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FUTURE CONDITIONS REPORT

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Foreword

The Corps of Engineers' comprehensive study of Chesapeake Bay is being accomplished in three distinct developmental stages or phases. Each of these phases is responsive to one of the following stated objectives of the Study Program:

1. To assess the existing physical, chemical, biological, economic and environmental conditions of Chesapeake Bay and its related land resources.

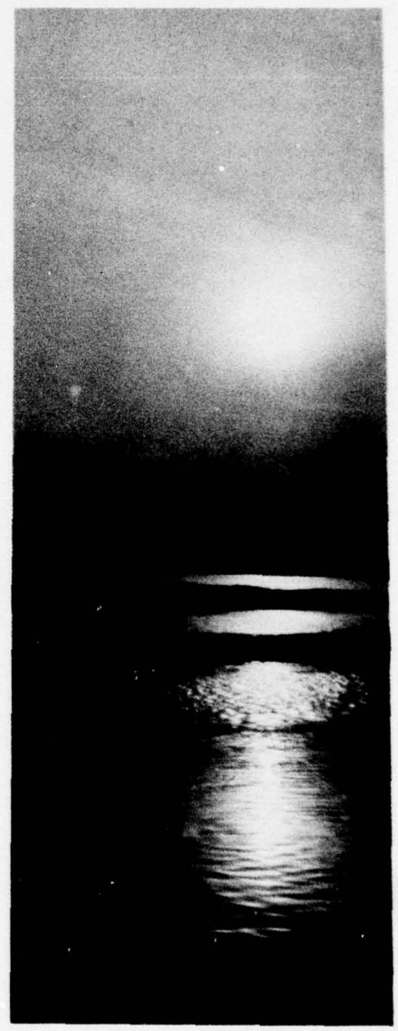
2. To project the future water resources needs of Chesapeake Bay to the year 2020.

3. To formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

In response to the first objective of the Study, the initial or inventory phase of the program was completed in 1973. The findings were published in a seven-volume report titled *Chesapeake Bay Existing Conditions Report.* This was the first published report to present a comprehensive survey of the entire Bay Region and treat the Chesapeake Bay as a single entity. Most importantly, the report contains much of the basic data required to project the future demands on the Bay and to assess the ability of the resource to meet those demands.

In response to the second objective of the Study, the findings of the second or future projections phase of the program are provided in this the *Chesapeake Bay Future Conditions Report.* The primary focus of this report is the projection of water resources needs to the year 2020 and the identification of the problems and conflicts which would result from the unrestrained growth and use of the Bay's resources. This report, therefore, provides the basic information necessary to proceed into the next or plan formulation phase of the program. It should be emphasized that, by design, this report addresses only needs and problems. No attempt has been made to identify or analyze solutions to specific problems. Solutions to priority problems will be evaluated in the third phase of the program and the findings will be published in subsequent reports.

The *Chesapeake Bay Future Conditions Report* consists of a summary document and 16 supporting appendices. Appendices 1 and 2 are general background documents containing information describing the history and conduct of the Study and the manner in which the Study was coordinated with the various Federal and State agencies, scientific institutions and the public. Appendices 3 through 15 contain information on specific water and related land resource uses, including an inventory of the present status and expected future needs and problems. Appendix 16 focuses on the formula-



tion of the initial testing program for the Chesapeake Bay Hydraulic Model. Included in Appendix 16 is a description of the Hydraulic Model, a list of problems considered for inclusion in the initial model testing program, and a description of the selected first year model studies program.

Listed below are the published volumes of the *Chesapeake Bay Future Conditions Report.*

Volume Number	Appendix Number and Title
1	Summary Report
2	1 – Study Organization, Coordination and History 2 – Public Participation and Information
3	3 – Economic and Social Profile
4	4 – Water-Related Land Resources
5	5 – Municipal and Industrial Water Supply 6 – Agricultural Water Supply
6	7 – Water Quality
7	8 – Recreation
8	9 – Navigation 10 – Flood Control 11 – Shoreline Erosion
9	12 – Fish and Wildlife
10	13 – Power 14 – Noxious Weeds
11	15 – Biota
12	16 – Hydraulic Model Testing

Syllabus

Chesapeake Bay is a vast natural, economic, and social resource. Along with its tributaries, the Bay provides a transportation network on which much of the economic development of the Region has been based, a wide variety of water-oriented recreational opportunities, a home for numerous fish and wildlife, a source of water supply for both municipalities and industries, and the site for the disposal of many of our waste products. The natural resources and processes of the Bay and man's activities interact to form a complex and interrelated system. Unfortunately, problems often arise when man's intended use of one resource conflicts with either the natural environment or man's use of another resource. It was the need for a plan to provide for the most efficient use of the Bay's resources that provided the impetus for the initiation of the Chesapeake Bay Study.

In 1970, approximately 7.9 million people lived in the Chesapeake Bay Region. By the year 2020, population is expected to more than double reaching a level of approximately 16.3 million persons. Employment is projected to grow at approximately the same rate as population; per capita income is projected to nearly quadruple; and manufacturing output is expected to increase by nearly 600 percent.

These increases in population, per capita income, and manufacturing output will cause additional demands to be placed on Chesapeake Bay's water and related land resources. The major purpose of the *Chesapeake Bay Future Conditions Report* is to forecast these future demands and assess the capacity of the system to satisfy them. The following is a summary of some of the more significant findings of the Report:

*Chesapeake Bay is one of the largest estuaries in the world, having a surface area of about 4,400 square miles, a length of nearly 200 miles, and over 7,000 miles of shoreline. Like many coastal plain estuaries, the Bay is a broad, shallow expanse of water varying from 4 to 30 miles in width, but having an average depth of less than 28 feet. Its maximum depth is 175 feet near Bloody Point, Maryland.

*The marshes, woodlands, and the Bay itself, provide an extremely productive natural habitat for over 2,700 different species. The sheer number of species alone forecasts the complexity of Bay biota in terms of partitioning species to communities and determining functional relationships that will aid in understanding the Bay as an ecosystem.

*More than half (57 percent) of the land in the Chesapeake Bay Region is covered by woodlands, forests, or wetlands. An additional one-third is in agricultural uses. Only about 7 percent of the land is used for residential, commercial, or industrial purposes.

*The land needed for residential purposes will approximately double between 1970 and 2020. The amount of land needed for industrial purposes will increase by about 50 percent if industry is to meet the projected increase in manufacturing output. Conversely, the land in crops and miscellaneous farmland is expected to *decrease* by approximately 22 percent. Although there is sufficient land in the Bay Region available for residential and industrial development, conflicts between competing land use types in preferred areas is expected to continue to be a problem in the future.

*There are currently 49 central water supply systems in the Bay Region which serve 2500 or more people. In 1970 these systems served about 76 percent of the people in the Region as well as many industries, providing a total of 872 million gallons of water per day (mgd). By the year 2020, 31 of these 49 systems are expected to have *average* water demands which will exceed presently developed sources of supply. The projected demands for water supplied through central systems will total approximately 2320 mgd by the year 2020. It is questionable whether or not new sources of water can be developed without placing undue stresses on the Bay system.

*Assuming significant increases in recycling rates, water intake by *all* Bay Region industry (i.e., centrally-supplied and self-supplied) is projected to experience only modest increases of about 13 percent. Water consumption, however, is expected to increase by nearly 800 percent over the same period. As a result of these factors, the volume of industrial discharge is projected to decrease by 24 percent.

*Total agricultural water demand, which includes uses for livestock and poultry, irrigation, and the rural domestic population, is expected to quadruple by 2020, with over 90 percent of the increase due to a rise in the demand for irrigation water. In those areas of the Bay Region with significant projected increases available supplies are expected to be sufficient to meet the future demand.

*Water quality conditions in the Bay vary widely due to a variety of factors: proximity to urban areas, type and extent of industrial and agricultural activity, stream-flow characteristics, and the amount and type of upstream land and water usage. Most of the major water quality problems occur in the estuaries of the Bay's tributaries and not in the Bay proper.

*Boating and sailing activity is projected to increase by more than five times, swimming by nearly four and one-half times, picnicking by a factor of three and one-half, and camping by almost six times. As a result of these increases, major deficits in the number of boating ramps, picnic tables, and camping sites are expected by the year 2020. Total Regional swimming pool and beach acreages are considered to be sufficient to meet demands through 2020 although there are acute existing deficits in most of the major urban areas.

*In the major ports of Baltimore and Hampton Roads, the movement of such bulk commodities as petroleum, coal, grain, and in the case of Baltimore, iron ore, are expected to continue to dominate waterborne commerce. Bulk oil traffic is expected to approximately double by the year 2020 in Baltimore and remain at about the 1972 level throughout the projection period in Hampton Roads. The increasing size of bulk carriers, along with the projected general increase in bulk traffic, will intensify the need for deeper channels in the major harbors of the Region. Foreign general cargo traffic is projected to increase by a factor of approximately six in both Baltimore and Hampton Roads between 1972 and 2020.

*Bulk oil is projected to continue to dominate waterborne traffic movements through the minor ports and waterways around Chesapeake Bay. The largest increases are expected on the Western Shore due to larger increases in population and income predicted for these areas as compared to the Eastern Shore. The level of petroleum traffic is critical because of the potential for environmentally damaging oil spills.

*Based on the damage that could be expected from a 100-year tidal flood, the tidal flooding problem is considered to be "critical" in 31 communities in the Bay Region. An additional 20,000 acres of land within the 100-year tidal flood plain has been proposed for future intensive development.

*Approximately 410 miles of Chesapeake Bay shoreline were identified as having "critical" erosion problems (based on intensity of development and existing rate of erosion). Over the last 100 years, approximately 25,000 and 20,000 acres of shoreline have been lost to erosion in Maryland and Virginia, respectively. An additional 44.4 miles of shoreline have the potential to become critical erosion problem areas in the future.

*In 1973, the total harvest of finfish and shellfish from Chesapeake Bay and its tributaries totaled 565 million pounds valued at approximately $47.9 million at the dock. When the combined recreational and commercial catches are taken into account, maximum sustained yields (i.e., the greatest harvest which can be taken from a population without affecting subsequent harvests) are projected to be exceeded for blue crabs, spot, striped bass, white perch, shad, weakfish, flounder, and the American eel by the year 2000. By 2020, catches of oysters, softshell clams, menhaden, and alewife are also expected to exceed their maximum sustainable yields.

*There are numerous areas in the Region which are of significant historical, archaeological, or ecological interest. These include nearly 800 properties which are included in the *National Register of Historic Places*, or have been nominated for that distinction, 20 properties designated as National Wildlife refuges or research centers, and thousands of recorded archaeological sites.

*Waterfowl hunting effort in the Chesapeake Bay Region is predicted to increase by 70 percent during the projection period. Big game hunting projections indicate a 141 percent increase while small game hunting is expected to decrease by about 13 percent. Existing hunting land access problems are expected to be aggravated by the increases in waterfowl and big game hunting effort.

*The demand for non-consumptive

wildlife uses including bird watching, bird and wildlife photography, and nature walking, is expected to approximately double over the projection period. As a result of these increases, an additional one million acres of publicly accessible land will be required to maintain the quality level that existed in 1970.

*The total demand for electricity in the geographical area containing the electric utilities serving the Bay is projected to increase by a factor of more than 5 by the year 2000 and a factor of approximately 13.5 by 2020. More and larger power plants will be required to meet this demand. By the year 1985, nuclear power is projected to account for approximately 44 percent of the Chesapeake Bay Region's power pool requirements. By 2020, the percentage is expected to increase to 72 percent.

*Water withdrawal by power plants is expected to decrease significantly from 12,660 mgd in 1972 to 2,250 mgd in the year 2020, due to projected increases in water recycling. Water consumption is projected to increase dramatically from about 130 mgd in 1972 to 1,170 mgd in 2020.

*Aquatic plants are vital elements of the Chesapeake Bay ecosystem and form the basis in the food chain for the Bay's productive fish and wildlife resources. There has been in recent years an as yet unexplained reduction in the numbers of some of the most beneficial aquatic plant species in Chesapeake Bay.

*Although noxious weeds such as Eurasian watermilfoil, water chestnut, and sea lettuce have caused widespread problems in Chesapeake Bay in the past, present populations are well below troublesome levels. The potential remains, however, for a reemergence of high concentrations of these plants in the future.

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Chapter I The Study and the Report

STUDY AUTHORITY

The authority for the Chesapeake Bay Study and the construction of the Hydraulic Model is contained in Section 312 of the River and Harbor Act of 1965, adopted 27 October 1965, which reads as follows:

> (a) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a complete investigation and study of water utilization and control of the Chesapeake Bay Basin, including the waters of the Baltimore Harbor and including, but not limited to, the following: navigation, fisheries, flood control, control of noxious weeds, water pollution, water quality control, beach erosion, and recreation. In order to carry out the purposes of this section, the Secretary, acting through the Chief of Engineers, shall construct, operate, and maintain in the State of Maryland a hydraulic model of the Chesapeake Bay Basin and associated technical center. Such model and center may be utilized, subject to such terms and conditions as the Secretary deems necessary, by any department, agency, or instrumentality of the Federal Government or of the States of Maryland, Virginia, and Pennsylvania, in connection with any research, investigation, or study being carried on by them of any aspect of the Chesapeake Bay Basin. The study authorized by this section shall be given priority.
>
> (b) There is authorized to be appropriated not to exceed $6,000,000 to carry out this section.

An additional appropriation for the Study was provided in Section 3 of the River Basin Monetary Authorization Act of 1970, adopted 19 June 1970, which reads as follows:

> In addition to the previous authorization, the completion of the Chesapeake Bay Basin Comprehensive Study, Maryland, Virginia, and Pennsylvania, authorized by the River and Harbor Act of 1965 is hereby authorized at an estimated cost of $9,000,000.

As a result of Tropical Storm Agnes, which caused extensive damage in Chesapeake Bay, Public Law 92-607, the Supplemental Appropriation Act of 1973, signed by the President on 31 October 1972, included $275,000 for additional studies of the impact of the storm on Chesapeake Bay.

STUDY PURPOSE

Historically, measures taken to utilize and control the water and land resources of the Chesapeake Bay Basin have generally been oriented toward solving individual problems. The Chesapeake Bay Study was initiated in 1967 to provide a comprehensive study of the entire Bay Area in order that the most beneficial use be made of the water-related resources. The major objectives of the Study are to:

a. Assess the existing physical, chemical, biological, economic, and environmental conditions of Chesapeake Bay and its water resources.

b. Project the future water resources needs of Chesapeake Bay to the year 2020.

c. Formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

In response to the first objective of the Study, the initial or inventory phase of the program was completed in 1973 and the findings were published in a document titled *Chesapeake Bay Existing Conditions Report.*

Included in this seven-volume report is a description of the existing physical, economic, social, biological and environmental conditions of Chesapeake Bay. This was the first published report that presented a comprehensive survey of the entire Bay Region and treated Chesapeake Bay as a single entity. Most importantly, the report contains much of the basic data required to project the future demands on the Bay and to assess the ability of the resource to meet those demands.

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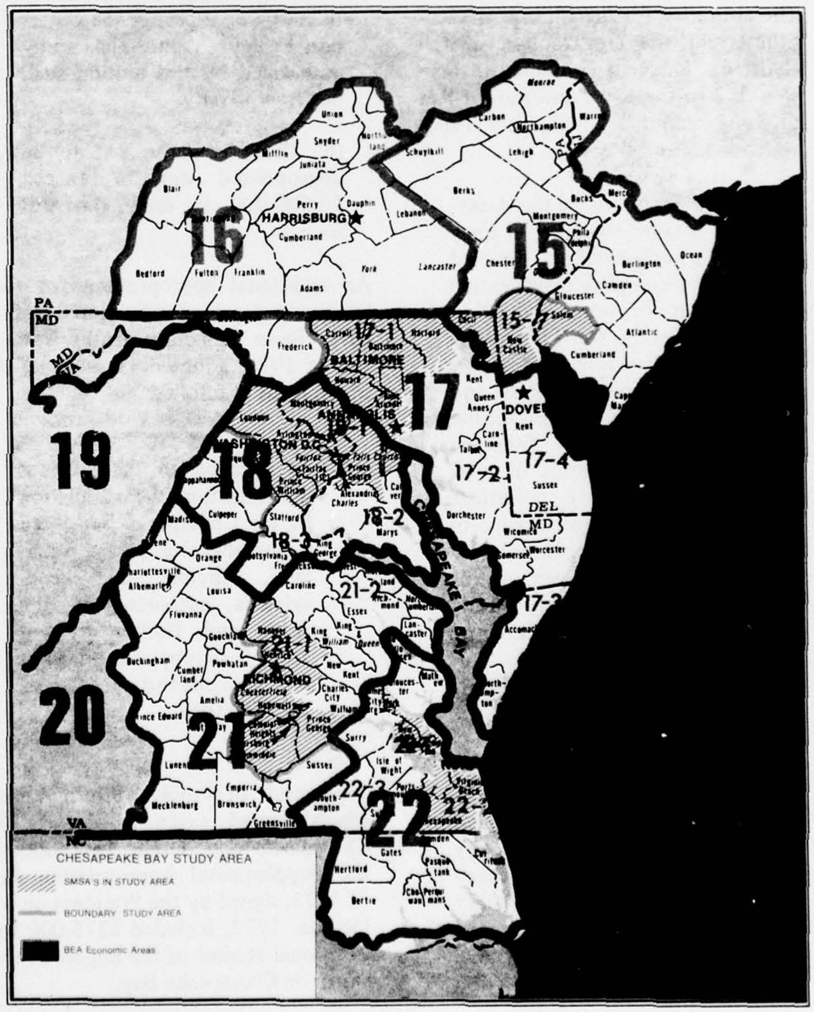
STUDY SCOPE

The expertise required for the conduct of the Chesapeake Bay Study and the *Future Conditions Report* includes the fields of engineering and the social, physical, and biological sciences. The Study is being coordinated with Federal, State, and local agencies having an interest in Chesapeake Bay. Each resource category or problem area has been treated on an individual basis with demands and potential problem areas projected to the year 2020. All conclusions are based on historical information supplied by the preparing agencies having expertise in that field.

Figure 1 : Chesapeake Bay Study Area



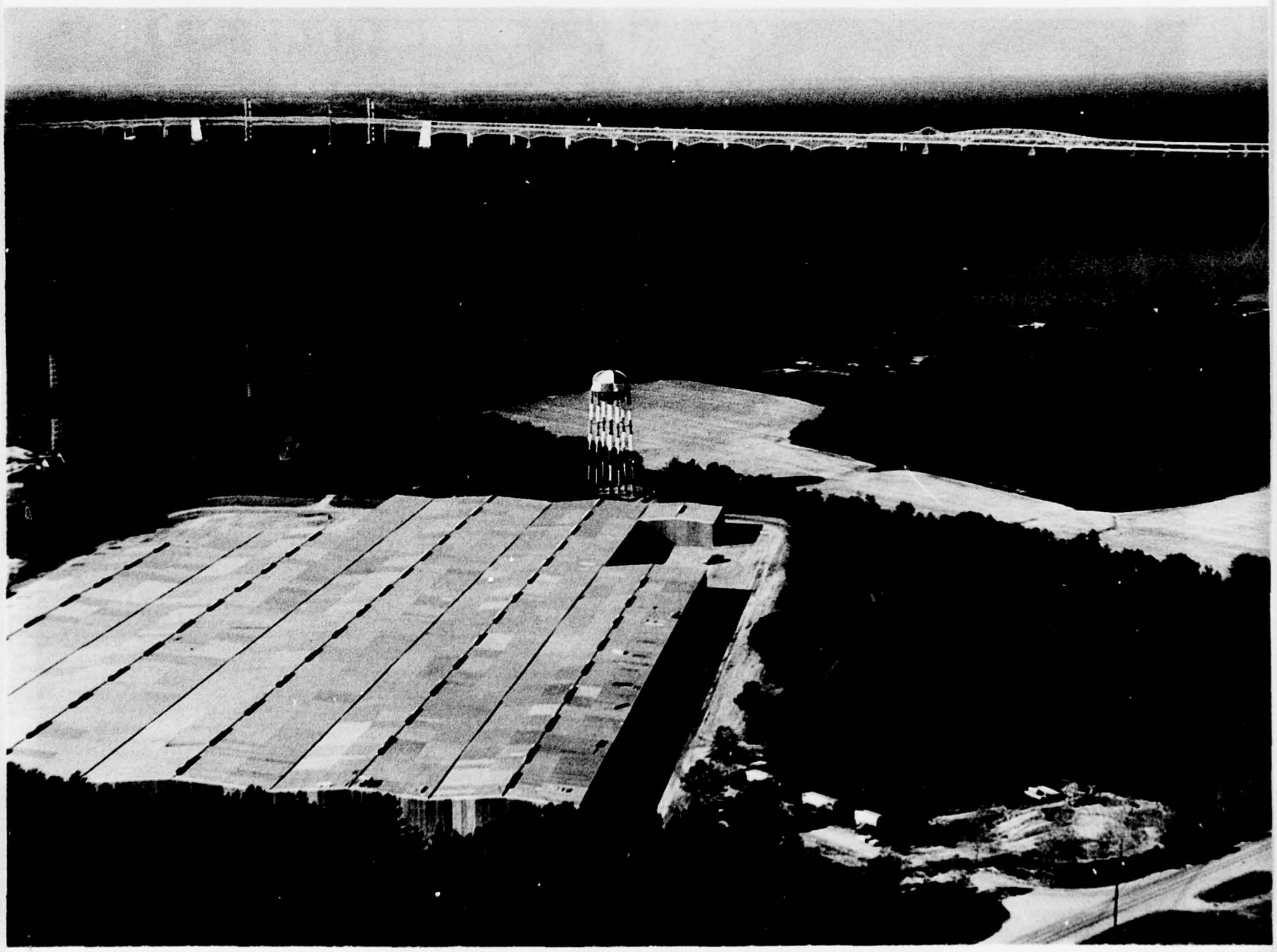
In addition, the basic assumptions and methodologies are tested for sensitivity in the "Sensitivity Analysis" sections. Only general means to satisfy the projected resources needs are presented, as specific recommendations are beyond the scope of this report.

As shown on Figure 1, the geographical study area encompasses those counties or Standard Metropolitan Statistical Areas (SMSA) which adjoin or have a major influence on the Estuary. The area delineated in Figure 1 is referred to as the "Study Area" or "Bay Region" throughout this report. Unless otherwise noted, this is the study area used in each of the Appendices. For purposes of projecting the future demands on the resources of the Bay, economic and demographic projections were made for all subregions and SMSA's within the Study Area. The subregions are listed in Table 1.

As directed in the authorization, the Study also includes the construction, operation and maintenance of a Hydraulic Model of Chesapeake Bay. Actual construction of the 14-acre Model and shelter was begun in June, 1973, and completed in April, 1976. Adjustment and verification of the

TABLE 1
CHESAPEAKE BAY STUDY AREA SUBREGIONS
(NUMBER AND NAME)

15-7	Wilmington, Delaware SMSA
17-1	Baltimore, Maryland SMSA
17-2	Maryland Eastern Shore
17-3	Virginia Eastern Shore
17-4	Delaware, Non-SMSA area (or Delaware Eastern Shore)
18-1	Washington, D.C. SMSA
18-2	Southern Maryland
18-3	Virginia, Non-SMSA area
21-1	Richmond and Petersburg-Colonial Heights, Virginia SMSA's
21-2	Virginia, Non-SMSA area
22-1	Newport News-Hampton, Virginia SMSA
22-2	Norfolk-Portsmouth, Virginia SMSA
22-3	Virginia, Non-SMSA area



Model is due to be completed in 1978. The Hydraulic Model provides a means of reproducing to a manageable scale many natural events and man-made changes thereby allowing the collection of the data necessary to assess the consequences of these happenings. As an instrument and physical display, the Hydraulic Model serves to educate the public relative to the complexity of the Bay's problems and conflicts. As an operational focal point, the Model will promote more effective liaison among the agencies working on the Bay waters, helping to reduce duplication of effort and aid in dispersion of knowledge among the interested parties.

MANAGEMENT RESPONSIBILITIES

Due to the large geographic area comprising the Chesapeake Bay Region and the complex problems which face the Estuary, a large number of Federal, State, and local agencies and interstate commissions are involved in various aspects of water resource management in the Region.

The Federal concern with natural resources is founded on the fact that these resources form the basis for much of our National wealth and future well-being. The concern for water resources, in particular, is shown by many legislative enactments by the Congress. A continually developing body of law has established varying degrees of National concern as evidenced by the existence of numerous Federal agencies with authority in such areas as navigation, flood control, drainage, irrigation, recreation, fish and wildlife conservation, water supply, and water quality.

Water resources management is not the exclusive domain of the Federal gov-

Chesapeake Bay Hydraulic Model.

ernment. State and local governments also play a vital role. Such governments often have their own management and construction programs, as well as having the responsibility to review and comment on proposed Federal projects. They are also an invaluable source of information due to their detailed knowledge of the areas within their jurisdiction. The States usually have one major executive level department responsible for natural resources. However, there are often additional State agencies and commissions in charge of certain aspects of water resources management outside of this organizational structure.

In addition to the Federal, State, and local agencies with water resource responsibilities, there are two interstate organizations which are directly involved in water resources management in the Chesapeake Bay Region: the Susquehanna River Basin Commission and the Interstate Commission on the Potomac River Basin.

For more information on the various agencies and commissions with management responsibilities pertaining to the Bay, it is suggested that Appendix 2 of this Report titled "Public Participation and Information" be consulted.

STUDY ORGANIZATION AND MANAGEMENT

The magnitude of the Chesapeake Bay Study, the large number of participants, and the complex spectrum of problems to be analyzed requires intensive coordination of activities. The initial planning of this Study was coordinated with the then National Council of Marine Resources and Engineering Development through its Committee on Multiple Use of the Coastal Zone. This study was conceived as a coordinated partnership between Federal, State, and local agencies and interested scientific institutions. Each involved agency is charged with exercising leadership in those disciplines in which it has special competence and is expected to review and comment on work performed by others. To realize these ends, an Advisory Group, a Steering Committee, and five Task Groups, as shown in Figure 2, were established.

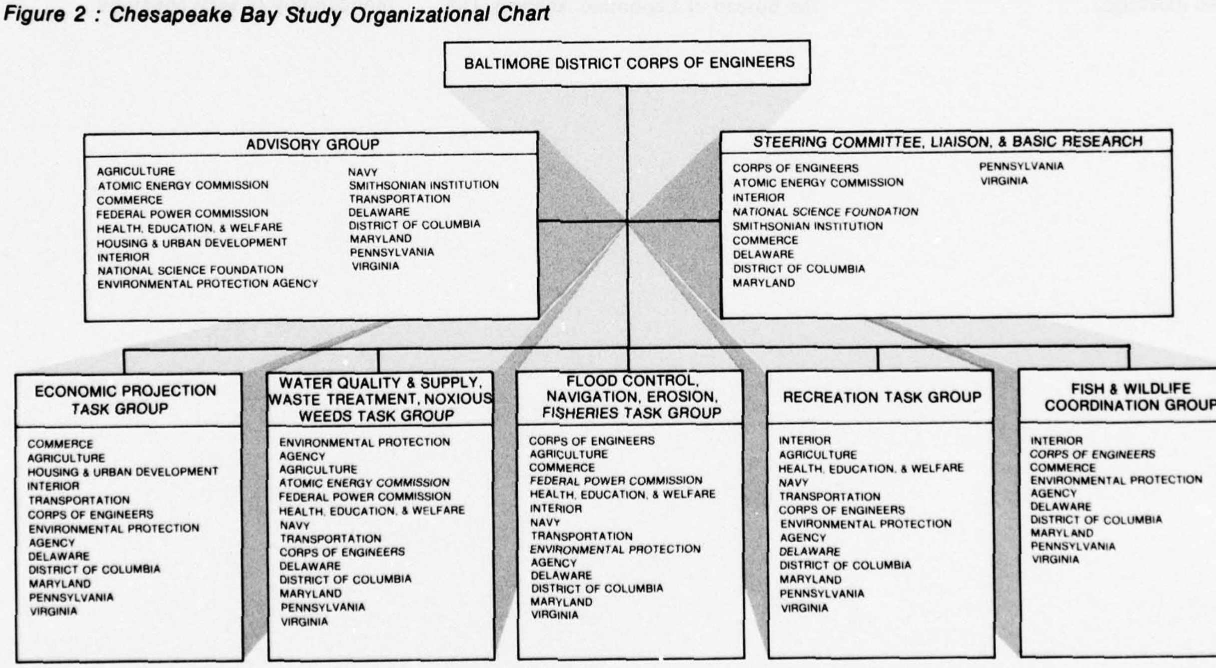
The overall management of the Chesapeake Bay Study is the responsibility of the District Engineer of the Baltimore District, Corps of Engineers. Appendix 1 of this Report, titled "Study Organization, Coordination, and History," contains more information on Study organization.

PUBLIC PARTICIPATION AND INFORMATION PROGRAM

The involvement of the public in the planning process is an important facet of the planner's responsibility. Citizen interest in resource planning is particularly evident in the water resource field where there is increased public awareness of ecology and concern for the environmental impact of the actions of man. Corps of Engineers policy is to fully inform the public about Corps studies and to encourage the public to meaningfully participate in the planning process.

A comprehensive plan for public involvement was prepared for the Chesapeake Bay Study. The purpose of this program is to provide an organized set of activities which establishes two-way communication between the planner and the public.

Figure 2 : Chesapeake Bay Study Organizational Chart



To date, a number of the public involvement techniques recommended in this comprehensive plan have been employed. An informal liaison has been established with the Citizens Program for Chesapeake Bay, Inc., an organization representing a wide range of groups with interest in Chesapeake Bay. This group has served as the Chesapeake Bay Study's citizens' advisory group. In addition, two sets of public meetings have been held: one at the onset of the Study to inform the public of the initiation of the Study and to solicit views as to what direction the Study should take; and the second near the completion of the future projections phase of the Study to inform the public of progress on the overall program and to solicit views regarding the findings of the Study and future Study direction.

Publications have been used to disseminate information concerning study objectives and outputs, history, and other data. In addition to the Study's planning reports, a number of other printed materials were prepared specifically for informing the public about the Study. These include a leaflet on the Hydraulic Model, reprints of articles, and transcripts from public meetings.

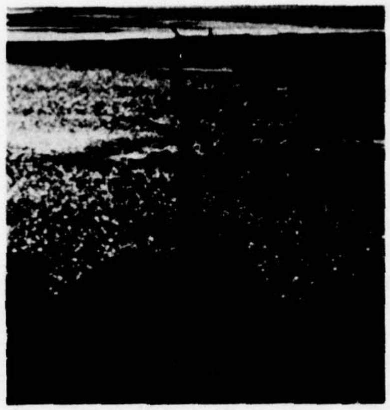
Another element of the public involvement program has been the production of a film, titled "Planning for a Better Bay," which describes the Bay's water and related land resources, its problems, and the Chesapeake Bay Study. The film has been viewed by thousands of people and is currently shown as part of the daily public tours being conducted at the Chesapeake Bay Hydraulic Model. The film is also shown at public presentations to various engineering or technical societies, local civic or service groups, environmental organizations, Bay-related businesses, and schools. The hundreds of presentations which have been given to date have made up an important part of the Bay Study's public involvement program. For more information concerning the Chesapeake Bay Study's public participation program consult Appendix 2, "Public Participation and Information."

SUPPORTING STUDIES

Although this report was prepared and coordinated by the Baltimore District, Corps of Engineers, much of the information was derived from other sources. The economic and demographic projections were prepared by the Bureau of Economic Analysis, U.S. Department of Commerce. Projections of industrial water supply were prepared specifically for this study by the Bureau of Domestic Commerce, U.S. Department of Commerce. All agricultural water demands, including rural domestic, livestock, and irrigation uses, were projected by the Economic Research Service, U.S. Department of Agriculture. All projections and inventories relative to recreational uses were made by the Bureau of Outdoor Recreation, U.S. Department of the Interior. The fish and wildlife portion of the Report was prepared jointly by the Fish and Wildlife Service, U.S. Department of the Interior, and the National Marine Fisheries Service, U.S. Department of Commerce. The Chesapeake Research Consortium prepared the "Biota" Appendix, and the projections of electric power needs were prepared by the Federal Power Commission.

Much of the initial data base and resource inventory for all resource categories addressed in the Study were presented in the *Chesapeake Bay Existing Conditions Report.* Other sources of information too numerous to mention here, are referenced in the bibliography of each appendix.

Chapter II The Chesapeake Bay Region



ENVIRONMENTAL SETTING AND NATURAL RESOURCES

GEOLOGY

The Chesapeake Bay Region is divided into two geologic provinces–the Coastal Plain and the Piedmont Plateau. These provinces run roughly parallel to the Atlantic Ocean in similar fashion to the Bay itself and join at the Fall Line (see Figure 3). This natural line of demarcation generally marks both the limit of tide as well as the head of navigation.

The Coastal Plain Province includes the Eastern Shore of Maryland and Virginia, most of Delaware, and a portion of the Western Shore. On the Eastern Shore and in portions of the Western Shore adjacent to the Bay, the Coastal Plain is largely low, featureless, and frequently marshy, with many islands and shoals sometimes extending far offshore. The Province is a gently rolling upland on the Western Shore and in the northern portions of the Eastern Shore. The Coastal Plain reaches its highest elevation in areas along its western margin.

The composition of the Coastal Plain is primarily unconsolidated, southeasterly-dipping, sedimentary layers such as sand, clay, marl, gravel, and diatomaceous earth resting on a base of hard crystalline rock. These layers, which can be readily seen in areas where wells have been drilled, increase in thickness towards the Continental Shelf (see Figure 4). In a few isolated areas and in locations where water has cut a deep channel, the basement rock is exposed in ridges.

The Piedmont Plateau is not, as its name implies, a plateau. It is characterized by low hills and ridges which tend to rise above the general lay of the land reaching a maximum height near the Appalachian Province on the west. Many of the stream valleys are quite narrow and steep-sided, having been cut into the hard crystalline rocks which are characteristic of the Province.

The parent material of the Piedmont Province is both older and more complicated than that of the Coastal Plain. The structurally complex crystalline rocks have been severely folded and subjected to great heat and pressure thereby creating metamorphic rocks.

SOILS

Soils consist of a thin layer of material made from broken and decomposed rock with added products of decaying organic matter called humus. The Study Area contains soils produced from the three major types of rock, namely igneous, metamorphic, and sedimentary. The first two types are found primarily in the Piedmont Province, whereas the Coastal Plain is composed of sediments.

Climate appears to have a definite effect on soil development. Although the Bay Area is generally characterized by a humid climate, local variations in temperature and rainfall produce some differences in soil type. Soil characteristics (texture, drainage, structure, particle size, physical composition, and degree of development) have had a strong role in determining soil usefulness. Richer, well-drained soils are more productive in terms of agriculture. Few crops can grow on soils which are poorly drained or which lack plant nutrients. Soils on the Coastal Plain are highly variable with regard to drainage characteristics and most need liming to neutralize their naturally acidic condition. Piedmont soils are medium-grained, easily tilled, and of generally higher fertility than those of the Coastal Plain. A few soils are impermeable when wet, retarding the movement of water and causing waterlogging. As a result, strong surface runoff causes serious erosion of slopes.

CLIMATE

The Chesapeake Bay Study Area is characterized by a generally moderate climate, due in a large part to the area's proximity to the Atlantic Ocean. Variations occur, however, on a local, short-term basis due to the large geographical size of the Bay Area.

Precipitation within the Bay Region was studied at selected stations during a 30-year sample record from 1931 to 1960. The average for the Study Area was 44 inches per year, with geographical variations from about 40 to 46 inches per year. Snowfall, included in the precipitation totals, averaged 13 inches per year and occurred generally between November and March.

Three types of storm activity bring precipitation to the Region. The first type consists of extratropical storms or "lows" which originate to the west, either in the Rocky Mountains, Pacific Northwest, or the Gulf of Mexico. The second is tropical storm or hurricane activity which originates in the Middle Atlantic or the Caribbean Sea region. The *third is thunderstorm activity* which is almost always on a local scale. It is this last activity which brings about the greatest amount of local variation in precipitation in the Bay Area.

Evapotranspiration, which includes water losses due to evaporation from land and water surfaces and transpiration from plants, amounts to approximately 60 percent of the annual precipitation or about 26 inches per year. Authorities estimate an annual evaporation of 36 to 40 inches from the Bay itself.

The average temperature for the Study Area is approximately 57 degrees Fahrenheit (°F). The Bay is oriented in a north-south direction, however, and covers a wide latitudinal area, allowing wide temperature variances. As a result, the temperature at the head of the Bay averages less than 55°F, while at the mouth it averages almost 60°F, with some peripheral effect due to the nearness of the Atlantic Ocean.

SURFACE WATER HYDROLOGY

The source of freshwater for the Bay is runoff from a drainage basin covering about 64,160 square miles. Approximately 88 percent of this basin is drained by five major rivers, including the Susquehanna, Potomac, Rappahannock, York, and James (see Table 2).

These river basins are subject to periodic large, climatic extremes, resulting in large fluctuations in flow, i.e., droughts and floods. Of these,

TABLE 2
BASIN CHARACTERISTICS OF MAJOR CHESAPEAKE BAY TRIBUTARIES

River Basin	Drainage Area at Mouth (Sq. Mi.)	River Length (Mi.)
Susquehanna	27,510	453
Potomac	14,670	407
Rappahannock	2,715	184
York	2,660	130
James	10,102	434

Figure 3: Chesapeake Bay Region Geological Provices and Fall Line

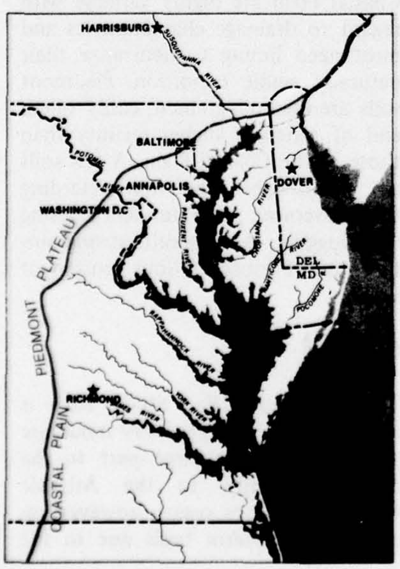
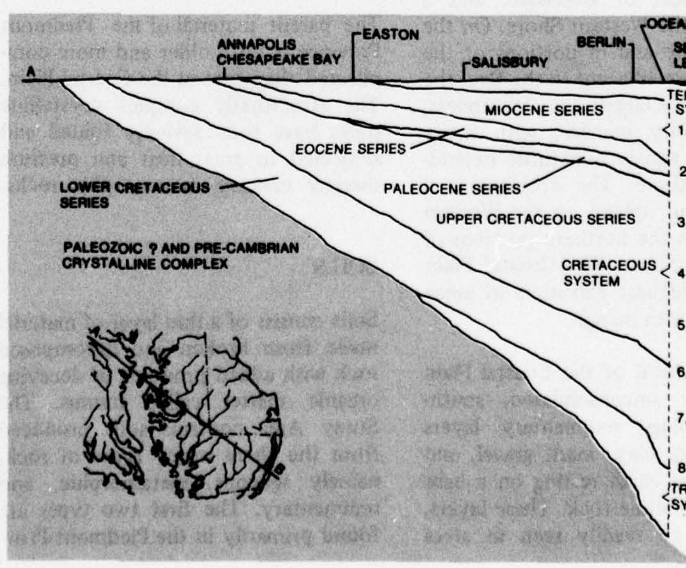


Figure 4: Geologic Cross-Section of the Coastal Plain Province in Maryland



droughts are the more geographically widespread and long-term in nature. The Susquehanna, Potomac, Rappahannock, York, and James Rivers together produce nearly 90 percent of the Bay's mean annual inflow of approximately 69,800 cubic feet per second.

GROUNDWATER RESOURCES

Large reservoirs of high quality freshwater are located in the groundwater aquifers of the Chesapeake Bay Region. Aquifers are subsurface sand and gravel-type materials with relatively high ability to conduct water. Water levels in the aquifers fluctuate according to the balance between precipitation and aquifer recharge, on the one hand, and evapotranspiration, runoff, and withdrawals on the other hand. In the Bay Area, of the average precipitation of 44 inches per year, an estimated 9 to 11 inches actually contributes to the recharge of the groundwater reservoirs.

Of the more productive aquifers in the Chesapeake Bay Area, the water-bearing formations known as the Columbia Group produce very high yields. Extensive areas on the Eastern Shore and portions of Harford and Baltimore Counties, Maryland, are the principal users. The Piney Point Formation is important in Southern Maryland, portions of Maryland's Eastern Shore and in areas near the Fall Line in Virginia. Lastly, the Potomac Group provides water to Anne Arundel, Charles, and Prince Georges Counties, Maryland and is the most important source of groundwater in the Coastal Plain of Virginia.

THE CHESAPEAKE BAY ESTUARY

The Chesapeake Bay Estuary is a mere youngster, geologically speaking. It is generally believed that the Bay was

Susquehanna River Near Its Mouth.

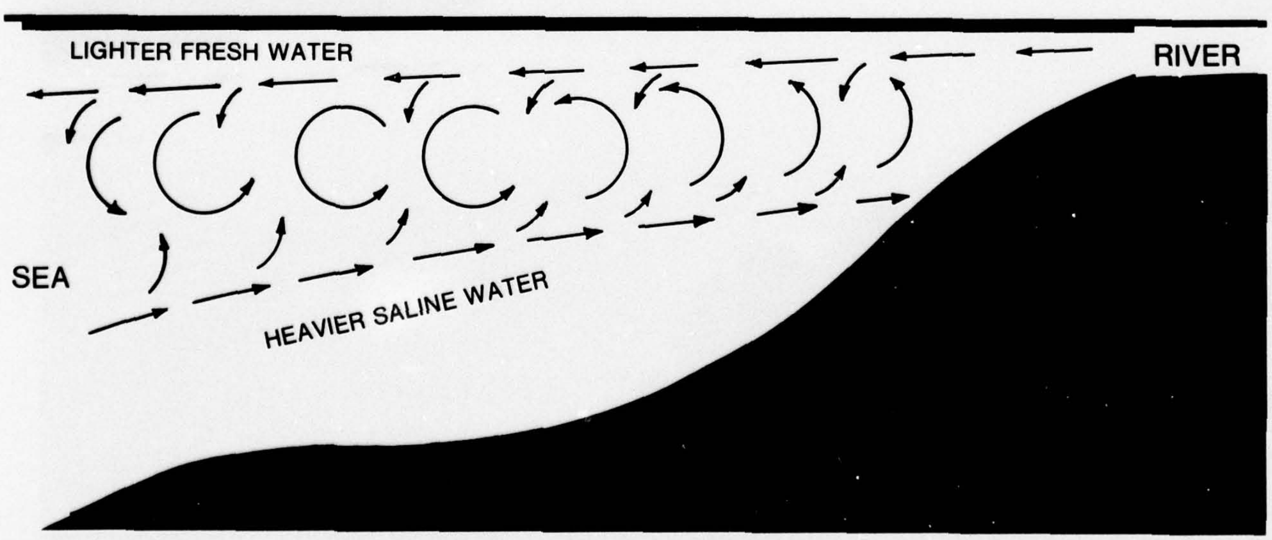
formed about 10,000 years ago, at the end of the last Ice Age, when the great glaciers melted and poured uncountable billions of gallons of water back into the world's oceans. As a result of this great influx of water, the ocean level rose several hundred feet and inundated large stretches of the coastal rivers. The ancient Susquehanna, which had drained directly into the Atlantic Ocean near what is now the mouth of the Bay, was one of these "drowned" waterways. Because the area around the old Susquehanna was characterized by relatively low relief, the estuary that was formed by this mixing of salt and freshwater covered a large geographical area but was relatively shallow. This newly formed body of water was later to be named "Chesapeake Bay." Chesapeake Bay varies from 4 to 30 miles in width and is about 200 miles long. Although the Chesapeake is the largest estuary in the United States, with a surface area of approximately 4,400 square miles, the average depth of the Bay proper is only about 28 feet and about two-thirds of the Bay is eighteen feet deep or less. There are, however, deep holes which generally occur as long narrow troughs. These troughs are thought to be the remnants of the ancient Susquehanna River valley. The deepest of these holes is about 174 feet and occurs off Kent Island.

Chesapeake Bay is a complex, dynamic system. Words like "restless," "unstable," and "unpredictable," which generally describe the young of most animal species, can also be used to describe the young estuary. The ebb and flood of the tides and the incessant action of the waves are the most readily perceptible water movements in the Bay. Average maximum tidal currents range from 0.5 knots to over 2 knots (1 knot equals 1 nautical mile of 6,076 feet per hour). The mean tidal fluctuation in Chesapeake Bay is small, generally between one and two feet. Except during periods of unusually high winds, waves in the Bay are relatively small, generally less than 3 feet in height.

Within the Bay proper, and its major tributaries, there is superimposed on the tidal currents a less obvious, non-tidal, two-layered circulation pattern that provides a net seaward flow of lighter, lower salinity water in the upper layer and a flow up the estuary of heavier, higher salinity waters in the deeper layer. This phenomenon is illustrated in Figure 5. The tidal currents provide some of the energy necessary for the mixing of the two layers.

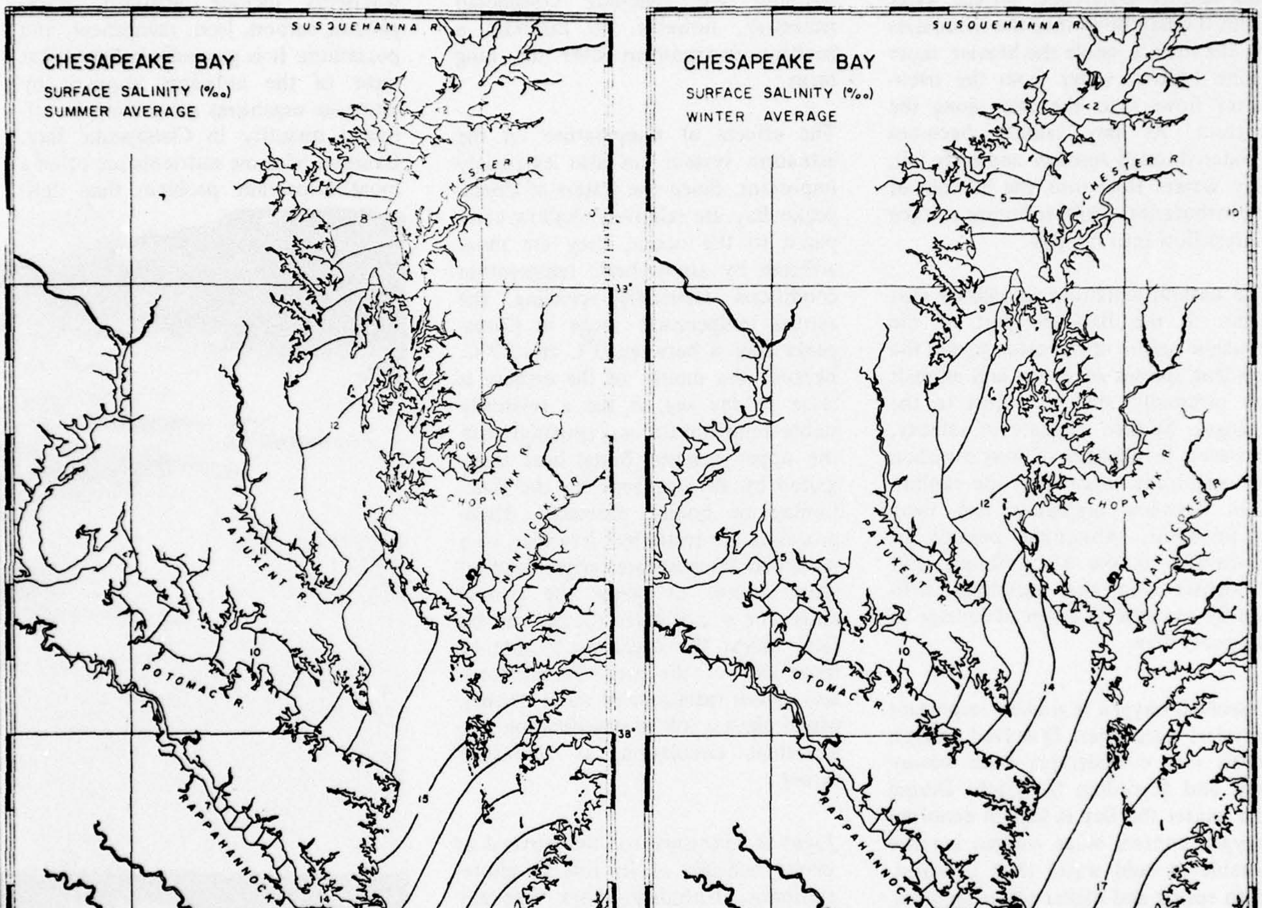
Tides and wave action (as well as other types of currents) are biologically significant in several ways. They provide mixing, transportation, and distribution of inorganic and organic nutrients. These water movements also affect the dispersion of eggs, larva, spores, gametes, and smaller advanced stages of resident plants and animals; remove waste products and bring food and oxygen to fixed bottom-dwelling organisms; and circulate chemical "clues" which aid predators in locating their prey. Tides and waves are also especially important ecologically to the intertidal zone (the shoreline area between high and low tides) of an estuary because of their wetting action which is beneficial to many plant and animal species. In sheltered waters, the mixing of water by tidal and wave action is important for the prevention of excessively high temperatures and salinity stratification which could be harmful to some biota. The turbulence caused by wave action also plays a role in aeration of the waters to provide sufficient oxygen for biotic respiration.

Figure 5 : Circulation in a Partially Mixed Estuary



The mixing in the estuary of sea water and freshwater creates salinity variations within the system. In Chesapeake Bay, salinities range from 33 parts per thousand at the mouth of the Bay near the ocean to near zero at the north end of the Bay and at the heads of the embayments tributary to the Bay. Higher salinities are generally found on the Eastern Shore than on a comparable area of the Western Shore due to the greater river inflow on the Western Shore and to the earth's rotation. Salinity patterns also vary seasonally according to the amount of freshwater inflow into the Bay system. Figure 6 illustrates these phenomena.

Figure 6: Geographical and Seasonal Variations in Salinities in Chesapeake Bay



Due to this seasonal variation in salinity and the natural density differences between fresh and saline waters, significant non-tidal circulation often occurs within the Bay's small tributary embayments. In the spring, during the period of high freshwater inflow to the Bay, salinity in the embayments may be greater than in the Bay. Because of this salinity difference, surface water from the Bay flows into the tributaries on the surface, while the heavier, more saline bottom water from the tributaries flows into the Bay along the bottom. As Bay salinity becomes greater through summer and early fall, Bay waters flow into the bottom of the tributaries, while tributary surface waters flow into the Bay.

The natural variations in salinity that occur in the Bay are part of the dynamic nature of the estuary, and the resident species of plants and animals are ordinarily able to adjust to the changes. Sudden changes in salinity, however, or changes of long duration or magnitude, may upset the equilibrium between organisms and their environment. Abnormal periods of freshwater inflow (i.e., floods and droughts) may alter salinities sufficiently to cause widespread damage to the ecosystem.

Dissolved oxygen is another important physical parameter. Dissolved oxygen levels vary considerably both seasonally and according to depth. During the winter the Bay is high in dissolved oxygen content since oxygen is more soluble in cold water than in warm. With spring and higher water temperatures, the dissolved oxygen content decreases. While warmer surface waters stay near saturation, in deeper waters the dissolved oxygen content becomes significantly less despite the cooler temperatures because of increasing oxygen demands (by bottom dwelling organisms and decaying organic material) and decreased vertical mixing. Through the summer, the waters below 30 feet become oxygen deficient. By early fall, as the surface waters cool and sink, vertical mixing takes place and the oxygen content at all depths begins to steadily increase until there is an almost uniform distribution of oxygen. While species vary in the level of dissolved oxygen they can withstand before respiration is affected, estuarine species in general can function in waters with dissolved oxygen levels as low as 1.0 to 2.0 mg/liter. Dissolved oxygen levels of about 5.0 mg/liter are generally considered necessary, however, to maintain a healthy environment over the long term.

The effects of temperature on the estuarine system are also extremely important. Since the waters of Chesapeake Bay are relatively shallow compared to the ocean, they are more affected by atmospheric temperature conditions. Generally speaking, the annual temperature range in Chesapeake Bay is between 0°C and 29°C. Because the mouth of the estuary is close to the sea, it has a relatively stable temperature as compared with the upper reaches. Some heat is required by all organisms for the functioning of bodily processes. These processes are restricted, however, to a particular temperature range. Temperatures above or below the critical range for a particular species can be fatal unless the organism is able to move out of the area. Temperature also causes variations in water density which plays a role in stratification and non-tidal circulation as discussed earlier.

Light is necessary for the survival of plants because of its role in photosynthesis. Turbidity, more than any other physical factor, determines the depth light will penetrate in an estuary. Turbidity is suspended material, mineral and/or organic in origin, which is transported through the estuary by wave action, tides, and currents. While the absence of light may be beneficial to some bottom dwelling organisms since they can come out during daylight hours and feed in relative safety, this condition limits the distribution of plant life because of the restriction of photosynthetic activity. This restriction of plant life (especially plankton in the open estuary) will reduce the benthic (i.e., bottom dwelling) and zooplankton populations which in turn will reduce fish productivity.

Nutrients are the minerals essential to the normal functioning of an organism. In Chesapeake Bay, important nutrients include nitrogen, phosphorus, carbon, iron, manganese, and potassium. It is generally believed that most of the nutrients required by estuarine organisms are present in sufficient quantity in Chesapeake Bay. Excesses of some nutrients are often a more important problem than defi-

ciencies. Excesses of nitrogen and phosphorus, for example, may cause an increase in the rate of eutrophication which, in turn, can eliminate desirable species, encourage the growth of obnoxious algae, and cause low dissolved oxygen conditions from the decay of dead organisms and other materials. Relatively little is known about the quantities of specific nutrients necessary for the healthy functioning of individual species, or more importantly, of biological communities.

While it is necessary to keep in mind the interactions of these physical and chemical variables when studying Chesapeake Bay, these parameters should not and, in fact, cannot be addressed separately. The Bay ecosystem is characterized by the dynamic interplay between many complex factors. As a simple example, the levels of salinity and temperature will both affect the metabolism of an aquatic organism. In addition, both salinity and temperature can cause a drop in the oxygen concentration in the water and thus an increase in the required respiration rate of the organism. While it is true the effects of these variables individually may be of a non-critical nature, the combined (or synergistic) effects of the three stresses may be severe to the point of causing death. These three parameters, in turn, also interact with other physical and chemical variables such as pH, carbon dioxide levels, the availability of nutrients, and numerous others. The subtle variable of time may also become critical in many cases. The important point is that the physical and chemical environment provided by Chesapeake Bay to the indigenous biota is extremely complex and difficult, if not impossible, to completely understand.

THE BIOTA OF CHESAPEAKE BAY

The estuary is biologically a very special place. It is a very demanding environment because it is constantly changing. The resident plants and animals must be able to adjust to changes in physical and chemical parameters. The requirement for adjustment to the almost constant ecological stress limits the number of species of plants and animals that are able to survive and reproduce in the estuary. Despite the fact that relatively few species inhabit the Bay, the Chesapeake, like most estuaries, is an extremely productive ecosystem.

