the headwaters, and as Type 5 (Bass feeder) downstream. The larger tributaries of the Monocacy River to the east of the River are generally classified as Type 4 (Sucker

APPENDIX VI. (Continued)

stream) in the headwaters, as Type 5 (Bass feeder) in the mid-reaches, and as Type 6 (Bass stream) in the lower reaches. The Potomac River in this sub-reach is classified as Type 9 (Catfish stream). Horsepen Branch, which enters the Potomac River at River Mile 137.9, is classified as Type 4 (Sucker stream). Seneca Creek is classified as Type 6 (Bass stream) in the lower reach, and its two major tributaries, Dry Seneca Creek and Great Seneca Creek, are classified as Type 4 (Sucker stream) in the headwaters, and as Type 5 (Bass feeder) downstream. Muddy Branch, which enters the Potomac River at River Mile 131.4, is classified as Type 4 (Sucker stream) in the upper half, and as Type 5 (Bass feeder) in the lower half. Watts Branch, which enters the Potomac River at River Mile 129.2, is classified as Type 4 (Sucker stream). Cabin John Creek is classified as Type 8 (Bullhead stream).

APPENDIX VII. RIVER MILEAGES IN THE POTOMAC RIVER ESTUARY: MARYLAND STATE PLANNING DEPARTMENT AND INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

The River Mileages used in this report are those recently developed by the Maryland State Planning Department. The table below has been prepared to compare these mileages in the upper Potomac estuary with those of the Interstate Commission on the Potomac River Basin to assist in locating points under the two systems.

Location	INCOPOT	Maryland State Planning Department
Point-of-Rocks	163.0	159.4
Great Falls	125.6	126.5
Little Falls (head of tide)	--	116.1
Fletcher's Boat House	104.5	114.8*
Three Sister's Island	103.1	113.4*
Roosevelt Island	101.6	111.9*
Memorial Bridge	100.7	111.0
Highway Bridge	99.7	109.9
Potomac Park	99.1	109.1
Hains Point	98.3	108.3*
Giesboro Point	97.4	107.4
Above Sew. Treat. Plant	96.1	106.0
Opposite Sew. Treat. Plant	95.6	105.4
Below Sew. Treat. Plant	95.3	105.1
Woodrow Wilson Bridge	94.4	103.4

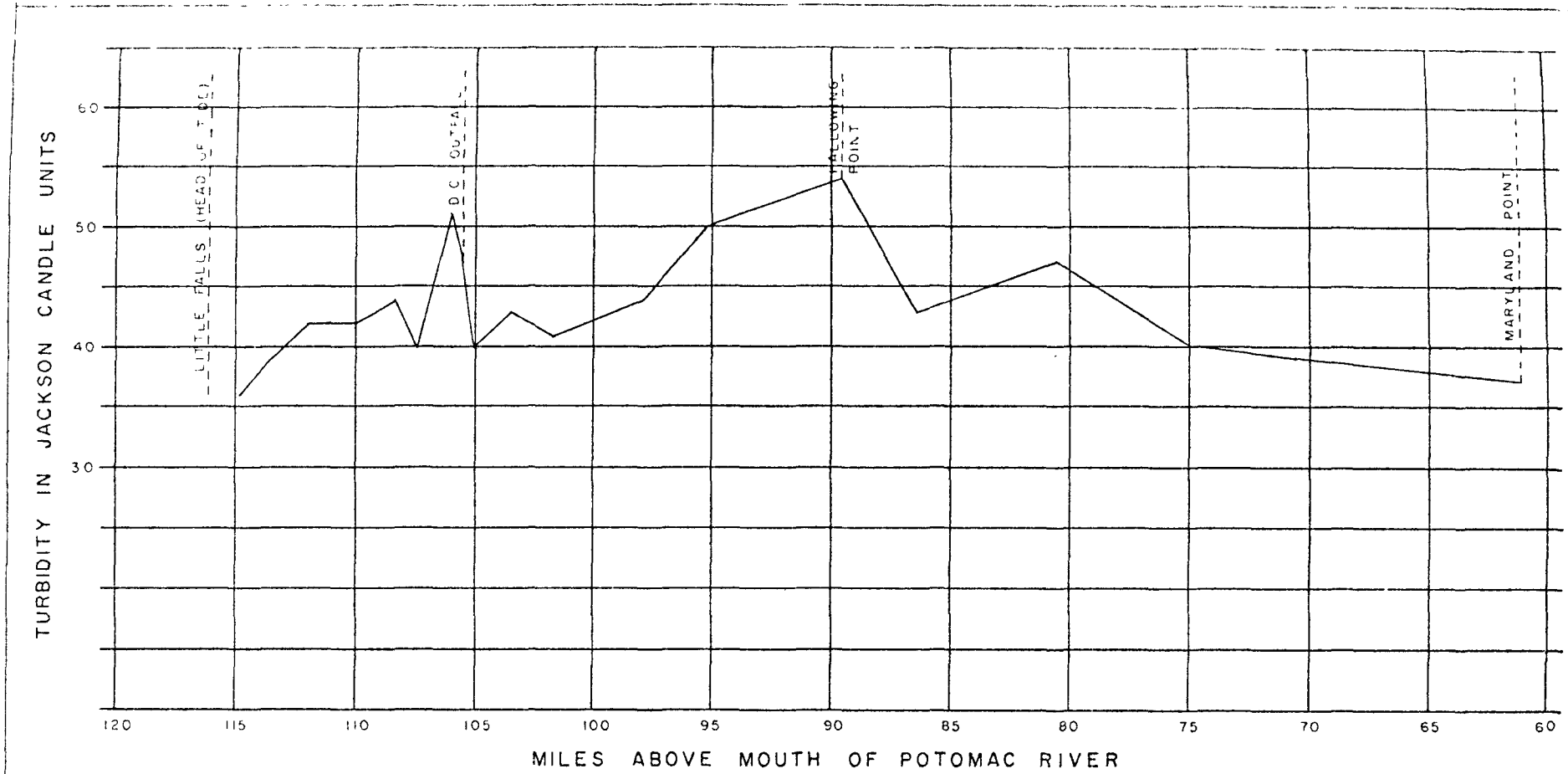
APPENDIX VII. (Continued)

Location	INCOPOT	Maryland State Planning Department
Fort Foote	92.9	101.7
Fort Washington	89.0	97.8
Mt. Vernon	86.4	95.2
Marshall Hall	85.0	93.8
Hallowing Point	80.7	89.5
Indian Head	77.5	86.3*
Stump Neck	72.7	80.4*
Sandy Point	67.3	75.0*
Smith Point	62.9	70.5*
Maryland Point	57.3	61.0*

* Calculated or estimated

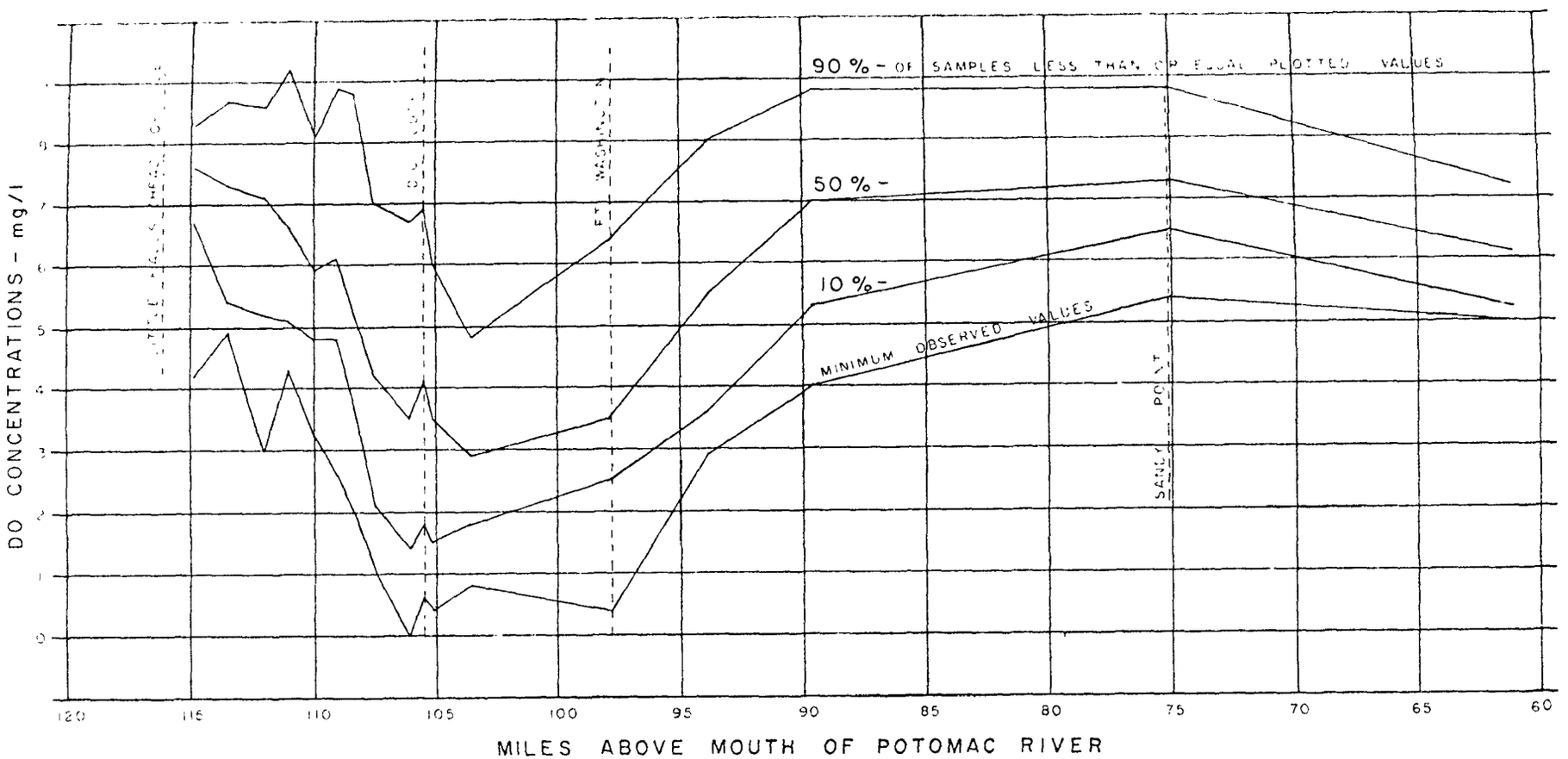
A P P E N D I X V I I I

F I G U R E S



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

POTOMAC ESTUARY
TURBIDITY vs RIVER MILE



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

POTOMAC ESTUARY - D.O. CONC.
JULY 15 - SEPT 15, 1960 - 1964

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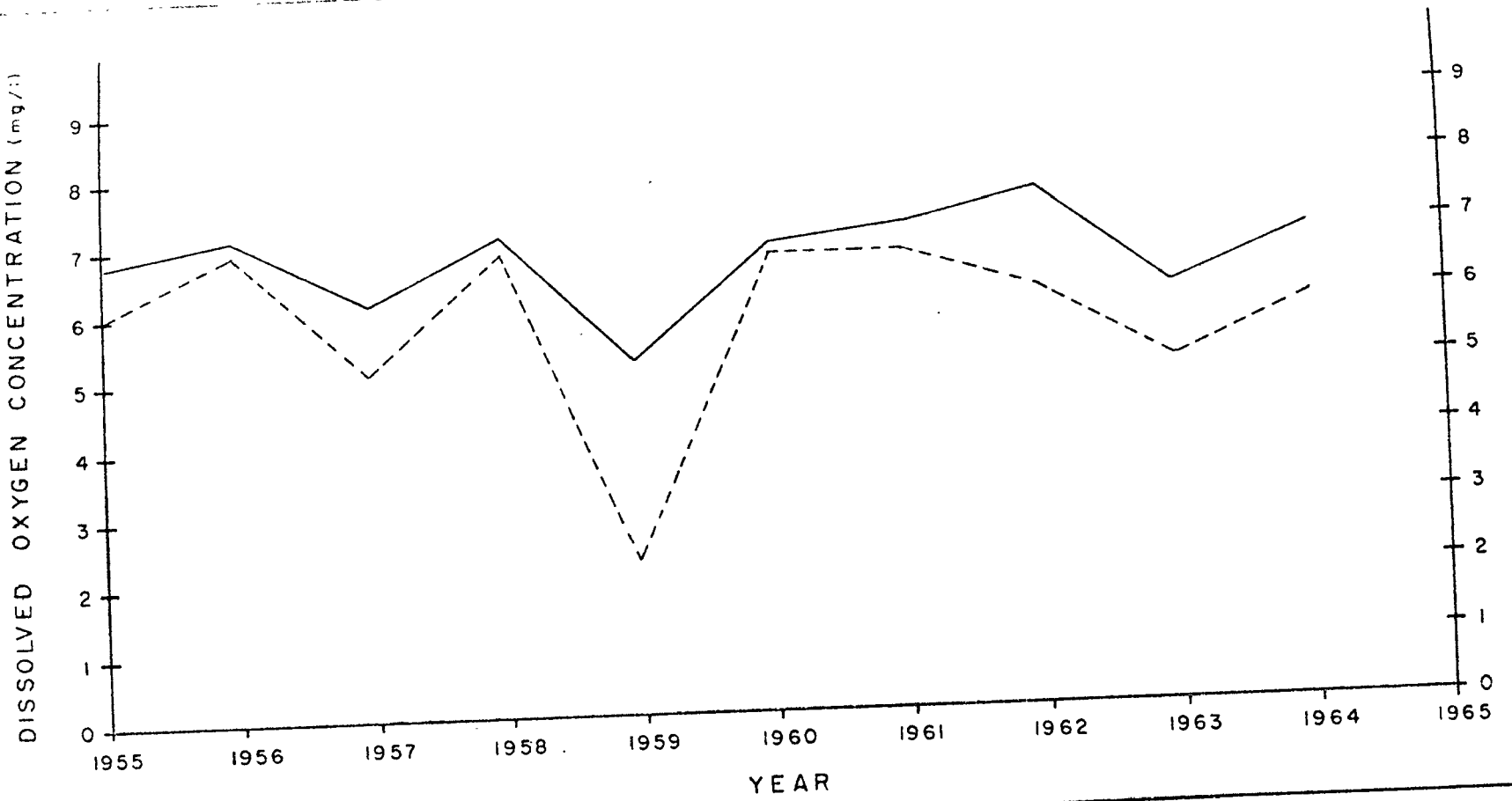
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

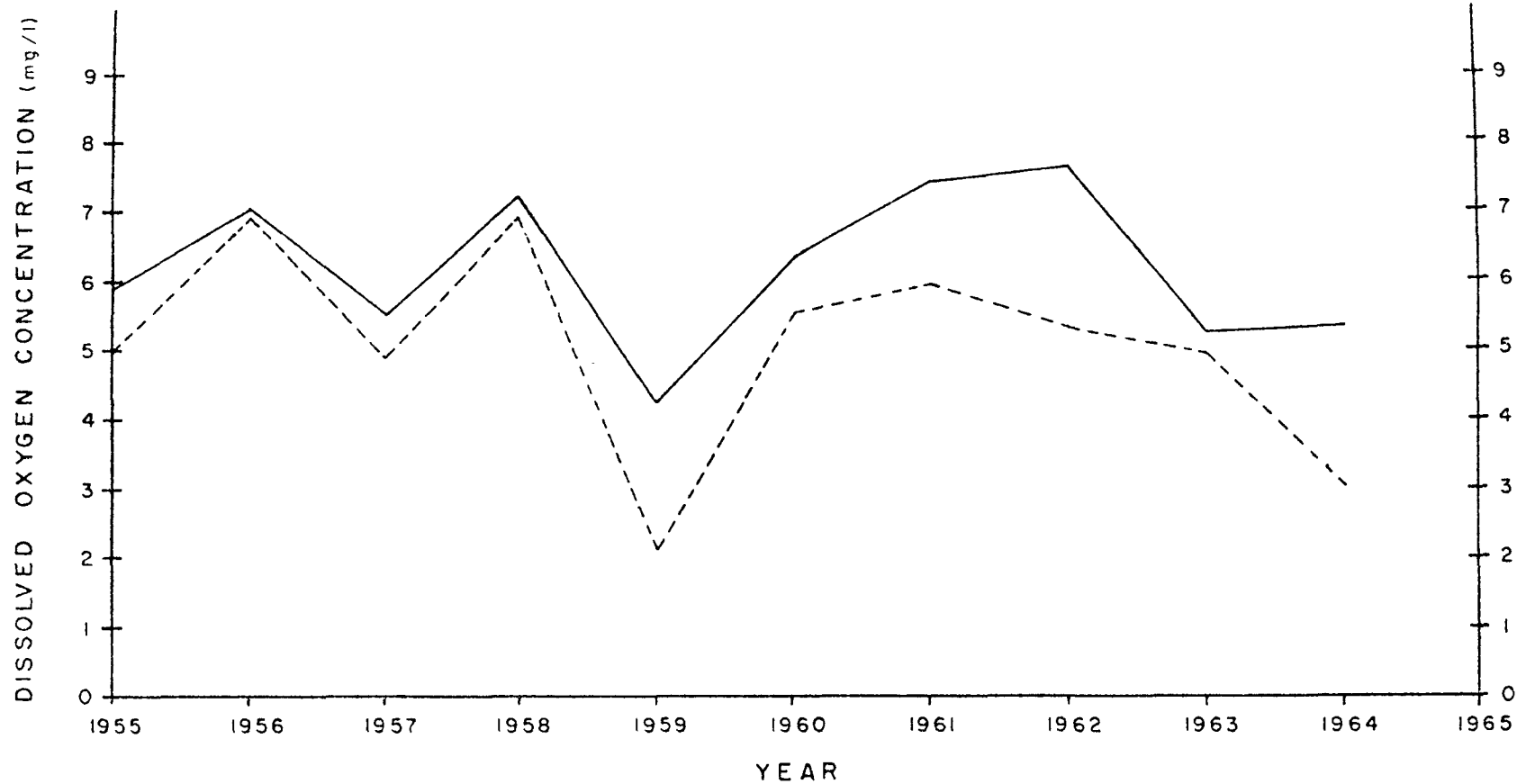
MIN. DISSOLVED OXYGEN CONC.
AT THREE SISTERS ISLAND
(RIVER MILE 113.4)

LEGEND:

——— MINIMUM CONSECUTIVE 28-DAY AVERAGE

- - - MINIMUM SINGLE VALUE DURING 28-DAY PERIOD

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE



LEGEND:

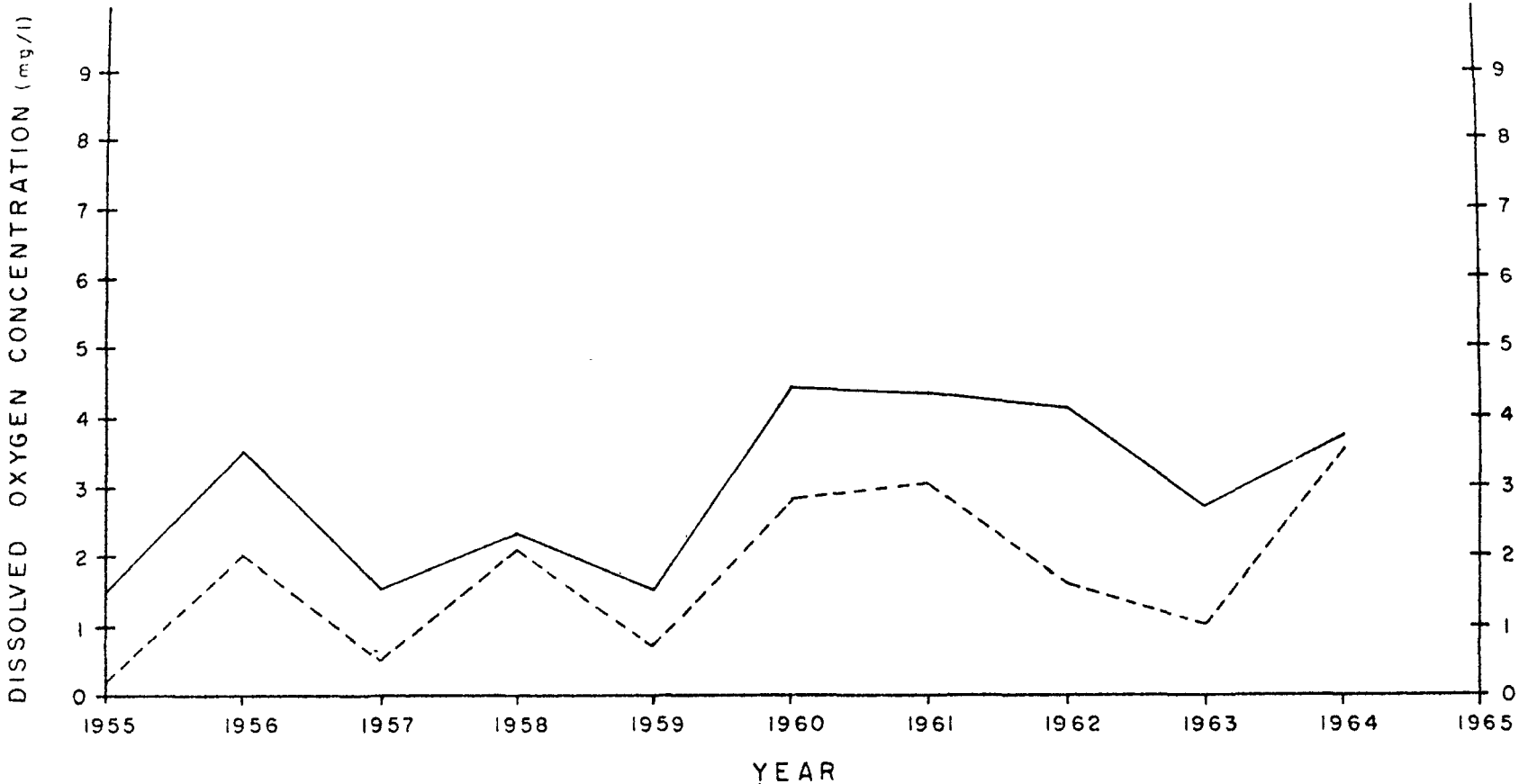
——— MINIMUM CONSECUTIVE 28-DAY AVERAGE

- - - - - - MINIMUM SINGLE VALUE DURING 28-DAY PERIOD

WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MIN. DISSOLVED OXYGEN CONC.
AT ROOSEVELT ISLAND
(RIVER MILE 111.9)

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MIN. DISSOLVED OXYGEN CONC.
AT GIESBORO POINT
(RIVER MILE 107.4)

LEGEND:

——— MINIMUM CONSECUTIVE 28-DAY AVERAGE

- - - - - - MINIMUM SINGLE VALUE DURING 28-DAY PERIOD

LEGEND.

——— MINIMUM CONSECUTIVE 28-DAY AVERAGE

- - - - - - MINIMUM SINGLE VALUE DURING 28-DAY PERIOD

WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MIN. DISSOLVED OXYGEN CONC. BELOW D.C. OUTFALL (RIVER MILE 105.1)

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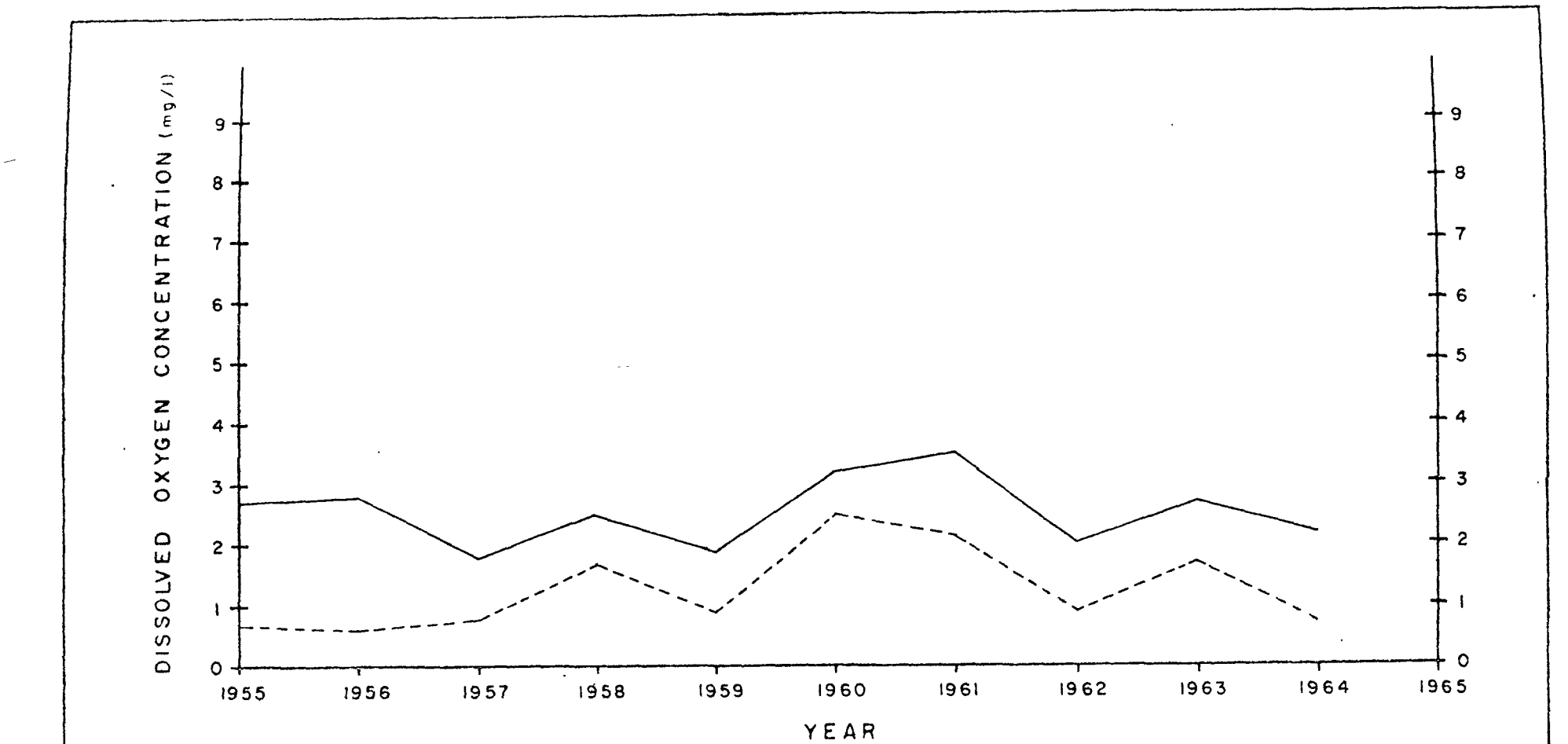
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

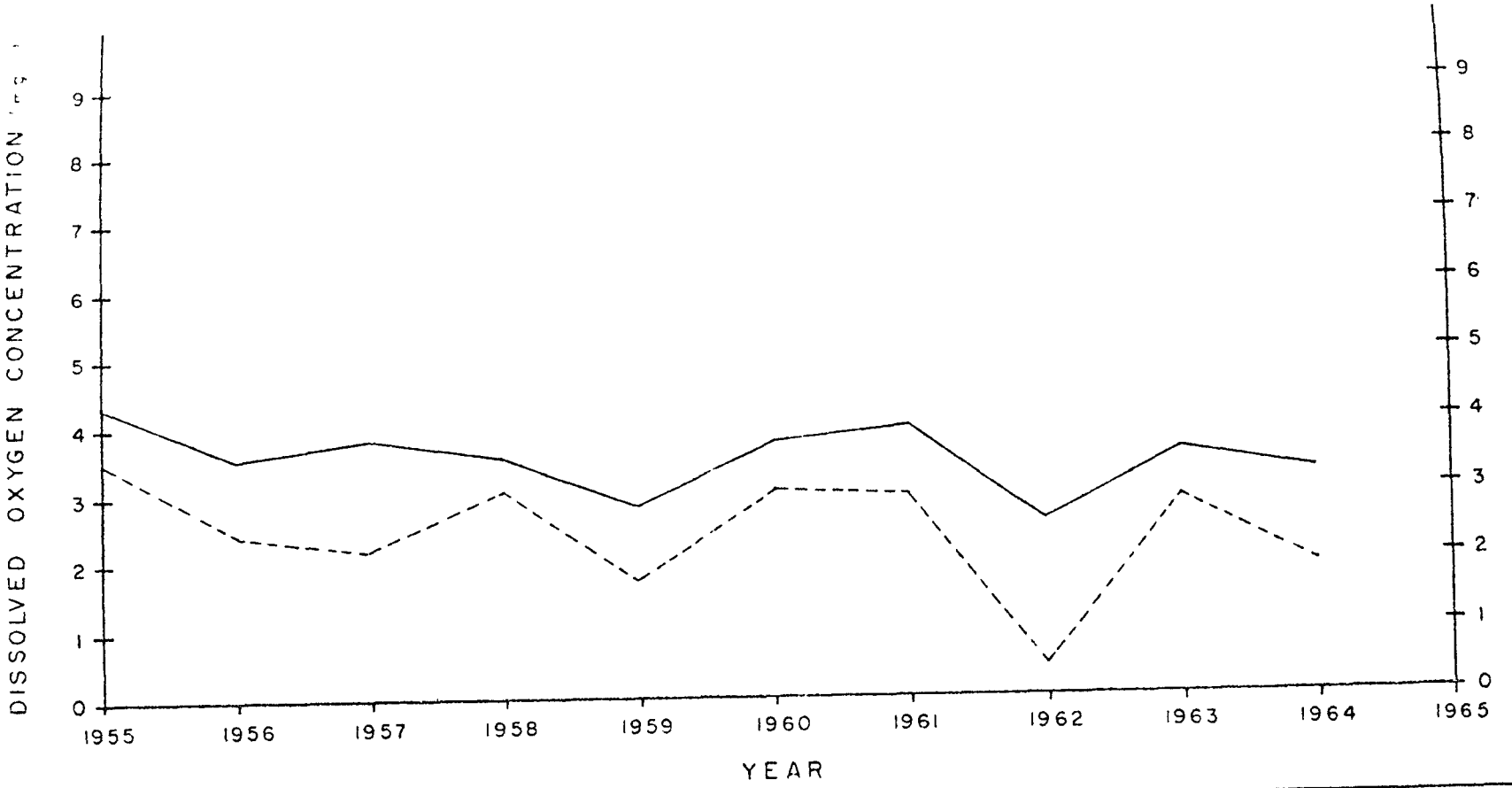
MIN. DISSOLVED OXYGEN CONC.
AT FORT FOOTE
(RIVER MILE 101.7)

