Chesapeake Technical Support Laboratory
Middle Atlantic Region
Federal Water Quality Administration
U. S. Department of the Interior

CURRENT WATER QUALITY CONDITIONS AND INVESTIGATIONS IN THE UPPER POTOMAC RIVER TIDAL SYSTEM

Technical Report No. 41

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CHAPTER I

INTRODUCTION

During the November 1969 progress meeting of the Potomac Washington Metropolitan Area Enforcement Conference, information was presented on water quality conditions and wastewater loadings in the upper Potomac tidal system during 1969. At the spring meeting of the Interstate Commission on the Potomac River Basin (ICPRB) at Indian Head, Maryland, April 16-17, 1970, a summary statement was presented giving data on waste loadings, water quality, and studies by the Chesapeake Technical Support Laboratory on the middle and lower Potomac estuaries as part of the joint study proposed in Recommendation 14 of the conference. A detailed oral presentation was also given by Dr. Lear on the "Ecology of a Eutrophic Estuarine Discontinuity."

Since there were no significant changes in water quality conditions and wastewater loadings as of November 1969, this report will concentrate on the status of investigations currently being conducted by the Chesapeake Technical Support Laboratory. Specific references will be made to the Potomac-Piscataway and the Anacostia wastewater assimilation and transport studies. Separate reports on both of these studies have been prepared and are available.

CHAPTER II

SUMMARY

Based on data obtained by personnel of the U. S. Geological Survey, Dalecarlia Filtration Plant, U. S. Army Corps of Engineers, D. C. Department of Sanitary Engineering (DCDSE), D. C. Department of Public Health (DCDPH), Chesapeake Technical Support Laboratory (CTSL) of the Federal Water Quality Administration (FWQA) and the several wastewater treatment agencies in the Washington metropolitan area, a statement on current water conditions and investigations of the upper Potomac River tidal system was prepared and is summarized below:

1. Fecal coliform densities in the area of Woodrow Wilson Bridge continue to be significantly lower as a result of the increased chlorination of treated waste discharges initiated in June-September 1969. For example, during the months of June, July, and August 1965, the median density was about 90,000 MPN/100 ml, while from September 1969 to April 1970, over 50 percent of the samples had fecal coliform densities less than 1000.

2. High fecal coliform densities were prevalent at times of high stream flow in the portion of the Potomac from Chain Bridge to Memorial Bridge, which is above the major wastewater discharges. These high densities can be attributed to a combination of land runoff from the upper Potomac basin, urban runoff, storm sewers and combined sewer overflows.

3. Tributaries of the Potomac in the Washington metropolitan area also contained very high fecal coliform densities at times. Cabin John

Creek had consistently high counts in 1969 with 25 out of 28 samples showing fecal coliform densities over 10,000.

4. A Potomac Estuary Technical Committee was formed to provide guidance and coordination in the study of water quality problems of the upper Potomac River tidal system.

5. Studies by CTSL are continuing in three major areas: (1) nutrient ecological responses, (2) nutrient transport, and (3) oxygen budget resources.

6. During February and March in 1969 and again in 1970, extensive phytoplankton blooms were detected in the Potomac from Smith Point to Gunston Cove.

7. Under summer conditions massive blooms of blue-green algae were prevalent from Fort Washington to Maryland Point. The densities of these blooms were about 5 to 10 times that reported in most other eutrophic waters.

8. Preliminary results of ecological studies of the Potomac estuary in the area immediately above the Route 301 Potomac River Bridge indicate that the decrease in the massive blue-green algae, Anacystis, is interrelated to (1) the increase of salinity from about 2,000 to 10,000 ppm, (2) the decline in nutrients, mainly phosphorus and nitrogen, and (3) the competition for available nutrients by the dominant marine communities in the area below the Route 301 Bridge.

9. Since the late 1930's the amount of phosphorus entering the Potomac from wastewater discharges in the Washington metropolitan area has increased about tenfold and nitrogen increased about fivefold.

The amount of BOD (carbon) since then, although increasing to about 200,000 lbs/day in 1957, has decreased to about 129,000 lbs/day in 1969.

10. The major shift from the balanced ecological communities in the Potomac toward nuisance blue-green algal growths appears to be related to increases in nitrogen and phosphorus, and not BOD (carbon). This shift in ecological communities has also been simulated in controlled studies.

11. Nutrient data from March 1967 suggest that while large phosphorus loadings enter the Potomac estuary during extremely high discharge from the river upstream, the effect appears to be a decrease rather than an increase in concentration in the upper Potomac tidal system. Most of the phosphorus which entered the tidal system from the upper basin, plus some in the system from the wastewater discharges, was adsorbed and deposited in the bottom sediments of the estuary.

12. Studies of nitrification rates suggest that the oxidation of ammonia nitrogen is not a significant factor in the oxygen budget when the water temperature is below 10° C. Studies are continuing to determine the effects of nitrogen on the eutrophication aspects.

13. Dye and mathematical model investigations of the Piscataway embayments and the Anacostia tidal system indicate that wastewater assimilation and transport rates are very low. Wastewater discharges into the embayments of the Potomac may require higher removal rates than those required by the enforcement conference.

14. An analysis of each individual embayment will be required before wastewater treatment levels can be determined.

CHAPTER III

DESCRIPTION AND LOCATION INDEX OF THE POTOMAC RIVER TIDAL SYSTEM

A. GENERAL DESCRIPTION

The Potomac River Basin is the second largest watershed in the Middle Atlantic States. Its tidal portion begins at Little Falls in the Washington metropolitan area and extends 114 miles southeastward to the Chesapeake Bay.

The tidal system is several hundred feet in width at its head near Washington and broadens to nearly six miles at its mouth. A shipping channel with a minimum depth of 24 feet is maintained upstream to Washington. Except for the channel and a few short reaches where depths up to 100 feet are found, the tidal system is relatively shallow with an average depth of about 18 feet.

Effluents from twelve major wastewater treatment plants, with a thirteenth under construction, serving a population of about 2,500,000 people, are discharged into the upper tidal system. The locations of the discharges from these treatment facilities are shown in Figure I.