There are a number of reasons why estuaries are so productive. First, the circulation patterns in the area of mixing of lighter freshwater with heavier sea water in a partially mixed estuary such as Chesapeake Bay tend to create a "nutrient trap" which acts to retain and recirculate nutrients (see Figure 5). Second, water movements in the estuary do a great deal of "work" removing wastes and transporting food and nutrients enabling many organisms to maintain a productive existence which does not require the expenditure of a great deal of energy for excretion and food gathering. Third, the recycling and retention of nutrients by bottom-dwelling organisms, the effects of deeply penetrating plant roots, and the constant formation of detrital material in the wetlands create a form of "self-enriching" system. Last, estuaries benefit from a diversity of producer plant types which together provide year-round energy to the system. Chesapeake Bay has all three types of producers that power the ecosystems of our world: macrophytes (marsh and sea grasses), benthic microphytes (algae which live on or near the bottom), and phytoplankton (minute floating plants).

AQUATIC PLANTS

As implied above, certain aquatic plants are critical to the health and productivity of Chesapeake Bay. Green plants use sunlight and the inorganic nutrients in the water to produce the energy to drive the estuarine ecosystem. Thus, these plants, ranging from the microscopic algae to the larger rooted aquatics, are the *primary* producers—the first link in the aquatic food chain. Aquatic plants exist in the natural environment in a myriad of shapes, forms, and degree of specialization. They are also found in waters of widely varying physical and chemical quality.

"Phytoplankton" is a general term for aquatic plants of both fresh and saline waters which are characteristically free-floating and microscopic. The most important of the phytoplankton are the green algaes, diatoms, and dinoflagellates. The population of these organisms is represented by relatively few species, but when they do occur, they are present in tremendous numbers. Phytoplankton are the principal photosynthetic producers in the marine, estuarine, and freshwater environments, and will grow in the water column to any depth that light will penetrate. Blue-green algae are another type of phytoplankton organism which are not generally considered to be of importance in aquatic productivity, but are best known for the nuisance conditions caused when their growth occurs in excess. Huge populations, or blooms, of these organisms located near the surface of the water reduce the sunlight available to bottom-dwelling organisms. The blooms can also give off objectionable odors, clog industrial and municipal water intakes, and generally cause nuisance conditions.

Macrophytes are, as the Greek roots of the word indicate, "large plants." Unlike the freely floating, or only weakly motile, and minute phytoplankton, the macrophytic aquatic plants are generally either rooted or otherwise fastened in some manner to the bottom. All of the forms require sunlight to conduct photosynthesis and most have defined leaflets which grow either entirely submerged, floating on the surface of the water, or out of the water with leaf surfaces in direct contact with the atmosphere.

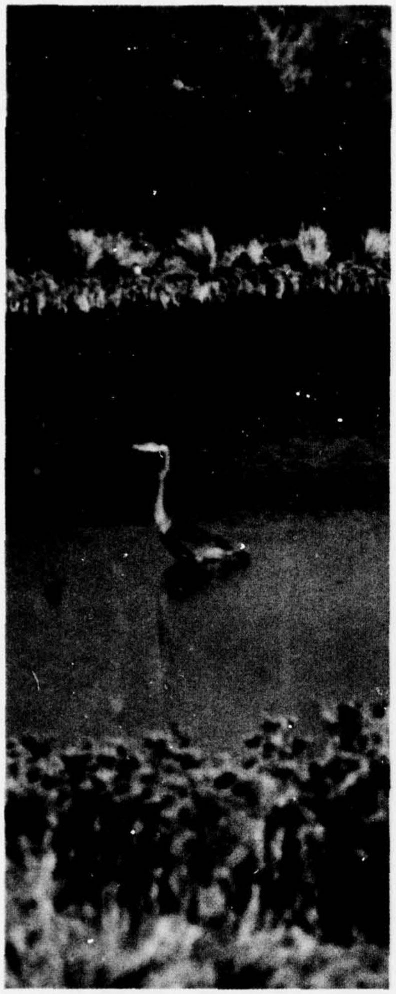
The distribution of Macrophytes ranges from entirely freshwater to the open ocean. These types of plants are not only important as food and habitat for fish and wildlife, but they are also important in the recovery of nutrients from deep sediments.

The "Biota" section of the *Chesapeake Bay Existing Conditions Report* and Appendices 14 and 15 of the *Chesapeake Bay Future Conditions Report* include a more detailed discussion of aquatic plants – their types and distribution, importance in the ecosystem, and the problems associated with them.

FISH AND WILDLIFE

The energy supplied to the ecosystem by the green plants of the Bay must be made available in some manner to the meat-eating predators, including man, which are higher in the food chain. This vital link is filled by many different varieties of organisms such as zooplankton and various species of worms, shellfish, crabs, and finfish. Zooplankton include small crustaceans such as copepods, the larva of most of the estuarine fishes and shellfishes, several shrimp-like species, and other animal forms that generally float with the currents and tides. Phytoplankton and plant detritus (along with adsorbed bacteria, fungi, protozoa, and micro-algae) are consumed directly by the zooplankton and other larger aquatic species.

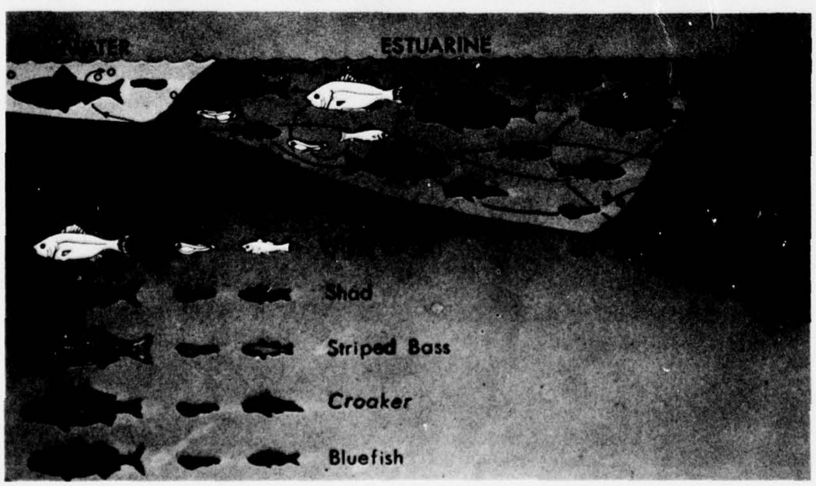
If man through his activity interrupts an established energy flow in the environment, he may cause energy losses to the system as well as other detrimental biological effects. Man's activities, for example, may cause the



loss of a detritus producing area (e.g., a stand of saltmarsh cordgrass) resulting in a decline of the organisms which primarily feed on detritus. A loss of this nature directly affects the next higher trophic level, thereby starting a chain reaction throughout the food web. Generally, in estuaries, there is a great deal of dependence of larger organisms on a few key smaller organisms that utilize detritus and micro-algae for food.

Like the aquatic plant communities, the aquatic animal communities are not spread homogeneously throughout the Bay. Although the entire Estuary serves as nursery and primary habitat for finfish, spawning areas are concentrated in the areas of low salinity and freshwater in the Upper Bay and corresponding portions of the major tributaries. The northern part of Chesapeake Bay, including the Chesapeake and Delaware Canal, is probably the largest of all spawning areas in the Bay. This area plus the upper portions of the Potomac, York, Rappahannock, James, and Patuxent Rivers, represent about 90 percent of the anadromous fish (i.e., those which ascend rivers from the sea to reproduce) spawning grounds in the Chesapeake Bay Region. The Bay serves as a spawning and nursery ground for fish caught from Maine to North Carolina. Some of the fish that use the Bay as a nursery include striped bass, weakfish, shad, alewife, blueback herring, croaker, menhaden, and kingfish (see Figure 7).

Figure 7: Fishes: Their Use of the Estuary



Oysters are abundant in many parts of the Estuary. The numerous small bays, coves, and inlets between the Chester and Nanticoke Rivers along the Eastern Shore and the lower portions of the Patuxent, Potomac, York, Rappahannock, and James Rivers account for approximately 90 percent of the annual harvest of oysters.

Some species of Chesapeake Bay fish and shellfish thrive in the saltier waters of the Estuary. The mouth of the Chesapeake, an area of high salinity, is the major blue crab spawning area in the Bay and its tributaries.

In addition to Chesapeake Bay's large resources of finfish and shellfish, the marshes and woodlands in the Area provide many thousands of acres of natural habitat for a variety of waterfowl, other birds, reptiles, amphibians, and mammals.

Chesapeake Bay is the constricted neck in the gigantic funnel pattern that forms the Atlantic Flyway. Most of the waterfowl reared in the area between the western shore of Hudson Bay and Greenland spend some time in the marshes of the Bay and its tributaries during their migrations. Good wintering areas adjacent to preferred upland feeding grounds attract more than 75 percent of the wintering population of Atlantic Flyway Canada geese. The marshes and grain fields of the Delmarva Peninsula are particularly attractive to Canada geese and grain-feeding swans, mallards, and black ducks. The Susquehanna Flats, located at the head of the Bay, support huge flocks of American widgeon in the early fall, while several species of diving ducks, including canvasback, redhead, ringneck, and scaup, winter throughout Chesapeake Bay. About half of the 80,000 whistling swans in North America winter on the small estuaries in or around the Bay. While the Chesapeake is primarily a wintering

ground for birds that nest further north, several species of waterfowl, including the black duck, blue-winged teal, and wood duck, find suitable nesting and brood-raising habitat in the Bay Region.

In addition to waterfowl, many other species of birds are found in the Bay Area. Some rely primarily on wetlands for their food and other habitat requirements. These include rails, various sparrows, marsh wrens, red-winged blackbirds, snipe, sandpipers, plovers, marsh hawk, shorteared owl, herons, egrets, gulls, terns, oyster catcher, and curlews. Many of the above species are insectivores, feeding

on grasshoppers, caterpillars, beetles, flies, and mosquitoes, while others feed on seeds, frogs, snakes, fish, and shellfish. There are numerous other birds which rely more heavily on the wooded uplands and agricultural lands for providing their basic habitat and food requirements. Among these species are many game birds, including wild turkey, mourning dove, bobwhite quail, woodcock, and pheasant. It should be emphasized that some of these species require both an upland and a wetland habitat. Modest populations of ospreys and American bald eagles also inhabit the Bay Region.

The Chesapeake Bay Region is also home for most of the common mammals which are native to the coastal Mid-Atlantic Region. The interspersion of forest and farmland and the proximity of shore and wetland areas form the basis for a great variety of ecological systems. The abundance of food such as mast and grain crops and the high quality cover vegetation found on the wooded uplands and agricultural lands support good populations of white-tailed deer, cottontail rabbit, red fox, gray fox, gray squirrel, woodchuck, opossum, and skunk. The various vegetation types found in wetland areas provide indispensible natural habitat requirements for beaver, otter, mink, muskrat, marsh rabbit, and nutria. In addition, there are numerous species of small mammals, reptiles, and amphibians which inhabit the Study Area and are integral parts of both the upland and wetland food cycles.

IMPORTANT PLANT AND ANIMAL ORGANISMS

As part of the work done for inclusion in Appendix 15 – "Biota," a survey of prominent Bay Area scientists was conducted to determine the most important plant and animal species based on economic, biological, and social criteria. For example, a species would qualify as an "important species" if it were either a commercial species, a species pursued for sport, a prominent species important for energy transfer to organisms higher in the food chain, a mammal or bird protected by Federal law, or if it exerted a deleterious influence on other species important to man. The common names of the 124 species and genera identified according to these criteria are presented in Table 3.

PLANT AND ANIMAL COMMUNITIES

Although the plants and animals of Chesapeake Bay have been treated separately in the previous discussion, in the real world they are inextricably bound together in communities. Bay communities are important because of the complex interactions between inhabiting organisms, both plant and animal, and between one community and another. In the "eelgrass" community, for example, the organic detritus formed by eelgrass, plus the microorganisms adsorbed on it, represent the main energy source for animals living in the community and for animals outside the community to which detritus is transported. In addition, eelgrass performs the following physical and biological functions:

1. It provides a habitat for a wide variety of organisms

2. It is utilized as a nursery ground by fish

3. It is a food source for ducks and brant

4. The plant physically acts as a stabilizing factor for bottom sediments, which allows greater animal diversity

5. It plays a role in reducing turbidity and erosion in coastal bays.

TABLE 3
IMPORTANT CHESAPEAKE BAY PLANT AND ANIMAL ORGANISMS–COMMON NAMES

Algae

Blue-green alga
**Diatom (4 genera)
Dinoflagellate (3 species)
Sea lettuce
Green alga
Red alga

Vascular Plants (Marsh and aquatic)

*Widgeongrass
Saltmarsh Cordgrass
Eelgrass
Horned pondweed
Wild rice
Cattails
Pondweeds
Arrow-arum
Wild celery

Cnidaria

*Stinging nettle
**Hydroid

Ctenophora (comb jellies)

Comb jelly (2 species)

Platyhelminthes (flatworms)

Flatworm

Annelida (Worms)

**Bloodworm
Clam worm
Polychaete worm (4 genera)
Oligochaete worm

Mollusca (Shellfish)

Eelgrass snail
Oyster drill
Marsh periwinkle
Hooked mussel
Ribbed mussel
Oyster
Hard shell clam

Mollusca (Shellfish) (Cont.)

**Coot clam
**Brackish water clam
Balthic macoma
Stout razor clam
Razor clam
*Soft shell clam
Asiatic clam

Arthropoda (Crabs, shrimp, and other crustaceans)

Barnacle
*Copepod (2 genera)
Opposum shrimp
Cumacean
Isopod (2 species)
Amphipod (5 genera)
Sand flea
**Grass shrimp
**Sand shrimp
**Xanthid crab (2 species)
Blue crab

Urochordata

Sea squirt

Pisces (Fish)

Cownose ray
Eel
**Shad, herring
Menhaden
Anchovy
Variegated minnow
Catfish, bullheads
Hogchoker
**Killifish
Silverside
**White perch
Striped bass
Black sea bass
Weakfish
**Spot
Blenny
Goby
Harvestfish
Flounder

Pisces (Fish) (Cont.)

**Northern puffer
Oyster toadfish

Reptiles

**Snapping turtle
**Diamond-backed terrapin

Aves (Birds)

Horned grebe
Cattle egret
Great blue heron
Glossy ibis
**Whistling swan
**Canada goose
Wood duck
**Black duck
Canvasback
Lesser scaup
**Bufflehead
**Osprey
Clapper rail
Virginia rail
American coot
American woodcock
Common snipe
Semipalmated sandpiper
Laughing gull
Herring gull
Great black-backed gull
Forster's tern
Least tern

Mammalia (Mammals)

Beaver
Muskrat
Mink
Otter
Raccoon
White-tailed deer

Endangered Species

Shortnose sturgeon
Atlantic sturgeon
Maryland darter
Southern bald eagle
American peregrine falcon
Ipswich sparrow
Delmarva fox squirrel

*Life histories discussed in the "Biota" Chapter of the *Chesapeake Bay Existing Conditions Report.*

**Life histories discussed in the "Biota" Appendix of the *Chesapeake Bay Future Conditions Report.*

Appendix 15 presents more detailed information on the eelgrass community as well as the "oyster" community, two of the most important in the Chesapeake Bay System, and the physical and chemical parameters which affect them.

It is evident from the preceding discussion that Chesapeake Bay is an almost incomprehensibly complex physical and biological system. When the human element is added, the complexities and interrelationships become even more involved.

THE PEOPLE

POPULATION CHARACTERISTICS

When Captain John Smith first explored the Chesapeake in 1608, it was an estuary which had yet to feel the impact of man to any significant extent. But, even before Captain Smith's voyage, people had settled on the shores of the Bay drawn by its plentiful supplies of fish and game. These settlements were inhabited by Assateagues, Nanticoke, Susquehannock, and Choptank Indians. It was the Indian that provided the names for many promontories of land and water courses. The relatively few wastes generated by the Indians were easily assimilated by the natural cleansing action of the Bay and its tributaries. Later, more and more people moved into the Bay Region, attracted first by a soil and climate favorable to the growth of tobacco, and later by the development of major manufacturing and transportation centers as well as the founding of the Nation's capital at Washington, D.C. By 1974, 366 years after Captain Smith's voyage up the Bay, there were 8.2 million people living in the Bay Region.

During Colonial times, the Chesapeake Bay Region was one of the primary growth centers of the New World. However, after the decline of the

City of Baltimore Inner Harbor.

Region's tobacco industry in the 19th century, population growth began to lag. This period of relative stagnation lasted until World War II when large increases in Federal spending (especially on defense) stimulated employment and population growth within all the economic subregions. As shown in Table 4, the areas around Washington, D.C. and Norfolk, Virginia, have experienced especially high rates of growth since World War II. Over half of the total population growth in the Bay Region between the time of the Jamestown settlement to the present occurred during the 1940-1970 period. Population in the Region has increased since the 1970 Census at an annual rate of approximately one and one-eighth percent to the estimated total in 1974 of 8.2 million. While this rate is considerably less than the average annual rate of 2.5 percent experienced during the 1940-1970 period, it was still higher than the National rate of approximately 1 percent annually during the 1970-1974 period.

The majority of the inhabitants of the Chesapeake Bay Area are concentrated in relatively small areas in and around the major cities. Approximately 90 percent of the population resided in one of the Region's seven Standard Metropolitan Statistical Areas (SMSA) in 1970. The number of urban dwellers increased by almost 1.5 million during the 1960-1970 decade while the rural population remained virtually the same. People have tended to move out of the inner cities and rural counties and into the suburban counties. Thirty-five of the 76 counties and major independent cities in the Area experienced a net out-migration during the 1960-1970 period. On the other hand, most of the suburban counties experienced growth rates in excess of 30 percent and in-migrations of at least 10 percent of their 1960 population. In the Bay Region as a whole, net in-migration accounted for about one-third of the 1.5 million increase in population during the decade of the 1960's. Most of this in-migration was in response to

TABLE 4
POPULATION GROWTH IN THE CHESAPEAKE BAY STUDY AREA DURING THE 1940–1970 PERIOD BY ECONOMIC SUBREGION

Study Area Portions of BEA Economic Regions*	1940 Population	1970 Population	Absolute Change	Percentage Change
Baltimore, Maryland	1,481,179	2,481,402	+ 1,000,223	+ 67.5
Washington, D. C.	1,086,262	3,040,371	+ 1,954,109	+179.9
Richmond, Virginia	437,103	728,946	+ 291,843	+ 66.8
Norfolk-Portsmouth, Va.	467,229	1,121,856	+ 654,627	+140.1
Wilmington, Del. SMSA	248,243	499,493	+ 251,250	+101.2
Total Study Area	3,720,016	7,872,068	+ 4,152,052	+111.6
Total United States	132,165,129	203,211,926	+71,046,797	+ 53.8

Source: U.S. Census Data
*See Figure 1

large increases in employment opportunities in the Bay Region.

In 1970, there were approximately 3.3 million people employed in the Study Area. About 91 percent of these worked in one of the Region's seven SMSA's. During the 1960–1970 period, total employment increased by about three-quarters of a million jobs or approximately 30 percent. The National gain during the same period was 19.5 percent.

Compared to the Nation as a whole, the Bay Region has a lower proportion of workers in the blue-collar industries, such as manufacturing and mining, and a higher proportion in the white-collar industries, such as public administration and services. Since employment in the white-collar industries tends to be less volatile, the Study Area has had consistently lower unemployment rates over the last several decades than the Nation as a whole. Also contributing to these relatively stable employment levels are the large numbers of workers whose jobs depended on relatively consistent Federal government spending.

Per capita income in the Bay Area was $3,694 in 1969, which was about 9 percent higher than the National figure. Median family income levels ranged from $16,710 in Montgomery County, Maryland, (one of the highest in the Nation), to $4,778 in Northampton County, Virginia. As shown in Table 5, there was a significantly higher proportion of families in the over $15,000 income bracket and fewer families whose incomes were below the poverty level in the Bay Area than in the Nation.

ECONOMIC SECTORS

MANUFACTURING

Generally speaking, the Chesapeake Bay Region has a lower proportion of its workers employed in heavy water-impacting industries than in the Nation as a whole (see Figure 8). For example, manufacturing activities in the Bay Region employed some 524,000 workers in 1970, or about 16 percent of the total employment in the Study Area. This figure was significantly lower than the National figure of approximately 25 percent. In addition, manufacturing employment in the Bay Region grew by 6 percent during the 1960–1970 period, which was well below the National growth rate of 13 percent.

Despite the fact that the manufacturing sector was not as important to the economy of the Study Area as in the Nation as a whole, the sector still has a great deal of significance. First, the navigation channels in Chesapeake Bay are used by many Area manufacturers as a means of shipping raw materials to their factories and finished products to market. Second, many manufacturing firms use water in their production process, usually for cleaning or cooling purposes. This water is often returned to the Bay system untreated or only partially treated. Industrial wastes are sometimes toxic as the recent kepone incident in the James River demonstrates.

As Figure 9 indicates, in addition to the fact that there is a relatively low proportion of workers in manufacturing in the Bay Region, the majority of the manufacturing industries which are located in the Area are not considered to be major water users (i.e., chemicals, pulp and paper, metals, petroleum refinery, and food and kindred products). The heavy water users that do exist are generally concentrated in the Upper Bay around Baltimore and in the Wilmington, Delaware SMSA. Employment in the chemical and metal industries is centered around Baltimore, Wilmington, and Richmond. Food and kindred

TABLE 5
FAMILY INCOME DISTRIBUTION FOR THE CHESAPEAKE BAY STUDY AREA AND THE UNITED STATES, 1969

	Percent Below Poverty Level	"Middle" Income Families	Percent Above $15,000
Study Area	11.2	61.3	27.5
United States	12.2	68.6	19.2

products employment is concentrated on the Eastern Shore, in the Washington SMSA, and in Norfolk. The only major pulp and paper mill in the Bay Region is located at West Point, Virginia. There is also currently only one major petroleum refinery in the Region which is located at Yorktown, Virginia. Other significant concentrations of manufacturing industries are: printing and publishing and the two machinery categories in the Washington area, transportation equipment around Norfolk-Portsmouth, and tobacco processing in the Richmond SMSA. A more detailed discussion of industrial activity in the Bay Region is provided in Appendix 3 – "Economic and Social Profile".

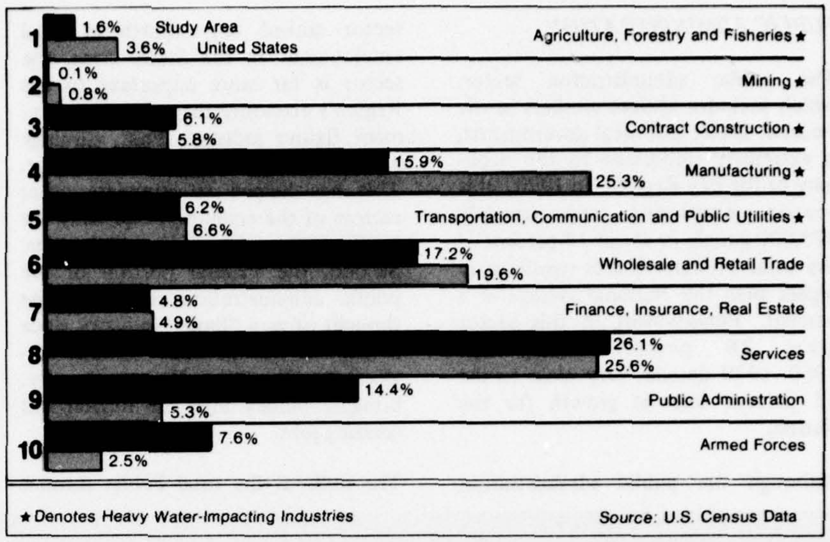
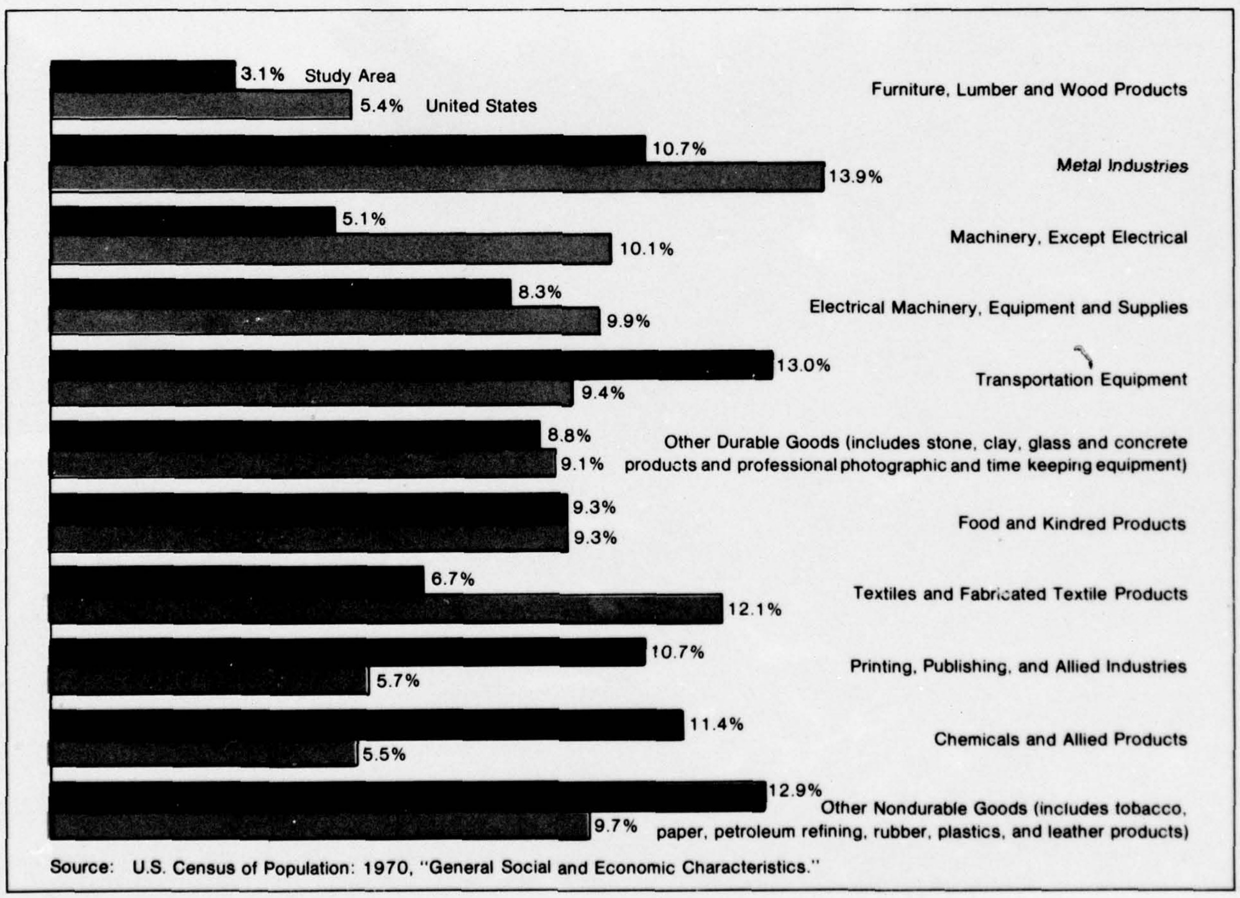


Figure 8: Employment by Economic Sectors, Chesapeake Bay Study Area and United States, 1970

Figure 9: Manufacturing Employment for the Chespeake Bay Study Area and United States, 1970



PUBLIC ADMINISTRATION

The public administration sector, which includes civilian workers in the Federal, State, and local governments, is extremely important to the economy of the Bay Region. In 1970, this sector employed approximately 475,000 people or about 14 percent of the total workers. This is significantly higher than the National average of 5 percent. Employment in this sector grew 36 percent during the 1960–1970 decade, very close to the 37 percent rate of growth for the Nation.

Although the public administration sector ranked only fourth in total employment in the Study Area, the sector is far more important to the Region's economy than these employment figures indicate. First, earnings are higher than average in this sector. This has helped to stimulate other sectors of the economy, especially the retail trade and service industries. Second, the Federal portion of the public administration sector can be thought of as a "basic" industry since it exports its "product" (public services) to the entire Nation, thereby, bringing money into the Region and creating jobs.

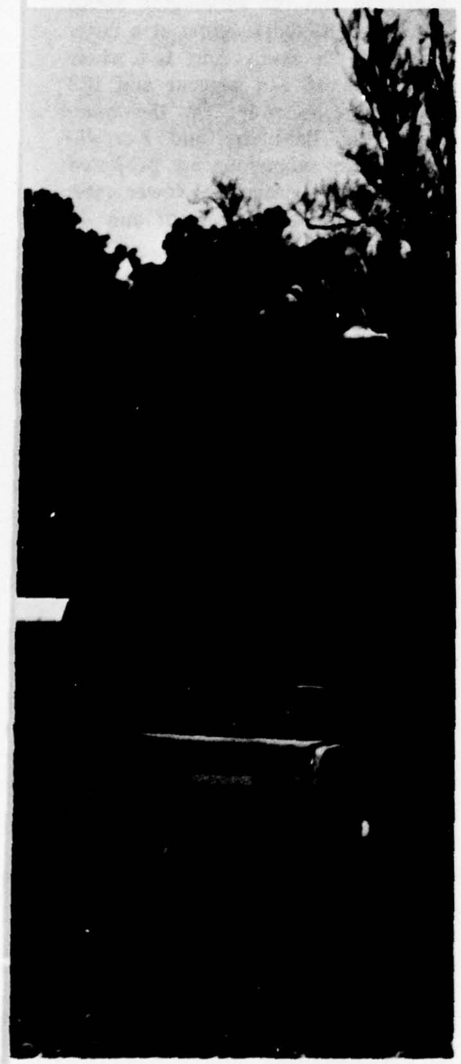
The bulk of the total Public Administration employment in the Study Area (almost 66 percent) is located in the Washington, D.C. area. Other concentrations of workers are in the Richmond, Virginia, vicinity, throughout much of the Baltimore, Maryland, SMSA, and in the Norfolk-Portsmouth area.

The public administration sector can be considered a "clean" industry from a water resources viewpoint. There are no special requirements for water for either processing or transportation purposes. However, fast-growing industries, such as the public administration sector, with its tremendous drawing capacity for workers and their fam-

ilies, can often cause rates of population growth that tax the ability of local government to provide services such as water supply and sewerage. The Washington, D.C. area with its until recently overloaded waste treatment plants and its increasingly inadequate water supply is a good example of this.

AGRICULTURE

Although less than 2 percent of the total workers in the Chesapeake Bay Region are employed in the agricultural sector (i.e., the actual planting, cultivation, and harvesting of raw agricultural goods), these activities



have a great deal of impact on the Area's economy and water and land resources. In 1969 (the latest data available at this writing), the value of all farm products sold by commercial farms in the Bay Region was approximately $589 million. Approximately 87 percent of the developed land in the Bay Region is used for agricultural purposes. Poor farming techniques, both in the past and present, have resulted in the extensive erosion of valuable soils which, in turn, has caused the siltation of many of the Bay's waterways. Run-off from fields sprayed with chemical fertilizers add large quantities of nutrients to the waterways. This practice has resulted in an increase in the amounts of undesirable algae and other vegetation in some waters, thereby decreasing the amounts of available oxygen in the water and, in extreme cases, causing fish kills. In addition, the use of insecticides in agricultural areas has caused significant damage to fish and wildlife populations in the Bay Region with the classic examples being the effects of DDT on the bald eagle and osprey populations.

FISHERIES

Just as the Indians and early settlers harvested the Bay's plentiful supplies of finfish, shellfish, and crabs, modern day watermen harvest and market large quantities of the Chesapeake's living treasures. In 1973, commercial landings of shellfish and finfish totaled 565 million pounds with a value at the dock of approximately $47.9 million. This catch amounted to an average of 200 pounds per surface acre of water. In addition, sport landings of finfish and shellfish in recent years have been estimated to be as large as the commercial catch for some species. However, even when the value of the sports fishing catch is added to the commercial catch value, the total is a very small percentage of the value of agricultural products, for example, and almost negligible when compared to value added in the manufacturing sector. On the other hand, the fisheries and watermen of Chesapeake Bay add a generous amount of regional color and tradition to the "way of life" in the Bay Region. These benefits are difficult, if not impossible, to measure.

Because agricultural products and seafood are often perishable, they are usually processed in close proximity to where they are harvested. As a result, the agricultural and seafood harvesting sectors in the Bay Region support locally important food processing plants.

ARMED FORCES

Still another important source of employment for residents of the Bay

Construction Activitites Can Have Severe Impacts.

Region is the Armed Forces. In 1970, there were approximately 250,000 members of the Armed Forces stationed within the Study Area, representing almost 8 percent of the total employment. This percentage was significantly higher than the National figure of 2.5 percent. The cities of Norfolk and Virginia Beach in the Hampton Roads area and Anne Arundel, Prince Georges, and Fairfax counties in the Baltimore and Washington, D.C., areas contained the largest numbers of military personnel.

CONSTRUCTION

The construction sector in the Bay Region employed approximately 200,000 people in 1970. Construction activities have had a great deal of impact on the water resources of the Bay Region. Much of the disturbed soil on construction sites becomes sediment in streams and rivers. This silt can adversely affect fish and wildlife populations, clog navigation channels, increase the costs of treatment for city and industrial water supplies, make water-based recreation less enjoyable, and generally lower the aesthetic quality of a waterway. Unfortunately, the areas in the Region with the most construction activity are the same areas in which there are already significant industrial and residential strains on the Bay.

OTHER SECTORS

The remaining Bay Region workers, which account for more than one-half of the total, are employed in one of the following sectors:

1. Wholesale and retail trade

2. Transportation, communications, and public utilities

3. Finance, insurance, and real estate

4. Services

"These jobs are generally 'supportive' of the economic sectors discussed previously. With the exception of the transportation and public utilities sectors which are discussed in more detail in the "Navigation," "Electric Power," "Water Supply," and "Water Quality" Appendices, they do not have a significant impact on the water resources of the Region. Many of these activities, however, exist in the Region because of the proximity of the Chesapeake Bay resource. For example, the Bay's land and water resources allow for the development of certain "regionally-unique" entertainment and recreation services which help to expand the service sector. These include such activities as private bathing beaches, pleasure and fishing boat rentals, and the operation of seafood restaurants serving regional specialities. Some of the other activities (e.g., finance, insurance, retail trade, real estate, and certain services) exist in the Bay Region because it is an area which is characterized by higher than average incomes and population growth rates. The location of the Nation's capitol in the Area also attracts many workers in these sectors due to the regulatory functions of the Federal Government and the desirability of companies in the regulated industries to maintain offices in the Washington area.

ECONOMIC AND DEMOGRAPHIC PROJECTIONS

OBERS SERIES C

The base projections used in the future needs analysis for most of the Appendices of the "Future Conditions Report" are based on the Series C OBERS projections of population, income, earnings, and manufacturing output prepared by the Department of Commerce and the Department of Agriculture. A special set of projections coinciding with the Chesapeake Bay Study Area and the subregions as delineated in Figure 1 was prepared by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. An explanation of the methodology used to prepare the OBERS projections and the special disaggregation by BEA is contained in Appendix 3, "An Economic and Social Profile." Figure 10 illustrates the great potential for growth that lies in the Chesapeake Bay Region.

The bulk of the total population and employment growth (about 52 percent in each category) is expected to take place in the Study Area portion of the Washington, D.C. Economic Area. This area is projected to experience population and employment growth rates of about 143 percent during the 1970–2020 period. The Richmond subregion and the Wilmington SMSA are also expected to grow at a faster rate than the Study Area as a whole with rates of 113 percent and 123 percent, respectively. On the other hand, the Baltimore and Norfolk-Portsmouth subregions are projected to grow at significantly lower rates with figures of 85 percent and 45 percent.

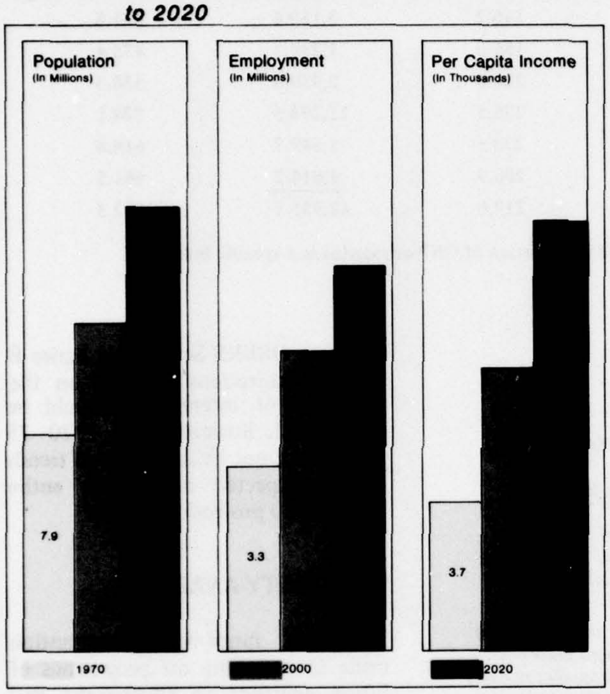
Real per capita income in the Study Area is projected to remain slightly above the National average through the projection period. Table 6 presents projections of population and per capita income by subregion.

One of the major driving forces behind the significant increases in population and income outlined above will be major increases in manufacturing output. As shown in Table 7, manufacturing output in the Chesapeake Bay Region is expected to increase by 563 percent. However, the proportion of total output accounted for by the heavy water-impacting industries as a group (i.e., Metals, Petroleum Refining, Food and Kindred Products, Chemicals, and Paper and Allied Products) is expected to decline slightly from 56.8 percent in 1969 to 54.3 percent in 2020. In addition, the manufacturing sector is expected to continue to account for a significantly lower portion of total employment and income in the Bay Region than in the United States.

OBERS SERIES E

Since the initiation of the future conditions phase of the Chesapeake Bay Study, another set of baseline projections derived from more recent economic and demographic data was prepared and released by BEA. These new projections, called the "Series E" OBERS projections, must be considered by all Federal agencies engaged in water resource planning as directed by the Water Resource Council. The basic differences between the assumptions made in preparing the Series C and Series E projections are shown in Table 8 and are discussed in more detail in Appendix 3 – "Economic and Social Profile." The Series E population projection of 14.1 million people for the total Study Area in the year 2020 is approximately 13.5 percent less than the Series C estimate for the same year. The Series E projections for the Study Area for 1980 and 2000 are also lower than the Series C projections for the same years by 4.5 percent and 7.3 percent, respectively. In addition, the Series E population projections for almost all the subregions are lower than the comparable Series C projections.

Figure 10: Population and Economic Projections for Chesapeake Bay Region to 2020



Recently released estimates of 1975 population by county prepared by the U.S. Bureau of the Census allow a comparison of actual population trends in the Chesapeake Bay Study Area with those trends that would be expected under the Series C and Series E OBERS projections. The 1975 population estimate for the entire Bay Region is approximately 370,000 less than the Series C and 162,000 less than Series E interpolated estimates. However, seven of the thirteen Study Area subregions had 1975 populations which were greater than either the Series C or Series E estimates. Much of the discrepancy in the total Bay Region estimates can be explained by a significant overestimate by both Series C and Series E of population growth in the Washington, D.C. SMSA. When population data for the Washington, D.C. SMSA is subtracted from the Bay Region totals, the remainder for the Region falls between the Series C and Series E estimates.

Based on the preceding analysis, it can be concluded that the applicability of estimates of future resource demands

TABLE 6

SERIES C PROJECTIONS OF POPULATION, PER CAPITA INCOME, AND TOTAL PERSONAL INCOME BY CHESAPEAKE BAY SUBREGION (IN CONSTANT 1967 DOLLARS)

	1969		1980		2000		2020	
	Population	Per Capita Income	Population (% Increase)[1]	Per Capita Income (% Increase)	Population (% Increase)	Per Capita Income (% Increase)	Population (% Increase)	Per Capita Income (% Increase)
Baltimore, Md.	2,463.3	$3,579	2,877.6 (16.8)	$4,912 (37.3)	3,714.0 (50.8)	$8,556 (139.0)	4,596.3 (86.6)	$14,769 (312.7)
Washington, D.C.	2,985.5	3,977	3,695.0 (23.76)	5,653 (42.1)	5,314.3 (78.0)	9,534 (139.7)	7,397.2 (144.4)	15,612 (292.6)
Richmond, Va.	727.5	3,454	871.8 (19.8)	4,828 (39.8)	1,180.1 (62.2)	8,290 (140.0)	1,555.0 (113.7)	14,184 (310.7)
Norfolk-Portsmouth, Va.	1,107.6	3,046	1,216.0 (9.8)	4,331 (42.2)	1,429.6 (29.1)	7,615 (150.0)	1,656.4 (49.6)	13,186 (332.9)
Wilmington, Del. SMSA	492.1	4,169	612.5 (24.7)	5,804 (39.2)	851.4 (73.0)	9,634 (131.0)	1,115.7 (126.7)	16,142 (287.2)
STUDY AREA TOTAL	7,776.0	$3,682	9,272.9 (19.3)	$5,182 (40.7)	12,489.4 (60.6)	$8,913 (142.1)	16,320.6 (109.9)	$15,030 (308.2)

[1] All percentage changes are calculated from 1969.

TABLE 7
MANUFACTURING OUTPUT FOR CHESAPEAKE BAY REGION (IN MILLIONS OF 1967 DOLLARS)
BY INDUSTRY, 1969 AND PROJECTED, BASED ON OBERS SERIES C

	1969	2000		2020	
	Output (1)	Output	Percent Increase (2)	Output	Percent Increase (2)
Lumber and Wood Products	154.8	433.4	180.0	807.4	421.6
Metals	977.4	2,279.9	133.3	4,095.0	319.0
Machinery, Except Electrical	233.0	835.8	258.7	1,885.9	709.4
Electrical Machinery	331.3	1,595.5	381.6	4,092.6	1,135.3
Transportation Equipment	815.1	2,534.4	210.9	4,979.7	510.9
Petroleum Refining	57.3	165.4	188.6	301.2	425.6
Food and Kindred Products	747.4	1,795.1	140.2	3,150.4	321.5
Textiles and Textile Products	229.8	657.4	186.0	1,230.3	435.4
Printing and Publishing	445.2	1,428.3	220.8	2,930.8	558.3
Chemicals	1,856.4	6,989.8	276.5	15,298.5	724.1
Paper and Allied Products	215.6	712.5	230.5	1,549.7	618.8
Other Manufacturing	719.3	2,207.7	206.9	4,614.2	541.5
TOTAL	6,782.6	21,635.2	219.0	44,935.7	562.5

(1) Output in the form of "gross product originating" which is defined as that portion of GNP originating in a specific industry.
(2) Percent change measured from base year (1969).

TABLE 8
A COMPARISON OF OBERS SERIES C AND SERIES E PROJECTIONS

Item	Series C	Series E
Growth of Population	Fertility rate of 2,800 children per 1,000 women	Gradual decline of fertility rate from 2,800 to the "replacement fertility rate" of 2,100 children per 1,000 women.
Military Establishment	Projects a decline to 2.07 million people by 1975 and thereafter a constant.	Projects a decline to 1.57 million persons by 1975 and thereafter a constant (due to smaller military establishment and the resultant smaller need for equipment and supplies a significantly slow rate of growth in the defense-related manufacturing industries is anticipated).
Hours Worked Per Year	Hours worked per employee per year are projected to decline at 0.25 percent per year.	Hours worked per employee per year are projected to decline at 0.35 percent per year.
Product Per Man-Hour	Projected to increase 3.0 percent per year.	Projected to increase 2.9 percent per year.
Earnings Per Worker	Earnings per worker in the individual industries at the national level are projected to converge toward the combined rate for all industries more slowly in the Series E projections than in the Series C projections.	
Employed Population	Projected to increase from 40 to 41 percent of the total population.	Projected to be between 43 and 45 percent of the total population (higher percentages with the E Series reflects expected higher participation rates by women).

based on OBERS Series C or Series E baseline projections depends on the subregion of interest. It should be emphasized, however, that 1970–75 trends may not be indicative of trends to be expected during the entire 1970–2020 projection period.

SENSITIVITY ANALYSIS

The most fundamental assumption made in preparing the projections of future demands on Chesapeake Bay presented in the *Chesapeake Bay Future Conditions Report* is that the Series C OBERS baseline projections of population, income, and manufacturing activity accurately reflect future trends in the Chesapeake Bay Region. However, in order to evaluate the impact on the resource of the Series E baseline projections, a "Sensitivity Analysis" section of each Appendix dealing with a resource use activity was prepared. These sections present future demands based on Series E baseline projections which can be compared to the Series C based projections of future demands. In addition, the sensitivity of future demands to changes in other parameters critical to

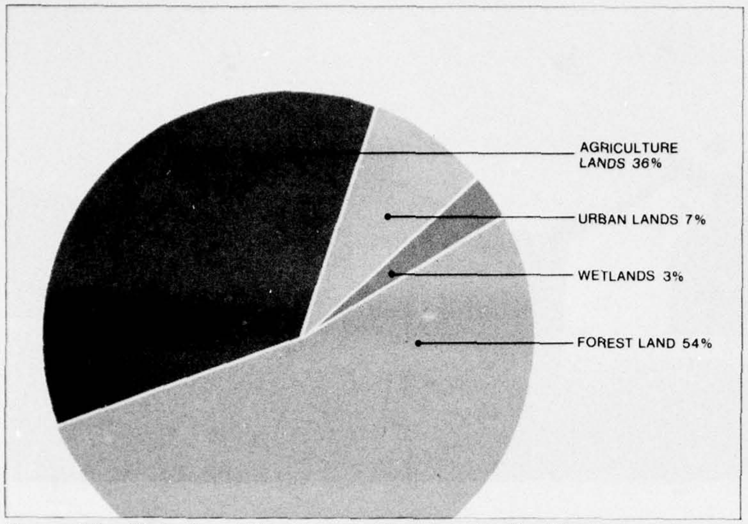


Figure 11: Major Land Use Types - Chesapeake Bay Region

the projection methodology was also evaluated. The findings of these analyses are summarized in this volume and a more detailed discussion is provided in the appropriate appendices.

LAND USE

The development of the land in the Chesapeake Bay Region began when the first group of Indians wandered into the Area thousands of years ago and established a village. Since then, virtually all of the vast expanse of virgin forest which existed at the time and thousands of acres of wetlands have been cut, drained, or filled by more recent settlers. The original purpose of this development was to provide land for the cultivation of tobacco and wheat. High tobacco and wheat prices created an almost insatiable demand for land. As the productivity of the soil decreased after producing several years of crops, the land was abandoned and new land was cleared. The abandoned land returned to woodlands. During the Nineteenth and Twentiest Centuries, factories, residences, port facilities, commercial establishments, and other physical manifestations of an increasingly industrialized society replaced many of the agricultural lands and second-growth woodlands. The following sections present a discussion of existing and future land use and related problems, as well as some alternative means of satisfying the identified needs.

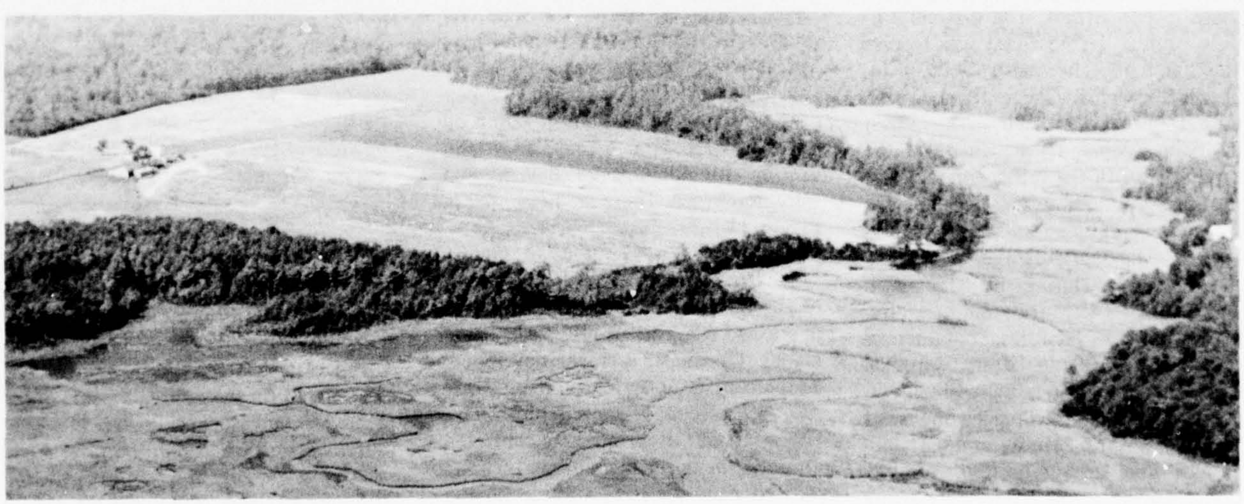
EXISTING LAND USE

For the purposes of this analysis, existing land use information for the Chesapeake Bay area was developed using remote sensing data obtained from high altitude aerial photography taken in 1970. These data were supplied by the U.S. Geological Survey (USGS) and are part of the Central Atlantic Regional Ecological Test Site (CARETS) project. Plates 4-1, 4-2, and 4-3 in Appendix 4, "Water-Related Land Resources" show the type and general distribution of the major land use activities in the area covered by the CARETS project (about 95 percent of the "Bay Region"). Based on the CARETS data, estimates of land use in the Chesapeake Bay Region were developed. These are presented in Figure 11.

a. *Urban Land:* About 43 percent of the Bay Region is considered to be developed (i.e., urban plus agricultural lands). Of the 43 percent developed, 83 percent is in agricultural uses and only 17 percent is considered urban. Urban land uses are concentrated around the principal urban centers located near the head of tide on the major tributaries of the Western Shore. Many smaller urban centers are found scattered throughout the Study Area, some serving as small ports, retail and wholesale trade centers, or political centers such as State capitals or county seats. Industrial, institutional, and military reservations (of which the Bay Region has many) are also included as urban lands. Industrial activities include a variety of uses ranging from those involving the design, assembly, finishing, and packaging of light products to heavy manufacturing activities such as steel, pulp, or lumber milling, electric power generating, oil refining, and chemical processing. Most frequently, industries are found in or adjacent to urban areas where good transportation facilities and ample manpower are available.

b. *Agricultural Land:* Land used for the production of farm commodities comprises over one-third of the Chesapeake Bay Region's land area. As such, it constitutes the second largest land use type in the Study Area, second only to forest lands. The major physical factors governing the use of land for agricultural purposes include rainfall, growing season, soil, drainage, temperature, evaporation, and the amount of sunshine. Other factors such as proximity to markets, tax laws, land tenure arrangements, and farming practices also influence the intensity and type of agriculture. The major agricultural areas in the Bay Region are located on the Eastern Shore of Maryland, Virginia and Delaware, in the rural portions of the Baltimore SMSA, in the northwestern portion of the Washington SMSA, and around Virginia Beach, Virginia.

c. *Forestlands:* Forestlands occupy more area in the Bay Region than any other land use type, approximately 54 percent. Since it was not possible to distinguish between public and private forestlands on the remote sensing data, both are included in Figure 11. The Virginia portion of the Study Area accounts for almost two-thirds of the total forest land. The Southern Mary-



land area also has a high proportion of woodlands.

d. *Wetlands:* The wetlands of the Bay Region, although accounting for only 3 percent of the total land area, are of crucial importance to the ecosystem of the Bay. Wetlands consist of seasonally flooded basins and flats, meadows, marshes, and bogs.

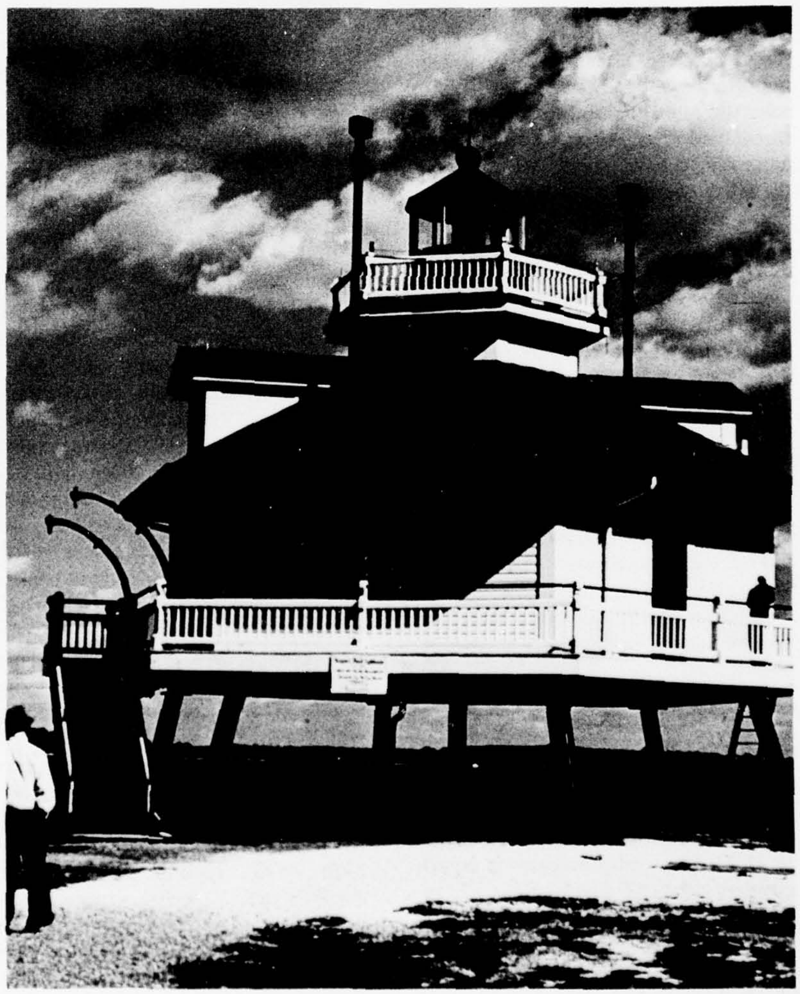
Each of the States in the Bay Area has legally defined its wetlands. Maryland defines its wetlands as all land under the navigable waters of the State below the mean high tide which is affected by the regular rise and fall of the tide. Virginia wetlands are defined as all that land lying between mean low water and an elevation above mean low water equal to the factor 1.5 times the tide range. Delaware defines its wetlands as those lands above the mean low water elevation including any bank, marsh, swamp, meadow, flat or other land subject to tidal action and including those areas connected to tidal waters whose surface is at or below an elevation of two feet above local mean high tide.

All of the counties of the Bay Region have some wetland areas of varying types and sizes, although it should be emphasized that not all wetland types are equally valuable to the ecosystem. The ecological value of a particular wetland area depends on such factors as the type of dominant plant, flushing action in the area which affects the availability of nutrients to the aquatic community, and the intensity of use of the wetland as habitat. The major concentration of wetland areas in the Chesapeake Bay system is found along the lower Eastern Shore.

e. *Archaeological, Historic, and Natural Areas of Significance:* The primary prehistoric archaeological resources within the Study Area are associated with Indian artifacts. The numerous Indian tribes which inhabited what is now Maryland, Virginia, and Delaware left much evidence of their existence in the form of clay pottery and stone artifacts. Thousands of archaeological sites have been recorded in the Region but due to monetary and manpower limitations, it is believed that only a fraction of the archaeological resources have been discovered. Almost the entire shoreline of the Bay and its tributaries are thought to be potential archaeological sites. Plates 4-7, 4-8, and 4-9 in Appendix 4, "Water-Related Land Resources," show the existing and potential archaeological sites in the Chesapeake Bay Region.