LEGEND:

——— MINIMUM CONSECUTIVE 28-DAY AVERAGE

[illegible] DURING 28-DAY PERIOD

[illegible] EALTH, EDUCATION & WELFARE



LEGEND:

——— MINIMUM CONSECUTIVE 28-DAY AVERAGE

- - - - - - MINIMUM SINGLE VALUE DURING 28-DAY PERIOD

WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MIN. DISSOLVED OXYGEN CONC.
AT FORT WASHINGTON
(RIVER MILE 97.8)

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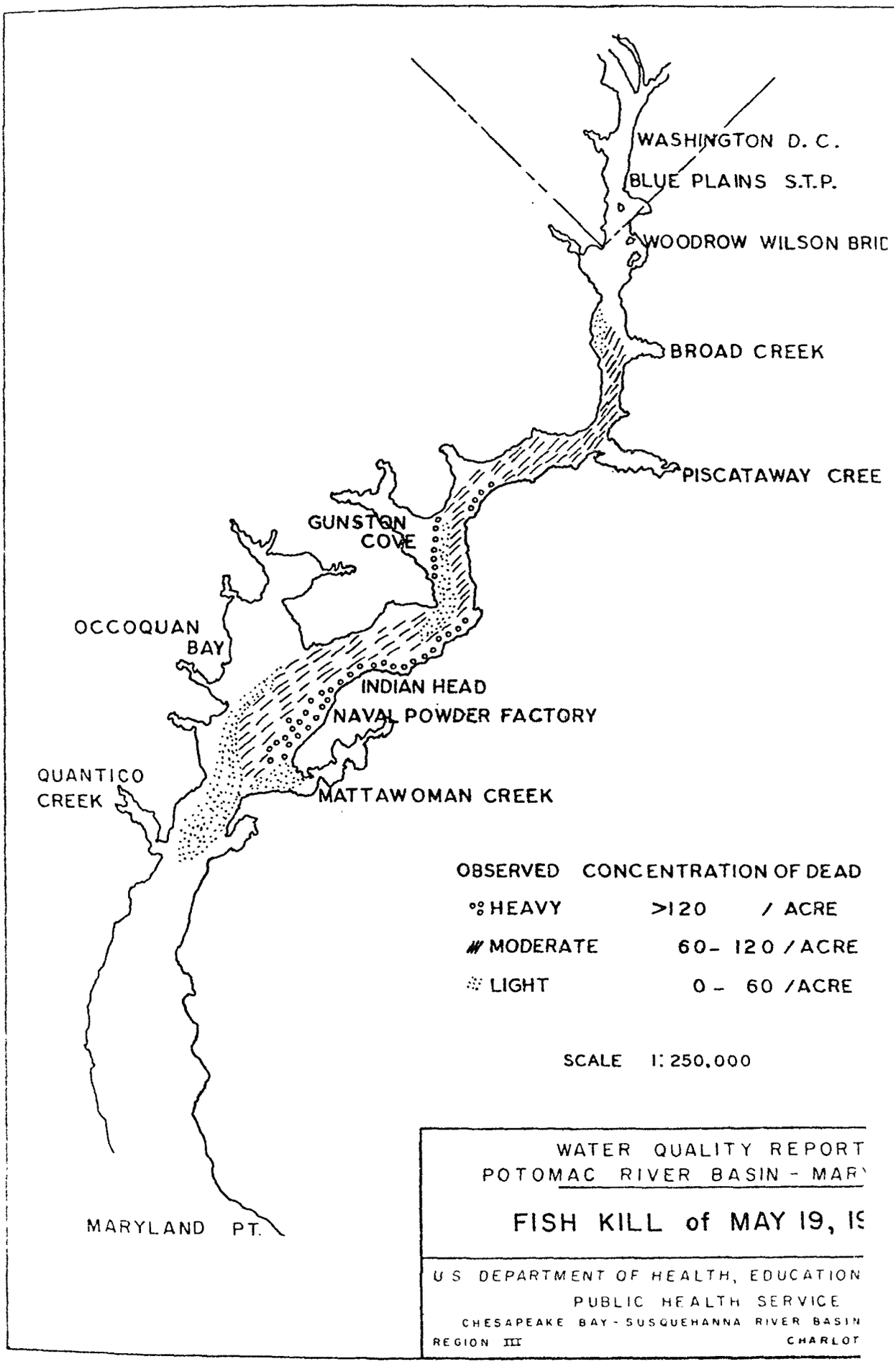
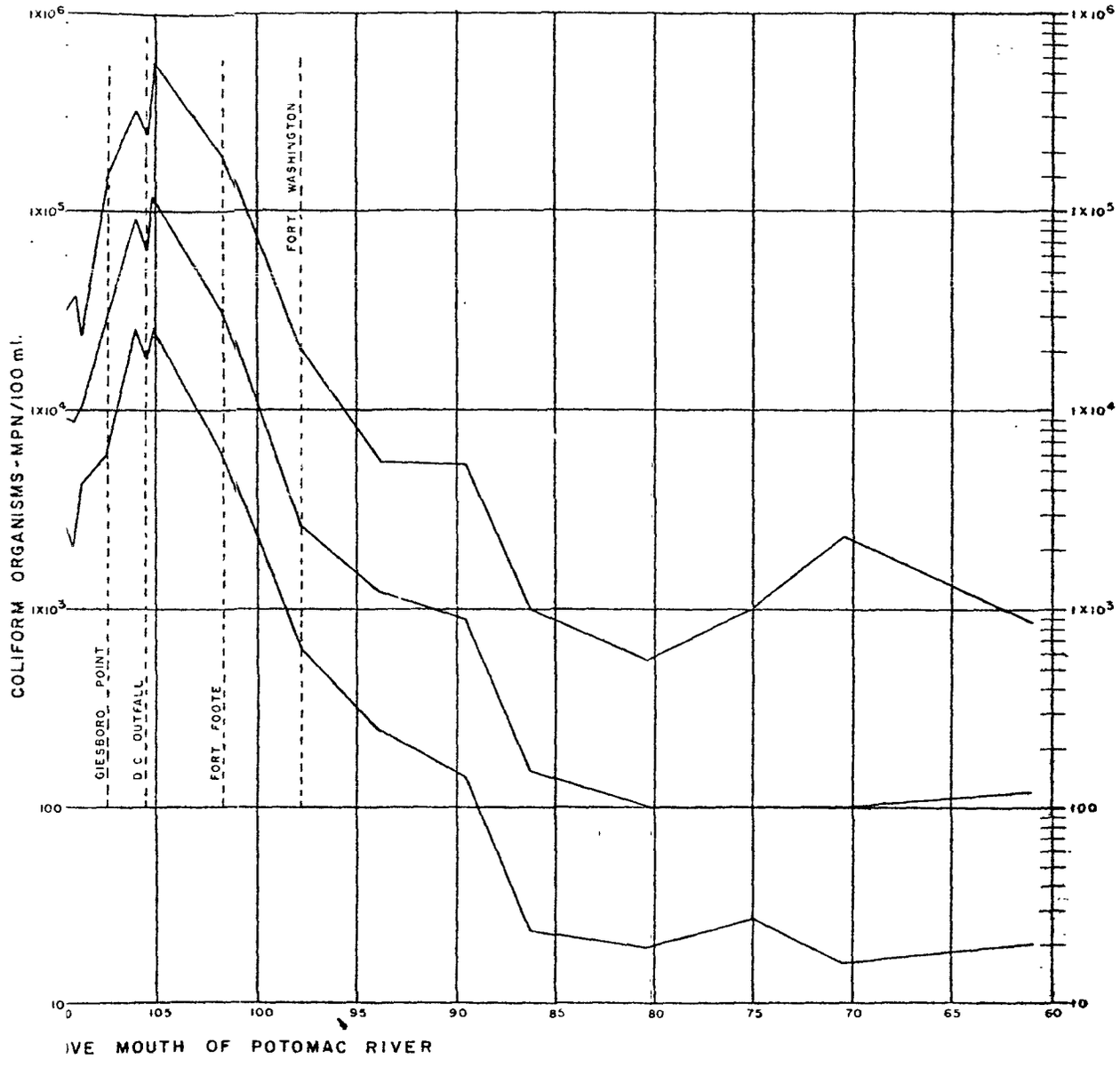
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE, VA


WASHINGTON D. C.
BLUE PLAINS S.T.P.
WOODROW WILSON BRIC
BROAD CREEK
PISCATAWAY CREE
GUNSTON COVE
OCCOQUAN BAY
INDIAN HEAD
NAVAL POWDER FACTORY
QUANTICO CREEK
MATTAWOMAN CREEK
MARYLAND PT.
OBSERVED CONCENTRATION OF DEAD
HEAVY >120 / ACRE
MODERATE 60- 120 /ACRE
LIGHT 0 - 60 /ACRE
SCALE 1: 250,000
WATER QUALITY REPORT
POTOMAC RIVER BASIN - MAR
FISH KILL of MAY 19, 1
U S DEPARTMENT OF HEALTH, EDUCATION
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASIN
REGION III
CHARLOT



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

POTOMAC ESTUARY - COLIFORM CONC.
JUNE - NOV, 1960 - 1964

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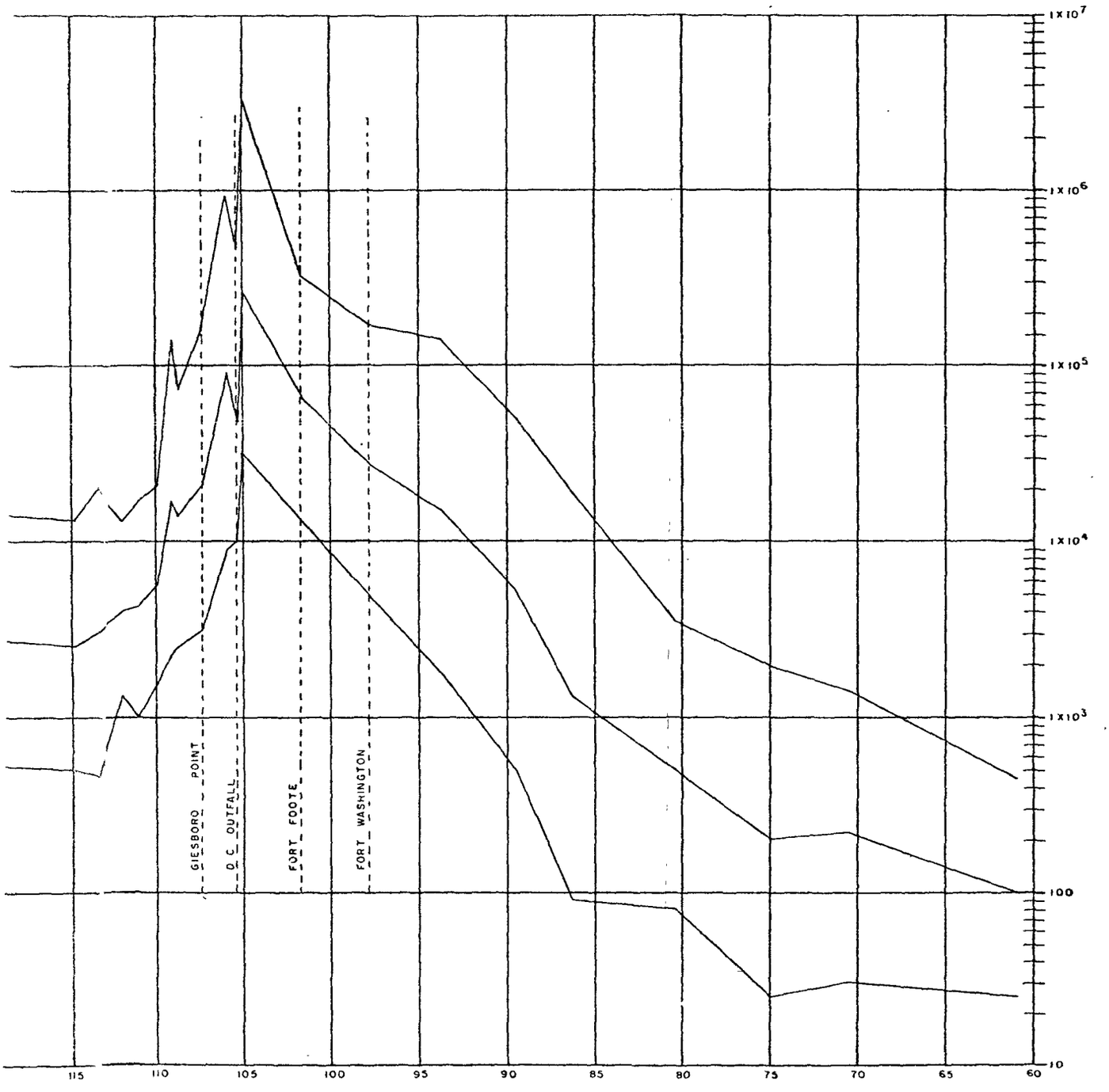
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III — CHARLOTTESVILLE, VA

FIGURE 9



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

POTOMAC ESTUARY-COLIFORM CONC.
DEC-MAY, 1960-1964

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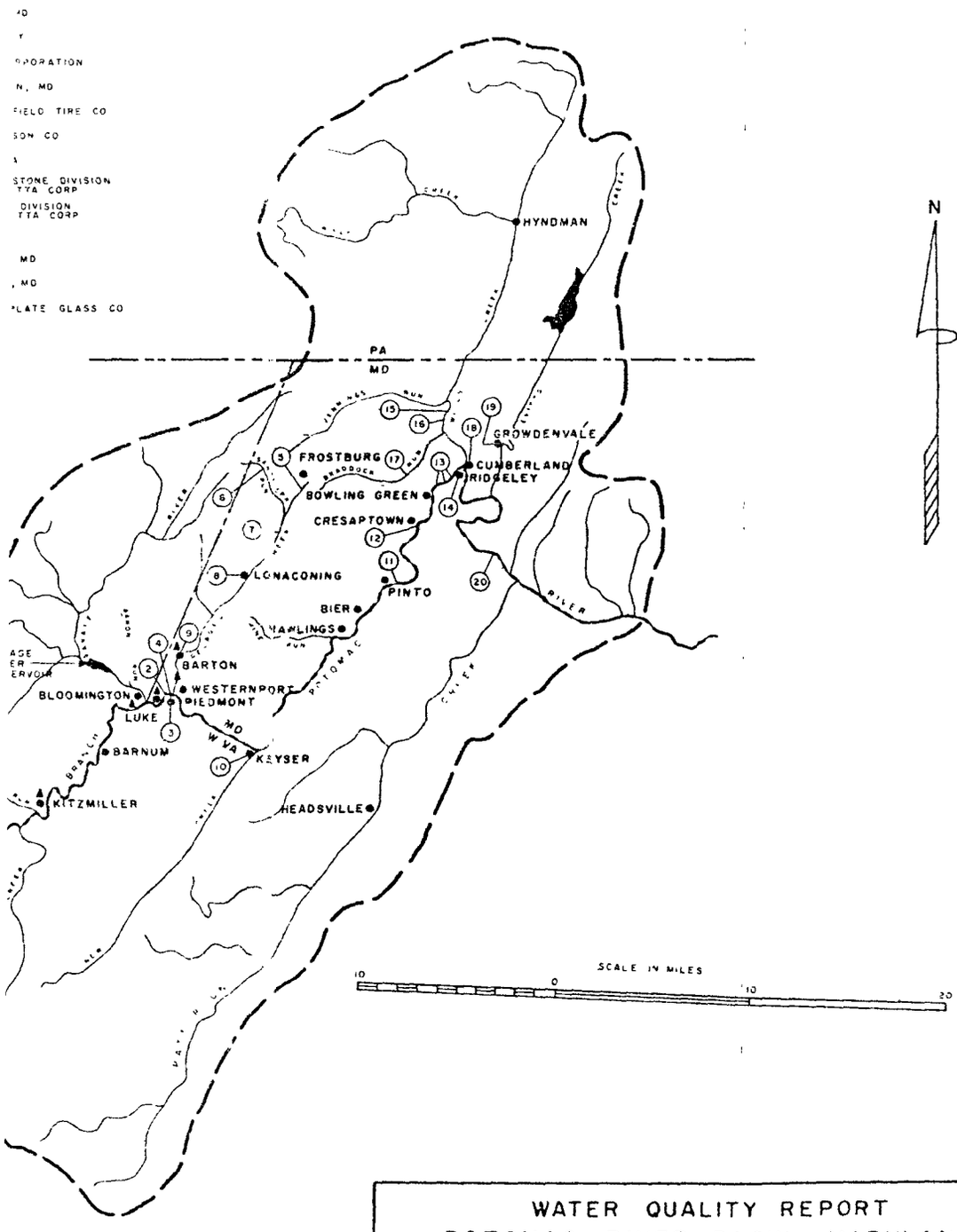
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY-SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE, VA

FIGURE



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN. & INDUS. WASTE DISCHARGES

NORTH BRANCH - POTOMAC RIVER

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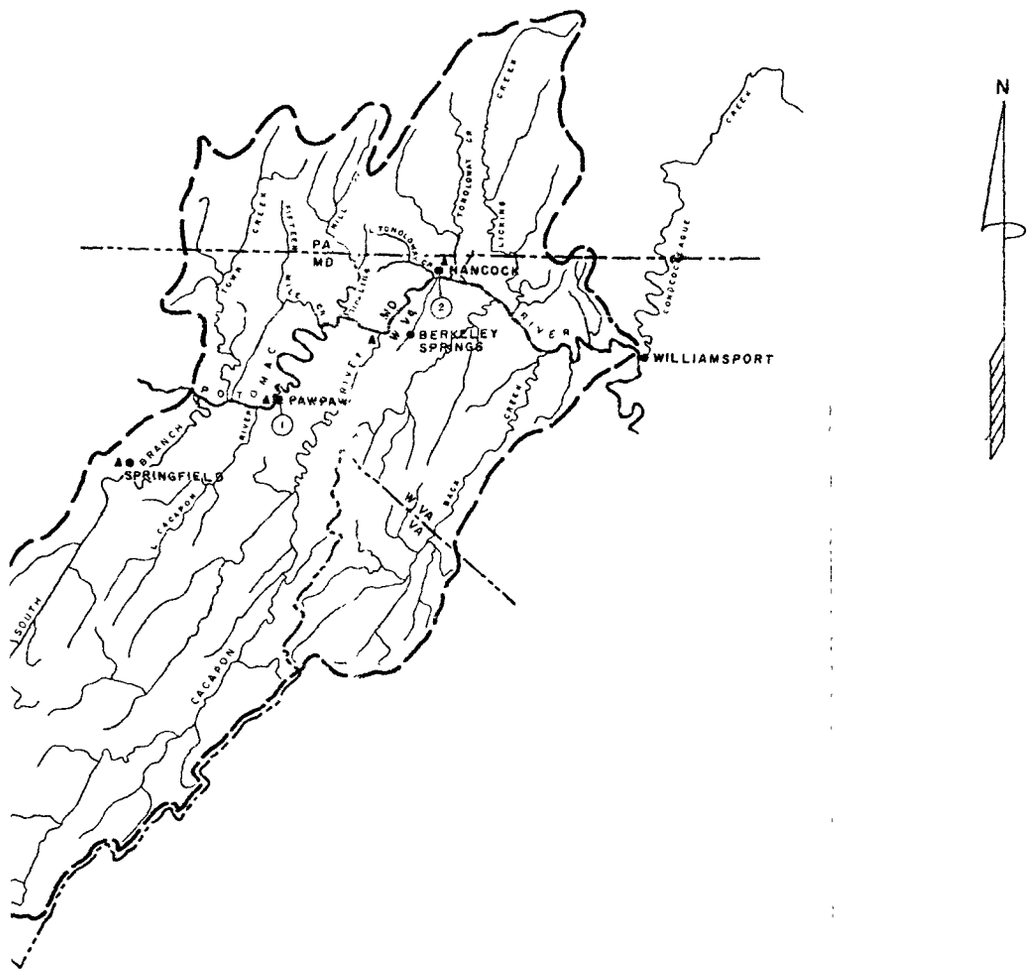
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III — CHARLOTTESVILLE, VA

FIGURE 12



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN. & INDUS. WASTE DISCHARGES

POTOMAC RIVER - SOUTH BRANCH POTOMAC TO CONOCOCHEAGUE CREEK

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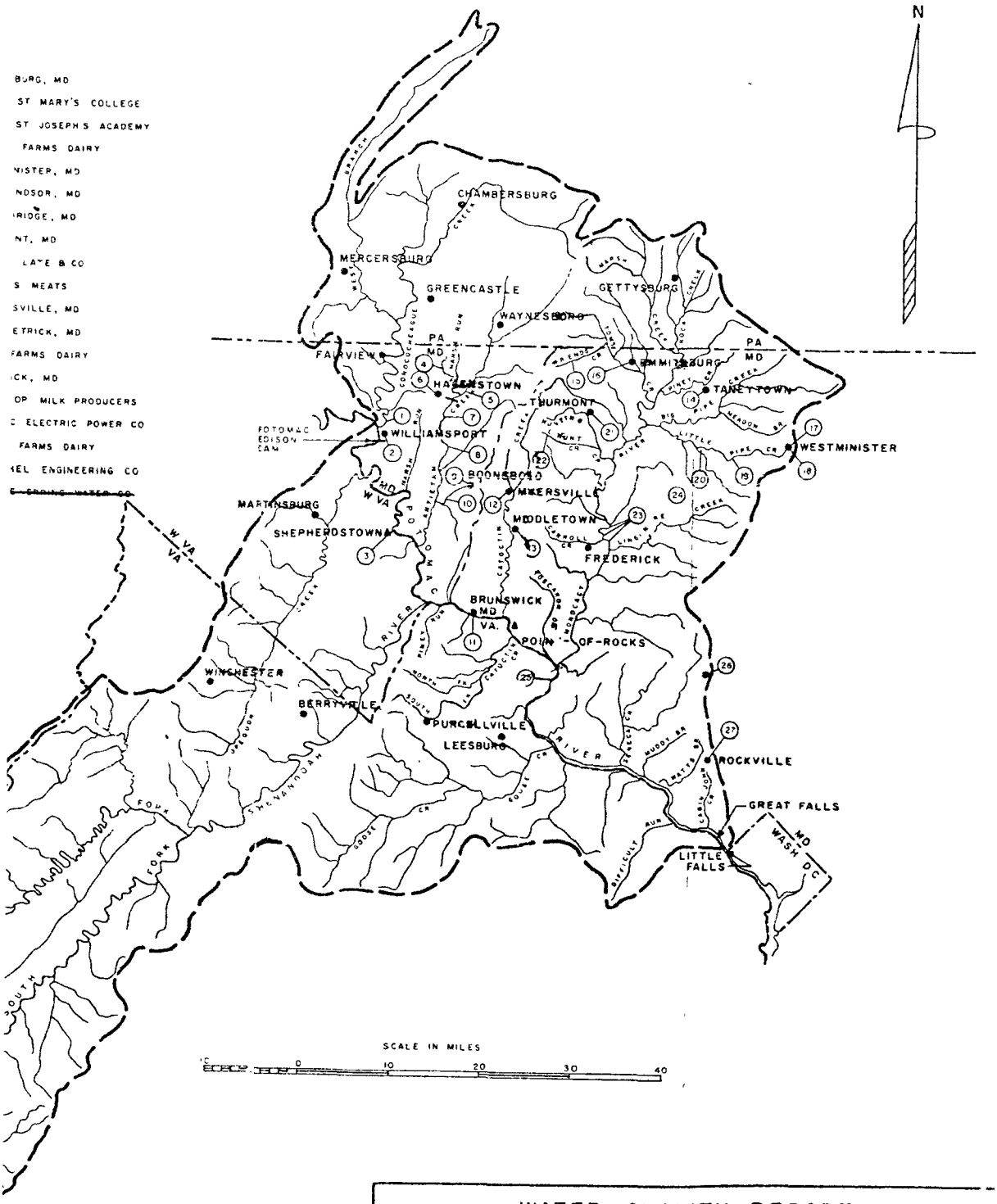
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III — CHARLOTTESVILLE, VA

FIGURE 1



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN. & INDUS. WASTE DISCHARGES
POTOMAC RIVER-CONOCOCHEAGUE CREEK TO LITTLE FALLS

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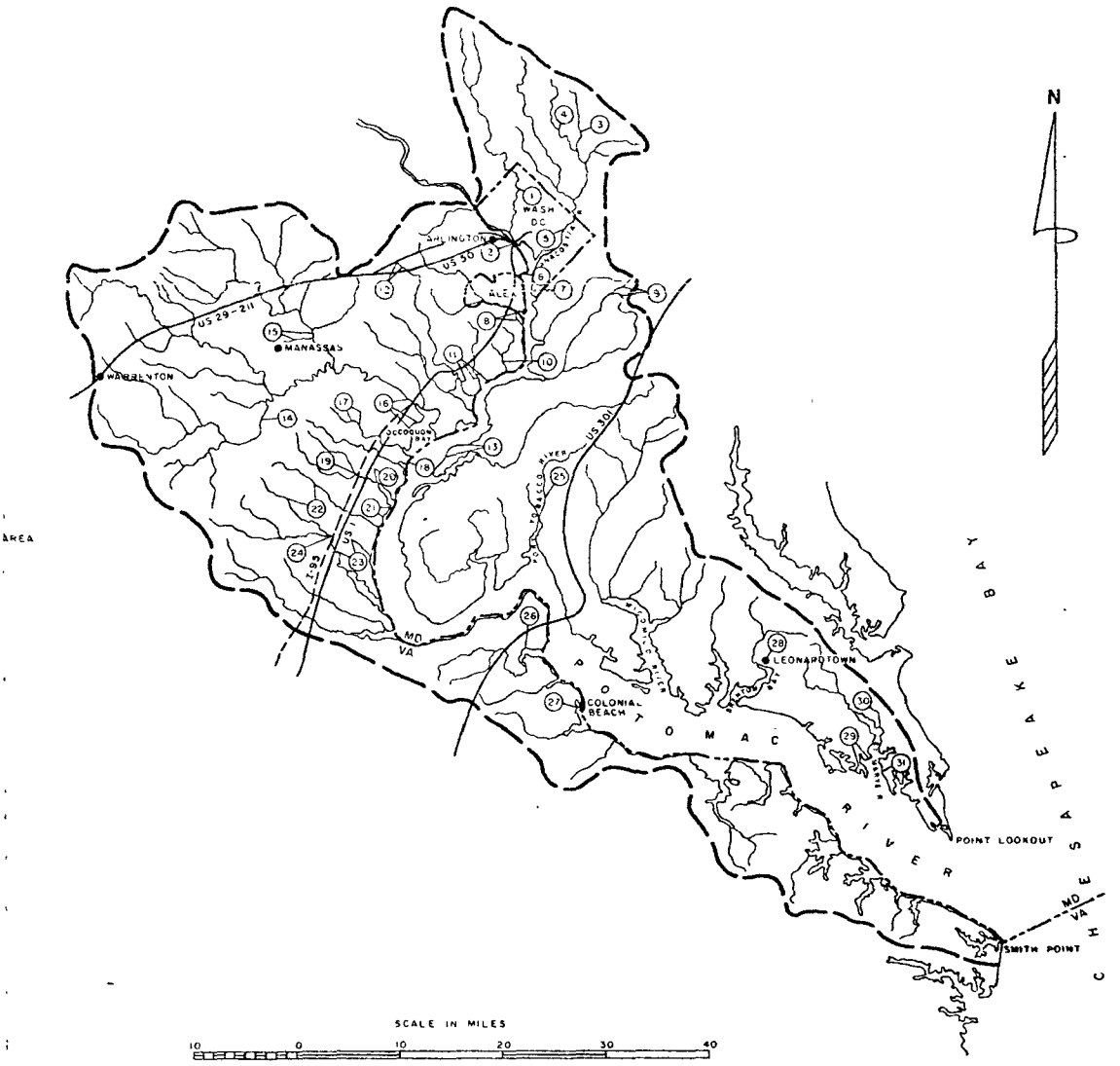
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY-SUSQUEHANNA RIVER BASINS PROJECT
REGION III — CHARLOTTESVILLE, VA

FIGURE 14



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN. & INDUS. WASTE DISCHARGES

POTOMAC RIVER ESTUARY

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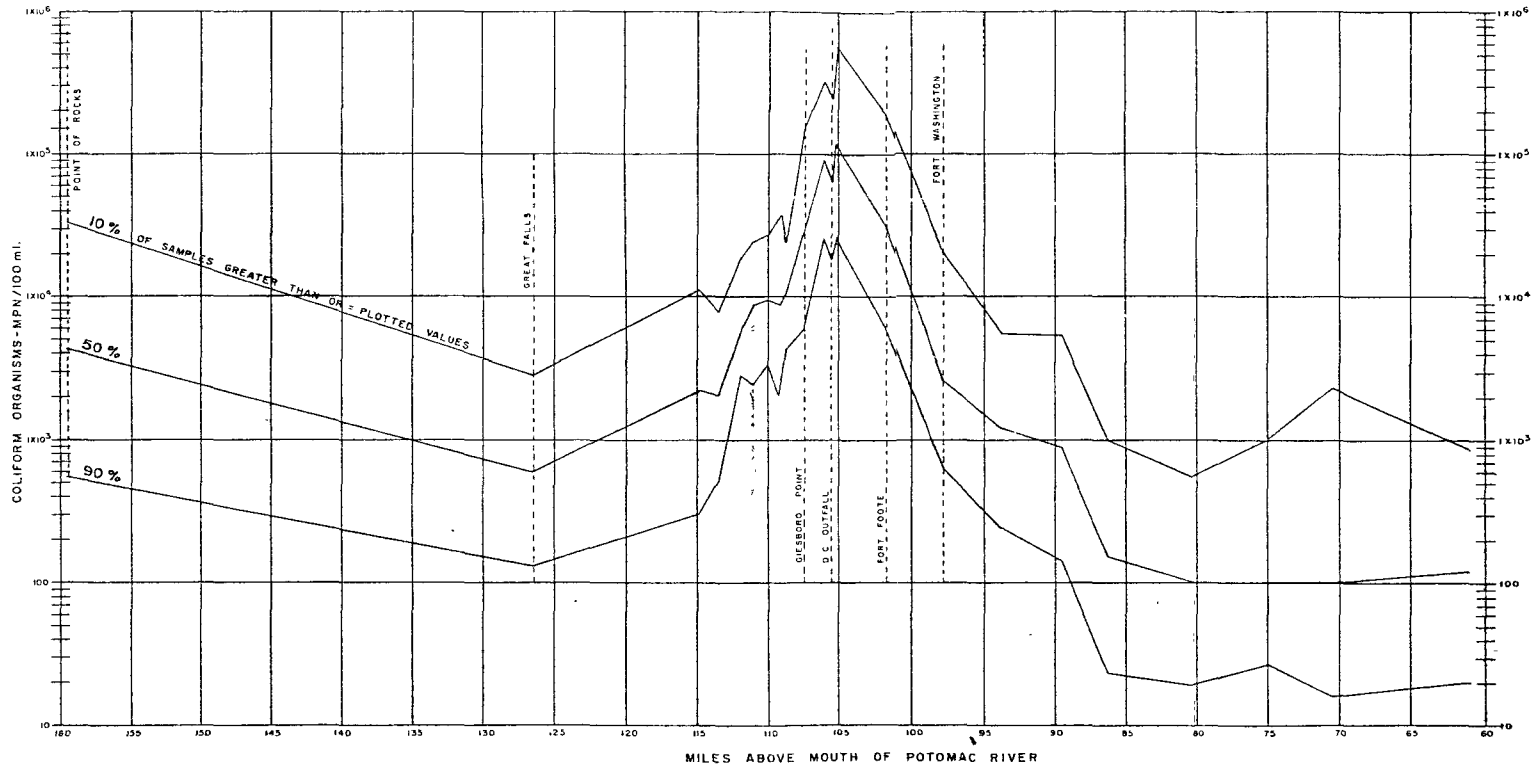
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY-SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE, VA