B. LOCATION INDEXES

To achieve uniformity in locating water quality sampling stations, wastewater effluents and related activities, a detailed location index was developed for the entire Potomac River tidal system. A starting point at the confluence of the Potomac with the Chesapeake Bay was established. Uniform river mile locations using statute miles have been developed for the primary sampling stations, landmarks, navigation buoys, etc. The data will be published by the CTSL in the near future.

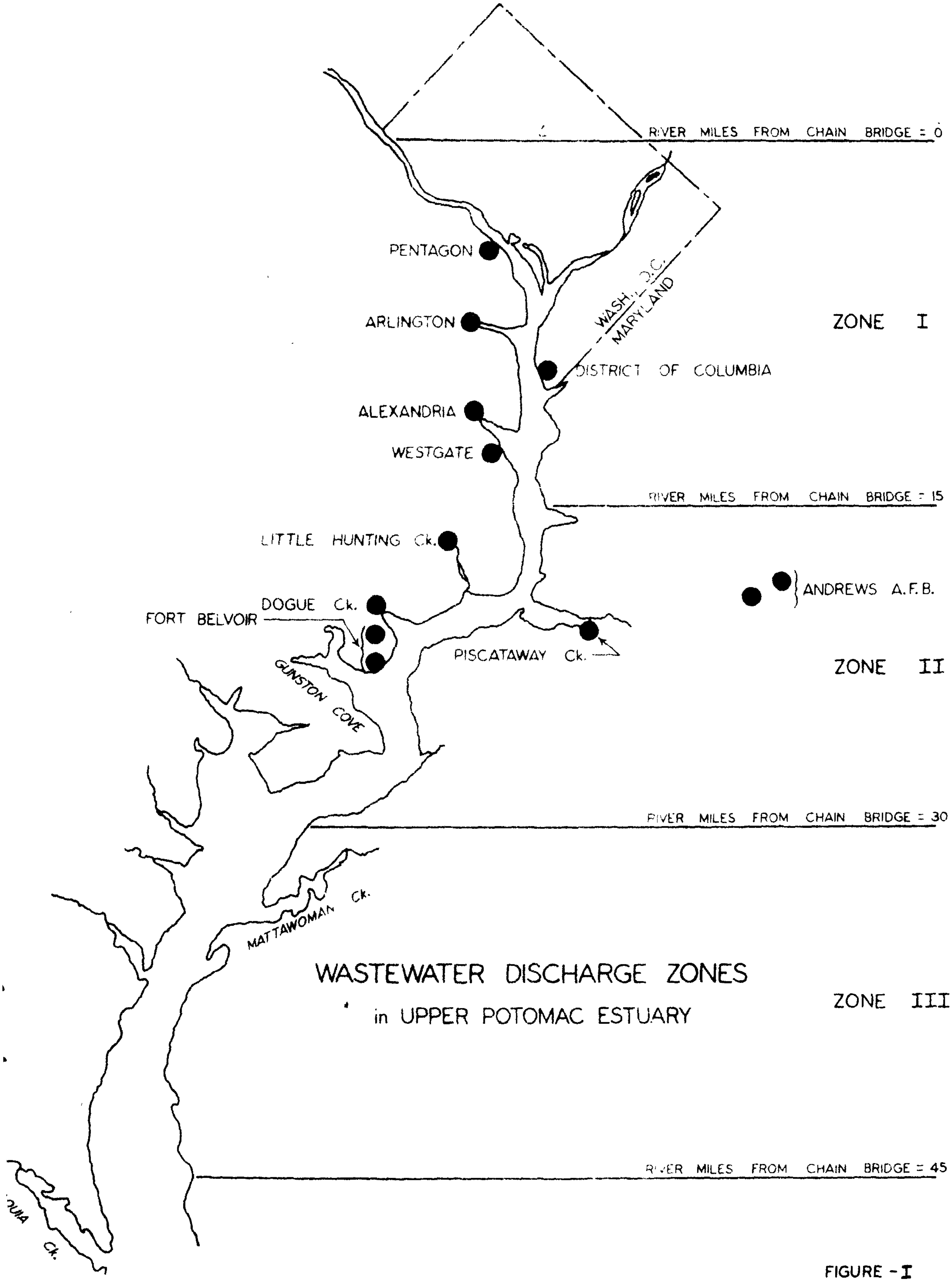

RIVER MILES FROM CHAIN BRIDGE = 0
PENTAGON
ARLINGTON
ZONE I
WASH., D.C.
MARYLAND
DISTRICT OF COLUMBIA
ALEXANDRIA
WESTGATE
RIVER MILES FROM CHAIN BRIDGE = 15
LITTLE HUNTING Ck.
ANDREWS A.F.B.
DOGUE Ck.
FORT BELVOIR
PISCATAWAY Ck.
ZONE II
GUNSTON COVE
RIVER MILES FROM CHAIN BRIDGE = 30
MATTAWOMAN Ck.
WASTEWATER DISCHARGE ZONES
in UPPER POTOMAC ESTUARY
ZONE III
RIVER MILES FROM CHAIN BRIDGE = 45
Ck.

FIGURE - I

1. Reaches of Potomac River Tidal System

For discussion and investigative purposes, the tidal portion of the Potomac River has been divided into three reaches as shown in Figure II and described below:

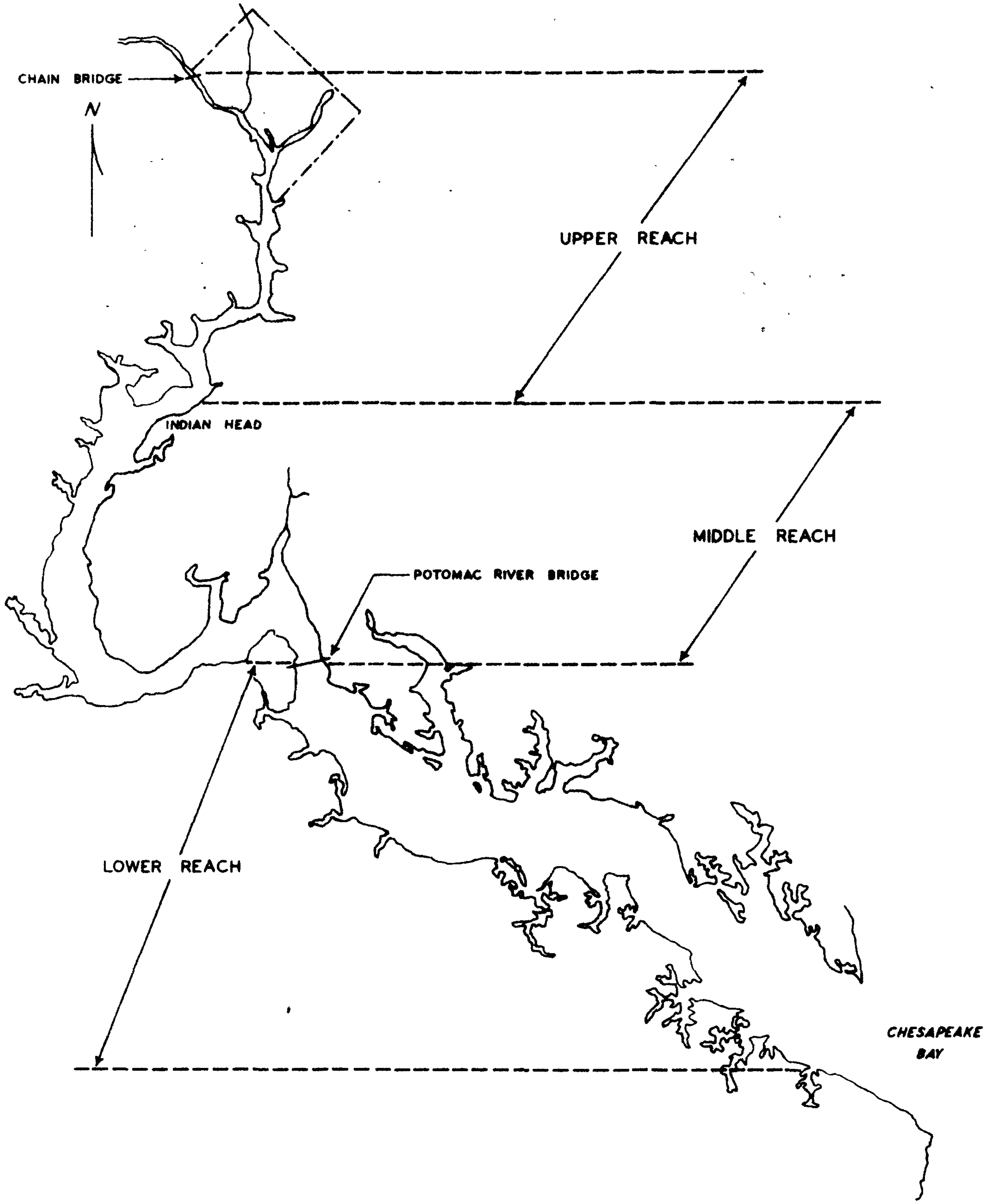
Reach	Description	River Miles	Volume cu. ft. x 10^8
Upper	From Chain Br. to Indian Head	114.4 to 73.8	93.50
Middle	From Indian Head to Rt. 301 Bridge	73.8 to 47.0	362.28
Lower	From Rt. 301 Bridge to Chesapeake Bay	47.0 to 00.0	1754.74

The upper reach, although tidal, contains fresh water. The middle reach is normally the transition zone from fresh to brackish water. In the lower reach, chloride concentrations near the Chesapeake Bay range from about 7,000 to 11,000 mg/l.

2. Zones of Upper Potomac Tidal System

To facilitate determination of water quality control requirements, the upper estuary was segmented by the CTSL into 15 mile zones beginning at Chain Bridge. Establishment of zones similar in physical characteristics allows flexibility in developing control needs. This zone concept was adopted by the conferees of the Potomac Enforcement Conference on May 8, 1969.

River mile distances from both the Chesapeake Bay and Chain Bridge for the upper three zones are given in Table I as well as in Figure II.



POTOMAC RIVER TIDAL SYSTEM

FIGURE - II

TABLE I

ZONES OF UPPER POTOMAC ESTUARY

Zone and Description	River Mile of Upper End of Zone		River Mile of Lower End of Zone	
	from Chain Bridge	from Chesapeake Bay	from Chain Bridge	from Chesapeake Bay
I Chain Bridge to Broad Creek	0.0	114.4	15.0	99.4
II Broad Creek to Indian Head	15.0	99.4	30.0	84.4
III Indian Head to Maryland Point	30.0	84.4	45.0	69.4

CHAPTER IV

WATER QUALITY CONDITIONS

A. UPPER POTOMAC RIVER TIDAL SYSTEM

During the November 1969 progress meeting, it was reported that there had been a significant reduction in the fecal coliform densities in the area of Woodrow Wilson Bridge [1]. This was a result of the installation of effluent chlorination facilities at all major wastewater treatment plants during June-September 1969.

Fecal coliform records at four stations in the Washington metropolitan area of the Potomac River, as summarized in Table II, support this November conclusion. Fecal coliform densities continued to be high during periods of considerable runoff in the area from Chain Bridge to Hains Point. These high counts can be attributed to (1) land runoff from above and below Chain Bridge, (2) storm sewer discharge, and (3) malfunctioning sanitary sewer systems.

Nevertheless, there continues to be a significant reduction in fecal coliforms from previous years in the treatment plant discharge area. As an example, in 1965 the median fecal coliform counts near Woodrow Wilson Bridge was about 90,000 MPN/100 ml for the months of June, July and August. Since September 1969, over 50 percent of the samples had fecal coliform counts of less than 1000.

There has been no significant change in dissolved oxygen readings in the Potomac estuary since November 1969. During the winter and spring

months, freshwater flows were near or above normal with the April flows at about twice the median flow. As a result of the higher flows and low winter and spring temperatures, the dissolved oxygen (DO) concentrations were above 8.0 mg/l.

DO concentrations were about 5.0 mg/l for the first week of May 1970 with a river discharge of 15,000-20,000 cfs. This can be compared to DO concentrations of less than 1.0 mg/l at the Woodrow Wilson Bridge in early May 1969 when a fish kill occurred.