The large number of historic sites in the Bay Region provides proof of the Region's historic significance and its fundamental role in the development of the Nation. Many of the sites relate to the earliest colonial settlements, the winning of National independence, the founding of the Union, the Civil War struggle, and the lives of National leaders. Within the Study Area are found such historically important items as the U.S. Frigate Constellation, the nation's oldest warship; the Annapolis Historic District, an early colonial port and capital of the U.S. during a short period in 1783–1784; Stratford Hall, home of Robert E. Lee, Commander of the Confederate Armies; Mt. Vernon, home of the first President of the United States; numerous battlefield sites commemorating some of the most important Civil War

Lighthouse at St. Michaels, Maryland - Historic.



and Revolutionary War battles; the Jamestown National Historic Site, first permanent English colony in North America; Williamsburg Historic District, capital of the Virginia Colony during much of the eighteenth century and an important social and cultural center of the English colonies during that period; and numerous historic and commemorative sites in the Washington, D.C. area. Appendix 4, Attachment A, lists nearly 800 properties within the Bay Area included on the *National Register of Historic Places.*

There are certain other areas of the Bay Region which are of special importance for their ecological or natural significance. Many of these have been identified, and in many cases are being protected. Included in these types of areas are: especially important wetlands or other floral habitats, faunal habitats (especially for threatened or endangered species), and naturally scenic areas. At present, there are twenty properties within the Study Area designated as National refuges or related properties (such as the Patuxent National Wildlife Research Center). The primary purpose of these refuges is to protect wildlife including certain endangered and threatened species. Biological research is conducted at a number of these facilities while limited hunting is offered at some. Within the Study Area, there are also 68 State fish and wildlife management areas and related properties including game farms, sanctuaries, and preserves. Plates 4-16, 4-17, and 4-18 of Appendix 4 show the Federal and State conservation and management areas in the Chesapeake Bay Region.

The Center for Natural Areas, Ecology Program, Smithsonian Institution, has also shown concern for the Bay's significant ecological and natural areas. In 1974, this group prepared a report entitled "Natural Areas of the Chesapeake Bay Region: Ecological Priorities," which surveys the endangered flora and fauna of the Bay Region and the areas of significant ecological importance.

Pocomoke River.

Maryland and Virginia have initiated programs to identify and designate certain rivers within their boundaries as scenic rivers. The Virginia Commission of Outdoor Recreation was directed by the General Assembly to study the Commonwealth's rivers for the purpose of designating those which should be protected to provide for the enjoyment of present and future generations. As a result of this survey, the Commission recommended establishment of a state scenic river system in 1970. Local and State land use controls are to be imposed along with numerous other standards to guarantee the protection of those rivers designated as scenic. The Maryland Legislature also recognized that certain rivers within the State plus their adjacent land areas possess outstanding scenic, fish, wildlife, and other recreational values. The State adopted a policy which protects the water quality of those rivers and fulfills vital conservation purposes by promoting the wise use of land resources within the scenic river system. Use is limited to "horseback riding, natural and geological interpretation, scenic appreciation, and other programs through which the general public can appreciate and enjoy the value of these areas as scenic and wild rivers in a setting of natural solitude." Table 4-28 of Appendix 4 lists the designated scenic and potential scenic rivers of the Chesapeake Bay Region.

FUTURE LAND USE

The expected future distribution of land uses in the Bay Region was developed from the relevant county, municipal, and regional comprehensive land and water use plans. Plates 4-4, 4-5, and 4-6 in Appendix 4 present this information based on a consistent land use classification system. Numerical estimates of future acreages for urban, agricultural, and forest lands are presented in the following sections.

a. *Urban:* The portion of land in residential uses in the urban areas can be expected to increase at roughly the same rate as population growth if the assumption is made that population densities will remain at about the same level over the projection period. This means that the demand for residential lands will increase by approximately 18 percent by 1980, 59 percent by the year 2000, and about 107 percent by 2020.

As discussed in Chapter II, manufacturing output in the Chesapeake Bay Region is projected to increase at a

TABLE 9
PROJECTED CROPLAND AND MISCELLANEOUS FARMLAND* FOR THE CHESAPEAKE BAY REGION
(THOUSANDS OF ACRES)

State	1980	2000	2020
Delaware	544	519	493
Maryland	1,614	1,493	1,362
Virginia	1,481	1,305	1,147
TOTAL CHESAPEAKE BAY REGION	3,639	3,317	3,002

*Miscellaneous farmland includes pasture, range, lands occupied by buildings, roads, ditches, ponds, and wastelands.

rate of approximately 560 percent between 1969 and 2020. It is not valid, however, to assume that land needed for industrial purposes will also increase by this percentage since output per worker and per unit of land will probably increase during this period. If the assumption is made that the productivity of land increases at about the same rate as the productivity of workers, about 3.0 percent annually, then the land needed for industrial purposes can be expected to increase by 28 percent over the 1969 acreage by 2000, and by 50 percent by 2020.

b. *Agricultural:* The projections of land in crops and miscellaneous farm uses (woodland on farms is included in the "Forests" category) in the Chesapeake Bay Region were derived from OBERS projections of these land use categories by State. Appendix 4 describes in greater detail the methodology used in determining projections of agricultural land use. The amount of acreage in cropland and miscellaneous farmland is projected to show a steady decline during the projection period as shown in Table 9.

c. *Forests:* Projections of private commercial forest lands were also disaggregated from OBERS projections by State. As indicated in Table 10, the projected acreage of private commercial forest land within the Study Area is expected to decline steadily over the projection period. It should be noted that public forest lands are not included in these figures.

d. *Wetlands:* Although no projections were prepared of future wetland acreages, it can be stated with a high degree of confidence that the demand for shoreline lands for such uses as marinas, vacation homes, or port facilities will increase in the future. However, more stringent Federal and State restrictions on the development or degradation of wetland areas along with a growing awareness of the ecological and economic importance of wetlands are likely to at least slow down the historic rate of wetlands destruction in the Chesapeake Bay Region. An Executive Order signed by President Carter in 1977 sets more stringent guidelines governing Federal activities in wetland areas.

PROBLEMS AND CONFLICTS

As shown in the previous section, the expected increases in the demand for residential and industrial land in the Chesapeake Bay Region is approximately offset by decreases in agricultural and forest use (each projected separately). The locations in which these land use changes will occur, however, has not been clearly defined. The conflict, then, is not one of enough land for development, but it is where the development should take place. Often the best agricultural lands or the most productive forests are also desirable for urban development. Without proper planning, other areas of special ecological, historical, or archaeological significance will continue to be destroyed in the wake of "urban sprawl."

SENSITIVITY ANALYSIS

Comparison of future land use demands computed using OBERS Series C projections, with those computed using Series E, yields no significant differences except in the demand for residential land. Residential land requirements obtained through Series E population projections were approximately 5 percent less than the Series C based projections for 1980, 7 percent less for 2000, and about 13 percent less in 2020. Due to a lack of data, it was not possible to develop Series E based projections of industrial land demands.

MEANS TO SATISFY THE NEEDS

There are numerous measures available to provide for the orderly development and proper use of the water-related land resources of the Chesapeake Bay Region. The following section presents a general discussion of

TABLE 10
PROJECTED ACRES OF PRIVATE COMMERCIAL FOREST LAND FOR THE CHESAPEAKE BAY STUDY AREA

	1980	2000	2020
Delaware	365,560	355,940	346,320
Maryland	1,983,456	1,935,296	1,860,654
Virginia	4,533,673	4,222,717	3,900,972
TOTAL:	6,882,689	6,513,953	6,107,946

these measures. A more thorough analysis is available in Appendix 4.

a. *Local Land Use Controls:* Zoning of geographical areas can be used to guide future land use decisions so as to encourage those which complement each other and preclude those which conflict. It has been used effectively to segregate residential uses from commercial and industrial uses, for example, as well as to preserve recreational areas, parks, conservation areas, and natural resources of special significance, and to control the development of flood-prone areas.

Subdivision regulations can be used to preserve open or agricultural lands by restricting land use to low-density, multiple-acre uses. Tax policies have also proven useful in controlling land use development. Through preferential tax treatment, or public land acquisition policies, the preservation and development of agricultural lands, open space areas, and conservation zones can be encouraged.

A few local governments within the Study Area have attempted to curb development and thereby control land use within their jurisdiction through "sewer moratoriums." Such measures prohibit the construction of new sewer systems or the extension of existing systems. Some of these same counties and towns have effectively used the provision of water and sewer services to guide growth to areas that have been planned for development. Such measures represent a primary means for a region to plan growth in accord with its public service and environmental capabilities.

b. *State Land Use Controls:* Although the final decisions for land use proceedings remain the discretion of the local authorities, the various States in the Study Area have recognized, to varying degrees, that local subdivisions often do not have adequate jurisdiction or, if the land use issue has more than a local impact, proper authority to provide desirable management of resources. The States have the legislative authority to intervene in such circumstances. The wetland laws of Maryland, Virginia, and Delaware are a good example of this type of authority. These laws seek to preserve the wetlands and to prevent their degradation taking ecological, economic, developmental, recreational, and aesthetic values into account.

c. *Federal Land Use Controls:* One of the most important Federal land resource management programs is the National Oceanic and Atmospheric Administration's Coastal Zone Management Program (CZMP). Through this program, the Federal Government assists the States in developing a plan for the management of land and water areas in the coastal zone. State programs seek to achieve wise use of land and water resources of the coastal zone and must give full consideration to ecological, cultural, historic, recreational, and esthetic values as well as needs for economic development. The Federal CZMP provides grants to the coastal states and territories to support two-thirds of the cost of developing a state program, four-fifths of the cost of administering the program, and one-half of the cost of acquiring, developing, and operating estuarine sanctuaries for research and educational purposes.

There are certain other Federal programs or items of legislation which either directly or indirectly address the control of land use. Examples include the National Environmental Policy Act of 1970, the Rivers and Harbors Act of 1899 (which makes it illegal to allow any refuse to be introduced into a navigable waterway), and the Water Pollution Control Act Amendments of 1972.

Future Federal legislation may very well be aimed at establishing a nationwide land use planning and policy process. Since 1970, various land use control bills have been introduced in Congress but none have, as yet, been passed by both Houses. Although each bill has been different from the others, all would have established some form of National land use policy. Each bill has been quite controversial and has met with great public opposition. If this opposition is alleviated, it is possible that some form of National land use policy will be adopted.

Chapter III Water Resource Problems and Needs

As population, industrial output, incomes, and leisure time in the Chesapeake Bay Region increase in the future, the demands on the Area's water and related land resources will, most certainly, also increase. The following sections of this chapter present a discussion of the current status and problems, as well as projected future demands, supplies, and needs for the following Chesapeake Bay water and related land resource use categories.

1. Water Supply
2. Water Quality
3. Outdoor Recreation
4. Navigation
5. Flood Control
6. Shoreline Erosion
7. Fish and Wildlife
8. Power
9. Noxious Weeds

In addition, alternative means of alleviating existing problems and meeting projected needs will be discussed. Unless otherwise noted, the projections of future demands in each section are based on OBERS Series C baseline projections. As previously discussed, each of the following resource use discussions has a "Sensitivity Analysis" section which includes an analysis of the sensitivity of the projected demands and supplies to changes in the basic assumptions made in the projection methodology.

WATER SUPPLY

CURRENT STATUS

The vast quantities of surface and ground water available in the Chesapeake Bay watershed are a primary source of water supply for numerous communities and industries. As shown on Figure 12, more than 2,460 million gallons of water per day (mgd) are used by municipal public water systems, industries, people living in rural areas, and farmers in feeding livestock and poultry and in irrigating. Many millions of gallons more water are used in generating electrical power, a subject which will be addressed in another section of this Summary.

Of this 2,460 mgd, approximately 900 mgd is brackish water used in industrial processes, 122 mgd is reused municipal wastewater, and the remainder is freshwater from ground and surface sources. Industrial and municipal systems accounted for over 96 percent of total water use.

MUNICIPAL WATER SUPPLY

Of the Bay Area's 7.9 million residents, approximately 6.5 million, or 82 percent, are served by public water supply systems. These systems range in size from those serving as few as 20 persons in small developments to large municipal systems serving commercial, institutional and industrial establishments and millions of individuals. For purposes of this analysis, "Water Service Areas," WSA's, were established for each water system serving a population in excess of 2,500. Together, these WSA's account for 96 percent of the water supplied and 93 percent of the population served by all the public systems.

Municipal water uses encompass a variety of needs which may be generally classified as domestic, commercial, industrial, institutional, and public. Domestic uses include those of the household, e.g., food preparation, washing, lawn watering, and sanitation. Uses within the commercial category include restaurants, hotels, laundries, and car washes; while hospitals and schools are classified as institutional. Public uses include fire protection, street cleaning, and water use in government buildings and institutions. Manufacturing industries use water for processing, boiler feed, cooling, and sanitary purposes. Depending on the extent and composition of a city's industrial component

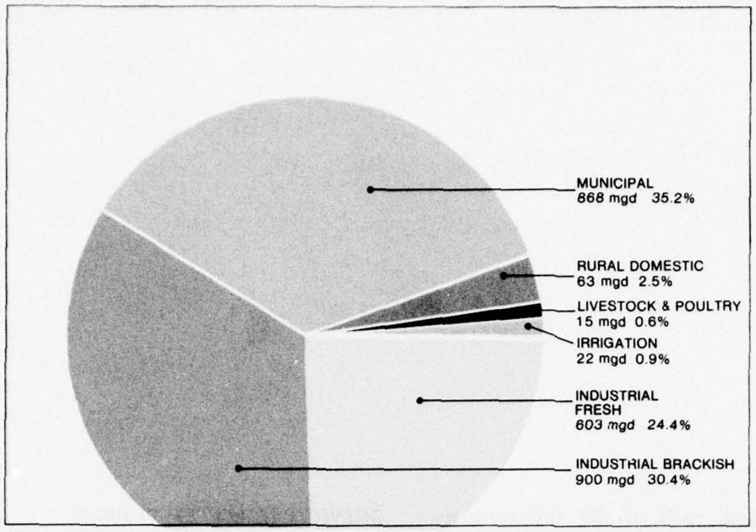


Figure 12: Average Water Use in the Chesapeake Bay Region by Type

and the tendency for local industry to pay for and use public water, a municipal system's industrial water use component may vary radically. There are public water supply systems in the Bay Area that supply no water to industry and others that support an industrial component that may exceed 50 percent of the total use.

Table 11 shows the population served and the average water use in each of the 49 WSA's in the Chesapeake Bay Area. Water use rates vary widely between the subregions, ranging from about 100 gallons per/capita per day (gpcd) to nearly 190 gpcd. For the entire Bay Region, water use averaged 139 gpcd in 1970. The importance of the metropolitan areas is evidenced by the fact that the Baltimore and Washington SMSA's account for 74 percent of the population and 77 percent of the total water used among the Region's WSA's. More detailed data for each community is presented in Table 5-1 of Appendix 5.

Use rates exceeding 150 gpcd occur in a number of cities: Cambridge, Crisfield, Salisbury, Leonardtown, Seaford, Baltimore, Washington, Hopewell, and Williamsburg. These high use rates can be attributed to several factors, not always consistent from system to system. For example, Hopewell's astonishing 689 gpcd is due to an estimated 22 mgd supplied to several large industries. Significant industrial uses also contribute to the high rates at Cambridge, Salisbury, and Baltimore, while institutional, military demands and tourism contribute to the higher than normal use at Williamsburg, Virginia. The extensive government activity and array of public facilities in Washington, D.C., cause use rates in the Washington area to be among the highest in the Bay Area. Another component of water use in most systems is leakage. In Crisfield, Maryland, for example, losses due to leakage constitute an unusually high 25 percent of the overall use. Most of the public systems have use rates that would be expected from an average amount of residential use and mix of other uses (approximately 80 to 150 gpcd).

In addition to the Water Service Areas (i.e., those systems defined previously as serving a population of 2,500 or greater), a large number of smaller public systems exist in the Bay Area. Slightly less than one-half million people are served by these small systems. In 1970, they provided approximately 37 mgd or about 4 percent of the total water use by centrally-supplied systems. A large portion of this demand occurred in the suburban counties adjacent to areas served by the larger systems. Approximately 58 percent of the persons supplied through small water supply systems resided in the Baltimore, Washington, and Richmond SMSA's in 1970.

TABLE 11
MUNICIPAL WATER USE IN 1970 BY CHESAPEAKE BAY SUBREGION

	Subregion	Population Served	Average Use, Mgd	Per capita Use, GPCD
17-1	Baltimore, Md. SMSA	1,673,820	260.3	156
17-2	Maryland Eastern Shore*	73,270	13.8	188
17-3	Virginia Eastern Shore	NO LARGE SYSTEMS		
17-4	Delaware Non-SMSA**	5,540	0.8	153
18-1	Washington, D.C. SMSA	2,726,500	382.2	140
18-2	Southern Maryland	22,500	2.2	97
18-3	Virginia Non-SMSA	19,530	2.6	133
21-1	Richmond-Petersburg-Colonial Heights SMSA's	501,690	74.6	149
21-2	Virginia Non-SMSA	2,600	0.3	100
22-1	Newport News-Hampton SMSA	263,260	27.3	104
22-2	Norfolk-Portsmouth SMSA	633,640	66.2	104
22-3	Virginia Non-SMSA	37,210	4.6	123
	BAY REGION TOTAL	5,959,560	831.2	139

* Includes Cecil County, Maryland.
** Includes Sussex County, Delaware, only.

INDUSTRIAL WATER USE

Industrial (i.e., manufacturing) water use in 1970 was inventoried by the Bureau of Domestic Commerce (BDC), U.S. Department of Commerce. The results of this inventory are presented in Table 12. The term gross use (G) includes all water actually used in a particular process, including that quantity recirculated. Intake (I) represents the actual withdrawal from the water body plus purchases. The consumption category (C) includes all water lost to evaporation and water incorporated into final products. Discharge (D) is merely the difference between intake and consumption (I-C). The final column lists the percent of the gross use that is recycled water [(G-I)/G]. As shown in Table 12, industries in the Baltimore SMSA, the Richmond and Petersburg SMSA's and the non-SMSA portion of the Norfolk-Portsmouth Economic Area (Subregion 22-3) account for approximately 86 percent of gross water use and about 82 percent of the total intake of water in the Bay Region. In addition, 99 percent of the total water intake of 1,615 mgd was used by only 3 percent of the approximately 5,800 manufacturing establishments in the Bay Region.

In addition to the concentration of water use among a relatively small number of plants, there is also a concentration of water use within particular types of industries. In the Chesapeake Bay Region, 82 percent of the gross water use is accounted for by three groups of industries: paper and allied products, chemicals and allied products, and primary metals (see Table 13).

In many industrial processes, significant decreases in water supply withdrawals could be realized if the recycling of wastewater was more widely used. The tendency of an industry to recirculate water, however, usually depends ultimately on economics. Water will be reused in a particular situation if the costs of recovery and recirculation are less than costs associated with the development of additional sources. In locations where water of acceptable quality is scarce or where the cost of treating wastewater is high, recirculation may be attractive. Conversely, in areas with plentiful supplies of high quality water or where wastewater treatment costs are low reuse is usually uneconomical.

A measure of the degree to which recirculation technology is utilized in each subregion is shown in the final column of Table 12, and for each major type of industry in Table 13. In the Bay Region the best recycling efficiency occurs in the paper industry in which 88.7 percent of the gross water used is recycled. In other words, nearly nine times as much water would be needed from the river, or other source, if recirculation was not practiced–645 vs. 73 mgd. The petroleum industry recycles least, primarily due to the once-through use of brackish water for cooling. However, National figures for the petroleum industry indicate recirculation rates at least 10-fold that in Chesapeake Bay.

The importance of brackish water in the Chesapeake Bay Area as a source of industrial water supply is evident from the information in Table 14. The total quantity of brackish water used was 899 mgd or 56 percent of all withdrawals by Bay Region manufacturers in 1970. Approximately 37 percent of industrial withdrawals was freshwater from ground or surface sources and the remainder was reused municipal wastewater.

TABLE 12
INDUSTRIAL WATER USE IN THE CHESAPEAKE
BAY REGION, 1970, mgd

	Subregion	Gross Use (G)	Intake (I)	Consumption (C)	Discharge (D)	Percent Recycled*
17-1	Baltimore, Md. SMSA	1,226.1	990.7	43.7	947.0	19.2
17-2	Maryland Eastern Shore	35.5	34.8	0.9	33.9	1.9
17-3	Virginia Eastern Shore	2.6	2.3	0.2	2.1	11.5
17-4	Delaware Non-SMSA	82.7	65.6	1.9	63.7	20.7
18-1	Washington, D.C. SMSA	5.4	4.7	0.2	4.5	13.0
18-2	Southern Maryland	0.8	0.8	0.1	0.7	0.0
18-3	Virginia Non-SMSA	32.9	27.4	1.8	25.6	16.7
21-1	Richmond-Petersburg-Colonial Heights SMSA's	400.5	286.8	14.0	272.8	28.4
21-2	Virginia Non-SMSA	52.4	26.5	5.0	21.5	49.4
22-1	Newport News-Hampton SMSA	114.9	100.2	0.7	99.5	12.8
22-2	Norfolk-Portsmouth SMSA	32.3	25.3	1.3	24.0	21.7
22-3	Virginia Non-SMSA	621.8	50.4	4.8	45.6	91.9
	TOTAL BAY REGION:	2,607.9	1,615.5	74.6	1,540.9	38.1

*Calculated by $\frac{G - I}{G}$

RURAL DOMESTIC

Rural domestic water supplies are required to serve the needs of persons that live in rural locations and that are not served by central water supply systems. Of the almost 1.4 million who lived in rural areas in *1970*, about 7 percent resided on farms. The non-farm component of the population includes persons that reside in the suburbs of the major metropolitan areas such as Baltimore, Washington, D.C., and Richmond. In fact, perhaps surprisingly, the two major areas in terms of rural domestic water use are the Baltimore and Washington SMSA's, comprising 40 percent of the total rural domestic use in 1970.

The total water use for rural domestic purposes amounted to approximately *63.1 mgd in 1970*. This has been rising rapidly since 1950 due to an increasing percentage of homes being served by in-house plumbing and running water. Homes with running water characteristically use 5 to 6 times the amount used in a home without these same conveniences. In 1970, approximately 80 percent of the rural domestic population resided in homes equipped with running water and these persons consumed about 95 percent of the total rural domestic supply. The rural domestic water demand comprises less than 3 percent of all water use in the Chesapeake Bay Region.

LIVESTOCK AND POULTRY

Water supply for livestock and poultry is required for two purposes—one, to sustain the resident farm animals and two, to produce livestock and poultry products for the market place. The

TABLE 13
WATER USE IN MANUFACTURING, BY INDUSTRIAL SECTOR,
CHESAPEAKE BAY REGION, mgd, 1970

Sector	Gross Use	Intake	Consumption	Discharge	Percent Recycled
Food & Kindred Products	79.7	74.3	5.6	68.7	6.8
Paper & Allied Products	644.8	72.8	7.6	65.2	88.7
Chemicals	402.5	328.1	14.5	313.6	18.5
Petroleum	81.6	76.3	0.7	75.6	6.5
Primary Metals	1,094.6	882.3	35.1	879.2	19.4
Other Manufacturing	304.7	181.7	11.1	165.0	40.0
TOTAL	2,607.9	1,615.5	74.6	1,535.3	38.1

TABLE 14
INDUSTRIAL WATER WITHDRAWALS, BY SOURCE, MGD
CHESAPEAKE BAY REGION, 1970

Subregion	Public	Self-Supplied Ground	Self-Supplied Surface	Self-Supplied Brackish	Self-Supplied Other	Total	Total Fresh	Percent Fresh
17-1 Baltimore, SMSA	70.0	14.4	2.9	781.2	122.2	990.7	87.3	7.8
17-2 Maryland Eastern Shore	3.0	30.0	1.1	0.7	0.0	34.8	34.1	97.9
17-3 Virginia Eastern Shore	0.3	1.9	0.0	0.1	0.0	2.3	2.2	95.7
17-4 Non-SMSA, Delaware	2.7	14.9	48.0	0.0	0.0	65.6	65.6	100.0
18-1 Washington SMSA	3.3	0.1	1.3	0.0	0.0	4.7	4.7	100.0
18-2 Southern Maryland	0.1	0.7	0.0	0.0	0.0	0.8	0.8	100.0
18-3 Non-SMSA, Virginia	0.2	0.1	27.1	0.0	0.0	27.4	27.4	100.0
21-1 Richmond-Petersburg-Colonial Heights SMSA	22.3	0.3	264.2	0.0	0.0	286.8	286.8	100.0
21-2 Non-SMSA, Virginia	0.2	16.0	0.1	10.3	0.0	26.6	16.3	61.3
22-1 Newport News-Hampton SMSA	4.6	5.0	0.0	90.6	0.0	100.2	9.6	9.6
22-2 Norfolk-Portsmouth SMSA	5.6	3.8	0.0	15.9	0.0	25.3	9.4	37.1
22-3 Non-SMSA, Virginia	0.6	44.9	4.8	0.0	0.0	50.3	50.3	100.0
TOTAL BAY AREA	112.7	132.1	349.5	898.8	122.2	1,615.5	594.5	36.8

livestock category includes animals such as beef cattle, dairy cows, sheep, hogs, and horses. Poultry includes chickens that are raised either for market or egg production, and turkeys.

In the Chesapeake Bay Region, livestock and poultry water consumption amounted to 14.7 mgd in 1967, or less than 1 percent of all uses Bay-wide. Easily the largest component of livestock and poultry water use was cattle and milk cows, which, despite an overall decline in the number of animals during the previous 20 years, used 55 percent of all water used by poultry and livestock in 1969. During this same period water consumption per animal has more than doubled due to the increased stringency of sanitation codes and increased milk production per milk cow.

Water use has increased in other categories as well. Broiler chickens, which have increased in numbers since 1950 by 160 percent, utilized 28 percent of the poultry and livestock water supply in 1969. Hogs and pigs accounted for an additional 9 percent. Declines since 1950 in absolute numbers as well as water use have occurred only for sheep and horses.

Most of the livestock and poultry water use is concentrated on the Delmarva Peninsula and in portions of the Baltimore and Washington SMSA's. Poultry water use predominates on the Eastern Shore, while dairy cow production is a significant source of water demand around the SMSA's. In the southern Virginia portion of the Study Area, hogs and pigs are an important source of water demand in the livestock and poultry water use category.

Potomac River at Great Falls.

IRRIGATION

The amount of water used for irrigation purposes varies greatly from year to year, depending on climatological conditions and crop patterns. Because of the generally moderate levels of precipitation (i.e., about 40 inches per year), the demand for irrigated land in the Study Area is not nearly as great as in the Southwestern or Great Plains areas of the United States. In 1969, irrigation water use amounted to 8 billion gallons in the Study Area, an increase of 18 percent over the 1964 figure. Only about 2.0 percent of the total land in crops in the Chesapeake Bay Region was irrigated in 1969. The use of water for irrigation purposes is concentrated on the Delmarva Peninsula. This area accounts for about 79 percent of the total irrigated water use in the Chesapeake Bay Region.

The major irrigated crops, in terms of acreages, were field corn (6 percent), other field crops (30 percent), vegetables (52 percent), and nursery and other crops (8 percent). According to the Soil Conservation Service (SCS), U.S. Department of Agriculture, over two million acres of farm land in the Study Area are potentially irrigable although about two-thirds would require additional treatment measures such as land leveling or drainage.

EXISTING PROBLEMS AND CONFLICTS

Provision of water for the people, industries, and farms of the Bay Area is not accomplished without the water supplier encountering certain problems. Growing affluence and economic

TABLE 15
PROJECTED WATER SUPPLY DEMAND
ON CENTRAL SYSTEMS (MGD)
CHESAPEAKE BAY REGION

		1970	1980	2000	2020	% Increase Over Study Period
17-1	Baltimore, Md. SMSA	268.4	326.1	424.4	561.0	109
17-2	Maryland Eastern Shore	18.6	23.8	35.1	50.2	170
17-3	Virginia Eastern Shore	0.8	1.0	1.5	2.2	175
17-4	Delaware Non-SMSA	1.9	2.8	5.1	8.4	342
18-1	Washington, D.C. SMSA	390.1	497.5	768.2	1,175.4	201
18-2	Southern Maryland	4.2	6.7	18.2	33.7	702
18-3	Virginia Non-SMSA	3.7	5.1	9.1	16.8	354
21-1	Richmond-Petersburg-Colonial Heights SMSA's	79.8	95.2	143.2	222.5	179
21-2	Virginia Non-SMSA	2.8	4.0	6.5	10.4	271
22-1	Newport News-Hampton SMSA	27.8	37.5	51.5	68.5	146
22-2	Norfolk-Portsmouth SMSA	66.9	80.7	111.1	147.3	120
22-3	Virginia Non-SMSA	6.8	10.7	17.1	26.6	291
	TOTAL	871.8	1,091.1	1,591.0	2,323.0	166

development with the accompanying increased demands for water have required municipal water authorities to expand treatment and distribution facilities and to search for new sources. In some urban areas that are located on or near the tidewater portions of the Bay, such as Baltimore, Newport News, Norfolk, and Portsmouth, nearby sources of freshwater have long since been developed. Increased competition for new sources at longer distances from the urban centers is thus occurring and the economic, institutional, and engineering problems associated with these large-scale projects are substantial. For example, Norfolk obtains a portion of its present supply from a source located 50 miles from the urban center.

Seasonal variations in flow, and longer-term cyclical trends in climate and hydrology, can cause problems for systems dependent for their supply on surface water. In addition, the periods of highest demand for water often coincide with the lowest river flows, thus complicating the situation further. This is exemplified in Washington, D.C., where supplies are obtained primarily from the Potomac River. The low flow of record, which occurred in 1966, would not be sufficient to meet today's maximum demands.

Degradation of sources is another major problem facing water users in the Chesapeake Bay Region. Surface waters, both reservoirs and free-flowing streams, are especially susceptible to pollution from municipal and industrial waste discharges, agricultural activity, and other upstream sources. Water users that depend on groundwater as a source of supply are also susceptible to contamination. Seepage from septic systems and landfills are notable sources of pollution in groundwater supplies, and saltwater intrusion is another problem affecting some areas around the Bay.

Conflicts also arise in attempts to develop new water supply sources. On-stream reservoirs and pumped storage reservoirs are solutions to requirements for surface water development, but increased competition for land and other economic, social, institutional, technical, and environmental problems must also be considered in the planning effort. Also, there is concern at several levels of society regarding proposals for large scale water diversions to serve the major water-short areas. Diversion of water from one watershed to another causes direct reduction of streamflow by the amount withdrawn, and may generate problems in the depleted reaches of the river. The ecological value of a waterway, for example, may be jeopardized by flow reduction, especially during periods of unusually low flows. States rights to river flows and the rights of individuals to flows that are undiminished in terms of quality and quantity (under the Doctrine of Riparian Rights) are other difficulties that complicate any type of large-scale water supply development.

FUTURE DEMANDS

The following sections present projections of average daily water use to the year 2020 for central water systems, self-supplied industries, rural domestic populations, livestock and poultry, and irrigation.

MUNICIPAL (CENTRALLY SUPPLIED)

Demands for water supplied through central systems has been projected to increase by approximately 170 percent Bay-wide by 2020 (see Table 15). Included in the tabulation are all central public systems, whether large or small, and the sum of demands for all uses, including domestic, industrial, commercial, and public. Projections were based on expected future per capita use rates and estimates of population served. A complete presentation of all demands on public water systems is presented in Appendix 5, along with all assumptions and

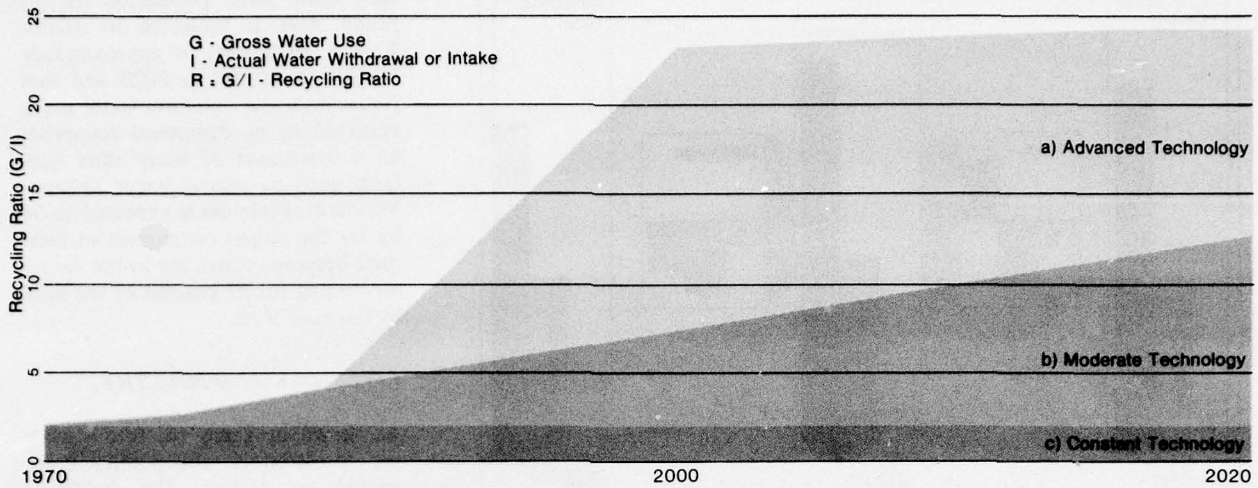


Figure 13: Trends in Industrial Water Use Technology

methodology used to make the projections.

As shown in Table 15, the Baltimore and Washington SMSA's are expected to continue to account for the largest share of the demand for centrally supplied water comprising 75 percent of the total demand in both 2000 and 2020. While the Washington SMSA is expected to experience the largest absolute increase in demand (nearly 800 mgd between 1970 and 2020), the water use in the Southern Maryland area is projected to increase about 700 percent, the largest percentage increase in the Bay Area. Demand is projected to at least double in all of the subregions by the year 2020. Demands in the Bay Area as a whole are expected to increase about 166 percent.

INDUSTRIAL WATER USE

A major consideration in the projection of industrial water supply demands is the impact that Federal water quality goals will have on industrial water use habits. The 1972 Amendments to the Federal Water Pollution Control Act (P.L. 92-500), require application of "best practicable" treatment technology by 1978, and of "best available" technology by 1983 (without further defining the quoted terms). In addition, the Act advocates that a goal of "zero discharge" of pollutants be sought. As industries begin to comply with this directive, and higher levels of waste treatment are achieved, the recycling of wastewater will probably become more economically competitive and consequently more attractive.

Thus, projections of recycling rates for the major water using industries in the Bay Area constituted a major task in the projection process. Recycling rates were derived for three cases which reflect various levels of technology implementation:

a) *advanced technology*–attainment of maximum theoretically possible recycling rates by the year 2000,

b) *constant technology*–maintenance of the rate of recycling at 1970 levels for all industries,

c) *moderate technology*–increase in recycling rates at levels intermediate to either a) or b) above, based on a straight line continuation of projections through 1980.

Plots of the resulting recycling ratios are shown in Figure 13. The derived recycling ratios from the two methodologies, a) and b) above, were felt to represent what might best be termed an "envelope" of possible future recirculation values. As a trade-off between the expected high costs associated with a), and the improbability of the assumptions associated with b), the third set of projections, case c), was derived to reflect a moderate future growth in water recirculation by industry. This is felt to be the most realistic projection set in terms of planning for Chesapeake Bay and forms the basis for the balance of the analysis presented here.

Industrial water use projections as determined under the assumptions of moderate technology [case (c) above] are shown in Table 16. Figure 14 shows the percent changes that occur over the study period in the gross water demand, intake, consumption, discharge, and recycling rate. Rapidly increasing recycling ratios, which increase from 1.61 in 1970 to 9.48 (a 489 percent increase) by 2020 cause the 13 percent *reduction* in intake by 2000. By the year 2020, however, due to the reduced influence of increases in recirculation rates, intakes show a net 13 percent *increase* over the study period.

Also of interest on Table 16 and

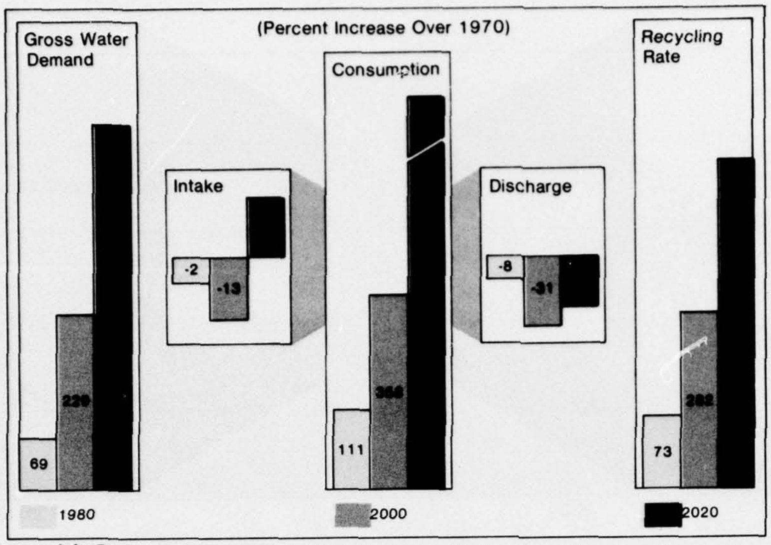


Figure 14: Projected Increase in Manufacturing Water Use, Chesapeake Bay Region

Figure 14 are expected trends in industrial water consumption and industrial discharges. Industrial water consumption (water lost from the process or incorporated into end products), for example, is shown to increase approximately 580 mgd, or about 775 percent between 1970 and 2020. This is due to the increase in recycling and the overall increase in manufacturing production. Increased consumption is also at least partially due to the expected increase in evaporative losses accompanying recirculation of water used for cooling purposes. Finally, discharges of industrial wastes are shown to actually decrease by approximately 24 percent over the projection period due to the increases in consumption and recycling rates. A full and complete presentation of the methodology used and the resultant projections of water requirements by industry is provided in Appendix 5.

RURAL DOMESTIC WATER USE

Total rural domestic water use for the Chesapeake Bay Region is presented in Table 17. A moderate increase of about 67 percent (40 mgd) is forecasted over the 50-year study period. The relative insignificance of this figure is evident in comparison with the 1,450 mgd increase in the amount expected to be supplied by central systems.

Increases in water use are expected in all subregions except Southern Maryland and the Newport News – Hampton SMSA. This reflects the facts that total farm population in the Study Area is projected to decline from a 1970 level of approximately 92,800 to 34,800 in 2020 and that future domestic non-farm water use is expected to be dampened somewhat by a conversion of many rural non-farm users to central water systems. Non-farm water use is expected to be by far the largest component of total rural domestic water use in the future accounting for 97 percent of the total by the year 2020.

LIVESTOCK AND POULTRY

As shown in Table 18, future water use for livestock and poultry is expected to decline. The Baltimore SMSA is the only subregion which is expected to experience a significant increase in livestock and poultry use during the projection period. The increases in the Baltimore area are due to significant projected increases in the number of milk cows and water use per animal. Broilers are expected to continue to dominate water use in poultry production on the Eastern Shore with slight increases projected for both numbers of broilers and water use. These increases, however, were not enough to offset the projected 19 percent decrease in livestock and poultry water use in the Bay Region by 2020.

IRRIGATION

As shown in Table 19, the demand for irrigation water is expected to increase dramatically in future years, by about 250 percent between 1980 and 2020. It should be noted that the values shown for 1980, 2000, and 2020 are the volumes of water needed during a dry year, while the figures for 1969 are the *actual* application rates during that year. Slightly over one-half of the irrigation need in 2020 occurs on the Eastern Shore of Maryland.

A major portion of the increase in total irrigation demand in the Study Area over the projection period is due to increases in the corn acreage and the proportion of corn acreage irri-

TABLE 16
PROJECTED INDUSTRIAL WATER USE
CHESAPEAKE BAY REGION, (mgd)

Year	Gross Water Demand	Intake	Consumption	Discharge	Recycling Rate
1970	2,607.9	1,615.5	74.6	1,541.3	1.61
1975	3,512.5	1,823.9	112.5	1,711.4	1.93
1980	4,408.2	1,581.4	157.5	1,423.9	2.79
1990	6,001.6	1,344.1	246.4	1,097.7	4.47
2000	8,591.5	1,397.8	341.3	1,056.5	6.15
2020	17,290.2	1,822.9	652.4	1,170.5	9.48

TABLE 17
PROJECTED RURAL DOMESTIC WATER USE
CHESAPEAKE BAY REGION, mgd

	Subregion	1970	1980	2000	2020	Percent Change During Protection Period
17-1	Baltimore, Md. SMSA	15.6	17.8	15.8	18.4	18
17-2	Maryland Eastern Shore	8.8	11.9	15.9	20.5	133
17-3	Virginia Eastern Shore	1.5	3.0	3.7	4.1	173
17-4	Delaware Non-SMSA	3.6	6.0	7.8	8.8	144
18-1	Washington, D.C. SMSA	10.6	10.1	12.5	13.9	31
18-2	Southern Maryland	4.3	5.8	5.1	3.9	-9
18-3	Virginia Non-SMSA	2.0	3.4	4.0	2.4	20
21-1	Richmond-Petersburg-Colonial Heights SMSA's	4.9	7.9	9.1	9.9	102
21-2	Virginia Non-SMSA	2.9	4.6	5.8	6.5	124
22-1	Newport News-Hampton SMSA	1.2	1.1	0.5	0.6	-50
22-2	Norfolk-Portsmouth SMSA	0.6	3.3	2.9	2.5	317
22-3	Virginia Non-SMSA	3.9	7.7	8.8	8.7	123
	TOTAL CHESAPEAKE BAY REGION:	59.9	82.6	91.9	100.2	67

gated. This is especially true on the Eastern Shore of Maryland where water used for corn irrigation is expected to account for approximately one-third of the entire Study Area irrigation water demands in 2020. Vegetables, soybeans, tobacco, peanuts, silage, vegetables, and nursery crops are also expected to exert increasing demands for irrigation water in the Bay Region.

TABLE 18
PROJECTED LIVESTOCK AND POULTRY WATER USE
CHESAPEAKE BAY REGION, (mgd)

	Subregion	1969	1980	2000	2020
17-1	Baltimore, Md. SMSA	2.6	2.9	3.2	3.8
17-2	Maryland Eastern Shore	4.2	2.7	2.6	2.6
17-3	Virginia Eastern Shore	0.2	0.1	0.1	0.1
17-4	Delaware Non-SMSA	2.6	1.5	1.3	1.3
18-1	Washington, D.C. SMSA	1.6	1.5	1.1	0.9
18-2	Southern Maryland	0.3	0.2	0.2	0.2
18-3	Virginia Non-SMSA	0.3	0.3	0.4	0.4
21-1	Richmond-Petersburg-Colonial Heights SMSA's	0.8	0.7	0.5	0.4
21-2	Virginia Non-SMSA	0.6	0.6	0.6	0.6
22-1	Newport News-Hampton SMSA	negligible	0.1	0.1	0.2
22-2	Norfolk-Portsmouth SMSA	0.2	0.3	0.2	0.2
22-3	Virginia Non-SMSA	1.2	0.9	1.0	1.3
	TOTAL	14.7	11.8	11.5	11.9

FUTURE NEEDS AND PROBLEM AREAS

MUNICIPAL SYSTEMS

Municipal source and system capacities were compared with projected demands to identify both the magnitude and time frame of emerging shortages of water and/or needs for expansion or development of the system. Table 20 lists the Water Service Areas (large public systems) and the water supply deficits (demand minus supply) expected in each of the communities during a hypothetical 30-day maximum demand period. Deficit numbers were based on the existing available supply during the driest 30 days of the driest year in fifty.

TABLE 19
PROJECTED DRY-YEAR IRRIGATION WATER USE,
CHESAPEAKE BAY REGION*, mgd

	Subregion	1969**	1980	2000	2020
17-1	Baltimore, Md. SMSA	2.9	38.2	42.9	47.9
17-2	Maryland Eastern Shore	32.5	94.0	232.2	722.2
17-3	Virginia Eastern Shore	15.9	66.6	49.6	39.1
17-4	Delaware Non-SMSA	12.2	96.9	111.3	136.8
18-1	Washington, D.C. SMSA	3.1	21.6	72.2	103.1
18-2	Southern Maryland	3.7	14.4	80.6	112.7
18-3	Virginia Non-SMSA	negligible	0.8	1.6	2.1
21-1	Richmond-Petersburg-Colonial Heights SMSA's	1.8	21.6	62.5	70.7
21-2	Virginia Non-SMSA	0.5	13.2	41.6	44.1
22-1	Newport News-Hampton SMSA	0.2	0.3	0.4	0.9
22-2	Norfolk-Portsmouth SMSA	4.4	9.3	8.4	9.1
22-3	Virginia Non-SMSA	2.5	10.5	90.6	68.7
		79.7	387.4	793.9	1,357.4

* Assuming a 90-day growing season.
** Actual observed use.

TABLE 20
PROJECTED WATER SERVICE AREA SUPPLY DEFICITS
CHESAPEAKE BAY REGION

Water Service Area	Deficits in the Existing Source of Water		
	1980	2000	2020
Maryland			
Aberdeen	4.1	10.8	20.6
Annapolis	1.5	2.6	3.2
Baltimore	0.0	0.0	72.0
Bel Air	1.1	2.8	4.4
Cambridge	0.9	1.8	3.2
Centreville	0.0	0.0	0.2
Chestertown	0.3	0.6	1.0
Crisfield	0.5	0.6	0.8
Crofton	0.4	1.2	1.3
Delmar	0.0	0.0	0.0
Denton	0.0	0.1	0.2
Easton	0.3	1.4	3.0
Edgewood (Perryman)	1.2	4.1	9.3
Elkton	0.0	0.0	0.0
Havre de Grace	0.0	0.0	0.0
Joppatowne	0.1	0.2	0.5
King's Heights (Odenton)	1.0	1.7	2.3
Leonardtown	0.0	0.0	0.0
Lexington Park	0.7	3.9	10.0
Maryland City	1.4	2.9	4.8
Pocomoke City	0.0	0.1	0.5
Princess Anne	0.0	0.1	0.4
Salisbury	0.0	0.6	2.0
Severna Park (Severndale)	4.0	5.0	9.3
Snow Hill	0.0	0.2	0.6
Sykesville-Freedom	0.0	0.1	1.0
Westminster	0.1	1.0	1.8
Waldorf	0.6	4.0	10.4
Washington Metropolitan Area			
Washington Suburban Sanitary Commission; Washington Aqueduct	0.0	23.0	329.0
Alexandria, Va.	0.0	4.7	11.9
Fairfax County Water Authority	25.5	132.0	308.0
Goose Creek (Fairfax City), Va.	6.8	27.6	63.1
Manassas, Va.	0.0	2.0	3.4
Manassas Park, Va.	0.2	1.8	4.3
Delaware			
Seaford	0.0	0.3	1.3
Virginia			
Ashland	0.0	0.0	0.0
Colonial Heights-Petersburg	0.0	0.0	0.0
Fredericksburg	0.0	0.0	0.0
Hopewell	8.6	15.3	35.6
Mechanicsville	1.0	4.3	11.0
Newport News	4.2	0.0	21.0
Norfolk	1.0	26.4	57.0
Portsmouth (incl. Suffolk)	4.0	15.0	29.2
Richmond	0.0	0.0	0.0
Smithfield	0.0	0.3	0.9
West Point	0.0	0.0	0.0
Williamsburg	3.0	4.7	7.0

REGION-WIDE FRESHWATER SUPPLY ANALYSIS

The identification of region-wide water supply shortages is accomplished through comparison of the total subregional resource capability and the summation of all demands—municipal, industrial, and agricultural within each subregion. Total water demand figures used to compute deficits were the same as numbers presented previously, except the municipal demand, which reflects a hypothetical 7-day peak demand period.

Excluded is an appraisal of cooling water consumption in electric power generation facilities—these are treated in the Power section of this report. To the extent that future power developments may consume portions of the freshwater supply, the amount consumed should be deducted from the available resource figures presented here. Institutional water needs, including uses in certain independently supplied hospitals, schools, and military establishments (not previously mentioned in this report) are also included in the following tabulations. Water uses within these institutions are assumed to remain constant throughout the study period.

Results of the region-wide water supply analysis are presented in Table 21. Measures of the available freshwater supply presented in the table are the combination of supply from all sources, including:

- *groundwater* – estimate of ultimate developable yield;
- *surface water* – 7-day, 10-year drought flows at point of departure from subregion; and,
- *impoundments* – safe yield of existing reservoir development.

Significant regional shortages are shown for the Washington, D.C. Metropolitan Area and the three subregions comprising Southeastern, Virginia.

SENSITIVITY ANALYSIS

The foregoing projections of future water supply demands are based on certain assumptions that were required to transform and simplify the many uncertainties of the future. Four areas of critical concern with regard to water supply were determined to be population growth, recycling in industrial water use, improved irrigation efficiencies, and political decisions which might require increased agricultural production.

One of the major shifts in the demographic profile of the United States in recent years has been the declining birth rate and the resulting decrease in population growth rates. The effect of reduced population levels would most likely be a reduction in the demand in all major water use categories assuming all other factors remain constant.

Future water needs for use in manufacturing may be influenced by even greater improvements in water reuse and recycling than have been anticipated in this report. Based on assumptions by the Bureau of Domestic Commerce, U.S. Department of Commerce, reduction of as much as 56 percent could occur in industrial water intake if conditions of "advanced technology" are attained as illustrated before in Figure 13.

A third area of possible impact on water demands includes future climate changes and irrigation efficiencies. Irrigation needs have been projected assuming drought conditions, and under conditions of more normal rainfall, irrigation demands can be expected to be considerably reduced. Projections of irrigation needs also assume that only 65 percent of the water applied is used by the plants, the balance being lost to drainage or evaporation. It is estimated that an increase in irrigation efficiency to 80 percent (a probable maximum) would result in a 19 percent reduction in demand.

A final consideration with regard to future agricultural water demands is the prospect of large scale exports of American agricultural products. If the United States becomes committed to exports of its food products to help alleviate a world shortage, agricultural production may increase in the Bay Area, resulting in greater demands for water.

TABLE 21
CHESAPEAKE BAY REGION FRESHWATER SUPPLY ANALYSIS
AND PROJECTED DEFICITS, mgd

	Subregion	Freshwater Supply	Future Deficits 1980	2000	2020
17-1	Baltimore, Md. SMSA	1,024*	0	0	0
17-2	Maryland Eastern Shore	865	0	0	0
17-3	Virginia Eastern Shore	250	0	0	0
17-4	Delaware Non-SMSA	290	0	0	0
18-1	Washington, D.C. SMSA	936**	0	62	1,015
18-2	Southern Maryland	234	0	0	0
18-3	Virginia Non-SMSA	119	0	0	0
21-1	Richmond-Petersburg-Colonial Heights SMSA's	678	0	0	110
21-2	Virginia Non-SMSA	170	0	0	0
22-1	Newport News-Hampton SMSA	73***	0	0	12
22-2	Norfolk-Portsmouth SMSA	106	22	62	114
22-3	Virginia Non-SMSA	84	16	179	315

* Assumes allowable withdrawal from Susquehanna River of 500 mgd.
** Increases to 1,073 mgd beyond 1990 due to Bloomington Project.
*** Increases to 93 mgd beyond 1990 due to Little Creek Project.

MEANS TO SATISFY THE NEEDS

There are many potential measures available which could be used in meeting the future water supply needs. Some of the more promising are free flowing streams, impoundments, groundwater, desalinization, and curtailed use of water. These measures are more fully discussed in the following paragraphs.

NATURAL STREAM FLOW

Rivers such as the Susquehanna, Potomac, Rappahannock, James, and Appomattox presently serve as major sources of water supply for the large urban and industrial areas located along their banks. It is expected that the use of these sources will continue, and indeed, that the withdrawals will be much expanded. The Susquehanna River, in particular, will experience increased demands both upstream and for possible diversion to the Baltimore area. Other interbasin diversions and the use of the upstream portions of the major subestuaries (e.g., the Potomac River) are also alternatives to be considered in meeting future demands.

IMPOUNDMENTS

A major problem in the use of natural stream flows as a source of water supply is the seasonal variation in flow. Peak demands often coincide with the season of lowest flow in the streams. Dam construction is a means by which reduction of variability can be attained, and the dependable flow or safe yield of a watershed increased. Water is stored in the reservoir during periods of excess flow for use during seasonal periods of low flow and high domestic demands. Over the long term, however, average stream flow must exceed demand by a substantial margin in order to maintain a minimum conservation pool, to allow for evaporation, and provide a minimal base-flow below the dam.

GROUNDWATER

Groundwater is another water supply source which can be developed to meet needs in deficit areas. Massive amounts of water are stored in the pore spaces of the soils and rock formations of the Bay Area. However, the amount recoverable is governed by economics, and the geo-hydrologic character of the area. Water withdrawals from wells will cause a lowering of the water table in a three dimensional cone of depression around the well often affecting the yields, capacities, and water quality of other wells in the area. Consequently, groundwater supplies generally serve their most valuable function in areas with small-scale, evenly dispersed demands, such as those for the rural domestic population, agricultural uses, small towns, and industries with relatively low water requirements. Establishments requiring concentrated large-scale water supply developments have invariably located in Western Shore areas where there is a greater potential for development of surface waters.

DESALINIZATION

Conversion of brackish water to freshwater is a technique which can be used in areas which have depleted their conventional sources of supply. Given a supply of sea water or other brackish source, freshwater can be derived by various methods including distillation, membrane, and freezing processes. Because the cost of desalinization is rather high, it is not normally used in water-rich areas such as the Chesapeake Bay Region.

INSTITUTIONAL MEASURES

Institutional arrangements (changes in law, custom, or practice) and policy changes can increase the efficiency of water use, or otherwise effect a dampening of demand. Examples include pricing and metering to encourage thrift, implementation of plumbing codes to encourage water-saving appliances, and restrictions on use during droughts. Homeowners, commercial establishments, and industries alike will curtail usage, to varying degrees, as water supplies increase in cost. Water use restrictions are most effective when they are applied to uses such as lawn watering, car washing, street cleaning, and non-critical commercial and industrial uses in such a way that major inconvenience and/or economic damage is not suffered by the community. Advancing technology and a change in public acceptance could also lead to the reuse of wastewater for municipal purposes in areas depleted of the more traditional sources.