FIGURE



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

POTOMAC ESTUARY - COLIFORM CONC.
JUNE - NOV, 1960 - 1964

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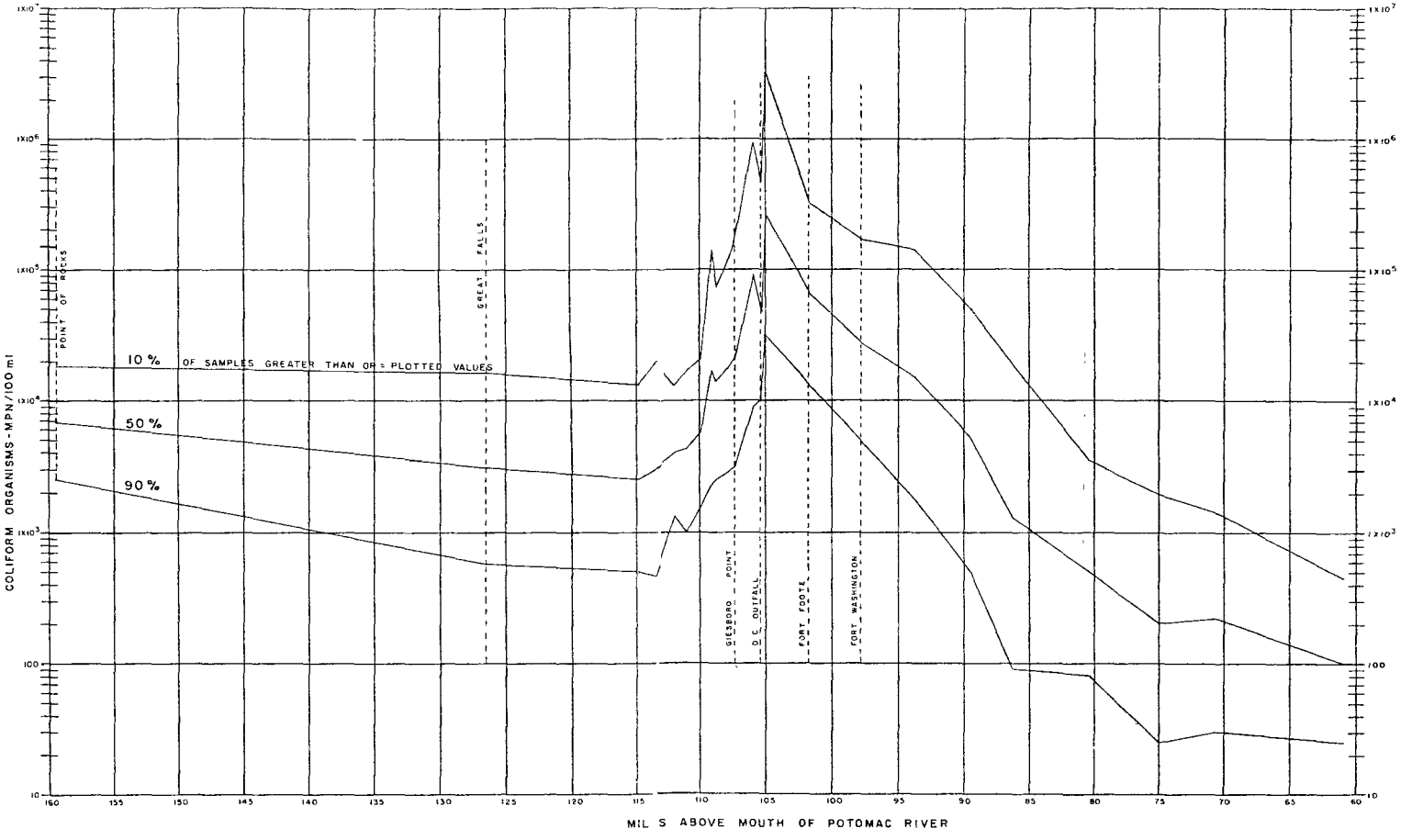
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE, VA

FIGURE 9



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

POTOMAC ESTUARY-COLIFORM CONC.
DEC-MAY, 1960-1964

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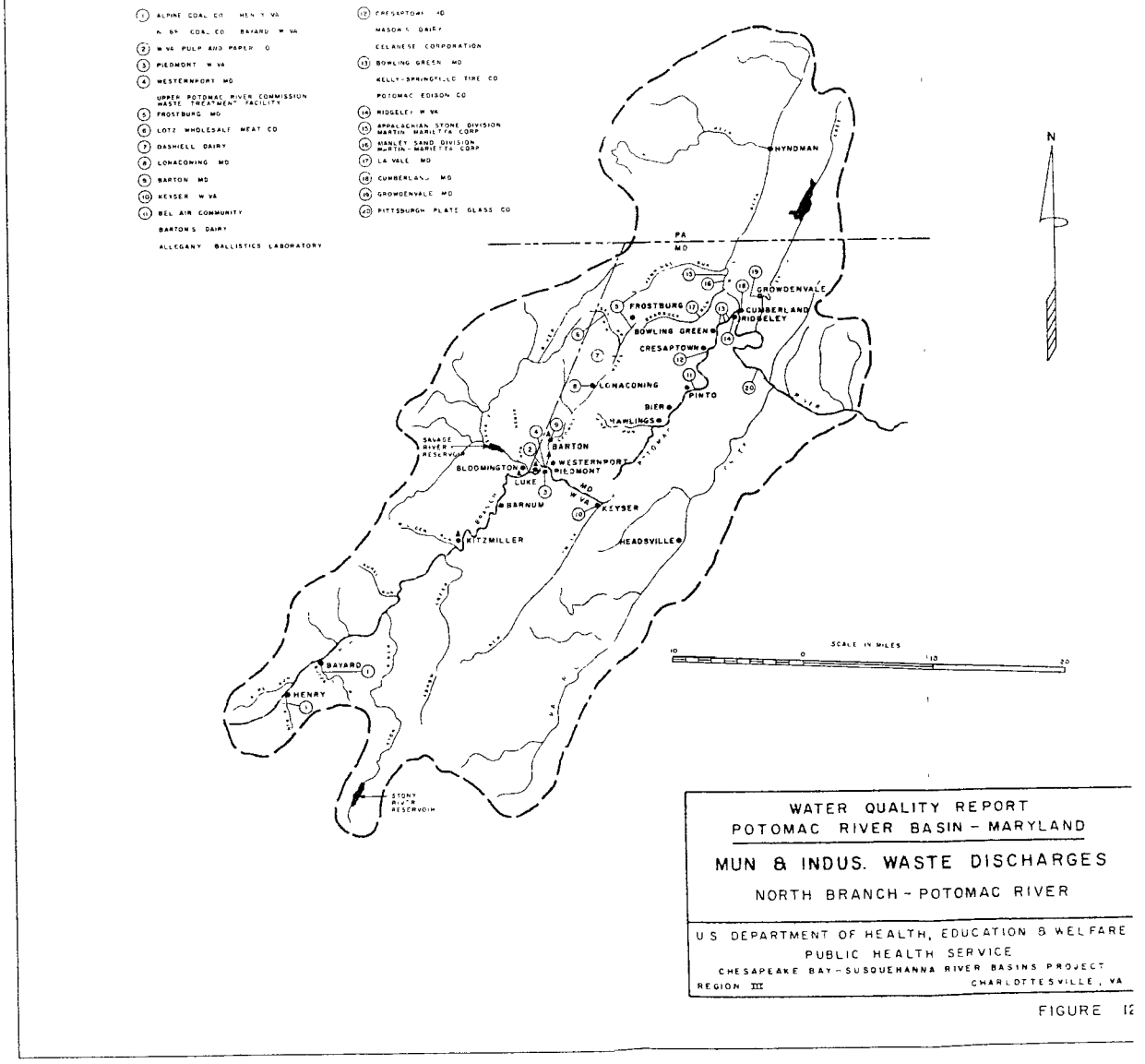
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY-SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE,

FIGURE


KEY
1 ALPINE COAL CO MEN Y VA
A BY COAL CO BAYARD W VA
2 W VA PULP AND PAPER CO
3 PIEDMONT W VA
4 WESTERNPORT MD
UPPER POTOMAC RIVER COMMISSION WASTE TREATMENT FACILITY
5 FROSTBURG MD
6 LOTZ WHOLESALE MEAT CO
7 DASHIELL DAIRY
8 LONACONING MD
9 BARTON MD
10 KEYSER W VA
11 BEL AIR COMMUNITY
BARTON'S DAIRY
ALLEGANY BALLISTICS LABORATORY
12 CRESAPTOWN MD
MASON'S DAIRY
CELANESE CORPORATION
13 BOWLING GREEN MD
KELLY-SPRINGFIELD TIRE CO
POTOMAC EDISON CO
14 RIDGELEY W VA
15 APPALACHIAN STONE DIVISION MARTIN MARIETTA CORP
16 MANLEY SAND DIVISION MARTIN-MARIETTA CORP
17 LA VALE MD
18 CUMBERLAND MD
19 GROWDENVALE MD
20 PITTSBURGH PLATE GLASS CO
HYNDMAN
PA
MD
GROWDENVALE
CUMBERLAND
RIDGELEY
FROSTBURG
BOWLING GREEN
CRESAPTOWN
LONACONING
PINTO
BIER
HAWLINGS
BARTON
WESTERNPORT
PIEDMONT
SAVAGE RIVER RESERVOIR
BLOOMINGTON
LUKE
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BARNUM
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HEADSVILLE
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SCALE IN MILES
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WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND
MUN & INDUS. WASTE DISCHARGES
NORTH BRANCH - POTOMAC RIVER
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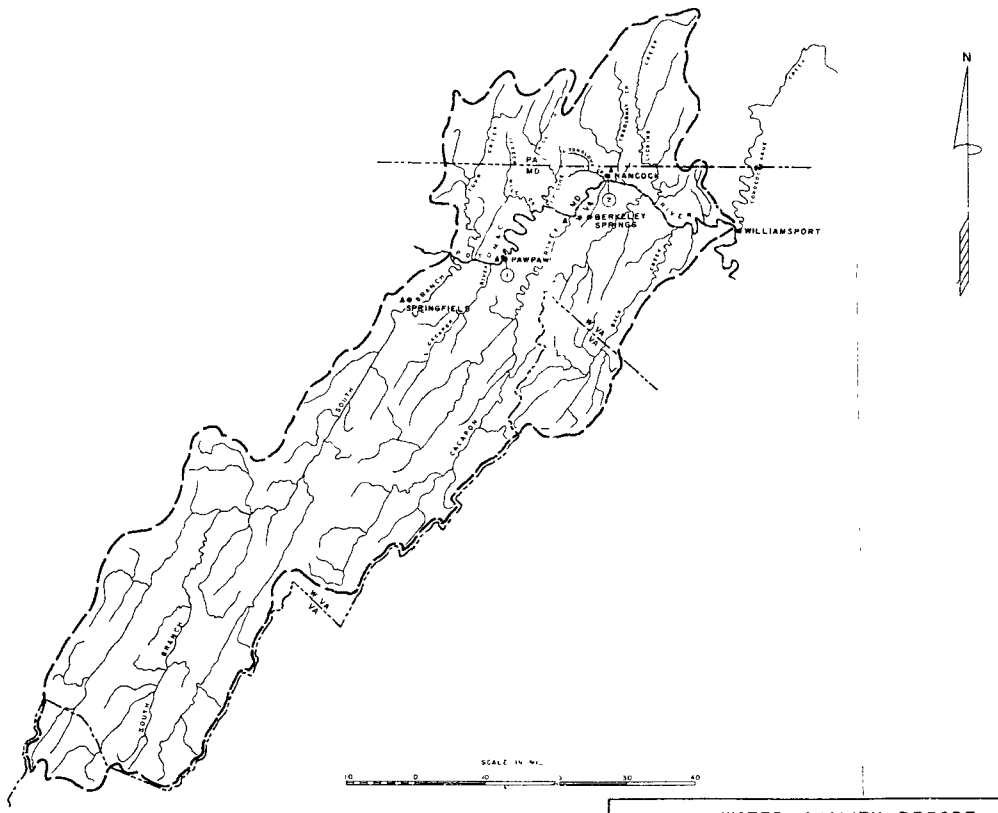
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III
CHARLOTTESVILLE, VA

FIGURE 12



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN. & INDUS. WASTE DISCHARGES
POTOMAC RIVER- SOUTH BRANCH POTOMAC
TO CONOCOCHEAGUE CREEK

U S DEPARTMENT OF HEALTH, EDUCATION & WELFA
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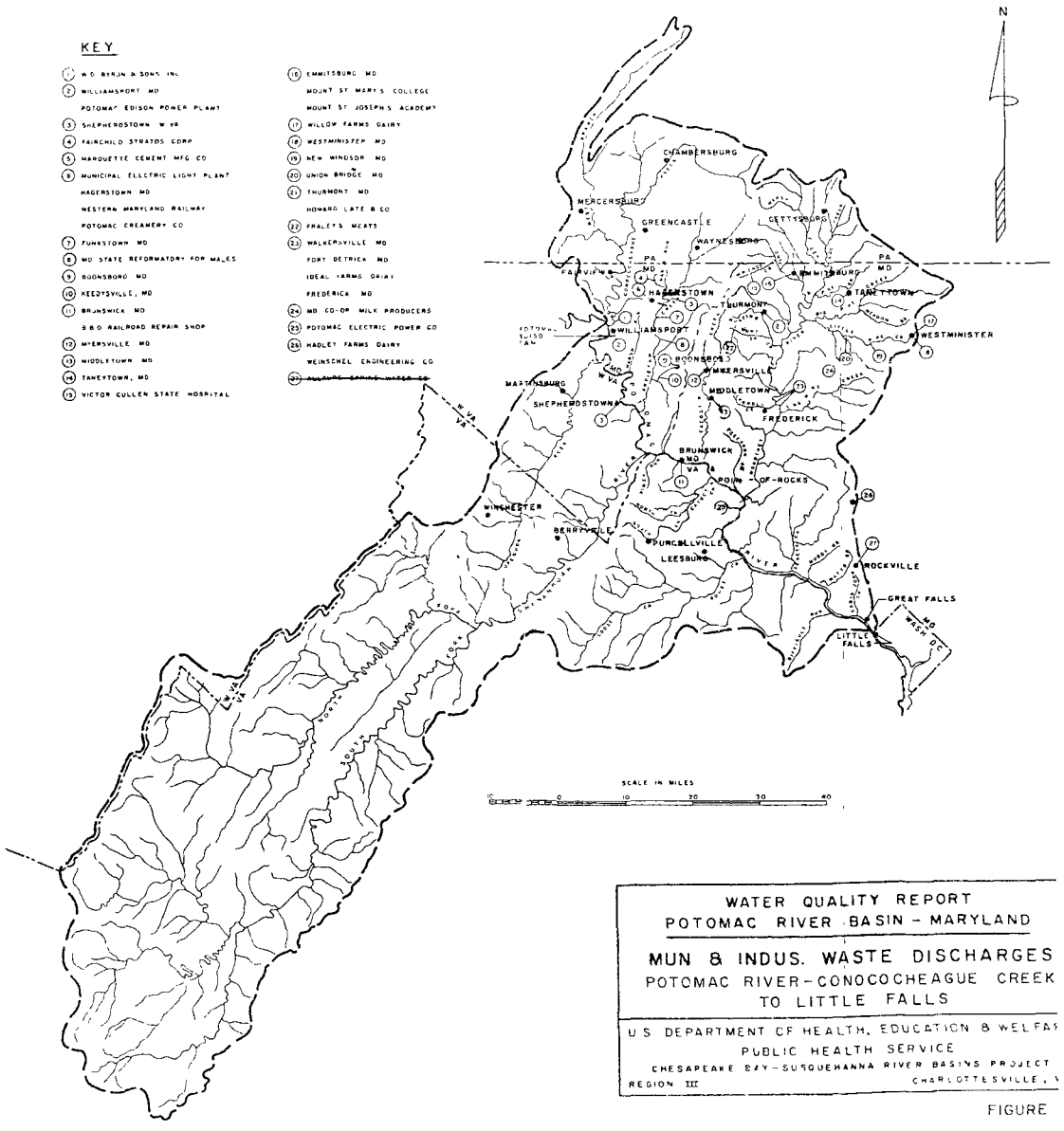
FIGURE



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN & INDUS. WASTE DISCHARGES
POTOMAC RIVER-CONOCOCHEAGUE CREEK
TO LITTLE FALLS

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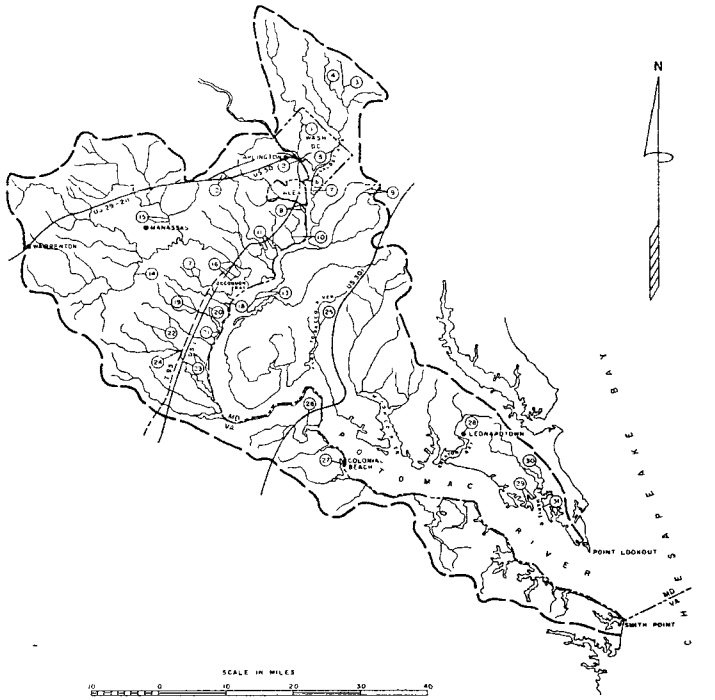
PUBLIC HEALTH SERVICE
CHESAPEAKE BAY-SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE, VA

FIGURE

KEY

(1) D C WEST [illegible] PLANT
(2) VA HEATING SEWAGE DISPOSAL PLANT
(3) MINERAL PIGMENTS CORP
(4) U S NAVAL ORDNANCE LABORATORY
(5) PEPCO BENNING GENERATING STATION
(6) ARLINGTON COUNTY VIRGINIA
(7) D C NAVAL RESEARCH LABORATORY
BLUE PLAINS SEWAGE TREATMENT PLANT
PEPCO POTOMAC RIVER STATION
(8) FAIRFAX COUNTY SAN DIST NO WESTGATE PLANT
(9) ANDREWS AIR FORCE BASE PLANT #1
ANDREWS AIR FORCE BASE PLANT #4
(10) FAIRFAX COUNTY LITTLE HUNTING CREEK PLANT
(11) FAIRFAX COUNTY DOGUE CREEK PLANT
FORT BELVOIR (U S ARMY) PLANT #2
FORT BELVOIR (U S ARMY) PLANT #1
(12) FAIRFAX VIRGINIA
~~VIENNA VIRGINIA PLANT~~
(13) POTOMAC HEIGHTS MARYLAND
INDIAN HEAD MARYLAND
U S NAVAL PROPELLANT PLANT-HOUSING, STORAGE & INDUSTRIAL AREA
(14) CAMP UPSHUR (U S MARINE CORPS)
(15) MANASSAS VIRGINIA
MANASSAS REGIONAL HIGH SCHOOL
(16) OCCOQUAN VA (WOODBRIDGE S D PLANT)
WOODBRIDGE S D MARUMSCO PLANT
WOODBRIDGE S D LYNWOOD-FEATHERSTONE PLANT
(17) M G GARBER TRAILER PARK
GARFIELD HIGH SCHOOL
(18) FREESTONE POINT VIRGINIA
(19) DUMFRIES TRIANGLE (2 PLANTS)
DUMFRIES SCHOOL
(20) MELROSE GARDENS SUBDIVISION
(21) QUANTICO MARINE CORPS RESERVATION
(22) BROWN FIELD OF U S M C (SUMMER)
RIFLE RANGES OF U S M C
(23) MIDWAY ISLAND HOUSING OF U S M C
CAMP BARRETT OF U S M C
(24) AQUIA MOBILE PARK
(25) LA PLATA MARYLAND
(26) U S NAVAL [illegible] ARGENS ASONSTORY AT DALGREN VIRGINIA
(27) COLONIAL BEACH VIRGINIA
(28) LEONARDTOWN MARYLAND
(29) ST MARY'S CITY MARYLAND
PINEY POINT MARYLAND (SUMMER)
(30) ST MARYS COLLEGE
(31) NAVAL AIR [illegible] ON & ELECTRONICS PROJECT



WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND

MUN. & INDUS. WASTE DISCHARGE

POTOMAC RIVER ESTUARY

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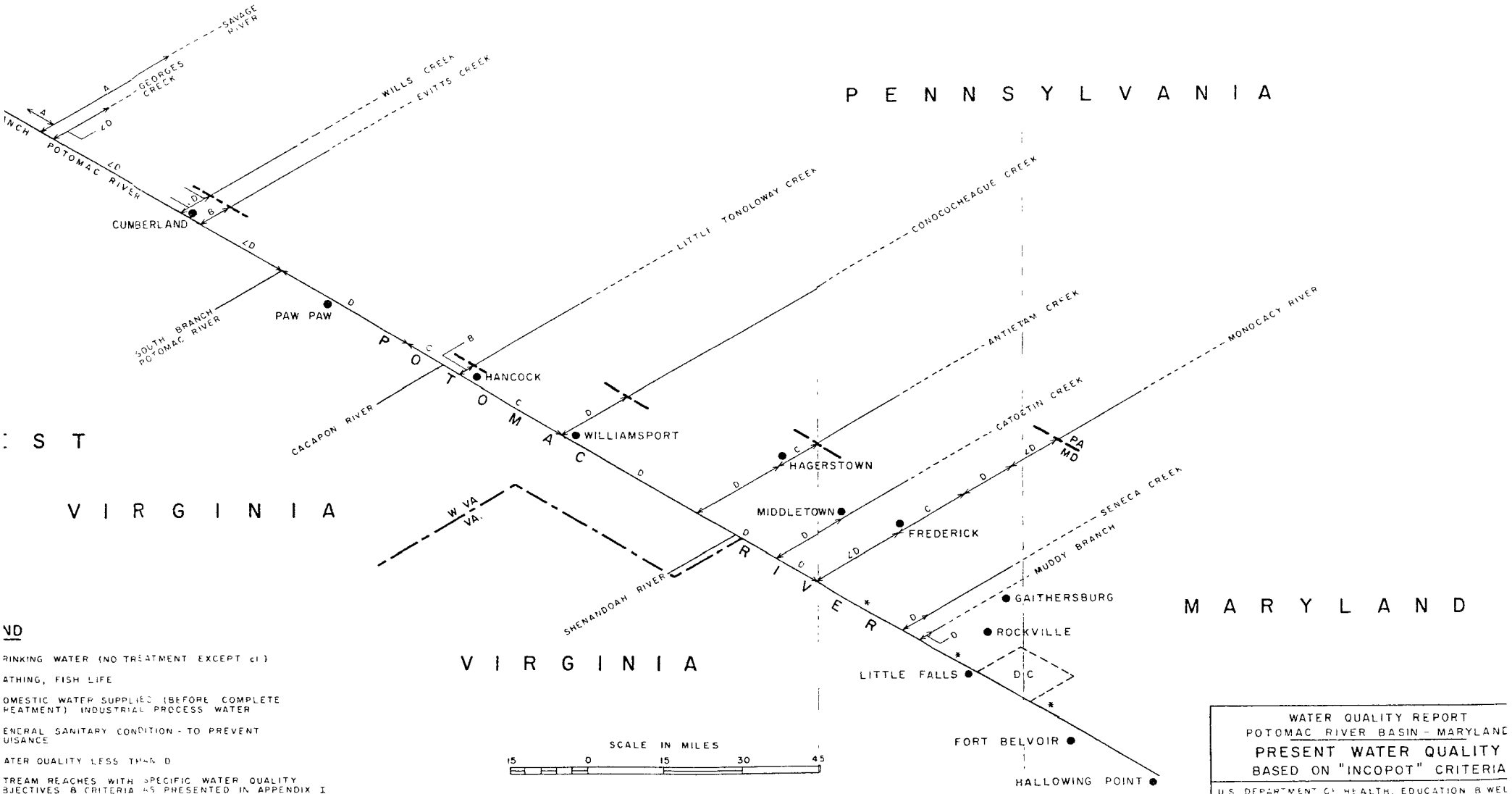
CHESAPEAKE BAY-SUSQUEHANNA RIVER BASINS PROJEC
REGION III CHARLOTTESVILLE

FIGURE



VD

RINKING WATER (NO TREATMENT EXCEPT cl)

ATHING, FISH LIFE

OMESTIC WATER SUPPLIES (BEFORE COMPLETE REATMENT) INDUSTRIAL PROCESS WATER

ENERAL SANITARY CONDITION - TO PREVENT UISANCE

ATER QUALITY LESS THAN D

TREAM REACHES WITH SPECIFIC WATER QUALITY BJECTIVES & CRITERIA AS PRESENTED IN APPENDIX I

WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND
PRESENT WATER QUALITY
BASED ON "INCOPOT" CRITERIA

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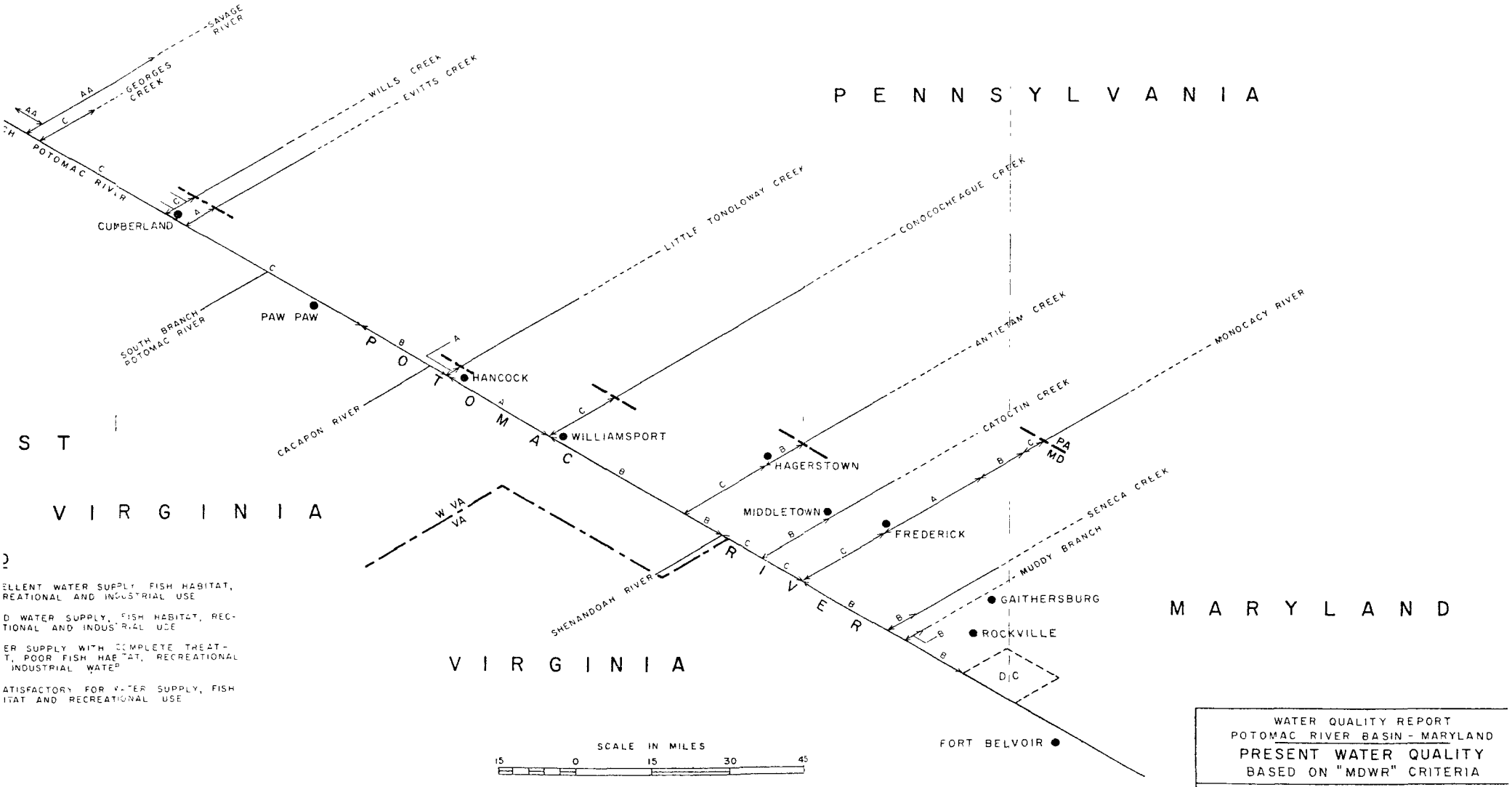
FIGUR



ELLENT WATER SUPPLY, FISH HABITAT, REATIONAL AND INDUSTRIAL USE

D WATER SUPPLY, FISH HABITAT, REC-TIONAL AND INDUSTRIAL USE

ER SUPPLY WITH COMPLETE TREAT-T, POOR FISH HABITAT, RECREATIONAL INDUSTRIAL WATER

ATISFACTORY FOR WATER SUPPLY, FISH ITAT AND RECREATIONAL USE

WATER QUALITY REPORT
POTOMAC RIVER BASIN - MARYLAND
PRESENT WATER QUALITY
BASED ON "MDWR" CRITERIA

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CHESAPEAKE BAY - SUSQUEHANNA RIVER BASINS PROJECT
REGION III CHARLOTTESVILLE, VA

FIGURE

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GENERAL

Water quality investigations in the Potomac River Basin have been conducted for the past several years by the Chesapeake Field Station as part of the Chesapeake Bay-Susquehanna River Basins Project. A map of the Potomac River Basin showing existing and proposed reservoirs is exhibited in Figure 1.

