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91ST CONGRESS } 2d Session } SENATE { DOCUMENT No. 91-58

# THE NATIONAL ESTUARINE POLLUTION STUDY

United States Dept. of Interior

## REPORT

OF THE

## SECRETARY OF THE INTERIOR

TO THE

## UNITED STATES CONGRESS

PURSUANT TO

Public Law 89-753

THE CLEAN WATER RESTORATION ACT OF 1966



MARCH 25, 1970.—Ordered to be printed with illustrations

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U.S. GOVERNMENT PRINTING OFFICE
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S. Con. Res. 53 Agreed to March 25, 1970

NINETY-FIRST CONGRESS OF THE UNITED STATES OF AMERICA

AT THE SECOND SESSION

*Begun and held at the City of Washington on Monday, the nineteenth day of January, one thousand nine hundred and seventy*

## Concurrent Resolution

*Resolved by the Senate (the House of Representatives concurring)*, That there be printed as a Senate document, in one volume, with illustrations, the National Estuarine Pollution Study, submitted to the Congress by the Federal Water Pollution Control Administration, Department of the Interior, in accordance with section 5(g)(3), Public Law 89–753, Clean Water Restoration Act of 1966, and that there be printed three thousand five hundred additional copies of such document, of which two thousand five hundred copies shall be for the use of the Senate Committee on Public Works and one thousand copies shall be for the use of the House Committee on Public Works.

Attest:

FRANCIS R. VALEO,
*Secretary of the Senate.*

Attest:

W. PAT JENNINGS,
*Clerk of the House of Representatives.*

## COMMITTEE ON PUBLIC WORKS

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Attest:

FRANCIS R. VALEO,
*Secretary of the Senate.*

Attest:

W. PAT JENNINGS,
*Clerk of the House of Representatives.*

## LETTER OF TRANSMITTAL

U.S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
*Washington, D.C., November 13, 1969.*

Hon. SPIRO T. AGNEW,
*President of the Senate,*
*Washington, D.C.*

DEAR MR. PRESIDENT: We are pleased to transmit the enclosed report of the National Estuarine Pollution Study pursuant to section of Public Law 89–753 which law was originated by the Committee on Public Works of the U.S. Senate. Also enclosed is a draft of proposed legislation to amend Public Law 89–753, the Federal Water Pollution Control Act, as amended, consistent with the findings of the study. The bill provides for the establishment of a national policy and comprehensive national program for the management, beneficial use, protection and development of the land and water resources of the Nation's estuaries and coastal zone. We recommend that the report together with the proposed bill be referred to the appropriate committee for consideration and we recommend that the proposed bill be enacted.

Section 5(g) of the Federal Water Pollution Control Act, as amended, directed the Secretary of the Interior to conduct a comprehensive study of the Nation's estuarine and coastal zones and to make recommendations regarding their management and the respective roles of Federal, State, and local governments. The study, which extended over a 3-year period, was conducted in cooperation with the Corps of Engineers, Water Resources Council, and every other Federal agency and office involved with estuaries; with all coastal States, and many concerned public and private organizations. Extensive public hearings were held in all coastal States; regional conferences were held with State administrators and State officials.

The Department of the Interior is broadly concerned with the whole area of natural resources and their most effective management. Nowhere is the need for effective management more noticeable than in the estuarine and coastal zone. Here is a situation where many uses compete, be they commercial uses, such as industrial and transportation, as against commercial fishing and outdoor recreation. Added to this are such intensive uses as offshore mining, particularly for sand, gravel, oil, gas and sulphur, as well as the discharge of wastes.

The enclosed draft bill establishes a national policy for the effective management and protection of the coastal zone. To accomplish this policy, the bill will add a new section 19 to the Federal Water Pollution Control Act, as amended, to provide for a cooperative program between the Federal and coastal State Governments. Federal grants may be made to the coastal States on up to a 50-percent matching basis for developing a comprehensive management program for the coastal zone. Upon approval by the Secretary of the Interior of a coastal State's management program, operational grants may be made to the coastal State on a matching basis for the purpose of implementing the program. The new section provides for a continuing review by the Secretary of the coastal States' performance in the implementation of the State management program.