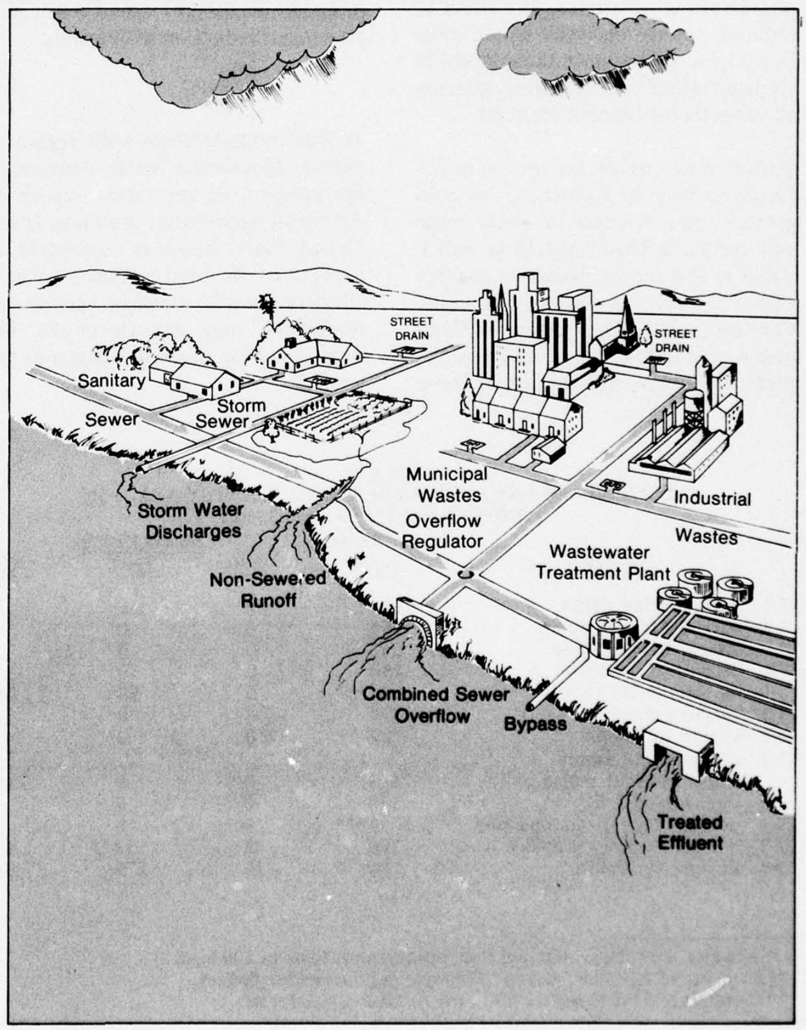
WATER QUALITY

CURRENT STATUS

INTRODUCTION

Water is one of the three basic resources essential for the support of life and without which a Nation, State, or community cannot develop or prosper. Normally, water contains minerals, nutrients, and aquatic organisms which occur naturally. Due to man's activities, however, additional materials are often discharged into the waters. Excesses may cause reductions in the quality of the water resource and render it unfit for intended uses.

Figure 15: Potential Sources of Water Pollution



Under such conditions, the water is termed "polluted," that is, it contains harmful or objectionable materials reducing its utility.

Water quality is the term used to describe the biological, chemical, and physical condition of the water in a river, bay, ocean, or underground. What is termed as "good" water quality differs depending on the intended use. Man requires water for drinking that is free of color, pathogenic bacteria, and objectionable taste and odor. Industries which use water primarily for cooling and steam production require water free of materials such as chlorides, iron, and manganese which may be harmful to equipment. Agriculture requires still a different quality of water that is free of degrading materials toxic to plant and animal life. Finally, each form of aquatic life requires water of varying qualities in order to assure its healthy existence.

Water quality problems generally arise when the waste loads imposed by man exceed the water's capacity to assimilate them adequately. The resulting degradation can be very costly, both economically and ecologically. Increased cost of water treatment for municipal and industrial use, the closing of shellfishing areas and the resulting income loss for persons employed by the fishing industry, the loss of valuable recreation areas, the degradation of aesthetic values, the corrosion of structures exposed to water, destruction of fish and wildlife habitats, and the general reduction in the use of receiving waters are all costs of polluted waters.

Figure 16: The Chesapeake Bay Water Quality Study Areas

The sources of water pollution may be classified as either "point" or "non-point" and are illustrated in Figure 15. Point sources are those in which the degrading material is discharged from a specific point. Non-point sources are those in which the degrading material reaches the water course through flows over a large area.

The major point sources of water pollution are:

1. Municipal sewage outfalls.
2. Industrial waste outfalls.
3. Combined sewer outfalls.

The major non-point sources of water pollution are:

1. Agricultural runoff.
2. Urban runoff.
3. Marine transportation spills.

This section of the report presents the findings of the Cheaspeake Bay Study as they relate to the quality of the waters of Chesapeake Bay and its tributaries. It is essentially a continuation of the 1970 inventory of water quality presented in the *Existing Conditions Report.* With the passage of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) much of the water quality work originally envisioned as part of the Chesapeake Bay Study has been accomplished at the State and local level. In order to avoid duplication of effort, the scope of the work for this analysis was revised to integrate into the Chesapeake Bay Study Program the ongoing State and local work concerning water quality in the Bay Area.

TABLE 22
CHESAPEAKE BAY WATER QUALITY STUDY AREAS

Study Area I – Baltimore

- Lower Susquehanna River
- Bush River
- Gunpowder River
- Patapsco-Back River
- Patuxent River
- Magothy River
- Severn River
- South River

Study Area II – Potomac

- Potomac River
- Occoquan River
- Anacostia River

Study Area III – Rappahannock-York

- Rappahannock River
- York River
- Pamunkey River
- Mattaponi River
- Ingram Bay
- Fleets Bay
- Mobjack Bay

Study Area IV – Lower James

- James River
- Appomattox River
- Back River
- Elizabeth River
- Lynnhaven Bay

Study Area V – Lower Eastern Shore

- Pocomoke River
- Manokin River
- Wicomico River
- Nanticoke River

Study Area VI – Upper Eastern Shore

- Choptank River
- Wye River
- Chester River
- Eastern Bay
- Northeast River
- Elk River
- C & D Canal

The geographical area considered for the water quality study is based on the river basins in the Chesapeake Bay's drainage area. Within the Chesapeake Bay Region, 18 separate river basin segments as designated by the States of Maryland, Virginia, and Delaware were combined to form six regional study areas. These are shown in Figure 16, and a complete listing of the major river basins within each study area is presented in Table 22.

The major source of information for this analysis was the State Water Quality Management Plans required by section 303(e) of P.L. 92-500, which provided projections of wastewater loadings and water quality needs for each river basin. "Problem area" information was taken from the State Water Quality Inventories prepared under Section 305(b) of P.L. 92-500.

WATER QUALITY PARAMETERS

The parameters used to measure water quality are of three major types: physical, chemical, and biological. The most important of these parameters are Biochemical Oxygen Demand (BOD), bacteriological indicators, suspended solids, dissolved solids, temperature, dissolved oxygen, nutrients, chlorophyll *a*, pH, and heavy metals. By monitoring and studying these water quality parameters, standards have been and are being developed to control water pollution. These standards, required of each state by P.L. 92-500, reflect the goal of water quality management for the present and future. A more detailed description of these and other important parameters is presented in Appendix 7, "Water Quality," and in the Glossary of this Summary.

EXISTING WATER QUALITY CONDITIONS

Characterizing the quality of the Bay's waters in one word is difficult because of the wide variety of conditions encountered in an area of this size; however, a blanket statement would probably conclude that the water quality of the Bay itself is good, with most of the severe problems occurring in the tributaries especially near areas of high population concentrations. However, increasing loads from municipal sewage treatment plants and industrial sources, as well as from agricultural and storm runoff, and marine transportation spills are causing stresses and problems, some very severe, throughout the Bay Region. In addition, as yet unidentified pollutants may be present in the Bay and its tributaries causing environmental damage. For example, preliminary results from a study by the Smithsonian Institution indicate a possible link between two widely used agricultural herbicides and the decline of certain aquatic grasses in Chesapeake Bay during the last decade.

Figure 17 summarizes the major water quality problems of the larger tributaries and their surrounding land areas. In general, municipal and industrial wastes have been found to be the major problems in the populated areas of Baltimore, Washington, Richmond, and Norfolk. Other less populated areas suffer mainly from agricultural and land runoff as well as smaller amounts of municipal discharges. The following sections present a capsulated summary of the existing water quality conditions as they relate to the established water quality standards for each of the six major water quality study areas in the entire Bay Region. More detailed information on water quality and the standards for these basins is presented in Appendix 7, "Water Quality."

a. *Study Area I - Baltimore.* Nutrients appear to be the major problem in the Lower Susquehanna River Basin as algal blooms have been on the increase over the past several years. Heavy municipal and industrial loads upstream have been identified as the major contributors. High nutrient concentrations have also been identified in other major rivers in the Baltimore Study Area including the Patuxent, Severn, South, Gunpowder, Bush, and Back Rivers.

In the Patapsco River, and especially the Baltimore Harbor Area, 32 major industrial dischargers and 10 major municipal dischargers along with the heavily urbanized development in the area are creating stressed conditions in the surrounding waters. Major problems include low dissolved oxygen contents, high bacterial concentrations, and undesirable levels of other pollutants such as heavy metals and oil.

The Patuxent River also suffers from the heavy development along its river banks. Eighteen major municipal facilities, increased construction and urban runoff, and faulty septic systems have been named as the principal contributors to the occasional low dissolved oxygen contents, turbid waters, and increased levels of nitrogen and phosphorus found in the waters. Bacterial concentrations have also caused problems in the area, especially during periods of low flow.

b. *Study Area II – Potomac.* Serving as the major water supply for the District of Columbia and surrounding areas, the Potomac River is stressed by the heavy urban development along its river banks in the Washington Area. Agricultural runoff from upstream sources contributes high volumes of nutrients and bacterial contamination prior to entering the metropolitan area.

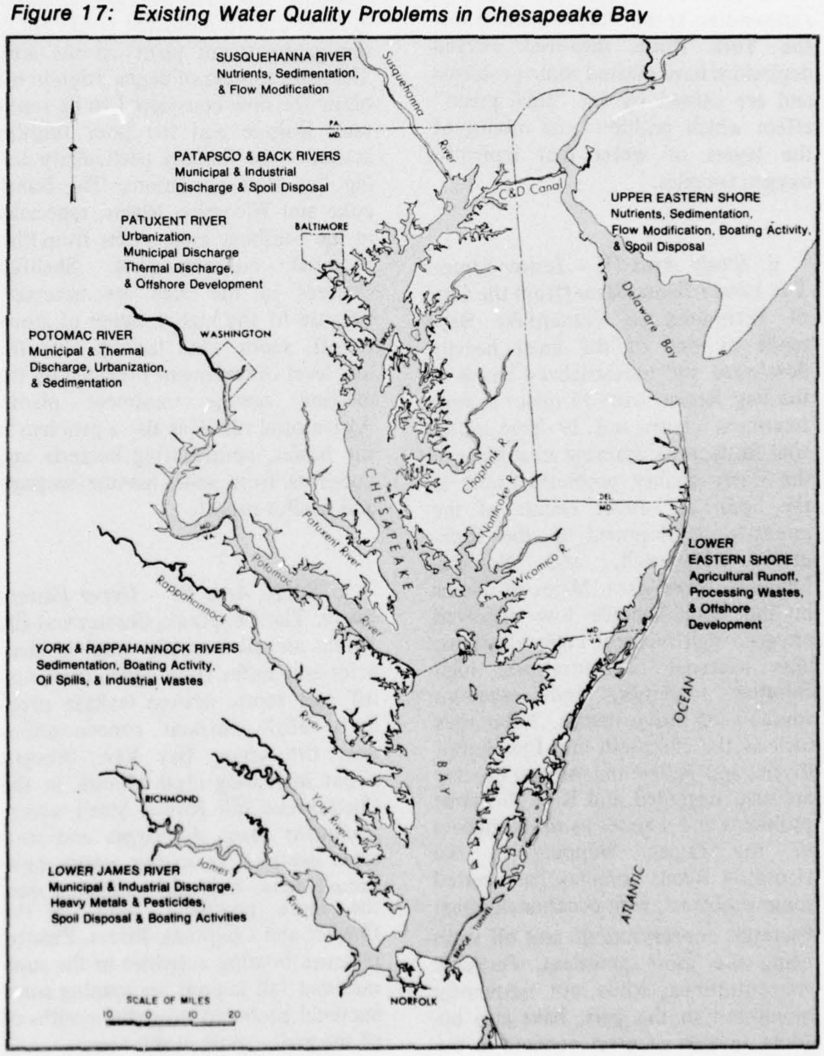
Near the District, high volumes of municipal wastewater (led by the 309 mgd from the Blue Plains Plant) and urban runoff cause some dissolved oxygen depletions while adding to the nutrient enrichment of the river. Improving as it nears Chesapeake Bay, the Lower Potomac River generally meets standards but still suffers from the development upstream and especially the sediment generated from urban and agricultural runoff. In 1973, over 3 million tons of sediment were emptied into the Potomac Estuary and primary production, while not heavily stressed, appears to have suffered.

Tributaries such as the Anacostia River, Piscataway Creek, Rock Creek, Occoquan River, Goose Creek, and Port Tobacco River also suffer from urban and agricultural runoff as well as discharges from the sewage treatment plants in the area. The main problems are high bacterial concentrations, occasional dissolved oxygen depletions, turbid waters, and increasing nutrient concentrations.

c. *Study Area III – Rappahannock-York.* The Rappahannock River Basin, extensively rural in nature, has relatively minor water quality problems with the exception of the waters near the City of Fredericksburg. High bacterial concentrations and occasional dissolved oxygen sags in the mainstream have been traced to extensive agricultural runoff throughout the entire basin and some of the smaller sewage treatment plants in the area which discharge partially treated wastes. The Great Wicomico River and Indian, Cockrell, and Dymer Creeks also experience high bacterial concentrations and occasional dissolved oxygen sags for much the same reasons. Boating activity near the Windmill Point area is causing some concern as bacterial concentrations, nutrients, and dissolved oxygen depletions have been on the increase.

The York River, near its headwaters, exhibits water of excellent quality. In the West Point Area, however, degra-

Figure 17: Existing Water Quality Problems in Chesapeake Bay



dations in the form of low dissolved oxygen, low pH, and high bacterial concentrations occur, mostly the result of urban runoff, landfill runoff, swamp drainage, and discharges from the nearby sewage treatment plant. Sedimentation is also a growing problem throughout the entire basin with the primary contributor being urban runoff, although only 2 percent of land area is in urban use.

King, Carter, and Sarah Creeks, all tributaries to the York River, have high bacterial and nutrient concentrations which are attributed to local STP discharges and marina activities in the surrounding areas. Near the mouth of the York River, dissolved oxygen depletions have created some problems and are caused by the "tidal prism" effect which prohibits the mixing of the layers of water that replenish oxygen supplies.

d. *Study Area IV – Lower James.* The Lower James River (from the City of Richmond to Chesapeake Bay) ranks as one of the most heavily developed and industrialized basins in the Bay Region with 35 major sewage treatment plants and 29 large industrial firms in its drainage area. Most of the water quality problems found in the basin are direct results of the intensive development in the Richmond, Hopewell, and Norfolk-Newport News Area. Major problems in the basin include low dissolved oxygen, high nutrient concentrations, high bacterial concentrations, high chlorine toxicities, and excessive amounts of heavy metals. Tributaries such as the Elizabeth and Lynnhaven Rivers, and Bailey and Ashton Creeks, are also degraded and have the same problems and sources as the mainstem of the James. Shipping in the Hampton Roads complex has created some problems, with occasionally high bacterial concentrations and oil spills being the most prevalent. Pesticide concentrations, while not frequently monitored in the past, have also become an area of great concern in the James Basin following the "kepone" incident of 1976. Illustrative of the magnitude of the concern was the closure, for a 7-month period, of the lower James River to all fishing, by Virginia Governor Mills Godwin in June of 1976.

e. *Study Area V – Lower Eastern Shore.* The Pocomoke River, while generally of good quality, has shown some degradation near the Pocomoke City, Snow Hill and Crisfield Areas. Low dissolved oxygen, high bacterial concentrations, and nutrient enrichment are the main problems. Improvement of water quality conditions, however, has been realized in recent months due to improved treatment at sewage treatment plants in the area. The main sources of degradation in the basin are now considered to be septic tank leakage and the poor flushing action of the Estuary particularly during low flow conditions. The Nanticoke and Wicomico Rivers, especially in the Salisbury area, suffer from high bacterial concentrations. Shellfish closures in the area are necessary because of the high volumes of storm runoff, septic tank leakage, and the low level of treatment provided by the existing sewage treatment plants. Agricultural runoff is also a problem in the basins, contributing bacteria and nutrients from soils, manure seepage, and feedlot runoff.

f. *Study Area VI – Upper Eastern Shore.* The Choptank, Chester and Elk Rivers are all basically rural in character and suffer from agricultural runoff and septic system leakage problems. High nutrient concentrations near the upper Bay have brought about increasing algal blooms in the Chester and Elk Rivers. Small sewage treatment plant discharges and scattered seafood packaging wastes have caused some bacterial problems near the more populated areas of the Chester and Choptank Rivers. Finally, pleasure boating activities in the summer and fall seasons are causing some bacterial problems near the mouths of all the major rivers in this area.

FUTURE WATER QUALITY NEEDS

MUNICIPAL WASTEWATER

Increasing levels of population and per capita income in the Chesapeake Bay Region will mean increased municipal wastewater volumes. Table 23 presents data by river basin on anticipated municipal wastewater flows and treatment needs. These projections were taken from the 303(e) State River Basin Plans currently being prepared. At the time this report was prepared, data were not available for all the river basins within the Study Area. In addition, the milestone years for which projections were provided were inconsistent from river basin to river basin due to differences in the preparing agency's methodologies and assumptions. A more detailed discussion of the projections of municipal wastewater flows together with estimates of future BOD loads may be found in Appendix 7.

As shown in Table 23, projected wastewater flows exceed the 1975 treatment plant capacity in all of the river basins for which projections were available. In addition to the need for more capacity, treatment plants providing more advanced treatment of the wastewaters will be required in most areas of the Bay Region in order to meet the requirements of PL-92-500.

INDUSTRIAL WASTEWATER

Industrial discharges will have a great bearing on the achievement of water quality management goals in the future, especially in highly industrialized areas such as Baltimore, Richmond-Hopewell, and Norfolk. Industrial discharges are a function of industrial water supply and consumption, the level of industrial development, and most importantly, the amount of water recycled. These parameters are discussed in detail in Appendix 5, "Municipal and Industrial Water Supply."

TABLE 23
FUTURE MUNICIPAL WASTEWATER TREATMENT NEEDS, SELECTED AREAS

River Basin	Projected Flow Year	Projected Flow (mgd)	Existing Capacity (mgd, 1975)	Deficit (mgd)
Lower Susquehanna	1995	3.27	1.87	1.40
Patapsco	1990	261.60	238.76	22.84
West Chesapeake	2000	32.80	19.40	13.40
Patuxent	2000	96.30	39.40	56.90
Washington Metro.	2000	543.80	344.64	199.16
Northern Virginia	2020	363.30	111.98	251.32
Rappahannock	2020	19.54[1]	8.38	11.16
York	2020	39.60[1]	2.98	36.62
James (Lower)	2020	386.00	163.97	222.03
Accomack-Northampton	2000	1.26	0.74	0.52
Pocomoke	2000	3.00	2.65	0.35
Nanticoke	1995	13.56	12.80	0.76
Elk	1995	4.99	3.40	1.59

[1]Based on total population and not population served.

The industrial discharge projections presented in Figure 18 are median range values which balance projections reflecting simple historical data on one hand and maximum attainable recycling technology on the other. The curve presented in Figure 18 acknowledges that, while recycling rates will indeed continue to improve, it is more likely that a lesser degree of implementation of technology in industrial water reuse will occur. Although the discharge projections do not specifically address actual concentrations of waste products or projected discharge loadings, they do, however, serve as an indicator of the marked decrease in industrial discharges that may be expected in pursuit of National water quality goals. It should be noted that the values presented in Figure 18 include only the five major water-using industrial groups in the Chesapeake Bay Region (i.e., chemicals, primary metals, paper and allied products, food and kindred products, and petroleum). These industries, however, account for about 82 percent of the total water withdrawals in the Bay Region.

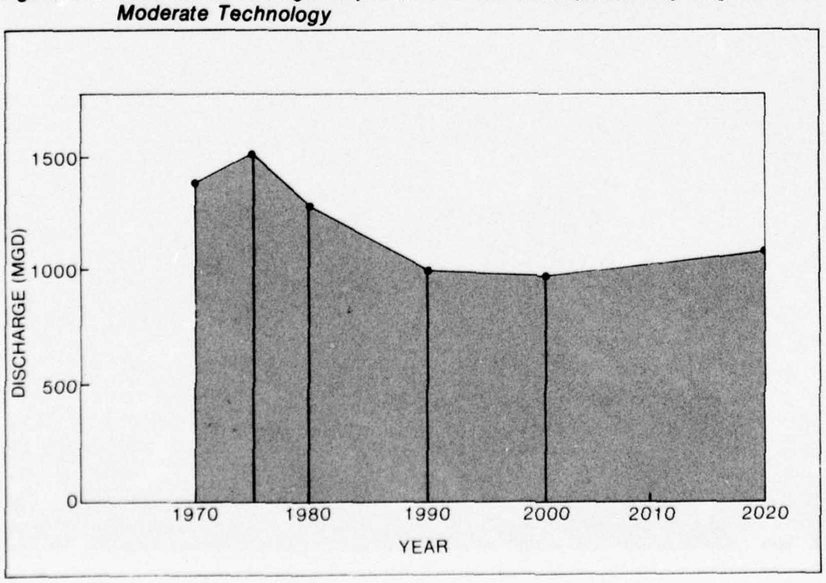
OTHER POINT AND NONPOINT SOURCE PROBLEM AREAS

a. *Thermal Discharges:* Increases in the demand for electric power, as outlined in Appendix 13, Electric Power, will create the additional problem of the disposal of heated cooling waters. In 1972, an average of nearly 7,700 mgd was discharged from power plants into Chesapeake Bay waters, almost 8.5 times the average discharge of sewage treatment plants in the Area. Projected withdrawals for 1980 are expected to be near 8,500 mgd; of which 3,500 are required for the Surry and Calvert Cliffs nuclear power plants alone. A major concern is the effect such heavy concentrations of heated waters will have on the aquatic environment. Complicating the problem are the physical characteristics of Chesapeake Bay, an estuary which is relatively shallow and of moderate temperature, thereby limiting its efficiency for the dispersion of heated effluents.

b. *Chlorine:* Chlorine, used widely as a fouling preventative in industry and as a disinfectant for municipal wastes, has in combination with elements in receiving waters been found to cause up to 90 percent reduction in primary productivity near wastewater treatment plant discharges. Future threats center around an overabundance of total chlorine residuals, due to the increased volumes of both municipal and industrial discharges as well as the required lowering of coliform densities in discharges which require increasing amounts of disinfectant.

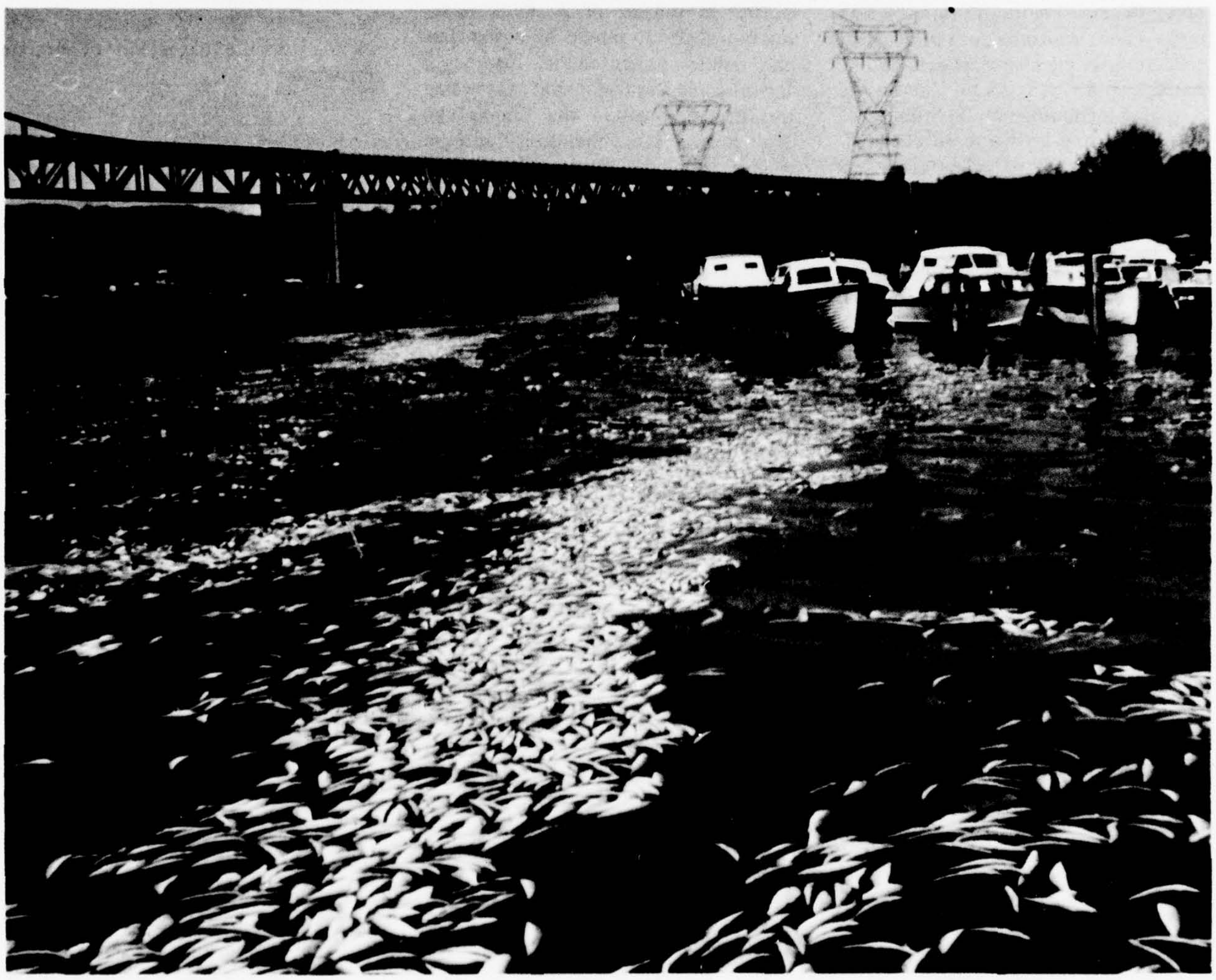
c. *Agricultural and Urban Runoff:* With approximately 40 percent of the Bay's land area in agricultural use, pollutants such as nutrients, pesticides, sediment, and animal waste products can be expected to continue to contribute a significant loading. Although the percentage of land in agricultural use is projected to decrease, intensive farming practices which attempt to grow the same or greater amounts of crops on smaller land areas may contribute even greater loadings than before. Urban runoff may be expected to increase markedly as population growth and urban expansion con-

Figure 18: Industrial Discharge Projections for the Chesapeake Bay Region with Moderate Technology



tinue. Large amounts of runoff containing oils, chemicals, and sediments cause significant problems near the major cities of the Bay Region.

d. *Oil and Marine Transportation Spills:* With the projected increase in both total traffic and the total amount of oil products shipped on Chesapeake Bay (see Appendix 9, Navigation) the probability of accidental spills may also increase. Other hazardous chemicals in transport will also be subject to accidental spills as Bay traffic increases. Other sources of oil, especially municipal discharges, have not yet been thoroughly researched. More detailed information on these subjects



can be found in Appendix 15, Biota.

e. *Sedimentation:* Sedimentation, a natural phenomenon the level of which has been increased beyond natural levels due to man's activities, can also be expected to increase in the future as population grows in the Bay Region. A projected doubling of population in the Chesapeake Bay Region between 1970 and 2020 means that the existing number of residences, office buildings, etc., will also roughly have to double, implying a tremendous amount of construction activity with its potential for causing sedimentation problems during the projection period.

f. *Recreational and Commercial Boating Activities:* The large and increasing numbers of both commercial and recreational vessels currently contribute a significant amount of raw sewage through direct overboard discharges. The problems caused by these discharges are expected to continue into the future until adequate pumping facilities can be installed to treat the sewage at marina and port facilities.

g. *Septic Tank Failures:* Failing septic systems, which cause major problems in many of the rural areas of the Chesapeake Bay Region can be expected to continue to plague those areas until either the old systems are repaired or sewer service can be provided. In those areas outside expected sewerage expansions and where poor soil conditions exist, new methods of handling wastes from individual homesites will have to be found before improvement can be expected.

h. *Solid Waste Leachates:* Seepage from the ever increasing number of solid waste dumps and sanitary landfill sites may also pose a serious threat to water quality in the future, especially in the contamination of groundwater supplies. Protection of both private and public water supplies by sealing them off from the potentially high amounts of sodium, potassium, calcium, magnesium, and organic pollutants characteristic of this leachate will be necessary to avoid contamination problems in the future. Also, some means of treating the collected leachate will be necessary.

MANAGEMENT AND OTHER PROBLEM AREAS

In pursuing the goals of improved water quality, numerous problems are being encountered by the responsible management agencies. Some common management-related problems are presented below:

a. *Financial Capabilities:* The adequacy of existing technology to meet goals and objectives of P.L. 92-500 does not appear to be a significant problem. The costs associated with implementing these improvements, however, appears to be a problem of great magnitude. In a 1973 report by the *National Water Commission* to the President of the United States, it was estimated that implementation of pollution abatement policy based on "Best Available" technology for treatment of both municipal and industrial point source wastes by 1983 would require expenditures of about $460 billion through 1983. Implementation of a true "no discharge" policy had been estimated to cost several times that amount. Figure 19 illustrates how costs increase as levels of treatment increase. As indicated, a clean-up of the last 1 percent of pollution involves a doubling of the already large costs involved in eliminating the first 99 percent.

b. *Manpower:* The need for well-trained personnel to operate wastewater treatment plants is important, as the ability of a treatment facility to achieve design efficiency is primarily dependent upon the skill and knowledge of the operator. The expected expansion and increased complexity of wastewater treatment plants in the future will require an increasing number of technically competent and adequately trained personnel.

c. *Lack of Data Base:* Basic data on water quality and the effects of changes in critical water quality parameters on the environment, provides a basis for planning, decision making, and evaluation. An existing and projected need is for expanded monitoring of trends in water quality to improve selection of effective management measures and for enforcement purposes. Equally important is the critical need for assurance that all potential users know what type of data is available so that they can obtain it when needed.

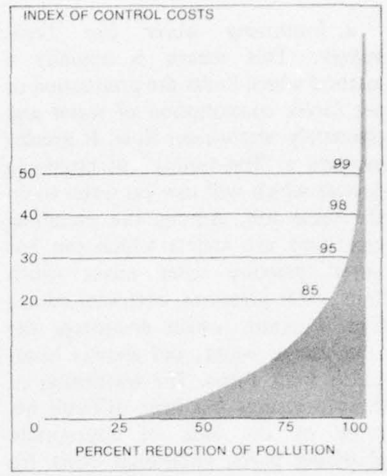


***Figure 19:** Pollution Control Costs as a Function of Control Levels*

MEANS TO SATISFY THE NEEDS

This section includes a description of those measures that can be employed to meet present and future water quality needs. The measures are discussed in terms of physical alternatives and management or legislative actions.

PHYSICAL ALTERNATIVES

There are two basic approaches to physically controlling or treating the increasing volume of wastewater flows. One of them involves the installation of water-saving devices and methods that cut down or limit the volume of wastewater generated. The other approach concerns the various methods and equipment available for treatment and disposal of waste products after generation.

a. *Improving Water Use Technology:* This means is actually a method which limits the production or per capita consumption of water and ultimately wastewater flow. It usually involves a "fine-tuning" of plumbing devices which will use less water to do the same job. Among the plumbing provisions are toilets which use less water, pressure relief valves which limit water pressures, customer education programs which encourage the wise use of water, and shower heads which limit flows. The institution of these measures has been difficult because of the lack of appropriate plumbing parts, additional costs for refitting older devices, and follow-up adjustments. Plumbing code revisions seem to hold the most hope in the future for instituting these measures.

b. *Increased Industrial Treatment and Recirculation:* In keeping with the requirements of present legislation, improvement in treatment technology (percent pollutant removal) will most likely result in water of better quality. This in turn will result in an increased ability of industrial plants to reuse this water in the production process and decrease volumes of flow to the rivers.

Two specific alternatives are pretreatment and by-product recovery. Pretreatment of industrial wastes removes the unique pollutants of an industrial process prior to discharge in municipal sewers. The potential use or sale of waste by-products of the industrial process will also create incentives for industry to re-circulate wastes and remove these pollutants as opposed to dumping them in watercourses. In the pulp and paper industries for example, certain wastes can be synthesized to produce artificial vanilla flavoring and other valuable by-products.

c. *Increased Municipal Treatment:* Increasing both the capacity and pollutant removal capabilities of Bay area sewage treatment plants can contribute greatly to the improvement of the surface waters of Chesapeake Bay. Emphasis can also be placed upon the construction and enlargement of regional sewage treatment plants which have shown the ability to treat wastes more effectively as well as more economically. Larger facilities also relieve overloading due to combined sewers and enable presently unserved areas to receive wastewater treatment.

d. *Cooling of Thermal Wastes:* Three methods of cooling the heated waters of power plants are currently available; wet towers, dry towers, and cooling ponds. In wet towers, the hot effluent is exposed to air circulating through a specially shaped tower. As water evaporates, heat is lost. Dry towers pass the effluent through a series of pipes over which cool air is passed and heat is lost by radiation. Cooling ponds are also a possible solution, but require larger areas than the other alternatives. Appendix 13, "Electric Power," presents more detailed information on alternatives available to reduce the problems associated with thermal discharges.

e. *Land Treatment of Wastewater:* In a land treatment operation, secondariiy treated wastes are transported to the land treatment site instead of being disposed of in the watercourses. The effluent is then stored, chlorinated, and applied to the land surface by a variety of basic means. The underlying concept is based upon the use of the soil mantle and its vegetative cover which acts as a "living filter" to remove pollutants. By this process the oxygen demanding substances are destroyed by oxidation, the nitrogen and phosphorous consumed by plant growth, and the purified water returned to the ecosystem by groundwater recharge. Heavy metals are also immobilized by adsorption on soil particles.

f. *Control of Non-Point Source Pollutants:* Actions which seek to reduce the amount of non-point source pollutants such as sediment, pesticides, oils, heavy metals, and coliform organisms are also very important in improving water quality in the Bay and its tributaries. Agricultural runoff policies which have proven most effective are contour plowing, ridge planting, the construction of sedimentation ponds and terraces, and the diversion and treatment of wastes from livestock feed yards. Urban runoff controls consist mainly of developing policies to implement separate storm drains and installation of retention basins which store runoff for later treatment or disposal.

g. *Other Physical Methods:* Techniques such as deep well injection of wastes, runoff controls, alternative means of wastewater disinfection, and methods for improving assimilative capacities of waterways are some other methods that have been proposed as at least partial solutions to the increasingly complex problems of waste disposal in the Chesapeake Bay Region. These alternatives are discussed in detail in Appendix 7.

MANAGEMENT AND LEGISLATIVE ACTIONS

a. *Management Actions:* The major management options available to reduce, re-distribute, or limit the demand for water and thereby the volume of municipal wastewaters, are pricing policies, sewer moratoriums, and consumer education. Pricing policies seek to reduce consumption of water by levying higher rates during those periods of time when the demand is high. Sewer moratoriums have been used in areas where demands for water and sewerage service have exceeded the ability to provide adequate treatment. These moratoriums usually prohibit the extension of old systems. This method of redistributing demand has been used effectively in the Washington Metropolitan area where counties in the surrounding metropolis have implemented moratoriums as emergency measures. Consumer education practices stress the voluntary conservation of water. The basic elements of a program of this type might involve the distribution of information on the water consumption characteristics of major appliances of all brands. Other programs might include door-to-door distribution of water saving packages containing instructions for correcting leaky and excessive water-using appliances as well as dye tablets to help detect leaks within the home.

b. *Legislative Actions:* For the present and near future, the requirements of the Federal Water Pollution Control Act Amendments of 1972 appear to serve as a schedule to implement the desired water quality goals for both the Chesapeake Bay Region and the United States. Appendix 7 provides a summary of the major provisions of PL 92-500 and other recent supplemental legislation.

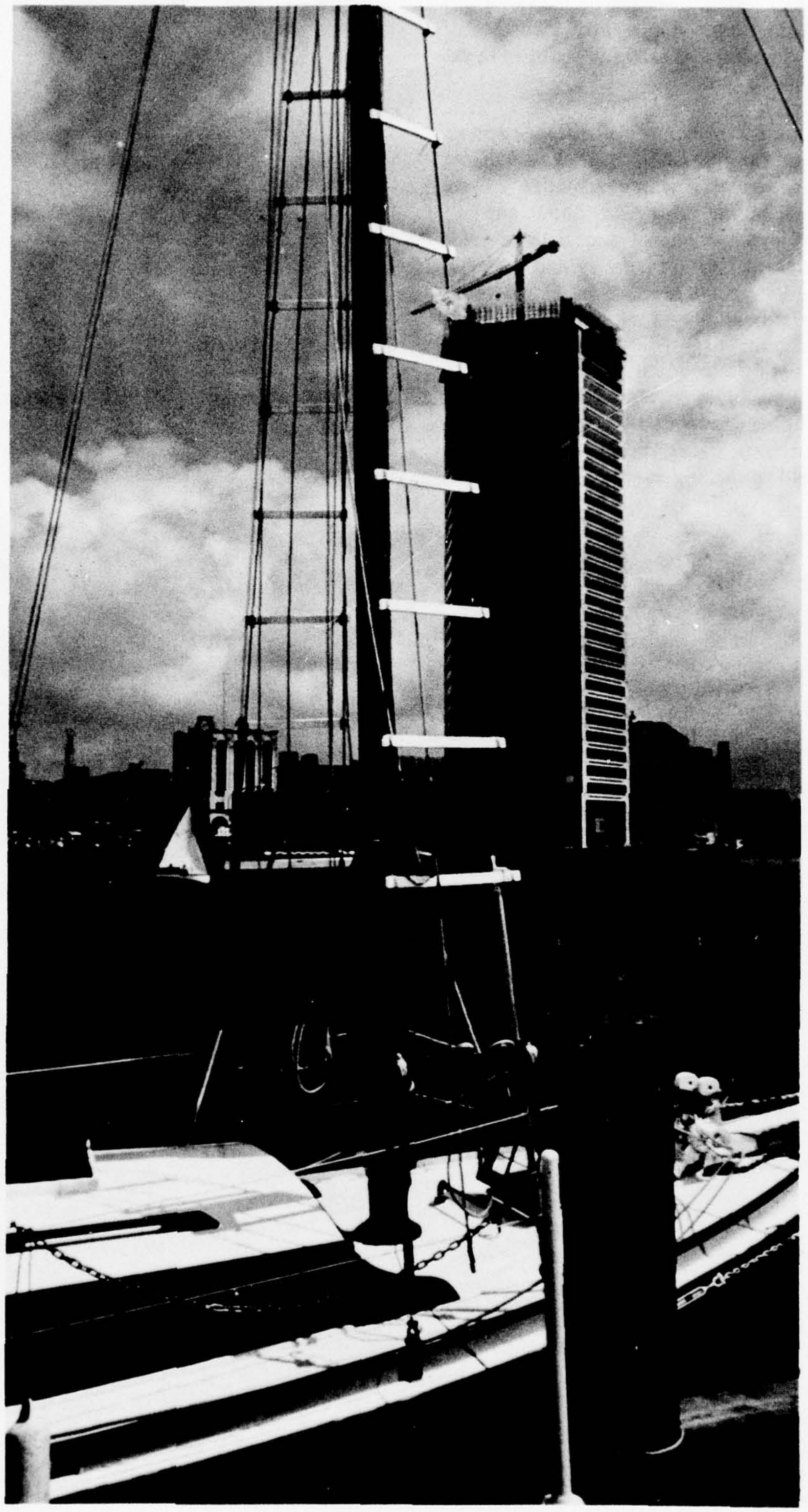
OUTDOOR RECREATION

CURRENT STATUS

EXISTING SUPPLY AND DEMAND

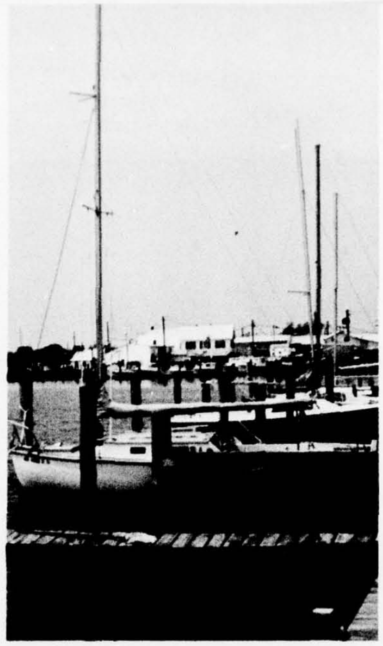
The Chesapeake Bay Region's approximately 7,300 miles of shoreline and 4,400 square miles of water surface area along with its temperate climate make it a very attractive place for water-related recreation activities such as sailing, boating, swimming, picnicking, and camping. In order to better plan for the use of the resource, Statewide Comprehensive Outdoor Recreation Plans (SCORP's) were prepared by all the States in the Study Area under the provisions of the Land and Water Conservation Fund Act of 1965. These studies included an inventory of existing boating, sailing, swimming, camping, and picnicking activities. The results of these surveys show that the Study Area had a public supply at the time of the survey of approximately 440 boat ramps, 20,200 camping sites, 26,600 picnic tables, and 2,500 acres of beach and swimming pools.

In many cases, the provision of facilities for public recreation have not kept pace with the burgeoning demand. In the Bay Region, the number of boat ramps and picnic tables are not sufficient to meet existing public demand. It is estimated that an additional 130 boat ramps and 13,600 picnic tables are needed. On the other



hand, there is presently a surplus of swimming and camping facilities in the Bay Region.

Due to the nature of outdoor recreation in the Chesapeake Bay Region, boating and sailing activities deserve special attention. Only about one-half of one percent of the water surface area of Chesapeake Bay and its tributaries would be required to meet current boating and sailing demands. The inability to satisfactorily meet current boating and sailing demands, however, is not due to an absence of water surface area, but as indicated above, to an insufficient supply of public slips and launching ramps. This is further



illustrated by the fact that the 28,000 trailer boats registered in Maryland in 1971 had access to the Bay through only 125 public boat ramps.

Figure 20 below presents the 1970 resident (those living in the Bay Region) outdoor recreation needs and surpluses by recreation subregion. The boundaries of these subregions conform to those of the State planning regions as defined in the SCORP's. Together these subregions make up the primary areas of recreation demand within the Chesapeake Bay Region. It should be noted that the Study Area used in this recreation analysis differs from the general Study Area defined

in Figure 1. For more information on what cities and counties comprise each recreation subregion, it is suggested that the "Recreation" Appendix be consulted.

As shown in Figure 20, the deficiency in boating ramps is most acute in the Baltimore and Washington Metropolitan Areas while the surpluses are the greatest in the much more sparsely populated areas of the Eastern Shore of Maryland and Tidewater Virginia. Because of this, boat owners in the Baltimore and Washington areas must often travel unusually long distances to launch their vessels in relatively uncrowded environs.

The large 2,100 acre surplus of swimming pool and beach acreage is due primarily to wide expanses of ocean beach on the Maryland, Virginia, and Delaware coasts. It is significant to note that the most highly urbanized regions, Baltimore, Washington, and Richmond show the greatest need for additional swimming space.

More subregions have a deficiency of picnic tables than of any other outdoor recreation facility. Only the Southern Maryland, Virginia Tidewater, and the Eastern Shore of Virginia subregions have a surplus of picnic tables. Typically, the greatest shortages are in the metropolitan areas of Baltimore and Washington which combined account for approximately 67 percent of the Bay Area's total net resident need. The Richmond and Hampton Roads subregions also have large picnic table needs.

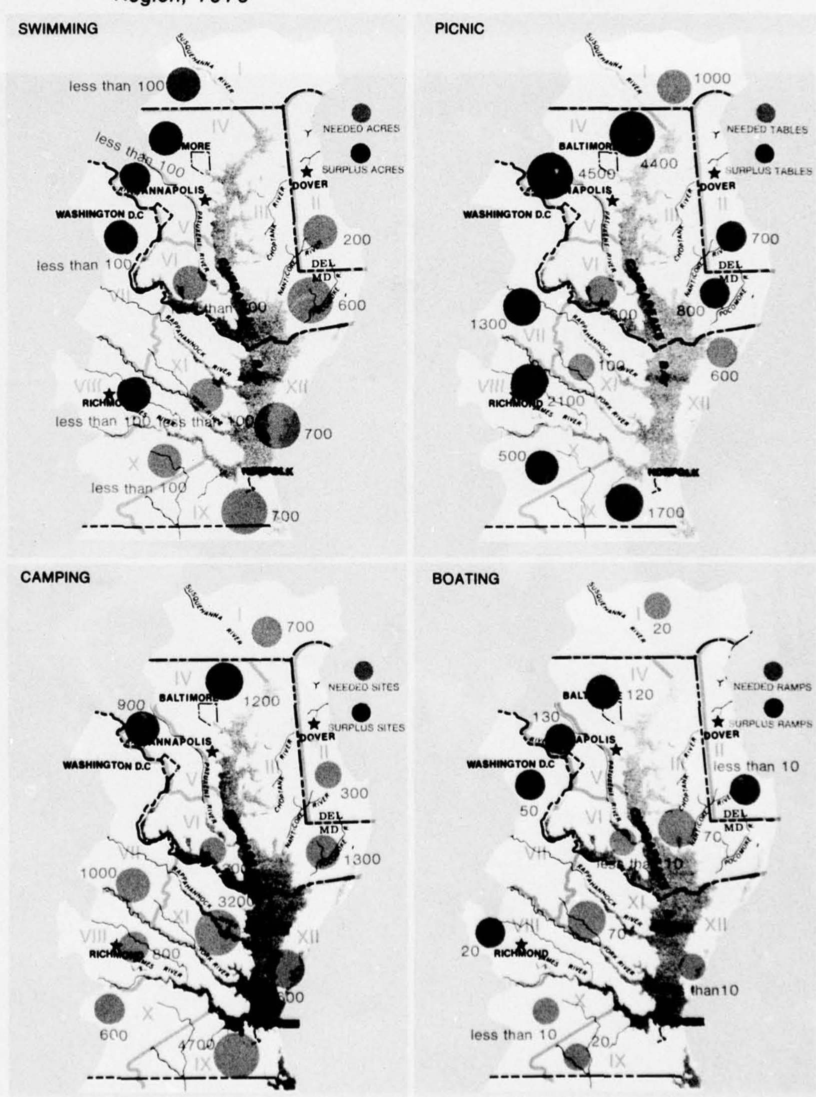
The Baltimore SMSA and Maryland portion of the Washington SMSA subregions are the only areas which presently lack an adequate number of camping sites to meet resident needs. Combined, these two subregions show a need for 2,100 camp sites. The remainder of the Bay Region has a present surplus of 15,500 sites, which means the entire Bay Region has a total surplus of 13,400 sites.

It is important to note that the outdoor recreation needs and surpluses presented in Figure 20 are resident demands only. Non-resident demand was not disaggregated by subregion-of-occurrence due to time and data constraints. If non-resident demand is taken into account, however, there is a substantial increase in the need for boating and sailing ramps, swimming acreage, picnic tables and camping sites.

PROBLEMS AND CONFLICTS

From the standpoint of the general public, Chesapeake Bay is one of the most inaccessible estuaries in the Nation. Private interests have responded to the deficits in public recreational facilities by providing facilities of their own. As a result, an estimated 47 percent of all land and water recreation areas in the Bay Region are in private control. Control of Chesapeake Bay's shoreline by private interests is even more extensive. For example, according to a study conducted by the Chesapeake Bay Interagency Planning Committee, only three percent of the Maryland shoreline is publicly-owned.

Figure 20: Distribution of Receational Needs and Surpluses, Chesapeake Bay Region, 1970

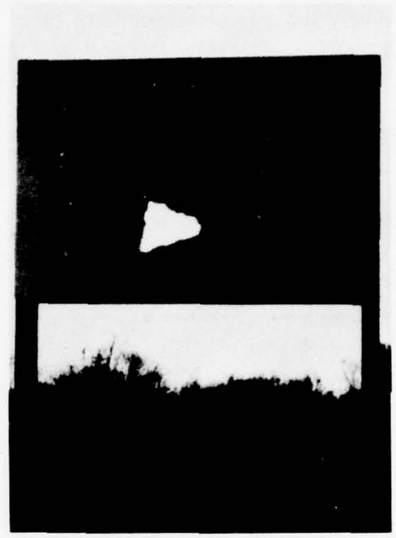


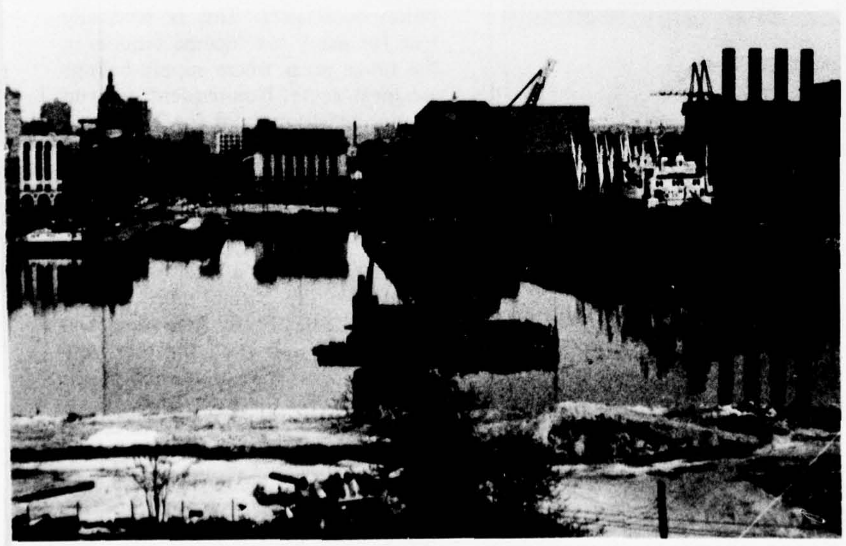
Much of the recreationally desirable land available is in competition with other forms of land development such as private homes, utility development, or military reservations. For example, in urban areas where recreation opportunities are most urgently needed, the shoreline has often been developed as major port and industrial complexes. A significant percent of the publicly-owned shoreline is held by the Federal government, primarily the military, and is unavailable for use by the general public.

Other factors interfere with the maximum recreational utilization of the Bay and its tributaries. Water quality has deteriorated in many sections of the tributaries precluding body-contact water recreation. This problem is especially severe in the urban areas where demands are the greatest. For example, the number of bathing beaches in Baltimore County approved for operation by county health officials has declined from 21 in 1966 to 6 in 1976.

The stinging sea nettle and the closely related comb jellies or ctenophores which reach peak abundance in the summer months also discourage water contact recreation. Other deterrents to recreation activities include the existence of extensive and often valuable wetlands and the occasionally objectionable growth of certain aquatic plants such as the Eurasian Watermilfoil and water chestnut which inhibit boating and swimming.

Recreational use of the Bay and its tributaries has created problems and conflicts in itself. For example, many



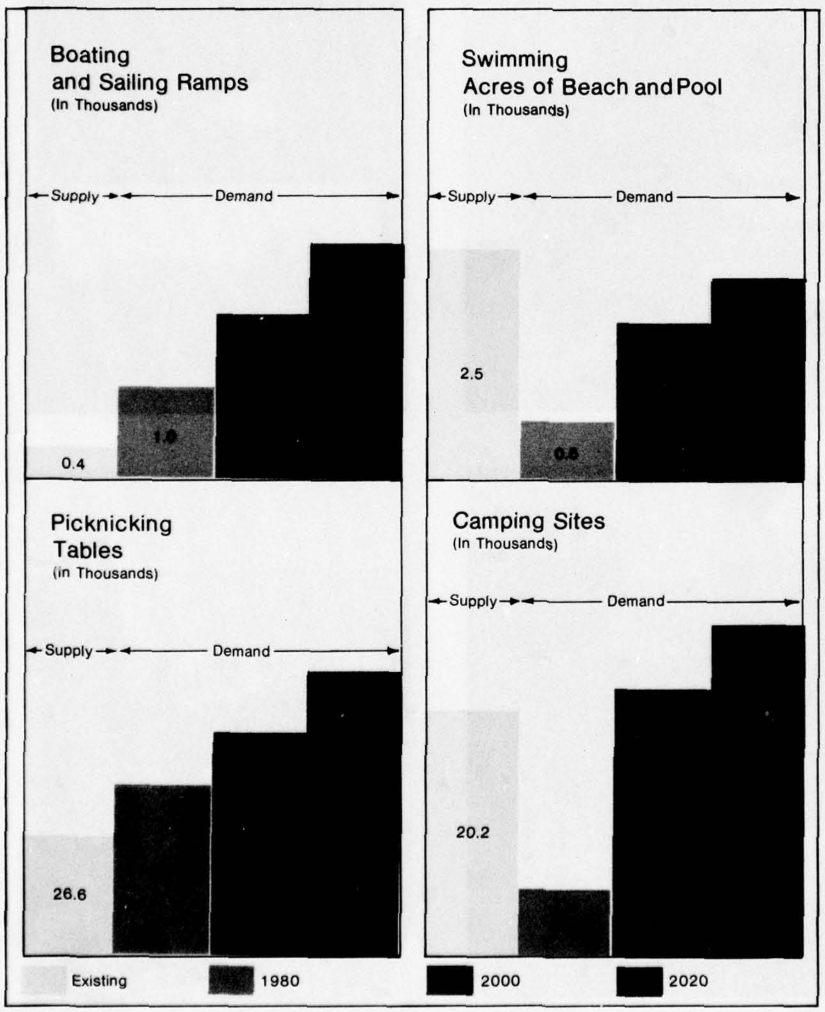


boaters are responsible for degrading water quality by dumping refuse overboard, discharging sewage effluent, and spilling gas and oil into the water. The result is unsightly debris, and in some cases, the closing of certain areas to both water-contact recreation and shellfish harvesting. In addition, recreational boating frequently conflicts with other aquatic activities such as swimming, fishing, commercial shipping, and private shore front property use (brought about by erosion of the shoreline from boat wakes). Finally, recreational boating has led to overcrowding of certain waterways, particularly those most accessible to the large urban areas. This has created dangerous, undesirable conditions for both boaters and swimmers.

FUTURE DEMAND AND SUPPLY

Figure 21 illustrates the relationship between existing supply and projected demand for boating and sailing, swimming, picnicking, and camping in the Study Area. As can be seen, the demand for boating ramps is expected to exceed the existing supply by almost six times by the year 2020. Most of the increase in demand is expected to occur in the three subregions surrounding Baltimore and Washington. These subregions are also projected to have the most critical supply deficits in 2020 with 1,150 ramps needed. A major supply deficit in 2020 is also expected in the Richmond subregion. The only subregions predicted by BOR to have a surplus of ramps through the year 2020 are the Eastern Shore of Maryland and Virginia and the Tidewater portion of Virginia. Of the total demand for boating ramps in 2020, almost 22 percent of the total will be accounted for by non-resident demand.

***Figure 21:** Projected Demand and Existing Supply for Boating and Sailing, Swimming, Picnicking, and Camping, Chesapeake Bay Region (Resident and Non-Resident)*



The need for swimming beaches and pools is also expected to increase significantly during the next 50 years. Although the entire Study Area has a supply excess over the projection period, supply deficiencies in the Baltimore, Washington, and Richmond metropolitan areas are expected to increase from approximately 200 acres of beach and swimming pool water surface area in 1980 to almost 400 acres in 2000 and over 550 acres in the year 2020. Large supply surpluses were projected for the Maryland and Virginia Eastern Shore, Delaware, and Hampton Roads subregions. These surpluses, however, were due to the large expanses of ocean beaches in these areas. Access to these beaches may be a problem for many Study Area residents due to financial and/or transportation constraints. This is especially true for many low-income families in the urban areas where supply deficits are most acute. Non-resident demand is expected to account for 22 percent of the total swimming demand throughout the projection period.