TABLE II

FECAL COLIFORM DENSITIES MPN/100 ml

Upper Potomac River Tidal System
D.C. Water Pollution Control Division Data
April 1969 - April 1970

Date	Chain Bridge	Memorial Bridge	Opposite Blue Plains	W.Wilson Bridge
4- 7	--	930	910	9,100
4-21	--	210	93,000	360
5- 5	--	150	2,300	3,600
5-12	--	150	73,000	--
6- 2	--	240,000	4,300	2,300
6-18	--	9,300	9,300	3,600
6-23	--	2,400	230	2,300
6-30	--	750	360	3,600
7- 7	--	11,000	2,300	4,300
7-14	23	36	230	1,500
7-28	4,300	240,000	93,000	24,000
8-11	4,300	4,300	7,300	11,000
8-18	1,100	3,000	1,500	360
8-25	1,500	360	910	230
9- 1*	230	230	360	230
9- 8	2,400	93,000	7,200	9,300
9-15	15,000	4,300	9,300	9,300
9-25	150	230	2,100	360
9-29	360	23	230	230
10- 6	730	110	730	360

TABLE II (continued)

Date	Chain Bridge	Memorial Bridge	Opposite Blue Plains	W.Wilson Bridge
10-20	23	23	9,300	360
10-29	23	36	230	23
11- 3	43	930	930	910
11-11	93	93	1,500	36
11-17	930	430	4,300	23
11-24	4,300	4,300	930	150
12- 1	23	73	910	150
12- 8	2,400	24,000	36	43
12-15	1,200	1,500	2,400	11,000
2- 2	24,000	110,000	110,000	110,000
2- 9	4,300	2,400	4,300	9,300
2-16	2,400	15,000	46,000	92,000
2-23	2,400	2,400	9,300	2,400
3- 2	150	230	240	23
3-16	73	430	1,500	1,500
3-23	930	930	230	4,300
3-30	4,300	2,400	9,300	15,000
4- 6	--	430	430	430
4-13	2,400	430	36	430

* By September 1969, all effluents from the wastewater treatment facilities were continuously chlorinated.

B. POTOMAC TRIBUTARIES

In the previous section, fecal coliform counts were shown to be high during times of high runoff. Sampling data for tributaries of the Potomac taken by the D. C. Department of Public Health in 1969 also show high counts as given in Table III. The locations of the six stations in the table are:

Tributary	Sampling Point	Miles from Potomac
Cabin John (Md.)	G. Washington Parkway	0.3
Rock Run (Md.)	David Taylor Model Basin	0.7
Seneca Creek (Md.)	River Road	0.7
Broad Run (Va.)	Leesburg Turnpike	2.0
Sugarland Run (Va.)	Leesburg Turnpike	0.5
Difficult Run (Va.)	Old Georgetown Road	1.0

For the months of June, July, August, and September, high fecal coliform densities were observed for all six stations. The data for the Cabin John station show high densities the year round, suggesting a periodically overloaded sanitary sewerage system in this watershed.

Data for other urban streams in the Washington metropolitan area, such as Rock Creek as reported by Aalto, et al [2], and Anacostia River by Jaworski et al [3], also indicated high fecal coliform densities. While increases in fecal coliforms occur during periods of high flow, the large increases were usually associated with either combined sewer overflows or defective sewerage systems.

TABLE III

FECAL COLIFORM SUMMARY - MPN/100 ml

Potomac Tributaries
D.C. Department of Public Health Data
1969

Date	Cabin John	Rock Run	Seneca Creek	Broad Run	Sugarland Run	Difficult Run
01-08	250,000+	25,000	--	600	4,000	250
01-15	250,000+	6,000	5,000	4,000	17,000	6,000
02-05	250,000+	1,200	400	500	10,000	400
02-12	400,000	400,000	400,000	250	--	400
02-19	25,000	2,500	1,200	600	2,500	600
04-09	25,000	250	250	400	4,000	400
04-16	250,000	1,200	1,200	250	2,500	600
04-23	25,000	7,000	2,500	2,500	3,000	7,000
04-30	250,000	4,000	500	400	--	600
05-07	250,000	12,000	6,000	--	6,000	1,200
05-14	25,000	500	1,700	1,300	6,000	6,000
05-21	200,000	250	200,000	1,200	5,000	60,000
06-04	250,000	30,000	250,000	60,000	120,000	120,000
06-11	6,000	600	4,000	600	25,000	4,000
06-18	25,000	2,500	2,500	4,000	4,000	4,000
07-09	25,000	6,000	1,700	25,000+	40,000	1,700
07-23	25,000	30,000	250,000+	60,000	250,000+	250,000+
08-13	170,000	25,000	6,000	2,500	25,000	4,000
08-27	120,000	60,000	25,000+	4,000	120,000	12,000

TABLE III (Continued)

Date	Cabin John	Rock Run	Seneca Creek	Broad Run	Sugarland Run	Difficult Run
09-03	4,000,000+	400,000+	250,000+	7,000	250,000+	250,000+
09-10	4,000,000	6,000	25,000+	4,000	6,000	12,000
09-24	120,000	6,000	3,500	1,100	12,000	1,700
10-01	12,000	40,000	1,700	2,900	25,000	2,500
10-08	25,000	6,000	4,000	1,700	60,000	7,000
10-22	12,000	4,000	6,000	4,000	250,000+	4,000
11-04	12,000	0	200	50	4,000	2,500
12-09	1,600	2,500	7,000	1,200	40,000	1,700
12-16	4,000	60	400	1,700	4,000	1,700

CHAPTER V

CURRENT ACTIVITIES

Studies to investigate the nutrients that stimulate algal growth and to determine the major driving forces producing dissolved oxygen stresses are continuing. The objectives of the ecological, nutrient transport, and dissolved oxygen budget studies are to: (1) determine the extent of present water quality degradation, (2) develop predictive capabilities for stresses from projected loadings, (3) determine the corrective actions required, and (4) evaluate the detailed ecological pattern during changes resulting from selective nutrient reductions.

Other tidal waters of the Chesapeake Bay are also currently being monitored to provide a basis for comparison. These waters include the Patuxent, Rappahannock, Chester, and Severn Rivers, and the upper Chesapeake Bay itself.

To provide input and guidance for the CTSL program in studying the Potomac, a Potomac Estuary Technical Coordination Committee (PETCC) was formed, with the first meeting held in November 1969. Members of PETCC include individuals from Maryland Department of Water Resources, Maryland State Department of Health, ICPRB, Maryland-National Capital Parks and Planning Commission, Virginia Water Control Board, Virginia Department of Economic Development, DCDPH, DCDSE, U.S. Army Corps of Engineers, and FWQA.