As an integral part of the project, large mathematical simulation models were developed. The models, after verification, are being applied to this river basin as well as others in the Chesapeake Bay drainage system. The general relationship of these models to management of Potomac water quality is shown in Figure 2 and the attached outlines.

While the hydrological principles and quality formulations applied are not new, the use of these models in the application of systems analysis techniques has substantially reduced analysis time and costs, has achieved a precision commensurate with the accuracy of data input and has allowed the engineer to observe the broad spectrum of water quality parameters synoptically.

CONCLUSIONS

The series of models presented have already proved their effectiveness to water quality managers. They have been instrumental in clarifying several points in the decision making process. The problems they have solved, and some current and envisioned future applications, are stated in more detail in the attached outlines.

From the successful experience in use of mathematical models in the water quality management and control programs, the Chesapeake Field Station has observed the following:

1. The relative time and money spent on systems analysis, because of the ability to use computers, have been reduced compared to that required for planning, assembling and analyzing the necessary field data for verification.

2. Field testing and verification of the models is expensive. Over a half million dollars have been expended in collection of field data and verification of the Potomac system to bring it to its present stage of usefulness. As much again will be required to develop the refinements desirable to complete the job.

3. There remains a communications gap between water quality administrators and engineers with respect to the capabilities of mathematical models. Much more emphasis should be placed upon bridging this gap in order to realize the full potential of the models.

4. Since the nature of the planning process is dynamic and continuing and the changes in technology rapid, the models require continuous updating in order to retain their usefulness.

SUBJECT: The Potomac Estuary Water Quality Model (See Figure 3)

PURPOSE: To define the effects of environmental changes such as low flow augmentation and increased waste treatment on the estuary's water quality.

ORIGIN AND DEVELOPMENT: The basic theory was developed by Dr. Robert Thomann at New York University. The model's digital computer program was written by the Re-Entry Systems Department of the Missile and Space Division of General Electric under a series of contracts sponsored jointly by the Delaware Estuary Comprehensive Study and the Chesapeake Field Station. A specialized analog version of the program was also developed for the Chesapeake Field Station by Electronic Associates, Inc. The model has been field tested and verified by the field station.

SCOPE: The Potomac estuary model as presently verified extends from the head of tide at Chain Bridge to the mouth of the estuary at the Chesapeake Bay. It is presently capable of simulating the effects of low flow augmentation, wastewater diversions, water supply withdrawals, and increased wastewater treatment on dissolved oxygen (DO), phosphorus, chloride and bacterial concentrations in the estuary. Solutions are available for both dynamic (time dependent) and steady-state situations.

PRESENT APPLICATIONS: Up to the present time, the model has been used in the following studies.

1. Determination of a range of feasible alternative plans to improve water quality in the estuary for the Water Quality Sub-Task Force of the President's Project Potomac. From this study it was concluded that there are technologically feasible alternatives to large upstream dams for water quality control.

2. Determination for the FWPCA enforcement programs of the degree of treatment required by waste treatment plants discharging to the Potomac Estuary to meet the water quality standards adopted by the District of Columbia and the State of Maryland. The model results indicated that a high degree of advanced waste treatment is necessary.

3. Results from the model were used by Dr. Robert Davis of Resources for the Future (RFF) in his study of the effects of advances in technological software on the planning process. Dr. Davis concluded that gains from the modeling technique could be a significant advantage in the planning process.

4. The model has been used to determine the feasibility of using the upper estuary as a future emergency water supply for the Washington Metropolitan Area. On the basis of water quality, this is a feasible alternative. The economics and esthetics of such a program have not yet been investigated.

FUTURE APPLICATIONS: Continuous improvement in the accuracy and efficiency of the model will be made. The Chesapeake Field Station will use the model in developing a range of alternative water quality management programs for the Potomac River basin. This will require linkage of the upstream water quality and hydrology models. Training of state and local agencies in the application of the model has been instituted.

SUBJECT: Water Quality Simulation and Verification Model (See Figure 4)

PURPOSE: To aid in analyzing field data, establishing and verifying water quality formulation parameters, and predicting the response of the water quality in the free flowing portion of the Potomac Basin to changes in waste loadings, flow, etc.

ORIGIN AND DEVELOPMENT: Developed at the University of Michigan and field tested at the Chesapeake Field Station.

SCOPE: With predictive algorithms for biochemical oxygen demand (BOD), DO, temperature and phosphorus, the model can be used in non-tidal waters for the following:

1. Establishing and verifying the parameters of the various quality formulations;

2. Predicting the water quality in a river for a given set of environmental conditions;

3. Planning of field studies;

4. Routing of an accidental spill;

5. Verifying and editing the system for the optimal flow release model.

PRESENT APPLICATIONS: As an integral part of the field station's activities, the model has been utilized for the following:

1. Determination of wastewater treatment requirements in the North Branch of the Potomac River basin in cooperation with the State of Maryland Department of Water Resources;

2. Determination of the need for and value of reservoir storage in that portion of the basin in "Appalachia" as requested by the U. S. Corps of Engineers;

3. Investigation of the effects of wastewater treatment and flow regulation on water quality in the Patuxent River basin;

4. Analysis of field data and establishment of well-defined water quality parameters for the Monocacy River basin;

5. Determination of the times-of-travel of accidental spills as requested for the pollution surveillance program of FWPCA.

FUTURE APPLICATIONS: Continued use in verifying the quality formulation is anticipated with possible expansion as needed to better describe the system.

SUBJECT: Optimal Flow Release Model (See Figure 5)

PURPOSE: To develop optimal-release sequences from multiple reservoir systems for water supply and water quality control.

ORIGIN AND DEVELOPMENT: Developed at the University of Michigan and field tested at the Chesapeake Field Station.

SCOPE: The model with quality algorithms as described in the verification link and using dynamic programming, can be used to determine reservoir release sequences based on various optimization criteria. For a given wastewater treatment policy, release sequences can be developed to maintain the "best" quality of water for a given flow requirement with minimum reservoir storage for a given quality level. Although the model, which also includes a least-cost of reservoir storage, is limited to non-tidal waters, it can readily be linked to the Potomac Estuary Water Quality Model.

PRESENT APPLICATIONS: The model, which is still in the developmental state, has been used to determine optimal reservoir release patterns for the proposed impoundments in the Potomac Basin. Since general coefficients were used in some of the sub-basins, the results of model should be considered preliminary only.

FUTURE APPLICATIONS: After verification of the quality formulations in the entire Potomac system, the field station will be in a better position to investigate the various alternatives of water quality management, such as the relative economy of advanced waste treatment as compared to flow augmentation.

SUBJECT: Reservoir System Simulation

PURPOSE: To investigate the hydrologic performance of the existing and proposed reservoir systems in meeting given flow requirements for quality control and water supply.

ORIGIN AND DEVELOPMENT: Initially developed by the U. S. Corps of Engineers, the model was expanded by RFF and reprogrammed for the IBM 360 computer by the Chesapeake Field Station with the assistance of RFF.

SCOPE: Using either historical flows or synthetically generated traces (e.g., the synthetic hydrology model as developed by the Harvard Water Resources Group), the model can be used for the following:

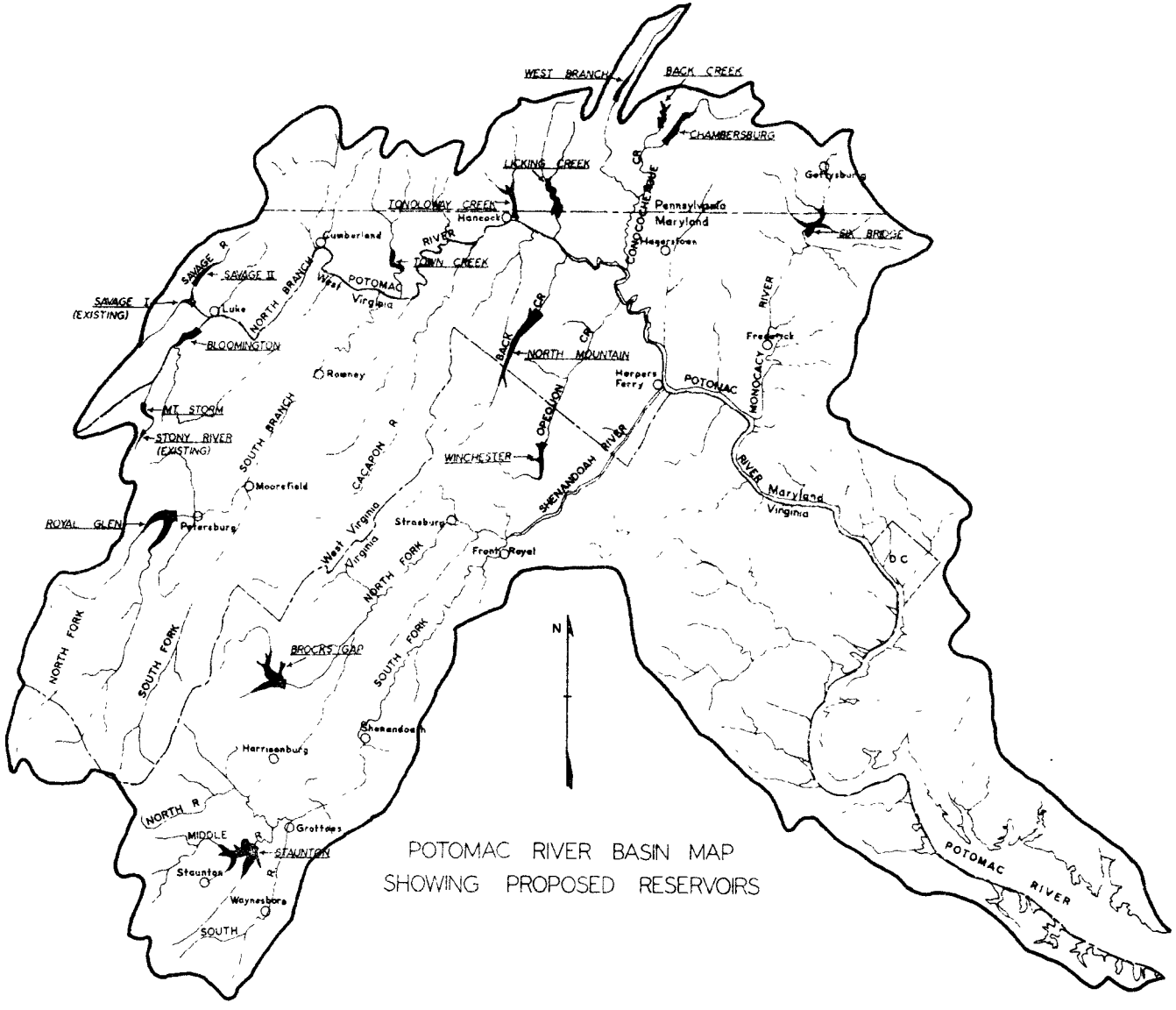
1. Studying the performance of a proposed or existing reservoir system with respect to specific water supply and/or water quality flow requirements in the Washington Metropolitan Area or other critical sections of the basin;

2. Scaling reservoir systems to meet desired targets;

3. Determining the performance of a reservoir system in terms of probability of failure at a given level of performance.

PRESENT APPLICATIONS: Dr. Robert Davis of RFF has demonstrated, utilizing the data from the 1963 U. S. Army Corps of Engineers study, that there are sufficient differences in the choices of both on the matter of kinds of solutions and action to be taken in water quality management for the Potomac Estuary.

FUTURE APPLICATIONS: Once the quality formulations are verified and optimal release sequences developed, the simulation will be invaluable in investigating the consequences of the various alternative solutions to Potomac Basin water resource problems.



POTOMAC RIVER BASIN MAP
SHOWING PROPOSED RESERVOIRS

FIGURE 1

USE OF MATHEMATICAL MODELS AS AIDS TO DECISION MAKING IN WATER QUALITY CONTROL*

By

Charles R. Hall** and Leo J. Hetling***

* Presented at the Sixty-Third National Meeting of the Americam Institute of Chemical Engineers, St. Louis, Missouri, February 19, 1968

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ABSTRACT

A method of utilizing existing water quality and hydraulic computer models to arrive at least cost solutions of water quality problems is presented. The alternatives considered are reduction of waste loads by treatment, industrial process modification, and construction of reservoirs for low flow augmentation. The application of the methods to water resources problems in the James River Basin is discussed. The least cost solution of the water quality control problem is presented along with a subjective analysis of various alternatives.

Key Words: Water Pollution, Mathematical Models, Low-flow Augmentation, Systems Analysis, Optimization Methodology, Decision-making, James River Basin

INTRODUCTION

The Chesapeake Field Station* of the Federal Water Pollution Control Administration has been participating in water quality control management and planning studies for the past several years. Since its inception, the Field Station has attempted to make maximum use of the newly developing tools of systems analysis and operations research in its efforts. It quickly found that in this area there is a rapidly growing wealth of theory, and that much of the theory has been translated to mathematical forms and programmed for rapid solution on high speed digital computers. However, it was also found that the application of these new tools to the solution of real life problems is not widely practiced. It is their application to an actual water quality problem that is the subject of this paper.

The primary objective of the study being presented was to determine the optimum blend of waste treatment and storage (for low flow augmentation) necessary to meet a specified dissolved oxygen (DO) standard in the James River Basin.

* During the period in which the study reported on here was made, both authors were employed at the Chesapeake Field Station.

THEORETICAL CONSIDERATIONS

Before discussing the case study, a description of the computer models used and the analytical concepts with which the study was approached will be presented.

The Computer Models Utilized -

The theory behind the actual computer programs and models utilized will be only dealt with briefly here since the objective of this paper is not a discussion of modeling techniques but to show how existing models and programs can be used to aid in the decision-making process. The three computer programs described below which have been utilized in the study are well documented elsewhere.

1. Oxygen Sag Model [1]

This program uses the basic Streeter-Phelps [2] formulation of the oxygen sag curve, a function describing the inter-action of the fundamental biological and physical processes that simultaneously remove and regenerate dissolved oxygen in a free flowing stream. The program offers adaptations to the basic formula to enable the inclusion of the effects of benthic organisms and photosynthesis on the oxygen balance. As programmed, the model is capable of computing the flow required to maintain a stated DO objective in a river system receiving multiple point source waste loads. It is important to realize that, as used in these studies, this computed flow requirement is totally unrelated to the actual hydrology of the system. It is, in fact, a theoretical flow required to meet the quality constraint one hundred percent of the time.

2. Segmented Esutary Model -

This program was designed to simulate the oxygen relationships in a tidal river or estuary. The basic principles of the model utilized were developed by Thomann.[3] The model incorporates a term to account for longitudinal diffusion caused by tidal action into the Streeter-Phelps equation and employs an incremental or segmented approach to the problem rather than a continuous function solution. Both the steady state [4] and time dependent [5] versions of this model have been programmed. The steady state version was used in the present study to compute the flow requirements necessary to meet the quality objective in the tidal segment of the river. In essence, this model serves the same purpose in the tidal river as the Oxygen Sag Model does in the free flowing portions.

3. Hydrologic Simulation Model -

This program[6] simulates the hydrologic nature of a river system. Stream flows (either historic or synthetic) are routed through the river system and compared to required target flows (computed outside of the model) at various locations in the basin and the pertinent statistics regarding failures computed. Reservoirs can be introduced into the system and their effect on the statistics noted. In short, this model provides the means of determining the reliability of the hydrology in the basin to meet the required flows and the effect variation in the amount of storage provided has on this reliability.

Analytical Concepts -

The following theoretical discussion presents a general outline of the computational procedures with which the study was approached.

These procedures utilize the three river system models described above to arrive at the least cost combination of treatment and storage that

will satisfy DO quality objectives at various probabilities of failure (reliability).

In this theoretical discussion, only the following two policy constraints were assumed.

1. Treatment and storage will be given equal consideration. That is, no uniform treatment policy will be adopted and computations will begin with a system having no treatment and no storage for water quality control. The base could just as well be some level of treatment and some existing reservoir configuration.

2. A water quality (DO) standard has been established. (The procedure could be applied to various other standards to show the cost of attaining these standards).

In addition to these policy constraints, it was assumed that the following as inputs to the river system models were available.

1. Waste loadings (lb/day 5-day BOD)
2. Parameters defining the self-purification of the river (K_1, K_2, K_3, etc.)
3. Layout of system geometry
4. Historic river discharge records
5. Statistical analysis of water temperature

Given a particular river system, the flow required to assimilate a specific waste load and maintain a specified water quality is primarily a function of temperature. By selecting design temperatures for seasons corresponding to the seasons for which the analyses are to be made (e.g., months) a minimum flow requirement that will meet the quality constraint can be computed for each month using either the Oxygen Sag or Segmented Estuary Model. These seasonal flow requirements can be arranged to form a matrix, the columns

of which represent the months and the rows of which represent the various waste loading levels (either changedby improved waste treatment or, in the case of industrial waste, a percent reduction in loadings due to process changes).

Waste Loading Level	Matrix A Flow Required to Meet Quality Objective Months Jan.	Feb.	Mar.	Apr.	May	. . . . .	Dec.
1	Q_{11}	Q_{12}	.	.	.	.. ..	.
2	Q_{21}	Q_{22}	.	.	.	.. ..	
3	Q_{31}						
4	.						
5	.						
.	.						
.	.						
1	.						
n	.						

For example, in Matrix A shown above, row one might represent the flow required with no treatment and column one represents the flow required in January.

The row matrices of Matrix A can be introduced into the Hydrologic Simulation model described previously to compute the failure probability for each element of the row matrices as well as for the row matrix itself. This program is capable of handling a large river system with various waste loadings and thus minimizing the quantity of data coding and the number of computer runs

required. The probability of failure for each location in the river system is computed by the program simply as the number of deficient seasons divided by the total number of seasons on the historic or synthetic record. The vector of probabilities formed by consideration of the different waste loading levels is essentially a conversion of the elements in Matrix A to a vector, the components of which are failure probabilities for the system at various waste loading levels.

Similarly, by step increasing the potential storage capacity of a reservoir placed in the system and rerouting the dilution flow requirements through the hydrologic model, a number of such probability vectors can be computed.

A family of curves as shown for Figure 1 can be drawn from the data thus generated.

A new matrix can then be extracted from these curves. The rows of this matrix correspond to allowable loads and the columns refer to selected risk factors (probabilities).

Matrix B

Allowable Loading Levels	Quantity of Storage, cfs-months Risk Factor, 1 month per x years				
	1/5	1/10	1/20	1/30	1/50
T_1	S_{11}				
T_2					
T_3					
T_4					
T_5					
n					S_{ij}

Given cost curves for both storage and treatment, the elements of the second matrix can be mapped into cost. By adding the cost for treatment to each of the corresponding elements in the cost matrix, a matrix of total system cost is formed. The position of the minimum cost in each column will identify the least cost treatment and storage combination to meet the desired standard at that particular failure rate. The costs for each failure rate can then be ranked, listing the corresponding combination of treatment and storage.

III. A CASE STUDY - THE JAMES RIVER BASIN

The case study presented herein is a preliminary evaluation of the potential of the water resources in the James River Basin for meeting present and future water needs. The study was performed by the authors while employed by the Federal Water Pollution Control Administration as part of the Water Resources Study for Appalachia authorized by Congress in the Appalachian Regional Development Act of 1965. The Federal Water Pollution Control Administration, cooperatively with the U.S. Corps of Engineers, Virginia State Department of Water Resources, Virginia State Water Control Board, and other Federal and State agencies, is currently evaluating present and future water resource needs of the James River Basin toward formulating a comprehensive program to enhance and preserve the beneficial water uses in the Basin. While the case study presented in this paper was based on information existing at the time of the study, the findings are not final and should not be interpreted as representing the Basin program to be formulated.

General Basin Description -

The James River Basin is narrow and irregular with headwaters in the Allegheny Mountains at the West Virginia state line. The river flows generally southeasterly 340 miles through four physiographic regions: the Valley and Ridge, the Blue Ridge, the Piedmont, and the Coastal Plain (Figure 2). The total area drained is 10,060 square miles, of which 80 are in West Virginia at the edge of the Appalachian region. There is a total fall of 988 feet from the headwaters to the "Fall Line" separating the Piedmont and Coastal Plain at Richmond. From this point, the James is an estuary that joins the Chesapeake Bay at Hampton Roads.

Here we will focus our attention on that portion of the main stem of Craig Creek from a proposed dam site (Hipes) to its confluence with the James River, that portion of the Jackson River extending from the Gathright Dam site to its confluence with the James River and the main stream of the James River from its confluence with the Jackson River up to and including the James estuary immediately below the City of Richmond.

Gathright is a multipurpose reservoir under construction on the Jackson River approximately 19 miles upstream from Covington, Virginia, which will provide 60,700 acre feet of storage for flood control, recreation and water quality control.

The Hipes site on Craig Creek has been selected by the Corps of Engineers as the most feasible site for reservoir storage in the basin both from an economic and design standpoint. In this study, our analysis was limited to increased storage at the Hipes site for water quality control. Reservoir cost data for this site were provided by the U.S. Corps of Engineers.

Water Quality Control Flow Requirements

Dissolved oxygen is the water quality indicator upon which the design of control measures was based in this study. A minimum monthly average DO of 5.0 mg/l was the planning objective.

There are presently two areas in the James River Basin, Lynchburg and Richmond, within the sphere of influence of the Hipes reservoir site that experience recurrent DO problems. Figure 3 indicates the effect of wastes discharged in these two vicinities on the DO of the river. Economic and engineering projections of industrial and municipal waste loads to the James River showed that, although the provision of biological treatment would improve the existing conditions, the projected growth and resulting waste loads in these areas require that control methods in addition to conventional waste treatment be considered. A detailed description of the projections and resulting loading has been given elsewhere. (7)

To form a basis on which to plan for possible water quality control needs, the 50-year period ending in the year 2020 has been divided into two 25-year treatment plant design periods. The required monthly river discharge in the critical sections below Lynchbirg and Richmond under present conditions and at the end of each of the 25-year periods was calculated using the water quality models previously discussed. The results are shown in Tables 1 and 2 for three levels of waste treatment. The waste treatment levels considered are defined as follows:

Level 1 - Conventional secondary treatment operated at an efficienty of 85 percent removal of 5-day BOD. The provision of this level or its equivalent in BOD reduction is considered to be prerequisite to low flow augmentation.

WATER QUALITY CONTROL FLOW REQUIREMENT TO MAINTAIN 5.0 mg/l
AVERAGE DO OBJECTIVE IN THE JAMES RIVER AT LYNCHBURG

Design Period		Treatment Level(1)	Annual Cost(2) 1000's Dollars		Flow Requirements in cfs												Reliability Factor(3)
From	To		Initial	Final	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Present	N.A.	I	N.A.	N.A.	220	240	290	420	460	690	690	690	580	450	300	250	99.5
		II	N.A.	N.A.	200	220	260	380	410	640	640	640	510	400	270	230	
		III	N.A.	N.A.	180	200	230	340	370	570	570	570	470	360	240	210	
1970	1995	I	base	base	300	300	370	550	620	900	900	900	750	580	380	320	96.6
		II	175	205	240	270	320	480	540	780	780	780	670	500	330	280	98.6
		III	745	855	210	230	280	400	450	670	670	670	570	420	290	240	99.8
1995	2020	I	base	base	320	380	450	650	720	1100	1100	1100	900	700	470	400	91.9
		II	210	240	280	320	390	560	610	900	900	900	760	600	400	340	94.4
		III	1055	1180	240	270	310	450	490	700	700	700	600	470	330	280	99.5
Mean Monthly Flow(4)					4749	5822	7280	6149	4048	2437	1608	1959	1437	1919	2242	3445	
Minimum Monthly Flow(4)					631	690	2741	1798	1190	910	503	458	421	431	511	729	
Mean Monthly Maximum Temperature (°C)					9	11	15	23	25	32	32	32	29	24	16	12	

(1) Treatment Levels I, II, and III represent 85, 90, and 95 per cent BOD removal respectively.

(2) Total cost including operation, maintenance, and amortization of capital at three and one-fourth per cent for 25 years. (ENR = 1090).

(3) Per cent of months out of 37 years of historic record that flow requirements were met. Gathright assumed operating for maximum need at Covington.

(4) From USGS gage on the James River near Holcombs Rock, Virginia.

WATER QUALITY CONTROL FLOW REQUIREMENT TO MAINTAIN 5.0 mg/l
AVERAGE DO OBJECTIVE IN THE JAMES RIVER AT RICHMOND

Design Period		Treatment Level(2)	Annual Cost(3) 1000's Dollars		Flow Requirements in cfs												Reliability Factor(4)
From	To		Initial	Final	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Present	N.A.	I	N.A.	N.A.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	100.0
		II	N.A.	N.A.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	100.0
		III	N.A.	N.A.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	100.0
1970	1995	I	base	base	300	300	300	650	1000	1450	1550	1550	1350	900	300	300	96.2
		II	90	160	(1)	(1)	(1)	(1)	300	650	800	800	550	(1)	(1)	(1)	100.0
		III	930	1,320	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	100.0
1995	2020	I	base	base	400	400	500	950	1250	1650	1800	1800	1550	1150	600	400	94.8
		II	170	210	(1)	(1)	(1)	(1)	500	900	1050	1050	800	300	(1)	(1)	99.5
		III	1,530	1,810	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	100.0
Mean Monthly Flow(5)					10021	11662	13569	12066	7392	5238	3605	4520	3697	4138	4471	7387	
Minimum Monthly Flow(5)					1656	4103	6396	3776	3013	1684	1306	858	802	700	1113	1681	
Mean Monthly Maximum Temperature (°C)					8	9	13	20	24	29	30	30	28	23	16	12	

(1) Water quality control flow requirements are less than minimum daily flow recorded.

(2) Treatment Levels I, II, and III represent 85, 90, and 95 per cent BOD removal, respectively.

(3) Total annual cost including operation, maintenance, and amortization of capital at three and one-fourth per cent for 25 years (ENR = 1090).

(4) Per cent of months out of 37 years of historic record that flow requirements were met. Gathright assumed operating for maximum need at Covington.

(5) From USGS gage on the James River at Richmond (adjusted to include Kanawha Canal diversion).

Level II - Ninety percent removal of the 5-day BOD. This level will result in a further one-third reduction in treated waste load discharges and can be achieved by design modifications of conventional biological waste treatment plants.

Level III - Ninety-five percent removal of the 5-day BOD. This level of treatment can be achieved by conventional biological treatment in combination with oxidation ponds, chemical precipitation or some other method of advanced waste treatment.

The cost estimates shown in the tables for each treatment level represent the annual expenditures at the beginning and end of the design period to provide either Level II or III, over and above the annual cost of Level 1. Level 1 is considered to be a minimum level when considering low flow augmentation as an alternative to treatment. Costs were estimated from municipal treatment plant cost data compiled and analyzed by Frankel (8) and from cost data made available by industries in the Basin. The costs shown include total annual cost of operation, maintenance and amortization of capital at 3-1/8 percent over 25 years. The interest rate chosen is the same as that used by the U.S. Corps of Engineers, Norfolk District, for reservoir construction. Uniformity of interest rate was considered to be desirable for benefit evaluation.

The stream flow requirements necessary to assimilate the corresponding waste loads without depleting the average DO below 5.0 mg/l were computed by means of the digital computer simulation models discussed previously. For planning purposes, the mean monthly maximum water temperatures were used.

The probability at which the natural or regulated stream flows can be expected to meet the required stream flows is a measure of the reliability of the system. This probability is computed as the number of successful events divided by the total number of events considered. As applied to the monthly stream flow requirements, an event consists of a routing of an historical monthly average stream flow through the river system and comparing it to the corresponding monthly flow requirement. In this study we used the term "reliability factor", defined as the probability, as discussed above, multimplied by 100.

$$\text{Reliability Factor} = 100 \times \frac{\text{Number of Successful Months}}{\text{Total Number of Months in Historic Record}}$$

Thirty-seven years of historical stream flow data have been routed through the system and reliability factors computed for each of the flow requirement vectors shown in Tables 1 and 2. For planning purposes, a reliability factor of 99.6 has been chosen. On the basis of monthly flows, this represents one unsuccessful month out of 20 years. Hydrologic analysis of the historical records showed that this reliability is approximately equivalent to the 7-day, 10-year return frequency drought flow specified in the State of Virginia proposed water quality standards. It was assumed that Gathright Reservoir will be operational by the early 1970's. Hydrological routings, therefore, have been made with Gathright operating for maximum water quality control benefit. Table 3 shows the target flows assumed for operation of Gathright Reservoir.

The hydrological analysis has been facilitated by the application of a computer program developed by Fiering and Pisano[6] discussed earlier. Thirty-seven years of historic stream flow records were available for this study area. The period of record used was from October 1927 through September 1964. Figure 4 shows the system geometry as assumed for this study.