In 1970, there was a total of approximately 26,600 picnic tables in the Chesapeake Bay Study Area which was 24,800 tables short of the total resident and non-resident demand in the same year. By the year 2000, this is expected to increase to over 54,000 picnic tables and by 2020 approximately 95,000 tables. Typically, the greatest projected shortages are in the major urban areas of Baltimore, Washington, Hampton Roads, and Richmond. Moderate surpluses were projected for the Southern Maryland and Virginia Eastern Shore subregions. Non-residents will exert demands on picnic facilities which are expected to amount to a fairly constant 25 percent of total demand over the projection period.

The entire Study Area has a surplus of 11,400 camping sites with only the Washington and Baltimore areas showing current supply deficits. By the year 2000, however, there is projected to be a supply deficit of approximately 1,100 sites and by 2020 there is expected to be a need for over 12,500 sites. Once again, the Baltimore and Washington Metropolitan areas are expected to experience the largest deficits with resident demand alone in 2020 amounting to five and one-half times the existing supply. Existing camp sites in Hampton Roads, Tidewater Virginia, Petersburg-Hopewell, and the Eastern Shores of both Maryland and Virginia are expected to be sufficient to meet resident demands through the projection period. Non-resident demand for camping in the Study Area is estimated to be approximately 25 percent of total demand throughout the projection period. For more information on projections of facility requirements by subregions, see Appendix 8 of this Report.

SENSITIVITY ANALYSIS

Both the projected population of the Study Area and demand for outdoor recreation activities can vary as a result of economic and social changes as well as newly created or newly popular substitute activities. In order to determine the sensitivity of recreational demands, two factors were varied in this analysis—population projections and participation rates. The Series E OBERS population projections were substituted for the base projections (Series C) for use in the sensitivity analysis. Two sets of participation rates were also developed for this analysis, one which reduced the North Atlantic Regional Water Resources Study (NAR) participation rate (the base participation rate) by 15 percent and a second rate which was taken from a survey published by the Bureau of Outdoor Recreation (BOR) titled *"The 1970 Survey of Outdoor Recreation Activities."* Using various combinations of the population projections and the participation rates, a total of four sets of need figures was generated for this sensitivity analysis.

Generally, varying the population projections and the participation rates produced quite a difference in terms of recreation needs, demonstrating that recreation demand is quite sensitive to both population and participation rate. For example, boating and sailing needs (in terms of ramps) differ from the base projections by as much as 240 percent; beach acreage needs by as much as 50 percent; picnic table needs by up to 35 percent; and camping site needs by as much as 774 percent. Tables 8-22 to 8-29 in the "Recreation Appendix" present the results of the sensitivity analysis in more detail.

MEANS TO SATISFY NEEDS

If it is assumed that meeting future outdoor recreation needs within the Study Area is desirable, then there exists a number of means to help satisfy future boating and sailing, swimming, picnicking, and camping needs. The vast amounts of underutilized water-related land resources in the Study Area could be used for much of the future recreation activities. Among the underutilized resources are vast stretches of shoreline controlled by the Federal Government.

These areas include large tracts of military lands such as Aberdeen Proving Ground, Edgewood Arsenal, Quantico Marine Base, Fort Story, and Camp Peary Military Reservation. The "Baltimore Urban Recreation Analysis" prepared by BOR contains information and general findings directly related to the use of Federal and military lands in the Baltimore subregion. The report states that, "despite the more than 840 miles of shoreline in the Baltimore SMSA, less than 1.5 percent of the shoreline is available for public recreational use." Also, the Baltimore Regional Planning Council's document, "Chesapeake Bay: Shoreline Utilization in the Baltimore Region," reports that 12 percent of the Baltimore regional shoreline is in military use. Although it is recognized that it is not possible to open all of these military lands to the public for recreational use, the fact remains that they represent a very significant untapped resource.

Watersheds and water supply reservoirs also offer significant potential for multiple uses. Many of the water supply reservoirs and their adjacent lands are located on attractive, wooded upland sites which offer the potential for swimming, boating, picnicking, and camping. In the past, public health constraints, administrative policy and public opinion have discouraged or prevented joint use of water supply reservoirs. However, existing restrictions should be reexamined in the light of modern water treatment technology to determine if they are essential.

Land adjacent to river channels can also serve as a substantial additional resource base to meet recreation needs. The use of flood plain lands in urban areas for a variety of quality recreational experiences may also preclude development on those flood plains and thus reduce future flood losses. Harbor redevelopment and multiple use of waterfront areas in urban centers is another valuable source of recreation lands. These multi-use areas, which in many cases have become rundown and underutilized, could prove especially significant as recreation areas since they are adjacent to large populations.

Another excellent opportunity to meet outdoor recreation needs in the Chesapeake Bay Study Area is the further development of wild and scenic and recreational river systems. Rivers preserved in their natural free-flowing state offer a wide variety of recreational potential for such activities as canoeing, kayaking, rafting, and boating. In addition, the scenic vistas usually located near these rivers can provide ample opportunity for outdoor recreation pursuits including picnicking and camping. The States of Maryland and Virginia have enacted legislation aimed at the protection of some of the wild and scenic rivers within their State boundaries. Maryland adopted a policy which protects the water quality of certain designated rivers within the State and fulfills vital conservation purposes by wise use of resources within the scenic river system. Currently, eight rivers have been designated as scenic within the State. The Virginia General Assembly enacted the Scenic Rivers Act in 1970 to help coordinate efforts between Federal and State agencies to insure comprehensive water resource planning. To date, 10 Virginia rivers have been designated either scenic or potential scenic rivers. The former group will thus be protected for the enjoyment of present and future generations.

Public acquisition of new land for recreational use is frequently necessary, particularly in urban areas, where demand is great and existing recreational areas may be in extremely short supply. To accomplish such acquisition, funding at all levels of government will have to be increased, particularly in view of the escalating price of land.

An alternative to the costly purchase of new recreation lands is the expansion, intensification of use, and improvement of existing recreation lands. In taking such action, however, care is required to avoid creating overcrowded conditions or befouling recreational facilities to the point where they can no longer be enjoyed by anyone. Many of the existing recreational facilities within or adjacent to the Bay Region's urban areas are in particular need of intensification of use, where physically possible.

Three legislative measures have been found most effective in implementing a program of preserving, maintaining, and acquiring recreation lands to satisfy future outdoor recreation needs. These include zoning, which imposes land use restrictions; tax incentives to preserve open space lands for public use; and eminent domain which condemns private land for public use. By use of these three legislative actions, lands can be obtained or preserved for recreational use before residential or commercial development pressures occur. For example, in areas where vacation homes are popular, residential development around a community waterfront park area could be encouraged to facilitate maximum use and benefit from waterfront lands. Properly planned and spaced marinas, a legitimate use of waterfront lands, could be given a higher priority than shopping centers, for example, at the water's edge. Commercial development not dependent upon water access could be located inland.

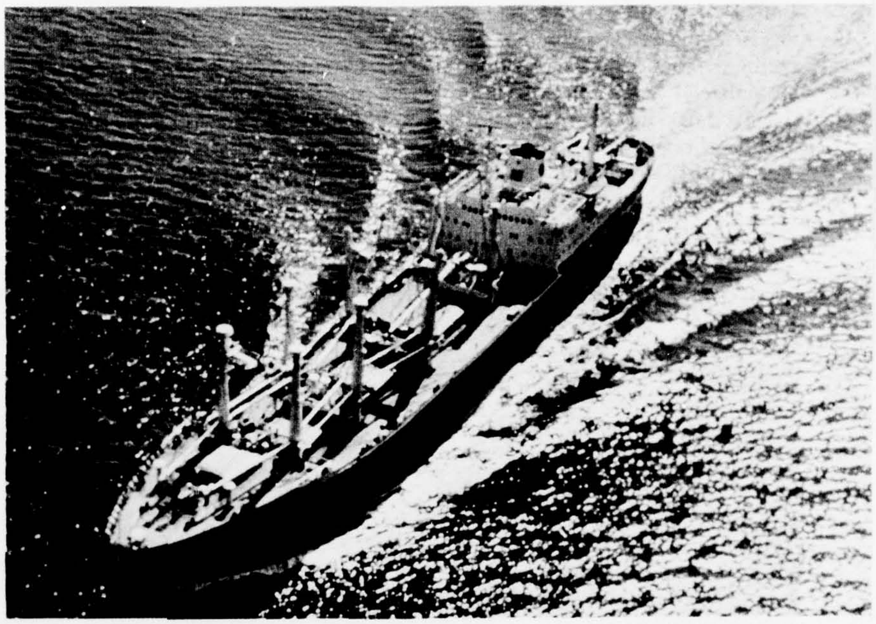
Meeting all future outdoor recreation needs may not be an entirely desirable goal. As discussed in the "Problems and Conflicts Section" above, recreation in the Bay Region has created certain problems including water pollution, conflicts in use of the aquatic environment, and overcrowding of waterways. As future recreation demands increase, these problems can also be expected to increase. By providing alternative outdoor recreation opportunities, however, the intensity of these problems can be reduced. In addition, the provision of recreation alternatives would serve to help meet the recreation needs in the Study Area.

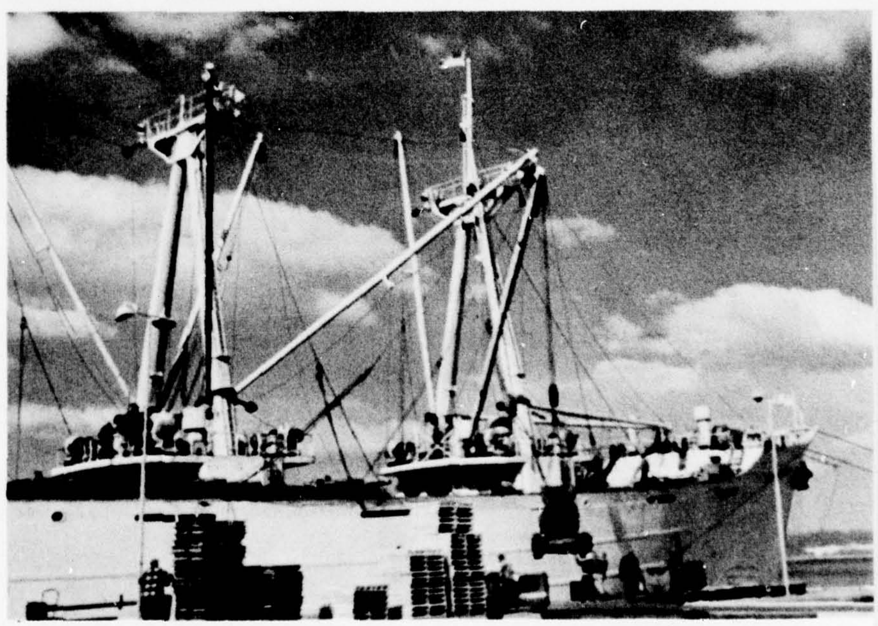
One important alternative means for meeting recreation needs is the development of recreation trails which would substantially add to the resource base in the Chesapeake Bay area. Because of the rich archeological, historical, and natural resources of the Bay Region, a trail system might include biking or hiking trails which would perhaps contribute to the tourism industry. The scenic rivers and their adjacent shoreline areas could provide opportunity for recreation pursuits ranging from nature walks to birdwatching. Outdoor games and sports such as tennis, golf, and horseback riding are other possible alternative means to help satisfy future recreational demands in Chesapeake Bay.

NAVIGATION

CURRENT STATUS

Transportation by water has changed drastically since Colonial times when oceangoing 500-ton sailing ships with





10- to 15-foot drafts plied the Chesapeake docking at individual plantation piers. Water-based transportation, however, has remained extremely important to the Chesapeake Bay Region's economy. A total of approximately 160 million short tons of cargo was shipped on Chesapeake Bay during 1974, nearly three-quarters of a ton for each man, woman, and child in the United States. About 80 percent of this freight passed through the ports of Baltimore or Hampton Roads. Approximately 70 percent of the total freight traffic in these two ports is foreign in origin or destination. Baltimore is basically an importing port. The major commodities coming into Baltimore are metallic ores and concentrates, petroleum and petroleum products, gypsum, sugar, iron and steel products, salt, and motor vehicles and motor vehicle equipment. The port leads the Nation in the importing of automobiles and ranks second in iron ore. The majority of these imported bulk commodities are processed by firms in the Baltimore area.

Hampton Roads, on the other hand, is an export-oriented port. Approximately 70 percent of the total freight tonnage passing through Hampton Roads in 1974 was coal and lignite to be exported. Hampton Roads leads the Nation in this category. The port's location in relation to the coal-rich Central Appalachians gives the port a locational advantage over the other East Coast ports in the coal exporting business. Hampton Roads also conducts important trade in the exporting of corn, wheat, soybeans, tobacco leaf, and grain mill products, as well as in the importing of petroleum products, gypsum, lumber and wood products, and chemicals.

These two Nationally significant ports also have important impacts on the regional economies. For example,

Containership Facilities.

according to the Maryland Port Administration (MPA), 65,000 workers are directly employed by port activities in the Baltimore area and another 100,000 in "port-related" industries. A similar study in Virginia for all the Virginia ports revealed that more than 53,000 people were directly employed by port-related activities and another 142,000 by "harbor-oriented" activities including naval installations.

Although Baltimore and Hampton Roads are the only major international deepwater ports in the Chesapeake Bay Area, there is also a significant amount of traffic in the harbors of some of the smaller ports such as Richmond, Yorktown, Hopewell, Petersburg, and Alexandria, Virginia; Piney Point, Annapolis, Salisbury, and Cambridge, Maryland; and Washington, D.C. The major commodities shipped through these ports are petroleum and petroleum products, construction materials, fertilizers, and seafood.

Due to the increasing size of oceangoing vessels during the past 100 years and the economies involved in the use of these ships, repeated deepenings and widenings of Chesapeake Bay's ship channels have been necessary. In the Port of Baltimore, for example, there have been many improvements made by the Federal government, the most notable being the authorized deepenings to 27 feet in 1881, 35 feet in 1905, 37 feet in 1930, 39 feet in 1945, and 42 feet in 1958. More recently, Congress has authorized an additional deepening of the main channels to 50 feet. In Hampton Roads there have also been numerous improvements of the area's many channels, starting in 1884. The main channel into Hampton Roads was deepened for the first time in 1907 to 30 feet, again in 1910 to 35 feet, in 1917 to 40 feet, and finally in 1965 to 45 feet.

In the Chesapeake Bay and its tributaries there are a total of 147 authorized navigation projects under the supervision of the Baltimore and Norfolk Districts of the Corps of Engineers. The State of Maryland has constructed 16 navigation projects in the Chesapeake Bay and tributaries. There are no State projects in Virginia.

Due to the high sediment loads present throughout most of the Chesapeake Bay system, many of the ship channels are in frequent need of dredging to maintain authorized depths. The frequency of maintenance dredging depends on the location of the waterway. Some waterways, such as the James River, require maintenance almost every year. On the other hand, the Rappahannock Shoal Channel (part of the Baltimore Harbor and Channels Project) has not been maintained since its deepening to 42 feet in 1964.

Two types of dredge material disposal have generally been used in the past in Chesapeake Bay—open water disposal and disposal in dyked impoundments. In the Upper Bay, open water disposal has been used. Uncontaminated dredge material was generally placed near the northern shore of Kent Island while contaminated material was disposed of in the Pooles Island area. In the lower Bay, the Craney Island Disposal Area has been used for all major dredge disposal operations for the Hampton Roads channels. The Craney Island site, constructed in 1957, is a Federally-authorized project located in the heart of the Hampton Roads port complex. The dyked area, which covers about 2,500 acres and has a capacity of about 125 million cubic yards, is expected to be filled to its design height of 17 feet above mean sea level by about 1980.

EXISTING PROBLEMS AND CONFLICTS

The major problems and conflicts relative to navigation and waterborne commerce in the Bay Region include:

a. The need for deeper channels to accommodate the larger ships now in the world fleet.

b. The maintenance of existing channel depths because of sedimentation and shoaling.

c. The disposal of dredge material from both the maintenance and the deepening of channel projects.

d. Accidental and deliberate discharges of wastes from commercial and recreational craft.

e. Shoreline erosion caused by the wakes from large ships.

f. Conflicts between recreational boating and commercial ships in or near the major ship channels.

g. Need for additional waterfront lands to accommodate expanding port facilities.

The first two problems mentioned above stem from a basic confrontation between man's water transportation requirements and the Bay's geological nature. For example, because the Chesapeake Bay is a relatively shallow body of water, major channel deepening projects designed to accommodate today's larger, more efficient ships require extensive dredging. In addition to the natural shallowness of the Bay, Nature's tendency to fill the Estuarine system with sediments and to convert it back to a riverine system causes many existing channels to experience shoaling problems. Dredging and dredged material disposal operations are consequently an important and necessary part of commercial navigation activities on Chesapeake Bay and its tributaries. The environmental impact of these operations has become a very controversial issue. The principal environmental effects of the actual dredging operation are:

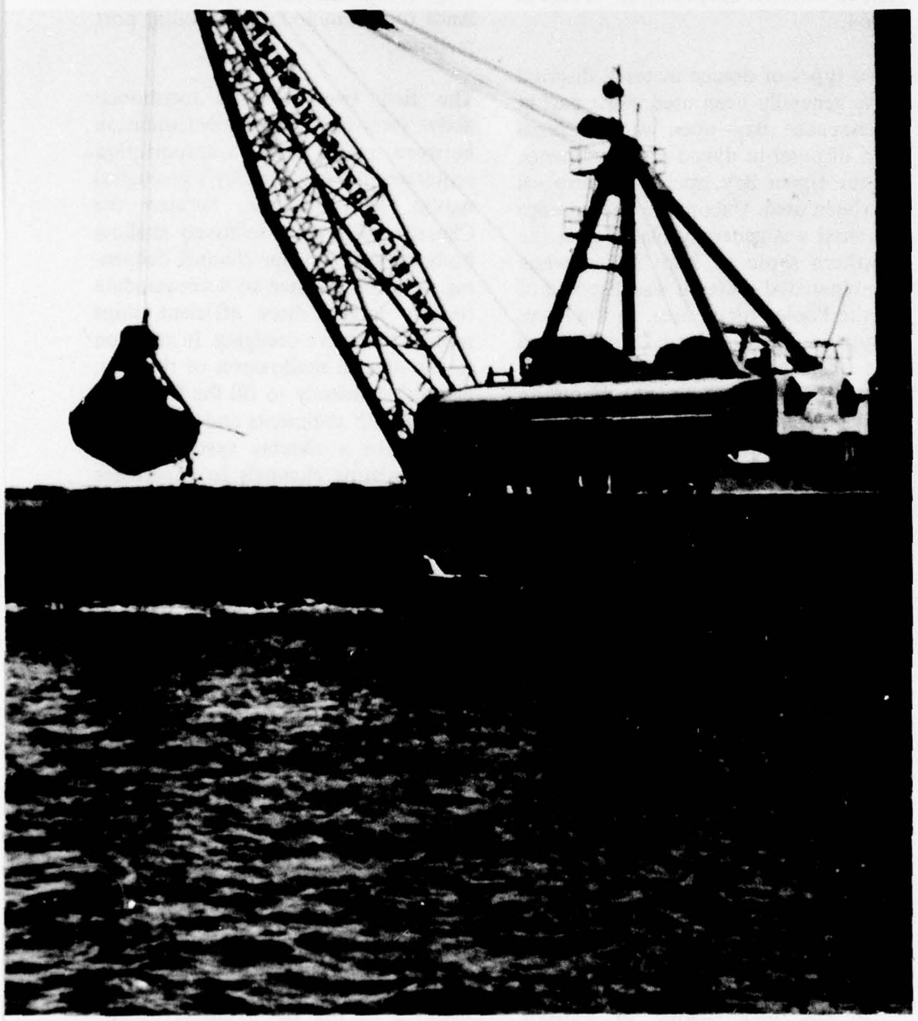
1. Removal by either dredging or filling of the original interface between the water and the bottom, which can be an area of high biological activity. In most cases, the effects of removal of the existing sediment-water interface are usually localized and of relatively short duration. The circulation patterns of the Bay's waters usually

provide opportunities for the reestablishment of available species within one or two years. It should be emphasized, however, that exceptions do occur (e.g., oysters because of their need for a hard bottom) and that a thorough analysis should be conducted if complications are to be avoided.

2. Changes in bottom contours, which may affect current and salinity patterns. In general, the creation of deepwater areas causes further saltwater intrusion. Saltwater intrusion can cause complex changes in an estuary's ecosystem. These changes may involve both beneficial influences such as the improved upstream transport of young crabs, fish, and other species as well as detrimental impacts such as greater penetration of oyster predators and parasites. The net effect will vary with the location and magnitude of the dredging activity as well as the season.

3. Turbidity caused by dredging can create various problems. Suspended sediments can clog and damage the gills of many kinds of animals, reduce photosynthetic activity, and reduce the buoyancy of eggs of marine animals. As the sediments settle, a coating may form on the bottom interfering with the attachment of young oysters to the beds and creating soft bottom layers that are uninhabitable for many benthic species. On the other hand, such sediments frequently occur naturally in estuaries and coastal waters, and many species can tolerate considerable quantities of suspended material. Sediments can also be beneficial to many types of organisms by providing the type of substrate needed by some animals and by carrying nutrients into the marine system.

Bucket and Scow Dredging Operation.



With regard to the problems associated with the disposal of dredged material, the major channels for Baltimore and Hampton Roads and the approach channels to the Chesapeake and Delaware Canal are by far the major problem areas. If for no other reason, the sheer volume of material that must be removed during either periodic maintenance or an overall deepening of these major projects creates disposal problems. There are also significant environmental problems associated with dredged material disposal.

Perhaps the most serious environmental problem, and certainly the most emotional, occurs when the dredged material is contaminated by industrial or municipal wastes. Heavy metals, such as mercury, zinc, and lead, along with such substances as pesticides and nutrient salts can have harmful and even toxic effects on aquatic life. There is very limited information on how available such materials become to the marine environment in various chemical forms once they reenter the water. For example, heavy metal contaminants may be tightly bound to the sediment particles physically or chemically, or at the other extreme, simply dissolved in the water mixed with the sediment. The soon to be completed Dredged Material Research Program being conducted at the Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi, is conducting research into these types of problems.

Another source of conflict between waterborne commerce activities and environmental quality is the deliberate discharge or accidental spilling by vessels of oil, garbage, sewage, and other wastes into the Bay. Unfortunately, these discharges and spills often occur in congested harbor areas with poor flushing action which causes further degradation of often already poor water quality. Although the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) prohibit the discharge of harmful quantities of oil or hazardous substances in the waters of the United States, there is probably no practical way to stop the element of human error. A valve not completely closed, a lack of attention while filling tanks, or worst of all, tanker collisions, could have disastrous environmental, as well as economic, consequences.

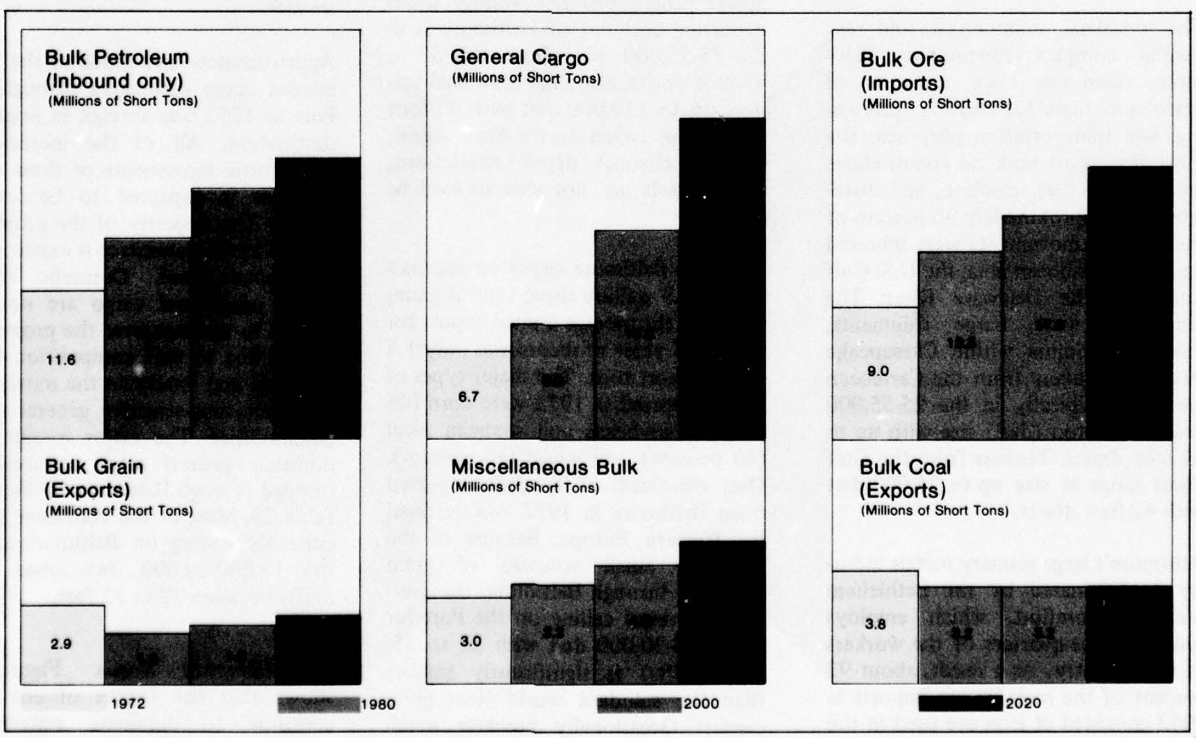
Waterborne commerce-related activities can also have significant impacts on other aspects and uses of the Chesapeake Bay resource. First, the wave action caused by passing ships is a major cause of erosion in some areas of the Bay. Second, recreational fishing and boating can be disrupted by the wakes from passing ships. In addition, large areas of the Bay and its tidal tributaries are precluded from recreational uses because of their use as anchorages, ship channels, or dredge disposal areas by commercial navigation interests and/or the military. On the other hand, large commercial and military vessels must be constantly on the alert for the smaller recreational vessels to avoid collisions or swampings. Lastly, the development of a major port is dependent on the concurrent development of land-based port-related facilities. However, the development of shoreline land for terminal facilities may in some cases conflict with existing wetlands or proposed recreational use of the same land. Also, port-related facilities, because of their locational requirements, may be subject to tidal flooding and shoreline erosion.

EXISTING AND PROJECTED DEMANDS

The following sections present the projected waterborne commerce demands on a commodity group basis for the individual ports and waterways considered in this study. Due to the type of analysis, it was considered to be appropriate that additional existing information also be presented with the projected demands.

In addition to the Ports of Baltimore and Hampton Roads, projections were prepared for those Chesapeake Bay waterways with over 200,000 short tons of commence in 1970. Because of the differences in relative importance to the Chesapeake Bay Region and the Nation of the various harbors and waterways included in this analysis, projections were made to varying degrees of detail. Baltimore and Hampton Roads were analyzed in depth on a commodity group and in some cases an individual commodity basis. On the other hand, projections for several of

Figure 22: Projected Waterborne Commerce - Baltimore Harbor



the smaller waterways (in terms of tonnages) were made for two groups only—bulk oil and the total of all other commodity groups.

There are essentially three types of waterborne movements addressed in this analysis—foreign, coastwise, and internal. Foreign imports and exports refer to traffic between the United States and foreign ports. Coastwise receipts and shipments apply to domestic traffic receiving a carriage over the ocean, or the Gulf of Mexico (e.g., New Orleans or Puerto Rico to Baltimore). Internal receipts and shipments are confined to inland waterways such as Chesapeake Bay.

a. *Baltimore Harbor:* As shown in Figure 22, bulk commodities, especially petroleum and ore, are expected to continue to dominate waterborne traffic in the Port of Baltimore. General cargo movements, however, are expected to increase significantly over the projection period so that by 2020 the tonnage moved is expected to be higher than any other single commodity category.

The industrial, commercial, and residential complex surrounding Baltimore consumes huge amounts of petroleum fuels for heating, processing, and transportation purposes. The most important bulk oil commodities are residual fuel, gasoline, and distillate fuel. Approximately 90 percent of the bulk oil movements were inbound from the Caribbean area, the U.S. Gulf Coast, or the Delaware River. The remainder were barge shipments, mostly to points within Chesapeake Bay. The tankers from the Caribbean areas are typically in the 25-55,000 deadweight ton (dwt) size with up to 39-foot drafts. Tankers from the Gulf Coast range in size up to 75,000 dwt with 42-foot drafts.

Baltimore's large primary metals industry is dominated by the Bethlehem Steel Corporation, which employs roughly three-quarters of the workers in the industry. As a result, about 93 percent of the metallic ore imports in 1972 consisted of iron ore used in the production of steel. The ships carrying iron ore into Baltimore are the largest that call on the Port. The average iron ore vessel is in the 40-60,000 dwt range with 38 to 42-foot drafts. Vessels of this size use the existing 42-foot channel to the maximum extent. Occasionally vessels of well over 100,000 dwt bring iron ore into the Port although they are not able to fully load due to channel depth restrictions. Aluminum, manganese, chromium, and other non-ferrous ores and concentrates comprise the remaining 7 percent of metallic ore imports. Imports of non-ferrous metals are projected to increase at the same rate as iron ore imports.

Because of its proximity to the Appalachian coal fields in northern West Virginia and Pennsylvania, Baltimore is one of the leading coal exporting ports in the United States. Approximately 90 percent of the coal shipped out of Baltimore is used in the production of coke for foreign steel industries, mainly in Japan and Western Europe. The remainder is used in electric power generation. The average vessel exporting coal out of Baltimore is in the 35-55,000 dwt range with 37 to 42-foot drafts, although bulk coal carriers up to 120,000 dwt with 47-foot drafts have called on the Port. Again, due to channel depth restrictions, these vessels are not able to load to capacity.

In 1972, Baltimore exported approximately 2.9 million short tons of grain, although the average annual export for the last 5 years of record was only 1.5 million short tons. The major types of grain exported in 1972 were corn (45 percent) soybeans and soybean meal (40 percent), and wheat (13 percent). Over two-thirds of the grain exported from Baltimore in 1972 was destined for Western Europe. Because of the relatively small volumes of grain exported through Baltimore, the average size vessel calling on the Port for grain (15-30,000 dwt with 28 to 35-foot drafts) is significantly smaller than the standard world fleet grain carriers. Occasionally, however, much larger vessels enter the Port to load grain for export.

The miscellaneous bulk category for Baltimore Harbor contains such commodities as gypsum, sugar, salt, molasses, sulfuric acid, and fertilizer products. Approximately 72 percent of the movements of these commodities in 1972, were foreign imports with an additional 17 percent classified as domestic receipts. Practically all of these inbound movements were raw or partially processed materials shipped to Baltimore for further processing by factories in the Port area. These activities are especially important to the local economy because they generate jobs and income. Except for sugar imports, which are expected to remain constant over the projection period, the other commodities in the miscellaneous bulk category are projected to exhibit moderate increases in the level of shipments. The vessels carrying miscellaneous bulk commodities are not as large as those carrying petroleum, coal, ore, or grain. The largest vessels are about 35,000 dwt with up to 37 foot drafts but the average is much smaller.

Approximately two-thirds of the total general cargo commerce through the Port in 1972 was foreign in origin or destination. All of the increase in waterborne movements of these commodities is expected to be foreign traffic. The majority of the projected general cargo commerce is expected to be containerized. Domestic movements of general cargo are not expected to increase over the projection period due to stiff competition from railroads and trucks in the movement of often time-sensitive general cargo commodities. The major foreign and domestic general cargo commodities shipped through Baltimore are listed in Table 24. Most of the container ships currently calling on Baltimore are in the 15,000-20,000 dwt range with drafts between 28 to 32 feet.

b. *Hampton Roads:* Figure 23 shows that the export of coal will continue to dominate waterborne

TABLE 24
MAJOR GENERAL CARGO COMMODITIES
AND TYPE OF TRAFFIC, BALTIMORE HARBOR, 1972

Foreign	Tons (Thousands)	Percent of Total
Bananas and Plantains (I)	383	8.5
Lumber (I)	380	8.4
Metal Products (I & E)	1,272	28.3
Standard Newsprint (I)	100	2.2
Miscellaneous Chemicals (I & E)	294	6.5
Cars and Other Transportation Equipment (I & E)	500	11.1
Machinery (I & E)	285	6.3
Other Miscellaneous	1,301	28.7
Total	4,515	100.0
Domestic		
Metal Products (S)	1,175	54.2
Miscellaneous Chemicals (S)	216	10.0
Agricultural, Food, and Marine Products (R & S)	174	8.0
Lumber (R)	86	4.0
Other Miscellaneous	514	23.8
Total	2,165	100.0

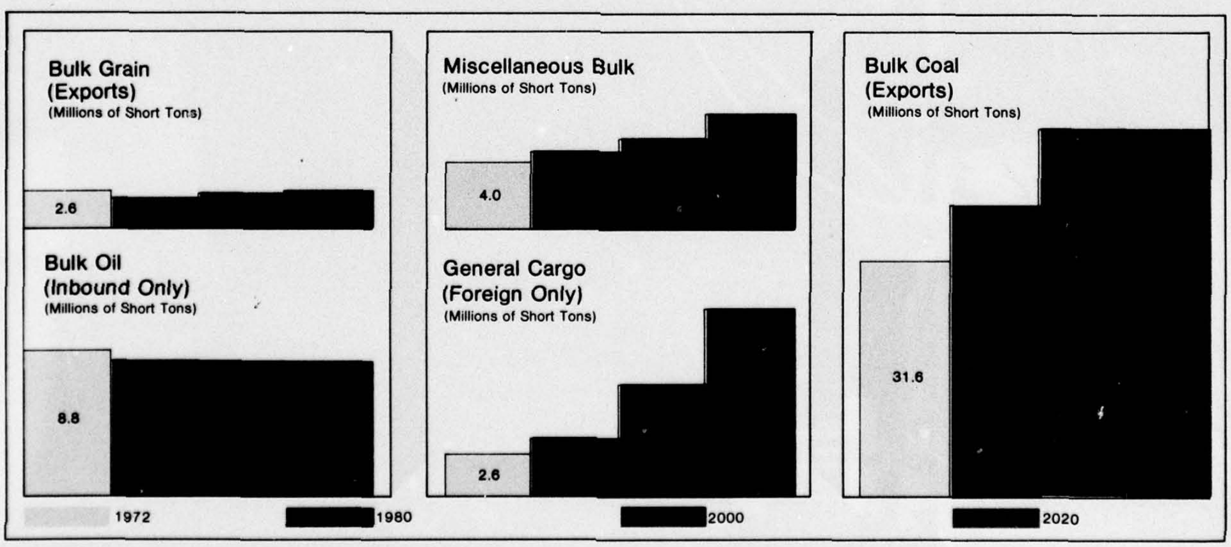
I = Imports E = Exports R = Receipts S = Shipments

commerce during the projection period. As in the case of Baltimore, general cargo movements are expected to show highly significant increases over the projection period. Waterborne movements of commodities in the remaining categories are expected to decrease slightly or show only moderate increases over the projection period.

The most important commodities within the bulk oil group were residual fuel, gasoline, and distillate fuel, accounting for about 92 percent of the bulk oil waterborne movements in 1972. Approximately three-quarters of the bulk oil passing through the port complex is either foreign or domestic inbound. Most of the remaining movements consist of petroleum distributed from Hampton Roads by barge to points within Chesapeake Bay. The major reason for the projected decline in the level of inbound bulk oil movements to Hampton Roads is the expected significant planned cutbacks in residual fuel use by public utilities. This type of use accounted for approximately one-half of the total petroleum consumption in the area in 1972. Increases in gasoline and distillate fuel movements are expected to almost offset the decreases in residual use.

Vessels carrying bulk oil commodities

Figure 23: Projected Waterborne Commerce - Hampton Roads

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into Hampton Roads are generally about the same size as those calling on the Port of Baltimore (i.e., up to 75,000 dwt with 42-foot drafts from the Gulf Coast refineries and usually between 25-55,000 dwt with up to 39-foot drafts from the Caribbean). These vessels, however, can normally enter Hampton Roads loaded to a deeper draft due to deeper channel depths, higher tidal range, and higher salinities.

Hampton Roads is the most strategically located port in the United States with respect to the rich Appalachian coal fields. Hampton Roads annually accounts for about 90 percent of the total U.S. overseas export. Approximately 90 percent of the coal exports leaving Hampton Roads consist of bituminous coal for the production of coke for metallurgical purposes with the remainder being used for electric power generation. About one-half of these exports in 1972 were shipped to Japan with the majority of the remainder going to Western Europe. The average size vessel carrying coal out of Hampton Roads is in the 50-75,000 dwt range with 38-46-foot drafts. However, vessels of over 100,000 dwt are not uncommon. The largest ship to ever call on the port was a vessel of 169,430 dwt which loaded coal bound for Japan. Due to depth restrictions, the vessel could not fully load.

Although far behind export coal, bulk grain is the second largest export commodity passing through Hampton Roads. Most of the grains exported through the port were grown in the Midwestern and South Atlantic states and are generally shipped to Western and Eastern European countries. The major types of grains handled are corn, wheat, and soybeans and soybean meal. Due to the relatively small volumes of export grain handled at Hampton Roads, the vessels carrying these commodities are significantly smaller than those handling coal. The average vessel is in the 25-35,000 dwt range with 32 to 26-foot drafts, although ships in the 100,000 dwt class occasionally call on the port.

Sand, gravel, and crushed rock accounted for almost one-half of the total movements in the miscellaneous bulk category. Other important commodities are limestone, building cement, and fertilizers. The commodities in this category are raw or partially-processed materials shipped into Hampton Roads from foreign and domestic sources for further processing (most by factories in the port area) or for distribution without processing. Movements of sand, gravel, and crushed rock are by barge while vessels carrying the other commodities generally average around 15,000 to 20,000 dwt with drafts of approximately 30 feet. Slightly over 80 percent of the total general cargo traffic was categorized as either foreign imports or exports. About 60 percent of the foreign traffic was containerized in 1970. These container vessels are generally in the 15,000 to 20,000 dwt range with drafts of between 28 to 32 feet. Table 25 lists the major foreign cargo commodities passing through Hampton Roads.

c. *Chesapeake and Delaware Canal.* Commerce through the C&D Canal is dominated by domestic movements of bulk oil and foreign movements of general cargo which together accounted for approximately 70 percent of the total traffic in 1972. The C&D Canal serves as a major passageway for oceangoing vessels calling at Baltimore. In 1972, approximately 58 percent of the vessels engaged in foreign traffic destined for or leaving Baltimore traveled through the C&D Canal. Figure 24 shows the projected levels of commerce for bulk oil and general cargo. Both types of traffic are projected to show moderate increases over the projection period.

In addition to bulk oil and general cargo, there are significantly smaller quantities of bulk coal, bulk ore, bulk grain, and miscellaneous bulk commodities passing through the C&D Canal. These movements were assumed

TABLE 25
MAJOR FOREIGN GENERAL CARGO COMMODITIES
AND TYPE OF TRAFFIC, HAMPTON ROADS, 1972

	Tons (Thousands)	Percent of Total
Lumber, Veneer, Plywood, and Other Wood Products (I & E)	246	10.6
Tobacco Leaf (I & E)	233	10.0
Machinery (I & E)	156	6.7
Motor Vehicles (I & E)	103	4.4
Basic Textile Products (I & E)	131	5.6
Metal Products (I & E)	268	11.5
Pulp and Paper Products (I & E)	118	5.1
Vegetable Oils, Margarine, Shortening (E)	88	3.8
Miscellaneous Chemicals (I & E)	88	3.8
Other Miscellaneous	897	38.5
TOTAL	2,328	100.0

I = Imports E = Exports

to remain constant during the projection period at the 1965-1972 average of about 1.1 million short tons although the potential exists for substantial increases if a significant number of Northeastern power plants switch to coal.

d. *James River.* Major flows of traffic on the James River consist of internal barge receipts of bulk oil at Richmond, Hopewell, and the Virginia Electric and Power Company's Chesterfield power plant and internal barge movements of commodities other than bulk oil (mostly sand and gravel). These two traffic flows accounted for 84 percent of the total waterborne movements on the James in 1972.

Figure 25 shows the projections of bulk oil and internal shipments for commodities other than bulk oil for the James. These two commodity categories are expected to continue to dominate James River waterborne commerce in the future accounting for over 90 percent of the total traffic in the year 2020.

There were also oceangoing movements of chemicals and general cargo commodities passing through Richmond and Hopewell which totaled about 500,000 short tons in 1972 but averaged 740,000 tons over the 1970-72 period. Total oceangoing commerce is assumed to remain constant at approximately 740,000 short tons over the projection period.

The oceangoing general cargo vessels calling at James River ports average about 5,000 dwt with about 22-foot drafts, although there are some vessels up to 12,000 dwt with loaded drafts of 30 feet. Most of the dry cargo ships and tankers handling chemicals are in the 20,000 dwt class with loaded drafts of over 30 feet. Since the main channel to the Richmond-Hopewell area has an authorized depth of only 25 feet, the larger vessels are not able to load to capacity.

e. *Potomac River:* Traffic on the Potomac is dominated by the movement of bulk oil into the River to help

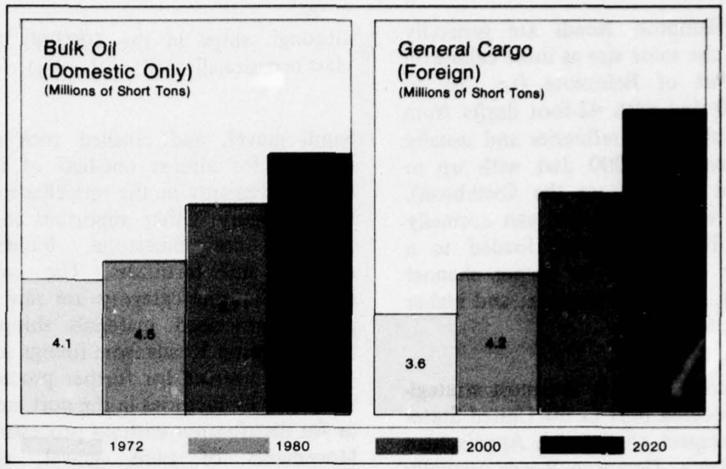


Figure 24: Projected Waterborne Commerce - Chesapeake and Delaware Canal

Figure 25: Projected Waterborne Commerce - James River

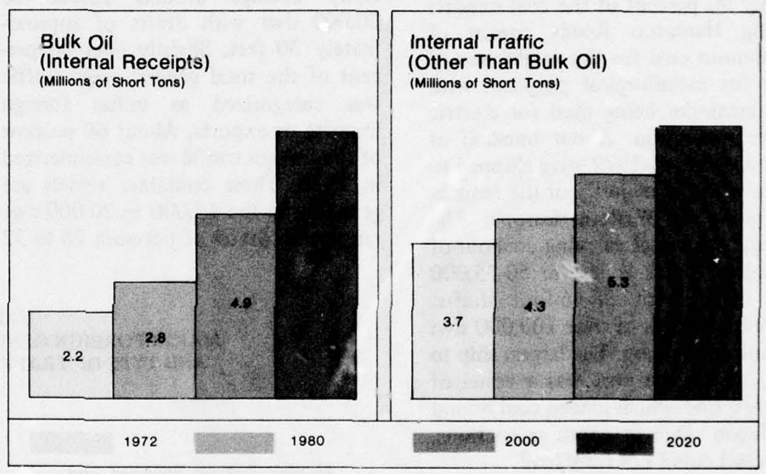


Figure 26: Projected Waterborne Bulk Oil Commerce - Potomac River.

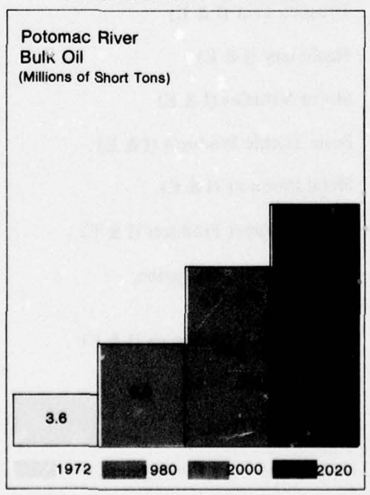
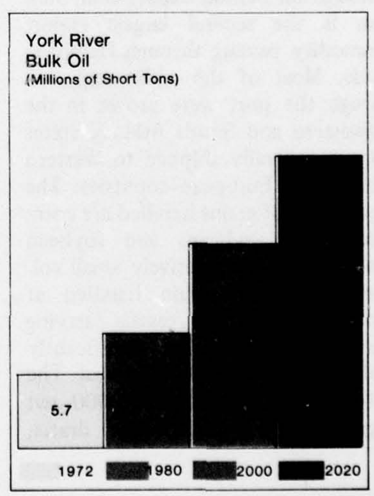


Figure 27: Projected Waterborne Bulk Oil Commerce - York River.



satisfy the Washington Metropolitan Area's tremendous demand for energy. This type of traffic accounted for approximately 87 percent of the total commerce on the Potomac in 1972. Most of the remaining traffic consisted of internal barge movements of sand and gravel to the Washington area from points along the Potomac River and foreign imports of newsprint into Alexandria, Virginia.

Waterborne bulk oil commodities destined for Washington are handled by the Steuart Petroleum Company's facility at Piney Point, Maryland, approximately 13 miles upstream from the confluence of the Potomac with Chesapeake Bay. Large oceangoing tankers, most in the 25-55,000 dwt size range with between 35 and 38-foot drafts, as well as barges from domestic sources, carry petroleum products into the Steuart facility where they are unloaded and redistributed by pipeline and barge to the Washington, D.C., and Southern Maryland areas. The Possum Point power plant, owned by VEPCO, is the only major petroleum products user on the river which has fuel sent directly to its plant, bypassing the Piney Point facility.

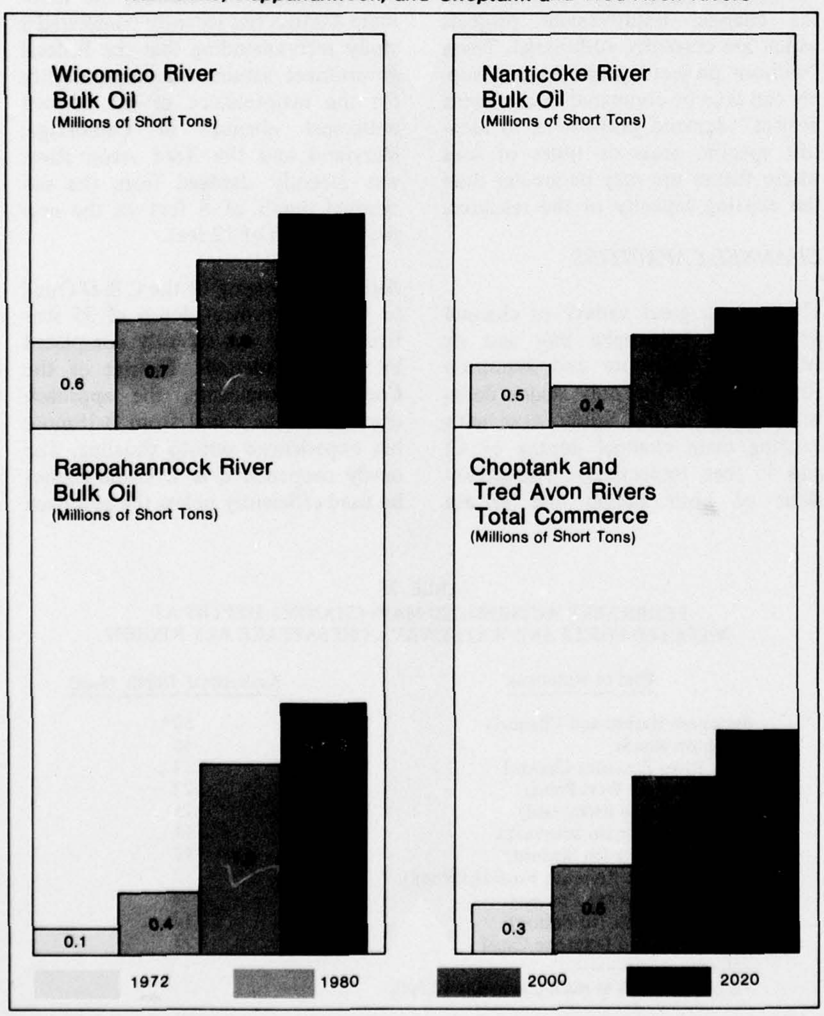
Despite expected significant decreases in residual fuel use by power plants in the Washington area, the total projected bulk oil imports and receipts at Piney Point illustrated in Figure 26 indicate a sizable increase in bulk oil movements on the Potomac over the next fifty years. This is due to large projected increases in waterborne imports and receipts of gasoline, distillate fuel, and other "clean" petroleum products expected as a result of higher than average increases in income and population in the Washington area in the future.

Traffic other than bulk oil on the River is expected to remain at a fairly constant 500,000 short tons during the projection period.

f. *York River.* The largest oil refinery in the Chesapeake Bay Region is located near the mouth of the York River at Yorktown. Although the 50,000 barrel/day refinery is not large by Delaware River or Gulf Coast standards where plants with capacities of 200,000 barrels/day are not uncommon, the facility still accounted for almost five million short tons of waterborne petroleum commerce in 1972. Total waterborne commerce on the York River in 1972 totaled 6.5 million short tons of which bulk oil commodities accounted for approximately 89 percent of the total. Other major users of bulk oil include a power plant at Yorktown, the only major pulp and paper mill in the Chesapeake Bay Region at West Point, Virginia, and the U.S. Navy at Cheatham. Total bulk oil projections are presented in Figure 27. The capacity of the Yorktown refinery is projected to increase to approximately 170,000 barrels/day by 2020.

Most of the vessels carrying crude petroleum into the Yorktown refinery are in the 70,000 dwt class with 41-foot drafts. These ships are unable to fully load due to depth restrictions in the York River approach channel.

Figure 28: Projected Waterborne Commerce for Selected Commodities-Wicomico, Nanticoke, Rappahannock, and Choptank and Tred Avon Rivers



g. *Other Waterways.* The Wicomico, Nanticoke, and Rappahannock Rivers are expected to continue to be dominated by inbound barge movements of bulk oil. As shown in Figure 28, the Rappahannock River is expected to experience by far the most significant increases in bulk oil movements of these three waterways mainly due to "spillover" into the area from the fast-growing Washington Metropolitan Area. The Wicomico and Nanticoke Rivers are expected to experience only moderate increases in bulk oil movements over the projection period. Of these three rivers, only the Rappahannock has any significant movements of commodities other than bulk oil. About 40 percent of the commerce on the river consisted of industrial chemicals, pulpwood and seafood. Movements of these commodities on the Rappahannock are assumed to remain constant at the 1970-1972 level of approximately 170,000 short tons.

Virtually all of the traffic on the Choptank River (including the Tred Avon River) was inbound, with about 10 percent being foreign oceangoing imports and the remainder classified as internal barge receipts in 1972. Bulk oil commodities accounted for a relatively small 40 percent of the total waterborne commerce. Other important commodity flows on the Choptank include slag (used for construction purposes), fertilizer, and fresh fish shipped from Iceland to Cambridge for processing. The majority of the projected increase in total traffic on the Choptank River, illustrated in Figure 28, is accounted for by increases in traffic other than bulk oil or fresh fish. Bulk oil movements are expected to show only moderate increases while imports of fresh fish are projected to decline slowly, but steadily, during the projection period. The vessels involved in the importation of fresh fish are refrigerated fishing craft which range in size up to 4,100 dwt with 22-foot drafts. These vessels are able to take advantage of the municipal channel in Cambridge which has a project depth of 25 feet.

FUTURE SUPPLY

METHODOLOGY

The future supply analysis is actually an analysis of the capacity of a harbor or waterway in terms of channel depths. The following section will present a general inventory of existing and authorized channel depths for the major waterways and harbors in the Chesapeake Bay Region. A more detailed listing of channel depths by commodity for each port considered in this analysis is presented in Table 9-6 of Appendix 9 – "Navigation." The basic assumption made in this assessment of future supply is that there will be no further development of the Bay's navigation system beyond the channel improvement projects which are currently authorized. These "without project" projections of supply can then be compared to the "with project" demand projections to identify specific areas or types of uses where future use may be greater than the existing capacity of the resource.

CHANNEL CAPACITIES

There are a great variety of channel depths in Chesapeake Bay and its tributaries. Baltimore and Hampton Roads contain the only major deepwater ports in the Study Area with existing main channel depths of 42 and 45 feet, respectively. The dimensions of both public and private branch channels within these port complexes vary considerably. With the exception of the Chesapeake and Delaware Canal, which primarily serves the Port of Baltimore, and the York River Entrance Channel, which handles petroleum products, the remaining Federal channels are 25 feet in depth or less and handle barge traffic almost exclusively. Table 26 lists the Federally authorized main channel depths for the ports and waterways for which projections were prepared in this study.

The deepening of the main channel to Baltimore to 50 feet was authorized by Congress in 1970. Preconstruction planning for this project has recently been initiated. In addition, the Baltimore District has recently completed a study recommending that the Federal government assume the responsibility for the maintenance of the 25-foot municipal channel at Cambridge, Maryland and the Tred Avon River was recently dredged from the old channel depth of 8 feet to the new project depth of 12 feet.

Although dredging of the C & D Canal to the new project depth of 35 feet from 27 feet was recently completed by the Philadelphia District of the Corps of Engineers, the approach channel to the Canal from Baltimore has experienced serious shoaling. The newly deepened C & D Canal cannot be used efficiently unless the approach

TABLE 26
FEDERALLY AUTHORIZED MAIN CHANNEL DEPTHS AT SELECTED PORTS AND WATERWAYS, CHESAPEAKE BAY REGION

Port or Waterway	Authorized Depth (feet)
Baltimore Harbor and Channels	50*
Hampton Roads	45
York River Entrance Channel	37
York River (to West Point)	22
James River (to Richmond)	35
Wicomico River (to Salisbury)	14
Nanticoke River (to Seaford)	12
Rappahannock River (to Fredericksburg)	12
Choptank River (to Denton)	8
Tred Avon River (to Easton)	12
Chesapeake and Delaware Canal	35

*Existing depth in main channel is 42 feet.

channel is dredged to the 35 foot project depth.