This chapter presents specific areas currently being investigated. Included are recent findings within each of five study areas: wastewater composition, nutrient response, nutrient transport, dissolved oxygen budget, and discharges into embayments.

A. WASTEWATER COMPOSITION

1. Historical Trends

While the population in the Washington metropolitan area increased eightfold from 1913 to 1969 as shown in Table IV, the phosphorus content in the waste discharges increased almost twentyfold. For the same time period the nitrogen loadings have increased about ninefold, from 6,400 to 52,000 lbs/day, while the BOD's have increased from 58,000 to over 200,000 lbs/day in the late 1950's. Since 1960 the BOD loading has been reduced to 129,000 lbs/day.

The twentyfold increase is a result of the rapid increase in use of detergents high in phosphorus content since the 1940's in place of the soap products formerly used in household cleaning usage. At the present time approximately 50 to 70 percent of all phosphorus in municipal waste discharges can be attributed to the use of detergents [17].

2. Evaluation of Sources

As previously reported [1] CTSL conducted a nutrient survey of the upper estuary during 1969 to determine the relative contributions of critical water quality parameters from the upstream freshwater inflow and wastewater discharges in the metropolitan area. The loadings for the first eight months are given in Table V and a summary of the relative percentages follows:

Parameter	Freshwater Inflow % of total	Wastewater Discharge % of total
BOD	45	55
Organic Carbon	68	32
Inorganic Carbon	89	11
Total Carbon	80	21
Total Phosphorus	14	86
Total Nitrogen	34	66

This summary shows that the parameters in order of most amenable to control measures using wastewater treatment are: (1) phosphorus, (2) nitrogen, and (3) BOD.

TABLE IV

Wastewater Loading Trends*

Discharge to Potomac

Washington Metropolitan Area

Year	Population of Service Area	Wastewater Flow (mgd)	BOD_5 (lbs/day)	T. Nitrogen as N (lbs/day)	T. Phosphorus as PO_4 (lbs/day)
1913	320,000	42	58,000	6,400	3,300
1932	575,000	75	103,000	11,500	6,000
1944	1,149,000	167	141,000	22,980	12,000
1954	1,590,000	195	200,000	31,800	16,700
1957	1,680,000	210	204,000	33,600	26,000
1960	1,860,000	222	110,000	37,200	30,000
1965	2,100,000	285	125,000	42,000	57,000
1968	2,415,000	334	130,000	53,000	61,000
1969	2,480,000	348	129,000	52,000	64,000

* In estimating phosphorus, allowances were made to reflect the effect of detergents.

TABLE V

BOD, CARBON, NITROGEN, AND PHOSPHORUS
SUMMARY OF CONTRIBUTIONS

Upper Potomac Estuary
January-August 1969

Parameter	Unit	Freshwater Inflow	Wastewater Discharge	Total
Flow	mgd	3,500	350	3,850
BOD	lbs/day	108,000	129,000	237,000
Inorganic Carbon	lbs/day as C	471,000	60,000	531,000
Organic Carbon	lbs/day as C	218,000	102,000	320,000
Total Carbon	lbs/day as C	689,000	162,000	851,000
Total Phosphorus	lbs/day as P	3,600	21,000	24,600
Nitrite and Nitrate	lbs/day as N	11,800	3,300	15,100
Total Kjeldahl Nitrogen	lbs/day as N	15,400	48,200	63,600
Total Nitrogen	lbs/day as N	27,200	51,500	78,700

B. NUTRIENT RESPONSE STUDIES

During 1969, field investigations were continued to further define the nutrient requirements (carbon, nitrogen and phosphorus) for producing nuisance algal growths. Considerable efforts were spent in defining eutrophic conditions in the salinity transition zone.

In the freshwater portions of the tidal system, large blooms of phytoplankton were observed in February and March of 1969 and again in 1970. Water temperatures at the beginning of these blooms were about 4° C. These blooms were primarily in areas between Smith Point and Gunston Cove.

Under 1969 summer and fall conditions as in previous years, large populations of blue-green algae, primarily *Anacystis* sp., were prevalent. An important aspect of these algal growths was that the "standing crop" as measured by chlorophyll *a* had concentrations ranging from approximately 75 to over 200 μg/l. This is about five to ten times that reportedly observed in most other eutrophic waters [15] [16].

The algal populations in the saline water areas were not as dense as those in the fresh water areas. Nevertheless in summer large populations of the dinoflagellates *Gymnodinium* sp. and *Amphidinium* sp. occurred producing the phenomenon known as "red tides."

1. Biological Discontinuity Studies

During the summer of 1969, a special ecological study was undertaken in a 20-mile portion of the Potomac estuary just upstream from the Potomac River Bridge at Morgantown. This area has been observed for several years [10] to be the lower limit in terms of distance from

Chain Bridge of massive blue-green algal blooms. The major purpose of this intensive study was to determine why algal blooms apparently decreased at this location.

The area of investigation was found to be a reach of rapidly increasing salinity downstream, the "salt wedge". An obvious biological discontinuity was found in this reach with marine organisms dominant at the lower end.

Tentative conclusions from this study indicate:

1. The massive blooms of the blue-green alga Anacystis currently terminate in this reach for three interrelated reasons: (1) the increase of salinity from approximately 2 to 12 parts per thousand, (2) a decline in nutrients, especially nitrogen and phosphorus, and (3) the competition for available nutrients by the essentially marine dominated biological community in the lower reach is apparently successful under present conditions.

2. These observations may be useful for predicting the time, duration and extent of a possible similar invasion of blue-green algae in other fresh water tributaries at the head of the Chesapeake Bay, especially the Sassafras, Bohemia, Elk, and Northeast Rivers.

3. When firmer conclusions can be drawn from continued observations, the effects of disposal of nutrients from treated sewage into saline waters as compared to fresh waters may assist in optimizing the increase in estuarine water productivity by controlled addition of nutrients, or at least minimize any stress to the estuarine system caused by these additions.

5. Single sets of daily observations were difficult to interpret, but the aggregate of 15 cruises over a six weeks period showed some statistically significant patterns.