The Bureau of the Budget advises that the enactment of this legislation would be in accord with the program of the President.

Sincerely yours,

WALTER J. HICKEL, *Secretary of the Interior.*

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## Part VII. Collection of Supporting Information

# THE NATIONAL ESTUARINE POLLUTION STUDY

VOLUME I

[illegible]

# PART I. INTRODUCTION

> This place without all question is the most pleasant and healthful place in all this country and most convenient for habitation * * *
>
> It aboundeth with all manner of fish. The Indians in one night will catch thirty sturgeons in a place where the river is not above twelve fathoms broad. And as for deer, buffaloes, bears, turkeys, the woods do swarm with them, and the soil is exceedingly fertile. *From the Journal of Capt. Henry Fleete, the first white man to sail the Potomac River, Washington, D.C., 1632.*

Man has had a long and intimate association with the sea. It has borne his commerce and brought food to his nets; its tides and storms have shaped the coast where his great cities have grown; the broad estuaries have provided safe harbors for his ships; and the rhythm of its tides has taught him the mathematics and science with which he now reaches for the stars.

Throughout recorded history the sea and its estuaries have been used as a limitless resource; now, however, the impact of man on his environment has taxed the resources of many estuarine zones to the limit of endurance and reached into the depths of the ocean itself.

For 300 years the estuarine zones of this continent have provided the harbors through which a growing Nation's commerce moved and around which great centers of population and industry developed. The fisheries of the estuaries and neighboring oceans yielded a variety of staple and exotic foods to feed the burgeoning population, while the adjacent farmlands benefited from equitable temperatures and seepage of water throughout the estuarine zones.

These 300 years of unrestrained exploitation have seen the world of the estuarine zone evolve into three distinct but interacting environments.

There is first the natural ecosystem, a dynamic *biophysical environment* of land, water, and life, which follows a steady evolutionary pattern of its own, except when man has changed it. Its elements taken together comprise the total ecology of the estuary.

The second is the *socioeconomic environment*, the user's world, a system of social and economic pressures directed toward exploitation of the natural environment, either by ignoring what happens to it, modifying it deliberately, or using it in its natural state.

Third, there is the *institutional environment*. This is the realm of law, a system composed of those devices man has created in the form of law and organization to regulate his activities.

Increasing use and misuse of the Nation's estuaries have created and intensified many problems. Once productive shellfisheries have been completely smothered by sedimentation or closed by pollution; once deep and beautiful harbors are silted up and unnavigable, except for carefully marked dredged channels; passage of anadromous fish is blocked by polluted estuarine zones; thermal discharges affect entire ecosystems; diversion of rivers has caused salt water intrusion into ground water; and untreated or inadequately treated municipal and industrial waste discharges have damaged fisheries, added to siltation, and made many areas unsuitable for the increasing recreational use the present society demands.

There was little awareness of the danger to future generations as long as the ability of the natural environment to absorb the effects of the socioeconomic environment seemed unlimited, and the problems of pollution and environmental damage were isolated. But now, in the second half of the 20th century, the entire Nation must face the results of those 300 years of exploitation, and weld the three estuarine environments into a national program to preserve, study, use, and develop the estuarine zone. Action is needed now. The purpose of this study is to recommend that action.

## The Study Directive

The Congress, in passing the Clean Water Restoration Act of 1966 (Public Law 89–753), section 5(g), directed the Secretary of the Interior to study the problems surrounding pollution of the estuarine zone, and to make recommendations to the Congress for an effective national estuarine management program in which the Federal, State, and local governments, as well as public and private interests, will have clearly defined responsibilities.

The recommended program was to be based on a careful evaluation of existing relationships among the three estuarine environments; the effects of pollution on uses; and also the effects of demographic and use trends on pollution of the natural environment were to be considered.

All existing pertinent information was to be assembled, coordinated, and organized to serve as a factual base for the study, and additional investigations and surveys were to be carried out to supplement existing information. The study was to be conducted in cooperation with other Federal agencies, State and local governments, and other institutions and individuals. Everyone with an interest in the estuarine zone was to be consulted.

The report was to include not only the recommendations for a national program, but also an analysis of the importance of estuaries in the economic and social environment and the effects of pollution on the natural ecosystem. A discussion of the major economic, social, and ecological trends was to show what the future might hold; and recommendations were to be made for research and study to acquire basic knowledge needed to manage future trends.