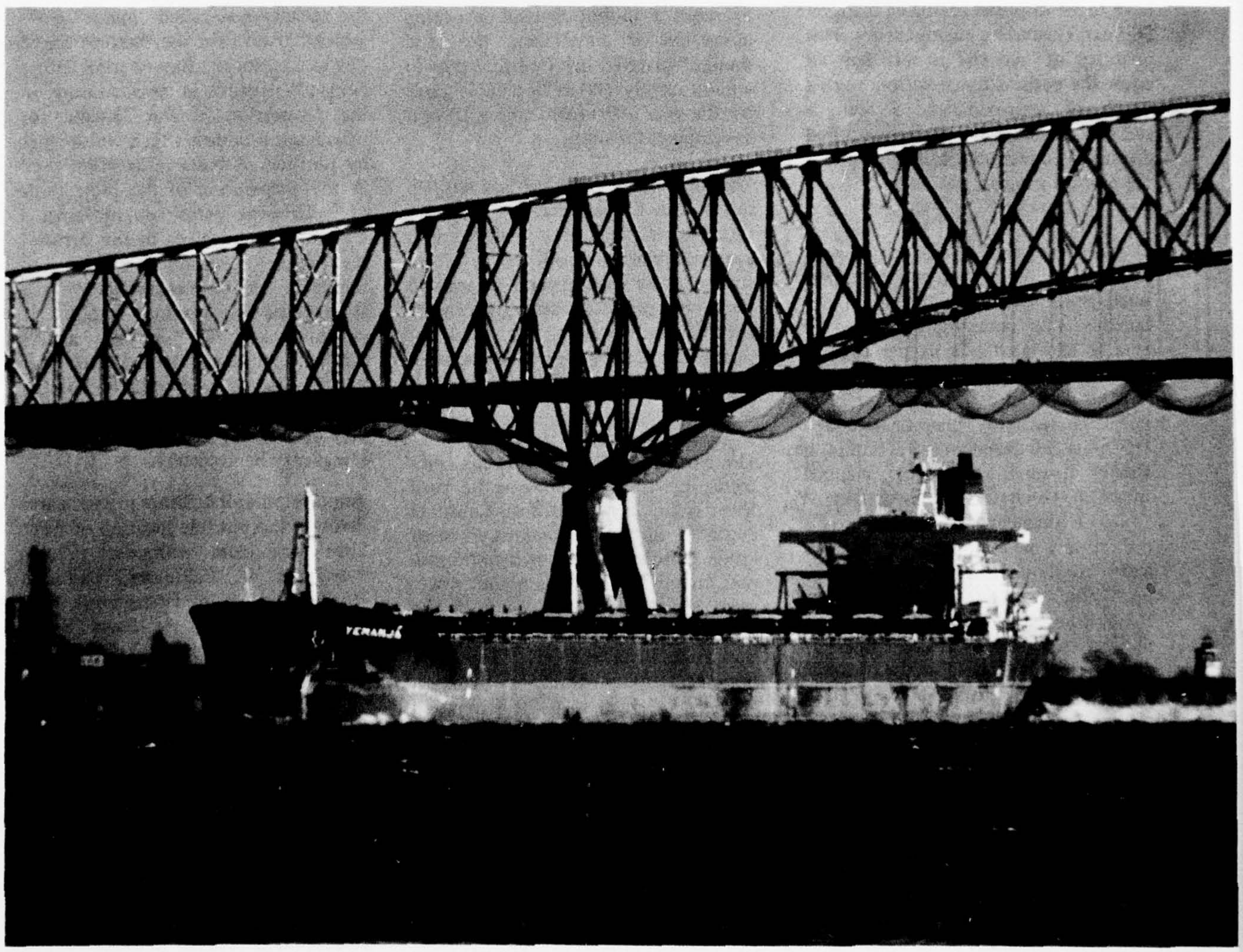
Although an authorized depth of 35 feet was authorized for the James River in 1962, a follow-up study completed in 1972 found that dredging to the 35-foot depth was no longer economically justified.

FUTURE NEEDS AND PROBLEM AREAS

There are several types of commodity movements on Chesapeake Bay in which the existing channels are unable to handle present or projected ship sizes without serious losses in economic efficiency. These losses develop when large vessels must enter or leave a port only partially loaded because of depth limitations. When these efficiency losses are severe enough to outweigh any competitive advantage an area might have for the movement of a certain commodity, severe economic consequences may result. In the case of imported raw materials processed in the port area, economic losses may be severe enough to cause cutbacks in production or even plant closings resulting in the loss of jobs, income, and tax revenues to the region.

The most critical commodity movements in terms of existing or potential inefficiencies through the Ports of Baltimore and Hampton Roads are the bulk commodities such as iron ore, coal, grain, and petroleum products. Most of the larger vessels carrying these commodities into the two ports cannot fully load or must lighter before entering the harbor.

In the case of Baltimore Harbor, the authorized 50-foot project, if constructed, will eliminate most of these inefficiencies. Despite the very large increases expected in containerized traffic in Baltimore, channel depths are not expected to be a constraint



due to the relatively small size of containerships when compared to the world fleet of tankers and ore carriers.

Another major navigation-related problem in the Baltimore Harbor area is the disposal of dredged material. Maintenance dredging by the Corps of Engineers and other public and private interests has been repeatedly delayed because of the lack of agreement on an economically and environmentally acceptable disposal site for the dredged material. The magnitude of the disposal problem is immense. If the 50-foot project is completed, it is estimated that approximately 150 million cubic yards of dredge material will have to be disposed of during the next 50 years (including maintenance). This quantity of material is sufficient to cover the entire City of Baltimore to a depth of approximately 2 feet. A suitable disposal site will be identified during preconstruction planning for the 50-foot project.

In the Hampton Roads area, inefficiencies in the movement of export coal, grain, and some of the miscellaneous bulk commodities would be greatly alleviated if a deeper channel were to be authorized and funded. The Norfolk District of the Corps of Engineers is currently investigating the feasibility of deepening the Hampton Roads channels. A deeper channel might also benefit the movement of crude oil through Hampton Roads to the refinery at Yorktown on the York River by allowing larger tankers (i.e., up to 90,000 dwt) to enter Hampton Roads where they can be lightered for the trip to Yorktown. One disadvantage of this plan would be the possibly damaging environmental consequences of a major oil spill during these lightering operations.

As in the Baltimore Harbor case, the container vessels carrying general cargo in and out of Hampton Roads are not expected to increase significantly in size in the foreseeable future. Therefore, it is not expected that channel depths will be a significant constraint to the movement of containerships through Hampton Roads.

The dredge material disposal situation has not been nearly as critical in the Hampton Roads area as in Baltimore. This is due to the existence of the Craney Island Disposal Area. The site is nearing its capacity, however, with complete filling expected around 1980.

The seriousness of this approaching problem becomes evident when it is noted that maintenance dredging alone between 1980 and 2020 will produce approximately 150 million cubic yards of material to be disposed of or utilized in some manner. If, for example, a 55-foot channel deepening alternative is undertaken, the total dredged material involved increases to approximately 280 million cubic yards by the year 2020 (assuming a 10-year development period).

With the recent widening and deepening of the Chesapeake and Delaware Canal to 35 feet, it is believed that channel dimensions will not be a constraint to the general cargo vessels and petroleum products carriers which use the Canal. However, the need for maintenance dredging in the approach channels to the Canal is a continuing problem.

The most immediate waterborne commerce related problem facing the York River is the lack of sufficient channel depth to allow large tankers to bring crude petroleum and petroleum products directly to the refinery and power plant without lightering. In 1972, the Norfolk District recommended that the York River entrance channel be improved by providing a two-lane, two-level channel into the River; the inbound lane to provide a depth of 50 feet, and the outbound lane a depth of 37 feet. However, these recommendations are subject to further investigation if the major Hampton Roads channels are recommended and authorized for deepening beyond 45 feet. It is possible that if the Hampton Roads channel is deepened beyond 50 feet, the most economically acceptable alternative is a combination of continued lightering and deepening of the York River entrance channel.

A potential problem area concerns the significant increase in crude petroleum receipts and petroleum product shipments projected for the Yorktown refinery. An increase in this type of traffic, estimated to rise almost 100 percent by 2000 and over 200 percent by 2020, means the potential for oil spills will probably also increase. The area of the York River around Yorktown supports important commercial and sport fisheries which could be adversely affected by an oil spill.

The ability of the existing channels in the remaining so-called "minor" ports and waterways on the Western Shore of the Chesapeake Bay to meet future demands depends in large measure on the proportion of the demand for petroleum products which will be met by pipeline. A basic assumption used in the preparation of the projections of waterborne petroleum movements was that all increases in the demand for petroleum products in the Bay Region would be met by waterborne, as opposed to pipeline, receipts. If pipeline capacities increase significantly, then it can be expected that the existing channels will be able to efficiently meet future demands. If they do not, then some channel deepenings may be necessary.

Another potential future problem area involves the possible location of three large petroleum refineries (Crown Petroleum in Baltimore, Hampton Roads Energy in Portsmouth, and Stewart Petroleum at Piney Point, Maryland). If all three of these facilities are built and become operational, approximately 25 million additional tons of crude petroleum and as much as 23.5 million tons of petroleum products could be shipped on the Bay's waters. An expansion in petroleum movements of this magnitude would obviously increase the chances of environmentally damaging oil spills.

Another facility designed to handle petroleum products, although of a different type, is scheduled to begin operations at Cove Point, Maryland, in the near future. This facility will distribute liquid natural gas from Algeria to a seven state area. Because of the extremely low temperatures involved, there is virtually no danger of a spill since the liquid gas would vaporize upon contact with the much warmer air. There is some potential damage, however, of a fire or explosion in the event of a collision with another vessel. Because of this, extraordinary safety procedures are taken when transporting liquid natural gas. As the total number of vessels on Chesapeake Bay increases in the future, the potential for collisions is also likely to increase.

SENSITIVITY ANALYSIS

When OBERS Series E based projections of waterborne commerce are compared to those used in this report (Series C based), significant decreases in the projected level of traffic for many commodities are noted. This was particularly true in the Baltimore area where a slower rate of growth in defense-related manufacturing was forecast under Series E. For example, projections of iron ore imports through Baltimore are expected to remain below 10 million short tons throughout the projection period as compared to projected imports of over 22 million short tons using OBERS Series C as a base. In Hampton Roads, general decreases in waterborne commerce are due in large part to an assumed decline in the Nation's military force under Series E projections.

Most of the smaller ports and waterways also showed some reduction in the level of traffic due to the generally lower levels of population and income projected under Series E assumptions. The major exceptions to this generality are the Potomac, Rappahannock, and York Rivers. Table 9-7 in Appendix 9 presents a detailed comparison of waterborne commerce projections based on Series C and Series E assumptions.

MEANS TO SATISFY NEEDS

This section presents the major existing or potential waterborne commerce related needs as identified in previous sections and a brief discussion of some of the alternatives which could be employed to satisfy these needs.

(1) *A need to accommodate large bulk vessels expected to dominate the world bulk trade in petroleum, coal, iron ore, and grain.* The most obvious solution to the problem of accommodating larger vessels than existing channels can handle is to deepen the channels to the required depths. There are, however, rather important economic and environmental considerations which may preclude further deepening. First, there are existing tunnels under the main channels in both Baltimore and Hampton Roads which, in effect, limit their depths since the cost of lowering these tunnels would probably be prohibitive. Second, as channel depths increase, the volume of dredge material to be disposed of from both deepening and maintenance operations increases (usually more than proportionately).

There are several alternatives to the deepening of shipping channels to accommodate larger vessels. One is to use "restricted draft" vessels which are characterized by much wider beams to allow a larger tonnage of cargo to be carried by a vessel of a given draft. However, such vessels are not presently widely available and their costs are generally higher for a given deadweight tonnage.

Another alternative to deepening existing channels is the development of so-called "superports." Under this alternative, one or more superports would be constructed in deep water off the Eastern Coast. Very large vessels, on the order of 300,000 dwt with approximately 75 foot drafts would unload at the deepwater terminal where the cargo (e.g., crude oil, coal, iron ore) would be transported to the mainland by barge or pipeline. However, this alternative is often not acceptable for economic, environmental, or social reasons.

(2) *A need for an economically and environmentally acceptable method of dredge material disposal.* Given that a channel should be maintained or deepened, there are numerous alternative ways to dispose of dredge material. The cheapest and easiest method of dredge material disposal is to deposit the material either adjacent to the channel or to barge it to a nearby deep underwater site. In the past, there were two major open water disposal sites used in the Bay—Pooles Island Deep and Kent Island. At this time, however, mainly for environmental reasons, the use of open water disposal in the Bay in the near future appears unlikely.

Open water disposal in the Atlantic Ocean is another possibility for the disposal of dredge material. The major advantage to this alternative is the almost limitless physical capacity of the ocean. This alternative has been used in the past in the Hampton Roads area, but the Baltimore area is too far from the ocean for this type of disposal to be economically feasible.

In addition, the Council on Environmental Quality has recommended to the President that ocean disposal of polluted dredge material be phased out as soon as alternatives can be found and implemented.

Another alternative method of dredge material disposal is a dyked containment structure. Both the Craney Island site, which has served the Hampton Roads dredge needs for a number of years, and the proposed Hart-Miller Islands site in Baltimore are this type of structure. These specific projects are discussed in more detail in Appendix 9. In general, dyked disposal sites are one of the least expensive forms of disposal and they can eventually support such uses as ballfields, parks, nature trails, and boat launching ramps. Local acceptance of these usually very large structures has been very hard to secure in the past due to the disruption caused by the construction and filling operations.

Other methods of dredged material disposal and/or utilization such as underwater sanitary landfills, "on-land" disposal at land-locked sites, beach nourishment, or the manufacture of bricks, have economic and environmental advantages and disadvantages depending on the project site, quality of the dredged material, and other variables. For the most part, however, these alternatives are best suited for smaller projects and are not solutions to long-range or large dredge material disposal problems.

(3) *A need to alleviate potential congestion problems in port, channel, and anchorage areas.* One possible solution to the potential congestion and traffic management problems was recently recommended by the Fifth Coast Guard District to the Commandant in Washington, D.C. After a two year study of the movements of commercial vessels on Chesapeake Bay, Coast Guard marine safety experts recommended implementation of a comprehensive traffic management system. The plan, which was oriented towards the Port of Baltimore and specifically to the movement of liquid natural gas into the Cove Point terminal south of Baltimore, would require the installation of government-operated communications centers at both ends of the Bay. With this network, marine traffic could be controlled in a manner similar to air traffic at a major international airport. This management responsibility has traditionally been delegated to ship pilots and captains. The Coast Guard had not yet made a final decision on the Fifth District's recommendations.

(4) *A need to minimize the potential conflicts between commercial and recreational users of the Bay's waters and beaches.* Minimizing potential conflicts between commercial and recreational uses of Chesapeake Bay can best be minimized by a careful selection of dredge material disposal sites, anchorages, and even channels to avoid, whenever possible, popular boating and sailing, fishing, swimming, and nature areas. Lightering sites, especially for petroleum, should be located where possible accidents would have the least effects on recreation areas.

(5) *A need to minimize the erosion damages from waves caused by commercial and military vessels.* As mentioned earlier, erosion caused by the wakes from ships is a serious problem in some areas. The simplest corrective action is to lower permitted vessel speeds in areas of high erosion potential, thus decreasing the eroding power of the ship-induced waves. Today's merchant ships, however, are extremely expensive to operate so that delays caused by reduced speed limits could increase shipping costs considerably, thereby offsetting any benefit to the shoreline areas affected by erosion. Another possible solution to the erosion problem would be the provision of non-structural or structural shoreline protection measures in the critically eroding areas.

(6) *A need to minimize accidental spills and eliminate deliberate discharges of wastes from commercial and recreation craft.* As discussed earlier, a comprehensive traffic management system for the Bay would reduce the potential for a collision or accident that could result in a massive spill. Appropriate Federal, State, and local controls with substantial penalties for non-compliance would probably be effective in reducing the number of occurrences. Lastly, response teams can and are being established at Federal, State, and local levels to minimize damage in the event of an accidental spill.

In response to Public Law 92-500 the provision of holding tanks or other suitable flow-through devices on all ships will be very effective in eliminating this problem. Attendant with the inclusion of ship board tanks and devices is the need for shore-based facilities that can treat the effluent pumped from ships.

(7) *A need to provide additional lands to accommodate expanding port facilities.* The present and future needs for lands to be used for port-related facilities requires that the appropriate transportation and planning agencies of State and local governments develop zoning and land use plans that will insure the orderly development of the necessary improvements. As part of the development of the appropriate land use plans, consideration will have to be given to the impact on adjacent lands, the need for lands for competing uses such as recreation, and conflicts with natural phenomenon including hurricane flooding and shoreline erosion.

FLOOD CONTROL

CURRENT STATUS

THE TIDAL FLOODING PROBLEM

Since man first settled on the shoreline of Chesapeake Bay, he has been subject to periodic tidal flooding which has resulted in immeasurable human suffering and millions of dollars of property damage. Serious tidal flooding in the Chesapeake Bay Region is caused by either hurricanes or "northeasters." Hurricanes which reach the Middle Atlantic States are usually formed either in the Cape Verde Region or the western Caribbean Sea and move westerly and northwesterly. In most cases these storms change to a northerly and northeasterly direction in the vicinity of the East Coast of the United States.

As a hurricane progresses over the open water of the ocean, a tidal surge is built up, not only by the force of the wind and the forward movement of the storm wind field, but also by differences in atmospheric pressure accompanying the storm. The actual height reached by a hurricane tidal surge and the consequent damages incurred depend on many factors including shoreline configuration, bottom slope, difference in atmospheric pressure and wind speed. Generally the tidal surge is increased as the storm approaches land because of both the decreasing depth of the ocean and the contours of the coastline. An additional rise usually occurs when the tidal surge invades a bay or estuary and hurricane winds drive waters to higher levels in the more shallow waters. Tidal surges are greater, and the tidal flooding more severe in coastal communities which lie to the right of the storm path due to the counterclockwise spiraling of the hurricane winds and the forward movement of the storm.

"Northeaster" is a term given to a high intensity storm which almost invariably develops near the Atlantic Coast. These storms form so rapidly that an apparently harmless weather situation may be transformed into a severe storm in as little as 6 hours. Most northeasters occur in the winter months when the temperature contrasts between the continental and maritime air masses are the greatest. The East Coast of the United States has a comparatively high incidence of this type of storm, with the area near Norfolk, Virginia, being one of the centers of highest frequency.

In the course of recorded history, the Chesapeake Bay Region has been subjected to about 100 storms that have caused damaging tidal flooding. The accounts of most of the storms that occurred prior to 1900 are very brief and are usually found only in early newspaper articles and private journals. The earliest known account of a great storm in this Area appeared in Arthur P. Middleton's *Tobacco Coast.*

This storm was the great "Hurry-Cane" of August 1667 in which fields were inundated, crops were torn to shreds, houses and barns were carried away, and even the largest vessels were washed up on the beach. J. Thomas Scharf, in his *History of Baltimore City and County,* states that one of the most destructive storms of later times occurred in July 1837. The water rose twenty feet above its normal level and many sections of the city were flooded by more than five feet of water. However, the elevation and the area inundated by these early tidal floods was seldom accurately documented and it was not until the early part of the 20th century that a program to maintain continuous records of tidal elevations was initiated. The damages and loss of life suffered during these early floods is also not well documented.

TABLE 27
TIDAL ELEVATIONS DURING RECENT CHESAPEAKE BAY STORMS

Storm	Tidal Elevations (Feet Above Mean Sea Level)			
	Norfolk	Mid-Bay	Washington	Baltimore
August 1933	8.0	7.3	9.6	8.2
September 1936	7.5	–	3.0	2.3
October 1954 "Hazel"	3.3	4.8	7.3	6.0
August 1955 "Connie"	4.4	4.6	5.2	6.9
August 1955 "Diane"	4.4	4.5	5.6	5.0
April 1956 "Northeaster"	6.5	2.8	4.0	3.3
March 1962 "Northeaster"	7.4	6.0	–	4.7

Shown in Table 27 are the recorded tidal elevations at several locations for the most severe floods that have occurred in this Century. It should be noted that the relative severity of flooding varies around the Bay since it is a function of changes in storm paths and variances in climatological and astronomical tide conditions.

The hurricane of 23 August 1933 was the most destructive ever recorded. The hurricane center entered the mainland near Cape Hatteras, passed slightly west of Norfolk, Virginia, and continued in a northerly direction passing just east of Washington, D.C. It moved at or near the critical speed for producing the maximum surge, and its time of arrival coincided with the astronomical high tide as it proceeded upstream. The results were tides ranging from 8.0 feet above mean sea level (msl) at Norfolk to as high as 11.0 feet (msl) at Washington, D.C. In addition to flooding damage, the high winds associated with this storm generated very destructive waves which caused extensive shoreline erosion.

Shown in Table 28 is an estimate of the damages that were caused by the four most damaging storms that have passed through the Bay Region. The estimates reflect the actual physical damages that occurred, updated to reflect 1975 price levels. These figures do not reflect the damages that would result from a recurrence of these

TABLE 28
TIDAL FLOOD DAMAGES OF RECENT CHESAPEAKE BAY STORMS

Location	Storms and Damages in Thousands of Dollars			
	August 1933	October 1954 "Hazel"	August 1955 "Connie"	March 1962
Baltimore Metro Area	$23,500	$6,900	$11,500	Negligible
Washington Metro Area	12,000	4,800	300	Negligible
Maryland Tidewater Area	11,400	9,100	1,800	Negligible
Norfolk Metro Area	8,500	Negligible	Negligible	$ 4,800
Virginia Tidewater Area	Negligible	Negligible	Negligible	24,700

storms under today's conditions due to differences in intensity of development in the flood plain.

FLOOD PROBLEM AREAS

Existing flood problem areas were identified by considering the degree of tidal flooding that would be experienced by those communities located along the shoreline of the Bay and its tributaries. The analysis was limited to communities or urbanized areas since residential, commercial, and industrial development would suffer the greatest monetary losses as a result of a tidal flood.

The initial step in the analysis was to identify all Bay communities having a population of 1,000 or greater that are located either in total or in part within the "Standard Project Tidal Flood Plain." The Standard Project Tidal Flood (SPTF) is defined as the largest tidal flood that is likely to occur under the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic region. The Corps of Engineers in cooperation with the U.S. Weather Bureau determined that for the Chesapeake Bay Region the SPTF would average approximately 13 feet above mean sea level (msl). The above figure is a static or standing water surface elevation which would occur in conjunction with an astronomical high tide and does not include the effects of waves. Superimposing waves characteristic of a hurricane that would produce a tidal surge of 13 feet above msl, wave heights of approximately 5 feet could be expected. Based on the above combination of tidal surge and wave action the SPTF would inundate areas up to approximately 18 feet above msl. However, for purposes of ease in delineating the flood area, an elevation of 20 feet above msl was assumed for the SPTF elevation.

The next step in the flooding analysis was to identify those communities

TABLE 29
FLOODPRONE COMMUNITIES, CHESAPEAKE BAY REGION

STATE OF MARYLAND

Anne Arundel County
- *Arundel on the Bay
- *Avalon Shores (Shady Side, Curtis Pt. to Horseshoe Pt. and West Shady Side)
- Broadwater
- Columbia Beach
- *Deale
- Eastport
- Franklin Manor on the Bay and Cape Anne
- Galesville
- Rose Haven

*Baltimore City

Baltimore County
- Back River Neck
- *Dundalk (Including Sparrows Pt.)
- *Middle River Neck
- *Patapsco River Neck

Calvert County
- Cove Point
- North Beach on the Bay
- Solomons Island

Caroline County
- Choptank
- *Denton
- Federalsburg

Cecil County
- Elkton
- Northeast

Charles County
- Cobb Island

Dorchester County
- *Cambridge

Harford County
- Havre de Grace

Kent County
- *Rock Hall

Queen Anne's County
- Dominion
- *Grasonville
- Stevensville

St. Mary's County
- Colton
- *Piney Point
- St. Clement Shores
- St. George Island

STATE OF MARYLAND (Cont.)

Somerset County
- *Crisfield
- *Smith Island

Talbot County
- Easton
- Oxford
- *St. Michaels
- *Tilghman Island

Wicomico County
- Bivalve
- Nanticoke
- *Salisbury

Worcester County
- *Pocomoke City
- *Snow Hill

COMMONWEALTH OF VIRGINIA

Independent Cities
- *Fredericksburg
- *Hampton
- *Norfolk
- *Portsmouth
- *Virginia Beach
- *Chesapeake

Accomack County
- Onancock
- Saxis
- *Tangier Island

King George County
- *Dahlgren

King William County
- *West Point

Northampton County
- *Cape Charles

Westmoreland County
- *Colonial Beach

York County
- *Poquoson

*WASHINGTON, D.C.

*Indicates "critically" floodprone communities.

that should be classified as "floodprone." In order for a community to be designated as floodprone, at least 50 acres of land that were developed for intensive use had to be inundated by the SPTF. Intensive land use was defined as residential (four dwelling units/acre or greater), commercial (including institutional), or industrial development. The 59 Bay Region communities identified as floodprone are shown on Table 29. Approximately 82,000 acres of land in these communities were found to be located in the SPTF flood plain.

The last step in the flooding analysis was to further examine the communities designated as floodprone and classify each as to whether or not the tidal flood problem was considered to be "critical." The flood problem was considered to be critical if the Intermediate Regional Tidal Flood (IRTF) inundated 25 acres or more of intensively developed land and also caused significant physical damage. The IRTF is defined as that tidal flood which has a one percent chance of occurrence in any one year, generally referred to as the 100-year flood. Elevations for the 100-year tidal flood were approximated for points around Chesapeake Bay based on historical records. The flood heights used were found to range between 6.0 and 11.0 feet above msl. The communities asterisked on Table 29 are classified as "critical floodprone areas." Approximately 27,000 acres of land in these 32 communities were found to be in the 100-year tidal flood plain.

FUTURE TIDAL FLOOD PROBLEM AREAS

The criteria used for designating an area as future floodprone was that 50 acres or more of land proposed for intensive land use fall within the Standard Project Tidal Flood Plain. Areas were considered to be "critically" floodprone if 25 acres or more of land proposed for intensive land use were within the 100-year flood plain. The communities found to be critically floodprone in the future are shown on Table 30. Based on a comparison of the existing and future acreage it should be noted that an additional 58,430 acres of land is proposed for intensive development within the Standard Project Tidal Flood Plain and 19,460 acres of land within the 100-year flood plain.

TABLE 30
CRITICAL FUTURE FLOODPRONE AREAS, CHESAPEAKE BAY REGION

STATE OF MARYLAND

Anne Arundel County
Arundel on the Bay

Baltimore County
Dundalk (Including Sparrows Point)

Cecil County
Elkton
Northeast

Kent County
Rock Hall

Queen Anne's County
Grasonville
Stevensville

Somerset County
Smith Island

STATE OF MARYLAND (Cont.)

Talbot County
St. Michaels

Wicomico County
Salisbury

Worchester County
Pocomoke City

COMMONWEALTH OF VIRGINIA

Independent Cities
Hampton
Norfolk
Virginia Beach
Chesapeake

York County
Poquoson

SENSITIVITY ANALYSIS

The sensitivity of changing the criteria for the selection of the critical floodprone areas from the 100-year to the 50-year flood was investigated. The area inundated by the 50-year tide would be approximately 10 percent less than the area inundated by the 100-year tide. While a 10 percent reduction in acreage is significant, it should be noted that all communities listed in Table 30 would still be classified as critical floodprone areas if the 50-year tidal flood was adopted as a criteria.

MEANS TO SATISFY NEEDS

NON-STRUCTURAL SOLUTIONS

a. *Flood Insurance:* Until recently, insurance against flood-caused losses was virtually non-existent. Now, however, flood insurance is available in floodprone communities under the Federally-subsidized National Flood Insurance Program. A cooperative effort of the Federal Government and the private insurance industry, the program is operated by the Federal Insurance Administration of the U.S. Department of Housing and Urban Development (HUD). In return for making low cost insurance available for existing floodprone property, the program places certain obligations upon the community. The community is required to adopt and enforce land use and other control measures that will guide new development in floodprone areas so that flood damage is avoided or reduced. Most of the affected counties and local jurisdictions in the Region are enrolled in the Flood Insurance Program.

b. *Flood Proofing:* Flood proofing is actually a combination of structural changes and adjustments to properties subject to flooding. Although it is more economically applied to new construction, it is also applicable to existing facilities. Flood proofing is recommended where traditional collective types of flood protection are not feasible and where moderate flooding with low stage, low velocity, and short duration is experienced.

Flood proofing measures can be classified into three broad types. First, there are permanent measures which become an integral part of the structure. Second, there are standby measures which are used only during floods, but which are constructed or made ready prior to any flood threat. Third, there are emergency measures which are carried out during a flood according to a predetermined plan.

Permanent measures essentially involve either the elimination of openings through which water can enter or the reorganization of space within buildings. For example, unnecessary doors and windows can be permanently sealed with brick; a watertight flood shield at a doorway opening can also serve as the door; valves can be installed on basement sewer pipes to prevent flood water from backing up into the basement; or boilers, air conditioning units, and other immobile machinery can be moved to higher elevations and replaced with movable furniture or stock. Adjustments such as these can be most easily undertaken in existing buildings during periods of remodeling or expansion.

Standby measures are most desirable when it is necessary to maintain access into structures at points below selected flood protection levels. For example, display windows at commercial structures must not be blocked in order to serve their main purpose. These types of openings cannot be permanently flood proofed, but they can be fitted with removable flood shields. Since the placement and installation of such devices requires several hours, a flood warning system has to be established before such flood proofing measures can become effective.

Emergency measures are carried out during an actual flood experience. These measures may be designed to keep water out of buildings, for example, the sandbagging of entrances or the use of planking covered over with polyethylene sheeting. More often they are intended only to protect equipment and stock. A widely used emergency measure is the planned removal of contents to higher locations when a certain flood stage is reached. Again, an effective flood warning system is crucial to the effectiveness of this type of measure.

c. *Other Non-Structural Measures:* Other non-structural measures used in reducing flood damages are: permanent or temporary evacuation of the flood plain, land use controls and building codes designed to control the extent and type of future development in the flood plain, and public awareness programs to make the potential hazards of tidal flooding known to the prospective developer and/or homeowner.

STRUCTURAL SOLUTIONS

Structural solutions are defined as those man-made structures that are designed to protect an area from tidal flood damages. Floodwalls and levees are two examples of these types of structures. While differing in design, appearance, and cost, floodwalls and levees serve essentially the same purpose. Both are constructed near the shoreline to protect landside development from inundation by tidal floodwaters. Floodwalls are generally concrete and may have vertical, curved or stepped faces. Levees are usually earth embankments having a top width of approximately 10 feet and side slopes that vary between 1 on 2 and 1 on 4. Levees are generally less expensive than floodwalls and are particularly applicable in areas where construction materials are nearby and there is sufficient area between the shoreline and the development for their construction. Floodwalls may be used where the close proximity of the development to the shoreline precludes the construction of levees.

Because of the high cost of providing this type of protection, the applicability of levees and floodwalls in the Bay Region would generally be limited to those highly developed urbanized areas where there is extensive residential, commercial, or industrial development that is subject to damaging flooding. It should also be noted that providing a levee or floodwall of sufficient height to protect against a major tidal flood could severely restrict the use of the shoreline for recreational or transportation and shipping purposes. Also, the protection may be considered unacceptable from an aesthetic standpoint if the view of the water body is restricted.

A breakwater is another type of flood protection structure. It is designed to break the force of storm waves and thus reduce the damage that would be experienced by storm waves breaking on shoreline development. Breakwaters are also used to create harbors of refuge that provide safe mooring for recreational and commercial craft. Breakwaters may be either shore connected or located offshore and are generally classified by either the construction materials or the method of construction. Different types of breakwaters may be constructed of stone or concrete blocks (rubble-mound breakwaters), stone-asphalt mixtures, reinforced concrete shells filled wtih stone or sand, steel sheet piling cells filled with sand, timber cribs filled with rubble, or mobile or floating breakwaters which may be moved into place when a tidal flood is predicted. The most common type of breakwater in the Chesapeake Bay Region is the shore connected, rubble-mound breakwater. In the sheltered waters of the Bay and the sub-estuaries this type of protection is very effective and usually can be constructed with materials that are available locally.

Recreational and commercial craft are particularly susceptible to damage caused by the large waves associated with tidal flooding. Harbors of refuge provide areas of calm water for the safe mooring of all types of craft. Harbors of refuge can be naturally sheltered areas such as coves or inlets or existing marinas, and mooring areas protected through the use of breakwaters as discussed above.

Other structural measures including bulkheads, revetments, groins, and beach nourishment that are used primarily for shoreline erosion control also have some applicability as flood control measures. A detailed description of these measures is included in Appendix 11 – Shoreline Erosion.

SHORELINE EROSION

CURRENT STATUS

THE SHORELINE EROSION PROCESS

The shorelands of Chesapeake Bay are composed of three physiographic elements–fastland, shore, and nearshore (Figure 29). The fastland is that area landward of normal water levels. The shore is the zone of beaches and wetlands which serve as a buffer between the water body and the fastland. Lastly, the nearshore extends waterward from the mean low water level to the 12-foot depth contour. In the Chesapeake Bay proper, the nearshore is generally comprised of a shallow water belt more than 1,000 feet wide before the 6-foot mean low water depth contour is encountered. From the 6-foot contour outward, the depth increases at a more rapid rate.

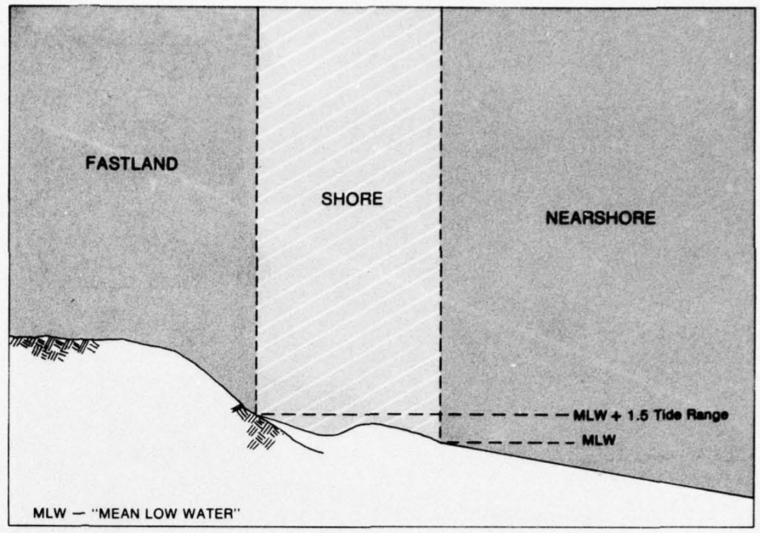


Figure 29: Shorelands of Chesapeake Bay

While the causes of shoreline erosion are complex and not completely understood, the primary processes responsible for erosion are wave action, tidal currents, and groundwater activity. Waves generated by wind are the cause of most of the shoreline erosion in the Bay Region. The amount of wave energy which reaches the shoreline is dependent on the slope of the nearshore. A shallow nearshore will dissipate more wave energy than a deep nearshore. In addition, less wave energy is received by a shoreline if there is a shoal, tidal flat, or aquatic vegetaion immediately offshore. Similarly, a wide beach is better than a narrow beach for wave dissipation. Conversely, where the shoreline has none of the above natural features and wave action is strong, undercutting of the ground landward of the beach will cause sliding, slumping, and resultant loss of fastland.

Waves associated with hurricanes or other large storms can be extremely damaging. These storms can generate very large, steep wind waves which can remove considerable material from the shore zone and carry it offshore. Strong winds of these storms often raise water levels and expose to wave attack lands of higher elevation that are not ordinarily vulnerable.

Erosion problems caused by tidal currents are usually most severe in constricted areas such as inlets to lagoons and bays or at entrances to harbors. In addition to creating currents which cause erosion, the tides constantly change the level at which waves attack the beach, thereby aggravating the problem.

Another process which contributes to the erosion of the shoreline is the seepage of groundwater through the fastland and into the exposed shore zone. As shown on Figure 30, taken from the Chester River Study prepared by the State of Maryland and the Westinghouse Electric Corporation, water percolates downward through porous soils and flows out through exposed bank faces often causing an erosion of bank materials. This process is accelerated where man has removed the natural cover on the land adjacent to the banks thus increasing the amount of rainfall seeping into the ground.

To a much lesser degree, three other factors contribute to the shoreline erosion problem in Chesapeake Bay. First, the long term rise of sea level has resulted in the inundation or loss of land to the Bay. An average rise of 0.01 feet per year has been recorded in the lower Chesapeake Bay. At Fort McHenry in Baltimore, Maryland, the National Ocean Survey tide gage indicated a 0.6 foot rise in mean sea level between 1902 and 1962. These seemingly insignificant rates of increase can over the years inundate significant land area particularly where shorelands have very gentle slopes. Second, rainfall runoff can cause or contribute significantly to shoreline erosion, particularly in areas where the adjacent shoreline is rolling and broken and soils are made up of easily erodible materials. Last, in some areas of the Bay, especially around busy harbors and waterways such as the Chesapeake and Delaware Canal, the wakes from passing ships are a significant erosive force.

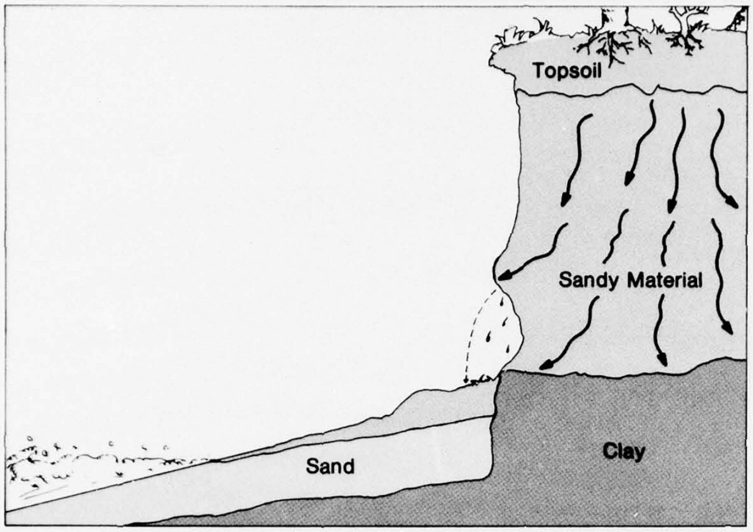
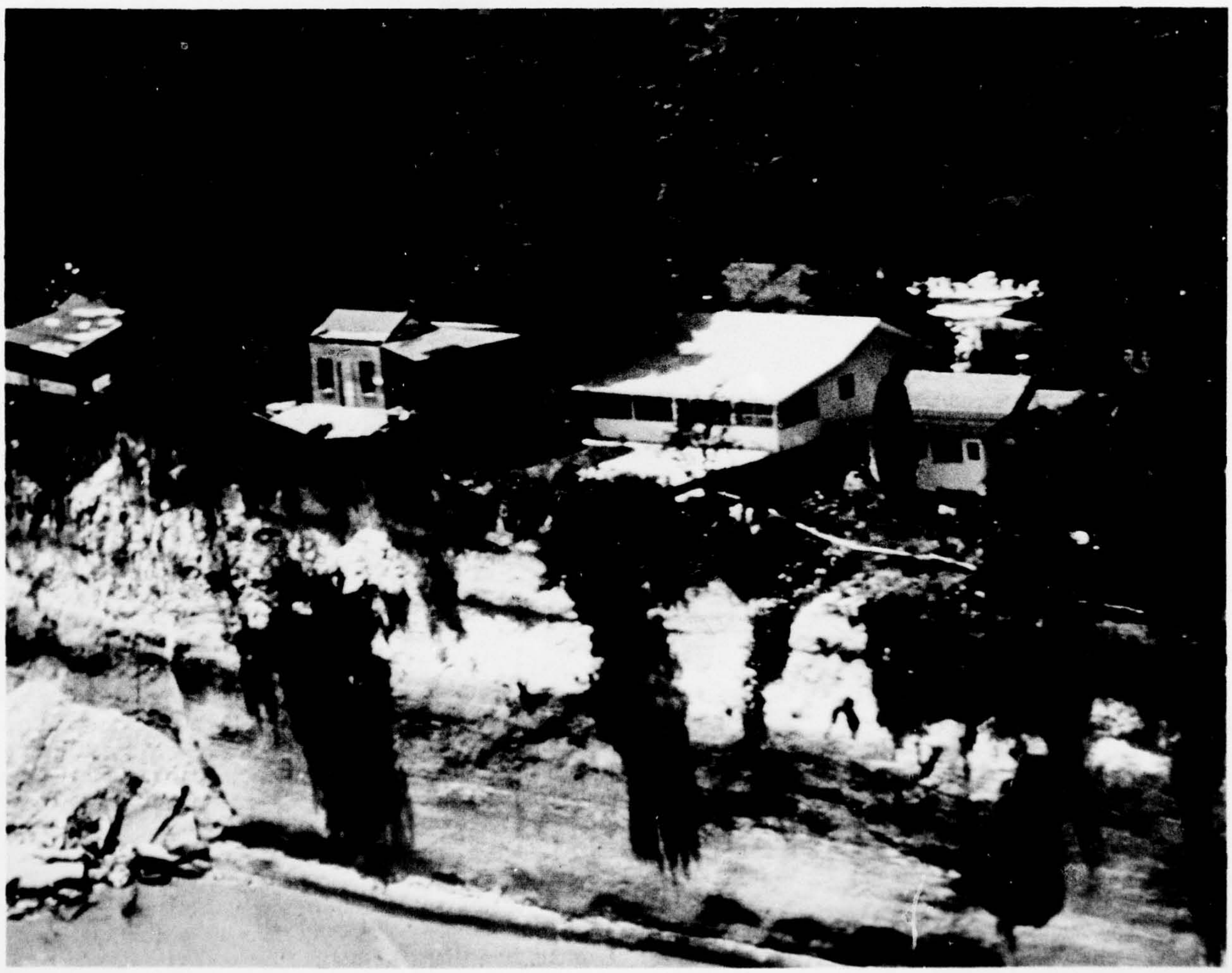


Figure 30: Shoreline Erosion Caused by the Seepage of Groundwater

EXISTING PROBLEMS AND CONFLICTS

The natural processes discussed in the preceding paragraphs have claimed thousands of acres of land around Chesapeake Bay and its tributaries. Over the last 100 years alone, approximately 45,000 acres of land have been lost due to tidal erosion. The configuration of the shoreline has changed markedly in some areas; and certain islands, some of which exceeded 400 acres in size, have ceased to exist.

The most significant impact of the loss of this amount of land has been on the landowners who have witnessed the loss of both valuable shoreland and improvements that may have been



constructed too close to the shoreline. Attempts to try to arrest the rate of erosion through either poorly designed or constructed protective measures have further frustrated property owners when their efforts proved futile. In many cases, man has accelerated the rate of erosion by eliminating natural protective devices such as vegetative cover that inhibit erosion.

Sediment, the product of erosion, has also had significant impacts on both the natural environment and man's use of the resource. Sediment from shoreline erosion may eventually be deposited in either natural or man-made navigation channels requiring maintenance dredging and the problems normally associated with the disposal of the dredged material. In addition, sediment also has a considerable impact on water quality and the biota of the Bay. Sediment can cover productive oyster beds and valuable aquatic plants. The reduced light penetration into turbid waters can also be very detrimental to aquatic life.

In order to define those areas or reaches of tidal shoreline along the Bay and its tributaries that are suffering "critical" losses of land, an inventory of historical erosion rates and the adjacent land use was compiled. The erosion rates used in the compilation were developed by the Maryland Geological Survey and the Virginia Institute of Marine Sciences for the Maryland and Virginia portions of the Bay, respectively.

In the determination of the shoreline erosion rates the shoreline was broken down into workable lengths called "reaches," which range from several hundred to several thousand feet in length. These reaches were established based on physiographic characteristics including the erosion or deposition rate. The inventory of the erosion rates on a reach by reach basis for each tidal county in Maryland and Virginia is included in Tables A-1 and A-2, respectively, of Appendix 11–Shoreline Erosion.

Using these erosion rates along with land use information developed by the

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U.S. Geological Survey as part of the CARETS program, reaches were designated as having critical erosion problems if they met or exceeded the following criteria:

1. The erosion rate was equal to or greater than 3 feet per year regardless of adjacent land use.

2. The erosion rate was equal to or greater than 2 feet per year and the adjacent land use was intensive, i.e., residential, commercial, or industrial.

It should be noted that in those reaches where the erosion rate fell between 1.5 and 2.0 feet per year, the rate was "rounded" upward to 2.0 feet per year. This conservative approach was taken to compensate for the fact that the average rate for a reach probably dampened some severe rates at specific sites within the reach.

Using the above criteria and assumptions, approximately 403 miles of shoreline were identified as existing "critical erosion reaches." Table 11-1 of Appendix 11 lists each critical reach by county and state, the land use in the reach, reach length, erosion rate and an evaluation of existing structural shoreline protection measures within the reach. Plates 11-1 through 11-3 in Appendix 11 show the location of these critical reaches. Tables 31 and 32 in this Summary list the amount of critically eroding shoreline by county for Maryland and Virginia.

FUTURE SHORELINE EROSION PROBLEMS

The method employed to delineate future problem areas is essentially the same as that used to define the existing critical areas. It was assumed that the historical erosion rates were reflective of future erosion rates in the same reaches. It was further assumed that future land use adjacent to the shoreline would develop as shown in the latest regional, county, or municipal land use planning documents. Given the historical erosion rates and projected future land use adjacent to the shoreline, the entire Bay shoreline was surveyed to determine if any future development was proposed in areas subjected to significant shoreline erosion.

TABLE 31
LENGTH OF CRITICALLY ERODING SHORELINE STATE OF MARYLAND

County/City	Length of Critical Shoreline Miles
Anne Arundel	32.4
Baltimore	5.0
Calvert	9.6
Cecil	9.3
Charles	8.2
Dorchester	61.6
Harford	5.7
Kent	9.9
Queen Anne's	24.0
Somerset	23.0
St. Mary's	20.6
Talbot	27.1
Wicomico	23.1
TOTAL	259.5

It was determined that an additional 44.4 miles of Bay shoreline has the potential to become a serious problem. (See Tables 33 and 34). This is in addition to the over 400 miles of shoreline that is currently classified as critical based on existing development.

TABLE 32
LENGTH OF CRITICALLY ERODING SHORELINE COMMONWEALTH OF VIRGINIA

County/City	Length of Critical Shoreline Miles
Accomack	24.2
Essex	7.6
Gloucester	7.0
Hampton	14.2
Isle of Wight	7.7
Lancaster	8.4
Mathews	9.7
Middlesex	7.7
Northampton	10.4
Northumberland	18.3
Richmond	3.5
Surry	3.8
Virginia Beach	6.0
Westmoreland	10.4
York	4.0
TOTAL	142.9

TABLE 33
FUTURE CRITICALLY ERODING REACHES (MARYLAND)

LOCALITY WATER BODY/ REACH DESIGNATION

Anne Arundel County

Chesapeake Bay
- Bodkin Point
- Persimmon Point

Calvert County

Chesapeake Bay
- From approximately ½ mile north of Plum Point to Parker Creek
- From approximately ½ mile north of Flag Ponds to Cove Point
- Cape Anne

Cecil County

Northeast River
- Charlestown to Carpenter Point
- Northeast Heights to Red Point

Kent County

Chesapeake Bay
- 2 miles south of Tolchester Beach to Tavern Creek

Queen Anne's County

Chesapeake Bay
- Broad Creek to ¾ mile south of Carney Creek

Chesapeake Bay
- Jackson Creek to Piney Cove

Eastern Bay
- Greenwood to Bennett Point

Wicomico County

Nanticoke River
- Roaring Point
- Bivalve Harbor to 1 mile north

TABLE 34
FUTURE CRITICALLY ERODING REACHES
(VIRGINIA)

LOCALITY WATER BODY/ REACH DESIGNATION
Gloucester County
Ware River
Ware River Point to Old House Creek
Mobjack Bay
Ware River Point to Turtleneck Point
York River
Sandy Point to east of Perrin River
City of Hampton
Back River
Harris Creek to North End Point
Lancaster County
Rappahannock River
Wyatt Creek to Greenvale Creek
Navy Auxiliary Air Force to Mulberry Creek
Mulberry Creek to Curletts Point
Corrotoman River
Eastern Shoreline
Northumberland County
Potomac River
Eastern Shoreline of Wilkens Creek
Chesapeake Bay
Taskmers Creek to Warehouse Creek
Richmond County
Rappahannock River
Morattico Creek to Tarpley Point
Tarpley Point to Sharps Road Point
Sharps Road Point to Rechardson Creek
Waverly Point to McGuire Creek
Westmoreland County
Potomac River
Ragged Point to Jackson Creek
York County
York River
Skimino Creek to 1.8 mile south

SENSITIVITY ANALYSIS

The sensitivity of the number of miles of shoreline which are expected to experience critical erosion problems in the future was tested by varying the erosion rate. If the critical erosion rate was assumed to be 1 foot per year, the additional length of critical shoreline was found to be approximately 80 miles or nearly double the 44.4 miles classified as critical using the 2 feet per year criteria. When the criteria was raised to 3 feet per year, it was noted that the length of critical shoreline was reduced to approximately 20 miles. It is obvious that the length of shoreline expected to experience future critical erosion problems is highly sensitive to changes in the erosion rate. It is felt, however, that the 2 feet per year erosion rate criteria is the most reasonable assumption.

MEANS TO SATISFY NEEDS

There are many structural and non-structural measures that can be employed to prevent, arrest or mitigate the effects of shoreline erosion. These measures must be used with care, however, as the forces of erosion are unpredictable, varying from place to place and with meteorological events. Often a combination of both non-structural and structural measures is the only way to cope with these forces.

NON-STRUCTURAL SOLUTIONS

Nonstructural solutions consist of devices which enhance the effectiveness of natural protective features and regulatory actions that can be employed to avoid a land use-erosion conflict. The following nonstructural measures have applicability in shoreline erosion problems in Chesapeake Bay.

a. *Marsh Creation.* As previously mentioned, marshes tend to buffer the shoreline against wave action and its consequential erosive forces. Under certain conditions, marshes can be created by selective placement of material in the nearshore zone and the seeding and transplanting of native plants such as saltmarsh cordgrass *(Spartina Alterniflora)*. A possible source of material for the creation of marshes is dredged material from channel maintenance and deepening projects. The use of this material would not only serve to provide erosion control and create additional fish and wildlife habitat, but it could help solve the problem of finding acceptable disposal sites for dredged material.

b. *Vegetative Cover.* In addition to improving the ability of the shoreline and fastland areas to resist erosion, vegetation can trap windblown material and thus aid in the formation of a protective dune. Vegetation as a sole protection against erosion has proven to be unsuccessful except in well-protected areas. Its widest application has been its use in conjunction with other structural measures such as bulkheads and groins. It has also been used to stabilize backfills of bulkheads and in combination with groins in the creation and stabilization of beaches.

c. *Regulatory Actions and Public Awareness Programs.* Land use regulations can be used to set aside critically eroding reaches for such non-intensive uses as recreation or open space. This action would prohibit development of structures that would be threatened by a rapidly receding shoreline.

A second approach is to adopt building codes which would allow for development in eroding areas but that would require the construction of the appropriate erosion control measures. The developer would be required to provide continuous protection for the length of the reach.

A public awareness program could be used to advise the public as to the location and severity of shoreline erosion and could also provide information as to the structural and nonstructural measures that could be used to control erosion.

Marsh Creation.

STRUCTURAL SOLUTIONS

Structural solutions are defined as those man-made structures that are designed to either prevent waves and tidal action from reaching erodible material or that retard the longshore transport of littoral drift (i.e., the movement of sediments parallel to the shore in the nearshore zone by waves and currents) and thus aid the build-up of the natural nearshore defenses. Bulkheads and revetments are the most commonly used structures that prevent erosive forces from reaching the fastland while groins and beach nourishment are most frequently employed in the Region to build up the nearshore. The following paragraphs include a general discussion of the above mentioned structural measures and their general design characteristics.

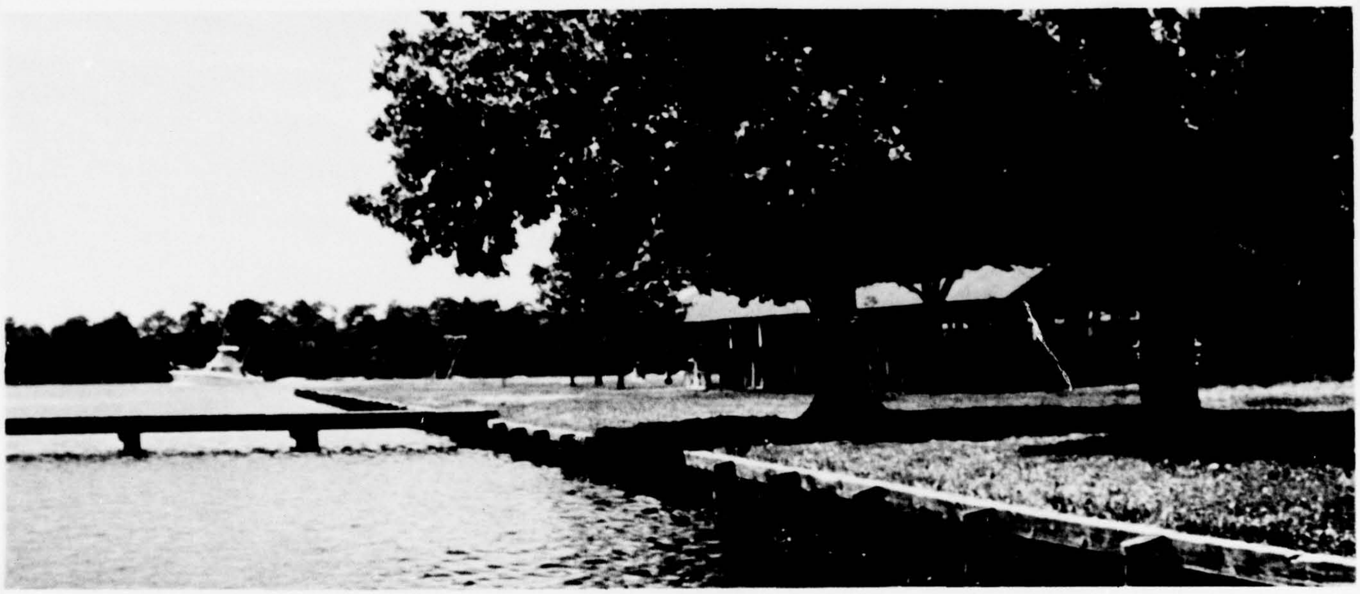
a. *Bulkheads.* The main purpose of a bulkhead is to retain the earth behind it, to deflect the energy of incoming waves, and to prevent flooding. Bulkheads which are essentially vertical walls, can be constructed of wood, stone, concrete, or metals, but are commonly made of wood, with a framework of pilings and cross-timbers called wales covered with a sheathing of thick boards nailed or bolted to the framework. Areas around Chesapeake Bay where such protection can be

Riprap Protection.

most effectively used are in sheltered waters such as coves, harbors, and in small bays. In open waters, such as on the Bay proper, bulkheads may be relatively ineffective as the severity of the water action causes scouring at the bottom of the structure and eventually undermines the bulkhead itself.

b. *Revetments.* A revetment consists of armoring the sloping face of the shore with one or more layers of riprap or concrete. The sloping characteristic in this design serves to dissipate wave energy as the water rolls up the incline. Riprap is composed of stone, chunks of concrete, rubble or brick and it is the most common type of revetment construction employed in the Bay Area. The irregular surface of riprap also serves to break up water momentum and provide niches which capture sediment and thus adds stability. Gabions consisting of riprap enclosed in wire mesh cages may also be used. These baskets capture sediment and grow protective vegetation which eventually blends the structure into the surroundings. Properly designed revetments can effectively retard erosion even in severe cases. In certain ineffective attempts to halt erosion, unsuitable materials such as junked car bodies, engines, and tires have been used as riprap to absorb wave energy.

c. *Groins.* A groin is a barrier-type structure which extends perpendicular to the shoreline into the nearshore zone of sand movement. The basic purpose of a groin is to interrupt alongshore sand movement in order to



Bulkhead Protection.

