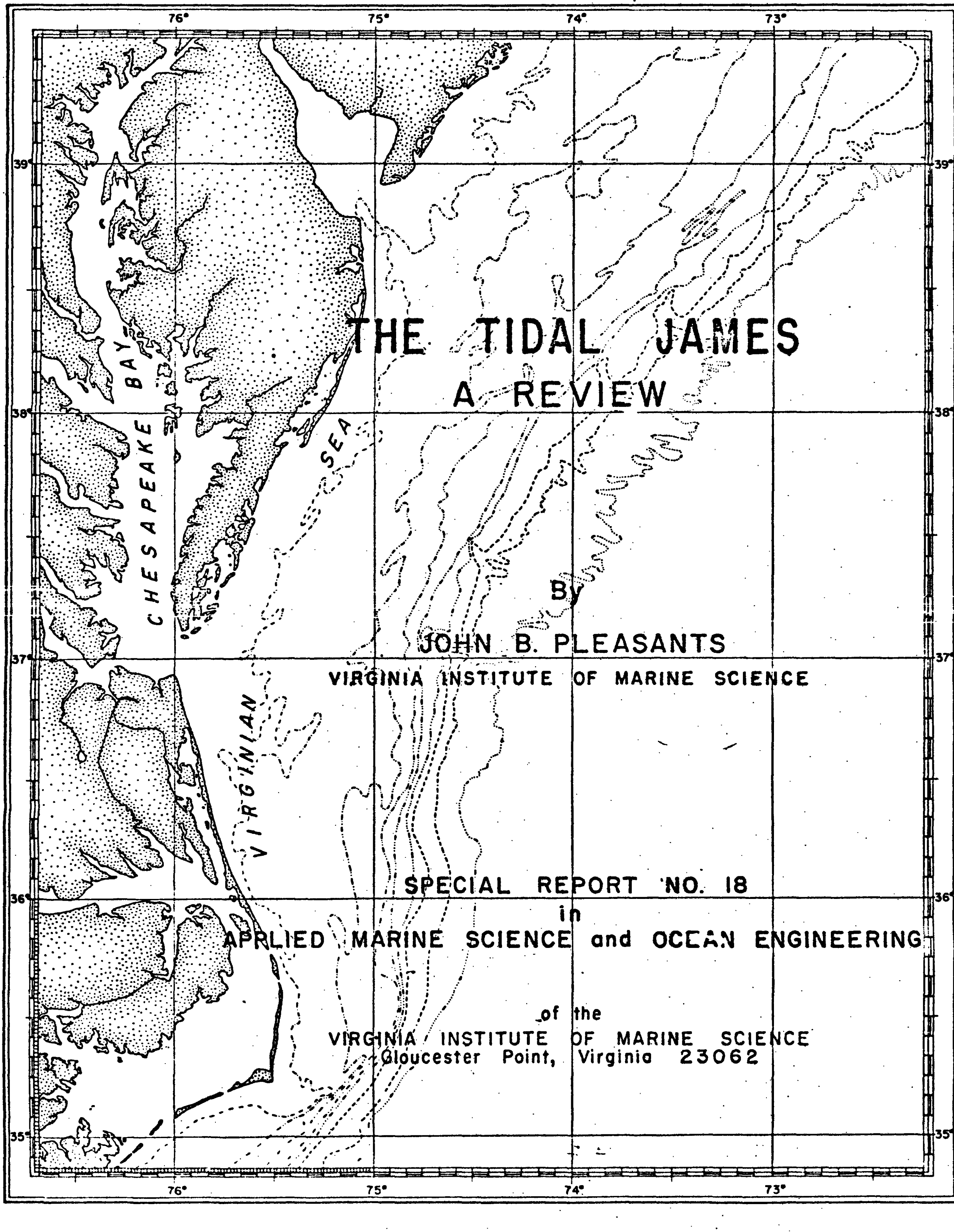

THE TIDAL JAMES
A REVIEW

By

JOHN B. PLEASANTS

VIRGINIA INSTITUTE OF MARINE SCIENCE

SPECIAL REPORT NO. 18
in
APPLIED MARINE SCIENCE and OCEAN ENGINEERING
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VIRGINIA INSTITUTE OF MARINE SCIENCE
Gloucester Point, Virginia 23062

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William J. Hargis, Jr.
Director
13 August 1971

ACKNOWLEDGMENTS

A paper of this sort is by nature the assemblage of facts derived from the work of many specialists by a synthesizer or author who is necessarily a generalist. It is therefore obvious that without the complete cooperation of the outstanding specialists in the various fields at the Virginia Institute of Marine Science, this paper could not have been readily completed. I am particularly grateful for the frequent assistance rendered by Dr. Morris L. Brehmer, Head of the Division of Applied Marine Science and Ocean Engineering. Dr. William J. Hargis, Jr., Director of the Virginia Institute of Marine Science and Principal Investigator of this project, gave his personal attention to many phases of this report, a kindness which I deeply appreciate.

Thanks are due to my hard-working secretary, Mrs. Phyllis Howard, for the many rough, smooth-rough, and smooth pages she cheerfully typed.

The work leading up to this report was accomplished under provisions of Task Order Number 1 of Master Agreement Number NASI-10720-1 entitled "Detailing the Technical Information Base on Environmental Quality of the James River" from the Langley Research Center of the National Aeronautics and Space Administration. Our special thanks are due to Messrs. Andrew R. Wineman and Beverly W. Lewis of NASA-Langley for their assistance and interest in this work.

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I. INTRODUCTION

I. Introduction

This report on the current status of the Tidal James River has been prepared in partial fulfillment of NASA Master Agreement NAS1-10720, as contracted between the National Aeronautics and Space Administration, and the Virginia Institute of Marine Science.

It has been said that the root cause of the deteriorating quality of our waters is the increasing density of our population and their rising standard of living. Therefore, in order to give a complete picture not only of the water quality of the lower James but also of conditions affecting it, a discussion of the population statistics and economic conditions of the Tidewater counties has been included. Further, a report such as this could not be considered complete without mention of the various engineering projects, both envisioned and complete, which have an effect on the James, the people who reside on its shores, and the species which inhabit its waters. This has also been included.

Finally, it should be noted that preparation of this report is in many respects a labor of love. We who have known the mighty James, have enjoyed its majestic beauty, realized the economic advantages which it offers, and delighted in the produce of its waters, are deeply concerned with the preservation of these values for our posterity.

Figure I portrays the Tidal James River.

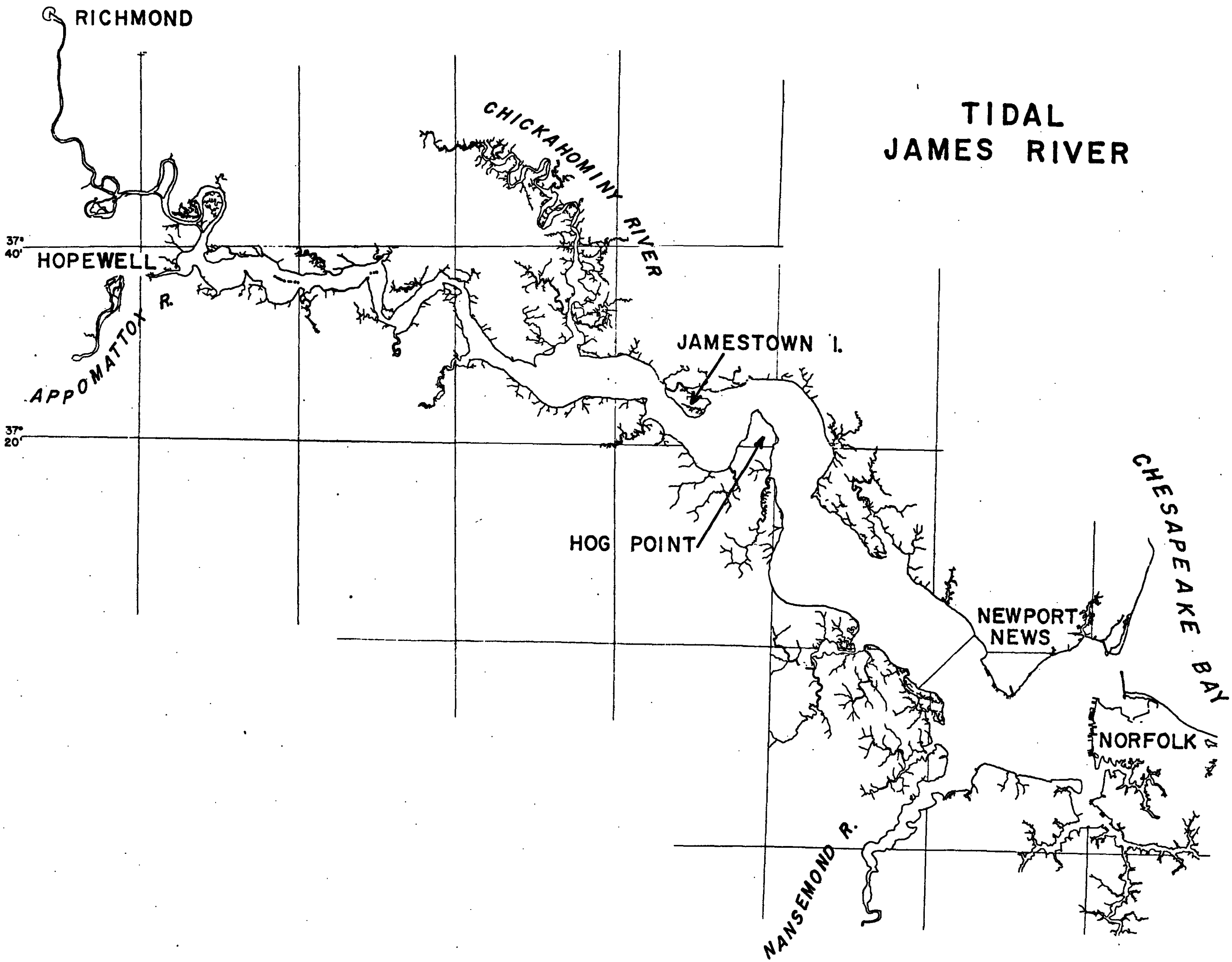

TIDAL
JAMES RIVER
RICHMOND
HOPEWELL
37° 40'
37° 20'
APPOMATTOX R.
CHICKAHOMINY RIVER
JAMESTOWN I.
HOG POINT
NEWPORT
NEWS
CHESAPEAKE BAY
NORFOLK
NANSEMOND R.

Figure I

II. HISTORIC

II. Historic

The James River is the southernmost - and the greatest - of the three great Virginia rivers that flow from the west into the southern portion of the Chesapeake Bay. It provides 16% of the freshwater inflow of the entire Bay, and at its confluence with the Bay is located one of the world's finest natural harbors, Hampton Roads.

The James drains the largest of Virginia's river basins, extending from the Virginia - West Virginia boundary on the west to the bay on the east, and all tributaries, except some insignificant ones in Monroe County, West Virginia, lie within the boundaries of the Commonwealth.

The basin of the James in Virginia includes 9,980 square miles, and all or parts of 38 counties. In West Virginia, part of one county and 80 square miles are included.[1]

The James itself is formed at the confluence of the Jackson and Cowpasture Rivers, about four miles below Clifton Forge. It has here an elevation of 988 feet above sea level, and an average width of 230 feet between this point and Glasgow. At Richmond the river becomes tidal, and the average width between Richmond and the mouth of the River is 4000 feet.[2] The head of navigation is at Richmond, 90.8 miles above the mouth via the three cut-offs at Turkey Island, Jones Neck, and Aiken Swamp - Dutch Gap. These cut-offs were completed between 1933 and 1937, and shortened the Hopewell - Richmond distance by 10.8 miles.[3]

Table A gives an appreciation of the variations in width of the Tidal James:

TABLE A[4]

Point	Miles above Mouth	Width
Mouth	0	4.9 mi.
Jamestown	30	1.5 mi.
Hopewell	69	3600 ft.
Richmond	90.8	1000 ft.

The James has played a large and important role in the history and development of Virginia and the nation since the first permanent settlement of English-speaking peoples in the United States was founded on Jamestown Island, on the river's northern shore, in 1607. It has provided drinking water, food, an easy method of transportation, water for industry and agriculture, and recreation for Virginians since that time.

Early descriptions of the river are sketchy. Too, there is a certain air of "press-agentry" about them, designed perhaps to lure additonal colonists, or at least impress their Lordships in London with the desirability of providing greater support. As an example, in 1607 the Council in Virginia at Jamestown wrote to the Council in London:

> We are set down eighty miles within a river, for breadth, sweetness of water, length navigable up into the country, deep and bold channel, so stored with sturgeon and other sweet fish as no man's fortune has ever possessed the like. And, as we think, if more may be wished in a river it will be found.

It has been said that he who gazes upon the Thames in London looks not upon a river but upon "Liquid History". Here, in the James River, is the

"Liquid History" of early America. Here sailed and planned John Smith, that driving, practical soldier; here lived the great chief Powhatan and his daughter Pocahontas; here 104 colonials landed in the spring of 1607, only to be reduced by privation and disease to 38 by the following autumn. Later, in 1619, the first legislative body assembled in North America met in the church at Jamestown, and in March of 1622, the Indians, who the week before had professed eternal friendship, fell suddenly upon the settlers, slaughtering three hundred seventy-four, a quarter of the English population. The toll might have been higher, except that an Indian boy named Chanco warned the colonist with whom he lived, who in turn alerted Jamestown. Among those killed was John Rolfe.[6]

On the banks of the tidal James lie the great plantations, some gone, some in ruins, some preserved, which were established by the Virginians of long ago. Shirley, on the north bank, was the home of Ann Carter, whose union with Light-Horse Harry Lee produced great Robert Edward Lee; Bermuda Hundred; Westover, ancestral home of the Byrds; and Turkey Island where William Randolph established his line, whose descendants included Lee, Jefferson, and Richard Bland. Upper and Lower Brandon, Carter's Hall and Claremont must also be mentioned.

The importance of providing transportation for men and goods to the Western frontier was not lost upon the Virginians; in 1774 Washington recommended that the James be connected by canal to the Kanawha River, which flowed westward into the Ohio. In 1785 the James River Company devoted to this project was organized, with Washington as President. After twenty years work, the company began to pay large dividends and in 1820 was purchased by the state. By 1840, one could travel from Richmond to Lynchburg by horse-drawn canal boat in slightly over thirty hours, compared to ten days by the pole-propelled bateaux. The canal packets were pulled by three horses which were changed every 12 hours and maintained a speed of four miles per hour. By 1860, forty-four hour service was provided to Lexington and forty-seven to Buchanan.[7] The War Between the States, and the advent of the railroads, ended the vision of a water connection from the James through the Ohio to the Mississippi.

Improvements to the James above Richmond, discussed above, were of transient importance. The tidal James, however, is of far greater concern to commerce and navigation. Improvements here have been considered since the first half of the 19th century, and have been sponsored with one exception[8] by the city of Richmond and the Federal Government.

Improvements Sponsored by Richmond[9]

1829 - Requested survey by Federal Government of Richmond - Hampton Roads section.

1836 - Congress voted $500 for survey.

1837 - Survey complete. Committee of Richmond City Council provided assistance.

1838 - Congress appropriated $2,000 for spar buoys to aid navigation.

1850 - Congress approved $3,500 for beacons at various points.

1852 - As a result of activities by the city of Richmond, the Federal Government appropriated $45,000 for improvement to the James and Appomattox to be divided equally between the two.

1854 - Col. R. E. DeRussey, Corps of Engineers, US Army, was appointed to take charge of work on the James in cooperation with the City Council. Work commenced on the Richmond Bar.

1855 - Channel through Richmond Bar completed with a depth of "15 to 20" feet, 100 feet in width. Work commenced on Rocketts Reef, about 2-1/2 miles below Richmond. This was not to complete until 1880.

After the War Between the States, the Federal Government, which had already been heavily involved, assumed full charge of the supervision of improvements to the lower James which it has since retained.

Improvements Sponsored by the Federal Government[10]

1870 - Project approved by Congress to excavate a channel between Richmond and the mouth of the James, and complete the cut-off at Dutch Gap. Channel to be 180' wide with a least depth of 18' at high water.

1884 - Work complete, but channel only 100' wide. Artificial obstructions emplaced during War Between the States removed, least depth of 12-1/2' at low water achieved. Dutch Gap canal opened and enlarged, reducing distance between Richmond and Hopewell by 5 miles.

1884 - Act adopted by Congress in 1884 (as modified in 1902 and 1905) provided for channel 22' deep from Newport News to Richmond, with widths of 400' to City Point (Hopewell), 300' to Drewry's Bluff, and 200' to Richmond. A turning basin 400' by 600' was to be constructed at Richmond.

1930 - Work on previous project 43 percent complete. Further modification by Congress provided for 25' channel 300' wide to Hopewell, 200' wide to Richmond Deep Water Terminal and 18' deep and 200' wide from Deep Water Terminal to Richmond lock gates. Cut-offs across Turkey Island, Jones Neck and Dutch Gap-Aiken Swamp are included.

1947 - Work authorized in 1930 complete.

Additional work on the James River has been authorized but not initiated; this will be discussed in succeeding sections.

III. GENERAL

A. METEOROLOGICAL
B. ECONOMIC
C. POPULATION
D. INDUSTRIALIZATION
E. TRANSPORTATION

A. Meteorological

The climate throughout the James River basin is temperate, as determined by the latitude, prevailing westerly winds, the influence of the Atlantic Ocean, and its overall topography. Average annual weather factors are as follows:

Precipitation: 42.5 inches

Snowfall: 17 inches (about 1.7 inches of precipitation)

Temperature: 57° F

Growing Season: (freeze to freeze)
143 days (Highland County)
254 days (Norfolk)

The western portion of the basin is subject to cooler summers and more severe winters than the eastern, and has moderate (15 to 20 inches or more) snowstorms, while the eastern is sometimes subject to the effects of hurricanes in the summer and early fall. Average annual temperatures are higher near the ocean (Newport News...61.7°F) than in the mountains (Hot Springs...51.0°F). Ice of six or more inches in thickness rarely remains for 10 to 15 days below Richmond, while in the western portion of the basin ice in some streams has been noted to a depth of one foot or greater for periods in excess of 30 days. Damage from ice flows or jams is rare.

Winter storms often divide at the east-west center of the basin, with frozen precipitation to the west and rain to the east, due to the moderating influence of the ocean.

Prevailing winds are from the west and northwest in the mountainous areas, and from the south in other portions of the basin. The coastal areas of course have frequent easterly sea breezes.

The average velocity is 8 to 10 MPH; however, 80 MPH and more may be expected during storms. Intense thunderstorms are far from rare, and most wind damage in the area occurs from their activity.

Rainfall is heaviest in the extreme southeast portion of the basin, averaging up to 50 inches per year, while along the West Virginia border it averages only 38 inches. In the broad area between, 40 to 44 inches is the annual average.

Tide tables for the East Coast of North and South America, published for 1971 by the U. S. Department of Commerce, give the following figures for the James:

TABLE B

Station	Tides (feet) Mean	Spring*
Newport News	2.6	3.1
Jamestown Island	2.0	2.4
City Point (Hopewell)	2.6	3.0
Richmond (Locks)	3.2	3.6

*This refers to certain configuration of the sun and moon relative to the earth which produces the highest tides, rather than a season of the year.

B. Economic

Historically, Virginia began as an agriculturally based colony, and the James River provided an easy and inexpensive method for moving produce.

A great deal of the land in the basin is still devoted to agriculture, but manufacturing is on the increase, and, in terms of value added, amounted to over $2 billion in 1968.[11]

Manufacturing employment, which is on the rise, will be discussed under Industrialization. Manpower is made available for manufacturing employment as technology enables agriculturists to sustain or increase production with fewer people.

Though many once-productive farms in the James River basin have been converted to housing developments, or otherwise removed from the agricultural scene, farming continues to play an important part in the economic life of the basin and the state. Agriculture utilizes about 60% of the land in the James River Basin, 25% is urban, and 15% is devoted to other uses.[12] Tobacco still retains the importance first realized by the colonials, and peanuts, fruit, poultry, dairy products, and lumber contribute heavily to the economy, as do soybeans, livestock, cotton, and hay.

Total farm income in 1965 was approximately $568 million, and value added to agricultural products, which reflects processing, wholesaling, and retailing, was estimated at $3 billion.[13]

The seafood industry is concentrated in the tidewater area and quantities of oysters, crabs, clams, and finfish are harvested annually.

During the recent governmental effort to end inflation, the term GNP -

Gross National Product - has become a familiar one. It refers, of course, to the yearly total of the market value of newly produced goods and services, not resold in any form. An analogous concept for the James River Basin, the GBP - Gross Basin Product - is utilized by the Virginia Division of Water Resources. In accordance with this concept, the following figures are given:[14]

TABLE C

GBO Estimates
James River Basin, 1968

Source	Billions of 1968 dollars
Finance	3.0
Government	1.5
Regional Gross Manufacturing Output*	4.5
Agriculture	.1
Retail/Wholesale	2.2
Gross Basin Output	11.3

*Estimated 1968 dollar value of all regionally manufactured products for the year.

Source: Division of Water Resources

The Virginia Division of Water Resources Comprehensive Plan for the James River Basin, Volume II... Economic Base Study, contains a further discussion of this concept, along with three ranges of projections of gross manufacturing output as well as value added, together with much other economic information.

For ease of handling, the political sub-divisions that surround the tidal James have been separated into discrete units for economic evaluation by the Virginia Division of State Planning and Community Affairs. These are:

Metropolitan Areas:

Richmond - Chesterfield - Henrico (includes Hanover, Goochland, and Powhatan Counties)

Petersburg - Hopewell - Colonial Heights (includes Dinwiddie and Prince George Counties)

Newport News - Hampton (includes Williamsburg and York, and James City Counties)

Norfolk - Portsmouth (includes the cities of Chesapeake, Virginia Beach and Suffolk, and Nansemond County)

Counties

Charles City County

Surry County

Isle of Wight County

Each economic unit will be discussed in turn. The short titles used below are intended to include all political sub-divisions as previously delineated.

Richmond Area

The basic industries of the Richmond area are manufacturing, agriculture, state and federal government, rail transportation, hotel type services, health and medical services, higher education, regional religous organizations, and non-local wholesale and retail trade, trucking and warehousing, banking and insurance, as well as utility services, and business services. The most important of these is manufacturing, which, in March of 1965, accounted for 21% of total employment.[15] At this time, supporting industries accounted for 57% of total employment.[16]

The areas leading employer is the tobacco industry.

From 1960 to 1965, the population of the area grew at a rate of 12.5%.[17]

Petersburg Area

There is some overlap between this and the previous area, particularly as regards the Matoaca district and the southern part of the Bermuda district of Chesterfield County, because of commuter patterns.

Manufacturing, which accounted for 25% of the total employment in March of 1965, is the most important of the basic industries.[18] Also important are the federal government (mainly Fort Lee) state institutions and the travel trade. Supporting type industries accounted for 47% of total employment in March of 1965.[19]

The area had a population growth rate of 12.9% from 1960 to 1965.[20]

Newport News Area

Federal government employment, which accounted for 28% of total employment in 1965, is the most important basic industry in the area, and 2/3 of this employment is military.[21] Other basic industries are manufacturing, agriculture, travel trade, port and port related activity, higher education, and institutional employment. Supporting industries accounted for 43% of total employment in 1965.[22]

The federal government is mainly represented by civilian and military personnel of the Army and Air Force. The Army personnel are stationed at Fort Eustis and Fortress Monroe, with the last being the headquarters of the Continental Army Command. The Air Force personnel are stationed at Langley Field, along with NASA personnel.

By far the single greatest employer in the manufacturing field is the Newport News Shipbuilding and Drydock Company which provided 76% (20,000 workers) of the total manufacturing jobs in March of 1965.[23]

Of interest is the number of small technical - scientific research organizations, generally related to NASA - Langley, in the area.

The area's population growth was 18.8% from 1960 to 1965.[24]

Norfolk Area

This is the largest metropolitan area located entirely within the state. The federal government also comprises the single largest employer in this area, accounting for 36% of total employment in 1965.[25]

Other basic industries are manufacturing, port related activity, agriculture, travel trade, and higher education. Supporting industries accounted for 46% of employment in 1965.[26]

The great majority of the personnel employed by the federal government in this area are military personnel. Most military and civilian employment is at the numerous naval installations in the area, with the Norfolk Naval Base and the Norfolk Naval Air Station together having more than half the civilian employees.