### EXTENT OF THE ESTUARINE ZONE

The geographical scope of this study was stated in the Clean Water Restoration Act in this manner: "* * * the term 'estuarine zones' means an environmental system consisting of an estuary and those transitional areas which are consistently influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and intertidal areas, bays, harbors, lagoons, inshore waters, and channels, and the term 'estuary' means all or part of the mouth of a navigable or interstate river or stream or other body of water having unimpaired natural connection with open sea and within which the sea water is measurably diluted with fresh water derived from land drainage."

Explicitly included in these definitions is all of the strip of land and water where the continent and the islands meet the sea, except those few stretches of coast where there are no embayments and where there is no land runoff. Yet even these have already felt the impact of the expanding socioeconomic environment, as the recent oil well blowout off Santa Barbara, Calif., demonstrated.

Implicit in the study directive is the charge to develop a program to protect the Nation's coastal land and water resources from the impact of pollution, and other disruptive pressures of the expanding social and economic environment, in the coastal region of the Nation. The investigations of this study and the recommendations presented in this report therefore include consideration of man's impact on the entire coastal environment, whether it occurs in a bay, marsh, or along an ocean beach.

*The term "estuarine zone," as used in this report, refers to the geographic zone including the coastal counties between the landward limit of tidal influence and the 3-mile limit to seaward.* Nevertheless, the true limits of the estuarine zone differ for each of the three major environmental systems that make up the estuarine environment. The dissimilarity between the definition and the actual zone of influence of the estuarine zone constitutes one of the major problems a national estuarine management program faces.

The natural estuarine environment extends from the landward limit of tidal influence to the measurable seaward effect of fresh water runoff. This may vary in width from a few yards off some parts of the California coast to 50 miles off the Mississippi Delta.

The geographic range of the social and economic estuarine environment, the user's world, depends solely on man's ability and need to get to and use the estuarine environment. In terms of direct use, everything between the head of navigation landward and in sight of land seaward would be included.

The limits of the estuarine institutional environment are those of the political subdivisions that include parts of the estuarine zone. This includes the 274 coastal counties, the 24 coastal States, the Territories, the District of Columbia, a variety of interstate compacts and commissions, and the Federal Government.

The landward and seaward limits of the estuarine zone used in this study were set for the purposes of collecting and analyzing information pertinent to the study. The limits do not suggest that this zone can be isolated from either the upland rivers or the ocean, nor that this zone can be managed effectively without recognizing the problems in these and other environments.

## The National Estuarine Pollution Study

The congressional assignment to the Secretary of the Interior was delegated to the Federal Water Pollution Control Administration. The Administration established an Office of Estuarine Studies (now the Estuarine and Oceanographic Programs Branch) to carry out the study as directed by the Congress.

Immediate steps were taken to insure that all interested parties could participate actively. Representatives of each bureau chief in the Department of the Interior formed an ad hoc Estuarine Advisory Committee, which was later formalized into an advisory group to the Office of Marine Resources. Each Federal executive department head and each coastal State or territorial Governor designated a representative to coordinate his participation. National scientific, cultural, and user organizations were invited to participate, and 30 public meetings were held throughout the estuarine zone to obtain the views of individual citizens. Numerous consultations were held with groups and individuals expressing interest.

All of these groups and individuals were asked to assist by providing information and opinion about the value, use, and pollution of the estuarine resource. The Federal Water Pollution Control Administration regional offices worked closely with State agencies in collecting information, and other Federal agencies provided information collected by or through them. Some 22 contracts were negotiated to obtain particular types of information and to prepare case studies of specific estuarine systems. To organize and coordinate the vast amount of quantitative information, an automated information storage and retrieval system, the National Estuarine Inventory, was developed. The list of information to be included in the inventory was developed with the cooperation of all Department of the Interior agencies and represents a consensus of what the Department regards as the basic information necessary for effective estuarine management.

The recommended national management program (pt. III), probably the single most important result of the study, was reviewed at two stages by the coastal States and all concerned Federal agencies. The Department of Interior agencies have reviewed not only the recommended program, but also the discussions of supporting material leading to the recommended national program (pts. II, IV, V, and VI.)