Revetment at Oxford, Maryland.

accumulate sand on the shore or to retard sand losses. Some groins or groin fields interrupt the flow of sand to downdrift areas thus causing damage to these shorelines. In order to minimize damage to the shoreline downstream from a groin, it has to be designed with the top profile not higher than that of a beach of reasonable dimensions. When full, a groin of this type will permit the stream of sand to pass over its top and continue on downstream to nourish the neighboring shores. Groins should not be built unless properly designed for the particular site and the effects of the groins on adjacent beaches have been adequately studied by an engineer experienced in this field.

d. *Beach Nourishment.* Another measure which can be used either singularly or in connection with the previously mentioned measures is beach nourishment. Beach nourishment is the addition of sand from another source to an eroding natural beach thereby replacing the material lost to erosion and extending the natural protection provided by the nearshore. To restore an eroded beach and stabilize it at the restored position, material is placed directly along the eroded sector and additional material is stockpiled at the updrift end of the problem area. The stockpiled material will then maintain the restored portion of the beach. When conditions are suitable for artificial nourishment, long reaches of shore may be protected by this method at a relatively low cost per linear foot of shoreline.

FISH AND WILDLIFE

The fish and wildlife of the Chesapeake Bay Area contribute in many ways to making the Bay what it is today, both in terms of commercial markets and in terms of recreational enjoyment. Increasingly, people are turning to the out-of-doors for use of their leisure time, and fish and wildlife contribute both directly and indirectly to the value of the outdoor experience. Sport hunting and fishing, for example, are major activities of outdoor enthusiasts, as are such activities as birdwatching and nature photography. In addition, commercial interests rely on fish and wildlife resources as a source of income and employment. The future requirements for fish and wildlife for commercial and recreational uses are the subject of this section. The strictly biological value of fish and wildlife as part of the Bay ecosystem is discussed in Chapter II.

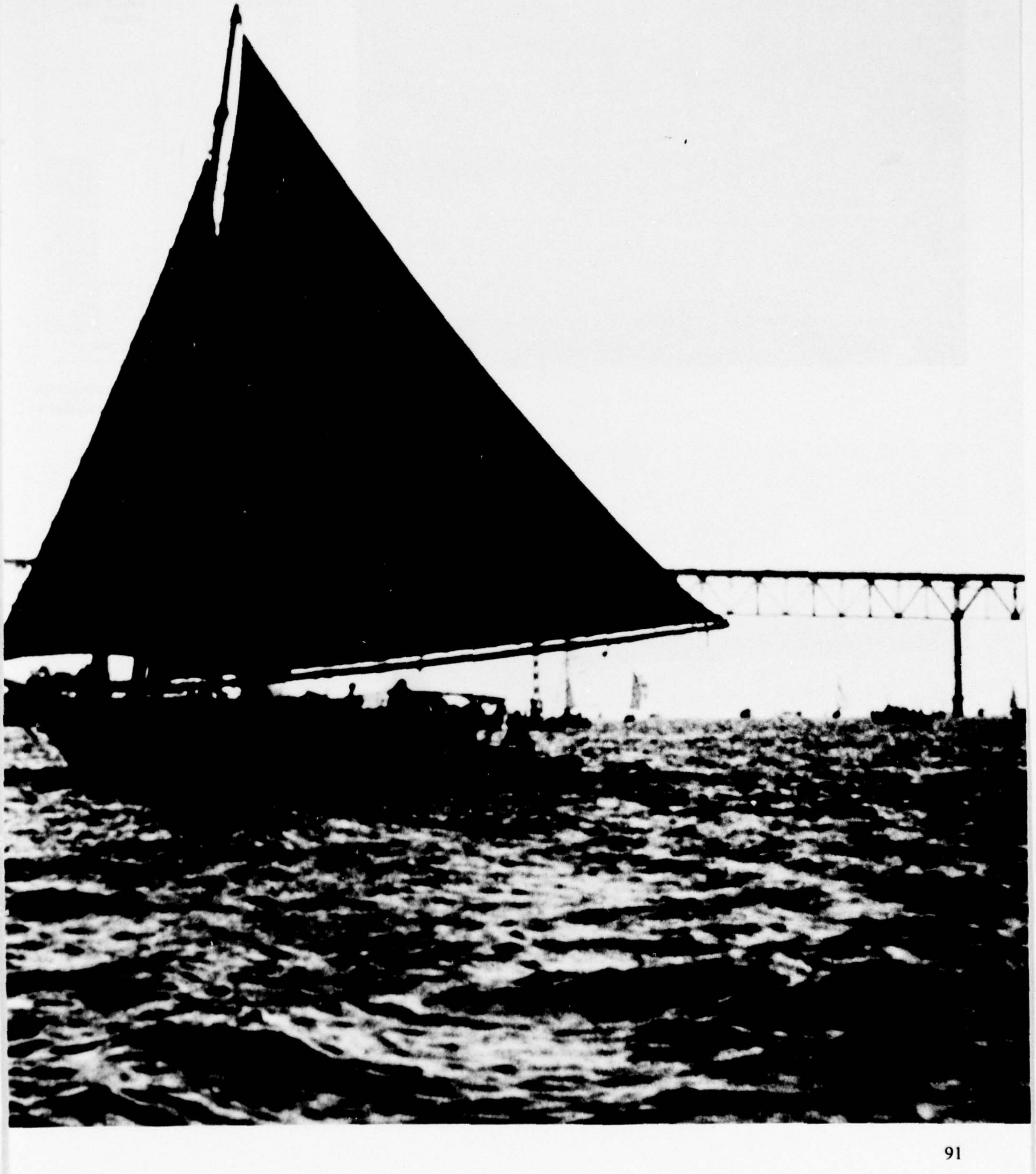
CURRENT STATUS

COMMERCIAL FISHERIES

A commercial fishery is a business that involves catching, or "harvesting," a particular finfish or shellfish, deliverance of the product to the wholesale market, and subsequently "processing" the product for the retail trade. "Harvesting" and "processing" are the terms used to describe the two particular sectors of the commercial fishing industry.

In the harvesting sector, average commercial landings during the period 1966 to 1970 totaled 381 million pounds worth nearly $30 million. About 82 percent of this total harvest of finfish and shellfish was landed in areas located on Chesapeake Bay proper, as shown in Table 35, with the balance being landed in tributaries to the Bay. Finfish consist of both edible and industrial species. The latter include mainly menhaden and alewives, which together averaged 243 million pounds worth $3.7 million between 1966 and 1970. Menhaden alone accounted for 90 percent of all finfish landings by weight in 1970. Edible finfish types include striped bass, weakfish, shad, catfish, bluefish, and white perch, among others.

Shellfish, which are commonly harvested commercially, include crabs, oysters, and soft clams. Based on data presented in Table 35, shellfish harvests between 1966 and 1970 averaged 88 million pounds (excludes shell weight of clams and oysters) worth $23 million. The fact that shellfish represent the big money crop in Chesapeake



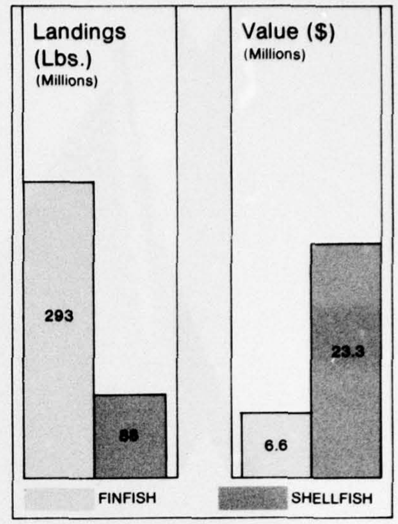


Figure 31: Average Finfish and Shellfish Harvest, 1966-1970, Chesapeake Bay Region.

Bay is illustrated in Figure 31 which compares finfish with shellfish in terms of both landings weight and value. Shellfish comprise only 24 of the total commercial harvest by weight, but a substantial 78 percent of the total value.

The most recent data available on commercial harvests of finfish and shellfish in Chesapeake Bay are for 1973. During the year, commercial landings of bluefish exceeded all previous records at 2.8 million pounds as did landings of the gray sea trout which were 4.4 million pounds. This is a 93 percent increase in poundage for the latter species and a 134 percent increase in value over 1972. Landings of croaker were up 188 percent after being very scarce the previous 6 years. In contrast, landings of alewives in 1973 were nearly half of the 1970 catch and commercial catches of yellow and white perch were also down markedly from 1970 levels.

Commercial shellfish harvests in 1973 were of comparable magnitude to harvests of 1966-1970, in terms of both weight and value. Of interest, however, is the fact that oysters were harvested in Maryland waters in quantities unexceeded since 1937, despite the impacts of Tropical Storm Agnes in 1972, and that harvests in Virginia were the *lowest* on record. This apparent discrepancy can be explained by the fact that oysters in Maryland experienced good reproductive years in 1969 and 1970 which resulted in oysters of sufficient size to survive the large freshwater influx due to Agnes. Oysters in the State did not have a good reproductive year during the 1971-1976 period, however, and this is expected to affect future landings. Factors affecting the Virginia oysters include a disease which invaded the Commonwealth's oyster beds in the early 1960's; poor reproductive years prior to 1973; and the effects of Agnes. The clam landings, and to a lesser extent crab catches, in both States were down considerably from previous years due to a large extent to the effects of Tropical Storm Agnes.

Employment in the harvesting and processing sectors is also an important component of the commercial fishing industry. The most recent data from 1973 show employment in the commercial harvesting sector to be about 17,400 full-time and part-time fishermen operating nearly 12,000 vessels of various sizes. The number of fishermen in the Chesapeake Bay Region has stayed relatively constant since 1954, fluctuating between a low of 16,800 in 1962 to a high of 20,200 in 1955. The number of vessels has also stayed fairly constant during this period.

In addition, in Maryland and Virginia, about 7,100 persons were employed in the processing sector in wholesale and processing plants in 1973. Since fresh seafood is highly perishable, much of

TABLE 35
COMMERCIAL FISHERY HARVEST
AVERAGE 1966-1970
CHESAPEAKE BAY AND TRIBUTARIES (1)
(IN THOUSANDS)

Water Area	Acres	Finfish – Edible		Finfish – Industrial		Shellfish		Total	
		Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Chesapeake Bay (2)	2,041	24,177	1,443	234,976	3,590	54,244	8,166	313,397	13,199
Chester River	35	436	54	6	Negl.	2,012	889	2,454	943
Choptank River	69	880	118	7	Negl.	4,800	1,730	5,687	1,848
Nanticoke River	18	506	67	24	1	537	236	1,067	304
Patuxent River	30	260	39	5	Negl.	896	500	1,161	539
Wicomico River	10	96	11	9	Negl.	143	93	248	104
Potomac River	310	11,006	590	3,974	73	10,543	4,673	25,523	5,336
Rappahannock River	98	4,898	219	1,993	35	7,498	2,005	14,389	2,259
York River	55	2,513	113	1,577	30	3,856	572	7,946	715
James River	166	4,695	264	1,125	20	3,834	4,398	9,654	4,682
TOTAL STUDY AREA	2,832	49,467	2,918	243,696	3,749	88,363	23,262	381,526	29,929

(1) This table was based on preliminary unpublished data developed in 1972.
(2) Bay proper exclusive of tributaries.

Sport Fishermen Display Their Catch.

Commercial Crabbing Center on the Eastern Shore.

the Chesapeake Bay catch is processed and wholesaled in close proximity to where the landings are made. Average annual employment in the Chesapeake Bay seafood wholesaling and processing industries has been characterized by modest gains since the early 1950's. The number of establishments has declined steadily, however, since the late 1950's when the average number of establishments in the Region was 704. This fact reflects the National trend in recent decades toward larger establishments of higher employment. Most of the seafood processing and wholesaling establishments in the Chesapeake Bay Region were located in the Northern Neck area of Virginia (i.e., the tidewater portion of Virginia between the Potomac and Rappahannock Rivers) and on the middle and lower portions of the Maryland and Virginia Eastern Shore.

Chesapeake Bay Crab Feast.

COMMERCIAL FURBEARERS

A significant economic resource of the Bay Region, but one that is often overlooked, is the furbearing mammals of the wetland and terrestrial habitats found within the Study Area. Furbearing species commonly trapped in the Study Area are beaver, gray fox, red fox, mink, muskrat, opossum, otter, raccoon, skunk, weasel, and bobcat. The muskrat is of primary economic importance since it provides approximately 69 percent of the total income of Bay trappers. The fur harvest for the 1971-72 season in Maryland and Virginia was valued at approximately $1.8 million, including the meat value of certain of the species (especially muskrat). Although specific data are not available, a major portion of the total bi-state fur harvest is felt by experts to derive from the Bay Region. In addition, it should be noted that the value of the harvest represents money paid trappers and does not represent economic activity generated in the processing and retailing sectors of the industry.

SPORT FISHING AND HUNTING

Increases in income, population, and available leisure time have stimulated increases in sport fishing and hunting in the Chesapeake Bay Area. Recreational fishing accounts for a significant portion of the total landings for several species of fish within the Study Area, including, in order of pounds landed in 1970: spot, striped bass, white perch, weakfish, shad, croaker, flounder, yellow perch, catfish, and bluefish. All of these but striped bass, flounder, and catfish actually exceeded the commercial catch, demonstrating the importance of recreational fishing in the Bay. Shellfish are also taken by a considerable number of people on a recreational basis. It has been estimated that blue crabs are sought by as many people as are game fish, and that the recreational quantity caught may equal the whole commercial harvest. Definitive statistics on recreational harvests of shellfish are not available.

Hunting is also an important form of recreation within the Study Area. Upland forests, farm lands, wetlands and open water are utilized as a source of food or shelter for various species of game animals. The upland forest and farm land provide habitat for deer, rabbit, squirrel, woodchuck, raccoon, and opossum as well as game birds such as turkey, quail, dove, woodcock. and others. More closely associated with the Bay are the many species which depend on the wetlands and open water for their habitat requirements. The most significant of these are the numerous species of waterfowl which winter in the Bay area and provide many man-days of hunting experience for outdoor enthusiasts, as well as significant economic benefit to the Region. Expenditures for licenses, hunting land leases, food, lodging, gasoline, club memberships, and equipment are estimated to amount to $300 to $500 annually per waterfowl hunter. The estimated annual value of waterfowl hunting in the State of Maryland is 10.5 to 17.5 million dollars.

NON-CONSUMPTIVE UTILIZATION OF RESOURCES

The wetland and upland habitat as well as the waters of the Bay and its tributaries provide habitats which support an extensive variety of flora and fauna. These organisms provide a source of recreation to large numbers of people who enjoy birdwatching, nature walking and nature photography. Research indicates that the number of people in the U.S. in 1970 that participated in these non-consumptive outdoor activities was about 9 percent higher than the number of people fishing and hunting. Aside from the enjoyment which is gained from an association with the natural resources of the area, the Bay, its tributaries, associated wetlands, and upland areas provide valuable educational services as classrooms for natural science studies.

Bird Watching - A Non-Consumptive Outdoor Activity.

EXISTING PROBLEMS AND CONFLICTS

With growth of the population and development of the economy in the Bay Area, conflicts have arisen between the need for more intensive use of the existing land and water resources and the need for these same resources to maintain fish and wildlife populations. This is especially true in the wetland areas where dredge-and-fill operations have been performed to develop industrial and agricultural lands, and to provide for second home development, and marinas.

Water quality problems, which have also become more pronounced with increased economic development and population growth, have serious implications for fish and wildlife. Almost every activity of man in the Chesapeake Bay Area produces a waste product that often is most conveniently dumped in a nearby river or stream. These tributaries invariably flow to the Bay. Problems that result are as varied as the constituents themselves. With the many new substances being developed each year, the task of assessing the effects on the environment of the resulting effluents and the possible interrelationships between constituent and other variables, such as temperature and salinity, may already be impossible.

Conflicts and problems also arise within the internal workings of the various elements of the fish and wildlife management structure. This is because management of the wildlife, fisheries, and shellfish resources of the Chesapeake Bay and its tributaries is

the responsibility of several organizations including the Federal Government, the States of Maryland, Delaware, and Virginia, and the Potomac River Fisheries Commission. The inconsistencies in laws promulgated by these organizations create conflicts in the management practices and utilization of the resource. In the case of migratory birds, for example, the basic regulations regarding bag limits and the number of days a species may be hunted during a season are set by Federal regulation. However, the actual dates for the opening of a season are determined by the States under guidelines set forth by the Federal regulations. The hunters of a state having a later opening date, therefore, often feel that they will have a decreased chance for success since the species sought has been previously hunted in a neighboring state and may be "gun shy." Crabbing regulations are another example of this type of problem. Virginia allows the dredging of wintering crabs which are buried in the Bay bottom while Maryland forbids this activity. Many Marylanders feel that this dredging depletes the supply of crabs which would be available to them the following season. Also, the management and regulation of anadromous fish catches in the Lower Chesapeake Bay obviously affects the fishery in the Upper Bay. For example, concentrated offshore fishing efforts for herring (under the jurisdiction of the Federal Government) have greatly reduced the spawning runs of this species in the Bay each spring.

Fluctuations that occur in finfish and shellfish populations are another problem to be considered. Historically, the populations of many species have varied cyclically over periods of years, due to complex biological factors such as predator-prey relationships; physical and chemical factors such as changes in salinities due to long term drought or rainy periods; or man-caused factors such as pollution or level of exploitation of the resource. These causative factors are far from being understood, much less controlled. Fluctuations in Maryland blue crab populations, as indicated by landings, are a classic example of this "boom" or "bust" phenomenon. For example, in the State of Maryland between 1953 and 1957 the catch went from 28 million bushels down to 16 million and then back up to slightly less than 32 million bushels. The all-time record low harvest for Maryland of 10 million bushels in 1968 was followed in 1969 by a respectable 25 million bushels (the all-time record high for the State was 37 million bushels). There are at least two major factors in explaining the volatility of the blue crab population. First, its short life span of two to three years creates a high "turnover" of crabs. Second, the crabs caught in Maryland are transported as larva and tiny crabs from their spawning grounds in Virginia into the upper Estuary. The condition of the upper Estuary when the young crabs arrive and the physical, chemical, and biological stresses they must endure during their journey are critical to the Maryland harvest the following years. It is interesting to note that in 1968 when the Maryland catch dropped by nearly two-thirds, the Virginia catch was off by only about one-fifth.

The striped bass population in Chesapeake Bay also follows distinct cycles. There are several factors suspected of producing a "dominant-year class" including some little understood biological mechanism which triggers a larger than normal hatch when the adult population has declined below a certain level. This phenomenon has also been observed in other species. Some researchers believe that the number of rockfish (striped bass) in the Bay is inversely related to the bluefish population since the more aggressive bluefish compete for the same food supply and even prey on the young striped bass. As the blue crab and striped bass examples indicate, often drastic fluctuations in species populations are a natural phenomenon. However, since the reasons for this phenomenon are not completely understood, it is extremely difficult to separate the natural fluctuations from fluctuations caused by man-related factors such as excess nutrients, thermal effluents, sedimentation, or other pollutants.

FUTURE FISH AND WILDLIFE NEEDS

FINFISH AND SHELLFISH

Needs for fish and shellfish resources were obtained through comparison of future demand with available supply. Functions of future demand involved such parameters as market price, projections of commercial and recreational catch, and costs of the harvesting effort. Population dynamics for each species were based, in part, on estimates of maximum sustainable yields (MSY's). MSY's are defined as the greatest harvest which can be taken from a population without affecting subsequent harvests.

Typical supply versus demand curves are shown in Figure 32 to illustrate the relationship between MSY, supply, demand, and commodity price. The term "supply" refers only to the amount commercially harvested. Excess demand is shown for the years 2000 and 2020 where the demand curves do not intersect the supply curve. In these cases, sufficient supplies cannot be had at any price since the MSY has been exceeded. Sustained harvesting beyond the MSY results in eventual decline in the species population due to overharvesting. As total harvest of a species approaches MSY, it was assumed that recreational catches will have precedence over those in the commercial sector. As a result, commercial catches of many recreationally important species are actually projected to decline over the projection period.

Results of the analysis, conducted as described above for each species, are shown in Table 36. All of the commercially and recreationally important species, with four exceptions, are projected to experience commercial and recreational pressures which will exceed their MSY's at some time during the projection period. MSY is expected to be exceeded for half of the species by the year 2000. Of this latter group, with the exception of the blue crab and American eel, projected increases in recreational catches are the major reason for the early exceedence of MSY. Oysters, soft clams, menhaden, and alewife are primarily commercial species which explains, at least in part, the later period for MSY exceedence. Catfish, scup, sea bass, and yellow perch populations are capable of withstanding significant increases in fishing intensity, without adverse effect. All four species are underutilized commercially for a

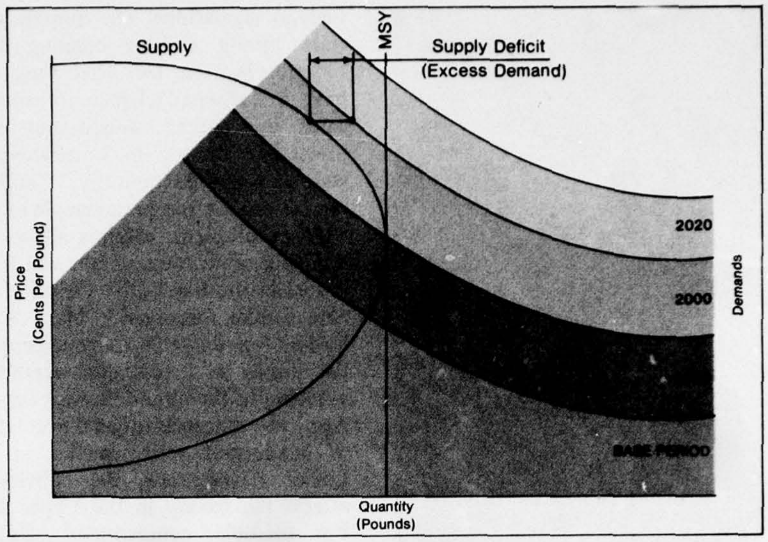


Figure 32: Fisheries Supply and Demand Functions

TABLE 36
PROJECTED PERIOD OF EXCEEDENCE OF MAXIMUM SUSTAINABLE YIELD (MSY) FOR THE MAJOR COMMERCIAL AND SPORTS SPECIES

	Base Year Catches*		Period of MSY Exceedence		
Species	1,000 lbs	Percent MSY	Prior to 1980	1980-2000	2000-2020
Blue Crab	61,373	94		X	
Oysters	23,740	79			X
Softshell Clams	5,412	90			X
Menhaden	449,790	90			X
Alewife	21,110	84			X
Spot	14,193	96	X		
Striped Bass	11,159	96		X	
White Perch	7,225	64		X	
Shad	7,120	93		X	
Weakfish (Sea Trout)	5,174	81		X	
Flounder	4,575	89		X	
Catfish	2,440	54	(will not be exceeded before 2020)		
Scup	2,281	35	(will not be exceeded before 2020)		
Sea Bass	2,084	42	(will not be exceeded before 2020)		
American Eel	1,692	99			
Yellow Perch	1,511	44	(will not be exceeded before 2020)		

* Represents commercial plus recreational catch except for blue crabs, oysters, and soft clams.

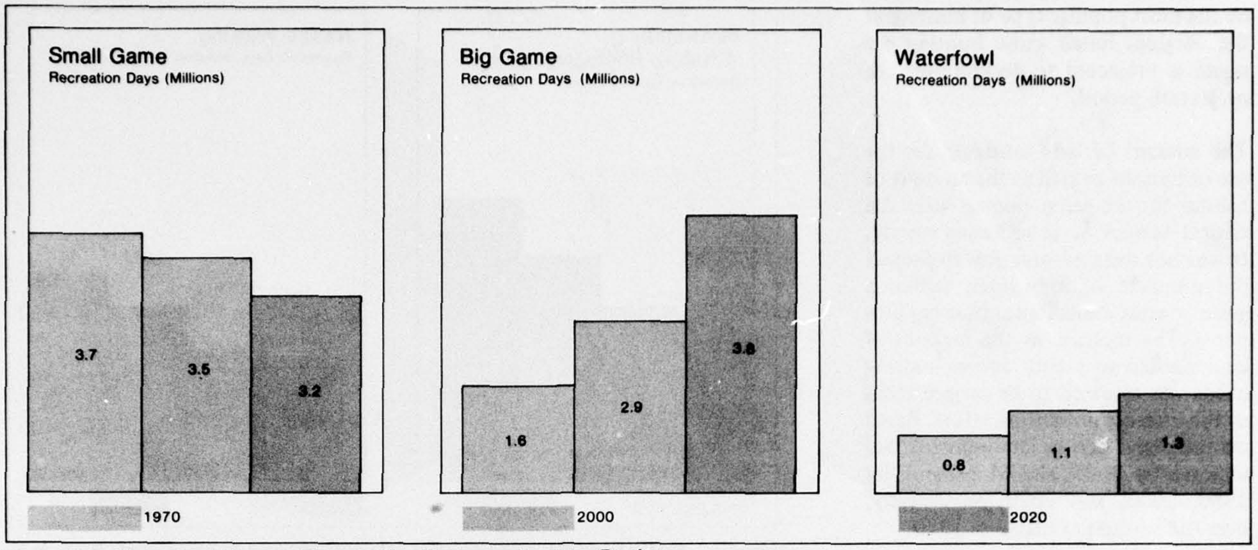


Figure 33: Projected Hunter Effort in the Chesapeake Bay Region

number of social and economic reasons.

It should be noted that as commercial and recreational demands increase relative to the capacity of the fisheries, the market system responds by increasing prices. For example, the prices, after adjustment for inflation, of blue crabs, oysters, and striped bass are expected to increase by 525 percent, 194 percent, and 967 percent, respectively, between 1970 and 2020. The upward pressure on prices is especially acute due to the basic assumption used in the analysis that as catches approach MSY, recreational utilization of these finfish and shellfish species will take precedence over commercial uses.

THE HARVESTING AND PROCESSING SECTORS

Future needs in the harvesting and processing sectors of the commercial fisheries industry will be affected by the projections of future market price and demand presented in the previous section. The decrease in commercial landings indicated for a majority of the finfish species for which projections were made was interpreted as revealing a contraction in the finfish segment of the *harvesting* sector. While increases in commercial landings of some finfish species were revealed, most notably yellow perch, catfish, sea bass, and alewife, these are not considered to be large enough to offset the employment losses in the declining fisheries.

Of the projections made for the three shellfish species, the predicted increases in oyster landings was the only result considered to be significant to the harvesting sector. The predicted landing increases, however, cannot be interpreted as implying a need for expansion of employment in the oyster harvesting industry. Of critical importance is the present capacity of the oyster fishery and the degree to which it is utilized. Currently, in Maryland, for example, each licensed oysterman is limited to a catch of 25 bushels per day. Assuming two persons per rig, the catch limit would be 50 bushels. Experience has indicated that various rigs are capable of harvesting two or three times this quantity. In light of this, it was concluded that the present capacity of the harvesting sector of the oyster industry would be sufficient to meet future demands.

The future of the processing sector was found to be a function of the projections for alewife, menhaden, oyster, blue crabs, and clams. Since commercial catches of these species are generally expected to increase or remain fairly constant over the projection period, the projections of yield appear, at a minimum, to be capable of supporting a processing sector of current size and degree of utilization.

WILDLIFE

Future needs for wildlife in the Chesapeake Bay Area were determined in terms of recreation days of hunter participation for small game, big game, and waterfowl. Hunting demands were based on license price, population, and expected hunter participation rates. For big game, since hunter effort in this category has historically been insensitive to license price, projections were made a function of population only. The projected demands for small game and waterfowl hunting were made based on the assumption that license prices will increase in the future.

As shown in Figure 33, waterfowl hunting, perhaps economically the most important type of hunting effort in the Bay Region, is projected to increase by 70 percent during the projection period. Big game hunting is projected to increase at the highest rate of any of the three types of hunting effort in the Bay Region (141 percent) and by 2020 is expected to be the most popular type of hunting in the Region. Small game hunting demand is projected to decline over the projection period.

The amount of land available for the use of hunters as well as the amount of habitat for the game animals were the critical factors in determining supply. It was not deemed practical to project the numbers of individuals within a given species available for hunting purposes. The increase in the amount of land needed to satisfy future hunting needs was assumed to be proportional to the increase in hunting effort. Based on this, land access requirements will increase by 7, 35, and 61 percent, by 1980, 2000, and 2020, respectively, over the amount available in 1970.

Factors affecting the accessibility of land to hunters, and the maintenance and health of game populations include:

1) conversion of farm and woodlands to urban and suburban land uses;

2) reluctance of land owners to open private lands to recreationists;

3) single-purpose leasing of agricultural and other lands for hunting;

4) impact of large-scale modern farming on reduction of habitat;

5) single species tree farming practices which decrease wildlife use;

6) use of herbicides for weed control which eliminates small game habitat.

NON-CONSUMPTIVE WILDLIFE

Future needs for wildlife to support such non-consumptive uses as bird watching, wildlife photography, and just plain enjoyment of nature, are expected to increase with future population and increases in leisure time. As shown in Figure 34, non-consumptive wildlife utilization in terms of recreation days in the Chesapeake Bay Area (excluding nature walking) is projected to increase at a slightly higher rate than the population. Nature walking is expected to increase at a rate equal to population growth. A total increase of 34.6 million recreation days is projected to occur by the year 2020.

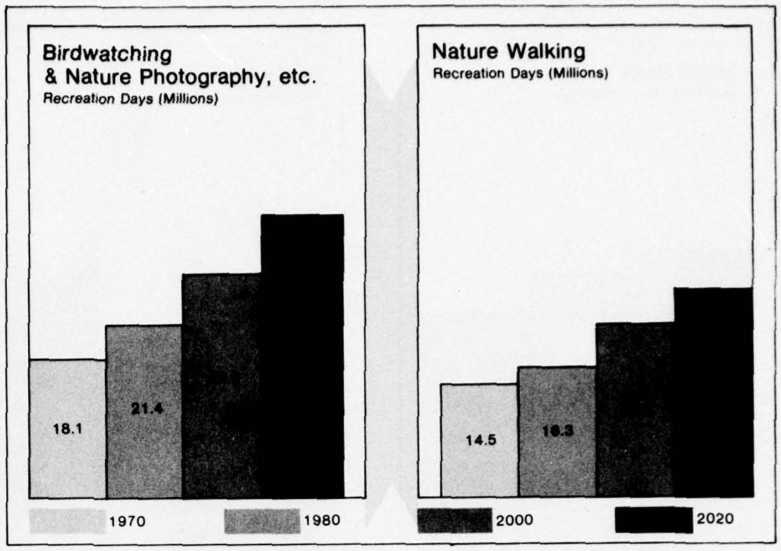


Figure 34: Projected Non-Consumptive Wildlife-Related Outdoor Activity in the Chesapeake Bay Region

As in the hunting analysis, the factors most affecting the provision of a quality non-consumptive recreational experience are the availability of suitable habitats for wildlife and the provision of public access. At the present time the amount of land and wildlife habitat which is available to the non-consumptive resource user in the Study Area includes about 814,000 acres of public, semi-public and park lands. An additional 11.5 million acres of privately owned agricultural lands, woodlands and wetlands are located in the Bay, an unknown quantity of which is accessible to the public. Assuming a constant percentage of the resources users will continue to use the non-public areas, future projections can be made regarding the acreage of public lands required to provide non-consumptive resources users with an experience of equal quality to the present recreational experience. These projections are shown in Table 37.

TABLE 37
PUBLIC LAND REQUIRED TO MEET FUTURE NON-CONSUMPTIVE RECREATIONAL DEMAND

Year	Number of Rec Days	Acres of Public Land
1970	18,130,000	814,000
1980	21,448,000	964,000
2000	30,871,000	1,387,000
2020	41,078,000	1,845,000

The most significant problem facing the provision of land for non-consumptive wildlife purposes is the inevitable conflicts with other land uses in a developing area such as the Chesapeake Bay Region. For the bird watcher, wildlife photographer, and nature walker, a quality experience relies upon a variety and abundance of wildlife in a natural uncrowded setting. Because of expected increases in population and development pressures, there is a threat of degradation in many areas. For example, the development of lands adjacent to recreational areas may cause overutilization, noise, and the disappearance of seclusive species, all of which reduce the desirability of the area.

MEANS TO SATISFY THE NEEDS

SHELLFISH

Demands for oysters, blue crabs, and softshell clams are projected to exceed MSY by the end of the projection period. The supply of oysters can, and presently is, being supplemented by the management and cultivation of the species by both State and private interests. More intensive effort in this regard would help to satisfy the expected demands over the projection period. The cultivation of softshell clams, while not presently practiced, is a possible means of meeting excess demands for this species. The possibility also exists that other species may be harvested to fulfill some of the demand for softshell clams. The substitution could derive from an increased harvest of hard clams (which unfortunately are already over harvested in some areas), or more likely from utilization of a species such as the brackish water clam *(Rangia cuneata)*, which at present is not sought commercially.

The cost of culture practices for blue crabs would probably be prohibitive due to fluctuations in the natural supply and market price. This variability would keep the culture of the species from being profitable on a regular basis. Thus, if the need is to be satisfied, it will probably be by increasing the blue crab harvest in other areas such as South Carolina or Louisiana and importing into the Bay Region.

INDUSTRIAL FINFISH

The demand for both menhaden and alewife, the major industrial species in Chesapeake Bay, is projected to exceed the MSY by 2020. Since artificial cultivation of most estuarine finfish species is either uneconomical or impractical, substitute species or products will have to be found in order to fulfill the needs for the products derived from these species. For example, soy beans are currently being processed to produce many products which can be substituted for menhaden and alewife. Agriculture cannot, however, be considered as the ultimate solution to meeting these demands since the production capabilities of these lands are finite and they must also be used to meet the demands for other products.

NON-INDUSTRIAL FINFISH

Edible species commonly sought by sport and commercial fishermen in the Bay include white perch, striped bass, shad, flounder, spot, weakfish, eel, yellow perch, sea bass, scup, and catfish. Of these eleven species only the last four are projected to have supplies that will meet the demands through the year 2020 as shown earlier in Table 36. When considering the means to satisfy the needs for these species, a first alternative might be a management program to insure increased production of these species by improving habitat, or by controlling the harvest of individual species based on population surveys.

If management practices are to be effectively implemented on a Bay-wide basis, records of the sport fishing utilization are necessary. One method of providing this information and at the same time providing funds for the initiation of management and research programs would be through the sale of salt water fishing licenses. Although this proposal has been suggested and rejected previously, it is still a viable method for gaining the data and knowledge necessary to insure continuance of a quality fishery in the Bay.

The harvest of under-utilized species has provided an interim solution to the fulfillment of the needs for fisheries products on previous occasions and could be an aid in the fulfillment of the needs for overall production in the future. Care should be taken, however, to provide management practices to protect the under-utilized species from depletion once a market is opened. Such exploitation has occurred with the surf clam. Because of a lack of restrictions and an available market, vast areas of once productive surf clam beds have been rapidly depleted.

WILDLIFE

The lack of information concerning factors that influence the population of many wildlife species, and possible future changes in human utilization of these species hinders an accurate determination of future needs. Due to this, any consideration of the means to satisfy the needs must, of necessity, be in generalized terms. Because the projections indicate greatly increased demands for wildlife resources, the means to be discussed in this section will include methods for increasing supply and availability.

As implied previously, the problem of maintaining an adequate supply of wildlife to meet all our projected needs must be considered on two levels—the primary level being the requirements that must be met in order for wildlife to sustain viable populations; the secondary level being a problem of providing access to the wildlife for human use. As is the case with public acquisition of key wildlife habitat, the solution to these two problems may coincide.

Other than the actual hunting of the animals, wildlife populations are impacted by two major areas of man's activities. These are land use and pollution, with land use probably the most significant.

If the land use problem is to be resolved, a firm commitment on the part of the public and responsible public officials will be required to conserve existing desirable wildlife habitat, reclaim certain lands to support desired wildlife types, acquire additional public lands, and discourage land use practices which are unnecessarily destructive of wildlife habitat. These measures would help insure stabilization and enhancement of wildlife populations. Strict zoning will be required to regulate land use. Coupled with zoning, purchasing mechanisms such as bond issues should be developed to buy those lands considered especially important to wildlife. If purchase is not desirable, then long-term leasing arrangements offer an alternative, in conjunction with tax incentives to affected land owners.

Pollution, a by-product of civilization, also has a significant effect on wildlife populations. A prime example of the adverse impact of pollution on wildlife is the absence of many species of fish-eating furbearers along stretches of water that are polluted. Other examples include the impact of chlorinated hydrocarbons on the reproductive success of fish-eating carnivorous birds such as the osprey and bald eagle, and the as yet unknown effects of trace metal consumption by certain species of waterfowl and shore and wading birds. Oil pollution can also cause a serious adverse impact on aquatic oriented bird populations. In the Bay Region, thousands of bird deaths have resulted from oil spills. The solution to this type of problem lies with careful and thorough enforcement of existing pollution control laws and with the vigorous pursuit of new technology to control and abate pollution sources.

Other than the need for viable wildlife populations themselves, is the need for increased land access to the resource. Purchase of additional lands particularly valuable to wildlife certainly offers a partial solution to meeting these needs. Land purchase, of course, should not be considered a complete answer to land access shortages. Combined with purchase of lands especially valuable to wildlife, a program of wildlife access leases could also be instituted. Such leases could be an adjunct to the wildlife management leases previously proposed. The purpose of the combined wildlife management and access lease would be to provide large areas where wildlife habitat can be actively managed and where access by the wildlife viewer and hunter would be allowed on a managed basis. A fee for all wildlife users

An Ospray on Its Nest.

could be charged to supply funding for the program. Success of such a program would depend to a large extent on cooperation between the wildlife utilization groups, the involved state agencies, and the individual land owners.

There are undoubtedly numerous other approaches to the problems. A key realization that must underlie any successful solution is that the threat to fish and wildlife is not the sole responsibility of the sport and commercial fisherman nor the hunter or commercial trapper. The real threats to these resources are adverse land and water uses and an apathetic attitude on the part of the public toward preserving fish and wildlife habitat. If these factors can be incorporated into a comprehensive conservation, enhancement, and preservation program directed toward maintaining quality habitat, then an effective program can be developed to balance human utilization with the productive capability of the resource. Until such programs are in effect the resource manager will be faced with a continuously dwindling resource base and a concurrent and continuous increase in resource needs.

ELECTRIC POWER

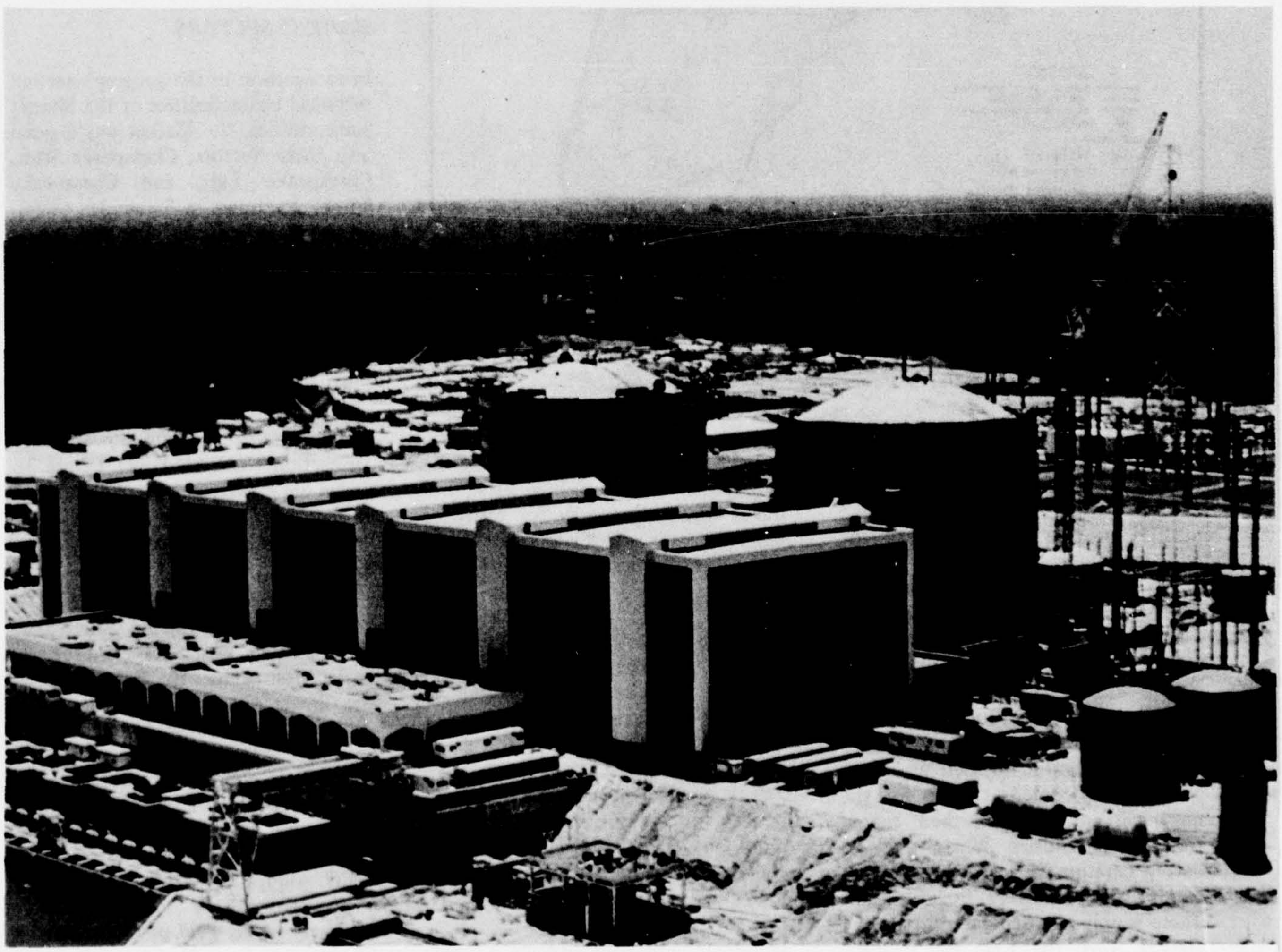
CURRENT STATUS

POWER REQUIREMENTS AND GENERATING FACILITIES

In studying the electric power resources of Chesapeake Bay, a geographic area encompassing the electric utilities serving the Bay Region was defined. This area, the Chesapeake Bay Market Area, is delineated in Figure 35.

The total number of utilities serving the Chesapeake Market Area is 74. The utilities are of varied ownerships:

A Nuclear Power Plant Under Construction.



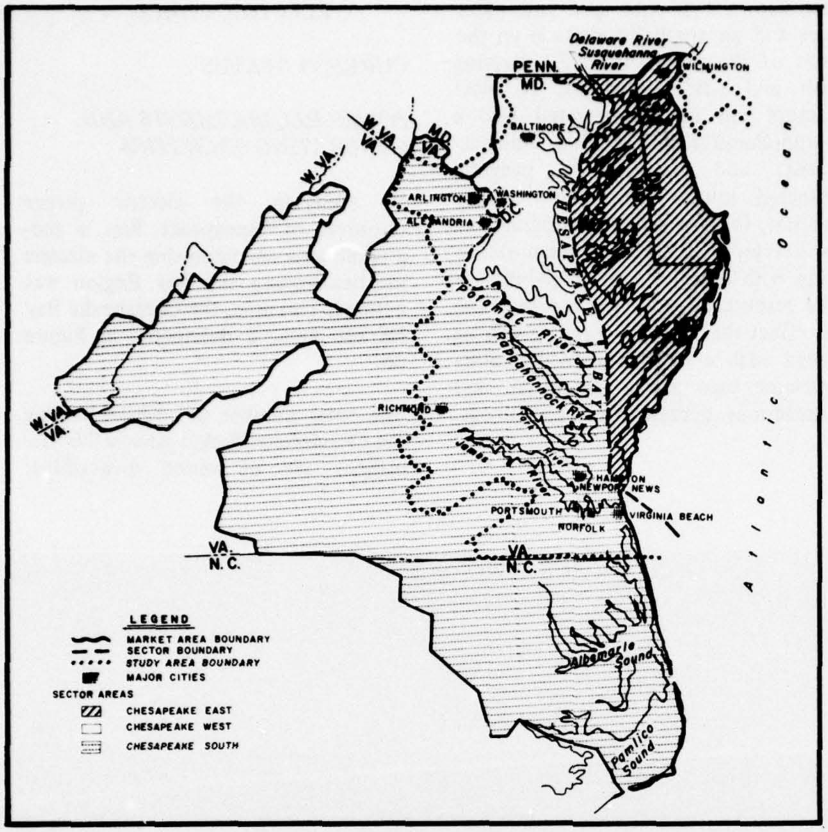


Figure 35: Chesapeake Bay Market Sector and Study Area

private corporations, municipalities, consumer cooperatives, and the Federal government. Investor-owned utilities provide 90 percent of the energy requirements for the Market and are responsible for 95 percent of the electricity generated. They also operate virtually all of the transmission facilities. The municipally-owned utilities are small and derive most or all of their energy from the large investor-owned utilities with only minimal generation of their own. The cooperatively-owned utilities for the most part purchase all their energy from other utilities. Where they do have generating capacity, it is in small plants with relatively little output. There is only one Federal utility in the Market Area, the Kerr and Philpott Project. This project, operated by the U.S. Army Corps of Engineers, produces wholesale energy for many of the cooperatives in Chesapeake South and other utilities outside the Market Area.

The utilities within the Chesapeake Market Area operate as bulk power suppliers, wholesale generators, or wholesale purchasers. The bulk power suppliers operate substantially all of the generating and transmission facilities in the Chesapeake Market. They, besides furnishing their own franchise requirements, sell large amounts of energy to other utilities, mainly municipals and cooperatives.

Wholesale generators operate a generating plant and sometimes associated transmission lines and sell the entire output to other utilities under long-term contracts. There are two such utilities in the Market Area, the Kerr and Philpott Project and Susquehanna Electric Company; both operate hydroelectic plants.

Wholesale purchasers are the most numerous of the utilities in the Chesapeake Market. They buy energy at bulk rates from bulk power suppliers or wholesale generators and resell it to their own retail customers. In several instances the purchased energy is supplemented by a minor amount of self-generation. They are of municipal, investor, or cooperative ownership.

MARKET SECTORS

In recognition of the geographical and technical characteristics of the Market Area utilities, the Market was divided into three Sectors: Chesapeake West, Chesapeake East, and Chesapeake South. As shown in Figure 35, Chesapeake West includes the Baltimore-Washington corridor of the Pennsylvania-New Jersey-Maryland power interconnection (PJM Pool); Chesapeake East takes in the Delmarva Peninsula portion of the PJM Pool; and Chesapeake South covers the Virginia portion of the Virginia-North Carolina-South Carolina power interconnection (VACAR Pool). Figure 36 shows the relative energy requirements in each market sector as of 1972. A brief description of each sector follows.

a. *Chesapeake West.* There are three utilities which serve the Chesapeake West sector: the Potomac Electric Power Company, Baltimore Gas and Electric Company, and the Southern Maryland Electric Cooperative. The energy requirements of Chesapeake West in 1972 were 28,252 gigawatthours while the amount of energy generated was 32,311 gigawatthours. Almost all of this excess energy was delivered to more northerly members of the PJM pool outside the Chesapeake Bay Market with only

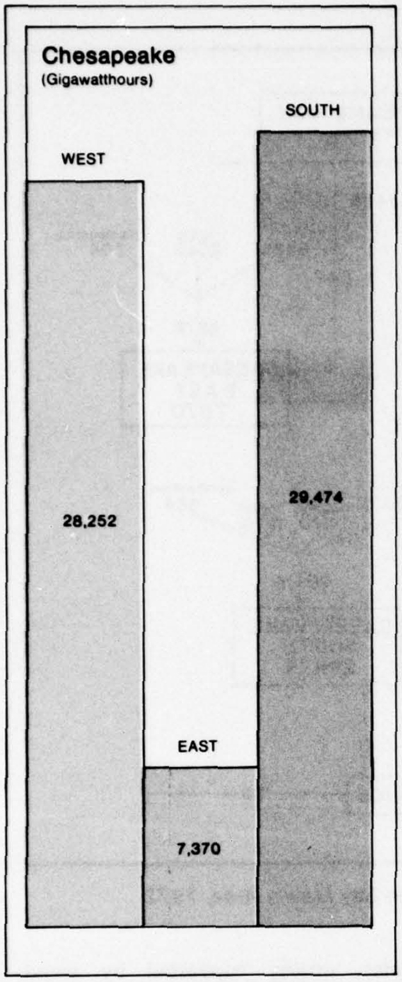


Figure 36: Total Energy Requirements of Chesapeake Bay Market Sectors, 1972

minor amounts flowing into Cheapeake South. The generating facilities are all in investor-owned utilities with 86 percent of the total generation accounted for by fossil steam plants and the remainder by combustion plants. Southern Maryland Electric Cooperative purchases its entire needs from the Potomac Electric Power Company. It is the largest cooperative in the Market Area with energy requirements in 1972 of 676 gigawatthours.

b. *Chesapeake East.* Chesapeake East has 24 utilities: 8 investor-owned, 13 municipally-owned, and 3 cooperatives. The largest investor-owned utility, Delmarva Power and Light Company, supplies more than half of the Sector's energy requirements and accounts for about 2/3 of its generation. The energy used in this Sector in 1972 was 7,370 gigawatthours while 8,876 gigawatthours was generated. Approximately 65 percent of the energy was generated in fossil steam plants, 11 percent in combustion facilities, and 24 percent in a single hydroelectric plant at Conowingo on the Susquehanna River in Maryland. The bulk of the excess generation came from the hydroelectric plant and was delivered to the more northernly parts of the PJM Pool beyond the Market boundaries. Easton Municipal, the Market Area's only isolated utility, is located in Chesapeake East. Easton's entire energy requirements of 75 gigawatthours in 1972 were furnished by this combustion plant.

c. *Chesapeake South.* Three investor-owned utilities, 23 municipals, 20 cooperatives, and one Federally-operated project serve Chesapeake South. The energy requirement of this Sector in 1972 was 29,474 gigawatthours while 26,414 gigawatthours were generated. There was a modest net import of electricity, almost entirely from outside the Chesapeake Bay Market Area. Virginia Electric and Power Company accounting for about 90% of both energy and generation is the major utility in Chesapeake South. The only other significant generation in the Sector is at the Kerr and Philpott Project of the Corps of Engineers. This project produced 698 gigawatthours from its two hydroelectric plants, which was delivered at wholesale rates to cooperatives in the Sector and certain utilities beyond the Market boundaries. Fossil fuel steam plants accounted for 70 percent of total generating capacity, nuclear steam for 13 percent, combustion plants for 9 percent, and hydro facilities for 8 percent.

Fossil Fueled Power Plant.

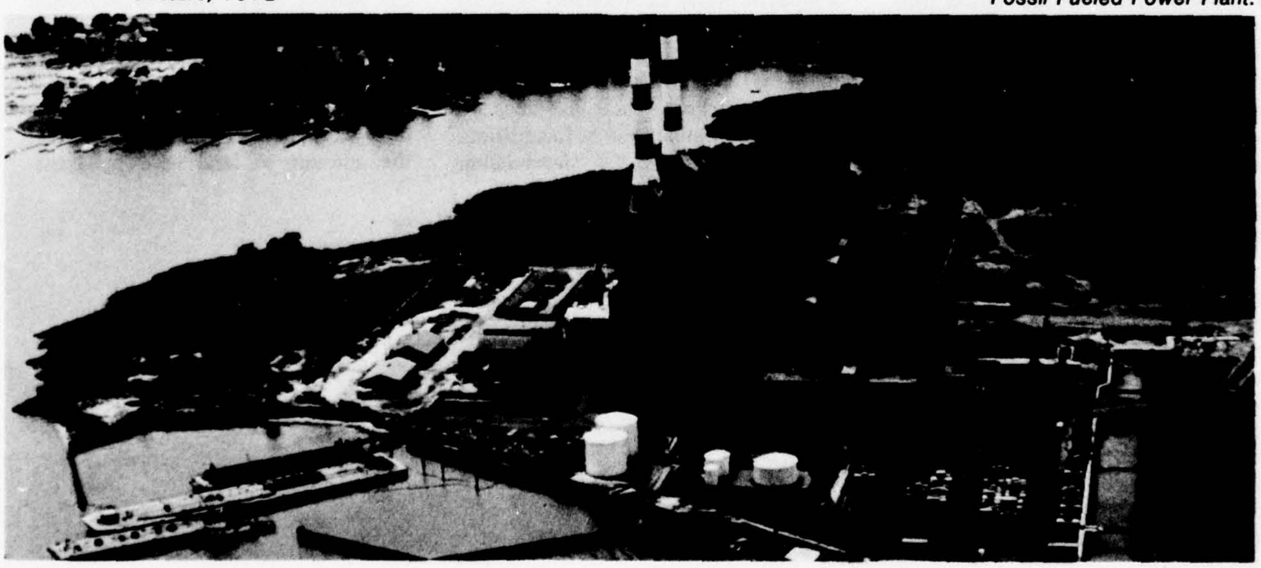


Figure 37 shows the "energy account" for the Chesapeake Bay Market Area in 1972. This energy account is a flowchart showing the source and disposition of energy for each of the three Sectors. For example, in Chesapeake East, 8,876 gigawatthours of electricity were generated during the year–6,429 by fossil fuel plants, 2,243 by hydroelectric plants and 204 by combustion plants. Of the total generation of 8,876 gigawatthours, 2,426 were sold to customers outside the Chesapeake Bay Market Area. On the other hand, utilities in the Chesapeake East Sector bought 847 gigawatthours of electricity from utilities outside the Market Area. In addition, 73 gigawatthours of electricity were bought from industrial and commercial concerns in the Market Area which operate generating plants for their own internal use. The 7,370 gigawatthours figure represents the total energy requirements of the Chesapeake East Sector–the net sum of total generation, receipts, and deliveries. Similar, more detailed energy accounts are presented for each Sector in Appendix 13–"Electric Power."