2. Ecological Trends as Related to Nutrient Loadings

A review of past eutrophic trends with estimated nutrient loadings from wastewater discharges into the Potomac was made. In Table IV it can readily be seen that while the present BOD (carbon) loading is the same as in the late 1930's, there is about ten times as much phosphorus and five times as much nitrogen now being discharged.

The effect of these increased nutrient loadings can be seen in Figure III. The change in the ecology from 1913 has been dramatic. Several nutrients and growth stimulants have been implicated as causes of this accelerated eutrophication with nitrogen and phosphorus showing promise of being the most manageable.

The historical plant life cycles in the upper Potomac estuary can be inferred from several studies. Cumming [4] surveyed the estuary in 1913-1914, and noted the absence of plant life near the major waste outfalls with "normal" amounts of rooted aquatic plants on the flats or shoal areas below the urban area. No nuisance levels of rooted aquatic plants or phytoplankton blooms were noted.

In the 1920's an infestation of water chestnut appeared. This was controlled by mechanical removal [5].

In September and October of 1952, another survey of the reaches near the metropolitan area, made by Bartsch [6], revealed that vegetation

NUTRIENT ENRICHMENT TRENDS AND ECOLOGICAL EFFECTS
IN THE UPPER POTOMAC TIDAL RIVER SYSTEM

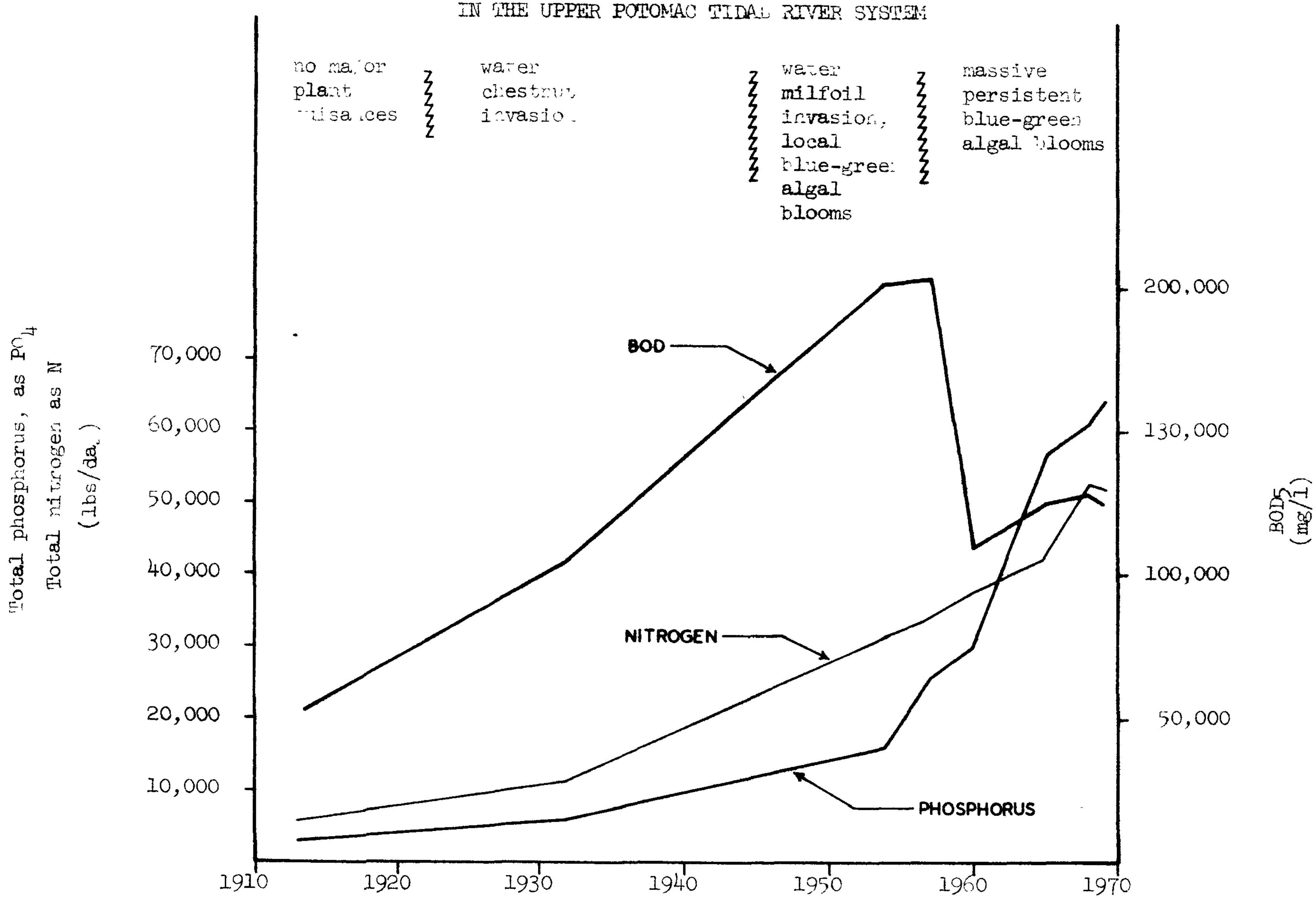


FIGURE - III

in the area was virtually nonexistent. No dense phytoplankton blooms were reported, although the study did not include the areas downstream where they were subsequently found.

In August and September of 1959, a survey of the area was made by Stotts and Longwell [7]. Blooms of the nuisance blue-green alga Anacystis were reported in the Anacostia and Potomac Rivers near Washington, D. C.

In 1958, nuisance conditions of the rooted aquatic plant water milfoil developed in the Potomac estuary. The growth increased to major proportions by 1963, especially in the embayments from Indian Head downstream [8].

These dense stands of rooted aquatic plants which rapidly invaded the system also dramatically disappeared in 1965 and 1966. The decrease was presumably due to a natural virus [9].

Subsequent and continuing observations by the CTSL have confirmed persistent massive summer blooms of the blue-green alga Anacystis at nuisance concentrations from the metropolitan area downstream at least as far as Maryland Point [10].

Data as presented below for comparable flow and temperature conditions for September-October 1965 and October 1969 indicate that algal populations have not only increased in density but have become more widespread.