In the manufacturing group, the food and related products industry was the leading employer. This industry is based on locally produced agricultural products (the processing of peanuts and hams in the Suffolk - Nansemond area) and the seafood produced from local waters (waterfront areas of Norfolk, Portsmouth, Chesapeake, and Virginia Beach...the harvesting and processing of oysters, clams, crabs, and finfish).

In the port and port related activity sector, approximately 70% of the total import-export tonnage and 80% of the total non-manufacturing employment of Hampton Roads was accounted for by the Norfolk area. Approximately one third of all manufacturing employment in the area was related to this sector in March of 1965.[27]

The net population growth from 1960 to 1965 was 12.1% for this area.

Charles City County

This is a largely rural area. The county, particularly the western portion, serves as a bedroom for the Richmond metropolitan area. An analysis made in 1960 indicates more than 60% of the residents are employed outside the county, and this is believed to have since increased.[28]

Agriculture is the most important industry, accounting for 17% of the total employment in March 1969. Also of importance as employers are manufacturing, fisheries and the federal government (U. S. Fish and Wildlife Service at Harrison's Lake Fish Hatchery).[29]

Supporting industries employed more than 75% of the total job holders in March of 1969.[30]

Charles City County's population experienced a growth rate of 12.1% from 1960 to 1970.[31]

Surry County

This county, too, is largely rural, with agriculture (peanuts and hogs) accounting for 49% of the total employment.[32] The other basic industry is manufacturing. Supporting industries account for 49% of the total employment.[33]

The county experienced a negative net growth rate of -2.2% between 1960 and 1966.[34]

It is possible that the nuclear power plant, under construction by VEPCO at Hog Point, will have a beneficent effect upon the local economy.

Isle of Wight County

Manufacturing is the primary employer in this area, accounting for approximately 50% of the jobs in March of 1968.[35] Other important basic industrial employers include agriculture, fisheries, a military base wholesaling operation, and the federal government.

Supporting industries employed 32% of the work force in March of 1968.[36]

The leading sector of employment in manufacturing was in food and related products, with over 2000 workers, largely at two nationally known producers of hams and other pork specialties. The paper industry, nearly as important, accounts for 1800.[37]

Population in Isle of Wight County increased by 10.6% from 1960 to 1968.[38]

The Virginia Division of State Planning and Community Affairs publishes an excellent series of Projection and Base Analyses for all economic regions in Virginia. The above brief comments were extracted from the latest issues available.

C. Population

The James basin covers one fourth of Virginia's total area, and in it reside more than two million people.

Major cities along the James include Lynchburg, Richmond, Hopewell, Portsmouth, Norfolk, and Newport News.

The Tidewater portion of the James basin contains the main population centers of the area. These are the Richmond - Henrico - Chesterfield area at the fall line, and the Norfolk - Newport News area at its juncture with the bay. Petersburg, Colonial Heights, Hopewell, and Suffolk also have considerable population, but the remainder is largely rural - agricultural.

Population projections for the state, the entire basin, and the Tidewater area, based on most probable growth rates, are given in table D.

TABLE D

Population Projections (Medium Range - Most Probable)

Area	Year			
	1968	1980	2000	2020
Richmond	216,451	230,300	254,400	281,200
Chesterfield	111,392	170,000	325,400	623,000
Hanover	36,163	58,300	105,300	190,200
Henrico	160,606	200,500	286,500	409,300
Goochland	10,466	20,100	29,900	44,400
Powhatan	8,076	14,600	21,700	32,200
Metropolitan Area	588,148	693,800	1,023,200	1,580,300
Petersburg	37,944	40,600	46,700	53,700
Hopewell	21,157	29,200	47,800	78,400
Colonial Heights	14,291	20,200	33,100	54,200
Dinwiddie	25,911	33,900	48,400	69,200
Prince George	30,858	50,100	90,500	163,400
Metropolitan Area	130,161	174,000	266,500	418,900

Area	1968	1980	2000	2020
			Year	
Newport News	136,430	168,800	241,200	344,600
Hampton	85,771	132,200	216,600	355,000
Williamsburg	10,891	12,700	15,500	18,900
York	32,533	56,700	112,800	224,500
James City	16,016	20,300	36,700	66,200
Metropolitan Area	281,641	390,700	622,800	1,009,200
Norfolk	305,585	325,000	359,000	396,800
Portsmouth	127,208	135,000	149,200	164,800
Chesapeake	85,771	132,200	216,600	355,000
Virginia Beach	158,506	253,000	408,900	738,500
Suffolk	11,981	13,400	14,200	15,000
Nansemond	35,945	46,100	64,600	90,500
Metropolitan Area	724,996	904,700	1,212,500	1,760,600
Charles City	6,516	7,700	10,400	14,000
Surry	5,951	6,300	6,800	7,400
Isle of Wight	18,989	23,200	31,200	42,100
Grand Total, Tidewater James Area	1,756,402	2,200,400	3,173,400	4,932,500
Total James Basin	2,356,000	3,006,000	4,296,000	6,441,000
Total Virginia	4,692,675	6,033,000	9,000,000	14,000,000

Source: Virginia Division of Water Resources

Note: High and low population estimates are also available from the same source, Virginia Division of Water Resources, Comprehensive Water Resources Plan, James River Basin, Volume I - Introduction.

D. Industrialization

Tidewater Virginia has been historically an agriculturally-based area, with seafood, shipping, and, in a strong supporting role, the military providing additional impetus to the economy.

In the last two decades, however, manufacturing has played an increasingly important role. During the early '50's, the rate of increase of manufacturing employment was equal to that of the nation as a whole; from 1955 to 1964 the state averaged a growth rate in manufacturing employment of 2% annually, when, significantly, the United States showed very little growth. During the national high growth rate of 1965-66, Virginia closely approximated national growth; since that time it has exceeded it. Considering the year 1950 as an index of 100 for both the United States and Virginia, 1970 finds Virginia's index of manufacturing employment at approximately 158, while the nation's is about 127.[39] From 1960 to 1969, manufacturing employment in Virginia increased by 34.7% as against a national average of 20.1%.[40]

Virginia's manufacturing industry structure is highly diversified and geographically wide-spread. The greatest single concentration is in the Richmond area; the next, the Norfolk - Newport News area. These two, of course, are connected by the tidal James. Hopewell, between the two, also is an industrial area. Major employment sectors are as follows:

Richmond	Hopewell	Norfolk - Newport News
Tobacco	Chemicals	Transportation
Printing	Paper	Food
Paper		Printing
Food		
Apparel		

Richmond (cont.)

Primary Metals
Fabricated Metals
Chemicals
Lumber
Nonelectrical Machinery

Source: Virginia Employment Commission, as reported in Virginia Facts and Figures 1971.

Electrical power is of course a prerequsite to modern industry. The tidal James area is supplied in this regard by the Virginia Electric and Power Company (VEPCO).

VEPCO presently has plants at the following locations in the tidal James area:

TABLE E

Present Capacity (12-31-70)
Tidal James Area

Station Name	Location	Generation Type	Capacity (MW)
Chesterfield	Chesterfield Co.	Fossil Steam	1,383
Portsmouth	Portsmouth	Fossil Steam	597
		Combustion Turbine	194
Reeves Ave.	Norfolk	Fossil Steam	89
Surry	Hog Point, Surry Co.	Combustion Turbine	41
Twelfth Street	Richmond	Fossil Steam	79

Source: VEPCO

In order to provide sufficient power for estimated future growth, as well as to provide a more adequate reserve for present users, VEPCO has programmed construction of the following additional plants:

TABLE F

Proposed Additional Plants
Tidal James Area

Station Name	Location	Installation Year	Generation Type	Capacity (MW)
Surry	Hog Point, Surry Co.	1971	Nuclear Steam	820
Surry	Hog Point, Surry Co.	1972	Neclear Steam	820

Source: VEPCO

There also exsist in the area of our interest many privately owned or specially dedicated power plants with considerable capacity. These are in Table G.

TABLE G

Non-Public Power Plants
Tidal James Area

Station Name	Location	Generation Type	Capacity (KW)
Norfolk Naval Shipyard	Portsmouth	Fossil Steam	27,000
U. S. Navy	Norfolk	Fossil Steam	10,000
Va. Chemicals Inc.	West Norfolk	Fossil Steam	600
U. S. Air Force	Newport News	Diesel	1,500
Allied Chemical Corp.	Hopewell	Fossil Steam	20,000
Continental Can Co.	Hopewell	Fossil Steam	14,400
Kirk Lumber Co.	Chuckatuck	Fossil Steam	250
Hercules, Inc.	Hopewell	Fossil Steam	9,440
James River Paper Co.	Richmond	Hydro	315
American Tobacco Co.	Richmond	Fossil Steam	2,300
David M. Lea Co.	Richmond	Fossil Steam	750
DuPont	Richmond	Fossil Steam	27,000
Seaboard (Federal Paper Board Co.)	Richmond	Fossil Steam	2,500
Hull Street (Federal Paper Board Co.)	Richmond	Fossil Steam	750
Miller MFG	Richmond	Fossil Steam	800
U. S. Tobacco Co.	Richmond	Fossil Steam	800

Source: Virginia Division of Water Resources

E. Transportation

Transportation is an important aspect of the growth of any area, and the Tidewater portion of the James Basin is certainly no exception. Waterborne transportation is, of course, of primary importance to this report, with highway, rail, and air transportation being of interest chiefly for their influence upon waterborne, and also to complete the economic picture.

Historically, the James River has served since the days of the European exploration of Virginia as a convenient method of transporting men and equipment into the interior of the state, and to return produce from the inland plantations to the seaports of the lower bay. The roads through the dense woods of the early periods were unsatisfactory for any sort of commerce; the river was safer, faster, easier, and not load-limited.

When the country became more settled, and as the settlements moved further west, transportation of goods was accomplished by the construction of an extensive canal system, which finally totalled nearly 460 miles in length, and included locks, dams, culverts, aqueducts, and tunnels. This has been discussed in an earlier section of this paper.

The major navigation project on the James River is the 25 foot channel. It is described as follows:

> James River Navigation Channel - The existing project is maintained at a 25-foot depth from the mouth to the deepwater terminal below Richmond, Virginia, thence 18 feet to Richmond lock in the upper harbor. The width is maintained at 300 feet to Hopewell, thence

200 feet for the remainder of the channel. A study is underway to determine the economic feasibility of improving the channel to a 35-foot depth and 300-foot width to the deepwater terminal at Richmond.

Source: Corps of Engineers, 1971.

Other projects, of lesser importance to the James itself, including those in Hampton Roads, are discussed in the section on Projects. This section also contains a discussion of the proposed 35 foot channel.

Hampton Roads is one of the world's great seaports. Richmond and Hopewell are also seaports, although the size of visiting ships is limited by the physical dimensions of the present channel. Richmond has the distinction of being further west than any other port on the Atlantic Seaboard, and considerable economic justification has been given for the proposed 35' channel from Hampton Roads.

Table H is a compilation of commerce on the James River for the years 1959-1969.

TABLE H

Comparitive Statement of Commerce
on the James River, 1959-1969
(thousands of short tons)

Year	Richmond	Hopewell	Points Below Richmond*	Total
1959	2,807	791	2,608	5,415
1960	2,917	782	2,269	5,186
1961	3,069	704	2,555	5,624
1962	3,379	759	2,892	6,270
1963	3,426	811	3,036	6,461
1964	3,699	909	3,136	5,835
1965	1,730	694	3,373	5,103
1966	1,618	894	2,983	4,601
1967	1,647	659	3,548	5,195
1968	1,807	841	3,807	5,613
1969	1,775	767	3,242	5,017

*Includes tonnage handled at Hopewell.

Note: Figures are rounded to nearest 1,000 short tons, and therefore may not total.

Source: Corps of Engineers, Personal Communication, 1971

Hampton Roads, the famous harbor at the mouth of the James, is surrounded by the cities of Newport News, Norfolk, Portsmouth, Hampton, and Chesapeake. In 1969, Hampton Roads led the nation in volume of exports, ranked second only to New York in total foreign trade tonnage.[41] The chief import was residual fuel oils; the leading export, coal.

Recently, the use of containers has revolutionized seaborne cargo handling; Hampton Roads has experienced explosive growth in this area. In calendar 1969, an increase in containers handled of 77.9% was experienced over calendar 1968: for fiscal 1970, the increase was 97.5% over fiscal 1969.[42] Total cargo handled was as follows:

TABLE I

Hampton Roads Cargo
(Thousands of Short Tons)

	1968	1969	% Increase
Imports	6,500	7,969	22.6
Exports	35,561	39,872	12.1
Total	42,060	47,840	13.7

Note: Figures are rounded to nearest 1,000 short tons, and therefore may not total.

Source: Annual Report of Virginia State Port Authority, 1969-1970.

The area of the tidal James is also well served by land and air transportation. Highways U. S. 60, 460, and Interstate 64[43] provide generally east-west connections; U. S. 1, 17, 13,[44] 301, and Interstate 95 run generally north-south. The river is bridged at Newport News by the Hampton Roads Bridge-Tunnel, (Interstate 64) and the James River Bridge (U. S. 17). The river is next bridged below Hopewell by state route 156; at Richmond, state route 161 and 147, U. S. 60 and 360, and Interstate 95 all cross. Plans exsist for a crossing between Richmond and Hopewell by Interstate 295, a Richmond Beltway, and, in Hampton Roads, a second bridge-tunnel, parallel to and alongside the present Hampton-Norfolk connection, is under construction.

Railways, too, are well represented. The Seaboard Coast Line, the

Chesapeake and Ohio, the Richmond, Fredricksburg, and Potomac, and the Southern all run north and south through Richmond. The Norfolk Southern line runs south from Norfolk, and the Norfolk and Western, and the Chesapeake and Ohio connect the ports of Hampton Roads with Richmond and the west.

Airlines in the Tidewater James area connect to all points; the major airports are at Richmond (National, Piedmont Aviation, United, Eastern), Newport News (National, Piedmont, United, Allegheny) and Norfolk (United, Piedmont, National, Allegheny).

IV. CURRENT STATUS

A. WATER QUALITY STANDARDS
B. FLOW RATES
C. MONITORING
D. WATER WITHDRAWALS
E. EFFLUENT DISCHARGES
F. NUTRIENT LEVELS
G. BACTERIAL LEVELS
H. SALINITY
I. IMPORTANT SPECIES
J. SEDIMENTATION AND EROSION

A. Water Quality Standards

To discuss water quality intelligently a first requirement is to establish the standards against which it is to be measured. In Virginia, such standards are the responsibility of the State Water Control Board, which was established in 1946.

Effective in July 1970, the Water Control Board promulgated the following standards:

1. All waters within this State shall at all times be free from all substances attributable to sewage, industrial wastes, or other wastes in concentrations or combinations which contravene established standards or interfere directly or indirectly with beneficial uses of such waters; except that limited zones will be permitted for the mixture of treated sewage, treated industrial wastes,, and other waste effluents with receiving waters. The boundaries of mixing zones will be determined on a case by case basis. However, these zones shall generally occupy as small an area and length as possible, and shall not prevent free passage of fish or cause fish mortality.

2. Stream standards will apply whenever flows are equal to, or greater than, the minimum mean 7-consecutive day drought flow with a 10-year return frequency.

3. In lakes and impoundments the temperature of the

epilimnion, in those areas where important organisms are most likely to be adversely affected, shall not be raised more than 3° F, above that which existed before the addition of heat of artificial origin. The increase is to be based on the monthly average of the maximum daily temperature. Unless a special study shows that a discharge of heated effluent into the hypolimnion (or pumping water from the hypolimnion for discharging back into the same water body) will not produce adverse effects, such practice shall not be approved. Maximum temperatures consistent with the standards established for waters immediately above and below the lake or impoundment will be established for these waters.

4. Any tributary stream which is not named in a specific section description, or otherwise, shall carry the same classification and standards of quality assigned to the stream or section to which it is tributary.

5. In addition to other standards established for the protection of public or municipal water supplies, the following standards will apply at the raw water intake point:

Constituent	Concentration
Physical:	
Color (color units)	75

Inorganic Chemicals	mg/l
Alkalinity	30-500
Arsenic	0.05
Barium	1.0
Boron	1.0
Cadmium	0.01
Chloride	250
Chromium, hexavalent	0.05
Copper	1.0
Fluoride	1.7
Iron (fiterable)	0.3
Lead	0.05
Manganese (filterable)	0.05
Nitrates plus nitrites	10 (as N)
Selenium	0.01
Silver	0.05
Sulfate	250
Total dissolved solids (filterable residue)	500
Uranyl ion	5

Organic Chemicals	mg/l
Carbon chloroform extract (CCE)	0.15
Cyanide	0.20
Methylene blue active substances	0.5
Pesticides:	
Aldrin	0.017
Chlordane	0.003
DDT	0.042
Dieldrin	0.017
Endrin	0.001
Heptachlor	0.018
Heptachlor epoxide	0.018
Lindane	0.056
Methoxychlor	0.035
Organic phosphates plus Carbamates	0.1
Toxaphene	0.005
Herbicides:	
2, 4-D plus 2, 4, 5-T, plus 2, 4, 5-TP	0.1
Phenols	0.001

Radioactivity:	pc/l
Gross beta	1,000
Radium-226	3
Strontium-90	10

In addition to the general rules, it has been deemed necessary to establish secondary or special rules according to climate, geographical area, and stream (or segment of stream) use. This is done by establishing major classes as listed in table J on the following page.

Subclasses to Complement Major Water Class Designations are as follows:

Subclass A

Waters generally satisfactory for use as public or municipal water supply, secondary contact recreation, propagation of fish and aquatic life, and other beneficial uses.

Coliform Organisms - Fecal coliforms (multiple-tube fermentation or MF count) not to exceed a log mean of 1000/100 ml. Not to equal or exceed 2000/100 ml. in more than 10% of samples.

Monthly average value not more than 5000/100 ml. (MPN or MF count). Not more than 5000 MPN/100 ml. in more than 20% of samples in any month. Not more than 20,000/100 ml. in more than 5% of such samples.*

Note: *With the exception of the coliform standard for shellfish waters, the enforceable standards will be those pertaining to fecal coliform organisms. The MPN concentrations are retained as administrative guides for use by water treatment plant operators.

TABLE J

MAJOR CLASS	GEOGRAPHICAL AREA or OTHER DESCRIPTION of WATERS	DISSOLVED OXYGEN mg/l Minimum	Daily Average	pH	TEMPERATURE °F Rise above Natural	Maximum
I	Open Ocean (Seaside of the Land Mass)	5.0	--	6.0-8.5	4.0(Sept.-May) 1.5(June-Aug.)	--
II	Estuarine (Tidal Water - Coastal Zone to Fall Line)	4.0	5.0	6.0-8.5	4.0(Sept.-May) 1.5(June-Aug.)	--
III	Free Flowing Streams (Coastal Zone and Piedmont Zone to the Crest of the Mountains)	4.0	5.0	6.0-8.5	5	90
IV	Mountainous Zone	4.0	5.0	6.0-8.5	5	87
V	Put and Take Trout Waters	5.0	6.0	6.0-8.5	--	70
VI	Natural Trout Waters	6.0	7.0	6.0-8.5	--	70

Subclass B

Waters generally satisfactory for use as public or municipal water supply, primary contact recreation (prolonged intimate contact; considerable risk of ingestion), propagation of fish and other aquatic life, and other beneficial uses.

Coliform Organisms - Fecal coliforms (multiple - tube fermentation or MF count) with in a 30 day period not to exceed a log mean of 200/100 ml. Not more than 10% of samples within a 30-day period will exceed 400/100 ml.

Monthly average not more than 2400/100 ml. (MFN or MF count). Not more than 2400/100 ml. in more than 20% of samples in any month. Not applicable during, nor immediately following periods of rainfall.*

All of the state's waters are in one or another of the major classes, and each is assigned to either subclass A or B. Waters utilized for primary contact recreation (such as swimming) are assigned to subclass A and all others to subclass B.

Special instructions are frequently attached to individual stream segments.

Note: *With the exception of the coliform standard for shellfish waters, the enforceable standards will be those pertaining to fecal coliform organisms. The MPN concentrations are retained as administrative guides for use by water treatment plant operators.

The James River, exclusive of the non-tidal (or free-flowing) portions of its tributaries, is classed as II B from the Old Point Comfort - Fort Wool line to the fall line at Richmond. This includes the Chickahominy River to Walker's Dam, and the Appomattox River to the head of its tidal waters.[45] Tidal tributaries of all three rivers are included.

In addition, the lower portion of this segment of the James, from the Old Point Comfort - Fort Wool line to Barrett Point (Buoy 64) has special requirements, viz:

> Coliform organisms - The median MPN shall not exceed 70/100 ml., and not more than 10% of the samples ordinarily shall exceed an MPN of 230/100 ml., for a 5-tube decimal dilution test (or 330/100 ml., where a 3-tube decimal dilution is used) in those portions of the area most probably exposed to fecal contamination during the most unfavorable conditions.
>
> In addition, the shellfish area is not to be so contaminated by radionuclides, pesticides, herbicides or fecal material so that consumption of the shellfish might be hazardous.

These special rules are for protection of the valuable shellfish beds located in this area.

The tidal portions of the Elizabeth and Nansemond Rivers have additional special requirements aimed at improving present water quality.

The Commonwealth of Virginia State Water Control Board pamphlet

"Water Quality Standards", effective 20 July 1970, gives a complete description of standards and the various stream segments to which they apply.

B. Flow Rates

Water quality in rivers obviously depends heavily upon flow rates, both for the mechanical flushing action of the waters, and purely for the purpose of dilution. The old catch phrase "The solution to pollution is dilution" while no longer accepted as a complete answer, still possesses a certain validity.

Since our main area of interest is the tidal James, the major input to the river may be considered as the point where the James becomes tidal, at Richmond. Other large inputs are from the Appomattox and the Chickahominy Rivers, each of which has a stream gaging station relatively near the point where they become tidal. It should be mentioned here that stream flow in tidal waters must be taken as the net difference in motion between upstream and downstream movement of the water, corresponding to the flood and ebb of the tide. Further downstream, stream flow becomes even more difficult to determine, since surface flow, whose overall direction is seaward, is superimposed upon a saltier undercurrent whose net flow is upriver. Their difference, of course, is the river input, and the total river flow seaward is their sum. This is discussed more fully in the section on Salinity, below.