TABLE 3

GATHRIGHT RESERVOIR RELEASE RULES

Operation for Year 2020 Water Supply and Water Quality
Control Flow Requirements at Covington

Design Year	Treatment Level	Flow Past Covington in cfs											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020	I	175	170	180	190	210	365	365	365	245	210	185	175
Design Temperature		9	8	12	20	21	26(1)	26(1)	26(1)	24	21	13	10

(1) Based upon controlled temperature release from Gathright.

Table 4 is a list of the U.S. Geological Survey stream gaging stations used and Table 5 lists the pertinent geographical locations of the system. Gage No. 6 was created for this study by adding the flows from the gage on Dunlap Creek with those at Falling Spring on the Jackson River. The resulting record was considered to be a reasonably good approximation of the flows that occur at Covington, the point of need for Gathright water quality control storage.

TABLE 4

STREAM GAGES USED IN HYDROLOGIC ANALYSIS OF JAMES RIVER BASIN

Gage No.	Description	Drainage Area (square miles)
1	Jackson River at Falling Spring	409
2	James River at Lick Run	1369
3	James River at Buchanan	2084
4	James River at Holcombs Rock	3250
5	James River at Bent Creek	3671
6	Dunlap Creek plus Falling Spring gage	575
7	James River at Casterville	6242
8	Cowpasture River near Clifton Forge	456
9	Craig Creek at Parr	331
10	Dunlap Creek near Covington	166
11	Maury River at Buena Vista	649

TABLE 5

DESCRIPTION OF COORDINATES FOR HYDROLOGIC ANALYSIS

Location	River Mile	Drainage Area (square miles)	Reference Gage[1]	Gage Adjustment Factors
Jackson River Gathright dam site	43.5	344	1	0.8411
Jackson River City of Covington	23.5	610	6	1.0000
Craig Creek Hipes dam site	14.8	327	9	1.0000
James River City of Lynchburg	250.0	3200	4	1.0000
James River City of Richmond	100.0	6760	7	1.0816

(1) See Table 4 for gage description.

ALTERNATIVE METHODS OF MEETING WATER QUALITY CONTROL OBJECTIVES

Probably, the most widespread methods for meeting specific water quality objectives with respect to dissolved oxygen are: (1) reduction of BOD waste loads by treatment at the source; and (2) regulation of stream flow by providing reservoir storage. Preliminary studies indicated that other methods such as instream aeration, waste storage, and piping of waste to bodies of water having a greater assimilation capacity did not appear to be feasible devices for pollution control in the Lynchburg and Richmond areas.

The analysis was, therefore, limited to an examination of storage and treatment either separately or in combination, as a means of meeting the water quality control needs of the portion of the James River described. From a cost evaluation of many possible combinations of storage and treatment, a single least cost alternative can be selected. Table 6 defines the pollution control alternatives that have been considered for this report. The treatment combinations considered include all possible combinations of the three treatment levels at Lynchburg and Richmond. The amount of reservoir storage in Hipes that is required to meet the average DO objective of 5.0 mg/l for each of the treatment combinations has been computed as previously discussed.

Figures 5 and 6 exemplify the method of handling the output from the program to determine storage requirements. By routing the historic flows through the system with various sizes of storage in Hipes and plotting the computed failure probabilities versus storage, the storage required to meet the desired reliability can be picked from the curve. These curves were

TABLE 6

STORAGE REQUIREMENTS CORRESPONDING TO ALL POSSIBLE COMBINATIONS OF TREATMENT LEVELS AT LYNCHBURG AND RICHMOND

Treatment Level		Required Storage in Hipes (acre-feet)
Lynchburg	Richmond	
Design Period 1970 - 1995		
I	I	75,000
I	II	27,000
I	III	27,000
II	I	75,000
II	II	0
II	III	0
III	I	75,000
III	II	0
III	III	0
Design Period 1995 - 2020		
I	I	128,000
I	II	62,000
I	III	62,000
II	I	[illegible]
II	II	27,000
II	III	27,000
III	I	128,000
III	II	0
III	III	0

developed for all of the alternatives considered. Only the curves for the selected alternate are shown as an example.

In the historic record of thirty-seven years, two months' failure would exceed the objective reliability factor of one month in twenty years. However, based on observations of the records from gages for which a longer historic trace is available, it was concluded that, for the limited record used, two failures (reliability factor = 99.5) would be accepted for design purposes. Future studies, perhaps utilizing synthetically generated flow records, are recommended to support this judgment decision.

The total pollution control alternative, therefore, consists of a specific treatment level at Lynchburg and at Richmond in conjunction with a specific storage volume at the Hipes site for stream flow regulation.

Since the benefit of storage for water quality control is generally evaluated on the basis of a fifty year period, it is necessary to select the long-range alternative first and then designate the minimum required short-term action plan, taking fullest advantage of the storage computed to meet the long-range needs. By so doing, the alternatives listed in Table 6 can be reduced to the six logical fifty-year pollution control alternatives shown with their respective costs in Table 8.

Pollution control by treatment is generally designed for a twenty to twenty-five year period of capital amortization. For comparative purposes, the alternatives and associated costs for a twenty-five year plan are given in Table 7.

DISCUSSION OF ALTERNATIVES

Alternatives 1 through 9 (see Table &) are designed to meet the stream DO objective through the year 1995. These alternatives are included

TABLE 7

COST COMPARISON FOR POLLUTION CONTROL ALTERNATIVES

Twenty-Five Year Plan

(1970 - 1995)

Alternative Number	Description of Alternative: Treatment Level Lynchburg	Richmond	Storage In Hipes (acre-ft.)	Cost of Alternative Present Worth 1970 (millions of dollars): Treatment	Storage	Total
1	I	I	75,000	0.00	9.87	9.87
2	I	II	27,000	2.15	6.10	8.25
3	II	II	0	5.41	0.00	5.41
4	II	I	75,000	3.52	9.87	13.39
5	III	II	0	15.88	0.00	15.88
6	III	I	75,000	13.74	9.87	23.61
7	I	III	27,000	19.32	6.10	25.42
8	II	III	0	22.58	0.00	22.58
9	III	III	0	33.06	0.00	33.06

TABLE 8

COST COMPARISON FOR POLLUTION CONTROL ALTERNATIVES

Fifty-Year Plan
(1970 - 2020)

Alternative Number	Description of Alternative: 1970 - 1995 Treatment Level		1995 - 2020 Treatment Level		Storage in Hipes (acre-ft)	Cost of Alternative Present Worth, 1970 (millions of dollars)		
	Lynchburg	Richmond	Lynchburg	Richmond		Treatment	Storage	Total
10	I	I	I	I	128,000	0.00	11.21	11.21
11	I	I	I	II	75,000	1.51	9.87	11.38
12	I	II	II	II	27,000	5.45	6.10	11.55
13	II	II	III	II	0	15.67	0.00	15.67
14	III	II	III	II	0	26.15	0.00	26.15
15	III	III	III	III	0	55.26	0.00	55.26

for comparison purposes. It is presently common practice to assume a fifty-year design period for storage for water quality control. These shorter range plans are presented because there are definite advantages to short-range planning in this day of rapid technological change. Advances in waste treatment technology and industrial production purposes could drastically alter the water requirements and waste production of the future.

Alternatives 10 through 15 are six feasible long-range (fifty years) water quality control plans from which the need for and value of storage in a multi-purpose reservoir on Craig Creek can be evaluated. Table 9 provides a subjective evaluation of these six alternatives. Although the rating of secondary effects is admittedly a somewhat arbitrary approach to making a non-monetary comparison of the different plans, it does present a method of acknowledging and considering effects that might not otherwise be included in the evaluation.

The following is a short description of each of the six fifty-year plans. The particularly significant secondary effects of each are also briefly commented upon.

Alternative 10 is what can be considered the minimum acceptable treatment level in combination with 128,000 acre-feet of storage for water quality control at the Hipes site. This is both the least costly alternative and the one requiring the most storage. Significant secondary benefits are increased low flows in the Fall Zone at Richmond and maximum performance stability. Since this alternative requires the minimum treatment and maximum storage, it is the least consistent with the goal of complete elimination of point-source pollution.

Alternative 11, the second least costly alternative, is judged insignificantly more expensive than Alternative 10 and the storage requirement

TABLE 9

SUBJECTIVE EVALUATION OF POLLUTION CONTROL ALTERNATIVES

Secondary Effects[1]	Pollution Control Alternative Rating[2] 10	11	12	13	14	15
a. Nutrient removal above Richmond for water supply and below Richmond for estuary eutrophication	2	2	2	3	3	4
b. Color removal--associated with paper industry, particularly below Lynchburg	2	2	2	3	4	4
c. Recreation--effects on river	2	2	2	2	1	1
d. Fishery--effects on river	?	?	?	?	?	?
e. Ability to take advantage of technological advances	-	1	2	3	4	4
f. Variability in performance	4	3	3	2	1	1
g. Aesthetic improvement--flow in Fall Zone at Richmond	4	4	3	2	1	1
h. Consistent with goals of complete elimination of point source pollution	-	2	2	3	3	4
TOTAL	12	16	16	18	17	19

(1) Effects incidental to principal objective of maintaining 5.0 mg/l DO.

(2) Definition of Ratings:
- Negative effect
1 No effect
2 Slight positive effect
3 Significant effect
4 Very significant effect
? Unknown effect

is reduced by about forty percent to 75,000 acre-feet. This reduction in storage is the result of the application of the second treatment level at Richmond beginning in 1995 and through the year 2020. The secondary benefits of this alternative are essentially the same as the first, with an additional slight positive effect in the area of eliminating point-source pollution.

Alternative 12 calls for the second treatment level at Richmond for the 1970 through 1995 design period and at both Richmond and Lynchburg for the 1995 to 2020 design period. The alternative requires 27,000 acre-feet of storage at Hipes and has a total cost that is again only insignificantly more expensive than the least costly plan. In the subjective evaluation, losses with respect to esthetic improvement for the Fall Zone at Richmond are balanced by gains in the ability to take advantage of technological advances.

Alternative 13 is almost one and one-half times as costly as the least cost alternate. The sharp rise in cost is due to the requirement of treatment level III which involves chemical precipitation and its correspondingly high operating costs. No storage above that provided by the Gathright Project is required. The 95 percent treatment level with chemical precipitation at Lynchburg would have the secondary benefit of significant color and nutrient reduction.

Alternative 14 requires the third level of treatment at Lynchburg for both design periods and the second level of treatment at Richmond for both design periods. No flow regulation other than that provided by Gathright for the Covington area is needed. The cost is substantially more than Alternative 13. The secondary benefits are somewhat higher in the nutrient and color removal categories but lower in performance variability and dependable flow in the Fall Zone.

Alternative 15 is five times as expensive as the least cost alternative due to the specified highest treatment level for all waste contributors in the Lynchburg and Richmond areas from 1970 through 2020. As in Alternatives 12 and 14, no storage is required. This alternative scores highest in scondary effects with very significant positive effects on nutrient and color removal, ability to take advantage of technological advances and consistency with the goal of complete elimination of point-source pollution.

SUMMARY AND CONCLUSIONS

In making this study, many conclusions were reached, some of which can be supported by the data presented while others are more subjective in nature. The more significant of these are:

1. In a given situation, low flow augmentation is still an economically feasible method of water quality control.
2. In using operations research and systems analysis principles in water quality control planning, translating theory to mathematical formulas and computer programming is only a small portion of the task facing engineers and scientists. Obtaining the data necessary to satisfy the input requirements of these models and evaluating and interpreting output in the light of political, economic and physical constraints, in fact, pose significant if not more difficult problems.
3. There is a need for greater emphasis by water quality control agencies on the establishment of water resource policy. Studies on the implication of various policy avenues by use of the case study technique are desirable.
4. From the experience encountered in the James River studies, the solution of the least cost alternative does not seem to lend itself, practically speaking, to a continuous solution. Cost curves for waste treatment are generally not continuous functions especially when complicated by existing treatment levels and policy constraints. The individual evaluation of discreet management plans not only is indicated to be a more practical approach but perhaps a more desirable and realistic one as well.

5. Mathematical models in water pollution control planning can provide a means whereby many system designs may be evaluated and thereby provide a more rational selection of the optimum design. It is the opinion of the writers, however, that the decision should not be based solely on the cost aspects of the total water resources picture. A subjective analysis of the project may show that the least cost solution may not be the optimum solution. In fact, there may be more than one "optimum solution" depending upon the vantage point of the decision maker.

6. Considerable field work followed by still more office work involving the use of large measures of engineering judgment were required to arrive at reasonable approximations of the system parameters and input data required for this study. For this reason, caution is advised in attempting to reduce all problems to a computerized systems analysis approach. For example, it probably would not be economically feasible to spend the money and manpower required to obtain models for very small, perhaps intermittent, creeks. In cases such as this a policy decision based on experience would appear to be more realistic.

7. Limited industrial waste reduction cost data present a major problem in making cost oriented evaluations such as this one although the help received from the industries in the study area indicated their willingness to provide such data as exist.

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PROBABILITY OF FAILURE VERSUS ALLOWABLE WASTE LOADING LEVEL

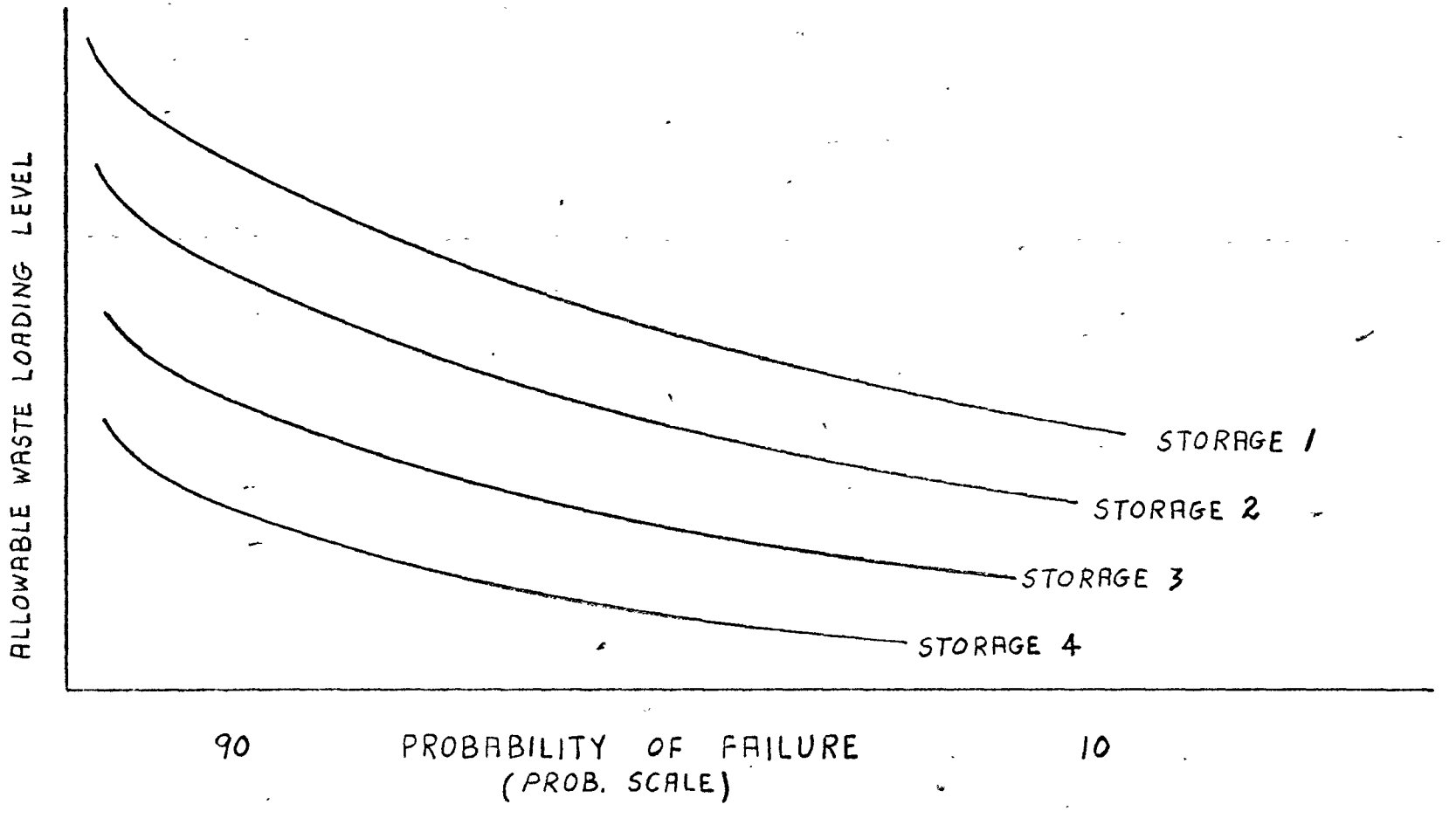
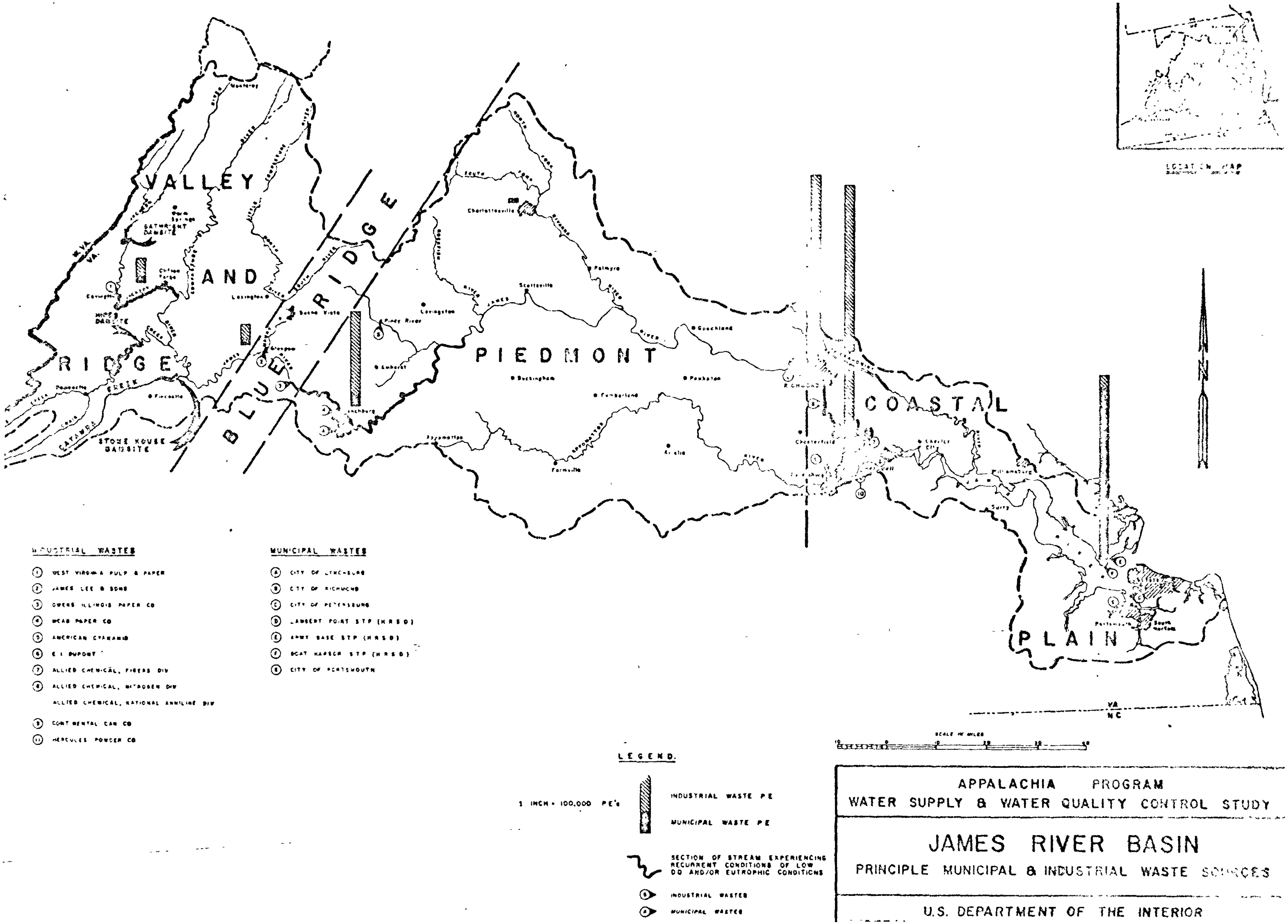


FIGURE 1


VALLEY
AND
RIDGE
BLUE
RIDGE
PIEDMONT
COASTAL
PLAIN
Lynchburg
Charlottesville
Scottsville
Palmyra
Goochland
Buena Vista
Lexington
Covington
Lovingston
Amherst
Buckingham
Cumberland
Powhatan
Farmville
Chesterfield
Surry
Williamsburg
Portsmouth
South Norfolk
STONE HOUSE DAMSITE
GATHRIGHT DAMSITE
LOCATION MAP
VA
NC
SCALE IN MILES
INDUSTRIAL WASTES
1 WEST VIRGINIA PULP & PAPER
2 JAMES LEE & SONS
3 OWENS ILLINOIS PAPER CO
4 MEAD PAPER CO
5 AMERICAN CYANAMID
6 E. I. DUPONT
7 ALLIED CHEMICAL, FIBERS DIV
8 ALLIED CHEMICAL, NITROGEN DIV
ALLIED CHEMICAL, NATIONAL ANNILINE DIV
9 CONTINENTAL CAN CO
10 HERCULES POWDER CO
MUNICIPAL WASTES
A CITY OF LYNCHBURG
B CITY OF RICHMOND
C CITY OF PETERSBURG
D LAMBERT POINT STP (H.R.S.D.)
E ARMY BASE STP (H.R.S.D.)
F BOAT HARBOR STP (H.R.S.D.)
G CITY OF PORTSMOUTH
LEGEND
1 INCH = 100,000 PE's
INDUSTRIAL WASTE PE
MUNICIPAL WASTE PE
SECTION OF STREAM EXPERIENCING RECURRENT CONDITIONS OF LOW DO AND/OR EUTROPHIC CONDITIONS
INDUSTRIAL WASTES
MUNICIPAL WASTES
APPALACHIA PROGRAM
WATER SUPPLY & WATER QUALITY CONTROL STUDY
JAMES RIVER BASIN
PRINCIPLE MUNICIPAL & INDUSTRIAL WASTE SOURCES
U.S. DEPARTMENT OF THE INTERIOR

JAMES RIVER

AVERAGE DISSOLVED OXYGEN FOR SAMPLING SURVEYS
CONDUCTED IN JULY AND/OR AUGUST, 1966

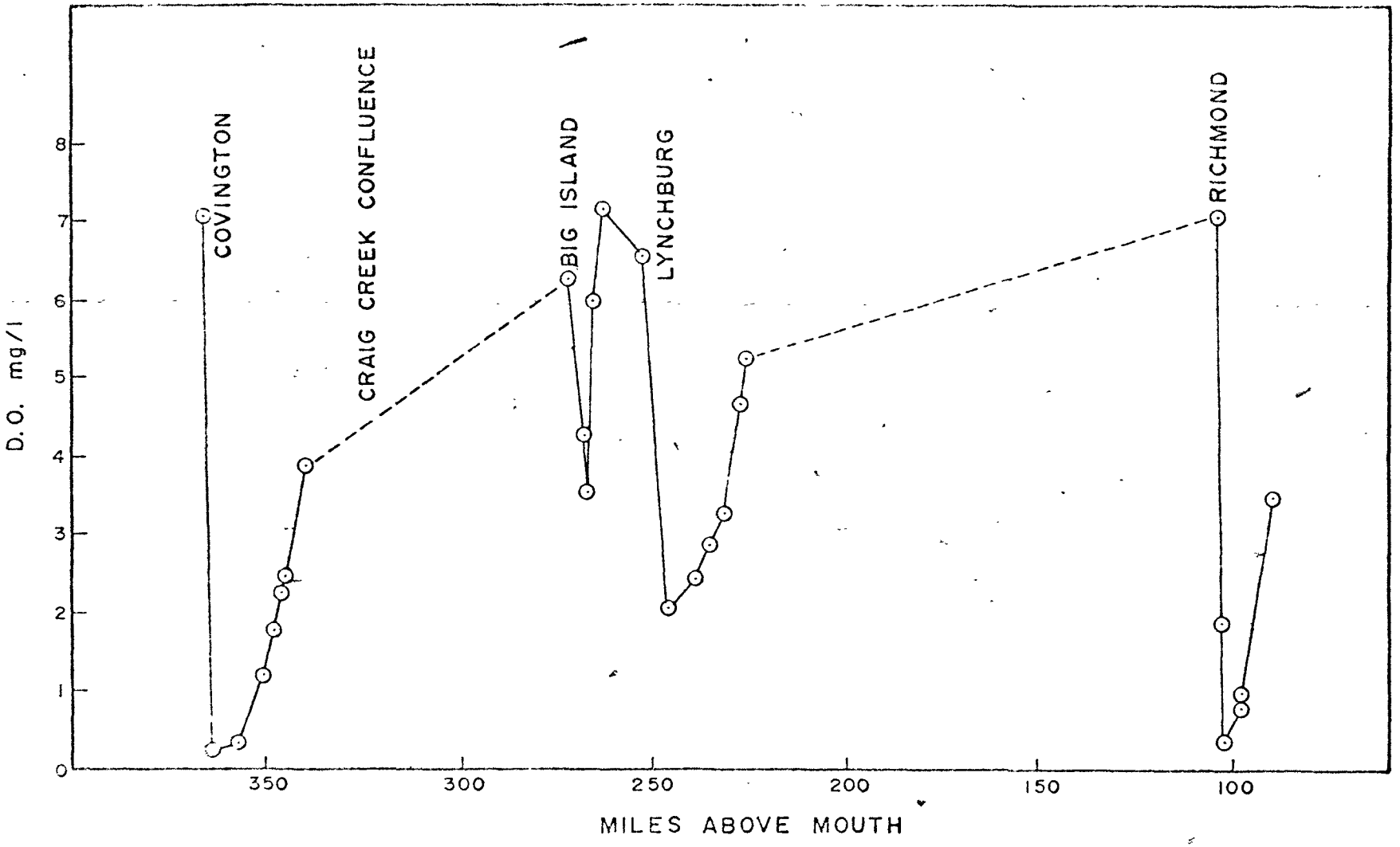


FIGURE 3

SIMPLIFIED SKETCH OF GEOMETRY
for
HYDROLOGIC ANALYSIS

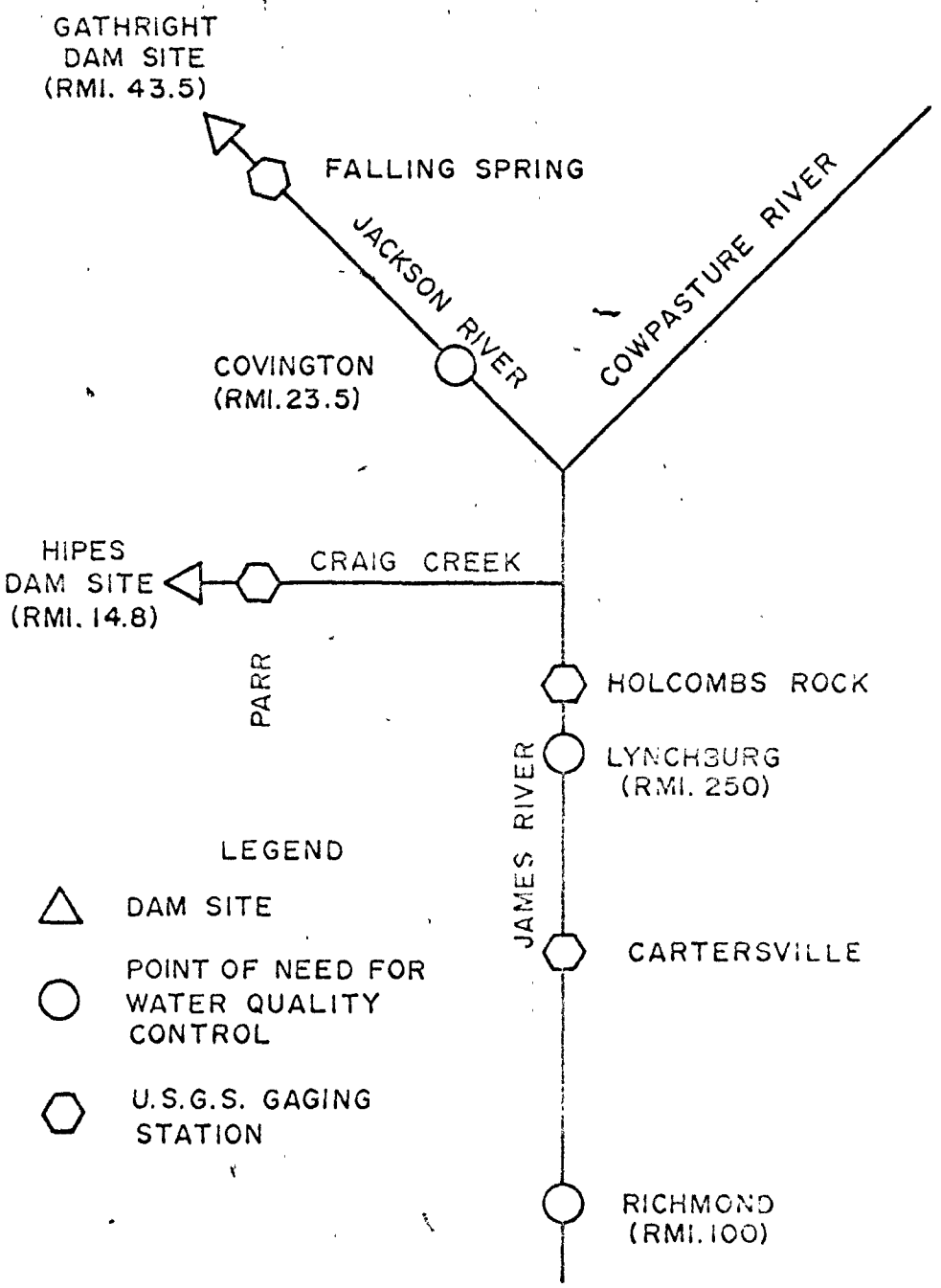


FIGURE 4

RELIABILITY OF WATER QUALITY CONTROL VS. STORAGE FOR LOW FLOW AUGMENTATION

(ALTERNATE NO. II AT 1995 CONDITIONS)