Potomac Estuary Location	River Miles from Chain Bridge	Chlorophyll a - µg/l		
		Sept. 15, 1965	Oct. 19, 1965*	Oct. 14-16, 1969**
Piscataway	18.35	49	90	74
Indian Head	30.60	36	75	120
Smith Point	45.80	61	56	70

* Single sample

** Average of a minimum of 5 samples

While data are limited for 1965, based upon these data and field observations the increase in nuisance algae appears to be significant. Sampling difficulty makes it impossible to quantify the increase at the present time.

These biological observations can be interpreted as an ecological succession. The initial response to a relatively light over-enrichment was the growth of water chestnut, which when removed allowed the increasing nutrient load to be incorporated into the rooted aquatic plant water milfoil (*Myriophyllum spicatum*). The water milfoil dieoff allowed the nutrients to be competitively selected by the blue-green alga *Anacystis*. Since *Anacystis* is apparently not utilized in the normal food chain, huge mats and masses accumulate and decay.

From these considerations it would appear that nuisance conditions did not increase directly with an increase in nutrients as indicated by the concentrations of phosphorus and nitrogen. Instead, the nutrient increase encouraged a given species to dominate the plant life in the aquatic environment. With a further increase in nutrients this species

was rather rapidly replaced in turn by another dominating nuisance form. This is indicated in Figure III where the massive persistent blue-green algal blooms were associated with large increases in phosphorus and nitrogen enrichment in the upper reaches of the Potomac River tidal system. The persistent massive algal blooms have been occurring since the early 1960's even though the amount of carbon (BOD) has been reduced by almost 50 percent.

Laboratory and controlled field pond studies by Mulligan [11] have indicated similar results. Ponds receiving low nutrient additions (phosphorus and nitrogen) had submerged aquatic weeds. Continuous blooms of algae occurred in the ponds having high nitrogen and phosphorus concentrations. An important aspect of Mulligan's studies is that when the aquatic resources were returned to their natural state, the ecosystem returned to its natural state. This is also supported by studies of Edmondson [12] on Lake Washington and Hasler on the Madison, Wisconsin lakes [14].

C. NUTRIENT TRANSPORT

A one-year cooperative sampling program with Steuart Petroleum Company has been completed. The survey was designed to determine the nutrient movement throughout the entire tidal system. Since 1969 was a nontypical stream flow year, the study was extended into 1970.

Nutrient data from 1969 taken at Great Falls, Maryland, indicated that large quantities of nutrients enter the tidal system during periods of high stream flow. A study of a high runoff period in 1967 revealed a significant phenomenon. Figure IV shows that the total phosphorus concentration on the early days of March was about 0.150 mg/l at Chain Bridge increasing to over 1.0 mg/l at Woodrow Wilson Bridge as result of wastewater discharges. At the same time the concentrations at Piscataway and Indian Head were 1.4 and 1.0 mg/l, respectively.

On March 7 and 8, the river discharge increased rapidly to about 139,000 cfs (Table VI). This resulted in a discharge on March 8 of over 1,208,000 lbs/day of phosphorus into the tidal system.

However, when the concentrations in the entire upper tidal system are compared to early March, a general overall decrease in phosphorus can be observed. Phosphorus concentrations during high flows are accompanied by high sediment loads and when they enter the slow moving tidal system, much of phosphorus was adsorbed onto the sediment particles and was removed from water as the sediment settled. CTSL conducted laboratory studies using Potomac River samples to confirm this removal of phosphorus by adsorption.