Stream flow for the major inputs to the James below Richmond are as follows:

TABLE K

ONE DAY DISCHARGE

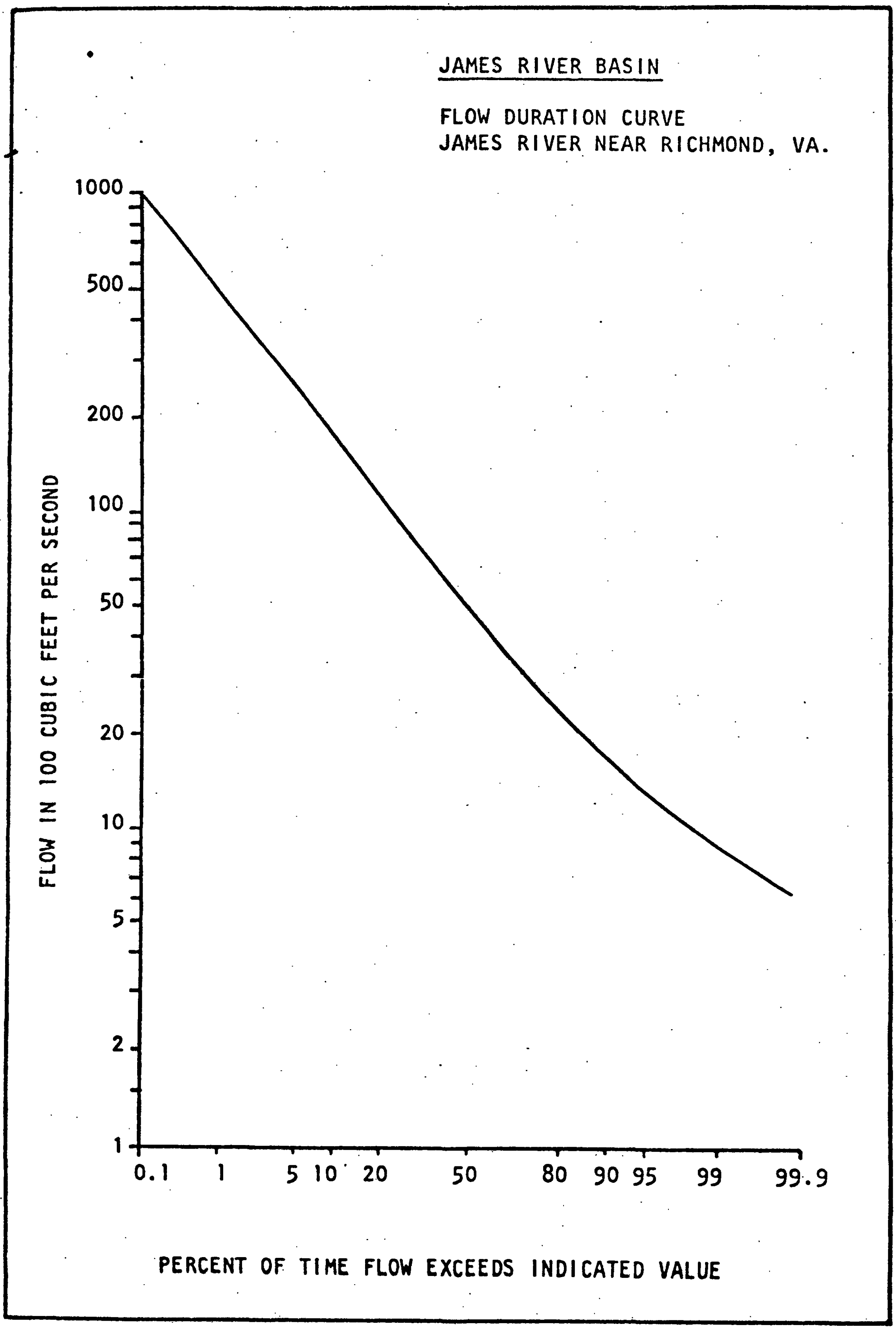
Station	Drainage Area(mi^2)	Location	Rate-Mean Average (CFS) Highest	Rate-Mean Average (CFS) Lowest	Average CFS (No. of Yrs.)
2-0370.00	None*	James River and Kanawha Canal near Richmond.* Lat. 37° 33' 52" Long. 77° 34' 28"	3860	0.0	862 (30 yrs)
2-0375.00	6757	James River near Richmond.* Lat. 37° 33' 47" Long. 77° 32' 50"	152,000.0	20.0	6371 (32 yrs)
2-0415.00	1335	Appomattox near Petersburg. Lat. 37° 13' 33" Long. 77° 32' 20"	27,700.0	19.0	1151 (40 yrs)
2-0425.00	249	Chickahominy near Providence Forge. Lat. 37° 26' 10" Long. 77° 03' 40"	6,680.0	4.1	263 (24 yrs)

*The Kanawha Canal, no longer in use, diverts water around the "James River near Richmond" gaging station (2-0374.00) and therefore a true picture of the James' flow requires both stations.

These figures have been taken from the Virginia Division of Water Resources publication "Flow Characteristics of Virginia Streams, South Atlantic Basin", basic data bulletin 34.

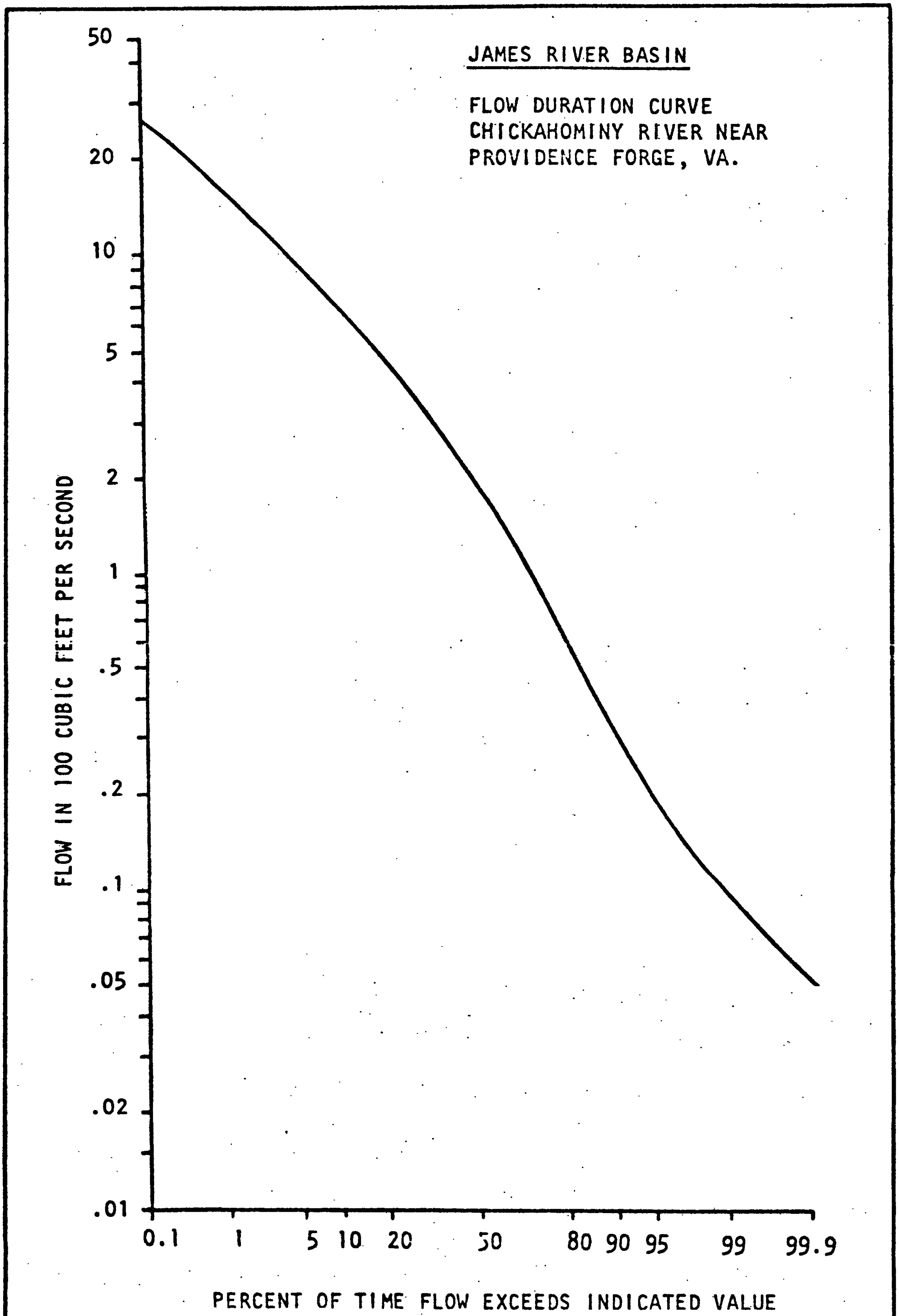
Also of great interest are flow duration curves which are a cumulative graphical display of the percent of time a certain flow is equalled or exceeded at a given gaging station. One of the prime purposes of these curves is to aid in decisions concerning power development, since they give a historical record of the availability of flow, and thus an indication of future possibilities. It is a record of average conditions over the years for which it has been compiled. It does not indicate, however, the sequence of flows. Flow duration curves for the four stations previously mentioned are given in figures II through IV. The "James River" curve, figure II, includes the flow of the Kanawha Canal. Only three figures, therefore, are presented here. Similar curves for other stations in the James basin, plus much other valuable hydrologic data, may be found in the Virginia Division of Water Resources Comprehensive Water Resources Plan for the James River Basin, Volume III... Hydrologic Analysis, from which these curves were taken.

These inputs, then, are the source of the great majority of the fresh water to the tidal James. This, in turn, in large measure controls the extent of the salt water intrusion into the James from seaward, and has important implications for many of the species that reside therein.



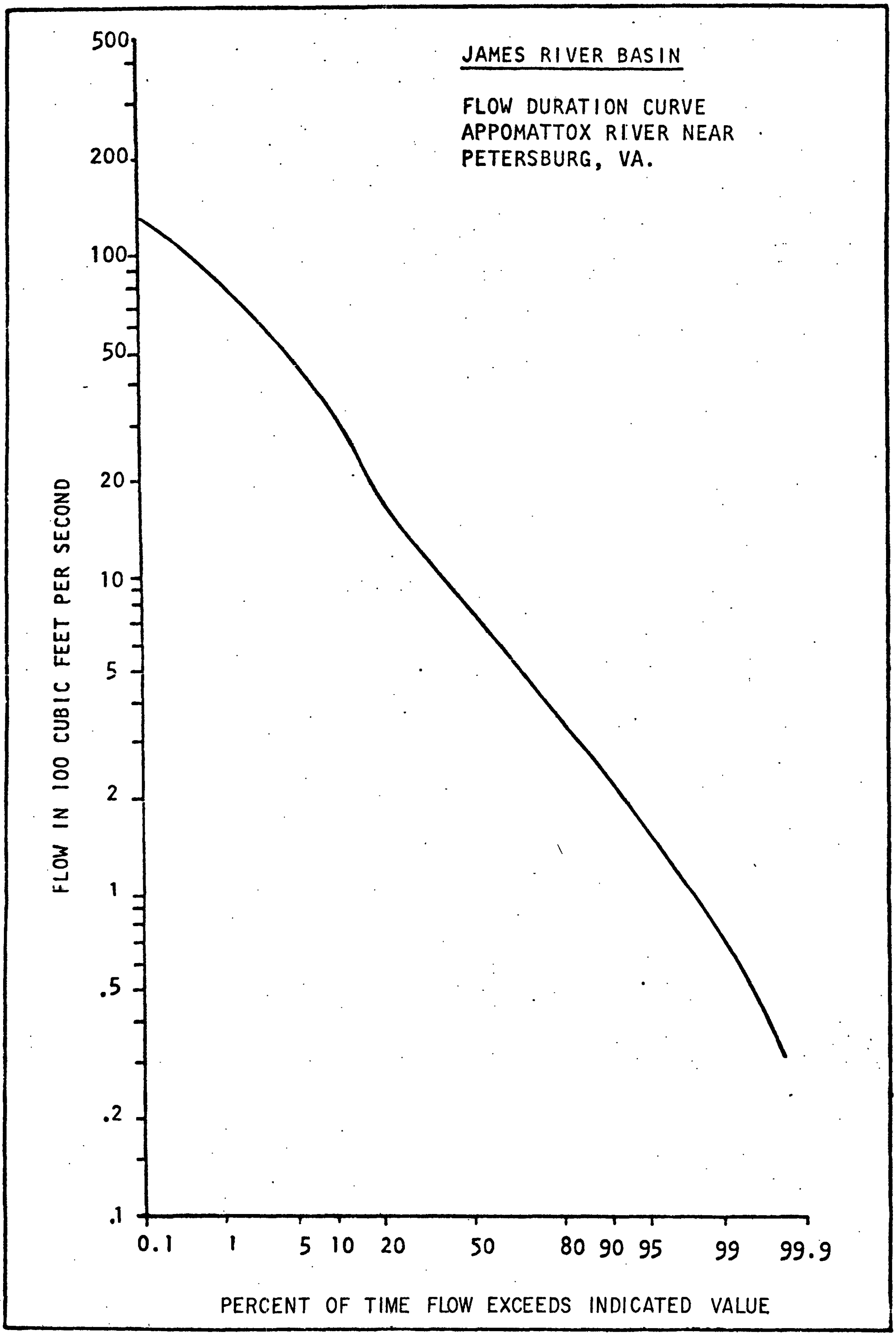
Source: Virginia Division of Water Resources

Figure II



Source: Virginia Division of Water Resources

Figure III



Source: Virginia Division of Water Resources

Figure IV

C. Monitoring

The State Division of Water Resources of the Department of Conservation and Economic Development, the State Water Control Board, and the State Department of Health are the agencies of Virginia which presently monitor water conditions on a continuing, year round basis. The locations at which these measurements are taken either have permanently mounted instruments, or are occupied on a regular basis by portable equipment.

The Virginia Institute of Marine Science also monitors the tidal portion of state waters, but generally in pursuit of special objectives or solutions to particular problems. Usually sampling continues only over relatively short periods of time for each task. However, for certain parameters and locations observations have been made over much longer periods. Continuous sampling has been conducted in the James, and more is planned by VIMS. Biological monitoring with associated hydrographic sampling has gone on for many years. Some special areas (such as the water off the end of VIMS pier at the entrance to the York River) have been sampled continuously over considerable lengths of time.

While each agency conducts monitoring to serve its own needs and discharge its own responsibilities, there are obviously considerable areas of overlap. This duplication problem is under attack by the Interagency Water Resources Coordinating Committee. Consideration is currently being given to the present and future monitoring needs of the various agencies, and programs to insure coordination and the compatability of data formats are being developed. A meeting of this ad-hoc committee was held in May of 1971 at the Virginia Institute of Marine Science, at which the monitoring needs and capabilities of the various agencies were discussed. Much of the information contained in this section is based on the minutes of this meeting.

Division of Water Resources

Responsibilities

The Division of Water Resources is charged with investigating the occurrence, availability, distribution, and quality of the water resources of the state and the existing and contemplated uses and needs of water for all purposes. The Division of Water Resources is also charged with the responsibility of formulating plans and programs which will assure that existing and contemplated future needs of water for all purposes will be met.

This agency is primarily interested in the availability and distribution of water, both surface and ground. It operates in close coordination with the United States Geological Survey to gather data on streamflow in the state. The DWR operates 72 recording gages in Virginia, and USGS 90. Over 100 partial record stations also furnish data on an occasional basis. There are 13 chemical monitoring stations throughout the state, 20 ground water level stations, 3 tide observation stations, and 4 suspended sediment stations.[46]

In the James Basin, there are 37 gaging stations, 21 operated by the DWR, and 16 by the USGS.

All of the stream gaging stations in the James Basin operated by these two agencies are above the influence of the tide, and hence beyond the scope of our immediate interest. DWR maintains no chemical, suspended sediment, or tide observation stations in the tidal James. Major contributors to the tidal James Estuary...the Appomattox and the Chickahominy, as well as the input ot the estuary from the James itself...have been described elsewhere in this paper.

At the May '71 meeting of the Inter-Agency Water Resources Coordinating Committee, the Division of Water Resources gave the following as important monitoring needs:

a. More chemical and biochemical monitoring of surface waters on a continuing basis.

b. More monitoring of suspended sediments.

c. Monitoring of surface water withdrawals.

d. Improved monitoring of chemical and physical characteristics of ground water, along with ground water levels and utilization.

e. Rate of travel for water must be determined in rivers over a wide range of stream flow rates.

f. Dispersion must be determined in tidal and non-tidal streams.

g. Fluctuations in flow at various tide stages must be determined for tidal waters.

Water Control Board

Responsibilities

The State Water Control Board is responsible for the enforcement of the Virginia State Water Control Law, which has four objectives: to protect existing high quality state waters and restore all other state waters to such condition of quality that any such waters will permit all reasonable public uses and will support the propagation and growth of all aquatic life, including food and game fish that might reasonably be expected to inhabit them; to safeguard the clean waters of the State from pollution; to prevent any increase in pollution; and to reduce existing pollution. The Board is authorized to establish water quality standards and to issue, revoke, and/or amend certificates for sewage and waste discharges into state waters under prescribed conditions. The Board has authority to issue orders, either directly or through the courts, to owners directing them to comply with water quality standards and other clean stream objectives. The Board disburses Federal (50 or 55%) and state (25%) grants to municipalities to aid in the construction of sewage works. The Board is also responsible for research and investigations to discover methods for preventing pollution and for the investigation of large scale fishkills believed to have resulted from pollution. The Board also investigates oil spills and other releases of foreign substances or hazardous material into state waters in conjunction with other state and Federal agencies.

The Water Control Board has approximately six hundred stations throughout Virginia, which are occupied on an average of once per month. Samples are collected manually, and returned to a central laboratory in

Richmond for analysis. Samples are analyzed both from a sanitation standpoint, and for the presence of heavy metals such as mercury, cadmium, lead, and so forth, in accordance with the water quality standards listed in the section on Water Quality Standards, above.

The Water Control Board has 29 monitoring stations in the tidal James and its tributaries.

Water Control Board monitoring needs were given at the previously mentioned Inter-Agency Water Resources Coordinating Committee meeting as being basically "the same as those of the Division of Water Resources."

The Water Control Board has underway a 3-phase program for updating their monitoring procedures. These are:

> Phase one:
>
> Trailers utilizing the Ohio River Sanitation Commission (ORSANCO) system will be taken to the various survey points. Under this system, the following water quality parameters can be rapidly measured by probes:
>
> Dissolved oxygen
> Ph
> Temperature
> Conductivity, and
> Nitrates
>
> Currently, as a forerunner of phase one, four trailers employing this system are being utilized in the New River Basin.
>
> Phase two:
>
> Permanent stations will be positioned at the various survey points for continuous monitoring, with manual collection of data.

Phase three:

> All stations will be tied to a central location in Richmond for remote readout, either by landline or radio, thus removing the need for periodic visits to collect data.

At present, industries report their effluent amounts and types to the Water Control Board which is only equipped to make spot checks. Most data received from industry is considered to be honest, but the current surveillance of effluents is held to be less than satisfactory.

Department of Health

The Department of Health has two sub-divisions involved in monitoring water quality, the Bureau of Sanitary Engineering, and the Bureau of Shellfish Sanitation. These will be treated in turn.

Bureau of Sanitary Engineering

Responsibilities

The Bureau of Sanitary Engineering is responsible for administering and carrying out a Sanitary Engineering Program for the State of Virginia. It exercises general supervision and control over 1159 public water supplies and waterworks in the State insofar as the sanitary and physical quality of the waters furnished may affect the health or comfort. The Bureau of Samitary Engineering is responsible to the State Health Commissioner for investigating the purity and fitness of any water supply for drinking and domestic use and has joint responsibility with the State Water Control Board over supervision and surveillance of waste-water collection and treatment facilities and maintaining stream standards which have been adopted for the streams in the State.

To satisfy its responsibility for safeguarding public water supplies, considerable testing of samples is performed. Routine bacteriological tests were conducted on 19,580 samples in fiscal 1969. In addition to tests conducted by the state, some 22 of the larger cities and counties (such as Richmond, Norfolk, and Fairfax County) conduct their own sampling program.

Chemical analysis is conducted on surface water supplies annually as a general rule. Ground water supplies, which are less subject to change, are chemically analyzed less frequently. Numerically, ground water is the source for the great majority of water supplies. This is particularly true of the rural areas of Tidewater. The more cosmopolitan areas, due to their greater concentration of demand, depend largely on surface water, utilizing ground water as a supplementary source in some cases.

Bureau of Shellfish Sanitation

Responsibilities

The sanitary supervision of the shellfish and crabmeat industries to protect the health of the consumer and assure the acceptability of the product on the receiving market is the responsibility of the Bureau of Shellfish Sanitation.

The Bureau of Shellfish Sanitation has in the past been largely concerned with the more saline portions of Virginia's waters, from which shellfish were taken. It has an estimated 3800 water sampling points in Tidewater, and three laboratories at which the samples can be analyzed. In the James River area, samples are taken on a monthly basis, and analyzed by the Bureau for radiological contaminants and bacteria. Other agencies of the state analyze the samples for heavy metals and pesticides.

The Bureau's bacterial analysis is for the most probable number of coliform and fecal coliform organisms per 100 milliliters.

In the lower James and its tributaries, the Bureau has about 171 sampling stations, centered in that portion of the river below Hog Point. Some of these, in Skiffes, College, and Long Creeks are not sampled regularly. Their surveys, over the years, have led to the establishment of several sections of the river in the area from Skiffe's Creek to Hampton Roads from which shellfish may not be directly sold. Instead, they must be relayed to a cleansing area for a period of 15 days prior to sale. These condemnation areas are shown in figure V.

Lately, a new factor has entered the shellfish picture in the form of the brackish water clam, Rangia cuneata. There have been several indications of commercial interest in this extremely abundant species, new to the Virginia area. This will require the surveillance of greatly increased areas by the Bureau, since it extends much further upstream than the traditionally sought shellfish species, which are the blue crab (Callinectes sapidus), the oyster (Crassostrea virginica), the hard clam (Mercenaria mercenaria) and the soft clam (Mya arenaria). These species, and their habitats, are more fully discussed in the Important Species section of this report.

The Virginia Institute of Marine Science conducts special purpose surveys in the James, which involve taking and analyses of "grab type" hydrographic samples as well as biological sampling. Some biological, chemical, geological and physical sampling while not of the "continuous type" has been carried out regularly, i. e. fortnightly, monthly, semi-annually or annually for many years. Further,the ten-year hydrographic efforts of the Chesapeake Bay Institute of the Johns Hopkins University which yielded the most meaningful early concepts of the physical features of the James and the entire Bay were carried out under contract to VIMS (the old Virginia Fisheries Laboratory) and the Office of Naval Research.

"Continuous" monitoring has been rare except for tidal data. However, such sampling has been made in situ through instrumentation over periods ranging from 24 to 48 hours or longer and extending even through several years.

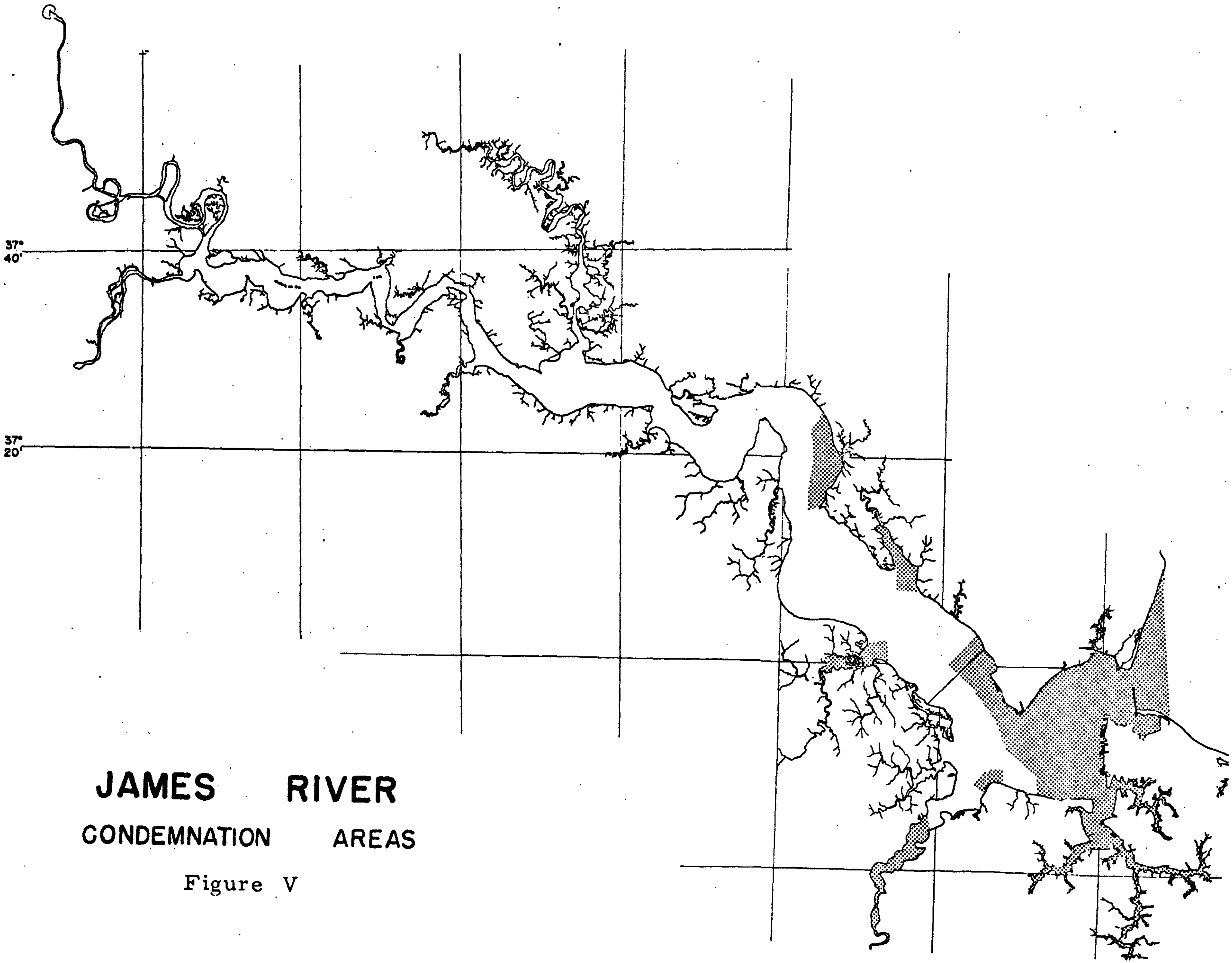
Plans have been made for wide scale continuous monitoring of areas of high interest, but these have not been consumated for lack of funding. These plans remain current and can be revived and implemented upon receipt of adequate financial support. A start has been made with the installation of instruments around Hog Point. An additional instrumented sampling station is set for the James River Bridge (Route 17). Hopefully, a more wide-spread network can be established in the near future. Additional support will be required.