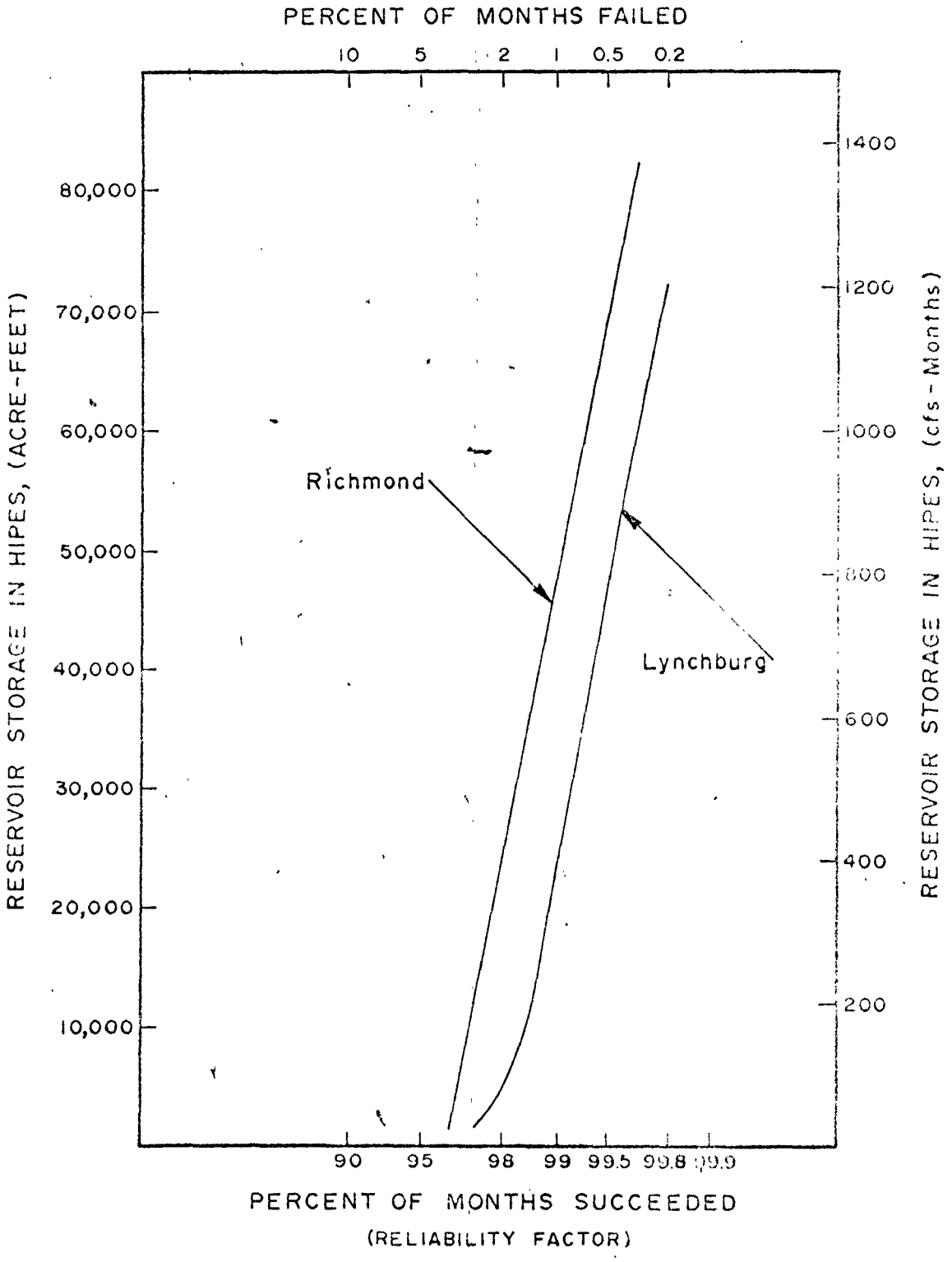


FIGURE 5

RELIABILITY OF WATER QUALITY CONTROL VS. STORAGE FOR LOW FLOW AUGMENTATION

(ALTERNATE NO. II AT 2020 CONDITIONS)

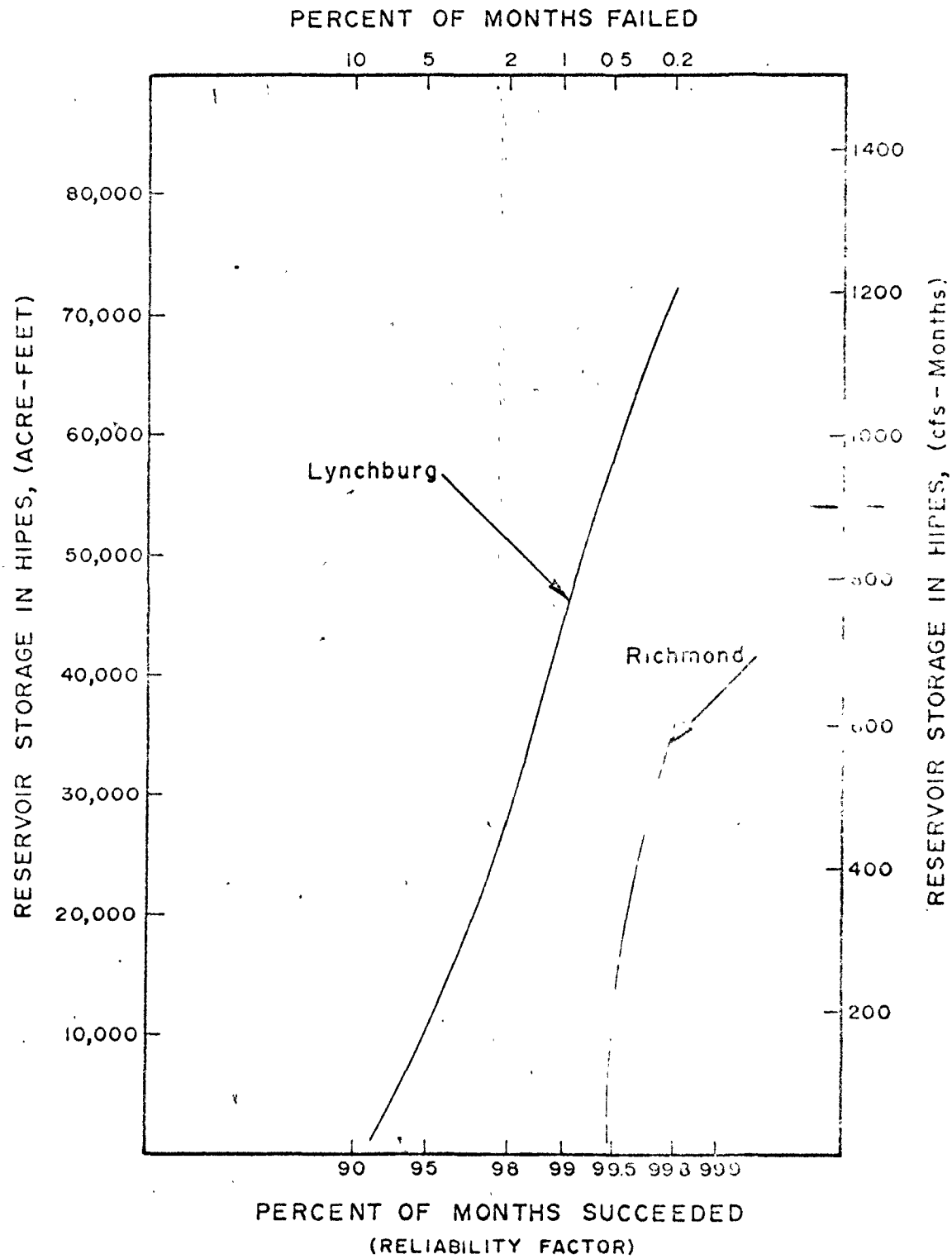


FIGURE 6

A WATER QUALITY STUDY

OF THE

PISCATAWAY CREEK WATERSHED

August 1968

Johan A. Aalto

and

Norbert A. Jaworski

Chesapeake Field Station
Middle Atlantic Region
Federal Water Pollution Control Administration
U. S. Department of the Interior

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CHAPTER I

PREFACE

The Washington, D. C., metropolitan complex is a rapidly growing area, changing not only the character of the land use of the upper Potomac Estuary Drainage Basin, but also placing increasing demands upon the water resources of the River and its Estuary. Since 1960, the population of the metropolitan area has grown from about 2,100,000 to the present estimated population of approximately 2,900,000.

Eight major municipal wastewater treatment facilities discharge to the Potomac Estuary. The treated discharges have a biochemical oxygen demand (BOD) of 100,000 pounds per day, equivalent to the untreated sewage from 600,000 people. This loading is about six times the natural capacity of the Estuary to assimilate oxygen demanding wastes and maintain a dissolved oxygen (DO) average of five milligrams per liter (mg/l).

The facility at Blue Plains discharges directly into the Potomac River and is the largest, serving the District of Columbia and large areas in Montgomery and Prince Georges Counties, Maryland. The remaining seven discharges are to embayments of the Potomac Estuary. The relative advantages of conveying treated wastewater directly into the Potomac Estuary instead of into the small embayments had not been previously investigated.

In recent months, public interest in the operation and effects of the Piscataway Wastewater Treatment Plant on Piscataway Creek

water quality caused considerable attention to be given to this area. The problem is twofold: first, the limited assimilative capacity of this small embayment and, second, provision of suitable "fail-safe" mechanisms and operating procedures in the wastewater treatment facilities to eliminate discharge of untreated sewage.

CHAPTER II

INTRODUCTION

A. Purpose and Scope

As part of the Chesapeake Bay-Susquehanna River Basins Project, the Chesapeake Field Station (CFS), Middle Atlantic Region, Federal Water Pollution Control Administration (FWPCA) has undertaken a comprehensive water quality management study of the Potomac River Basin. Important phases of this study are determination of the effects of wastewater discharges on water quality in the Potomac Estuary and recommendation of a program to achieve the approved water quality standards for this interstate river.

In recent months there has been considerable public interest in the operation of the Piscataway Wastewater Treatment Plant (PWTP) of the Washington Suburban Sanitary Commission (WSSC) and the effect of plant effluent on the water quality of Piscataway Creek. A series of field surveys was conducted by CFS on the efficiency of the PWTP and on water quality in Piscataway Creek.

This report contains the findings of the CFS studies to date. The purposes of this report are:

1. To provide information on:
    a. Efficiency of PWTP
    b. Effects of the discharge on the water quality in Piscataway Creek and the Potomac River
    c. General operation of the PWTP

2. To investigate and recommend alternative locations for the effluent discharge point from the PWTP.

Although the scope of this report is primarily limited to the Piscataway Creek and the adjacent reaches of the Potomac Estuary, other embayments in the area were investigated in order to compare the Piscataway results with similar embayments including three not receiving treated water discharges. In the future, the rapid growth of the area will require construction of additional wastewater treatment facilities in the lower embayments, such as Mattawoman Creek, and may result in similar problems in this and other embayments of the Potomac Estuary.

B. Authority

This survey was conducted and the report prepared under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.) which directs the Secretary of the Interior to prepare or develop programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters, in cooperation with State water pollution control agencies and with the municipalities and industries involved.

C. Acknowledgments

The assistance and the cooperation of the Washington Suburban Sanitary Commission, Maryland State Department of Health (MSDH),

Maryland Department of Water Resources (MDWR), and the Prince Georges County Cheverly Laboratory, enabled the CFS to collect, assemble, and evaluate the necessary data in a much shorter time than would otherwise have been required.

CHAPTER III

SUMMARY AND RECOMMENDATIONS

Intensive field investigations, sampling surveys, and data analyses have been conducted to determine the conditions in the Piscataway Creek and adjacent water by CFS, including the operations of the Piscataway Wastewater Treatment Plant of WSSC. A summary of the findings of these investigations, surveys, and analyses follows:

1. The Piscataway Creek Watershed, which is a Sub-Basin of the lower Potomac River below Washington, D. C., has a drainage area of about 80 square miles.
2. The Piscataway Basin is rapidly being developed into suburban residential areas with no major industrial development in the area. Andrews Air Force Base is located in the headwaters of the Basin.
3. The waters of the Piscataway Basin, including the embayment, are used for commercial and sport fishing. In the lower portion of the embayment near the Potomac Estuary there is a marina and a national park.
4. There are six municipal wastewater treatment facilities in the Piscataway Basin discharging, after secondary treatment, about 780 pounds of 5-day BOD into the waters of the Basin.

5. The Piscataway Wastewater Treatment Plant, which also serves parts of Prince Georges County outside of the Watershed, contributes about 80 percent of the domestic wastewater loading. The current population of the service area is about 110,000, with a projected population of over 600,000.

6. The Piscataway Wastewater Treatment Plant has a nominal design capacity of 5.0 million gallons per day (mgd). This facility was placed in operation in late 1967 and has a temporary discharge to the Piscataway embayment.

7. Since the Piscataway plant was placed into operation, the following have occurred.

   a. Flow exceeded nominal design capacity. For example, in June 1968, the average flow to the plant was 6.54 mgd.

   b. Untreated sewage has been by-passed to the Piscataway embayment, resulting in numerous complaints by local residents.

   c. Operational difficulties occurred at the treatment facility, resulting from power failures and inexperienced personnel.

8. Evidence of water quality degradation has been observed in the embayment near the pumping station and near the wastewater outfall. Chemical analysis of the water also

indicates high nutrient (phosphorus and nitrogen) concentration in these two areas.

9. Due to the very limited fresh water inflow and excessive weed growth, the water movement is restricted and thus reduces the overall effect of the periodic tidal flushing of the embayment in the vicinity of the pumping station and the temporary outfall.

10. During low tide, the water depth in the embayment near the discharge point is less than a foot. The effluent from the wastewater plant flows within 100 feet of the shoreline of a residential area downstream from the outfall.

11. In the lower Piscataway embayment near the Potomac Estuary and in the Estuary itself, extensive algal blooms have been occurring in recent years, apparently as a result of the wastewater discharges from the Washington metropolitan area. The dissolved oxygen in the upper Potomac Estuary below Washington often falls below 3.0 mg/l in the summer months.

After investigations following a series of complaints by residents in the area adjacent to the wastewater treatment plant, the Maryland State Department of Health directed that WSSC take the following actions:

1. Limit the flow into the plant to an average daily flow of 5.0 mgd;

2. Install an alarm system which would be activated during periods of by-passing of flows; and
3. Upgrade the general operating conditions of the plant, including training personnel.

WSSC has complied with this directive.

Since mid-July of 1968, analyses of the efficiency of the wastewater treatment plant by WSSC, MSDH, FWPCA's advanced waste treatment group, and CFS indicate that the efficiency is of very good quality.

As part of the water quality management program for the Potomac River, including Piscataway Creek, the following specific recommendations are presented for the WSSC facility:

1. As originally proposed by WSSC and approved by Maryland State Department of Health and FWPCA, an outfall should be constructed to the main channel of the Potomac Estuary.

2. An investigation should be made and appropriate action taken by WSSC to eliminate by-passing of untreated sewage to the Piscataway embayment.

3. To provide for better dispersion of the wastewater in marshy areas of the embayment, pending completion of the Potomac outfall, a channel should be excavated or temporary pipeline laid to convey the final effluent out to the southerly stream channel.

As guidelines for long-range planning, the following general recommendations have been developed as a result of the Piscataway investigation and the previous studies of the entire Potomac Estuary by CFS:

1. No new discharges of wastewater to the Estuary or to its embayments, temporary or permanent, should be approved until an engineering study has been made on the assimilative capacity of the receiving water and a plan developed to eliminate discharge of untreated wastes.
2. Inspections and efficiency studies should be made on all treatment facilities at least four times a year to insure high quality operation and to provide an opportunity for discussion of any operational problems with the plant personnel.

CHAPTER IV

DESCRIPTION OF AREA, WATER RESOURCES, AND WATER QUALITY STANDARDS

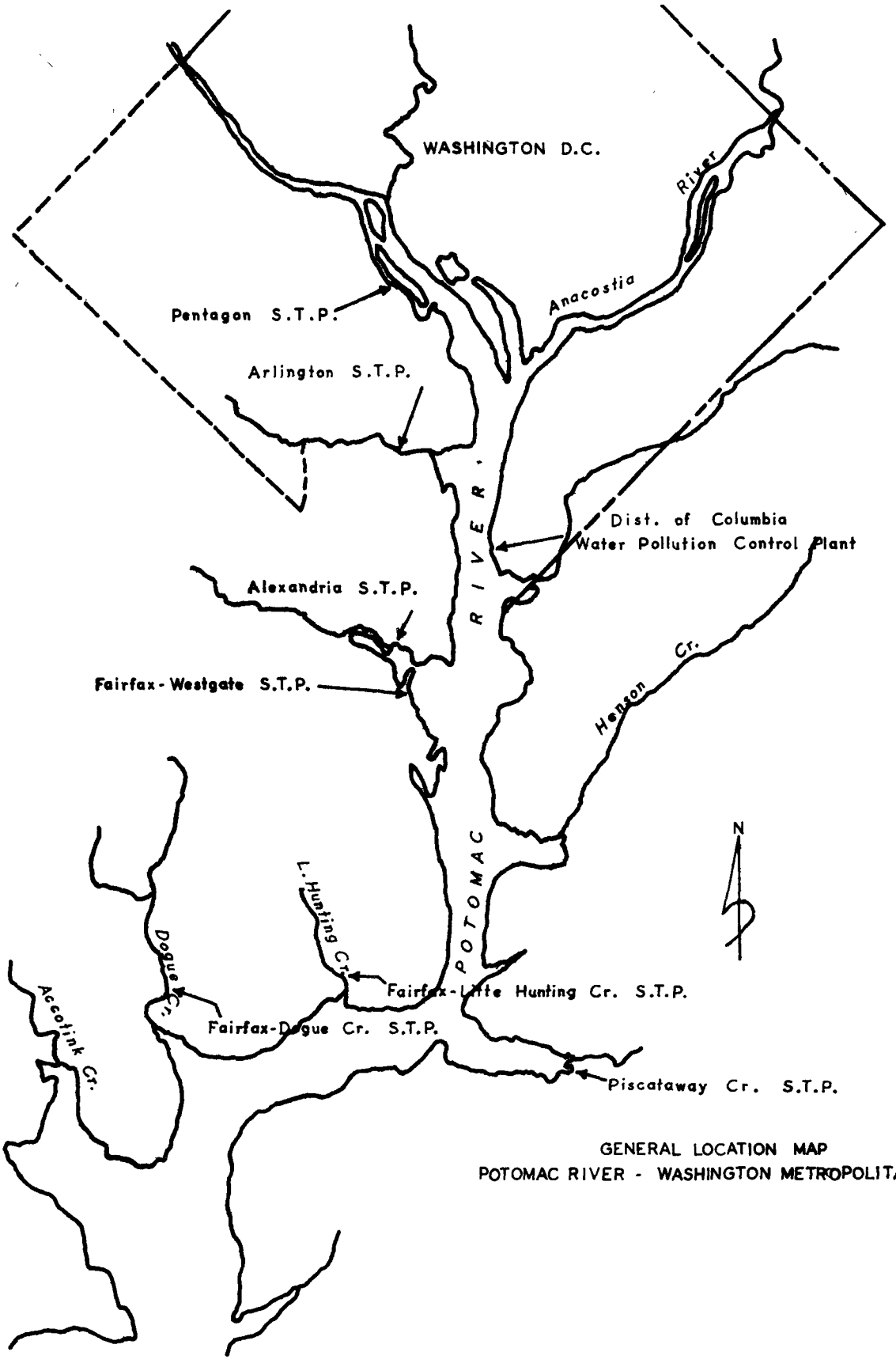
A. General

The Piscataway Creek Watershed has a drainage area of 81.5 square miles and is located about 12 miles southeast of the center of Washington, D. C. (see Figure IV-1). The Creek, which flows in a westerly direction, enters the upper Potomac Estuary about 98 miles upstream from the Chesapeake Bay.

Since it is located in the Washington metropolitan area, the Watershed is rapidly being developed into a suburban residential area. Housing for employees of Andrews Air Force Base, which is located partly in the upper portion of the Piscataway Sub-Basin, has also added to the urban development of the Basin.

There are no major industries in the Watershed. The only industrial discharges are from sand and gravel operations in the non-tidal portions of the Watershed.

Except for the embayment segment of Piscataway Creek, the Stream is small, sluggish, and, in the headwaters, the stream flow is intermittent. The maximum, mean, and minimum flows from a stream gaging station established near Piscataway, Maryland, in 1965, were 328, 19.7, and 0.0 cubic feet per second (cfs), respectively. Using the longer term records of Henson Creek, which has an average yield of 1.10 cfs per square mile, the average annual flow from the entire



GENERAL LOCATION MAP
POTOMAC RIVER - WASHINGTON METROPOLITAN AREA

FIGURE IV-1

Piscataway Creek Watershed is estimated to be about 90 cfs. The upper part of the embayment is a swamp with abundant growths of submerged and emergent aquatic plants. Tentative identification of the noted aquatic growths indicates that the majority of the emergent plants are reed grass, Phyragmites and Pontederia cordata. The submerged growths appear to be mostly coontails, Cereatophyllerm. The center and lower embayment is about four to six feet deep and has little or no submerged and emergent plants.

B. Water and Land Related Resources

The waters of Piscataway Creek are used for both tidal and non-tidal fishing. According to the Annotated Code of Maryland, the waters of Piscataway Creek above Maryland Route 224 are considered non-tidal.

Although sport fishing is not widely practiced due to the limited access to embayment waters, local residents have made catches of catfish, carp, perch, and rockfish in Piscataway Creek. During a CFS sampling survey, a local resident who has fished the Piscataway for the past 20 years stated that he had not noticed any great change in the fish population. He did indicate that there had been an increase in commercial fishing for carp and catfish in the swampy area of the embayment in recent years. Also, during many of the surveys, numerous species of fish were observed, especially in the marshy area of the embayment.

During the spring spawning period, herring are netted from the waters of Piscataway Creek. Larger catches are obtained near Indian Head Highway and other shallow portions of the upper embayment. According to a game warden of the Maryland Department of Game and Inland Fish, the 1968 herring run in Piscataway Creek was considered to have been good.

After long periods of hot, dry weather, crabs are often seen in the Piscataway Creek embayment. However, the crabs observed are too small in size and in number to have any sport or commercial significance.

There is a marina on the northern shore of Piscataway Creek near the confluence with the Potomac River. The marina provides slips for approximately 450 boats, 30 of which are covered.

Also on the northern shore of Piscataway Creek embayment and continuing along the shoreline of the Potomac River is the Fort Washington National Park. Historically, since the early 1800's this Fort had been the key defense position for the City of Washington, D. C. Since World War II, however, the Fort has been made into a National Park. This Park, which is operated by the U. S. National Park Service, had 413,000 visitors in 1967.

The remaining portion of the embayment, including the southern shore, has been developed for residential use and includes several small, private recreational areas and marinas.

C. Water Quality Standards and Implementation Plan

In 1967, the State of Maryland*

> ". . . in order to provide for the enhancement of the water quality where such quality has deteriorated or is deteriorating, for the conservation of water quality where such quality is good or satisfactory, and for the protection of lawful and reasonable uses . . ."

established both general and specific water quality standards for both inter and intrastate waters. A plan for implementation and enforcement of the water quality standards for all of Maryland's waters was also established. The standards and the implementation plan for the interstate waters were approved and adopted by the U. S. Department of the Interior in August 1967.

1. Water Uses

The uses of waters of the Potomac Estuary were grouped into six categories as follows:

"I - Shellfish harvesting

"II - Public or municipal water supply

"III - Water contact recreation

"IV - Propagation of fish and other aquatic life and wildlife

---

* Water Resources Regulation 4.8, General Water Quality Criteria and Specific Water Quality Standards for all Maryland Waters, Water Resources Commission and Department of Water Resources, Maryland State Office Building, Annapolis, Maryland 21401.

"V - Agricultural water supply

"VI - Industrial water supply"

For each of the water uses categories, bacteriological, dissolved oxygen, pH, and temperature standards were specified. The designated uses of applicable water zones of the Piscataway Creek watershed are presented below:

Waste of Water Zone	Water Use to be Protected
Piscataway Creek and Tributaries (Headwaters to Md. Rt. 224)	III, IV, V, VI
Piscataway Creek and Tributaries of Potomac River (From Md. Rt. 224 to Mouth)	III, IV

2. Water Quality Standards

Dissolved Oxygen (DO) is the parameter most indicative of water quality in a free-flowing stream or estuary of this type. Wastewater treatment requirements and/or flow regulation needs were determined using a mean monthly DO level of 5.0 mg/l with a minimum level of 4.0 mg/l. This is the approved standard for the waters of the Piscataway Creek in the study area. (See Water Resources Regulation 4.8 of the State of Maryland for other specific bacteriological, temperature, and pH standards.)

CHAPTER V

WASTEWATER TREATMENT FACILITIES

In the Piscataway Creek Basin there are seven wastewater discharges. One of the discharges is mineral, and the remaining six are organic in nature.

A. Andrews AFB Wastewater Treatment Facilities

Andrews Air Force Base has two wastewater discharges in the Basin. Plant Number 1, which discharges into Meetinghouse Branch of Piscataway Creek about 13 miles upstream from the Potomac, has an average flow of 0.65 mgd with a biochemical oxygen demand (BOD) loading to the River of 90 pounds per day. The Number 4 plant, which has an average flow of 0.06 mgd and BOD loading after treatment of 10 pounds per day, discharges into Paynes Branch of Piscataway Creek about 13 miles upstream from the Potomac River.

Both facilities consist of Imhoff tanks, trickling filters, secondary sedimentation, and chlorination. BOD removal efficiency of 89 percent and 83 percent for plants Nos. 1 and 4, respectively, is obtained. A summary of the water quality below the two discharges is given in Chapter VI.

B. Piscataway Creek Wastewater Treatment Facility

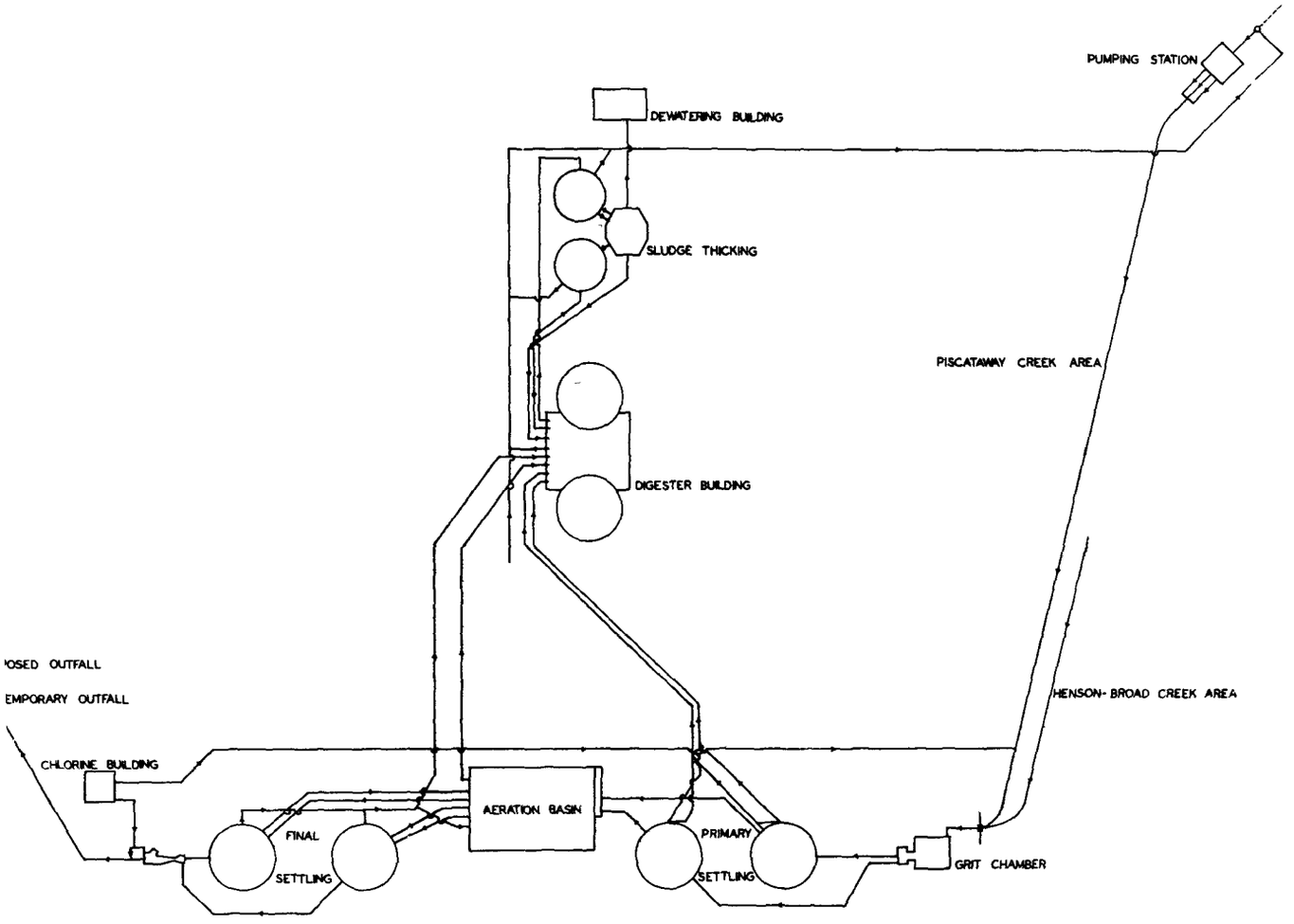
The treatment facility was placed in operation in late 1967 and has a design capacity of 5.0 mgd at a 5-day BOD removal efficiency of 90 percent. Flows above this capacity can be treated at a reduced

BOD removal efficiency. Provisions have been made on the site to expand plant capacity to 30 mgd.

The sewage is brought to the facility by two force mains, one from the Henson Creek area and the other serving the adjacent Piscataway Creek area. The plant provides activated sludge treatment with sludge digestion, conditioning and vacuum filtration. The effluent is chlorinated and discharged into a partly lined channel which flows into a marsh area of the embayment. A schematic diagram of the plant is given in Figure V-1. In an agreement recently signed with FWPCA, the WSSC is to design and build a 4.0 mgd advanced wastewater treatment (AWT) pilot plant consisting of lime precipitation and sedimentation, filtration, and carbon adsorption.