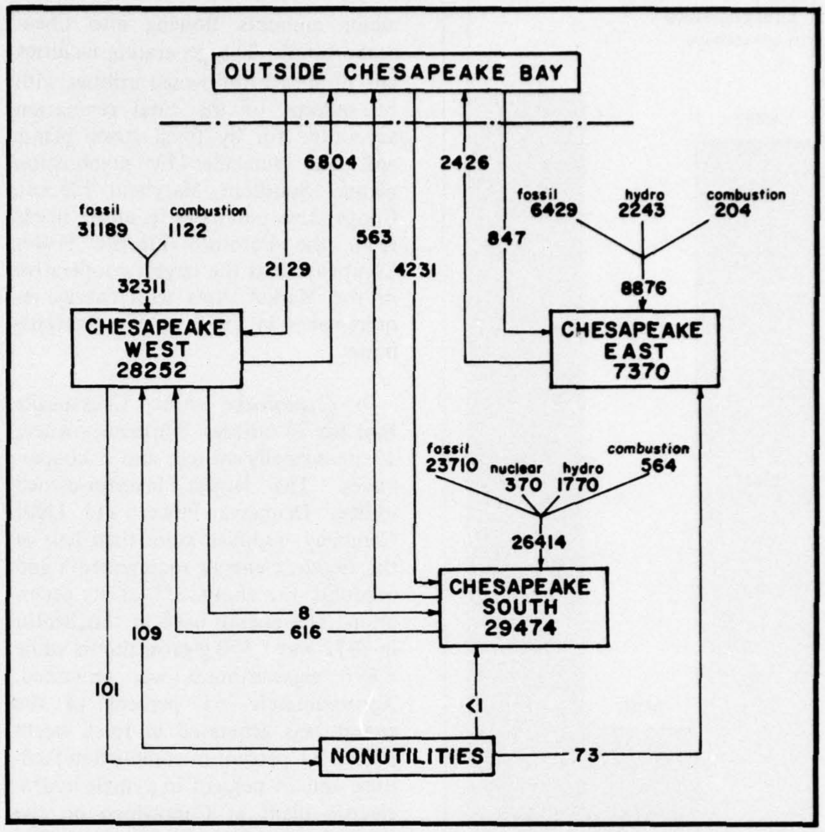


Figure 37: Energy Account for Chesapeake Bay Market Area, 1972

EXISTING POWER FACILITIES

As shown on Table 38, approximately 91 percent of the electric power produced in the Market Area was generated by fossil steam generation plants using coal, oil, or gas as fuels. Oil was the most frequently used type of fossil fuel in 1972. The remainder of the electricity was produced by hydropower, nuclear or combustion facilities. The only nuclear plant in operation at the time in the Market Area (located at Surry, Virginia) operated at less than full capacity during 1972. In 1973, the first year of full service for the plant, approximately 6,900 gigawatthours of electricity were produced. Another nuclear plant of similar capacity began operations in May, 1975 at Calvert Cliffs, Maryland. Shown in Figure 38 are the power plants which were located in the Chesapeake Bay Market Area in 1972.

In addition to the power plants themselves, many miles of major transmission lines are required in order for a modern utility to efficiently serve its customers. The Chesapeake Bay Market Area has approximately 2,672 miles of 230 to 500 kilovolt (KV) transmission lines. These size lines are supported by steel towers. In addition, 131 miles of 138 KV transmission lines, usually supported by wood frames although steel poles and towers are occasionally used, are located in the Market Area. These transmission lines have obvious adverse visual impacts on the environment and when the amount of right-of-way required is considered, they consume a surprisingly large amount of land. In 1972, the amount of land used by trans-

TABLE 38
PERCENT CONTRIBUTION OF FUEL TYPES
TO TOTAL ELECTRIC GENERATION – 1972

	Fossil Steam Generation					
Sector	Coal	Oil	Gas	Hydropower	Nuclear	Combustion
Chesapeake East	29	42	2	25	–	2
Chesapeake West	48	48	–	–	–	4
Chesapeake South	26	64	–	7	1	2
TOTAL MARKET AREA	36	54	<1	6	<1	3

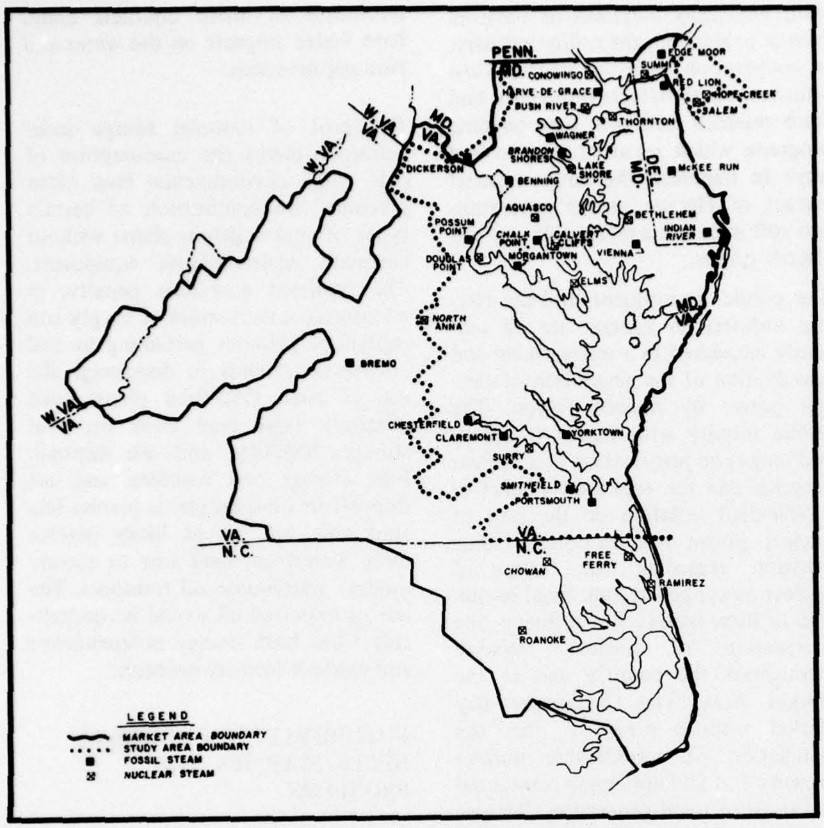


Figure 38: Chesapeake Bay Power Plant Location Map, 1972

mission lines and right-of-ways amounted to approximately 54,000 acres.

COOLING WATER REQUIREMENTS

The production of electricity by the steam cycle involves the condensation of exhaust steam back to water and the consequent release of waste heat. Nearly all existing steam-electric plants use cooling water in the process of removing the waste heat from the power generating system. The heated cooling water, having accomplished its task is returned to its source, in this case, usually Chesapeake Bay or one of its tributaries.

All but three of the steam plants in the Chesapeake Market employ "once-through" cooling (i.e., as opposed to re-cycled cooling waters). The rate of flow of the cooling water through the plant and the rise in cooling water temperature differ among plants because of variations in design and operating conditions of the facility. There is only a slight consumptive use of water in the once-through system due to the small evaporative losses caused by the increased temperature of the cooling water discharge. In general, the temperature rise of cooling water in the plant is usually in the range of 10°F to 25°F (6°C to 14°C). Maximum allowable temperature increases are established by Federal and State regulations. Large nuclear steam-electric plants, however, require approximately 50 percent more cooling water for a given temperature rise than a fossil plant of equal size. This has a great deal of significance since, as shown in the next section, nuclear plants are projected to supply a much larger portion of the Region's energy requirements in the future. Where adequate supplies of natural water are available, the once-through cooling system is usually adopted because it is the most economical method of cooling.

Where natural bodies of water of adequate size are not available at the site, or are excluded from use by water quality standards, cooling ponds or towers may be constructed. The only cooling pond installation contemplated for the Chesapeake Bay Study Area is at the North Anna plant on the North Anna River in Virginia which is presently under construction. Where cooling towers are used, the heated water is cooled for reuse by a stream of flowing air. The air flow is usually a natural draft rising through the tower which is contoured to create the necessary circulatory conditions. Such natural draft towers are huge structures, about 300 feet in diameter at the base and some 450 feet tall. Each tower provides cooling for a generating plant of about 500 to 1,000 megawatts.

In the "wet cooling tower" the warm water is sprayed into the stream of flowing air. This facilitates the heat dissipation by evaporation as air moves through the tower. The cooled water is collected in a basin under the tower from which it can be pumped back to the plant for reuse. The water which is lost through evaporation is replaced by withdrawals from a local natural water body. Currently, there is only one natural draft wet cooling tower in operation in the Chesapeake Bay Market Area. This plant is located at Chalk Point, Maryland, and has been in operation since 1975. However, many cooling towers of this type are included in the plans for facilities scheduled to be constructed in the future.

EXISTING PROBLEMS AND CONFLICTS

In addition to the conflicts of use which may arise in the Study Area as a result of multiple demands for water or land, the resolution of certain social issues currently affecting the utility industry could also influence use of water and land for the generation of electric power in the Study Area.

Prevailing controversies concerning the generation of electric power and its impact on the environment include such issues as esthetics, air pollution, water quality, impingement and entrainment of fish, radiological effects, and the disposal of nuclear wastes.

Steam generating plants are expansive installations that can present a relatively unsightly overall appearance and hydroelectric plants can often intrude on scenic areas. Both entail competitive use of water and may preclude other esthetic developments. Concealment of transmission towers and transmission lines is sometimes difficult; they cannot always be placed out of view or effectively blended into the surroundings.

The types and quantities of emissions from the combustion of fossil fuels in the production of electric power created a demand for air pollution control as a major siting criteria in planning future plants. The necessity for large quantities of cooling water introduces problems of fish impingement, entrapment, and entrainment. The effects of releasing this water in a heated condition and its impact on aquatic life are other issues of controversy. Environmental regulations currently prescribe the use of a closed cycle cooling system for generating units to be installed in 1985 and thereafter. The resulting reduction of heat input to the cooling water source is offset by an approximately twofold increase in evaporative water consumption. The varied impacts of the thermal and consumption effects may exchange an apparent current problem for a potential future problem.

During their operation nuclear power plants are permitted to release, under well controlled and carefully monitored conditions, low levels of radioactivity. Current technologies for the treatment and storage of radioactive wastes are characterized as currently adequate. The adequacy of these technologies however, are controversial.

With increasing emphasis on environmental protection, the utility industry, in cooperation with the Federal Government, some state governments, and some research institutes, have ongoing programs which are attempting to find ways to minimize the environmental impact of electric power generation and still maintain a reasonable cost for electric power.

The public, government, and the electric industry in general are all currently enmeshed in a reassessment and reevaluation of the generation of electric power by nuclear fission. The public inquiry with regard to safety and long-term justification of a nuclear program and the economic impact of double-digit inflation on the cost of nuclear power has introduced some question regarding the future of nuclear power generation. Final resolution of these issues could influence the utilization of nuclear capacity throughout the country and in the Market Area. The Chesapeake Bay Market utilities presently plan the installation of considerable nuclear capacity but still anticipate substantial additions of fossil generation. Because of the lower thermal efficiencies of nuclear units, increasing nuclear capacity increases water use about 50 percent for each nuclear unit which replaces a comparably-sized fossil unit. Land use for plant siting is reduced because large fuel storage and handling areas, needed for coal or oil, are not required for nuclear fuel, but transmission rights-of-way could require more land because of the need to site nuclear facilities further from the population centers. Opportunities for joint use of the land would also tend to be less because of the remote locations, but such settings might be attractive for recreational development.

Should future events constrain the installation of additional nuclear capacity base load requirements would have to be met with generation by coal or oil. In this regard, conflicts between the national energy and environmental interests and between these interests and the economic vitality of the electric utilities are currently evident and resolution of these conflicts could have varied impacts on the water and land requirements.

The goal of national energy independence favors the consumption of coal while environmental laws often preclude the combustion of certain types of coal in power plants without adequate environmental equipment. The resultant economic penalty, in addition to uncertainties of supply and regulatory postures pertaining to coal combustion, tends to discourage the use of coal. Coal-fired plants need relatively large land areas for coal storage, handling, and ash disposal. Fuel storage and handling and ash disposal in oil-fired plants involve less land area but would likely involve more waterfront land area to accommodate waterborne oil transport. The use of imported oil would be undesirable from both energy independence and national security postures.

FUTURE ELECTRIC POWER NEEDS, SUPPLIES, AND PROBLEMS

PROJECTED DEMANDS

In general, the projections of demand in this analysis were developed by extrapolating various historical trends and subjectively modifying those trends to reflect judgements regarding factors currently in force and which could plausibly continue into the future. The projections chosen reflect a belief that growth in the use of electric power will continue but at a somewhat reduced rate. This approach is believed to be moderately conservative with regard to the potential for energy conservation but recognizes the significant role electric power will continue to play in the National economy.

Even with "conservative" growth rates, the total use of electricity in the Chesapeake Bay Market Area is expected to increase by a factor of over 5 times by the year 2000 and approximately 13.5 times by the end of the projection period. As shown in Figure 39, the Chesapeake South Sector

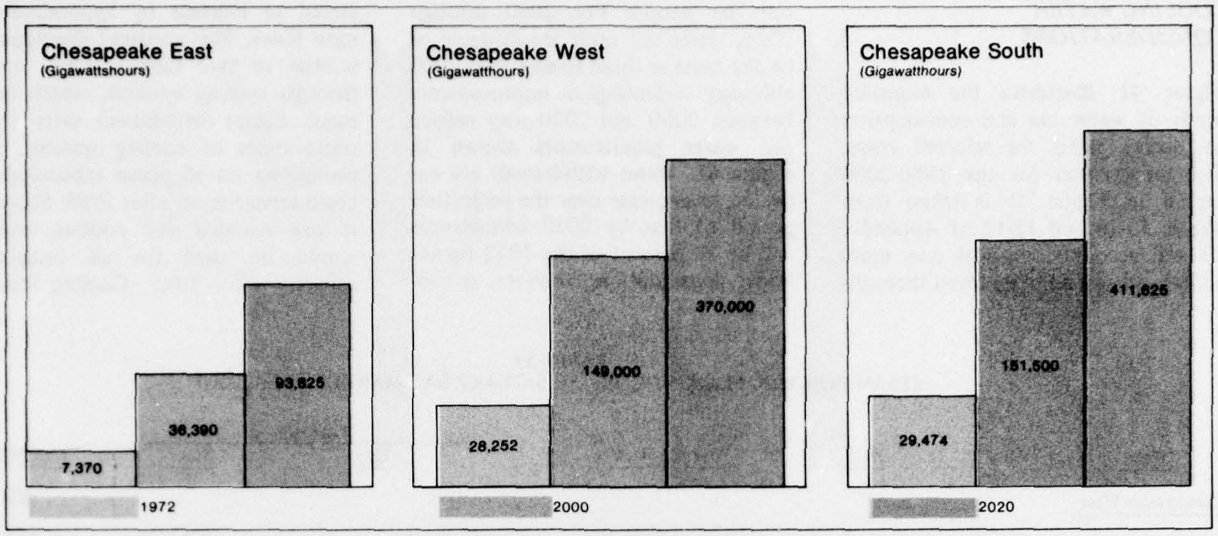


Figure 39: Projected Energy Requirements Including Peak Demand for Chesapeake Bay Market Areas

which includes the major metropolitan areas of Norfolk-Portsmouth, Hampton-Newport News, Richmond, and the Virginia suburbs of Washington, D.C. is expected to experience the highest rate of increase. While the rate of growth for the other Sectors are lower than those of Chesapeake South, the rates still reflect significant increases in electricity requirements for these sectors by the year 2020.

SUPPLY METHODOLOGY

The power supply facilities projected through 1985 are either in service, under construction or in the advanced design stage. Accordingly, the projected supply picture through this period reflects the generation already planned by utilities in the Market Area at this writing.

For the years after 1985 the supply program utilized current and expected trends in the relative proportions of steam generation to total generation and of nuclear generation to fossil. The capacity projected assumes all units projected for meeting Market Area loads after 1985 are located within the Market Area.

With regard to future water consumption and withdrawal rates by power plants, once-through cooling is prohibited, under the present EPA regulations, on all plants scheduled for service in 1985 and thereafter. Plants scheduled before 1985 employing the once-through system may retain them throughout the remainder of their useful lives. For this Study, it is assumed that all projected capacity on line after 1985 will employ the wet towers cooling method.

PROJECTED SUPPLY AND PLANT LOCATION

It is projected that by the year 1985, approximately 44 percent of the Market Area's total energy will be generated in nuclear power plants. By 2000, the percentage is expected to increase to 67 percent and to 72 percent by 2020. Fossil fuel steam plants are expected to remain the major source of electric power to the year 1985 at which time they are expected to generate 50 percent of total Market Area energy requirements. By the year 2000, however, fossil fuel's share dips to 29 percent and to 26 percent by 2020. It is anticipated that the remainder of the energy requirements will be met by hydroelectric and combustion type plants and possibly other generating modes presently not available.

Shown on Figure 40 are the projected steam electric power plant sites for the year 2000. Table 39 gives the sizes and locations of these plants. Consideration was given only to steam-electric plants, both nuclear and fossil fuel, because of their demands for cooling water and consequent potential impacts on the aquatic environment and shoreline areas. These two means of generation are expected to produce about 96 percent of the electrical energy required in the Chesapeake Market Area in 2000. The locations of future facilities is fairly well known through 1985, but, for installations scheduled beyond 1985, there is a great deal of uncertainty regarding specific sites. The location of these plants was based on several criteria including the availability of ample water supply, proximity to load centers, and the need to keep transmission lines short. In addition, sites in Maryland were selected in accordance with criteria developed by the Maryland Power Plant Siting Program although these sites were not necessarily those chosen under the Siting Program.

Because of the degree of uncertainty attending site location in the long-range future, no attempt was made to predict where plants would be located beyond 2000.

COOLING WATER CONSIDERATIONS

Figure 41 illustrates the expected levels of water use and consumption by power plants for selected years. The information for the 1980-2000 period in Figure 41 is taken from Tables 13-10 and 13-11 of Appendix 13 and accounts for both new units added and old units removed throughout the period. For 2000 through 2020, water use rates are assumed to be the same as those for the year 2000 although technological improvements between 2000 and 2020 may reduce the water requirements shown in Figure 41. Water withdrawals are expected to decrease over the projection period so that by 2020 withdrawals will be 18 percent of the 1972 figure. Water consumption, however, is projected to increase by approximately nine times. This apparent discrepancy is due to two factors. First, once-through cooling systems, which have much higher withdrawal rates than other types of cooling systems, are prohibited on all plants scheduled to begin service on or after 1985. Second, it was assumed that cooling towers would be used for all projected capacity after 1985. Cooling towers

TABLE 39
STEAM-ELECTRIC PLANTS IN THE CHESAPEAKE BAY MARKET AREA, 2000

Plant	Fuel	Service-Area	Location: City	Location: State	Capability
					MW
Chesapeake West					
Douglas Point	Nuclear	Potomac El Pr. Co.	Nanjemoy	MD	3400
Calvert Cliffs	Nuclear	Baltimore G&E Co.	Lusby	MD	3304
Bush River*	Nuclear	Baltimore G&E Co.	Bush River	MD	3000
Elms*	Nuclear	Potomac El Pr. Co.	St. Marys City	MD	3000
Lake Shore*	Nuclear	Baltimore G&E Co.	Millersville	MD	3000
Aquasco*	Nuclear	Potomac El Pr. Co.	Aquasco	MD	2700
Chalk Point	Fossil	Potomac El Pr. Co.	Brandywine	MD	1890
Morgantown	Fossil	Potomac El Pr. Co.	Newburg	MD	1801
Brandon Shores	Fossil	Baltimore G&E Co.	Foremans Corner	MD	1800
Wagner	Fossil	Baltimore G&E Co.	Arundel Village	MD	774
Benning	Fossil	Potomac El Pr. Co.	Benning	DC	580
					25249
Chesapeake East					
Summit	Nuclear	Delmarva P&L Co.	Summit Bridge	DE	3040
Conowingo*	Nuclear	Conowingo Pr. Co.	Conowingo	MD	3000
Thornton*	Nuclear	Delmarva P&L Ma.	Still Pond	MD	3000
Bethlehem*	Nuclear	Delmarva P&L Ma.	Bethlehem	MD	2700
Red Lion*	Fossil	Delmarva P&L Co.	Red Lion	DE	2000
Havre-de-Grace*	Fossil	Conowingo Pr. Co.	Havre-de-Grace	MD	1000
Vienna	Fossil	Delmarva P&L Ma.	Vienna	MD	962
Indian River	Fossil	Delmarva P&L Co.	Millsboro	DE	677
Edge Moor	Fossil	Delmarva P&L Co.	Edge Moor	DE	564
McKee Run	Fossil	Dover Municipal	Dover	DE	110
					17053
Chesapeake South					
Free Ferry*	Nuclear	Virginia E&P Co.	Barco	NC	3760
North Anna	Nuclear	Virginia E&P Co.	Minerva	VA	3760
Surry	Nuclear	Virginia E&P Co.	Surry	VA	3290
Chowan*	Nuclear	Virginia E&P Co.	Cofield	NC	2820
Ramirez*	Nuclear	Virginia E&P Co.	Mamie	NC	2820
Roanoke*	Nuclear	Virginia E&P Co.	Palmyra	NC	2820
Yorktown	Fossil	Virginia E&P Co.	Yorktown	VA	2660
Claremont*	Fossil	Virginia E&P Co.	Claremont	VA	2535
Possum Point	Fossil	Virginia E&P Co.	Dumfries	VA	2180
Smithfield*	Fossil	Virginia E&P Co.	Smithfield	VA	1690
Chesterfield	Fossil	Virginia E&P Co.	Chester	VA	1484
Portsmouth	Fossil	Virginia E&P Co.	Chesapeake	VA	1050
					30870
				Total	73172

* Plant projected and sited by FPC; all others are existing or scheduled by the utilities.

have much higher consumption rates than once-through cooling systems.

LAND USE BY POWER FACILITIES

Estimates of electric utility land use in the Chesapeake Bay Study Area was restricted to that required for large steam electric plants and the related high-voltage transmission rights-of-way. No attempt was made to estimate land use requirements associated with subtransmission or distribution facilities.

Power plant land requirements vary with regard to plant type, size, location and fuel use.

Table 40 shows projected land requirements for power plants within the Chesapeake Bay Study Area, as defined in Figure 1. The magnitude of the quantity of land needed for future power plant sites is obvious when it is realized that the land area of Washington, D.C. is about 42,900 acres.

It is reasonable to assume that the land occupied by future transmission lines will also increase significantly, especially considering the fact that nuclear plants will have to be located further away from population centers for safety reasons. This is somewhat offset by the fact that transmission lines will probably have a higher capacity in the future.

SENSITIVITY ANALYSIS

The projections of future demands for water and land by power plants in the Bay Region in the preceding sections were based on the assumption of a "conservative" growth in the demand for electric power. As part of the power analysis, the sensitivity of future demands for water and land to changes in the rate of growth was evaluated. Assuming a "high" rate of growth, which is an extension of historical trends, both water and land requirements would be expected to

Figure 40: Chesapeake Bay Power Plant Location Map, 2000

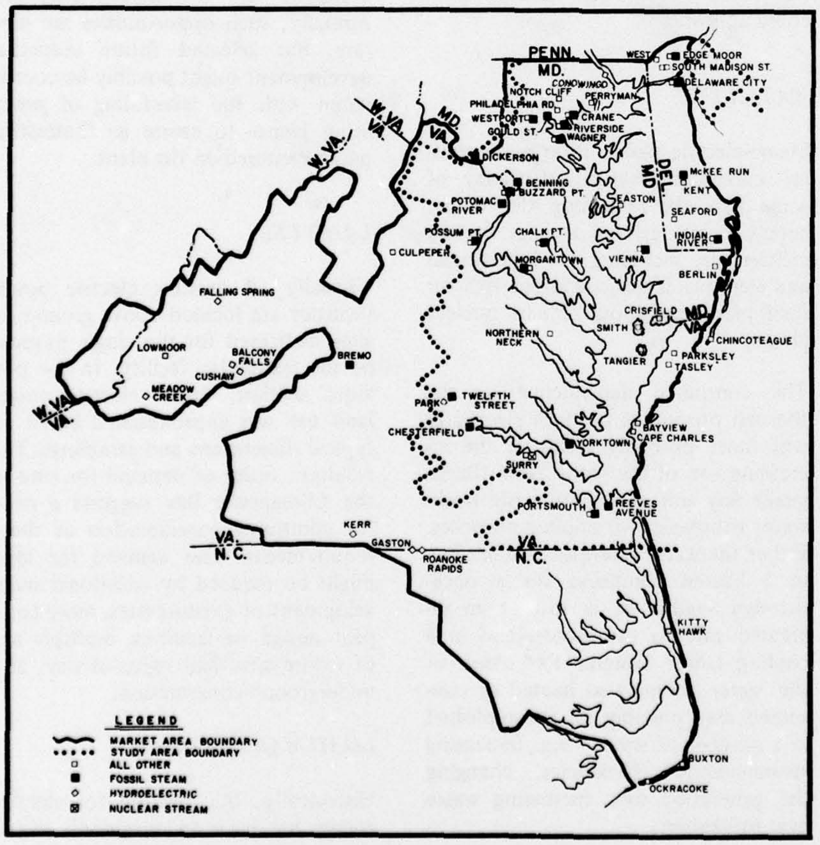


Figure 41: Projected Cooling Water in the Bay Market Area

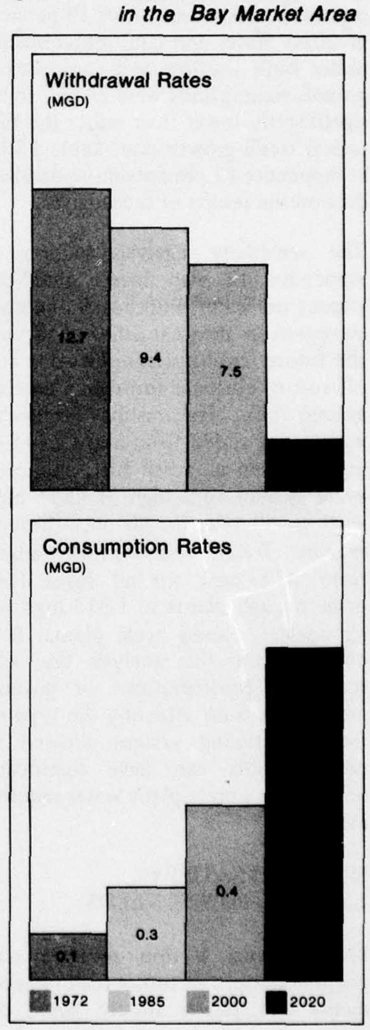


TABLE 40
PROJECTED LAND REQUIRED FOR STEAM ELECTRIC PLANTS
IN THE CHESAPEAKE BAY STUDY AREA (ACRES)

Sector	1985	2000	2020
Chesapeake East	3,300	8,400	21,800
Chesapeake West	6,700	16,500	41,300
Chesapeake South	6,100	9,200	26,700
TOTAL CHESAPEAKE BAY REGION	16,100	34,100	89,800

increase by approximately 30 percent in the year 2000 and about 95 percent in 2020. Under a "low" rate of growth assumption, which is a further dampening of the "conservative" growth trend, water and land requirements would decrease by approximately 20 percent in 2000 and about 30 percent in 2020. Water and land requirements under both the low and conservative growth assumptions were shown to be significantly lower than under the historical trend growth rate. Table 13-15 in Appendix 13 presents more detailed data on the results of this analysis.

The sensitivity analysis section of Appendix 13 also investigated the impact on water withdrawal and consumption in the year 2020 of varying the future fossil/nuclear plant mix and closed-cycle/once-through cooling system mix. The results for water withdrawal varied from a low of 1541 mgd with an all fossil fuel, all closed cycle system to a high of 4551 mgd with an all nuclear, all once-through system. Water consumption ranged from 452 mgd for all fossil fuel, once-through plants to 1,313 mgd for all nuclear, closed cycle plants. It is obvious from this analysis that any economic considerations or government regulations affecting the type of fuel or cooling system allowed in power plants can have significant impacts on power plant water requirements.

MEANS TO SATISFY ELECTRIC POWER NEEDS

The previous section presents one possible pattern of future load requirements and power supply based on reasonably expected economic and technological developments in the Chesapeake Bay Market Area. That portrayal is but one possibility of what may develop. By suitable extensions of utility technologies and applications of new philosophies of service modification (including public education programs designed to inform the public of the importance of energy conservation) the land and water use indicated might be altered dramatically. The sections which follow explore some of the areas where such modifications could appear.

WATER USE

Steam-electric plants offer a theoretical maximum thermal efficiency of some 55%, the remaining 45% of the energy being rejected as heat. Actual efficiencies, including the mechanical and electrical losses, are about 40% for fossil plants and about 25% for nuclear plants.

The continued dependence on the thermal process to produce electricity will most probably result in the increasing use of the water from Chesapeake Bay and its estuarine and freshwater tributaries for cooling purposes. Either the water is returned to the Bay in a heated condition for a once-through system or is lost at an increased rate to the atmosphere in a cooling tower system. Reduction of the water volumes so heated or consumed may possibly be accomplished in a number of ways – e.g., increasing steam-electric efficiencies, changing the generation mix, increasing waste heat utilization.

Steam-electric efficiencies may be increased through the development of better metals and other suitable materials in the heat transfer mechanism which could make possible a reduced production of reject heat corresponding to the same amount of electrical energy generated.

Hydroelectric and combustion plants could, to a limited degree, be substituted for steam-electric plants with the purpose of saving water; however the potential for additional hydro-electric generation is limited in the Study Area. In addition, combustion plants use an expensive grade of oil and are generally designed for limited operation. Such devices as magnetohydrodynamics, windmills, and solar cells use no water and may, conceivably, be brought into more common use early in the next century.

Reject heat is presently put to beneficial uses by providing steam for industrial and commercial purposes. Actually, such opportunities are now rare, but selected future industrial development might possibly be coordinated with the scheduling of generating plants to create an "industrial park" centered on the plant.

LAND USE

Virtually all existing electric power facilities are located above ground on sites dedicated for the single purpose of the particular facility. In the previous section, future electric power land use was approximated based on typical dimensions and samplings. The resultant order of demand for land in the Chesapeake Bay suggests a need for additional consideration of these requirements. The demand for land might be reduced by additional redevelopment of existing sites, more compact design of facilities, multiple use of future sites and rights-of-way, and underground construction.

LOAD MANAGEMENT

Historically, the demand for electric energy has been an outgrowth of the overall economic and social climate of the utility's territory. All demand was supplied in full without qualification other than economic return. Virtually all present day rate structures actually encourage energy use by lowering the unit price of energy as the consumption increases and by maintaining constant rates regardless of the time of day or season of year. In the interest of minimizing the water and land use necessary for electric power generation, demand manipulation and modification should also be considered. A possible means of restructuring rate schedules is the introduction of time dependency. The cost of producing electricity, and the ecological effects of such production varies throughout the day and year. If rates were made dependent on time, the price of the electricity could better convey to the consumer the costs associated with his demand for service and could encourage him to adjust his use toward the lower-priced periods of the day or year.

Much of the electrical energy purchased by the consumer is never transformed into useful work but is lost in the conversion process employed by the various household and industrial appliances and equipment. Part of the loss is due to the design of the appliance and part is due to the operation of the appliance by the consumer. By encouraging manufacturers and consumers to consider overall lifetime operating costs as well as the initial cost of the product, more efficient appliances could be marketed with a resultant reduction in demand.

NOXIOUS WEEDS

As previously mentioned in Chapter 2 of this Summary, the aquatic plants which inhabit the Chesapeake Bay Area waters are very important and serve as the primary producers or vital life line for other Bay species. Without the first link in the food chain provided by these plants, most forms of higher life within the Bay would suffer and the tremendous productivity of the Bay would decrease. However, as with any resource, an overabundance can also lead to problems. With some aquatic plants, excessive growths or heavy concentrations can cause conflicts and actually restrict the use of other resources. At this point, these plants become a hinderance and are termed "noxious weeds".

Noxious weed problems arise when the plants occur in such a place or to such an extent that they limit other beneficial water related uses such as navigation, recreation, fish and wildlife, water quality, and public health. In navigation channels, aquatic plants can and have grown sufficiently dense to block or impede boat traffic and present a navigation hazard. Recreation opportunities including swimming, boating and fishing have also been restricted as the result of excessive growths of several species. Fish and wildlife can be adversely affected when the plants occlude needed sunlight for food production, exhaust dissolved oxygen supplies, and "crowd out" plants which may be more desirable foods for waterfowl. Water quality problems that can be caused by excessive growths include low dissolved oxygen, reduction of the aesthetic value of water resources, and possible release of hydrogen sulfide gas from anaerobically decaying "blooms." Finally, public health can be endangered when the aquatic vegetation provides a favorable condition for the proliferation of mosquitoes which can transmit diseases such as malaria and encephalitis.

On a worldwide basis, noxious weed problems are of more concern in warmer latitudes than in the Chesapeake Bay Region. Central and South America, Africa, Asia, and the Southern United States all have more acute problems with the state of Florida alone spending almost $15 million annually on weed control programs. While certain aquatic plants have caused problems in the Bay Region in the past, today only an occasional isolated report of a noxious weed problem can be found. The problem species are still present in the Bay waters, but only as mere fragments of previous volumes, and none in sufficient numbers to require comprehensive control measures.

CURRENT STATUS

The plants which have caused the most widespread problems in Chesapeake Bay include Eurasian watermilfoil, water chestnut, and sea lettuce. While, as noted above, these species are presently not a problem in the Bay Region, a brief description of each is provided due to their potential for reemergence in the future. A more detailed discussion of the characteristics and history of each of these plants as well as other less prominent plants can be found in Appendix 14, "Noxious Weeds."

EURASIAN WATERMILFOIL

Eurasian watermilfoil is a submerged aquatic plant having an appearance as shown in Figure 42. Growing over a wide range of environmental conditions, the plant flourishes in water depths of up to 8 feet and in waters ranging from fresh to 15 ppt salinity. It roots easily in bottoms ranging from hard packed sand to muck, and under the right conditions grows rapidly to the water surface, sometimes forming a dense interwoven mat of material.

Known to be a native of Eurasia, the manner in which watermilfoil came to inhabit the waters of the United States is uncertain. It has been proposed, however, that either the plant came over in ships' ballasts which discharged into American waters, or that it came over initially in supplies of imported aquarium fish.

Watermilfoil problems were first documented in the Bay Area in the early 1930's and surfaced again in the late 1950's to early 1960's. The areas most affected by this weed were the Gunpowder and Middle River areas in the northern Bay Area and tributaries of the Potomac and Rappahannock Rivers in the lower Bay Area. From 1967 to the present time, however, Eurasian Watermilfoil has become increasingly scarce and its masses have

Figure 42: Eurasian Watermilfoil

been estimated at only one percent of its 1963 tonnage. In part, the reasons for the remarkable decline are two diseases which affect only the milfoil plants and the drought of the middle 1960's which caused salinities to increase above the plant's tolerance level.

WATER CHESTNUT

Like watermilfoil, the water chestnut is an import of Eurasian origin. The plant grows from seeds and produces as many as 10 to 15 rosettes or clumps of leaves which float on the water surface and can cluster up to 10 feet in diameter. A single rosette of the water chestnut is shown in Figure 43. The manner by which water chestnut distributes itself from one area to another is not fully understood, but the plant is known to tolerate no salinity and can grow in waters as deep as 15 feet. In areas of intense growth, the rosettes may become so crowded that the leaves are pushed upright out of the water forming a field of vegetation which makes boating, fishing, and other water related activities difficult if not impossible.

In the Chesapeake Bay Area, the water chestnut was first believed to have been planted as an ornament in goldfish ponds in Washington, D.C., before World War I. By 1923, the plant had spread to the Potomac River and ten years later almost 10,000 acres were infested near Alexandria, Virginia. More recently, the Gunpowder and Sassafras Rivers have had some water chestnut problems in 1955 and 1964, respectively. Today because of the many years of control efforts and expenditures for their removal, only yearly surveillance and hand pulling of the water chestnut is required to avoid problems.

SEA LETTUCE

Sea lettuce, a green alga with a worldwide distribution, grows mainly in estuaries and salt marshes of low current velocity, and salinity over 12 ppt. The general appearance of the plant is

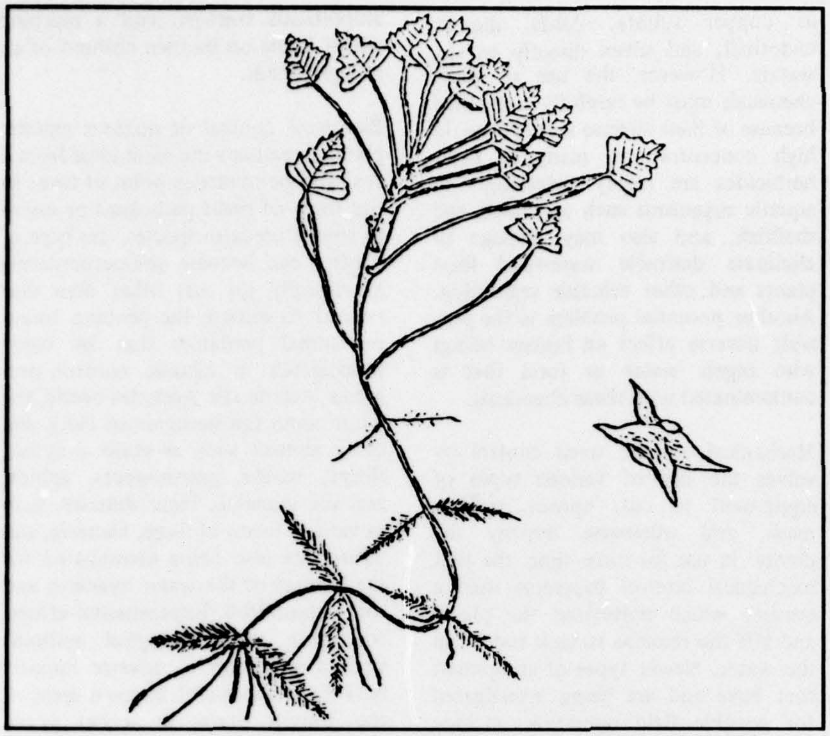
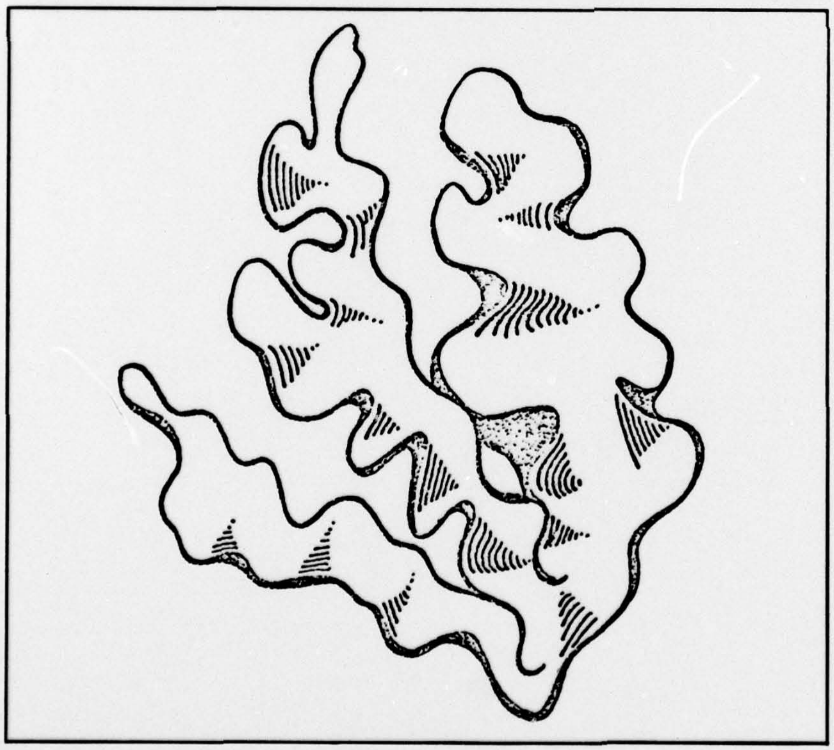


Figure 43: Water Chestnut

Figure 44: Sea Lettuce



shown in Figure 44. Typically, the plants grow at scattered 2 or 3 foot intervals to depths of about 20 feet, but are most abundant on shallow sand flats. When washed up on beaches, the lettuce rots and produces various gases, the worst of which is hydrogen sulfide. This noxious gas can discolor lead paint, tarnish silverware, and in sufficient concentrations create a health hazard.

Sea lettuce problems have been documented for many years in the Bay Area, Long Island Sound, and at the many places along the back bays of the Atlantic Coast of New Jersey. In Maryland, the sea lettuce problem peaked in 1965 with most of the problems occurring in the Potomac River and its tributaries. Virginia's sea lettuce problems have centered basically around the Norfolk Area where local shoreline residents requested relief regularly during the 1960's. Fortunately, most problems arising as a result of sea lettuce growth are only of a temporary nature. The floating mats of lettuce typically remain for from two to six weeks and are usually washed away by currents, alleviating the problem.

MEANS TO SATISFY FUTURE NEEDS

GENERAL

Although present water resource utilization is not hindered by the presence of aquatic plant growth in the Chesapeake Bay Area, the potential exists for problems to develop in the future. All plants require certain combinations of such growth factors as sunlight, salinity, temperature, and nutrients before growth and reproduction will occur. It is not known whether an improper balance of these growth factors or some other reason such as disease has caused the recent decline in many types of aquatic vegetation including noxious varieties in the Bay; but, new growth can be expected with the return of favorable conditions. If a resurgence of noxious plant growth creates conflicts with other uses of the

Bay's resources, consideration will have to be given to control measures. This section provides a brief overview of the various categories of control measures that have been employed in the past and that have some potential for use in the Bay Region. More specific discussion of these measures can be found in Appendix 14, "Noxious Weeds."

CONTROL MEASURES

Since the emergence of aquatic plant problems in America at the end of the nineteenth century, many methods have been devised to control plant growths. Today, more sophisticated measures have been devised, researched, and put into practice for the eradication of noxious weed problems. These measures fall into three basic categories: chemical control, mechanical control, and biological control.

One of the most direct, time effective, and efficient means of controlling nuisance aquatic growths is through the use of chemicals. This involves the direct application of substances such as copper sulfate, 2,4-D, diquat, endothall, and silvex directly to the waters. However, the use of these chemicals must be carefully controlled because of their adverse side effects. In high concentrations, many of these herbicides are highly deleterious to aquatic organisms such as finfish and shellfish, and also may damage or eliminate desirable waterfowl food plants and other valuable vegetation. Another potential problem is the possible adverse effect on human beings who ingest water or food that is contaminated with these chemicals.

Mechanical aquatic weed control involves the use of various types of equipment to cut, uproot, collect, mash, and otherwise destroy the plants. In use for some time, the first mechanical control programs used a crusher which pulverized the plants and left the remains to sink and rot in the water. Newer types of equipment that have and are being investigated for possible field operations include spray equipment, wood chippers, devices for transporting personnel and equipment over difficult terrain, amphibious tractors, and a machine which floats on its own cushion of air at high speeds.

Biological control of noxious aquatic plants is perhaps the most ideal from a cost and permanence point of view. In the form of plant pathogens or insect or animal predator species, this type of control can become self-perpetuating at virtually no cost other than that needed to initiate the process. Insect or animal predators that are being investigated in aquatic control programs include the Agasicles beetle, the white amur (an herbivorous fish), and other animals such as snails, crayfish, thrips, moths, grasshoppers, aphids, and the manatee. Plant diseases, such as various forms of fungi, bacteria, and viruses are also being investigated for the control of the water hyacinth and the watermilfoil. Experimental efforts to utilize these biological methods with a minimum of adverse impacts have been successful in some areas of the United States in recent years, although a complete understanding of the complicated process involved is still somewhat lacking.

Epilogue

Since Captain John Smith first explored Chesapeake Bay in 1608, many changes have taken place—changes which have resulted in a thriving, diversified economy and one of the highest standards of living in the United States for the residents of the Chesapeake Bay Region. However, this rise in the standard of living has not been without sacrifices or trade-offs regarding the Bay's resources. Man has cut vast virgin forests, destroyed many thousands of acres of wetlands, used the Bay and its tributaries as receiving waters for municipal and industrial wastes, and added huge quantities of sediments to the Bay's waters.

Man's misuse of the Bay's resources was usually not intentionally malicious. It was simply a matter of people performing the acts of living, working and playing, that have been the genesis of most of the Bay's problems. Compounding the situation was a general lack of understanding of the complexities and interrelationships of the Bay's ecosystem and the finite capacity of the Bay to assimilate wastes.

In 1974, 366 years after Captain Smith's voyage up the Bay, there were 8.2 million people living in the Bay Region. Population in the Bay Region has more than doubled since 1940. These rapid growth rates have compounded the Bay-related problems by overloading the capacities of existing water supply, waste treatment, and recreational facilities.

During the next 50 years, population is projected to more than double once again so that by the year 2020 approximately 16.3 million people will reside in the Bay Region. As a result of these projected increases in population, as well as expected increases in per capita income and manufacturing output, significant additional demands will be placed on Chesapeake Bay's water and related land resources. For example, 31 of the 49 major central water supply systems in the Region are expected to have average water demands which will exceed presently developed supplies; water consumption by both industry and power plants is projected to increase by nearly nine times; boating and sailing activity is projected to increase by more than five times and swimming by nearly four and one-half times; total waterborne commerce on Chesapeake Bay is expected to approximately double; and nearly 20,000 acres of land within the 100-year tidal flood plain have been proposed for intensive development.

Although there is much room for honest debate over the magnitude of the projected levels of demands on the Bay's resources presented in this report, there is no debate about the assertion that there will be continued development by man in the Chesapeake Bay Region. With proper planning, tomorrow's development will be tempered by a growing awareness of the environmental costs of unregulated growth, and also by the knowledge that environmental enhancement and preservation have often significant economic costs which cannot be disregarded. Informed decisions will have to be made concerning future uses of the Bay's resources based on a thorough analysis of *all* the costs and benefits—economic, environmental, and social.

Essential inputs to such a planning effort are both study and research designed to provide a better understanding of the incredibly complex ecological, economic, and environmental "system" called the Chesapeake Bay Region. An important part of such research should be work which is oriented toward gaining more knowledge of the role of the Estuary's natural physical and chemical processes in the overall health of the ecosystem. Research is also needed to provide a better understanding of the biological component of the ecosystem such as predator-prey relationships and the biological reasons for species population fluctuations. Also of critical importance is a need for methodologies to better estimate the value of such non-market items as an acre of wetland, a day of birdwatching, an endangered species habitat, or the aesthetic appeal of a clean river or bay.

There are numerous studies and research projects underway at all levels of government and at private institutions which are addressing these types of problems. Unfortunately, research efforts are sometimes not coordinated and therefore much time and money is lost due to duplication of effort and/or lack of direction.

In addition to their involvement in research efforts, a large number of Federal, State, and local agencies, as well as several interstate commissions, are involved in different aspects of water resource management in the Region. Inconsistencies in the laws promulgated by these various levels of government, many of which have conflicting interests, often create problems in what is essentially a regional resource– Chesapeake Bay.

The Corps of Engineers *Chesapeake Bay Existing Conditions Report* was the first major study effort which addressed Chesapeake Bay from a regional perspective. Just as important, the report contained much of the basic data required to project the future demands on the Bay. The primary focus of this study, the *Chesapeake Bay Future Conditions Report,* is to present the projection of water resource needs to the year 2020 with the purpose of identifying the problems and conflicts which would result from the unrestrained growth in use of the Bay's resources. This report provides the basic information necessary to proceed into the next phase of the program which is the formulation and recommendation of solutions to priority problems.

The Chesapeake Bay Hydraulic Model at Matapeake, Maryland, will be a major planning tool during the next phase of the study. The nine acre model will provide a means of reproducing, to a manageable scale, some of the physical phenomena (e.g., currents, tides, salinities) that occur throughout this large and complex system. In addition, as an operational focal point it will promote more effective liaison among the agencies working in the Bay Region by helping to reduce duplication of research and by leading to the accelerated dissemination of knowledge among interested parties. The model will also be extremely valuable as an educational tool for the public in the magnitude and complexity of the problems and conflicts facing Chesapeake Bay. Construction of the Chesapeake Bay Model was completed in May 1976. Verfication, or "fine-tuning" of the model is currently underway and is scheduled for completion in 1977.

Based on the findings of the *Future Conditions Report,* the capabilities and limitations of the Hydraulic Model, and input from the Study's public involvement program, exsting and potential management problems will be identified and prioritized. In prioritizing these problems, emphasis will be placed on (1) selecting problems for study that are considered to be high priority and that have Bay-wide significance; (2) maximizing the use of the Chesapeake Bay Hydraulic Model; and (3) avoiding any duplication of work being conducted under other existing or proposed programs. Major problem areas under consideration for further study during the next phase of the Study include the effects on the Bay and its people of extreme freshwater inflow conditions, navigation channel modifications, increases in power plant thermal effluents, tidal flooding, and wastewater dispersion.

The findings of the *Future Conditions Report* and the Chesapeake Bay Hydraulic Model will add tremendously to the growing body of knowledge of the Chesapeake Bay system. The system is immensely complex, however, and future increases in many types of demands will be great in magnitude and rapid in occurrence. We cannot hope to completely understand the workings of the entire system. We can, however, develop enough knowledge to identify future activites by man which would result in significant adverse or beneficial impacts on the integrity of Chesapeake Bay and the welfare of the people of the Region and Nation. The goal, not only of the Corps of Engineers, but also of all parties interested in the future of Chesapeake Bay, is a well-coordinated water-land management plan which will guide man in utilizing the resources of Chesapeake Bay to provide the greatest benefits to the greatest number of people.

Glossary

activity day: the participation by one person in a recreational activity during any portion of one day.

aquifer: a saturated underground geologic formation of sand, gravel, or other porous material, capable of transmitting water to wells or springs.

bacteriological indicators: total coliform bacteria include bacteria found in the soil, on plants, and in the excreta of man and animals. Fecal coliform bacteria, although harmless to man, are found along with pathogenic bacteria in domestic waste products. Since pathogenic bacteria have been proven to carry disease and methods for reliable detection of these organisms have not yet been developed, concentrations of fecal coliform bacteria have been used as indicators of pathogenic bacteria presence.

base load generating plants: plants which operate on a continuous, or nearly continuous, basis at or near capability.

Bay Region: *the geographical area which includes those counties or SMSA's which are located on Chesapeake Bay or one of its tidal tributaries (See Figure 1); same as "Study Area."*

biochemical oxygen demand (BOD): a measure of the oxygen depleting power of the organics in a waste water discharge.

bloom: the sudden development of conspicuous masses of organisms, such as algae, in bodies of water.

brackish water: a mixture of salt water from the ocean and freshwater from land drainage usually considered to have a salinity greater than 1 part per thousand.

chlorophyll: serves as a very important link in the photosynthetic process, which involves the transformation of light energy into chemical energy necessary for the growth of plants. High chlorophyll *a* (i.e., a form of chlorophyll found in water) values are generally indicative of high algal concentrations.

coastwise traffic: domestic traffic receiving a carriage over the ocean or the Gulf of Mexico (e.g., New Orleans to Baltimore or Puerto Rico to Hampton Roads).

combustion plant: a type of electrical generating facility which uses the power of combustion instead of steam to drive the turbine.

consumption: the amount of water lost between point of intake and discharge, by incorporation into products, evaporation, etc.

deadweight tonnage: the weight in tons of cargo, supplies, fuel, passengers and crew when loaded to the maximum.

detritus or detrital material: a non-dissolved product of disintegration or decay. Organic detritus forms the basis of the estuarine food chain.

dissolved oxygen (DO): the amount of oxygen dissolved in water. DO is dependent mostly on atmospheric pressure and temperature. Adequate DO is necessary for the survival of fish and other aquatic organisms.

dissolved solids:	measure the total amount of organic and inorganic material which has been chemically dissolved in water. Sulfates, carbonates, phosphates, nitrates, and chlorides are among the most common dissolved solids in surface waters.
distribution areas:	*the geographical area to which a product is shipped after being received in a port or processed in the port area.*
draft:	the distance from water level to the lowest point of the vessel underwater.
ecosystem:	the interacting system of living things to one another and their environment.
electrical generation:	the quantity of electrical energy produced by a generating plant or group of plants.
electrical requirements:	the quantity of electrical energy consumed by the customers, by miscellaneous internal uses, and by the losses of a utility or group of utilities. It is equal to the generation, plus the net receipts from other utilities.
endangered species:	those animal and plant species which are in danger of extinction throughout all or a significant portion of their range.
estuary:	a partially enclosed coastal body of water which has a connection with the ocean and within which freshwater from land drainage and salt water from the ocean are mixed.
eutrophication:	any change in an aquatic environment that is correlated with an increase in available nutrients.
Fall Line:	the geological boundary line where softer sedimentary formations of the Coastal Plain thin out as they come into contact with the harder crystalline rocks of the Piedmont Plateau.
gigawatthours:	the unit of energy equal to one billion watthours, the watthour being an extremely small unit.
gross water use:	the amount of water actually used within the plant taking into account the number of times the water is recycled (e.g., if 1,000 gallons of water are withdrawn from a water body and the recycling rate is two, then gross water use is equal to 2,000 gallons).
groundwater:	water found underground in porous rock or soil strata.
heavy metals:	*heavy metals* such as mercury, lead, zinc, chromium, cadmium, and arsenic are of importance because of their toxicity in relatively low concentrations to plants and animals and their relatively long lives. The most significant problem is that many fish and shellfish concentrate these materials in their tissues, affecting the natural food chain and presenting a consumption hazard for man.
hydroelectric power plant:	a type of electrical generating facility which converts falling water into electrical energy.
imports and exports:	traffic between the United States and foreign ports.
intake:	the amount of water actually withdrawn from a supply source.
Intermediate Regional Tidal Flood (IRTF):	the tidal flood which has a one percent chance of occurrence in any one year (generally referred to as the 100-year flood).
Internal traffic:	traffic between ports or landings wherein the entire movement takes place on inland waterways. Movements on Chesapeake Bay are considered internal.
maximum sustainable yield:	the greatest harvest which can be taken from a population without affecting subsequent harvests.
non-point sources:	those in which material reaches a water course through flows over a large area (e.g., runoff from an agricultural field into a waterway).
nutrients:	elements or compounds (e.g., carbon, nitrogen, and phosphorus) essential as raw materials for organism growth and development. Excessive concentrations can over-fertilize plant life.
OBERS baseline projections:	projections of population and economic activity prepared by the Bureau of Economic Analysis, U.S. Department of Commerce, and the Economic Research Service of the U.S. Department of Agriculture with the assistance of the Forest Service.

peak load generating plants: plants which operate only during periods of peak demand

pH: a measure of hydrogen ion concentration. "pH" reflects either acidic or alkaline conditions. Neutrality is represented by a pH of 7. Basic conditions (pH above 8.5) can decrease reproductive capabilities in many aquatic species and acidic water (pH less than 6) can exert stress or kill all forms of aquatic life.

point sources: those in which material is discharged through a specific point (e.g., effluent from a wastewater treatment plant).

pollutant: any gas, liquid, or solid whose nature, location or quantity contaminates the water (or other medium) to a level of quality which is less desirable.

power pool: two or more interconnected electric systems planned and operated on a coordinated basis.

recycling rate: the ratio of water intake to gross water use.

salinity: the concentration of dissolved solids in a water body.

Standard Metropolitan Statistical Area (SMSA): a designation of the U.S. Bureau of the Census which is defined as containing a city, or "twin" cities, with a population of 50,000 or more, and the socially and economically contiguous counties.

Standard Project Tidal Flood (SPTF): the largest tidal flood that is likely to occur under the most severe combinations of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic region.

steam power plant: a type of electrical generating facility which uses steam to drive an electrical generator. The steam is generated by heat from burning fossil fuels or from the fissioning of nuclear fuel.

Study Area: same as "Bay Region."

suspended solids: those which remain suspended in water and cannot pass through the holes in a standardized filter (typically one-millionth of an inch in diameter).

tidal flooding: the inundation of land by tides higher than those usually caused by hurricanes or "northeasters."

Water Service Areas (WSA's): a central water system serving more than 2,500 people.

waterborne receipts: commerce moving into a port.

waterborne shipments: commerce moving out of a port.

wetlands: an area characterized by high soil moisture and often high biological productivity, where the water table is at or near the surface for most of the year.

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