As an example of short term monitoring by VIMS, this summer ('71), as part of a project to develop mathematical and hydraulic models of the tidal James, some 70 sampling stations on 20 transects will be occupied between Richmond and Hampton Roads. At each, a detailed analysis of salinity, temperature, dissolved oxygen, and other parameters of water quality will be made. Tides and currents will also be analyzed at each station.

Longer term programs for specific areas are also in progress. Off Hog Point, baseline studies of water conditions are being conducted so that the effects of the effluent from the nuclear power plant being constructed there upon the stream may be determined. This project, which is cooperative between the Virginia Electric and Power Company (VEPCO) and VIMS, measures primary productivity, phytoplankton, zooplankton, temperature, salinity, fish population, and fouling organism, benthic density and diversity, and includes chemical analysis for oxygen and various metals. The Atomic Energy Commission and NASA are also supporting, through the Institute, part of the continuous, more intense and long-term sampling indicated above.

In addition, VIMS collects hydrographic data such as salinity, temperture, current velocity and direction, conductivity, O_2 levels, disc visibility, etcetera, each time a biological or geological "station" is made. The data are added to that already in our data banks, for future recall as necessary.

VIMS also conducts biological sampling on a continuing basis to determine fluctuations in population. This has been carried on over a period of several years. In the case of benthic fishes, for instance, monthly samples have been collected at ten mile intervals from the mouth of Chesapeake Bay up the York to fresh water in the Pamunkey River since 1956. Similar fishery observations have been made for extended periods in the James. In the case of the blue crab, sampling allows prediction by VIMS of the size of coming year-class of marketable crabs.



JAMES RIVER

CONDEMNATION AREAS

Figure V

D. Water Withdrawals

Water withdrawals in the James River basin are from two sources, surface water from streams, lakes, and reservoirs, and ground water from wells at different depths. These sources are utilized as follows:

Surface - Cooling water for the electrical generating industry.
Ground - Private water supply (domestic use) [47]
Surface and Ground - Public water supply. Industrial cooling and product make - up. Irrigation.

It should be realized that public water supplies are not used entirely for household purposes. A nationwide survey reported by the Journal of the American Waterworks Association in July of 1966, gives uses as follows:

Residential	45%
Commercial	18%
Industrial	32%
Municipal	5%
	100%

The four basic parts of the hydrologic cycle are precipitation, evaporation, surface runoff, and ground water. The first two were described as a part of meteorological conditions. Since our basic interest is water quality in the lower James River, surface water only will be discussed here.

Major surface water withdrawals [48] for the area of the tidal James are listed below, in Table L , under the following categories:

Public water supply
Industrial water supply
Steam-Electric Generating Withdrawal

The information in this section is based upon the Virginia Division of Water Resources Comprehensive Water Resources Plan for the James River Basin, Volume I.

TABLE L

MAJOR SURFACE WATER WITHDRAWALS

LOWER JAMES BASIN

Year of Use - 1967

From the James River:

Public Water Supply

User	MGD
City of Richmond	37.800*

* Includes 6.899 mgd for Henrico County, and 1.560 mgd for Chesterfield County.

Industrial Water Supply

User	Location	MGD
Allied Chemical Corp. (Fibers Div.)	Chesterfield County	50.000
American Tobacco Co.	Chesterfield County	6.300
E. I. DuPont de Nemours and Co. (Spruance Plant)	Richmond	33.400
Federal Board and Paper Co.	Richmond	
Southern Mill*		1.250
Seaboard Mill		1.500
Standard Paper Co.*	Richmond	3.500
Southern Materials Co.		
Chesterfield County		1.500
Henrico County		1.900
Allied Chemical Corp.		
Agriculture Div.	Hopewell	180.000
Plastics Div.	Hopewell	75.000
Continental Can Co.	Hopewell	15.000
Newport News Shipbuilding Corp.	Newport News	17.000

* Manchester Canal

Steam-Electric Generating

Plant	Units	Location	MGD
12th Street	3	Chesterfield County	102.00
Dutch Gap	5	Dutch Gap	590.00

From the Appomatox River:

Public Water Supply

User	MGD
Colonial Heights	1.076
Petersburg	6.199

Industrial Water Supply

User	Location	MGD
Old Dominion Water Co.	Prince George County	25.000

Old Dominion provides water for the City of Hopewell and the following industries:

Hercules

Continental Can

Firestone

Allied Chemical

Individual amounts are not available.

From the Chickahominy River:

Public Water Supply

User	MGD
City of Newport News*	27.256
Williamsburg	2.464

* Newport News supplies the city of Hampton

From the Elizabeth River:

Industrial Water Supply

User	Location	MGD
Smith Douglas Fertilizer Co.	Chesapeake City	2.000
Swift and Co.	Chesapeake City	1.500
Virginia Chemicals Inc.	Chesapeake City	4.070

Steam-Electric Generating

Plant	Units	Location	MGD
Reeves Ave.	2	Norfolk	101.000
Portsmouth	4	Portsmouth	514.000

From Minor Tributaries:

Public Water Supply

User	Tributary	MGD
Chesterfield County	Swift Creek	1.680
	Falling Creek	2.220

Industrial Water Supply

User	Tributary	Location	MGD
Kyanite Mining Co.	Spring Creek	Prince Edward County	1.728
West Sand and Gravel Co.	Gillies Creek	Henrico County	1.200

Source: Virginia Division of Water Resources

There is very little use of the James itself below Richmond for Public Water Supply purposes. This is due to two main causes; the pollutants added by Richmond and Hopewell, and the increasing salinity of the river below the stretches where these pollutants have been assimilated.

The major cities in Tidewater not listed in the table above depend largely on reservoirs and impoundments, and, to a lesser extent, on ground water.

As examples:

City	Sources		MGD
Norfolk	Lake Prince		-
	Burnt Mills		-
	Western Branch Reservoir		-
	Stumpy Lake Reservoir		-
	Nottoway River*		-
	Blackwater River*		-
		Subtotal	52.500
Portsmouth	Speights Run		-
	Lake Kilby		-
	Lake Cohoon		-
	Lake Meade		-
		Subtotal	14.682
	Groundwater		2.573
		Total	17.255

*Supplemental pumpage.

The major cities supply the lesser as follows:

Norfolk: Virginia Beach (also utilizes ground water)

Portsmouth: Suffolk

Both Norfolk and Portsmouth supply Chesapeake City.

The counties surrounding the tidal James - Isle of Wight, James City, Nansemond, Prince George, and Surry - all derive their public water supplies from ground water.

By far the greatest users of water from any source are the Steam-Electric Generating Plants. Most of the water withdrawn by them, however, is for cooling purposes, and is returned directly to the stream from which it was removed.

E. Effluent Discharges

Organic matter added to a natural body of water will be oxidized to carbon dioxide and water, provided sufficient time is allowed, and the organic loading is not too great for the amount of oxygen present in the water. To facilitate calculating amounts of oxygen required, effluents are often rated in terms of biochemical oxygen demand.

Biochemical oxygen demand (BOD) can be defined as the oxygen bacteria require to stabilize, under aerobic conditions, decomposable organic matter in water. While effluents that create BOD are certainly not the only pollutants that foul our waters, BOD is an extremely important parameter in judging water quality. Too, it provides a sort of "common denominator" by which different pollutants may be compared, and summed. Theoretically, an infinite amount of time is required for complete oxydation of biologically degradable material. It has been found, however, that the process is largely complete within a period of 20 days. Even this is too long for practical applications, so the use of "5-Day" BOD has become common. It must be remembered that only 70 to 80 percent of the total BOD has been completed at that time.

Waste discharges in the Tidal James are from two chief sources - domestic wastes (sewage), and industrial wastes. Many of these discharges are to smaller tributaries, and it is therefore more convenient to list such discharges by counties and cities, rather than by the bodies of water into which they flow.

Effluents are given in pounds per day of 5-day BOD, and only major contributers -- those who discharge more than 100 pounds per day...are listed.

TABLE M

MAJOR DISCHARGES

TIDAL JAMES RIVER AND TRIBUTARIES

(Data from 1967)

CITIES

City	Receiving Stream	5-Day BOD Pounds Per Day
Richmond	James R.	33,900[a]
Colonial Heights	Appomattox R.	1,350[b]
Petersburg	Appomattox R.	8,620
Chesapeake	S. Branch of Elizabeth River	350[b]
Hopewell	Baileys Creek	2,970
Portsmouth	Elizabeth River	12,060
Suffolk	Nansemond River	1,140[b]
Carolanne Farms	E. Branch Elizabeth River	228[b]
Fort Eustis	James River	4,200
Williamsburg	College Creek	375[b]

Hampton Roads Sanitation District (HRSD) plants provide services for all or part of the following cities:

Chesapeake

Hampton

Newport News

Norfolk

Virginia Beach

HRSD Plants	Location	Receiving Stream	5-Day BOD Pounds per Day
Army Base Plant	Norfolk	Elizabeth R.	9,450
Boat Harbor Plant	Newport News	Hampton Roads	18,200
James River Plant	Newport News	James River	175
Lamberts Point Plant	Norfolk	Elizabeth R.	28,400
Patrick Henry Plant	Newport News	Lucas Creek-Warwick	210
Western Branch Plant	Portsmouth	Elizabeth River	300
Washington Plant	Chesapeake	S. Branch Elizabeth R.	700[b]
Borough of Virginia Beach Plant	Va. Beach	Little Creek	8,000
Princess Ann Utilities Plant	Va. Beach	London Bridge Creek	100[b]

The last two plants are in the process of being connected, or recently have been connected, to HRSD. They do not discharge to the James River or its tributaries, but are included as part of HRSD.

COUNTIES

County	Location	Receiving Stream	5-Day BOD Pounds per Day
Chesterfield	Bellwood Depot	James River	240[b]
	Brighton-Bon Air	Powhite Creek	200[b]
	Falling Creek	James River	3,910[b]
	James River Lagoon	James River	180[b]
Prince George	Continental Can. Co.[c]	Gravelly Run	120[b]
	Fort Lee	Bailey Creek	1,200[b]
	Hercules Powder Co.[c]	Bailey Creek	140[b]

INDUSTRIAL DISCHARGES

Contributor	Location	Receiving Stream	5-Day BOD Pounds per Da
Albermarle Paper Co.	Richmond	James River	290
Allied Chemical Corp (Fibers Div.)	Chesterfield Co.	James River	960
American Tobacco Co.	Chesterfield Co.	James River	7,800
E. I. Dupont (Spruance Plant)	Richmond	James River	4,400
Federal Paper Board			
Seaboard Mill	Richmond	James River	1,530
Southern Mill	Richmond	James River	2,210
Standard Paper Co.			
Mill #1	Richmond	James River	250
Mill #3		James River	1,350
Allied Chemical and Dye Co. (Plastics Div.)	Prince George Co.	Gravelly Run	3,340
Continental Can Co.	Hopewell	Gravelly Run	39,840
Firestone Synthetic Fibers Co.	Hopewell	Cattail Creek	1,280
Hercules Powder Corp.	Prince George Co.	Cattail Creek	39,400
Smithfield Packing Co.[d]	Nansemond County	Pagan River	800[b]

[a] Plant effluents plus estimates of raw sewerage outfalls.

[b] Estimated.

[c] Sanitary Waste.

[d] 1959 report.

Source: Division of Water Resources.

F. Nutrient Levels

The James, like most river systems, is a multi-use resource. Among these uses is one currently in extreme disfavor, but for which exsists considerable economic justification and historic precedent. This use, of course, is for the disposal of wastes.

As strange as it may seem, over-enrichment of a stream sometimes results from the operation of sewage treatment plants. These plants generally remove wastes with high BOD and break them down into their basic chemical components before discharge. These components are the "action" ingredients of commercial fertilizers - phosphorus, nitrogen, and to some extent potassium. Indeed, "sludge" from sewage treatment plants is sometimes sold as fertilizer. These elements, then , actually fertilize the receiving stream, stimulating plant growth. This excessive plant growth can, in the absence of sunlight, remove all the available dissolved oxygen from a stream overnight. As these plants die and decay, they also add to the demand for oxygen, compounding the problem.

Addition of small amounts of nutrients, however, might better be called "enrichment" instead of "pollution", since a moderate increase in the microscopic plants of the water will benefit filter-feeders such as oysters, clams, menhaden, and the larval forms of many species. This, in turn, would benefit the larger carnivorous species that feed upon them.

Of course, if the added nutrients are beyond the assimilation capacity of the receiving stream and the dilution of the nutrients is inadequate, a phytoplankton bloom may occur that will prove an asthetic nuisance and a biological disaster.

Freshwater streams with oneway flows have a considerably greater ability to assimilate nutrients than does a tidal basin such as the James below Richmond, where the relatively low river flow, the enormous volume of water, and the flood and ebb of the tides combine to concentrate rather than disperse nutrients. For instance, if nutrients were introduced on a flood tide at Hopewell, they could be carried upstream by the tide. As the tide ebbed, these nutrients would be carried again past the point of their introduction to be reinforced by effluents being added at that time, thereby concentrating the nutrients.

An additional problem faced by an estuary is caused by the increased salinity of the seaward protion of the system. Freshwater algae, carrying the nutrients which caused their explosive growth, die when introduced by the river's overall downstream motion into the zone where salinity becomes a factor. This "transition" zone, discussed more fully in the section on Salinity, becomes, in effect, a dumping ground for the nutrients carried by the dying algae, as well as a source of oxygen for their decaying mass.

There are three main areas where nutrient enrichment of the tidal James occurs. These are:

> The head of tidal waters at Richmond,
> The area just below Hopewell, and
> The section near the mouth, where the effluents from the cities surrounding Hampton Roads are discharged.

In 1965-66, Dr. Morris L. Brehmer of the Virginia Institute of Marine Science conducted a study of nutrients in the James and Nansemond Rivers.[49]

Figure VI indicates the stations in the James at which data was taken. Figures VII and VIII give the nutrient levels and the biomass (as indicated by chlorophyll "a") level measured at six foot intervals in the water column during two different months; figures IX and X give nutrient levels in the top centimeter of sediment.

According to Brehmer,[50] the upper tidal portion, which has the least assimilation capacity, receives domestic wastes from the city of Richmond of which part has primary treatment, a part secondary, and about a third no treatment at all. In addition, about 2.7 metric tons of phosphorus and 8.2 metric tons of nitrogen from various sources are added each day.

Hopewell, a city of considerable industrialization, also adds large amounts of nutrients to the river as indicated by figures VII and VIII.

In the Hampton Roads area, though large amounts of nutrients are added, the volume of water involved is so great that thorough dilution occurs, and the resulting nutrient level is relatively low.

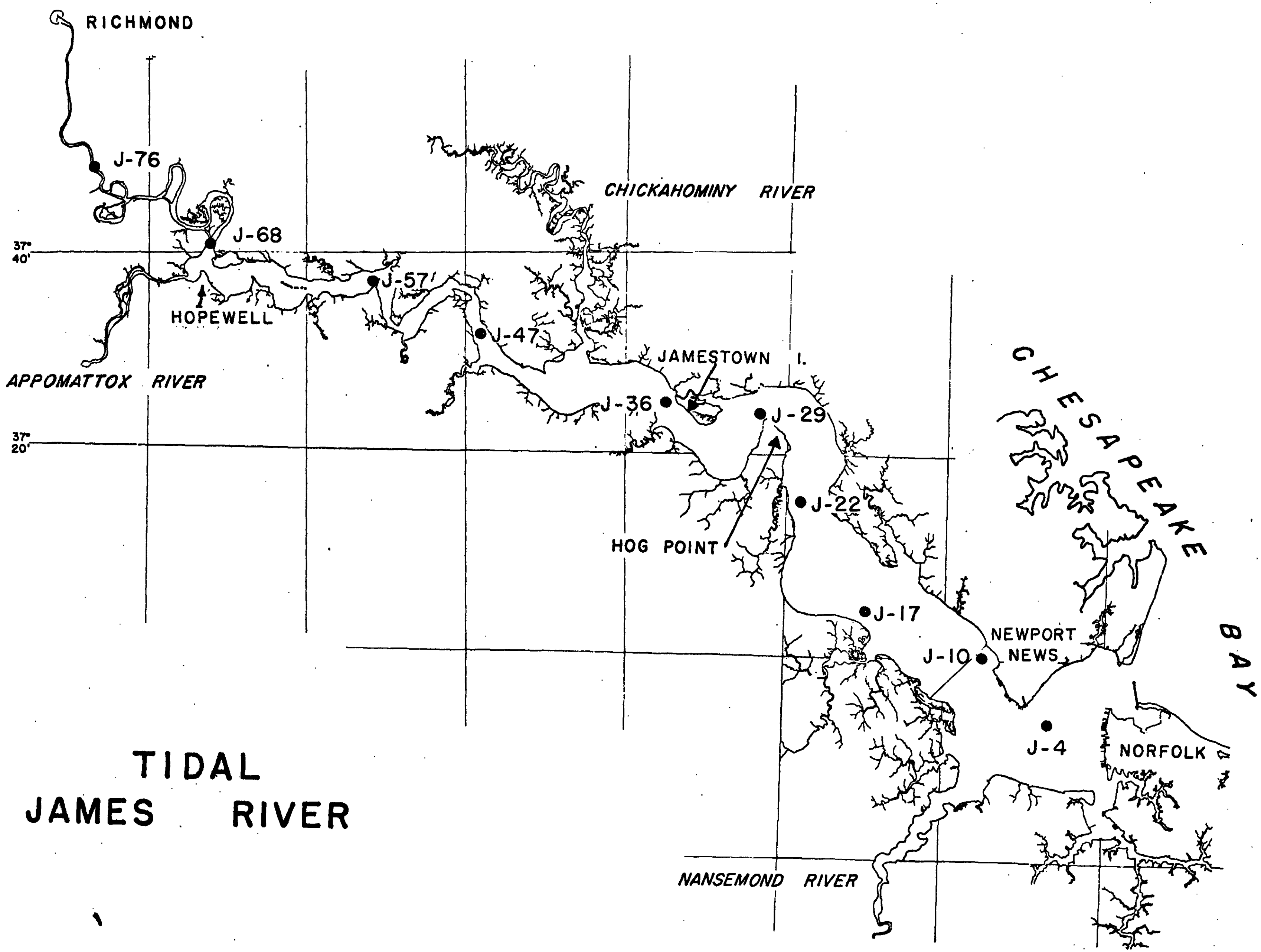


Fig. VI. -- James River. Sampling Stations Designated According to Miles from Mouth. Source: Brehmer, 1967.

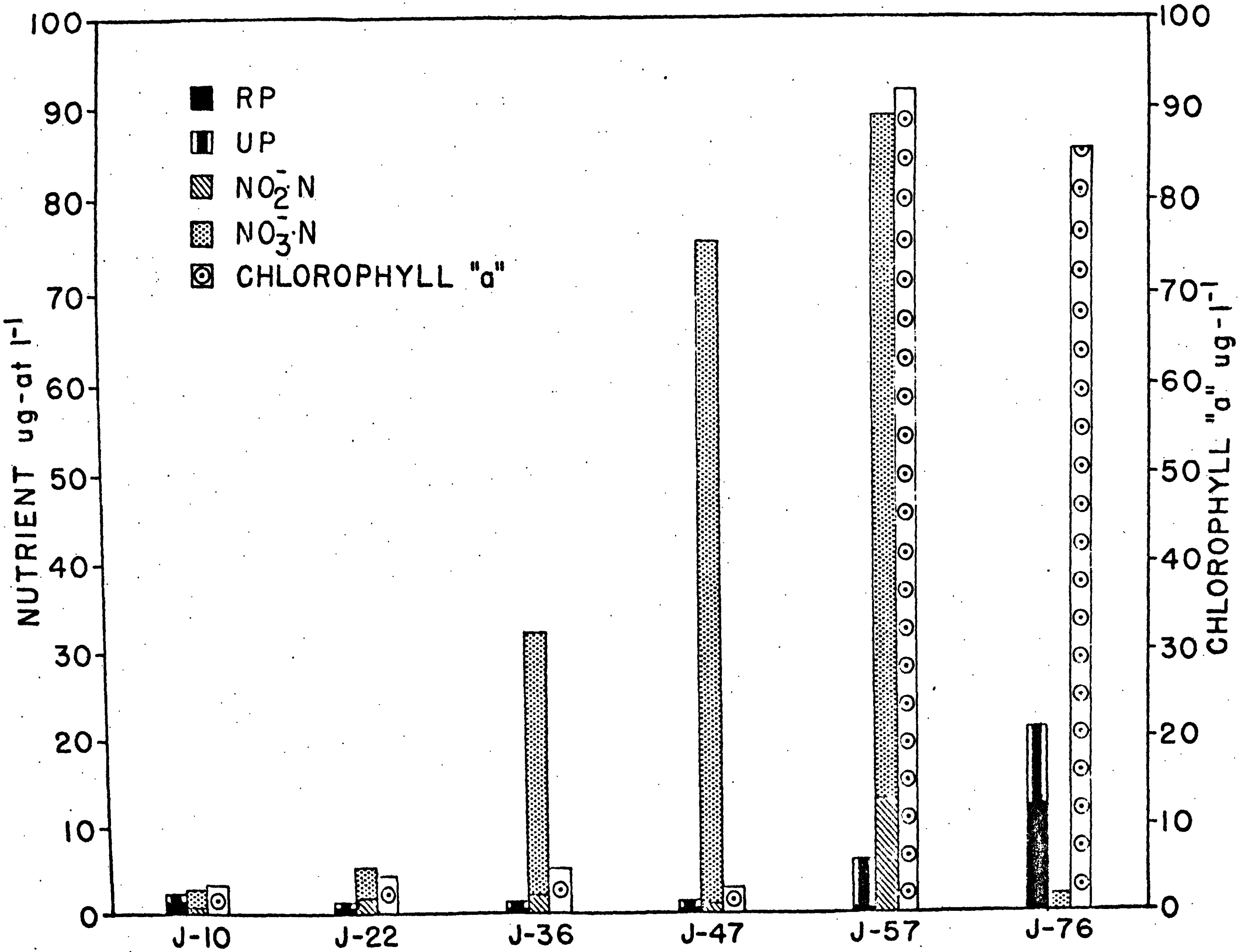


Fig. VII. -- Chlorphyll "a", Nitrite and Nitrate Nitrogen, and Phorphorus at Six Stations on the James River During September.

Source: Brehmer, 1967.