The major factors influencing effective utilization of the Piscataway Creek facility include operating problems, presence of a bypass, location of the temporary outfall, and high flows to the plant. In the first six months of the year, except for January, there were days during which the average daily flows were from 6.0 to 9.0 mgd. As can be seen in Table V-1, the average daily flows for the months of April, May, and June were above the nominal design capacity of the plant.

While the reported plant efficiencies in terms of BOD and suspended solids removal are high, these figures are misleading, since the influent figures were not representative of the untreated sewage. Nevertheless, excluding the times when the average flow was greater



SCHEMATIC OF PISCATAWAY WASTEWATER TREATMENT PLANT

FIGURE IX-1

TABLE V-1

PISCATAWAY WASTEWATER TREATMENT DATA

January - June 1968

As Reported by WSSC Personnel

	Flow			BOD			Suspended Solids		
Month	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Untreat.* (mg/l)	Treat. (mg/l)	Removal (%)	Untreat.* (mg/l)	Treat. (mg/l)	Removal (%)
January	0.00	1.58	4.23	98	15	84	138	19	79
February	0.70	3.72	6.05	143	23	85	152	17	89
March	0.90	4.24	6.50	205	18	91	364	19	88
April	3.30	5.36	7.13	359	33	91	785	27	96
May	5.10	5.89	9.10	362	38	90	799	29	96
June	4.27	6.54	9.10	496	45	91	1,921	53	97

* Untreated samples include some overflow from digesters, therefore not a good measure of the untreated wastewater.

than 5.0 mgd, as given in Table V-1, the plant is capable of providing 90 percent BOD removal.

Plans for the Piscataway Wastewater Treatment Plant, as originally approved by the Maryland State Department of Health, provided for an effluent lime some three miles long discharging the treated wastes into the main channel of the Potomac River. The plans and specifications as submitted were reviewed and approved for a construction grant by FWPCA.

When some difficulty developed in obtaining a right of way for an outfall to the Potomac, WSSC submitted plans and specifications for a temporary outfall to discharge into the head of the Piscataway embayment in July 1967. This was approved by MSDH.

Operational problems occurred in sludge handling, screen cleaning equipment jammed, and pumping stations were subject to power failures. No emergency stand-by power was provided in the original design, nor was there any alarm system to indicate failure of equipment in the system.

During the first six months of 1968, power failures and operational problems resulted in the discharge or raw or partially treated sewage into Piscataway Creek. The limited transport and assimilative capacity of the embayment obviously caused a degradation in its water quality far more than a similar accidental discharge would have caused in the Potomac River.

The discharge of untreated sewage and, to some extent, the overloading of the treatment plant suggest these three general needs which should be studied to identify actions which should be taken to prevent water quality degradation in all embayments of the Potomac Estuary in the future:

1. More frequent surveillance of the wastewater treatment facility by the appropriate State and County health agencies.
2. Incorporation into the design of the wastewater facility a "fail-safe" warning or stand-by system which will minimize uncontrolled discharges of untreated wastes.
3. Specialized engineering studies in the design and the selection of discharge points for the wastewater effluents. The study should also incorporate the affects of possible discharges.

The latter of the three needs is the primary area of concern in the surveys which were subsequently conducted by CFS.

C. Other Discharges

The remaining organic wastewater loadings into Piscataway Creek, about seven percent of the total, come from three sources, Cheltenham Boys Village, U. S. Naval Communications Station, and the Country Club Cleaners. These three, which have a total BOD

loading to the Piscataway Creek of 50 pounds per day, will probably be connected to the WSSC system in the near future as the sewer system is expanded. In Table V-2 is presented a complete listing of wastewater discharges into the Piscataway Creek Watershed.

TABLE V-2

WASTEWATER DISCHARGE

Piscataway Creek Basin

Name	Type of Waste	Design Capacity (mgd)	Volume of Waste (mgd)	BOD			Receiving Stream	Remarks
				Untreat. (#/day)	Treat. (#/day)	Removal (%)		
Andrews AFB #1	San.	0.913	0.645	830	90	89	Meetinghouse Br.	
Inland Materials, Inc. (Clinton, Md.)	Silt	---	---	---	---	---	Paynes Br.	Silt Ponds
Andrews AFB #4	San.	0.125	0.060	66	10	83	Paynes Br.	
County Club Cleaners	Laundry	Unk	0.015	25	4	84	Paynes Br.	
Piscataway Wastewater Plant	San.	5.000	5.000	4,000	635	84	Piscataway Bay	New Facility
Cheltenham Village (State of Md.)	San.	0.060	0.121	333	34	90	T. Piscataway Cr.	Overloaded
U. S. Naval Communications Station (Cheltenham, Md.)	San.	0.050	0.056	200	10	95	T. Piscataway Cr.	Loaded to Capacity

CHAPTER VI

EXISTING WATER QUALITY

A. Potomac River Near Piscataway Creek

1. Water Quality Monitoring Programs

Water quality in the Potomac River in the Washington, D. C., area has been monitored since the early 1930's by the Department of Sanitary Engineering, District of Columbia Government. Since the late 1950's, originally the U. S. Public Health Service and presently the Federal Water Pollution Control Administration has also conducted numerous water quality surveys in the upper Potomac Estuary. An automatic water quality monitor at Fort Washington was added to the existing system in the Potomac Estuary in 1964.

2. Water Quality in the Upper Potomac Estuary Near Piscataway Creek

The water quality in the Upper Potomac Estuary near Piscataway Creek is greatly affected by the wastewater discharges, as shown in Figure VI-1. Approximately 100,000 pounds of 5-day BOD and 136,000 pounds of suspended solids are discharged into the upper Estuary above Piscataway Creek each day.

As can be seen in Figure VI-1, BOD loading during the low flow months of June, July, August, and September, depresses the DO in the main channel of the Potomac Estuary below the State Standard of 5.0 mg/l. BOD data from the 1968 survey, as given in Table VI-1, exhibit similar effects on water quality.

BOD, DO and TEMPERATURE *

POTOMAC RIVER
near
PISCATAWAY CREEK
1967

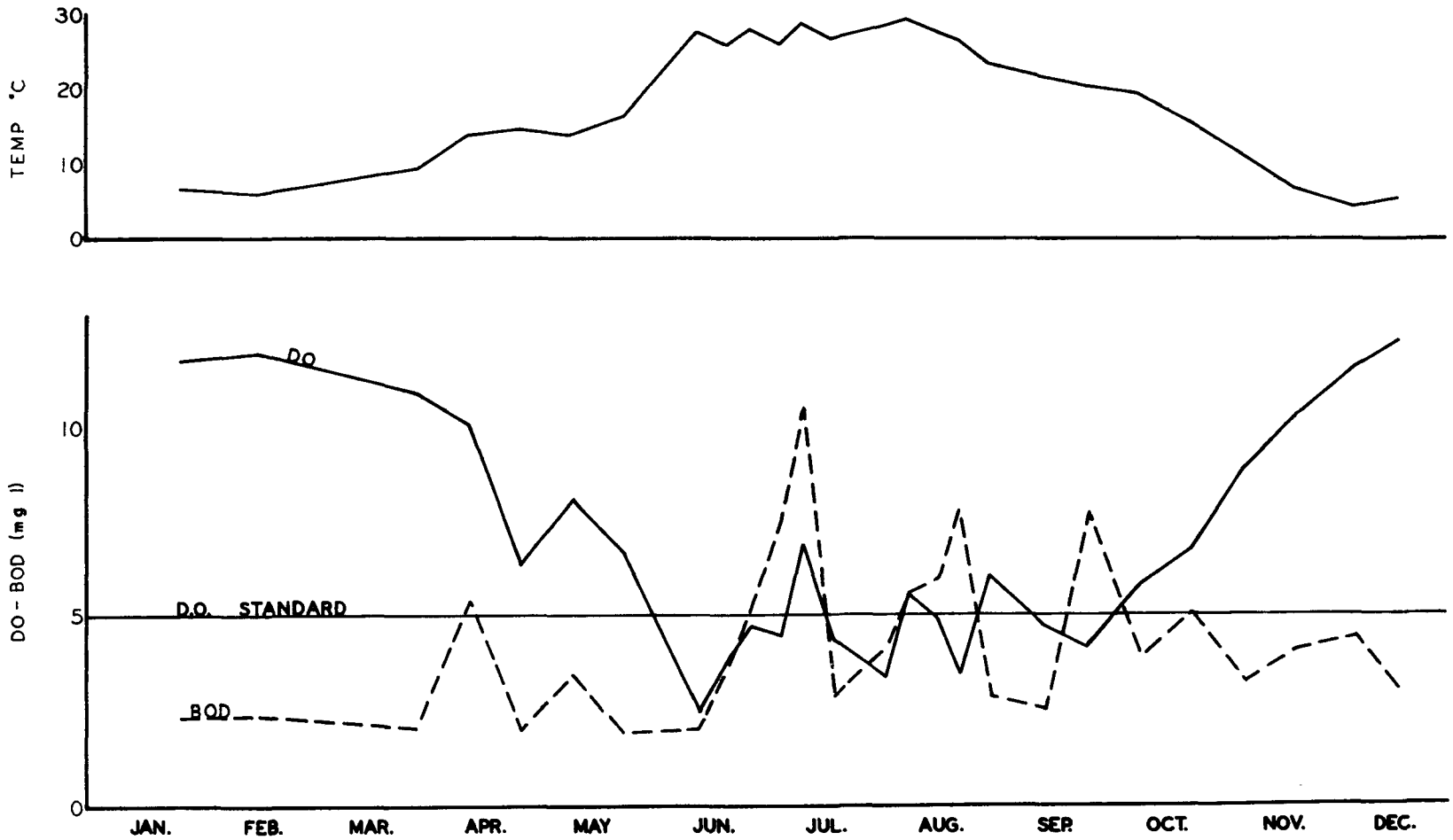


FIGURE VI-1

* Sampled by D.C. Water Pollution Control Plant

TABLE VI-1

WATER QUALITY DATA

Potomac Estuary near Piscataway Creek 1968

Date	Temp. (°C)	DO (mg/l)	BOD (mg/l)	T. PO_4 as PO_4 (mg/l)	TKN as N (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (µg/l)
5-15-68	19.5	1.5	3.8	1.51	2.27	0.34	18.0
6-10-68	26.6	6.9	3.8	0.59	LA	0.55	81.7
6-24-68	27.1	5.3	4.6	1.12	1.80	LA	4.5
7-08-68	28.7	4.2	ND	1.02	2.50	0.47	28.5
7-11-68	27.0	4.2	10.6	0.88	ND	0.99	78.8
7-22-68	30.4	3.4	4.6	0.78	1.76	1.62	ND
8-05-68	29.5	5.0	12.1	1.47	1.29	1.75	148.5
8-14-68	26.0	5.4	9.3	1.06	1.89	0.99	199.5

LA = Lab Accident

ND = Not Determined

A nutrient load is also associated with the large BOD and suspended solids loadings in all the wastewater discharges in the upper Potomac Estuary. Based upon current wastewater volumes, approximately 66,000 pounds per day of total phosphorus as PO_4 and 50,000 pounds per day of total Kjeldahl nitrogen (TKN) as nitrogen are discharged into the estuary.

During the past five years, extensive algal blooms have been observed in the upper Potomac Estuary. The blooms, consisting principally of Anacystis sp., Oscillatoria sp., and Chlamydomonas sp. occur in areas which are high in nutrient content.

As presented in Table VI-1, the nutrient concentrations for the Potomac Estuary for 1968 indicate a high concentration of phosphorus and nitrogen near the confluence with Piscataway Creek. For the months of May, June, July, and August, the average concentration of PO_4, TKN, and NO_2-NO_3 were 1.06, 1.89, and 0.99, respectively.

Associated with these high nutrient concentrations were high chlorophyll* levels in the Potomac Estuary near Piscataway Creek. As can be seen in Table VI-1, the chlorophyll levels for the latter part of July and for August were above 50 µg/l. During August, there was an extensive algal bloom in the entire upper Potomac Estuary.

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* Chlorophyll is a gross measure of algal concentrations or "standing crop." A chlorophyll level of 50 µg/l is considered to be a "bloom."

B. Upper Piscataway Area Watershed

Water quality in the upper Piscataway Creek has been monitored by personnel of Andrews Air Force Base above and below the discharge points of their waste treatment plants since 1967. A summary of the weekly sampling program is presented in Tables VI-2 and VI-3 for the Meetinghouse and Paynes Branch facilities, respectively.

As can be seen in these Tables, the effects of the wastewater discharges on DO and BOD in Paynes and Meetinghouse Branches are insignificant. The BOD below the two discharges is usually less than 0.5 mg/l larger than above the facilities, with the DO essentially the same above and below the discharges.

The water quality standard for DO, which is 5.0 mg/l monthly average, was met in Paynes Branch except for October of 1967. However, the DO above the discharge point at the same time was also below 5.0 mg/l. In general, the water quality in the headwaters of Piscataway Creek appear to meet the approved quality standards.

C. Piscataway Creek Embayment

A series of stream and wastewater treatment plant surveys was conducted by CFS in order to determine the effects of wastewater discharges on water quality in the Piscataway Creek embayment, especially those discharges in the Piscataway Basin and in the Potomac Estuary, and including land runoff. Sampling stations in the Piscataway Creek embayment are shown in Figure VI-2. The

TABLE VI-2

MONTHLY SUMMARIES OF BOD AND DO DATA*

Meetinghouse Branch STP

Piscataway Creek

		800 Feet Above Outfall		2 Miles Below Outfall	
Year	Month	BOD (mg/l)	DO (mg/l)	BOD (mg/l)	DO (mg/l)
67	January	1.5	10.3	2.3	10.0
67	February	5.0	9.5	4.6	10.3
67	March	1.7	10.2	2.5	10.1
67	April	2.5	9.1	1.6	10.6
67	May	1.5	8.6	0.8	7.3
67	June	2.4	7.3	1.7	5.3
67	July	2.4	7.3	1.7	5.3
67	August	1.3	6.4	1.6	6.8
67	September	1.9	6.6	1.5	5.6
67	October				
67	November	2.5	6.7	1.9	5.9
67	December	2.0	8.3	2.3	8.0
68	January	2.2	10.4	2.8	9.7
68	February	2.4	11.9	4.2	10.6
68	March	1.6	8.6	2.4	7.6
68	April	2.7	8.5	2.9	7.3
68	May	4.0	7.0	5.0	7.2
68	June	3.1	6.9	2.9	6.0
68	July	3.0	6.0	2.5	6.2

* Analysis made by Andrews AFB personnel four times per week.

TABLE VI-3

MONTHLY SUMMARIES OF BOD AND DO DATA*

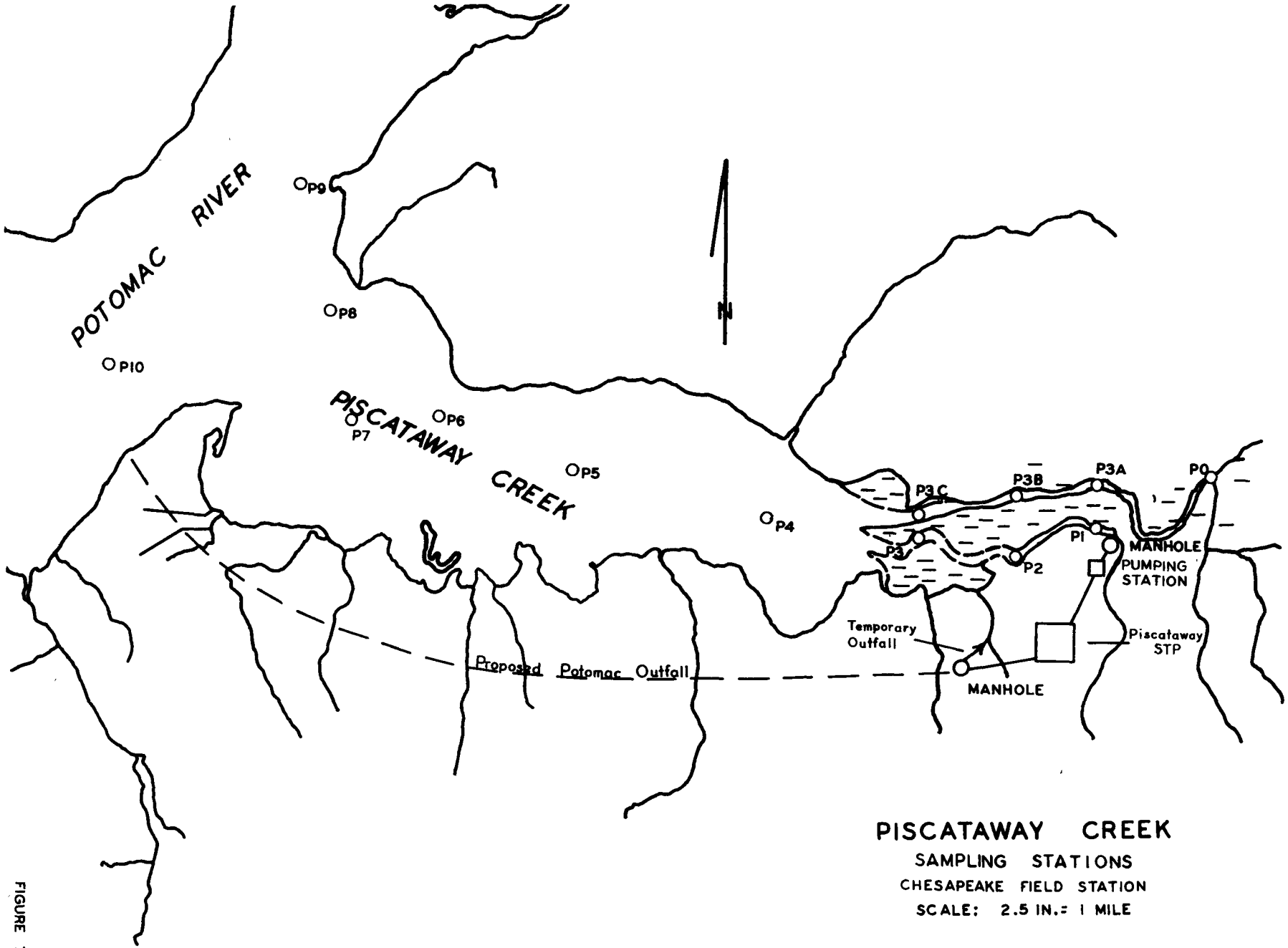
Payne Branch STP

Andrews Air Force Base

Piscataway Creek

		800 Feet Above Outfall		2 Miles Below Outfall	
Year	Month	BOD (mg/l)	DO (mg/l)	BOD (mg/l)	DO (mg/l)
67	January	2.9	6.5	2.2	6.4
67	February	3.2	8.9	3.9	10.4
67	March	1.0	9.6	4.5	11.0
67	April	0.6	7.2	1.6	9.5
67	May	1.2	7.0	2.1	7.4
67	June	1.3	6.3	2.0	6.3
67	July	1.8	6.3	2.0	6.3
67	August	1.6	6.3	1.4	6.4
67	September	2.3	5.3	2.0	5.5
67	October	2.9	4.9	2.7	4.4
67	November	2.1	6.1	2.6	6.3
67	December	1.9	8.4	1.4	8.2
68	January	1.5	8.7	1.4	8.6
68	February	2.4	11.2	2.8	10.1
68	March	1.9	8.8	2.7	8.4
68	April	2.0	8.2	2.6	7.3
68	May	3.9	6.3	2.0	6.8
68	June	1.9	7.4	3.3	5.9
68	July	3.2	6.0	3.3	5.9

* Analysis made by Andrews AFB personnel four times per week.



PISCATAWAY CREEK

SAMPLING STATIONS

CHESAPEAKE FIELD STATION

SCALE: 2.5 IN.= 1 MILE

FIGURE XI-2

surveys were incorporated into the larger program of the upper Potomac Estuary from the Washington, D. C., area to 301 Bridge near Morgantown, Maryland.*

1. Survey of July 11, 1968

Data from the embayment and waste treatment plant surveys are presented in Tables VI-4 and VI-5, respectively. The survey was conducted during high tide.

As can be seen in Figure VI-3, there was a pronounced algal bloom in the embayment during the survey. The algal concentration in the Potomac Estuary was about one-half of that in the Piscataway embayment.

The phosphorus values in the vicinity of the waste treatment facility were about twice those in the Potomac Estuary or in Piscataway Creek as it flowed into the embayment. The nitrite-nitrate (NO_2-NO_3) concentrations decreased with distance from the treatment plant, suggesting that denitrification was occurring. Since TKN data was not taken, no nitrogen balance was attempted.

The BOD in the embayment near the treatment facility was only slightly higher than in the Potomac Estuary (Figure VI-3). However, the BOD of Piscataway Creek at Indian Head Highway was less than 5.0 mg/l, suggesting that BOD in the embayment is coming from both the Potomac Estuary and the PWTP.

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* The data from this survey will be presented in a separate report by CFS.

TABLE VI-4

PISCATAWAY WASTEWATER TREATMENT PLANT DATA

July 11, 1968

Chesapeake Field Station

Parameter	Influent*	Effluent**
Average Flow (mgd)	4.20	4.20
Maximum Flow (mgd)	5.00	5.00
BOD (mg/l)	91.50	32.40
TKN as N (mg/l)	10.50	16.30
NH_3 as N (mg/l)	6.90	10.50
NO_2-NO_3 as N (mg/l)	1.79	0.08
T. PO_4 as PO_4 (mg/l)	9.65	15.71

* Based on a three-hour composite, 9:00 a.m. to 12:00 noon, on July 11, 1968, of the incoming wastewater from the Piscataway area only, and therefore is not a good measure of incoming characteristics.

** Based on a 24-hour composite, 8:00 a.m. on July 10, 1968, to 8:00 a.m. on July 11, 1968.

Table VI-5

PISCATAWAY CREEK SURVEY

July 11, 1968

Chesapeake Field Station

Station	Sta. No.	Sample Time	Water Temp. (°C)	Secchi Disk (Inches)	T. PO_4 as PO_4 (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (µg/l)	BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100 ml)	Coliform (MPN/ 100 ml)
Indianhead Hwy. Bridge	P-0	1225	21.5	-	.972	1.540	3.00	4.56	7.65	ND	ND
Pumping Sta. - Above Discharge	P-1	0930	23.0	6	2.510	.317	84.00	14.32	3.18	230	43,000
First Bend - Above Discharge	P-2	0955	24.5	8	2.261	.372	173.20	15.10	5.66	230	7,500
Near White Barrels Next to first home	P-3	1000	25.0	8	1.886	.350	220.50	14.52	8.09	93	23,000
Farmington Lodge Pt. - in Bay	P-4	1010	26.0	8	1.168	.419	201.00	12.62	12.05	15	230
In Bay - Out from Marina	P-5	1020	26.5	14	1.214	.667	72.00	11.90	4.50	210	750
Point - Below Marina in Channel	P-6	1030	26.5	18	.968	.774	43.50	11.54	5.05	230	430
Mid - Bay, Off First Two channel markers	P-7	1035	26.5	24	.934	.971	78.00	11.74	4.82	43	230
Confluence With Potomac Mid channel at marina	P-8	1040	26.5	24	.838	1.160	76.50	10.58	4.21	75	390
Off Monitor Sta. Buoy Potomac River	P-9	1045	27.0	23	.883	.992	78.75	10.60	4.18	93	230
Buoy 75 in Potomac River	P-10	-	26.5	24	.822	1.232	76.50	10.30	4.21	43	430

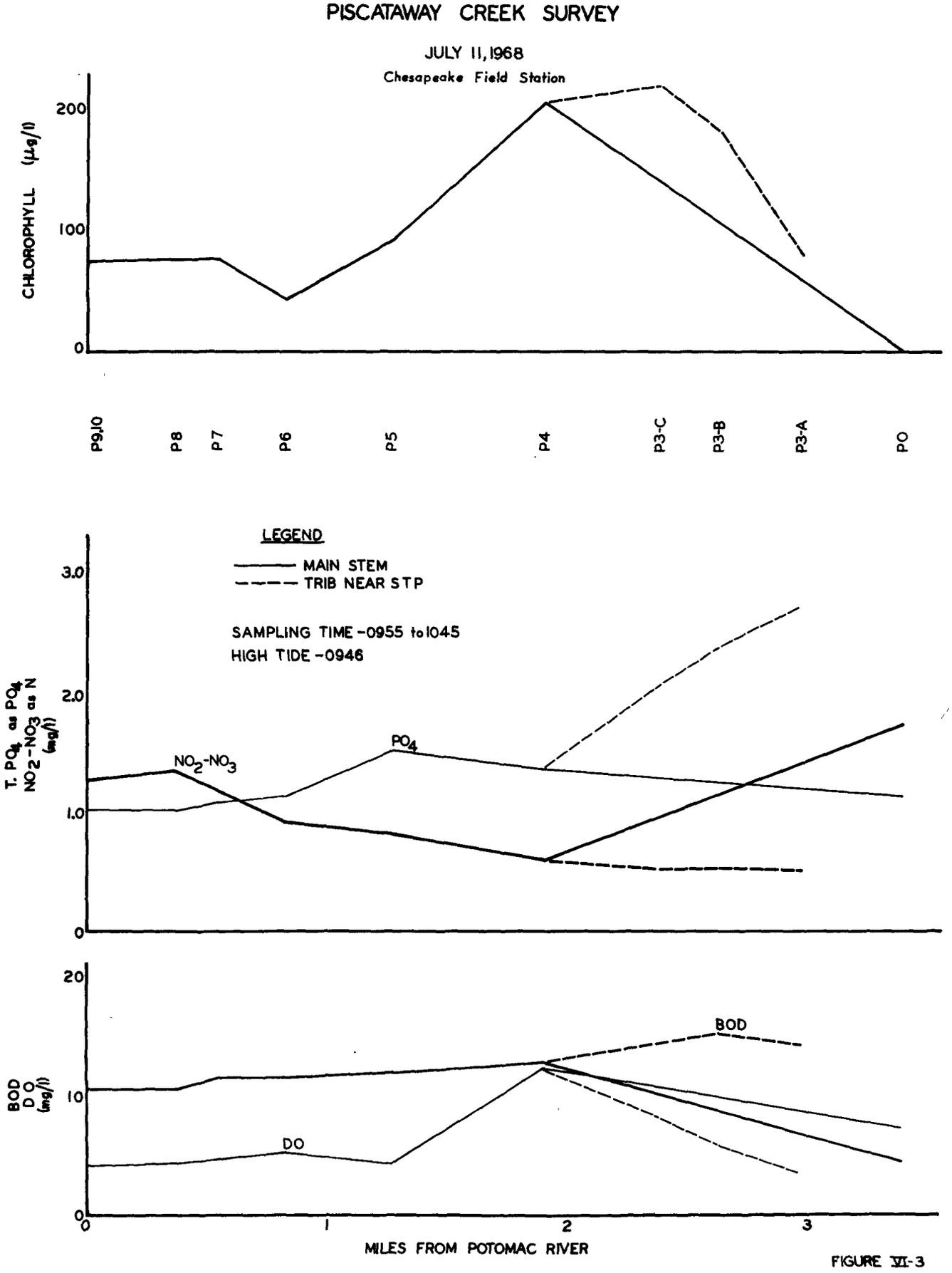
PISCATAWAY CREEK SURVEY
JULY 11, 1968
Chesapeake Field Station
CHLOROPHYLL (µg/l)
200
100
0
P9,10
P8
P7
P6
P5
P4
P3-C
P3-B
P3-A
P0
LEGEND
MAIN STEM
TRIB NEAR STP
SAMPLING TIME -0955 to 1045
HIGH TIDE -0946
T. PO4 as PO4
NO2-NO3 as N
(mg/l)
3.0
2.0
1.0
0
NO2-NO3
PO4
BOD
DO
(mg/l)
20
10
0
1
2
3
MILES FROM POTOMAC RIVER

FIGURE VI-3

At stations P-1, P-2, and P-3 in the southerly channel, coliform concentrations were the highest. The concentration of fecal coliforms, which is an indicator of human waste, was higher at stations P-1, P-2, P-5, and P-6 than at the remaining stations.

In the embayment and in the Potomac Estuary, DO concentrations below 5.0 mg/l were observed. As presented in Figure VI-1, a total of five stations had DO levels less than the adopted standards. The high concentration in the middle of the embayment was probably due to the oxygen production of the standing crop of algae.

While sampling the Piscataway embayment, numerous gas bubbles in the tributary near the wastewater plant were observed near the stations P-1 and P-2 by CFS personnel. Gas bubbles emanating from sluggish waters in marsh areas are common and, therefore, no special significance can be attached as to their causes.

During the survey, an analysis of the influents and effluents of the PWTP was made as given in Table VI-4. Although the influent sampling point was not representative of all the untreated wastewater, the data indicate that the facility was then producing a 5-day BOD removal efficiency of about 65 percent.

2. Investigation of August 6, 1968

As a result of an odor complaint, an investigation was made of the water quality conditions in the Piscataway Creek

embayment. During a reconnaissance of the area, no odor was detected. However, in a visit to PWTP later the same day, it was learned that there had been some operational difficulty at the treatment facility during the week-end of August 3-4, 1968, resulting in discharge of a poor quality effluent.

3. Intensive Surveys of August 14-16, 1968

To further define the effects of the wastewater effluent on the Piscataway embayment, a three-day intensive survey was conducted. Three surveys were made during ebb tide, as contrasted to flood tide for the July survey. The data for the three surveys are presented in Tables VI-6, VI-7, VI-8, and VI-9.

As can be seen in Figures VI-4, VI-5, and VI-6, the chlorophyll level for the embayment and the Potomac Estuary are indications of an extremely extensive algal bloom. In Piscataway Creek near Maryland 210 Highway, the chlorophyll drops off considerably.

The phosphorus and TKN concentrations were higher in the tributary near the facility, especially for the surveys on August 15 and 16. (See Figures VI-5 and VI-6.) The phosphorus and TKN in the main or northerly channel which flows on the opposite side of the embayment were relatively lower, as can be seen in Figures VI-4 and VI-6.