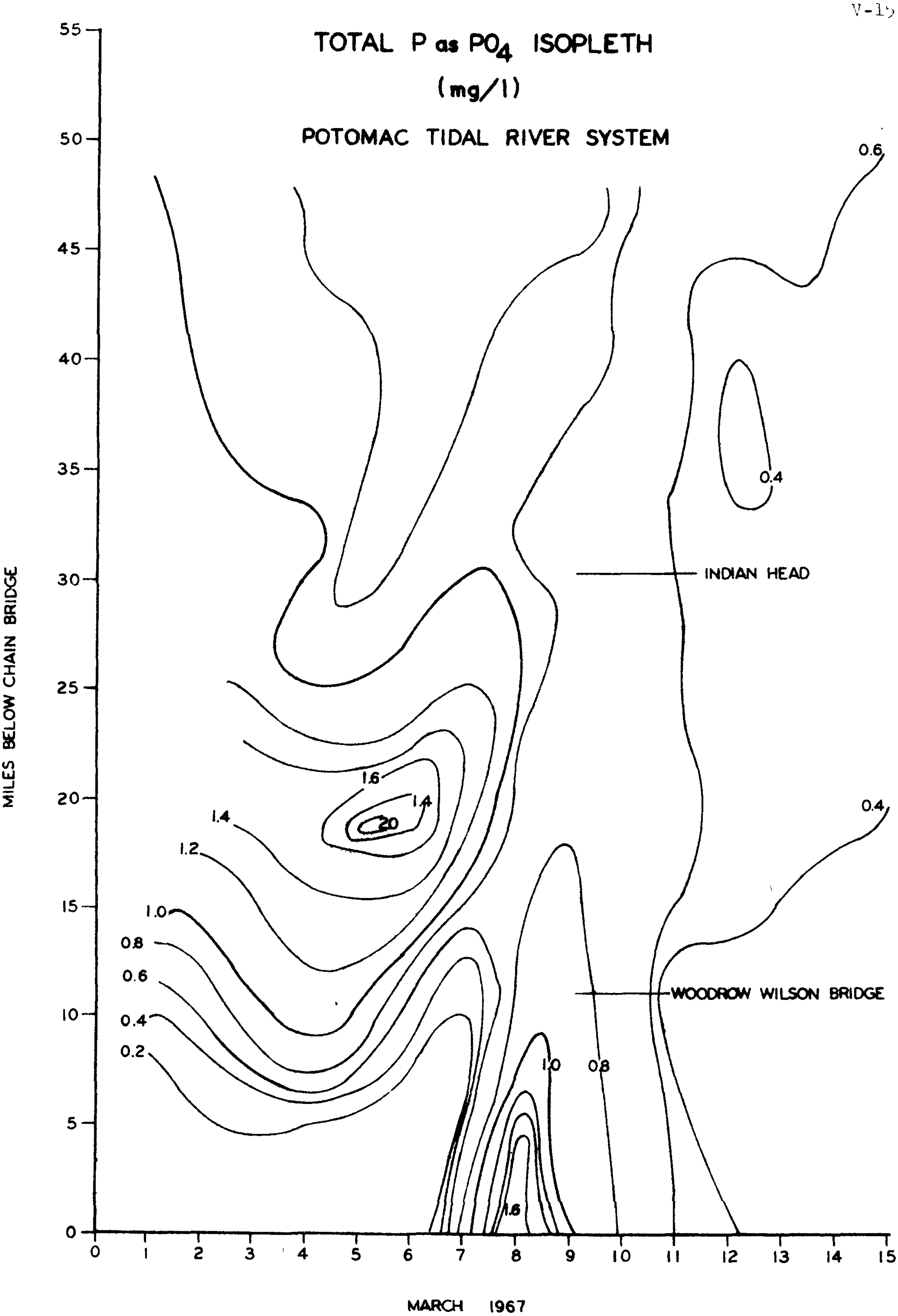

TOTAL P as PO_4 ISOPLETH
(mg/l)
POTOMAC TIDAL RIVER SYSTEM
MILES BELOW CHAIN BRIDGE
MARCH 1967
INDIAN HEAD
WOODROW WILSON BRIDGE
0.6
0.4
1.6
1.4
2.0
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1.0
0.8
1.6
0.4
0 5 10 15 20 25 30 35 40 45 50 55
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

FIGURE - IX

TABLE VI

RIVER DISCHARGE AND PHOSPHORUS LOADING

Potomac River at Washington, D. C.
March 1 to 14, 1967

Date	River discharge (cfs)	T. Phosphorus as PO_4 (mg/l)	T. Phosphorus as PO_4 (lbs/day)
3- 1	7,690	0.153	6,280
3- 2	7,010	--	--
3- 3	7,230	0.155	5,990
3- 4	7,270	0.132	5,130
3- 5	7,620	0.225	9,150
3- 6	8,590	0.177	8,120
3- 7	63,100	1.316	44,800
3- 8	133,000	1.701	1,208,000
3- 9	139,000	0.936	694,800
3-10	76,400	0.717	292,500
3-11	46,700	0.578	144,200
3-12	36,500	0.355	69,200
3-13	29,500	0.264	41,588
3-14	25,100	--	--

A more sophisticated mathematical model has been recently adapted to the Potomac Estuary to increase sensitivity in simulating the movement of nutrients and other pollutants. Once this capability has been developed and verified, technical areas to be investigated will include:

1. Sensitivity of nutrient concentrations in the upper, middle, and lower reaches to loadings in the upper reach, including contributions from land runoff,

2. The flow probability to be used in determining maximum permissible nutrient levels, including transport, such as seven-day-ten-year flow or the mean monthly flow,

3. Ecological, nutrient transport and nutrient response studies will be necessary to determine whether or not the same nitrogen, phosphorus and carbon removal levels are required during twelve months of the year in order to enhance the water quality in the upper, middle, and lower reaches.

4. Effects of withdrawal of water from the upper portion of Zone I as a supplemental water supply for the Washington metropolitan area on the allowable nitrogen, phosphorus, and carbon loadings from wastewater discharges, and

5. Development of seasonal nutrient loadings for Zones II and III of the upper reach and for the middle and lower reaches of the tidal system.

D. DISSOLVED OXYGEN BUDGET

Investigations of the oxygen budget are in three areas: (1) carbonaceous and nitrogenous oxygen demand from wastewater discharges, (2) oxygen production by phytoplankton, and (3) increased organic carbon and nitrogen loadings from phytoplankton, primarily in the middle and lower reaches. During 1969, preliminary CTSL studies were in the first two areas.

Preliminary analyses of nitrogen data from the past five years indicate that nitrification (the oxidation of NH_3 to NO_3) becomes a minor factor in the oxygen budget at water temperatures below 10°C. This observation would suggest that nitrogen removal from wastewater for the maintenance of oxygen standards would not be required at temperatures below 10°C. The need for nitrogen removal for the control of eutrophication is still being investigated as previously reported.

Effects of organic loadings on the dissolved oxygen budget in the middle and lower reaches is being intensively studied during 1970. During the summer months, dissolved oxygen in the lower reach is often depressed at greater depths, attributed partially to the decay of organic matter, mainly phytoplankton. Salinity differences between surface and bottom waters cause stratification resulting in poor mixing and consequently restrict aeration.

E. EMBAYMENT STUDIES

Except for the Blue Plains facility of the District of Columbia, all major wastewater discharges are into embayments of the Potomac River tidal system. As an interim measure to protect the embayments, the conferees at the Potomac Enforcement Conference applied the Zone I removal percentages to wastewater discharges in Zone II.

A study of the wastewater assimilation and transport capacity of the Piscataway embayment was recently completed [13]. One of the findings of the study was that this embayment has little capacity to assimilate and transport treated wastewater. The study further indicated if the same nutrient levels were to be maintained in the embayments as in the Potomac, only a limited poundage of the waste constituents could be discharged into the embayment if low nutrient levels are to be maintained. Moreover, if the plant were to be expanded to 30 mgd, a higher degree of removal than that currently agreed upon (96% for BOD_5, 91% for phosphorus, and 85% for nitrogen) would be required if the lower nutrient levels are to be maintained.

Preliminary analysis of the Anacostia River tidal system also indicates a limited assimilation and transport capability [3]. In this embayment, complete renovation or ultimate wastewater treatment (UWT) will be required if there are to be any large discharges in the upper portion of the Anacostia tidal system.

Based on the Piscataway and Anacostia studies, a re-examination of the removal requirements for embayment discharges is required. The

"real time" mathematical model previously mentioned includes all the major embayments. To complete the analysis, a dye release in each embayment will be required to verify predictive coefficients.

Nutrient response characteristics of the waters of the various embayments are currently being investigated by CTSL. Limited data attained in 1968 and 1969 indicate greater standing crops of algal populations in the embayment for given nutrient levels than in the main stem of the tidal river. The sampling program for the embayments, especially Piscataway, Dogue, Gunston Cove, Occoquan-Belmont, and Mattawoman was initiated in February 1970 to further explore these observations.

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