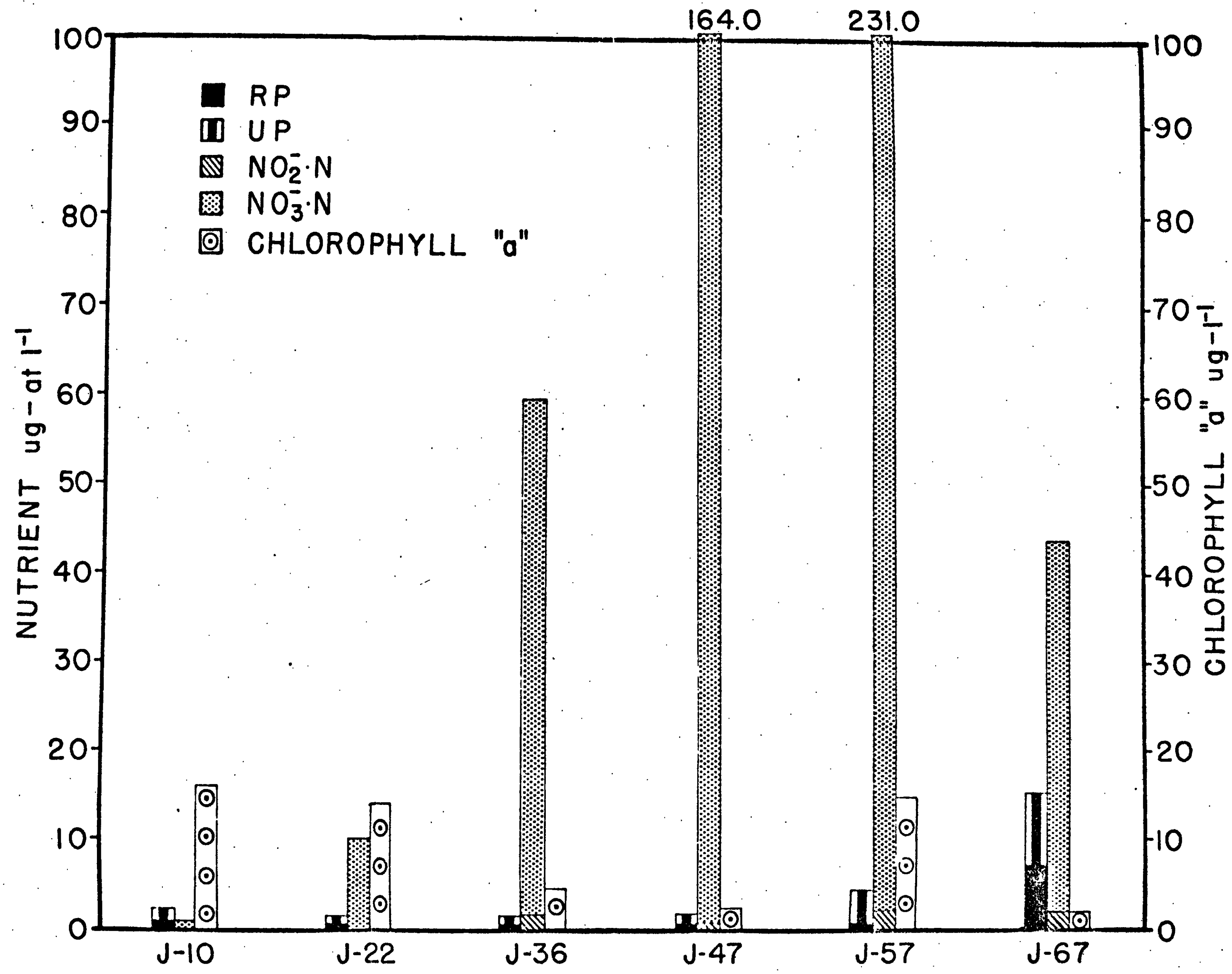


Fig. VIII. -- Chlorophyll "a", Nitrite and Nitrate Nitrogen, and Phosphorus at Six Stations on the James River During December.

Source: Brehmer, 1967.

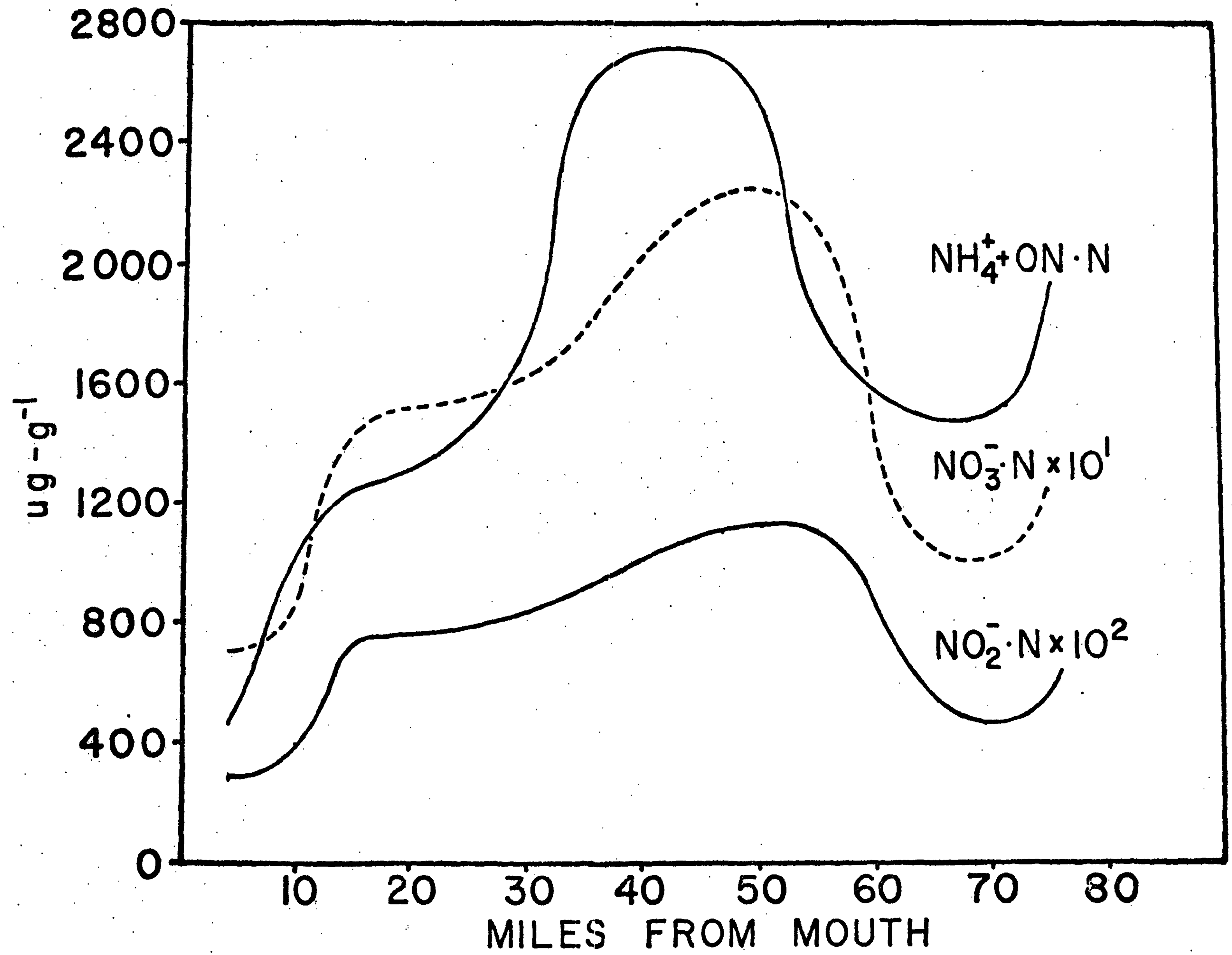


Fig. IX. -- Nitrite, Nitrate, Ammonia, and Organic Nitrogen in Top 1 cm of James River Sediments.

Source: Brehmer, 1967.

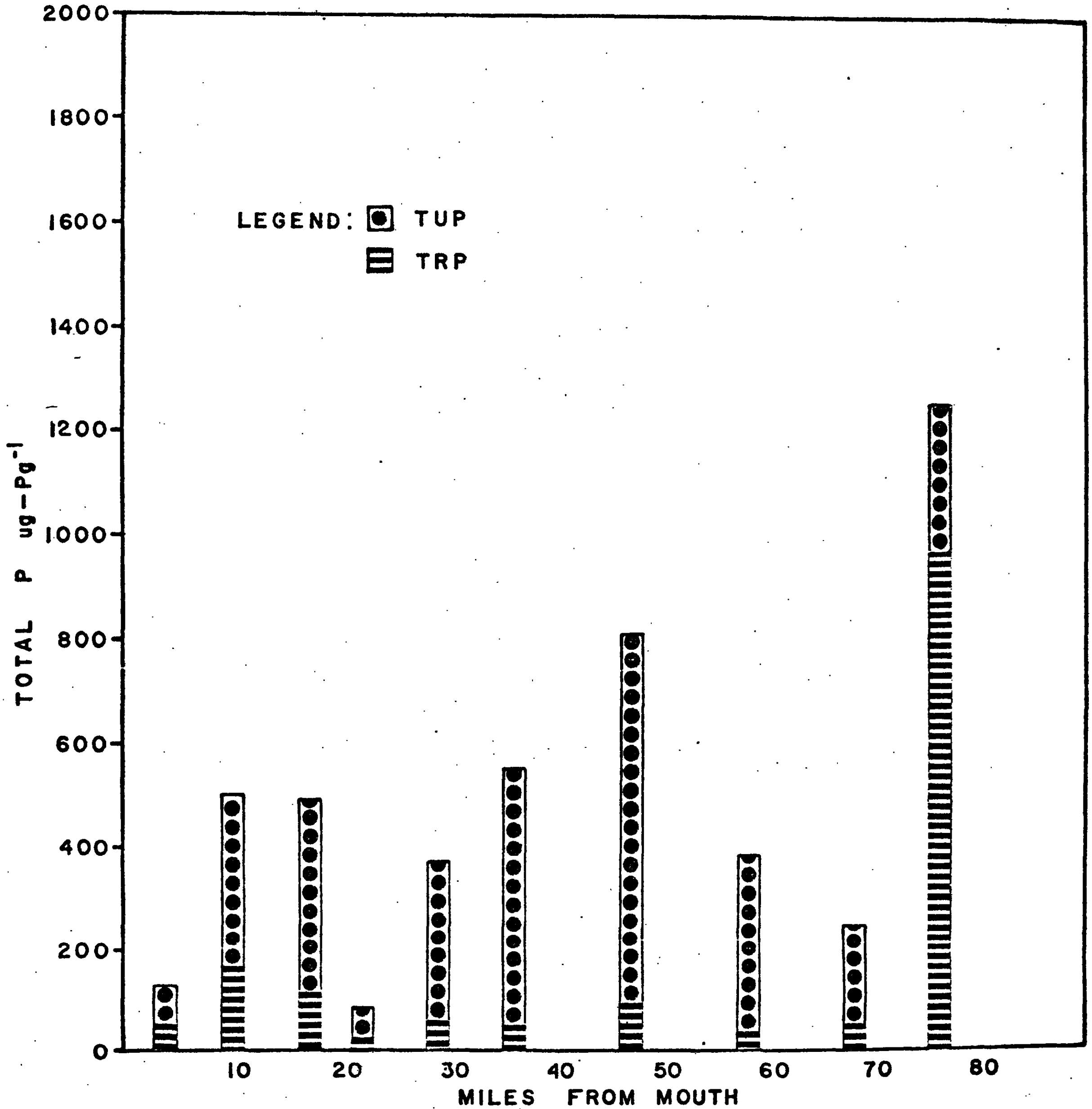


Fig. X. -- Total Unreactive and Reactive Phosphorus in Top 1 cm of James River Sediments.

Source: Brehmer, 1967.

G. Bacterial Levels

Bacterial levels in the Tidal James River are highest in the area between Richmond and Hopewell, frequently far exceeding the standards published by the State Water Control Board, outlined in the section on Water Quality Standards earlier in this report. Since the section immediately above Richmond is relatively free of such contaminations, the effluents added by that city, particularly the untreated sewage, are obviously responsible.

Bacterial levels taken at a point source are ephemeral, to say the least. They vary with stream flow, precipitation, depth, and effluent discharge rates to mention only some of the more prominent determining factors. They can, therefore, be expected to change, not only by the day or hour, but by the minute.

For this reason, data taken at any particular point in time or space should be regarded with skepticism. Data collected at points within an area, all of which are of the same order of magnitude, may be taken as an indication of levels in that area at that time.

Table N reflects data gathered by the State Water Control Board during the months of May and June, 1971. Readings were taken at mid-depths (except one) on the dates indicated. While certainly not definitive, area trends are apparent. Note the relatively high level of the Richmond - Hopewell sector, and the general improvement thereafter.

The readings for the Richmond - Hopewell sector, while seemingly high, are actually somewhat lower than might be normally expected, possibly due to heavy rains in May and June. According to Dr. Morris L. Brehemer of

VIMS, readings as high as 2,400,000 fecal coliform organisms per 100 milliliters have been recorded in this area.

Figure XI indicates the points on the Tidal James at which data was taken. The first three stations, just above and in Richmond, are not shown due to the scale employed. Not all points were sampled each month.

TABLE N

Fecal Coliform Levels
James River, Richmond and Below
May - June, 1971

Point	River Mile	Organisms per 100 ml. for May	June
Rt. 147 Bridge	117.14	100[a]	--
Boulevard Bridge*	112.98	800[a]	--
Rt. 360 Bridge	109.56	44,000[a]	--
Bury #175	107.95	400[b]	1,400[d]
Buoy #168	106.18	76,000[b]	2,800[d]
Buoy #166	103.22	> 80,000[b]	8,000[d]
Buoy #157	98.34	> 80,000[b]	4,600[d]
Buoy #155 (Dutch Gap)	96.76	> 80,000[b]	8,000[d]
Buoy #150 (Dutch Gap)	94.84	54,000[b]	1,800[d]
Buoy #126	81.61	6,500[b]	--
Buoy #118	80.01	3,000[b]	--
Rt. 156 Bridge (Jordan Point)	77.44	600[a]	--

TABLE N (Continued)

Point	River Mile	Organisms per 100 ml. for May	June
Buoy #86 (Windmill Point)	69.34	$< 100^{c}$	--
Buoy #74	56.22	$< 100^{c}$	---
Swann Point	42.92	$< 100^{c}$	$1,000^{e}$
Scotland Ferry Pier	41.27	$< 100^{c}$	$< 100^{e}$
Buoy #42 (Hog Point)	34.27	$< 100^{c}$	200^{e}
Buoy #24 (Mulberry Point)	26.07	$< 100^{c}$	$< 100^{e}$
Buoy #12	20.54	$< 100^{c}$	$< 100^{e}$
Rt. 17-I258 Bridge	13.54	$< 100^{c}$	--
Esso Pier (Newport News)	7.77	$< 100^{c}$	--

*Surface reading

[a] Readings made 13 May

[b] Readings made 6 May

[c] Readings made 11 May

[d] Readings made 13 June

[e] Readings made 14 June

Data from Virginia State Water Control Board.

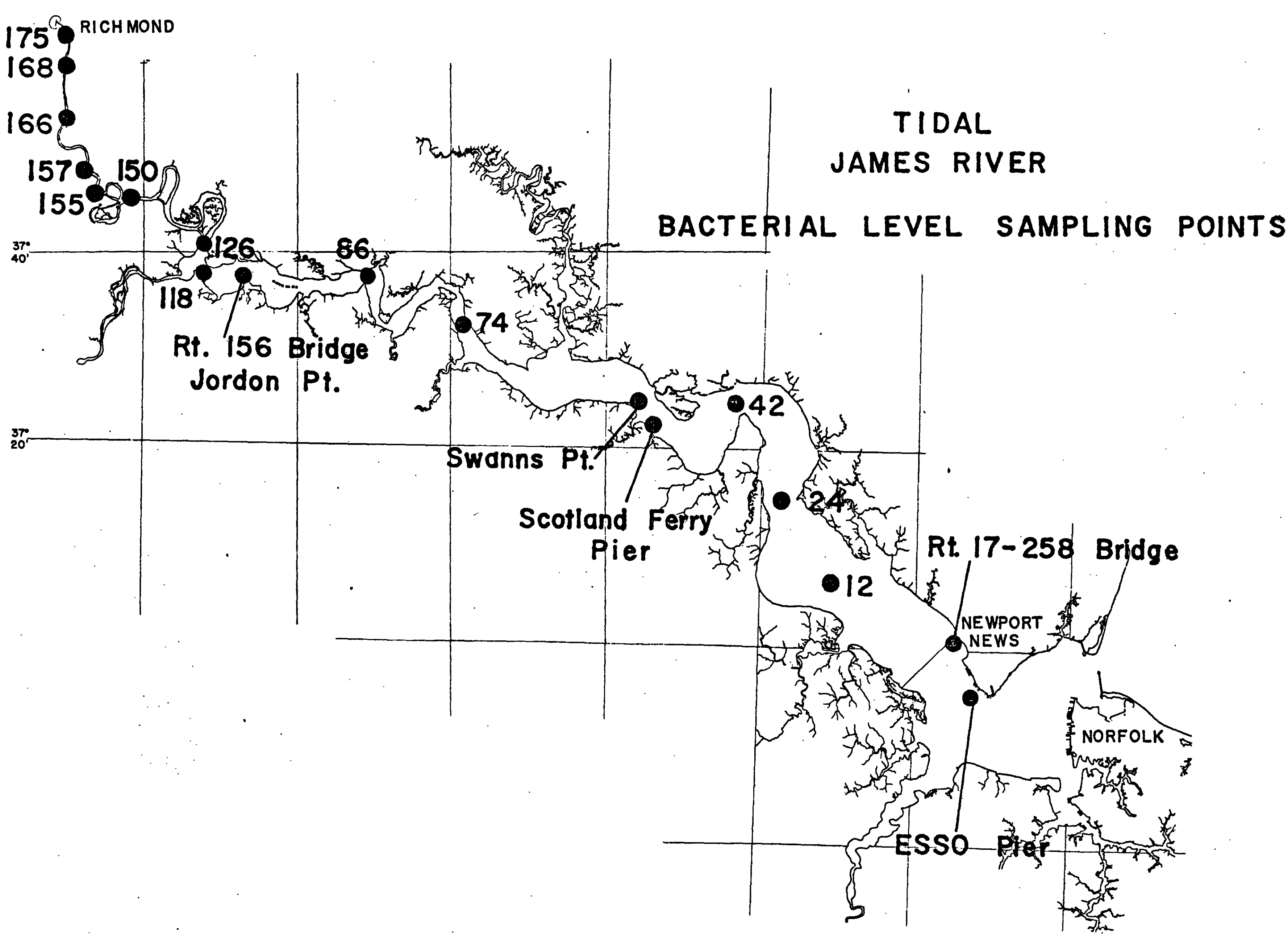

TIDAL
JAMES RIVER
BACTERIAL LEVEL SAMPLING POINTS
RICHMOND
175
168
166
157
150
155
126
86
118
74
Rt. 156 Bridge
Jordon Pt.
37° 40'
37° 20'
42
Swanns Pt.
Scotland Ferry
Pier
24
12
Rt. 17-258 Bridge
NEWPORT
NEWS
NORFOLK
ESSO Pier

Figure XI

H. Salinity

Salinity in an estuary plays a far more important role than the casual observer realizes. Upon its distribution and concentration depend a multitude of processes vital to all the species and communities which inhabit its waters.

The James estuary has a salinity distribution that is a classic example of a coastal plain estuary. To understand the processes that occur in the James estuary, a basic knowledge of the physics of estuarine circulation is necessary. It must be understood that only a small portion of the total discharge at an estuarine river's mouth is fresh water. This is so because an estuarine river has a freshwater input at the inland end, and, near the bottom, a saltwater input at the marine end. There is a gradient, therefore, from about 24 parts per thousand at the mouth to zero salinity at some point up the river. The saltier water, being heavier than the fresh, enters along the bottom in a sort of a wedge, hence the expression "salt wedge estuary". Between the waters of the salt wedge moving up the river, and the fresher surface water moving down, is an area of no net motion where vertical mixing takes place. The isohalines--or lines of equal salinity--do not run straight across the estuary. The earth's rotation causes them to be higher on the right-hand side, facing upstream, in the northern hemisphere. The isohalines move up and downstream following the ebb and flow of the tides, and heavy inflows of fresh water, or low inflows caused by droughts, also cause displacement.

If the freshwater input of a river is taken as 1R, the total discharge at the mouth may be many times as high--perhaps 10R, or 20R, or more. The additional water is the heavier saltier water which has crept in as a wedge underneath and, mixing upward, joined the river outflow. There is, of course, a gradual increase in flow with distance downstream. This mechanism of two-layered flow is of great importance to estuarine life, as we will see in the section on Important Species, below.

In the James, the average salt water intrusion reaches about 35 miles upstream from the mouth. This "transition zone" moves up or downstream with variations in fresh water inflow. Greater inflows move the zone downstream, and lesser flows upstream. This can be as much as 15 miles in either direction. Under the impetus of the floods caused by Hurricane Camille in August, 1969, the salt water wedge retreated as far downstream as the mouth of Deep Creek below Warwick River; during the extreme drought conditions of 1965, it penetrated to Jordan Point, 63.5 miles upriver. These points, along with the normal transition zone range, are indicated on Figure XII.

An average weak vertical salinity stratification exists, but data collected by VIMS personnel (Brehmer, 1965) indicate that a mixing between the fresh and salt layers occurs, and that in late summer, the system becomes nearly homogeneous with respect to salinity, as well as temperature.

Figure XIII portrays average salinity conditions in the James River for the period 1944-1965 for four different seasons of the year. The movement of the isohalines with the varying freshwater inflow is apparent.

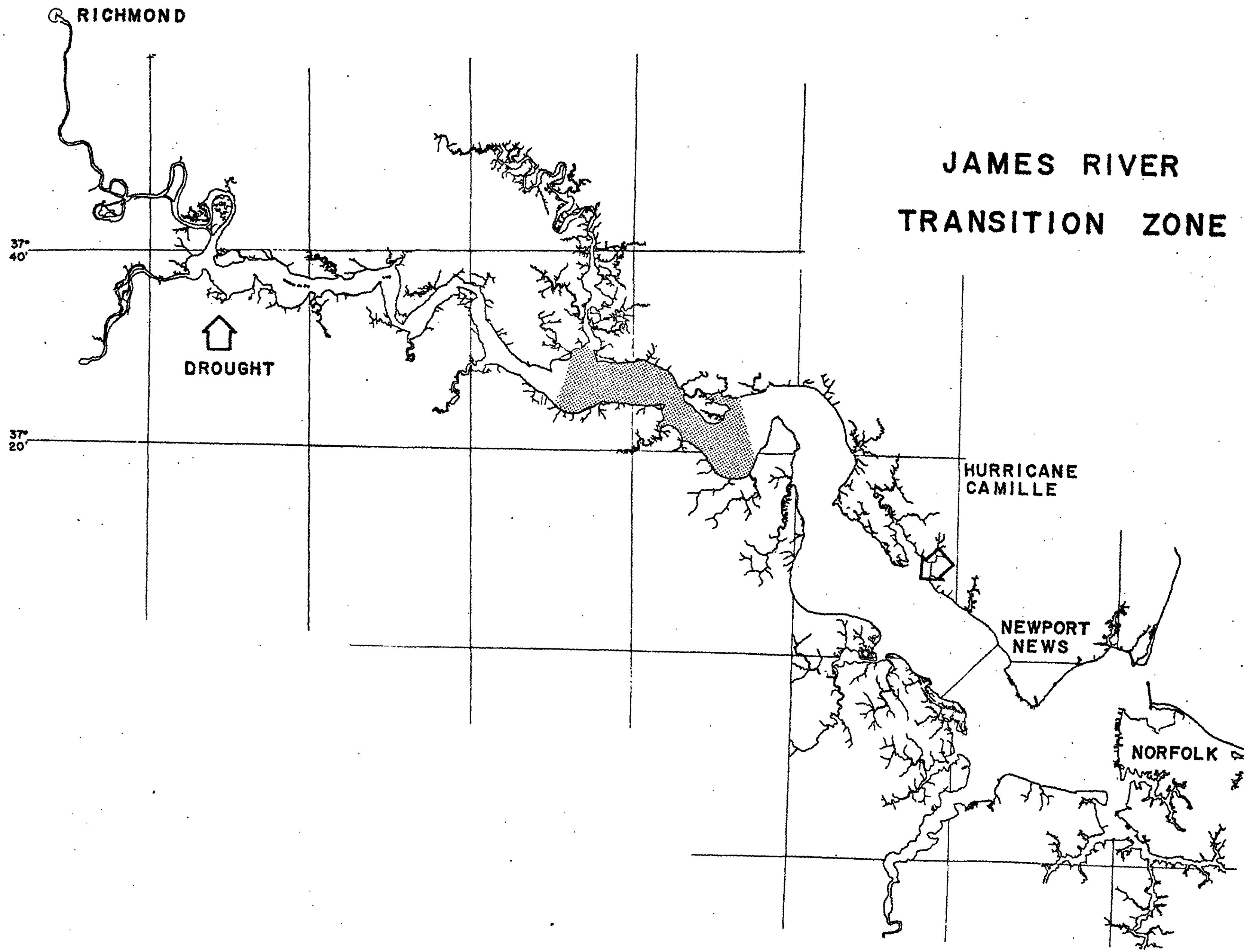
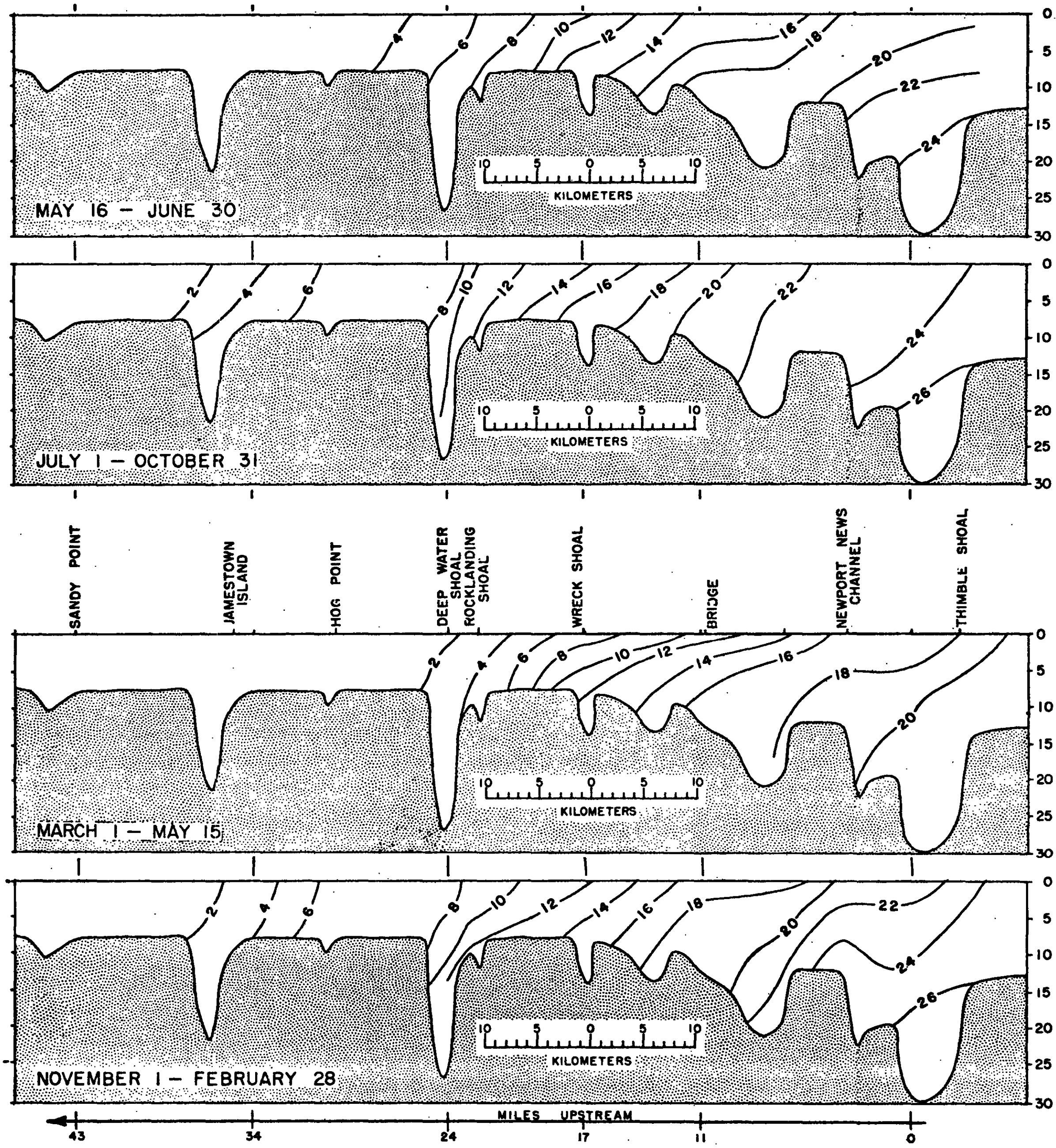