Nutrient data for the August 16, 1968, survey as presented in Figure VI-6 shows large nutrient concentrations in the Piscataway embayment near the confluence with the Potomac Estuary. These

Table VI-6

PISCATAWAY CREEK SURVEY

August 14, 1968

Chesapeake Field Station

Station	Sta. No.	Sample Time	Water Temp. (°C)	Secchi Disk (Inches)	T.PO_4 as PO_4 (mg/l)	TKN (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (ug/l)	BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100 ml)	Coliform (MPN/100 ml)
Indian Head Hwy. Bridge Rt. 210	P-0	0930	22.2	-	1.165	.544	.130	2.25	3.04	7.54	4,300	9,300
Pumping Sta. - Above Discharge	P-1	1000	23.0	14	.845	2.589	.188	43.50	6.84	2.31	930	46,000
First Bend - Above Discharge	P-2	1005	23.0	10	1.193	LA	.170	72.75	8.36	1.96	430	46,000
Near White Barrels Next to first home	P-3	1020	23.5	6	1.198	3.203	.217	132.00	3.44	6.52	230	24,000
On trib. Opposite Plant near posts channel	P-3A	1040	21.5	5	.879	.937	.642	43.50	6.98	6.59	2,300	15,000
On trib. Opposite Plant near channel to road	P-3B	1048	23.5	5	.990	2.291	.177	130.50	9.78	6.78	230	15,000
Near end of Cattails in Opposite trib.	P-3C	1055	24.0	4	1.023	2.633	.031	207.75	9.32	10.92	230	2,300
Farmington Lodge Pt. in Bay	P-4	1100	25.0	5	1.004	2.475	.244	209.25	7.56	12.38	39	150
In Bay - Out from Marina	P-5	1110	25.5	10	.918	1.899	.970	146.25	8.54	7.93	93	2,300
Off Point- Below Marina in Channel	P-6	1115	26.0	12	.967	1.987	1.022	162.75	8.00	6.20	430	4,300
Mid-Bay, Off First Two Channel markers	P-7	1120	26.0	12	.976	1.785	1.190	111.75	9.06	5.68	930	2,300
Confluence with Potomac Mid channel at markers	P-8	1130	26.0	12	.918	2.348	1.600	184.50	8.90	6.88	430	930

Table VI-6 (cont.)

PISCATAWAY CREEK SURVEY

August 14, 1968

Chesapeake Field Station

Station	Sta. No.	Sample Time	Water Temp. (°C)	Secchi Disk (Inches)	T.PO_4 as PO_4 (mg/l)	TKN (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (ug/l)	BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100 ml)	Coliform (MPN/100 ml)
Off Monitor Sta. Buoy Potomac River	P-9	1130	26.0	14	1.130	1.728	1.240	199.50	9.28	5.38	930	4,300
Buoy 76 in Potomac River	P-10	1150	26.0	12	1.179	2.405	3.210	192.00	11.60	5.27	43	9,300

Table VI-7

PISCATAWAY CREEK SURVEY

August 15, 1968

Chesapeake Field Station

Station	Sta. No.	Sample Time	Water Temp. (°C)	Secchi Disk (Inches)	T.PO_4 as PO_4 (mg/l)	TKN (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (µg/l)	BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100 ml)	Coliform (MPN/100 ml)
Indian Head Hwy. Bridge Rt. 210	P-0	1225	22.0	-	1.078	.911	1.360	4.50	3.02	8.12		
First Bend - Above Discharge	P-2	1032	23.0	14	2.466	3.321	.232	57.50	9.80	3.25		
Near White Barrels Next to first home	P-3	1045	24.2	11	3.628	5.645	.343	7.50	11.04	6.57		
Farmington Lodge Pt. in Bay	P-4	1100	25.0	10	2.006	3.003	.163	154.50	14.90	12.90		
In Bay - Out from Marina	P-5	1115	25.5	4	1.350	2.563	.169	173.25	11.82	10.88		
Off Point - Below Marina in Channel	P-6	1120	26.0	10	1.416	2.440	1.110	137.25	12.50	6.53		
Mid-Bay, off first two Channel markers	P-7	1124	26.0	10	1.688	2.165	1.360	9.00	11.34	5.39		
Confluence with Potomac Mid Channel at markers	P-8	1126	26.5	12	1.397	2.593	1.250	135.15	14.58	8.24		
Off Monitor Sta. Buoy Potomac River	P-9	1135	26.5	14	1.200	2.024	1.390	113.25	9.24	4.86		
Buoy 76 in Potomac River	P-10	1145	26.0	-	1.191	2.171	1.410	116.25	9.04	5.66		

Table VI-8

PISCATAWAY CREEK SURVEY

August 16, 1968

Chesapeake Field Station

Station	Sta. No.	Sample Time	Water Temp. (°C)	Secchi Disk (Inches)	T.PO_4 as PO_4 (mg/l)	TKN (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (ug/l)	BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100 ml)	Coliform (MPN/100 ml)
Indian Head Hwy. Bridge Rt. 210	P-0	1215	23.0	-	1.108	.482	1.318	4.50	3.94	7.62		
Pumping Sta. - Above Discharge	P-1	1140	23.0	10	3.437	4.723	.194	3.25	12.80	4.02		
First Bend - Above Discharge	P-2	1135	24.5	12	4.017	5.759	.273	133.50	13.74	3.78		
Near White Barrels Next to first home	P-3	1125	24.5	4	2.553	3.277	.317	123.00	8.74	6.52		
On trib. Opposite Plant near posts channel	P-3A	1055	23.5	4	1.169	1.867	.628	82.50	7.36	7.01		
On trib. Opposite Plant near channel to road	P-3B	1105	22.5	4	1.424	.717	1.195	18.00	3.96	6.04		
Near end of Cattails in Opposite trib.	P-3C	1110	23.0	6	.864	.518	1.273	195.75	3.74	6.87		
Farmington Lodge Pt. in Bay	P-4	1040	25.0	6	1.475	3.102	.180	279.75	9.64	9.57		
In Bay - Out from Marina	P-5	1030	25.5	11	1.037	2.813	.108	171.00	11.20	12.88		
Off Point - Below Marina in Channel	P-6	1020	26.0	11	1.007	LA	.473	173.25	10.72	8.69		
Mid-Bay, Off First Two Channel markers	P-7	1010	26.0	14	5.898	8.325	.807	180.00	16.52	6.06		
Confluence with Potomac Mid channel at markers	P-8	1000	26.0	14	1.078	1.771	1.136	138.00	10.42	5.35		

Table VI-8 (cont.)

PISCATAWAY CREEK SURVEY

August 16, 1968

Chesapeake Field Station

Station	Sta. No.	Sample Time	Water Temp. (°C)	Secchi Disk (Inches)	$T.PO_4$ as PO_4 (mg/l)	TKN (mg/l)	NO_2-NO_3 as N (mg/l)	Chlorophyll (µg/l)	BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100 ml)	Coliform (MPN/100 ml)
Off Monitor Sta. Buoy Potomac River	P-9	0935	26.0	15	.976	1.633	1.363	303.00	8.62	3.08		
Buoy 76 in Potomac River	P-10	0.950	26.0	15	1.525	4.434	1.246	130.50	12.32	3.68		

TABLE VI-9

WASTEWATER DATA*

Piscataway Wastewater Treatment Plant

August 14, 1968

Parameter	Influent	Effluent	Reduction (%)
Flow (mgd)	5.2	5.2	-
BOD (mg/l)	93.5**	17.5	82
S. Solids (mg/l)	-	8.0	-
T. PO_4 as PO_4 (mg/l)	11.0	8.6	22
TKN as N (mg/l)	11.2	9.6	14
NH_3 as N (mg/l)	12.7	7.7	39
NO_2-NO_3 as N (mg/l)	0.5	1.2	-140

* Based on a 24-hour composite.

** Based on an average of 3 analyses of the 24-hour composite.

PISCATAWAY CREEK SURVEY

AUGUST 14, 1968

Chesapeake Field Station

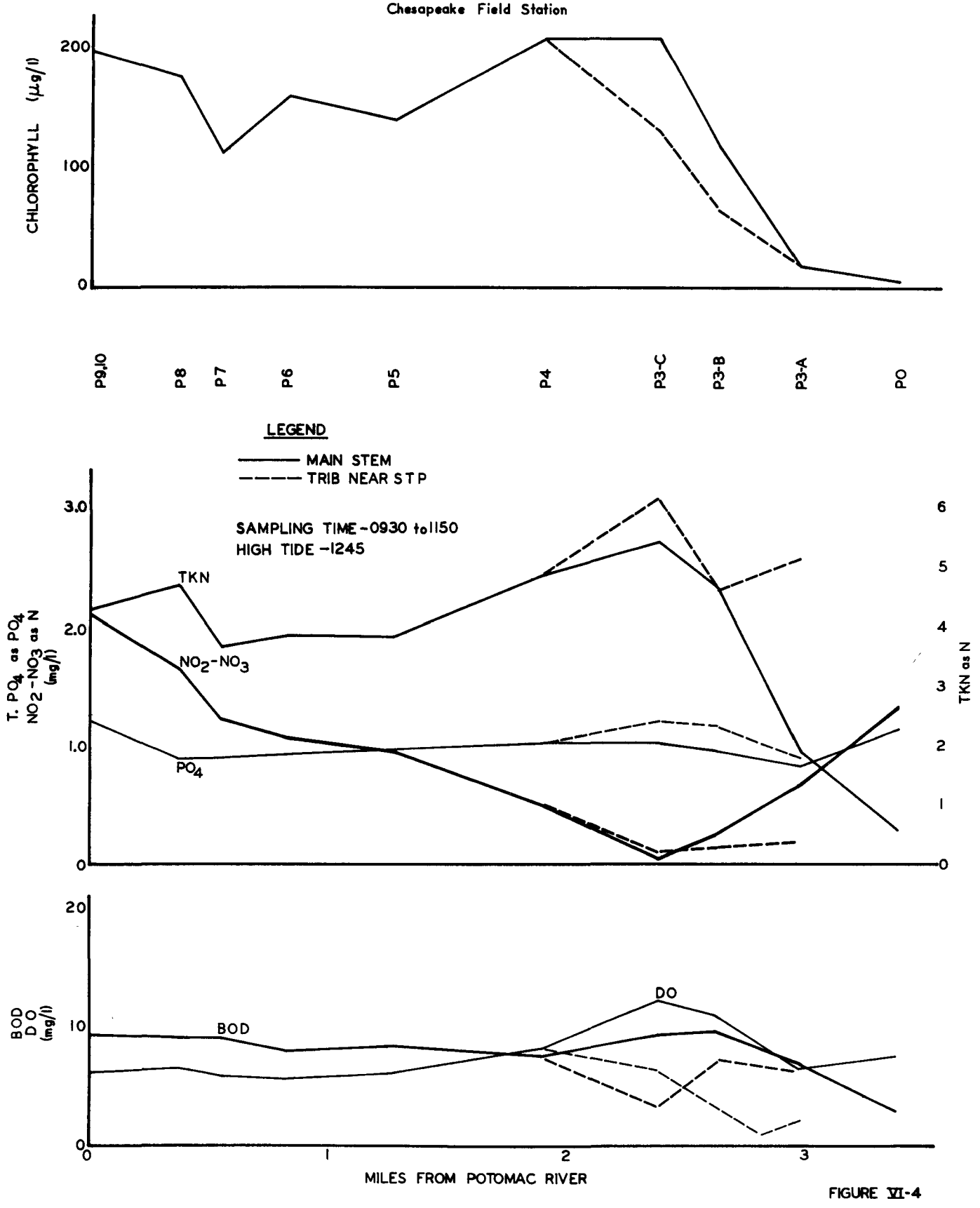

FIGURE VI-4

PISCATAWAY CREEK SURVEY

AUGUST 15, 1968

Chesapeake Field Station

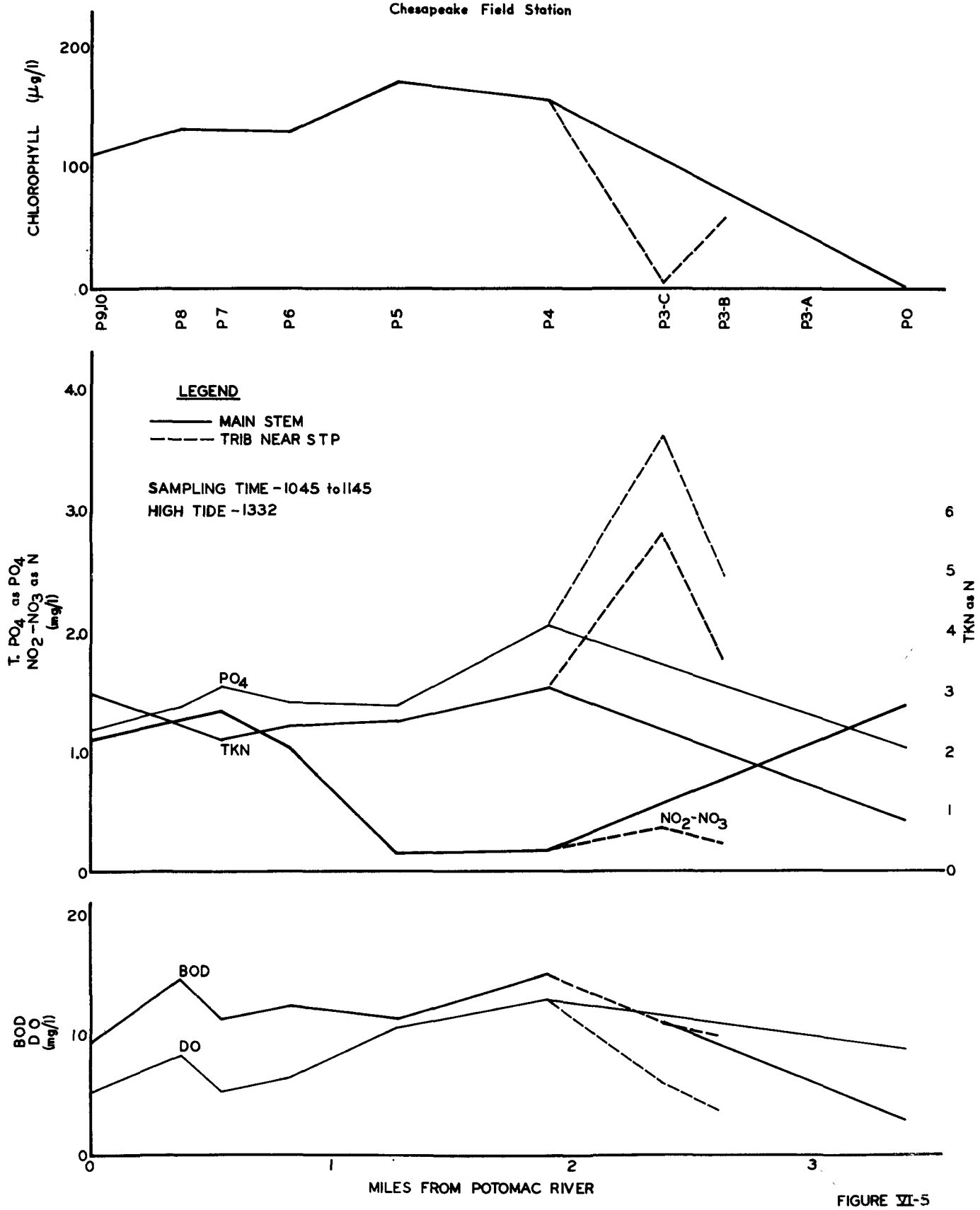

FIGURE VI-5

PISCATAWAY CREEK SURVEY

AUGUST 16, 1968

Chesapeake Field Station

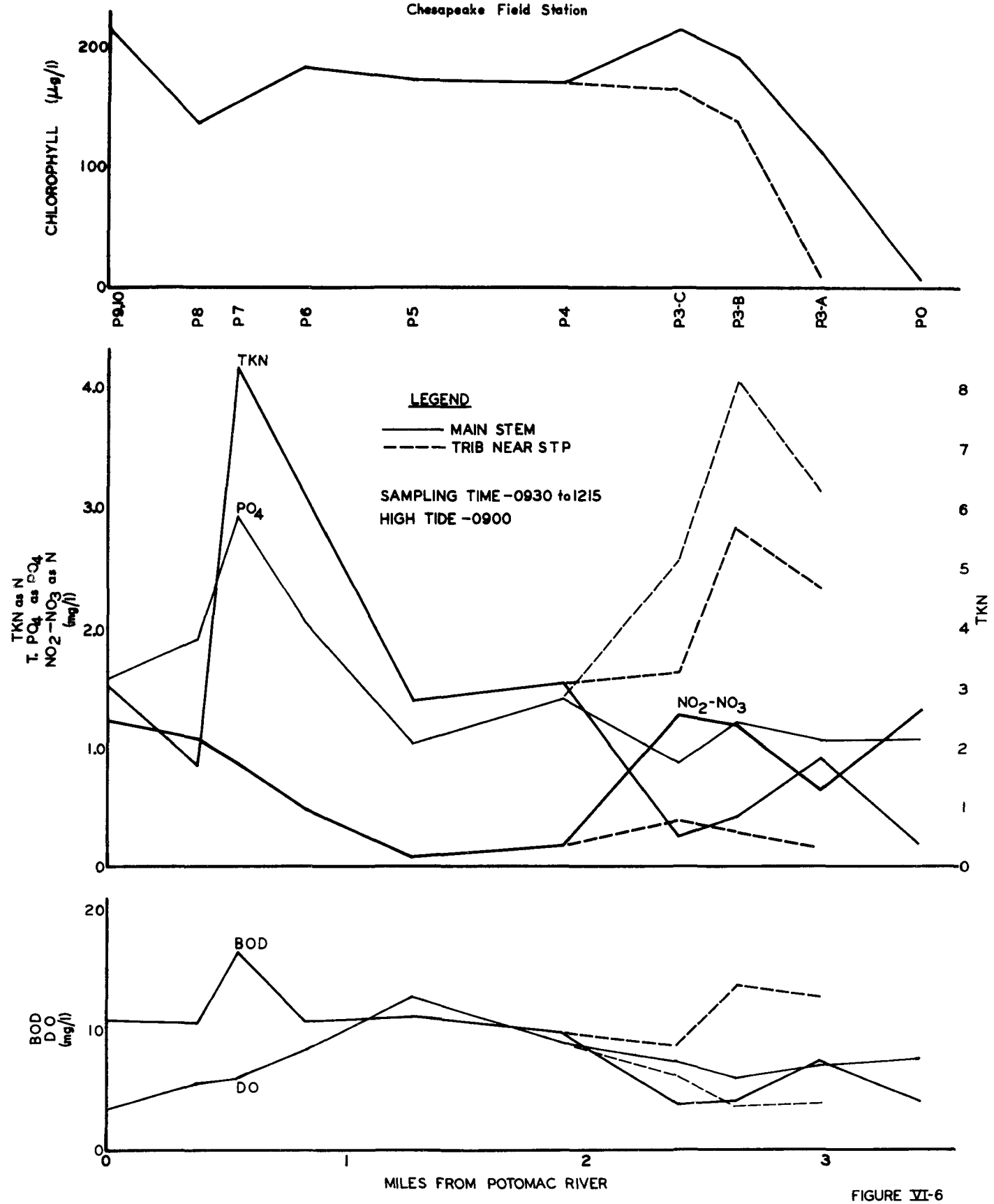

FIGURE VI-6

higher concentrations, which were observed at low tide, are probably the result of tidal flushing of the wastewater discharge.*

The BOD and DO determinations of the three surveys exhibit similar characteristics in the nutrient data, as also given in Figures VI-4, VI-5, and VI-6. However, the concentrations near the pumping stations near the manholes were not much different from the stations on the main channel.

In general, the BOD in the Potomac Estuary near Piscataway Creek was about 10 mg/l. The BOD in the Piscataway embayment was also about 10 mg/l, thus suggesting that BOD in Piscataway embayment is related more directly to BOD in the Potomac than to the Creek itself.

Using a tidal height prism of 2.4 feet and a surface area of 5.53 million square feet, it was determined that about 17,000 pounds per day of BOD enter and leave the Piscataway embayment from the Potomac Estuary. This compares to less than 1,000 pounds per day coming from wastewater effluents and the fresh water flow into Piscataway Creek.

Although the data required for determining exchange rates are not currently available for Piscataway embayment, it can readily be seen from the above calculations that organic loading, including

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* In later investigations it was determined that effluent does "hug" the southern shore, thus confirming the interpretation of the August 16 data.

the nutrients in the middle and lower Piscataway embayment, is controlled primarily by the quality of the Potomac Estuary. Nevertheless, it can also be seen in Figures VI-4, VI-5, and VI-6 that the effluent from the Piscataway Wastewater Treatment Plant does affect effluent and water quality in the embayment, especially in the small tributary on the southern shore.

Coliform concentrations of over 9,000 MPN/100 ml were observed in the upper portions of the southerly and northerly channels. The highest counts, over 24,000, were detected in the southerly channel near the manhole by the pumping station. As can be seen in Table VI-5, the highest fecal coliform counts are for the two uppermost stations in the main or northerly channel. Urban runoff from a recent rainfall may have been the probable source of these high fecal counts.

Results of the efficiency study of the wastewater treatment facility, as given in Table VI-9, indicates that the effluent leaving the plant is of very good quality. The BOD and suspended solids were 17.5 and 8.0 mg/l, respectively, for the 24-hour composite sample.

The influent to the plant appears to be very weak for a domestic sewage. The incoming wastewater ranges from about 70 to 120 mg/l of 5-day BOD, with an average of about 95 mg/l. Similar BOD concentrations for the influent were observed by MSDH and WSSC personnel.

4. Investigation of August 23, 1968

A complete inspection of the Piscataway area wastewater treatment plant and adjacent area was made by CES personnel on August 23, 1968. During the inspection of the plant, the following were observed.

a. The plant was operating efficiently.

b. The effluent, which was being monitored continuously by FWPCA, indicated that BOD was between 10 and 20 mg/l, with the suspended solids concentrations ranging from 4 to 17 mg/l.

c. An alarm system, which had been installed recently, appeared to be working satisfactorily. A log of each alarm activation is being kept by WSSC personnel.

d. Since the plant was placed into operation, no solids from the digester have been wasted. Start-up seed was being brought to the plant from the Laurel-Parkway facility of WSSC to aid in establishing the proper bacteriological cultures.

e. No evidence of recent by-passing or accidental spills was observed.

f. A maintenance crew was filling a gully formed by the effluent near the present terminal end of the discharge interceptor. As a result of this filling operation, a high silt load was picked up by the effluent stream.

An inspection at low tide was also made of the Calvert Manor area which is downstream from and adjacent to the WSSC facility. The combination of low tide and the large quantities of silt in the effluent clearly showed that effluent from the wastewater plant was flowing along the shore, near the site of the original Lord Calvert grant.* Under these conditions, the water is less than one foot deep, and the only discernable flow was the wastewater discharge.

The "tagging" of the effluent by silt particles clearly showed the course of the effluent. This confirms the reports of local residents of Calvert Manor that an accident or malfunction at the plant would readily be noticeable from the shoreline as, for example, during the early August breakdown when the area near the shoreline was reported to be an "open sewer" under low tidal conditions.

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* This historical site is currently being restored by the Claggett family.

CHAPTER VII

CORRECTIVE MEASURES

A. Existing Wastewater Treatment Facilities

As indicated in Chapter V, there are seven wastewater discharges in the Piscataway Watershed discharging about 5.8 mgd with a 5-day BOD loading of 780 pounds per day. All of the treatment facilities are currently providing secondary treatment with a BOD removal efficiency of 83 percent and greater.

Since August 1, 1968, as directed by the Maryland State Department of Health, the following actions have been taken by WSSC at the PWTP.

1. The flow into the plant has been limited to average daily flow of 5.0 mgd.
2. An alarm system has been intalled to indicate pumping or other mechanical difficulties which could result in by-passing untreated sewage.
3. General upgrading of plant operation.

The above actions by the Maryland State Department of Health and WSSC are endorsed in this report.

A major deficiency at the existing plant appears to be failure to provide stand-by electric power. If a power failure occurs, the incoming wastewater will be by-passed from a manhole near the plant's pumping station serving the Piscataway area or from the Broad Creek pumping station for the remaining service area.

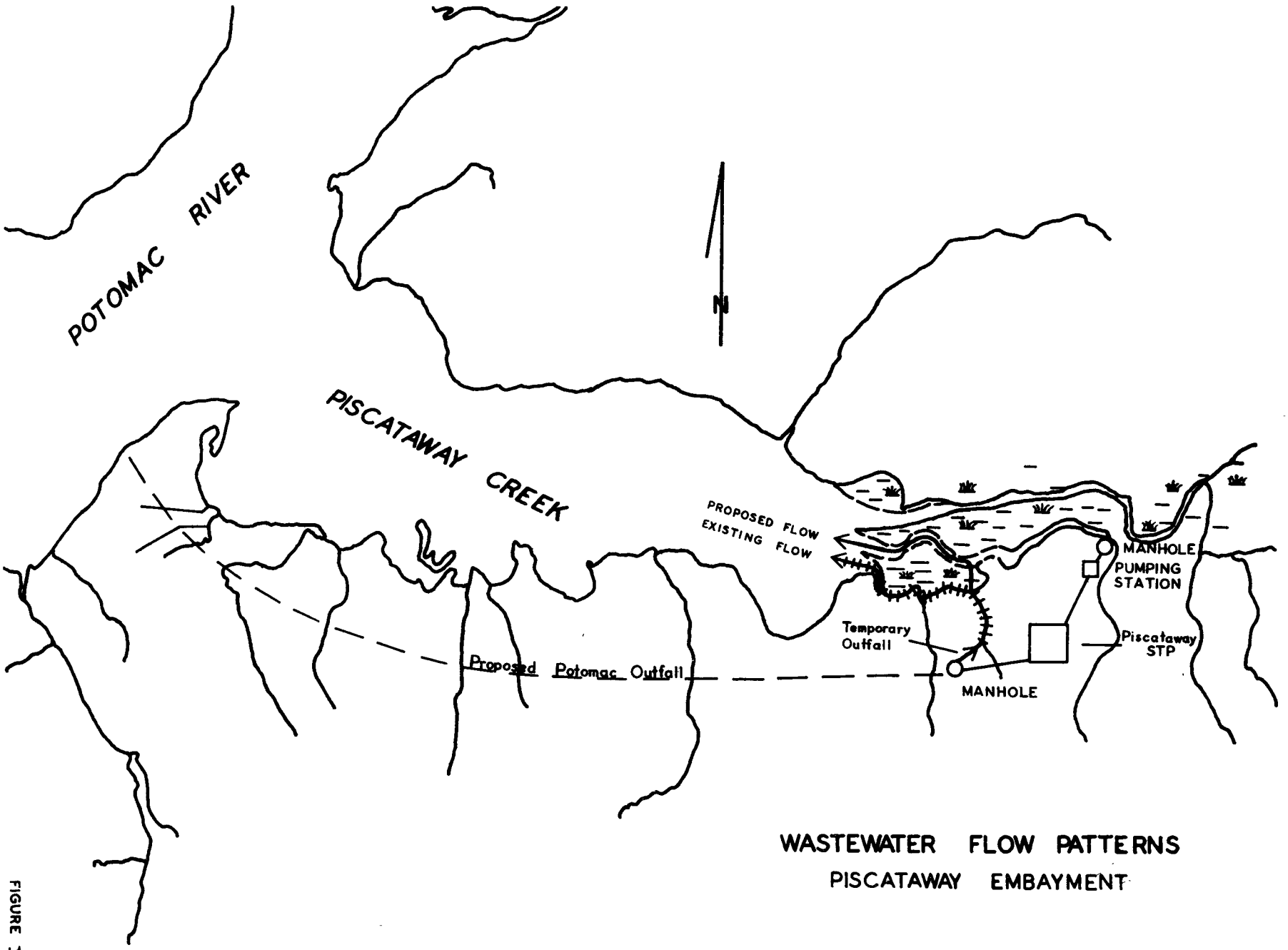
To eliminate or significantly reduce the incidence of overflows which have occurred in both service areas, it is recommended that stand-by power be provided at all pumping stations. As a precautionary measure, in case of dual failure, a plan for diverting or storing of the wastewater should be developed to prevent discharge of untreated sewage.

B. Existing Temporary Discharge Location of the Piscataway Wastewater Treatment Plant

As indicated in the previous chapter and as shown in Figure VII-1, the existing discharge location results in a wastewater flow pattern in the Piscataway embayment which flows along the shoreline. To eliminate this condition and to provide for better dilution and dispersion of the wastewater, it is recommended that the final effluent be conveyed to the southerly channel as shown in Figure VII-1.

The conveyance, which could be by an excavated channel or via a temporary pipeline, would provide a vehicle for continuous wastewater flow and prevent stagnant conditions. If a channel is excavated, a program to maintain the channel, including weed control, as required should also be initiated.

Since the current assimilative capacity of the Piscataway embayment is being exceeded by present wastewater loadings, it is recommended that the effluent outfall, as originally proposed by WSSC, be constructed as soon as possible. In addition, provision should be made to eliminate the discharge of untreated wastes.



WASTEWATER FLOW PATTERNS
PISCATAWAY EMBAYMENT

FIGURE VII-1

C. Expansion of the Piscataway Wastewater Treatment Facility and Potomac Interceptor

According to the 1969-1973 Sewerage Program of WSSC, the existing plant is to be expanded by 25.0 mgd. It has been estimated by WSSC that wastewater flow in the service area by 1980 will be about 30 mgd. Associated with the expansion program will be a 4.0 mgd advanced wastewater treatment plant.

Preliminary studies by CFS have indicated that the wastewater treatment level for all discharges into the Potomac Estuary will have to be provided as given below to meet established water quality standards.

Parameter	Percent Reduction
5-day BOD (Biochemical Oxygen Demand)	95
TKN (Total Kjeldahl Nitrogen)	85
PO_4 (Phosphates)	95

Using the projected population and current loading averages for the entire Potomac Estuary, this will result in the wastewater loadings from the 30 mgd Piscataway facility as follows:

Parameter	Current Treated Loading (#/day)	Projected Treated Loading* (#/day)
5-day BOD	635	[illegible],500
TKN	400	750
PO_4	390	500

* Treated loadings based on 95, 85, and 95 percent BOD, TKN, and PO_4 removal efficiency, respectively.

As can be seen when the projected and current loadings are compared, the projected loadings to the Piscataway embayment, even with addition of AWT, will be higher than from the existing 5.0 mgd facility.

Therefore, it is recommended that the effluent from the existing plant and the proposed expansion be conveyed to the Potomac Estuary.