JAMES RIVER
TRANSITION ZONE
RICHMOND
DROUGHT
HURRICANE
CAMILLE
NEWPORT
NEWS
NORFOLK
37°
40'
37°
20'

Figure XII



AVERAGE SALINITY, ‰, 1944 – 1965 **JAMES ESTUARY**

Source: Maynard Nichols, VIMS

Figure XIII

I. Important Species

Oysters

The American oyster, Crassostrea virginica, is by far Virginia's most important seafood commodity. The James River seed oyster producing area occupies a keystone position in the state, since from it comes virtually all the seed oysters upon which the remainder of the state's oyster areas depend.

An explanation of the terms used for grading oysters is germane at this point.

Basically, these terms are:

> Spat - nearly microscopic oysters newly attached to some surface.
>
> Seed Oysters - those of any size which are gathered from specific areas for the purpose of replanting, but generally those less than 2 inches in length, and
>
> Market Oysters - those three inches or over in length.

The "specific areas" referred to in the description of seed oysters are those public areas...in the James and one or two other restricted area...in which there is no "cull law", which requires oysters under three inches in length to be returned to the water. Therefore, any oyster taken from public rocks where no cull law is in force is, preforce, a "seed" oyster.

The seed area in the James extends on the western side of the river from Deepwater Shoals above Mulberry Point to Browns Shoal below the James River Bridge. On the eastern side, it runs from Horsehead Bar to the Nansemond River. The most productive area is centered on Wreck Shoal, off the Warwick River - Deep Creek confluence with the James.

To this area, during the seed months of October through May, come oystermen from all over the state to work the highly productive seed beds. Utilizing hand tongs, they gather 30 to 100 bushels of "seed" per day, which are sold almost on the spot to "buy boats" for $1.25 to $1.50 per bushel. The "buy boats" are the middlemen between the tongers and the planters, and, for a fee (approximately $.25 per bushel, freight, plus $.05 per bushel for planting) transport the oysters to the planter's grounds, and plant them for him.

The "buy boats" pay a tax of 1-1/2 cents per bushel to the state.

The transactions are strictly cash between the various members of the industry, and, given the difficulty of judging the volumes of large amounts of oysters, and in knowing exactly how many bushels are planted, it becomes obvious that considerable financial flexibility is inherent in these proceedings. This is, however, recognized by all concerned, and allowances are made therefor.

The predators upon the James River oysters are the drills (Eupleura caudata and Urosalpinx cinerea) and the oyster leech (Stylochus ellipticus). The pathogens that affect them are Dermocystidium marinum and the protozoan Minchinia nelsoni, or MSX. Of these, Urosalpinx and MSX are the most serious.

Fortunately, both drills and diseases are less tolerant of fresh water than are oysters, so that these pests are generally confined to the lower portion of the seed area by the fresh water inflow to the oyster areas, which keeps the waters saline enough for oysters, but too fresh for the most destructive organisms. This is obviously a delicate balance, and anything tending to disturb it must be viewed with concern.

In the years previous to 1960, the James River seed beds were considered virtually inexhaustible. At this time, several events took place almost simultaneously, and their combined effect has produced a drastic change in the oyster industry of the area.

One of these events was the appearance in the estuarine James of MSX. This disease, which is harmless to humans, caused oyster mortalities of 50 to 70 percent during the first year of exposure, and only slightly lower losses in succeeding years.

A second event whose consequences have not yet been fully realized was the failure of the once prolific "strike" or setting of oyster spat in the James River.

In the same time frame, a large soup company established plants in the area, creating a market for 1-1/2 to 2-1/2 inch oysters called "soups".

Thus, working in concert, these three events have

- --Reduced the total number of oysters in the lower beds (MSX).
- --Not created new oyster resources (failure of strike).
- --Created a direct market for small oysters once sold as seed (soup companies).

The portents are ominous.

Figure XIV indicates the occurrence of oysters in the James. The larger area is considered the "seed" area.

Finfish

The fishes of the Tidal James River may be divided loosely into several groups. For purposes of this paper, these will be considered as follows:

> Freshwater fishes - including large mouth bass, blue-gill, pickerel, and catfish. None of these have any great tolerance of salt, though some are occasionally found in brackish water.
>
> Anadromous fish - those that live in saline water, but spawn in fresh. These include the river herring, the shad, the striped bass or rock fish, and white perch, though the last may be considered semi-anadromous.
>
> The Summer Feeders - Those who enter the lower James during the warm months to feed. These include bluefish, flounder, grey trout, croaker, spot, menhaden, and puffer.
>
> The Off-Shore Breeders - those who spawn off-shore, but utilize estuaries as a nursery. This group includes the croaker and the menhaden.

Each group will be discussed in turn.

The Freshwater Fish

The freshwater fish occupy roughly that portion of the James above its confluence with the Chickahominy River. The tributaries to the James below this point, of course, have heavy populations in their fresh water portions. Particularly notable for its fresh-fish population is the Chickahominy River.

These species are mainly of interest to the sportsman, although a small commercial fishery exists for catfish in the fresh tidal waters. Snapping turtles, too, are fished commercially on a small scale in the fresh waters of the basin of the lower James.

The Anadromous Fish spawn in the fresh water, with the river herring in particular penetrating every tributary that is not polluted. In fact, of 105 tributaries examined, only one was so badly polluted as to be unproductive of these hardy fish. This was Bailey's Creek, below Hopewell, at mile 64. The fishery for river herring has declined from its former position of importance leaving this resource underexploited. (Unless the harvest at sea by foreigners is taking the harvestable surplus.)

Historically, before the erection of dams, shad reached to Lynchburg and beyond. The striped bass tends to remain somewhat further downstream, as does the white perch. Shad and striped bass support a significant fishery and both, particularly the striped bass, are valued by sportsmen.

Juvenile shad and herring go to sea in the fall after having spent the summer in freshwater nurseries, and return to spawn in fresh water at the age of four years. Striped bass remain in the area until they are about four years old, when they migrate northward up the coast each summer. The white perch population, however, spends its entire life cycle within the river system.

The Summer Feeders are marine fishes that enter the estuaries for the plentiful food they find there, returning to the ocean in the fall. The trout, the adult croaker, and spot penetrate to a salt level of about 3 parts per thousand. The bluefish, the flounder, the puffer, and the menhaden enter also, but do not penetrate quite so far. These species are generally highly prized by sportsmen, except the menhaden, and have considerable commerical value as well.

The Off-Shore Breeders, as the title suggest, actually spawn off-shore, where the eggs hatch. The larvae (or small juveniles) which are feeble swimmers at best, make use of the saltwater inflow in the salt wedge portion of the estuary to carry them well up into the brackish water of the lower James. These hatchings may take place as much as 50 miles off-shore, so wide-spread is the flow of the salt water which enters the bay from a great fan-shaped area on the continental shelf. The off-shore breeders, then, use the estuary of the James as a nursery, along with the other estuarine rivers and the Bay itself.

Some of the summer feeder group also fit into this category, including the menhaden and the croaker.

Prominent in the off-shore breeding group is the menhaden, which is especially mentioned here for its commercial importance. It is classified as an "industrial" fish, and used as a source of oil, meal, fish solubles, and animal food. So prolific are these fish that they comprise about 1/3 of the total United States fish catch by volume.

Commercial and sport fisheries are basically dissimilar in that the product of one is a protein food for the market; the other, a recreational experience. The term "commercial" is perhaps unfortunate since people are now willing to pay well for recreational experience, and this may generate as much economic activity as the food fishery or more. Salt water fishermen in Virginia are not licensed, however, and therefore even the number of participants is not known. This obviously renders difficult estimates of economic impact.

The commercial fishery applies itself to different species according to the season of the year. In spring, shad and striped bass; in summer, spot, croaker, trout, and other summer feeders; and in winter, shad and striped bass. The catfishery is nearly year round, but slows considerably in the cold weather.

Fishing effort, indicated by Figure XV, varies with the market, the fish populations, and the labor market. The decline shown is probably a product of all three.

Clams

Another important molluscan resource of the James River are the three species of commercially valuable clams which inhabit its waters in great quantities. Figure XVI indicates their distribution. Note that each prefers a different salinity range. Each will be discussed in turn.

The Hard Clam (Mercenaria mercenaria)

This species, the quahog of northern waters, is confined to the more saline waters of the estuary, and is the only one of the three potentially valuable species that is currently exploited.

All commercially economic concentrations of hard clams in the James are in areas that have been condemned for the direct taking of shellfish; therefore clams from these areas must be relayed to clean waters for a period of 15 days prior to sale. This is one of the reasons for the low usage of this resource, since the cost of relaying clams reduces their value about 1/3.

The Marine Resources Commission has established a season for the taking of these clams from 1 May to 15 August each year, during the warm water period of the year, when clams are supposed to cycle more water through their systems, and thus readily cleanse themselves after being relayed.

Catch of these clams could be increased several fold in the Tidal James, since they are very dense (2-300 bushels per acre) particularly off the Newport News Shipyard.

The Soft Clam (Mya arenaria)

This species, which is the "steamer" clam of clambakes, occupies a stretch of the James somewhat less saline than the hard clam. Their presence in considerable quantities is suspected, but not confirmed. Their distribution coincides with the all important seed oyster beds, and the only commercially feasible methods for taking these clams would prove destructive to the seed beds. The oysters are far more valuable; therefore the Mya go unexploited.

The Brackish Water Clam (Rangia cuneata)

This clam is a recent newcomer to Tidewater Virginia, although there are indications (Indian shell middens) that they were here previously. They were first noted in the area 10 to 12 years ago, and have been reported in immense concentrations two miles below Hog Island, on the western side of the river. Recent surveys reinforced by the reports of two VIMS graduate students indicate they extend some 25 to 30 miles above this point. In one area in the vicinity of Hog Island, hydraulic clam escalator sampling has returned two bushels per minute, which indicates concentrations of 5 to 700 bushels per acre. Though no commercial use is at present being made of this enormous resource, it is felt that a biomass of this size cannot long escape exploitation.

Blue Crabs

The blue crab is one of Virginia's most important marine species but relatively unimportant commercially in the James. The annual hard crab catch is less than 5% of the state total, while soft and peeler crabs amount to less than 1%.

The reason for the lack of commercial importance of the commercial importance of the crab in this area is not completely clear. The crabs are present but not fished to any extent. Contributing factors are:

> The extensive shoal areas in the river, which make crab pots impractical due to their vulnerability to waves, currents, and poaching.
>
> The presence of large merchant vessels in the channel, whose induced hydraulic disturbances make crabbing difficult in deeper waters.
>
> The proximity of the more financially rewarding oyster seed beds.
>
> The large numbers of pleasure boats, which increase mechanical destruction of traps, and leads to further poaching.
>
> The proximity and availability of shore jobs

whose financial returns are greater.

Females attain full growth within the nursery area, roughly between the confluence with the Chickahominy, and the Warwick River - Pagan River line. There they mate and migrate downstream to the higher salinity waters of the lower Chesapeake Bay, effectively completing their trip before December. They remain here during the winter and begin spawning in May. This may last through September, with each female carrying eggs for 10-14 days prior to hatching, and spawning at least twice during the summer. Larvae develop in high salinity waters, become megalopae (post larvae) and then juvenile crabs which move to the brackish water of the nursery grounds in early fall to complete the cycle.

The male-female ratio of crabs is one to one in the nursery area and below. Above, at the lower edge of the salinity transition zone, males predominate by a ratio of about 4/1. Above the zone, only males are found. Crabs are fewer above the zone, but the upper limit in the James has not been clearly established.

The Sea Nettle

This animal... *Chrysaora quinquecirrha*... is important to the area for its detrimental effect rather than the benefits it gives. It has a painful sting, caused by a protein toxin, which it uses to kill its normal planktonic food, and incidentally cause extreme discomfort to any human who contacts it. *Chrysaora* usually appears in May, and remains until September, a temporal range which unfortunately coincides with that of water sports. At times its numbers are so great as to cause complete abandonment of the water by swimmers, and unpleasant experiences for those others whose work or pleasure brings them into intimate physical contact with the waters of the estuary. Obviously, this has an adverse effect on tourism, and thus the economy of Tidewater.

It is abundant throughout the saline portion of the James estuary, but does not range into waters of less than 5 parts per thousand salinity. Its range in the James, indicated on Figure XVII, is from Hog Island to the mouth. The medusae are most abundant in the saline portions of the many tributaries to the estuarine James, such as the Nansemond and Warwick Rivers, and Deep Creek.

The life cycle of Chyrsaora is somewhat complicated. The adults are either male or female, and the eggs are fertilized externally. These undergo cleavage to form a free-swimming stage, where they are called "planulae". This stage is planktonic for a period ranging from a few hours to a few days, after which it settles on some firm substrate, attaches, forms tenacles, and enters the "polyp" stage. Polyps, which are perennial, are capable of asexually reproducing other polyps. Under the stress of undesirable external conditions, polyps can form podocysts, which are remarkably resistant. Upon the return of favorable environmental conditions, these can excyst, forming new polyps.

In spring, polyps undergo a process known as "strobilation" and resemble nothing so much as a roll of "Lifesaver" mints in a clear package. The "Lifesavers" are detached from the polyp in turn, each becoming a tiny, free-swimming medusa (ephyra) which rapidly grows to full adult size to repeat the cycle.

The medusae have few predators...on the newly strobilated ephyra, barnacles and sea anemones; on the adults, spider crabs and file fish. In the polyp stage, sea slugs (nudibranchs), sea spiders (pycnogonids), mud crabs, spider crabs, and hermit crabs are all sources of predation.

The sea nettle subsists largely upon plankton, with comb jellies (Mnemiopsis leidyi) playing a particularly important role in their diet.

This points up the involved nature of estuarine ecological problems, for the comb jelly feeds upon zooplankton, including the planktonic stage of the valuable oyster. If Chrysaora are "controlled", will the comb jellies undergo a population explosion? If so, what of the oyster?

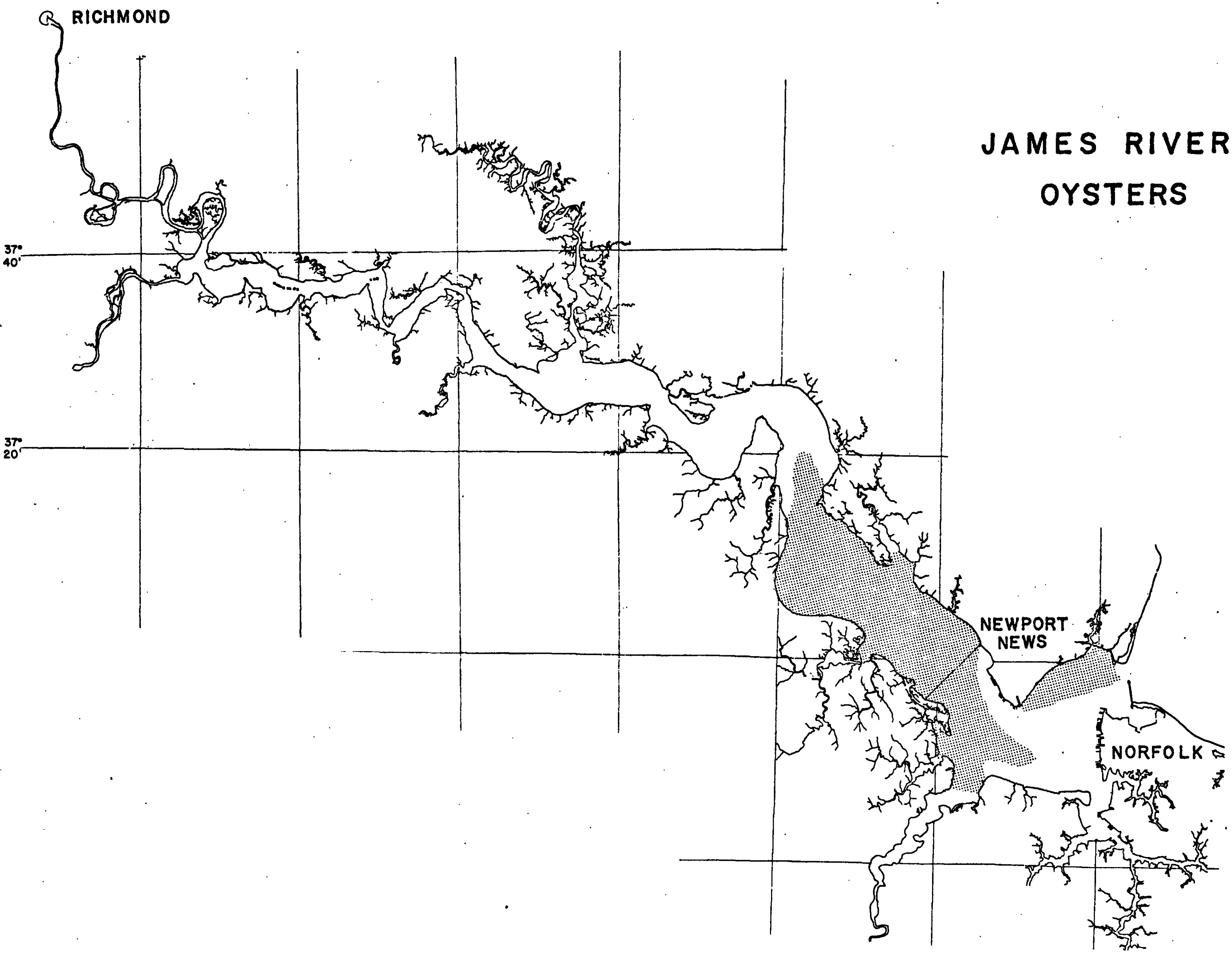

RICHMOND
JAMES RIVER
OYSTERS
37°
40'
37°
20'
NEWPORT
NEWS
NORFOLK

Figure XIV

AERIAL SURVEY OF POUND NETS IN JAMES RIVER 1959–1971

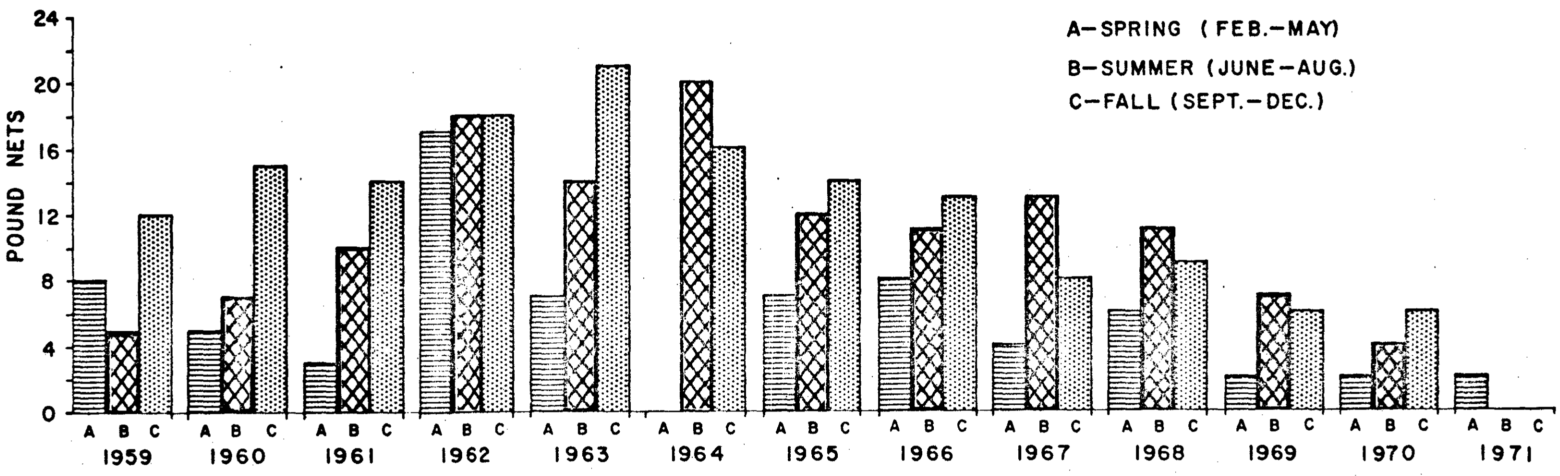


Figure XV

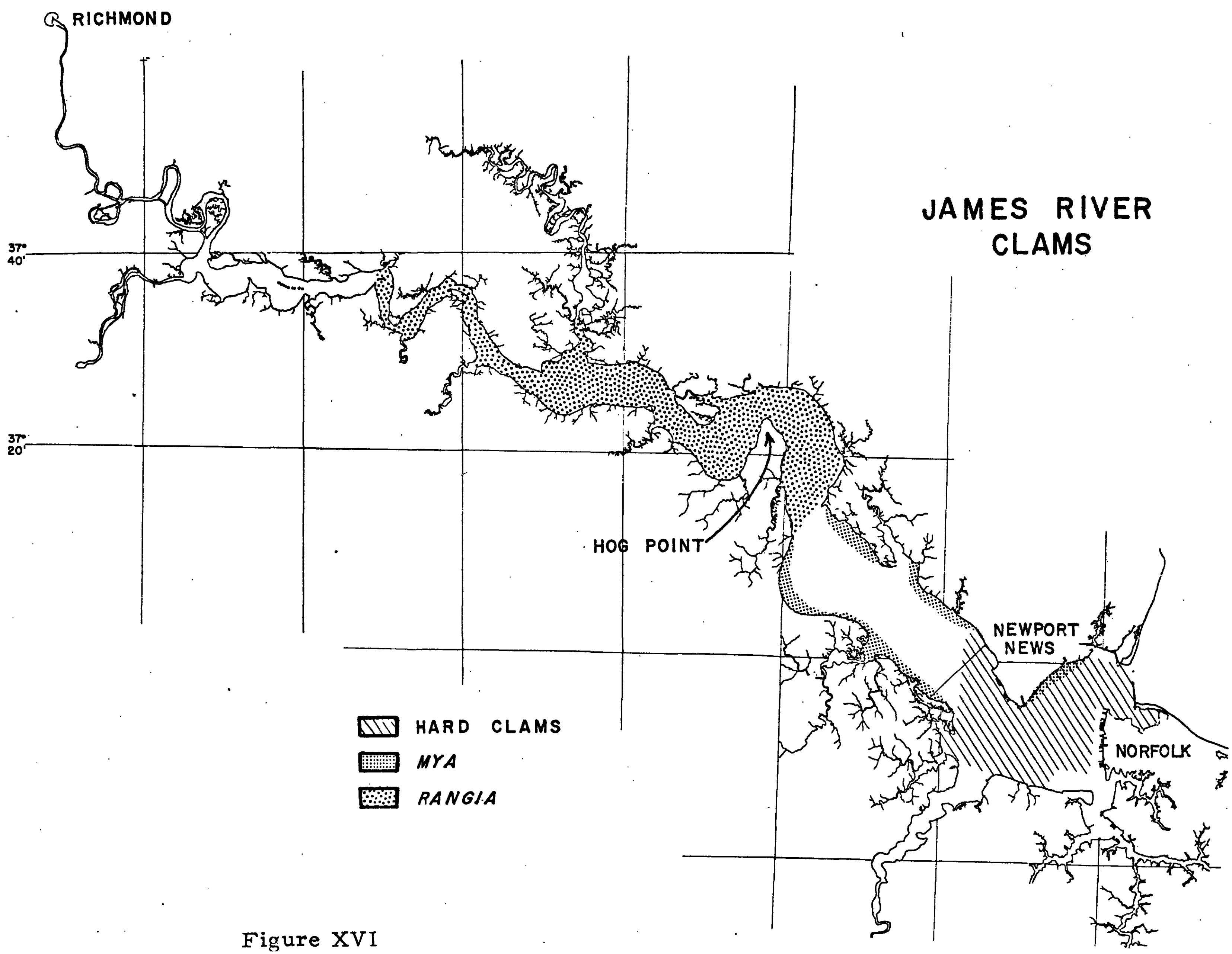

JAMES RIVER
CLAMS
RICHMOND
37°
40'
37°
20'
HOG POINT
NEWPORT
NEWS
NORFOLK
HARD CLAMS
MYA
RANGIA

Figure XVI

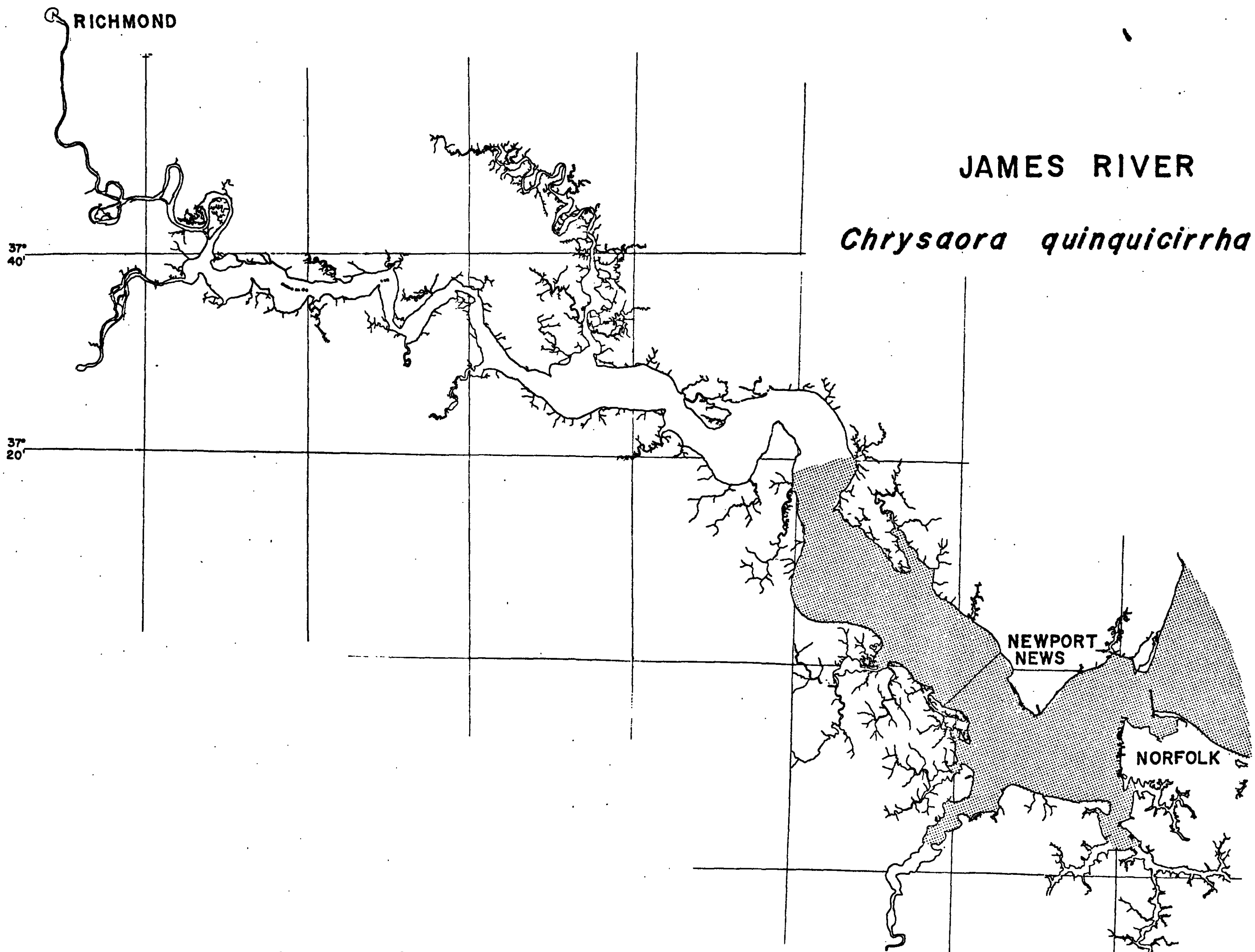

JAMES RIVER
Chrysaora quinquicirrha
RICHMOND
37° 40'
37° 20'
NEWPORT NEWS
NORFOLK

Figure XVII

J. Erosion and Sedimentation

Land erosion, and the sediments that result therefrom, are a serious nation-wide problem. An estimated 4 billion tons per year are produced. The extent of this problem in the James appears to be relatively - but only relatively - inconsequential.

The U. S. Army Corps of Engineers gives the following figures for channel sedimentation in the tidewater portion of the James:

TABLE O

River Section	Annual Maintenance Dredging (Cu Yd)
Between Richmond Harbor and Richmond Deepwater Terminal	35,000
Deepwater Terminal to Hopewell	170,000
Hopewell to Mouth	740,000
Total	945,000

Erosion of land has always been present, but human intervention with the natural order of things has greatly increased it. Forest fires, timbering, plowing of grasslands, and other improper uses of land have greatly increased the sediment loads of surface waters.

In terms of total tonnage, there seems little doubt that silt from the erosion of soil is the leading pollutant in the James River. Each rainstorm in the basin, no matter how slight, adds its portion to the turbidity of the river, even from lands where no degradation has occurred, or where best conservation practices are in force. Other pollutants as a general rule enter surface waters from point sources; these can be located, enumerated, and eventually controlled. Erosion, however, can take place anywhere in a basin, and wash sediment into streams from a nearly infinite number of points. The problem of controlling erosion, then, is extremely complex, since regulatory agencies must deal with individual owners of each land parcel, and somehow insure wise soil conservation practices by all.

In the classical estuary - which the tidal James generally closely approximates in regard to suspended solids - the highest concentration of sediments is found in that section of the river which is occupied by the transition zone between fresh and salt water, with concentrations falling off both up- and downstream. These conditions of course are heavily influenced by external conditions such as heavy rainfall, winds which may cause disturbing waves and currents, and droughts.

The lower James River exhibits a high degree of turbidity, even when compared to the remainder of Virginia's tidal streams. This is due, in part, to the enormous drainage area from which erosion carries particles of sediment to the main stream. In addition, there are extensive shoal areas in the James, with water depths of only a few feet. Silts deposited there are readily stirred up by currents, winds, and waves. The resulting turbidity has a depressing effect on biological action, since it reduces the penetration of the waters by the rays of the sun, and, further, plankton are trapped and physically removed as the particles re-settle.

Figure XVIII represents the classical configuration measured in May 1965 by Brehmer. Figure XIX represents measurements by the same scientist in June 1965 after a general 4" rainfall in the James Basin. Note the heavy sediment load in the second case in the J-50 to J-70 section, which is attributed to the effects of the run-off. Figure XX, from data taken in July, represents near steady state conditions during low flow.

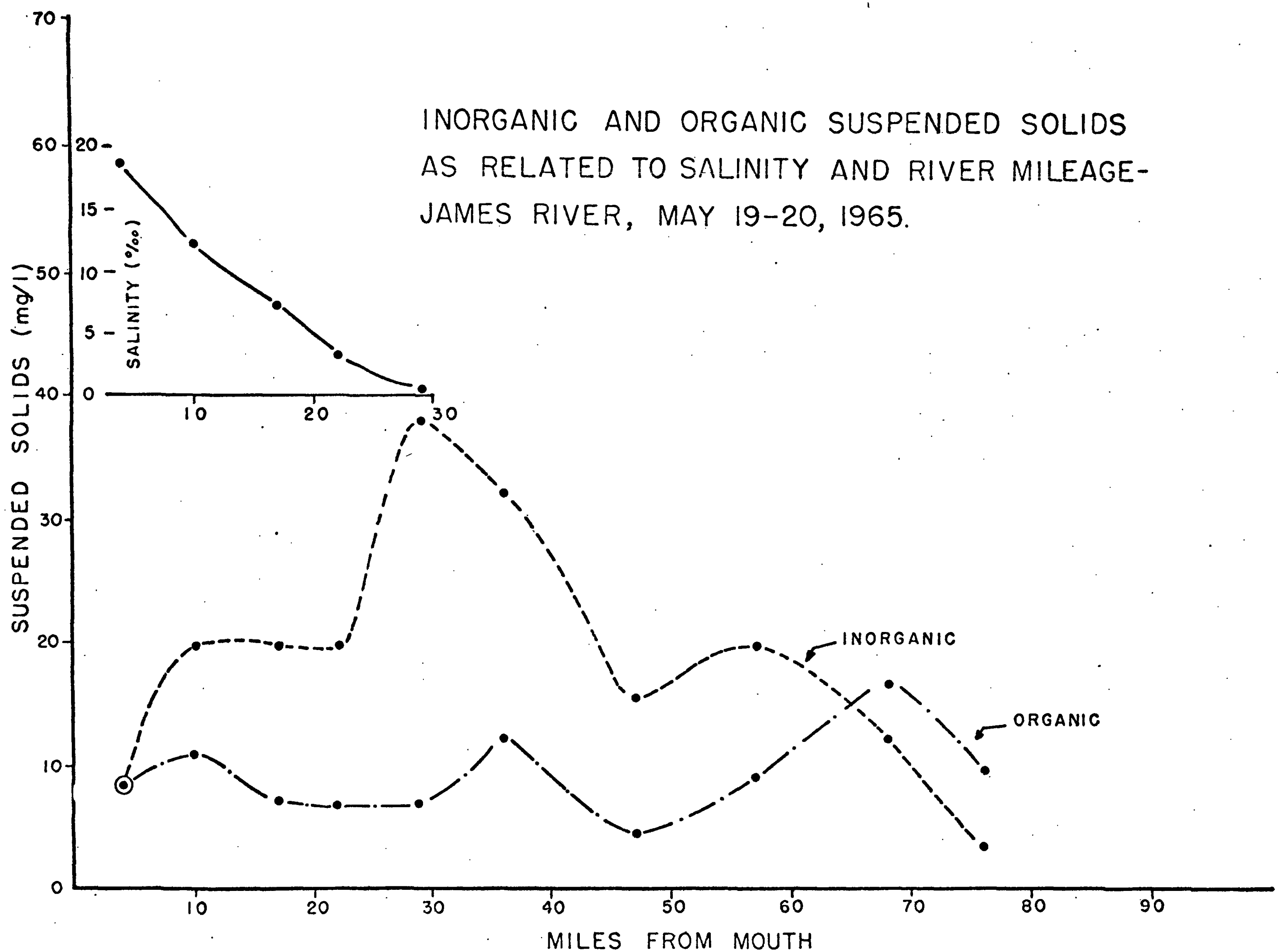


Figure XVIII

Source: Brehmer, 1965

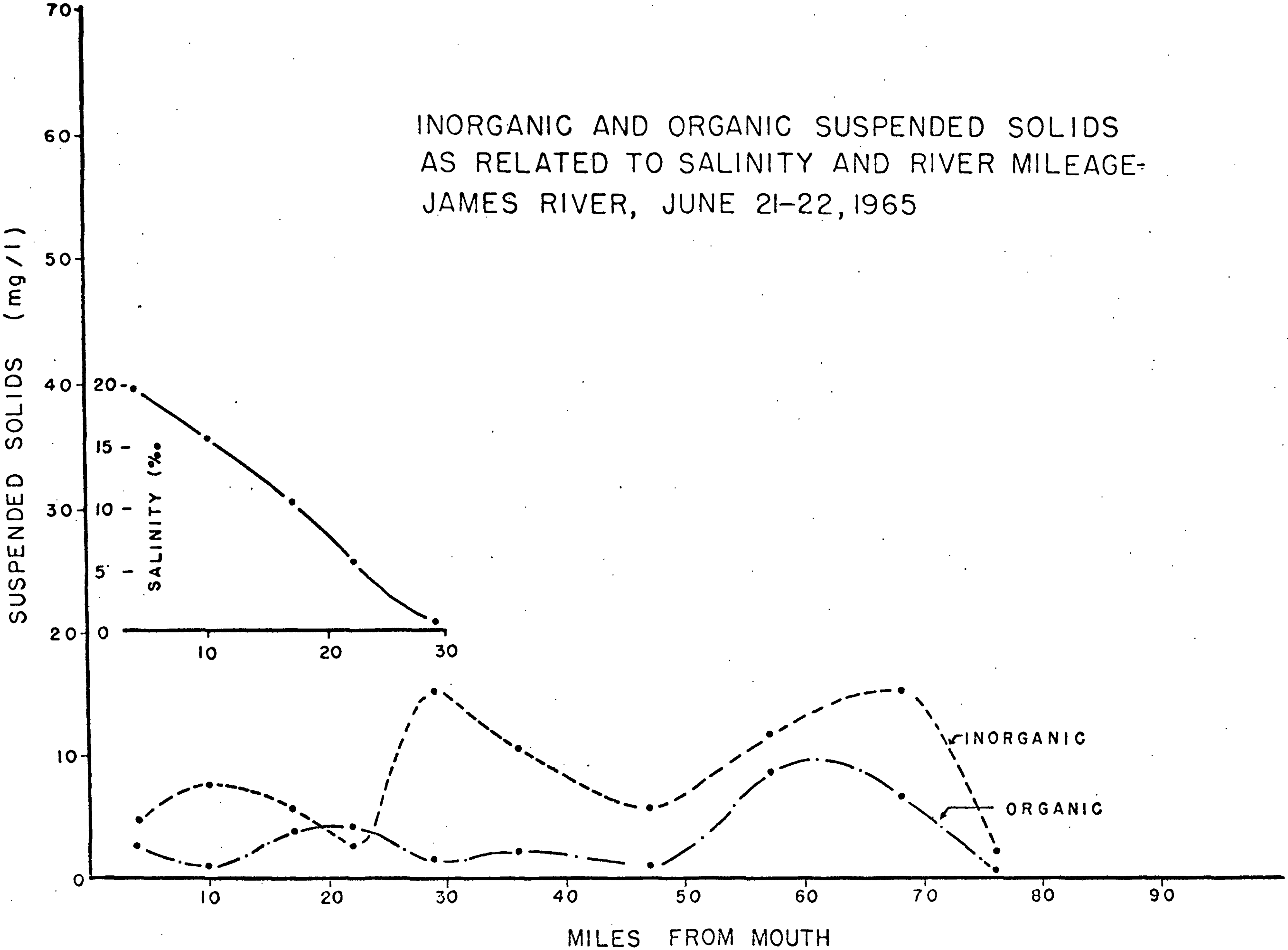


Figure XIX

Source: Brehmer, 1965

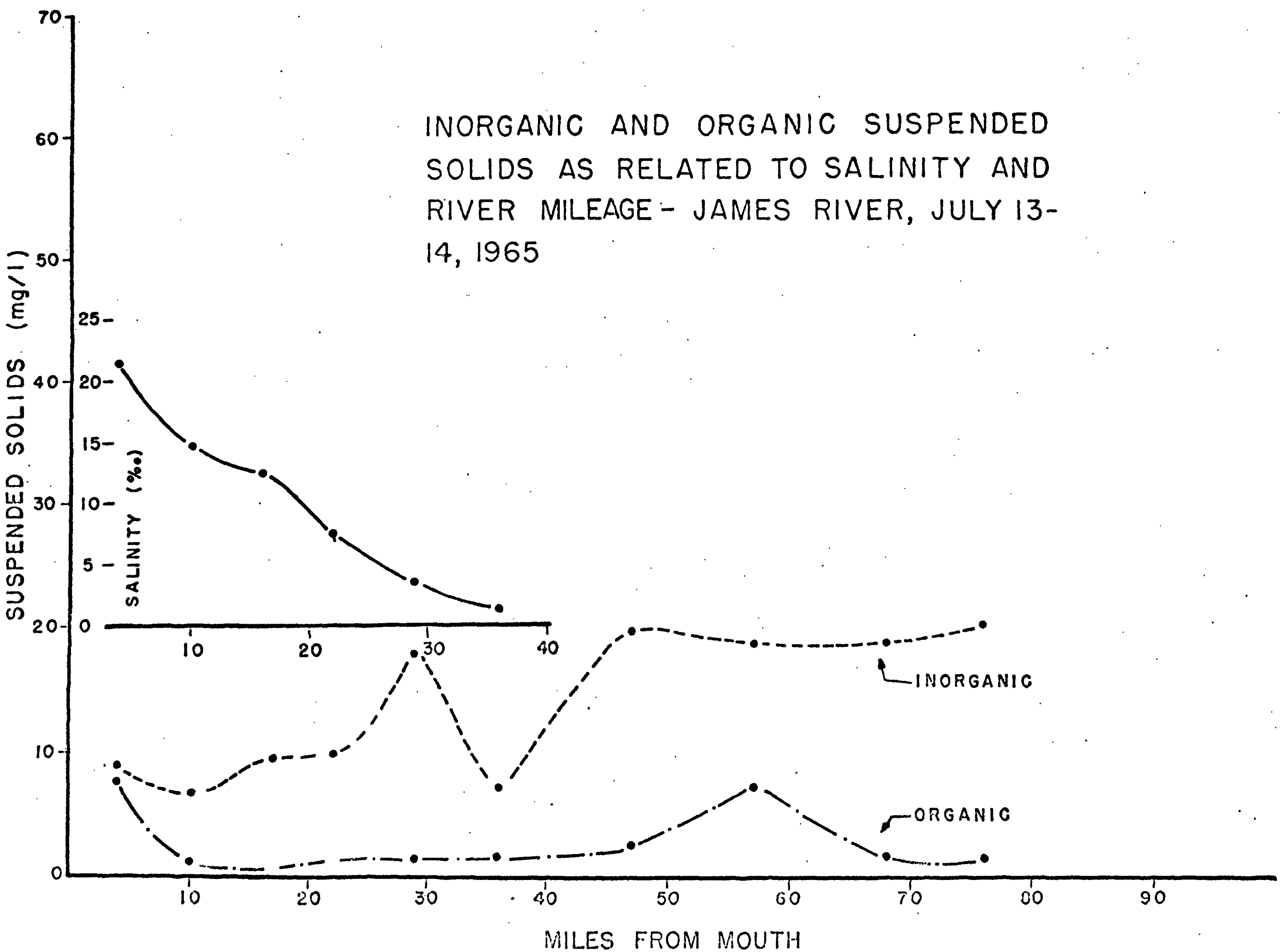


Figure XX

Source: Brehmer, 1965

V. PROJECTS

A. COMPLETED PROJECTS
B. PROPOSED PROJECTS

V. Projects

Of obvious importance to the current status of a river are the modifications made by man in his attempts to enhance the value of the stream for his purposes. Unfortunately, these modifications have, in the past, been largely concerned with economic gain, or with the protection from floods of man's works on the natural flood plains of the river. Some of these changes have proved of long term benefit; others, like the previously discussed navigation projects above Richmond, are no longer of value. None have, so far, proved ultimately degrading to the environment of the tidal James.

Some of the projects already completed are listed below:

A. Completed Projects
Tidal James River

The 25 foot channel

This project, completed in 1947, provides a 25' channel 300' wide to Hopewell, 200' wide to the Richmond deep water Terminal, and 18' deep and 200' wide from there to the Richmond locks. Turning basins are provided at Richmond lock (200' wide x 600' long x 18' deep) and, 4.4 miles down river, at the Richmond Deep Water Terminal (5,200' long, 200-700' wide, and 25' deep).[51]

Craney Island Disposal Site

On the flats opposite the entrance to the Lafayette River, which bisects the city of Norfolk from east to west, is an odd-looking, trapezoidal fill. This is the man-made Craney Island Spoil Disposal Site, which has some interesting attributes. Among these are:

It in effect extends the west bank of the Elizabeth River by 11,000 feet.

It reduces the distance from Newport News, on the northern bank to the closest point on the southern bank from 3-3/4 to 2-3/4 nautical miles.

It provides a convenient, inexpensive, and relatively innocuous spoil disposal area.

It is entirely man made, and the end product will be about 2,500 acres of extremely useful and valuable land.

Construction of the levees into which spoil could be pumped was commenced in August of 1954, and closure was effected when the east levee was completed in January 1957. Dimensions are as follows:

Shape: Trapezoidal - offshore dimension east-west 9000'; inshore dimensions east-west 11,000'; north-south projection 11,000'.

Area: 2546 acres

Elevation: Main levee +8' above mlw; step levee 18' above mlw (step levee approximately 100' inside main levee).

Capacity: Approximately 120,000,000 cubic yards.

Present Average Annual Deposit Rate: 5,580,000 cubic yards.

Estimated Date of Complete Fill: 1978[52]

Even though completely filled in 1978, no intensive land use is likely until 1985 since the soil must consolidate. This delay can be reduced if special engineering methods are utilized to speed compaction.

Hampton Roads Bridge Tunnel

This project, which connects Norfolk and Hampton, carries Interstate 64 beneath the waters of Hampton Roads. By its presence in the bottom, it limits the depth of the channel to about 45 feet, though the tube itself is somewhat deeper. Two islands were constructed as northern and southern termini of the tunnel; these were connected by open causeways to the mainland. Each island was located just shoreward of the 3-fathom curve. The northern island was built on a shoal area just westward of Old Point Comfort; the southern was attached to Fort Wool Island.

Prior to its construction, considerable concern was evinced by oystermen whose beds were in the area that siltation resulting from construction would bury their oysters. Total damage however was slight.

Few, if any, adverse enviromental effects have been noted from this project.

Appomattox River Channel[53]

In 1931 a channel from the mouth of the Appomattox River at Hopewell to Petersburg was completed. This channel as constructed was 80' wide, 10' deep, and 11.5 miles long. It is no longer maintained for commerce, but periodically cleared of snags for recreational purposes.

Phoebus Channel

This channel, completed in 1956, runs 3/4 of a mile from Phoebus to deep water in Hampton Roads. It is 12' deep and 150' wide.

Deep Creek Channel and Harbor

This project provides for an 8' deep channel 100' wide to Deep Creek entrance from deep water, a distance of about 9,040'. At the creek entrance the channel is 60' wide for the next 700'. The harbor, opposite Menchville, is 8' deep, 400' to 740' wide, and 1940' in length.

Hampton Creek Channel

This 12' channel extends from deep water in Hampton Roads 200' wide across Hampton Flats, 150' to Queen Street Bridge, 100' wide for 1300' in Herbert's Creek, and 80' wide to Kecoughtan Road. It was completed in 1949.

Nansemond River Channel

This project, completed in 1932, is 12' deep and 100' wide to a point 1/2 mile above Suffolk; thence 10' deep and 80' wide to Reid's Ferry. There is a 12' deep, 200' square turning basin at Suffolk.

Newport News Creek Channel

This channel has a depth for its entire length of 12', with widths varying from 200' to 60'. It extends from deep water in Hampton Roads to a turning basin 220' x 400' at the upper end of the boat harbor. It was completed in 1948.

Pagan River Channel

Completed in 1923, this 10' deep 80' wide channel runs 6.6 miles from the James River to Smithfield. It has no commerce, and is no longer maintained.

Nansemond Ordnance Depot Channel

This channel, 12' deep by 100' wide, runs 2400' from Hampton Roads to a turning basin 100' to 300' wide, and 300' long. It is not maintained due to lack of activity. It was completed in 1942.

Willoughby Channel

This channel was completed in 1931, and is 10' deep by 300' wide. It runs from Willoughby Spit to Hampton Roads, and is no longer maintained due to lack of commerce.

Newport News Channel

This channel has a project depth of 45', is 800' wide, and 4.5 miles long through the shoal area between Newport News and the Middle Ground. It includes 2 anchorages 45' deep, with a 1200' swinging radius. The channel was completed to a depth of 40' in 1931.

Lafayette River Channel

Completed in 1939, this channel is 8' deep and 100' wide from the Elizabeth River to the Hampton Boulevard Bridge; 6' deep to the mouth of Knitting Mill Creek, and up the full length of the creek.

Norfolk Harbor Channel

This channel is 45' deep, with widths of 1500' and 800' from Fort Wool to Lambert's Point, and 40' deep and of varying width from there for the next six miles. The main channel was completed in 1968.

Also to be considered for their effect on the tidal James are the many impoundments and reservoirs constructed by the various political subdivisions for their public water supplies. These are of interest because they block the normal flow of fresh water, thus affecting the characteristics of those portions of the estuary into which they previously flowed. Since construction of the impoundments, the water may be returned to the estuary at a number of points as sewage or industrial waste, or evaporated. This obviously changes a relatively simple situation to an extremely complex one whose ramifications are not clearly understood.

The major impoundments in the Tidal James basin, and the streams whose flow they interrupt, are listed in table P.

TABLE P

Major Impoundments
Tidal James Basin

Reservoir	Stream	County	Capacity (MG)
Lake Chesdin	Appomattox	Chesterfield	11,545
Falling Creek	Falling Creek	Chesterfield	302
Swift Creek	Swift Creek	Chesterfield	5,200
Chickahominy	Chickahominy	New Kent - Charles City	4,500
Diascond Creek	Diascond Creek	New Kent - James City	3,500
Lee Hall	Warwick River	James City - Newport News	844
Skiffes Creek	Skiffes Creek	York - Newport News	260
Burnt Mills	Western Branch	Nansemond - Isle of Wight	3,428
Lake Prince	Exchange Creek	Nansemond	3,700
Western Branch	Western Branch	Nansemond	6,200
Lake Cahoon	Nansemond River	Nansemond	1,700
Lake Kilby	Pitch Kettle Creek	Nansemond	750
Lake Meade	Nansemond River	Nansemond	1,600
Speights Run	Speights Run	Nansemond	475

Source: Virginia Division of Water Resources

B. Proposed Projects

The 35' Channel

This project as laid out consists of a channel, 35' in depth and 300' wide, from Hampton Roads to the Richmond Deep Water Terminal. A mooring basin at Hopewell, an enlarged turning basin at Deep Water Terminal, and a minimum turning radius of 3000' at all channel bends are provided. Total length of the project is 86.4 miles. The present 25' channel is admittedly inadequate for today's larger ocean going ships. In 1955 the Corps of Engineers, in response to a request made earlier by the city council of Richmond, made a study of the project, and concluded it was both feasible and economically sound, with a cost-benefit ratio of 2.2: 1. The oyster interests, who depend entirely on the James River seed beds, were concerned over the possible effect on these valuable resources. In 1964 a hydraulic model of the James was built, and studies were conducted by VIMS in conjunction with the Waterways Experiment Station of the Corps of Engineers at Vicksburg, Mississippi. These studies indicated that, while salinity and current changes would occur, they would have no significant effect on the production of seed or market oyters.

Meanwhile, construction of pipelines for petroleum products from Hampton Roads to the Richmond area reduced the expected savings of transporting this commodity by ship some 40%, thus lowering the cost - benefit ratio to 1.3: 1. The project is currently undergoing another feasibility study by the Corps of Engineers.

The Tidal Exclusion Dam

As a substitute for the 35' channel, it has been proposed that a tidal exclusion dam be constructed across the James at the relatively narrow portion at Jamestown Island, to increase the upstream water depth, thereby minimizing dredging required to permit larger ships to reach Richmond. The extremely large pool of freshwater formed would supply all area needs for fresh water for the foreseeable future. In this proposal, locks are to be used to raise ships to the higher level. A fish ladder could be provided to permit the by-passing of the dam by these creatures during migrations. Though advantages are apparent, defects in this plan are many; a few of the more obvious are:

> All water below the dam would be saline - all above fresh. The salinity gradient could not be tolerated by marine life.
>
> Much valuable low land, including many historic sites, would be flooded.
>
> The James River oyster seed beds...and thus the entire Virginia oyster industry as presently constituted...would be adversely affected, since the resulting higher salinity below the dam would permit encroachment by MSX, Dermocystidium, and drills on the seed areas.
>
> At the rate at which the communities at the head of the tidal James are currently adding nutrients, the freshwater pool would support an extremely large population of blue-green algae, be of poor quality for domestic use, and be aesthetically disastrous.
>
> Tidal patterns below the dam would be dramatically affected, and a standing tidal wave, instead of the current progressive wave, would be produced. High tides would be higher, low tides lower.

Extension of the Newport News Shipbuilding and Drydock Company Yard

Early this (1971) year, the Company requested the Corps of Engineers to extend its bulkhead line from 58th Street in Newport News to 70th Street, in a continuation of the present bulkhead line to the northwest, towards the James River Bridge. In June the Company received, for $96,000, a permanent easement for use of approximately 59.3 acres of public oyster ground in the area. This had been considered, and approved, by the Virginia General Assembly. These oyster grounds have been condemned for several years for the direct taking of shellfish, as noted in the section on Monitoring, above.

The shipyard intends to fill the area between the new bulkhead line and the shore, and, though no official reasons for so doing have been announced, local presumption relates it to an expansion of facilities in connection with the assembly-line production of ships.

The area involved is approximately one mile long, and 1/2 mile wide at its widest point.

Replacement Fill Area for Craney Island Spoil Area

As previously noted, the Craney Island Spoil Area will be completely filled by 1978. Since maintenance dredging will be a continuing necessity, a replacement fill area is highly desirable. Several areas have been suggested as possibilities; each has advantages and disadvantages. Some of these areas are:

> The Ragged Island area to the southeast of the lower end of the James River Bridge. There have also been suggestions that this area is under consideration for a housing development, which would probably require some filling of low-lying areas. Disposal here would likely be basically on land, which is generally preferable to shoreline encroachment, all other factors being equal.
>
> The presently prohibited area in Willoughby Bay, once used by the Navy seaplanes, but no longer required. This would allow the Navy to extend its property considerably.
>
> The area west of the present Craney Island Spoil Disposal Site. A levee from the northwest corner of the fill to the area of Pig Point would result in a considerably improved hydraulic shape.
>
> The fill area recently acquired by the Newport News Shipbuilding and Drydock Company, as described above. This area, however, is small.

Any area considered should, of course, be investigated throughly before a decision is made. Many of the physical consequences of the construction of such fill areas can be evaluated beforehand on the hydraulic model of the James at Vicksburg, Mississippi.

Second Hampton Roads Bridge-Tunnel

A second bridge-tunnel crossing of Hampton Roads from Hampton to

Norfolk is presently in the early stages of construction. This will be nearly a duplicate of the present connection, parallel to it, and in the same area. When complete, a four-lane over-and-underwater system will carry Interstate 64 across Hampton Roads.

Full completion is presently scheduled for fall of 1975.

Deep-Draft Channel Extension, Elizabeth River

This project encompasses the extension of the existing 35' channel in the Southern Branch of the Elizabeth River from the present turning basin for a distance of 1-1/2 miles, with a width of 250'. This new channel will culminate in a new turning basin, 800' square, and also 35'deep.

It is estimated that 3,000,000 cubic yards of spoil will be removed, with annual maintenance dredging of 30,000 cubic yards required. Spoil disposal is to be on land, at three sites totalling 557 acres in extent. This project is in its preliminary planning stages.

There are many other plans, more or less nebulous in nature, afoot for the James, particularly in the Hampton Roads area. For instance, an industrial park has been suggested for the Pig Point area, and a housing development is being considered for Ragged Island. The land produced by the Craney Island Fill Area is the subject of several development schemes, and controversy is beginning to develope over the uses to which it will be put. Because of its location, its development can have far-reaching consequences. Hampton Roads is the throat through which must pass all migrating finfish and crabs. Further, the saline water upon which oysters, clams, and many other estuarine creatures depend flows upstream along the bottom through this area. Therefore, if improper development of Hampton Roads were to lead to severe pollution of its waters, a biological disaster of the first magnitude could develop in the estuarine James.

VI. RESEARCH

A. CURRENT RESEARCH
B. REQUIRED RESEARCH

A. Current Research

Current research in the James River is generally concentrated in 4 large-scale projects. Not considered here are such continuing projects as the aerial survey of fishing nets, the periodic sampling of fish and crab populations, or the weekly tally of oyster spatfalls, though their importance is undeniable.

The Mathematical Model

Detailed data is being collected this summer (1971) on the currents, salinity, temperature, dissolved oxygen, and tides in the James River below Richmond. This information is being recorded at seventy stations on twenty transects in the Tidal James. One hundred hours is the minimum time to be spent on each transect, and readings will be taken every 30 minutes. Part of the field work involved the release of dye at Richmond, and the measurement of dye concentrations at various points downstream by extremely sensitive fluorometers, capable of identifying sub-visual concentrations.

A complicated mathematical formula...the model...will be developed to fit the parameters of the river as indicated by the collected data. Upon completion, the model will be used to calculate the movement of water masses in the river, and the effects of various changes to present conditions. Current velocities, changes in dissolved oxygen concentration with varying organic discharges, salinities, and dispersal rates of pollutants added at certain points can also be calculated.

The Hydraulic Model

During the studies of the possible effects of the deepening of the channel in the James River to 35 feet, a large scale model of the Tidal James was built at the Waterways Experiment Station of the Corps of Engineers, at Vicksburg, Mississippi. This scale model was based on broad surveys of the James estuary conducted in 1960 and 1964. The model covers the tidal portion of all major tributaries, including the Elizabeth, Nansemond, Pagan, Warwick, Chickahominy and Appomattox Rivers. It also reproduces a portion of lower Chesapeake Bay, and about 200 square miles of the Atlantic Ocean. Scale of the model is 1:1000 horizontally, and 1:100 vertically. These scale ratios fix the other ratios utilized, which are:

Salinity 1:1

Velocity 1:10

Time 1:100

Discharge 1:1,000,000

Volume 1:100,000,000

The model is 550 feet in length and 130 feet wide at its widest point. It is housed in a shed to prevent disturbances by winds, rains, and other external phenomena.

Tidal cycles, including tide-induced currents, can be faithfully reproduced to scale. Salinity of the "ocean" is kept at the proper level by the addition of salt to counteract the fresh water inflow, which is admitted through the James (at Richmond) and the Appomattox, Chickahominy, and Nansemond Rivers.[54]

Salinity samples can be taken simultaneously at all depths at all stations in each cross-section of the river under study.

Permanent point tidal gages are located throughout the model at the stations occupied by standard gages on the real James. Tide heights can be judged to .001 foot.

Current velocities are measured with minature current meters to accuracies of .02 ft/sec.

Sedimentation rates in various areas can also be measured.

The model was molded so that portions could be removed to represent channel deepening, and other sections could be emplaced to represent the decrease in depth in the spoil areas caused by deposition of the dredged material.

Tests were run without, and then with the new channel, at three different levels of freshwater inflow. The data collected, while indicating salinity increases in some areas, showed that these were of a minor nature, and would be of little or no consequence. The effect on current velocities was also negligible.

Other ideas can be tested as well. Some experiments that have been performed, or are proposed, concern:

> The thermal effects of the effluents to be discharged at Hog Point by the Surry nuclear power plant.
>
> The effects of various river fill areas.
>
> The selection of optimum locations for sewage outfalls.
>
> Sedimentation problems at piers and in channels.
>
> The dispersal and diffusion of pollutants.
>
> The movements of oyster larvae and other plankton.
>
> Optimum spoil disposal area.

The Chesapeake Bay Model

A large hydraulic model is to constructed of the Chesapeake Bay and its tributaries, along the same lines as the model of the James discussed in the preceding paragraphs. This is a cooperative venture, with VIMS surveying the lower bay, the Chesapeake Biological Laboratory (Maryland) the middle bay, and the Chesapeake Bay Institute (Johns Hopkins) the upper bay. This model will be constructed at Matapeake, Maryland, on Kent Island, and will be considerably larger than the James model. As an example, the James portion alone will stretch some 500 feet.

In connection with its responsibilities in this area, VIMS is currently collecting data on the James River. The information being gathered to produce the mathematical model of the Tidal James, discussed in a previous portion of this section, will also be used to construct the James portion of the new model.

The capabilities of the Chesapeake Bay model, and the uses to which it will be put, will parallel those of the James model, but will of course allow the entire bay to be manipulated as a unit.

The Surry Nuclear Plant

As previously mentioned, the Virginia Electric and Power Company (VEPCO) is constructing a nuclear power plant at Hog Point in Surry County. Water from the James will be used as a coolant, and returned to the stream.

Prior to commencement of construction, two well known oceanographers of the Chesapeake Bay Institute,[55] acting as consultants for VEPCO, utilized the James River Hydraulic Model to predict waste heat distribution from the plant effluent. Based on their work, the State Water Control Board approved construction.

Currently, under contract with the Atomic Energy Commission, VIMS and VEPCO are collecting baseline data by three distinct methods:

> By boat (surveying and monitoring), twice weekly.
>
> By thermal and tide gages permanently mounted in seven towers in the area of interest, recording on a continuous basis.
>
> By aircraft overflights, which through the cooperation of NASA - Wallops, make infra-red photographs of the area.

In addition, biologic sampling is conducted on a routine basis for the various species that inhabit the area.

When the plant becomes operational similar data will be collected. This will enable VIMS to:

> Check the model's predictions of surface temperature patterns and gradients against actual conditions that have resulted. This will permit verification of the capabilities of the model, and possibly improvements in predictive techniques.
>
> Discover the effect of the discharge on the river and its inhabitants, if any. Designers of future installation in other estuaries will utilize this knowledge in their planning.

B. Required Research

This topic is difficult to delineate since research can be conducted on almost any thing or any phenomena at any depth, from gross features to ultrastructure.[56]

In general, the research required for the Tidal James is the same as that for any coastal estuarine system. Perhaps it is best to discuss merely the general areas in which we feel research should be conducted, and leave delineation of specific projects to the individual researcher.

Of course, any such list must be considered partial.

Research is required in the area of:

<u>Water Quality</u>

- Industrial Wastes
  - Chemical
  - Thermal
  - Radiological
  - Food processing
- Agricultural Wastes
  - Biocides
  - Fertilizers
- Domestic Wastes
- Oil and similar spills
- Eutrophication
- Storm drainage
- Alteration of freshwater inputs
- Monitoring
- Modeling of estuaries
- Equipment, instruments, and facilities
- Mapping

Air - Water Interaction

Mass, momentum and energy exchanges

Reaeration mechanisims

Wave generation

Wind wave induced turbulence

Land - Water Interactions

Causes and rates of erosion

Mechanics of erosion

Erosion protection

Effects of sedimation on biota

Sediment transport

Channel stability

Effect of biota on flocculation rates

Predicted extent of flooding in various areas

Storm effects

Transportation of chemicals by sediments

Effect of sediment particle size on light penetration

Optimum land use to prevent sedimentation

Effects of spoil disposal, and optimum methods therefor

Toxicity of sediments

Methods of water access over wetlands without destruction

Influence of man-made structures on fish movements

Optimum shoreline protection methods

Hydrography and Fluid Dynamics

- Circulation patterns under various meterological conditions
- Details of net water transport
- Influence of current patterns on various organisms
- Relation of tides to various organisms and processes
- Tide discharge patterns from marsh creek networks
- Flushing rates
- Entrainment
- Diffusion
- Dissipation
- Interfacial turbulence
- Mixing coefficients
- Mixing rates of dissolved and particulate materials
- Effects of various man-made modifications on hydrography of streams

There are also research requirements in the area of the uses of resources. These may be generalized as follows:

Recreational Resources

- Control of pests
- Methods to evaluate recreational benefits
- Assesment of effect of recreationists on water quality
- Degree to which various pathogens are waterborne or infectious

Maintenance of sanitary levels at bathing beaches

Biologic and economic impact of sports fisheries

Hydrological Resources

Evaluation of quality and quantity

Desalination

Pollution dilution

Tests to determine water taste and enumerate bacteria and viruses

Biological Resources

All phases of aquaculture, including:

genetics
feeding
environment
spawning
detection and treatment of disease

Seed production potential of estuaries and methods to increase it

Pest, disease, and predator control

Health determinations of wild populations

Results of introduction of exotic species

Increased mechanization in all phases of seafood industry, and its economic effects

Improvements to fishery statistics

Stock assessment

Natural mortalities

Distribution of pesticides, heavy metals, and trace elements in food chains

Utilization of fresh and salt wetlands by various organisms

Effect of pesticides and fertilizers on plankton

Concentrations of toxics by organisms

Long term effects of pollutants

Tolerance limits of pollutants by various organisms at all stages of development

Life cycles of various species

Behavioral studies as affecting harvesting of seafoods

Causes of fluctuations in abundance

Population size prediction

Reasons for changes in migratory patterns

Geological Resources

Methods of removal of sand and gravel without damage to biota

Extent of resources

Wetlands Resources

Methods of preservation, mapping, and evaluation

Productivity

Complete definition of roles, composition and inhabitants

Impacts of pollutants

Interactions between wetlands modifications and inlet - marsh systems

Effects of development

Shorelines Resources

Response to extreme events and long term processes

Methods to stabilize

Bottoms Resources

Effects of modifications

Detailed maps of sediments

Also to be considered are the various management problems. These, however, are not so much problems of research in themselves, but rather the combination and organization of facts supplied by researchers into structures to achieve the desired results. As an example, researchers could provide facts on the value of wetlands to enable managers (legislators, in this instance) to draft legislation providing for their preservation instead of development. Again: facts revealed by research into desalinization could enable managers (city managers) to turn to saline waters for domertic purposes instead of creating new impoundments. The list of examples is practically endless; I feel however that these come under the heading of use of facts rather than their discovery.

A far more complete listing of research requirements as well as management problems to which solutions must be sought is contained in the VIMS Special Scientific Report No. 57, The Environmental, Resource-Use and Management Needs of the Coastal Zone (Hargis and Laird, 1971) on which this section is largely based.

FOOTNOTES

[1]Division of Planning and Economic Development, Proposed Development of the James River (Virginia Department of Conservation and Development, October, 1948), p. 5.

[2]Ibid., p. 6.

[3]Corps of Engineers, Review Report on James River, Virginia (Norfolk, Virginia: U. S. Army Engineer District), p. 3.

[4]Ibid.

[5]James Wharton, The Bounty of the Chesapeake, Fishing in Colonial Virginia (Williamsburg, Virginia: The Virginia 350th Anniversary Celebration Corporation, 1957), p. 5.

[6]The husband of Pocahontas prior to her death. Blair Niles, The James from Iron Gate to the Sea (Toronto, New York: Rinehart and Company, Incorporated, 1945), p. 62-63.

[7]Ibid., p. 208-210.

[8]A private company to improve the river from Bermuda Hundred to a point 1 mile below Richmond was incorporated by the state in 1845. No work was accomplished. G. R. Young, Report on James River, Virginia in accordance with House Document 308, 69th Congress, 1st Session (Norfolk, Virginia: United States Engineer Office), Volume I, Appendix I, p. 3.

[9]Ibid., p. 2-3.

[10]Ibid., p. 4-5.

[11]Virginia Division of Water Resources, James River Basin Comprehensive Water Resources Plan, Volume II - Economic Base Study (Richmond, Virginia: Virginia Department of Conservation and Economic Development, 1970), p. 1.

[12]Ibid., p. 73.

[13]Ibid.

[14]Ibid., p. 34.

[15]Division of State Planning and Community Affairs, Projections and Economic Base Analysis: Richmond Metropolitan Area (Richmond, Virginia, 1967), p. 6.

[16]Ibid.

[17]Ibid., p. 23.

[18]Division of State Planning and Community Affairs, Projections and Economic Base Analysis: Petersburg - Hopewell - Colonial Heights Metropolitan Area (Richmond, Virginia, 1967), p. 5.

[19]Ibid.

[20]Ibid., p. 16.

[21]Division of Planning, Projections and Economic Base Analysis: Newport News - Hampton Metropolitan Area (Richmond, Virginia, 1967), p. 4.

[22]Ibid.

[23]Ibid., p. 5.

[24]Ibid., p. 17.

[25]Division of State Planning and Community Affairs, Projections and Economic Base Analysis: Norfolk - Portsmouth Metropolitan Area (Richmond, Virginia, 1967), p. 4.

[26]Ibid.

[27]Ibid., p. 6.

[28]Division of State Planning and Community Affairs, Projections and Economic Base Analysis: Charles City County (Richmond, Virginia, 1971), p. 4-5.

[29]Ibid., p. 4.

[30]Ibid.

[31]Ibid., p. 13.

[32]Division of State Planning and Community Affairs, Projections and Economic Base Analysis: Surry County (Richmond, Virginia, 1968), p. 4.

[33]Ibid.

[34]Ibid., p. 13.

[35] Division of State Planning and Community Affairs, Projection and Economic Base Analysis: Isle of Wight County (Richmond, Virginia, 1969), p. 4.

[36] Ibid.

[37] Ibid., p. 5.

[38] Ibid., p. 14.

[39] Peggy M. Ware, ed., Virginia Facts and Figures (Richmond, Virginia: Division of Industrial Development, 1971), p. 5.

[40] Ibid.

[41] Ibid., p. 21.

[42] Virginia State Ports Authority, Annual Report - Ports of Virginia (Norfolk, Virginia, 1970), p. 2-3.

[43] Not fully complete.

[44] The Chesapeake Bay Bridge Tunnel.

[45] Approximately to the U. S. Route 301 bridge over the Appomattox.

[46] Numbers in this paragraph are approximate.

[47] Private water supplies for domestic use do not require certification by State Department of Health.

[48] Major users are defined as those greater than 1 million gallons per day (mgd). This includes all steam-electric generating plants on the lower James. Irrigational use of surface water is relatively inconsequential and is therefore ignored.

[49] Morris L. Brehmer, "Nutrient Assimilation in a Virginia Tidal System" in National Symposium on Estuarine Pollution, Standard University, August 23 to 25, 1967. p. 218-249.

[50] Ibid., p. 221-222.

[51] Corps of Engineers, Review Report on James River, Virginia (Norfolk, Virginia, 1962), p. 7-8. This project, because of its obvious importance to the tidal James, is re-described here for emphasis.

[52] Division of State Planning and Community Affairs, Craney Island Study (Richmond, Virginia, 1971), p. 7.

[53] All the following data on channels extracted from Corps of Engineers Report, as published in Division of Water Resources, James River Basin Comprehensive Water Resources Plan, Volume I - Introduction (Richmond, Virginia: Department of Conservation and Economic Development, 1969), p. 27-28.

[54] The Nansemond River inflow combines that of the Elizabeth, Pagan, Warwick, and Nansemond Rivers.

[55] Drs. Donald Pritchard and J. Carpenter.

[56] Dr. W. J. Hargis, Jr., Director, VIMS, uses the term "infinitely exspansible".

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