## Organization of the Report

The report is organized to point out the relationship of the biophysical, socioeconomic, and institutional environments within the estuarine zone, and also to point out that technical management is a different matter from institutional management, even though there is a strong dependence between them.

Part II, "Summary and Conclusions," presents a summary of information (presented in more detail in pts. IV and VI) leading to the recommended national program.

Part III, "Recommendations—The Proposed Program," presents in full the recommendations for a comprehensive national program of estuarine management (presented in more detail in pt. V), tying together the needs of the biophysical environment, the demands of the socioeconomic environment, and the responsibilities of the institutional environment.

Part IV, "The Importance of the Estuarine Zone," discusses the biophysical and socioeconomic environments of the estuarine zone, shows the interaction of the two environments, and points out how the demands of the one will affect the other if present trends in development continue without effective control by the institutional environment. The emphasis here is on technical management problems.

Part V, "Development of the Comprehensive National Program," discusses the institutional environment as it presently exists, shows the role each level of government plays, and points out what role each should play to achieve effective management. The emphasis here is on institutional management problems in the estuarine zone.

Part VI, "The Development of Data on the Estuarine Zone," discusses the present state of knowledge about all three of the major estuarine environments, and presents a program of studies and research efforts designed to close up knowledge gaps and provide the basis for sound technical management through rational institutional management.

Part VII, "Collection of Supporting Information," describes in general terms the mass of reference materials from which the information in this report was derived. These materials consist of several thousands of documents, including transcripts of estuarine public meetings, profiles of Federal and State agencies, the study's contractors' reports, and published reports in the scientific literature which relate to estuarine resources.

In-text citations to published material, referenced in the following volumes of this report, are indicated by a number in parentheses, such as (V–1–1), which refers to the references list at the end of the appropriate chapter. Likewise, figures and tables are referred to in text by a number, such as figure V.1.1, or table V.1.1. Appendices follow the appropriate chapter.

In essence the report presents a technical analysis of the estuarine zone, identification of scientific knowledge gaps, and an inventory of the available knowledge, all of which form the basis for the recommended comprehensive management program for the Nation's estuarine resources.

This recommended national program is based on institutional management with multiple long-term use as a common denominator. Formation of the organizations to accomplish this and the active implementation of these recommendations will permit maximum use of the entire estuarine zone while preserving it for the benefit of future generations.

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## PART II. SUMMARY AND CONCLUSIONS

The estuarine zone is an ecosystem. That is, it is an environment of land, water, and air inhabited by plants and animals that have specific relationships to each other. This particular ecosystem is the interface between land and ocean, and one of its key components is human society.

The social and economic environment that forms human society must be regulated by manmade laws intended to provide justice to each individual as a part of the socioeconomic environment. The biological and physical environment of the estuarine zone, in contrast, obeys natural laws which are equally complex and are less flexible than manmade law. The welfare of American society now demands that manmade laws be extended to regulate the impact of man on the biophysical environment so that the national estuarine zone can be preserved, developed, and used for the continuing benefit of the citizens of the United States.

To apply manmade laws and regulations to the nautral estuarine environment, it is necessary first to understand what natural conditions govern that environment, and then to understand how the socioeconomic and biophysical environments affect each other. Only then can there be developed an institutional environment which can effectively weld all three environments into one smoothly functioning self-sustaining ecosystem.

### The Biophysical Environment

Laws regulating the socioeconomic environment exist at several levels of governmental authority. The Constitution presents general guiding principles, State constitutions operate within this framework while establishing a more detailed body of law designed to satisfy the needs of the statewide socioeconomic environment, and local ordinances regulate in detail the activities carried out in specific locations.

The biophysical environment is also subject to a heirarchy of laws, regulations, and conditions. The general guiding principles are those fundamental natural laws which govern all life on the earth; at the interfacial zone between land and sea the effects of these laws appear as universal dominating environmental factors. The structure of the coastline, formed and modified in obedience to these general conditions, imposes a second level of natural law which exerts its primary effects on water movement in the estuarine zone; and, within each structural form exists a host of organisms living according to specific natural ordinances which govern their relationships.

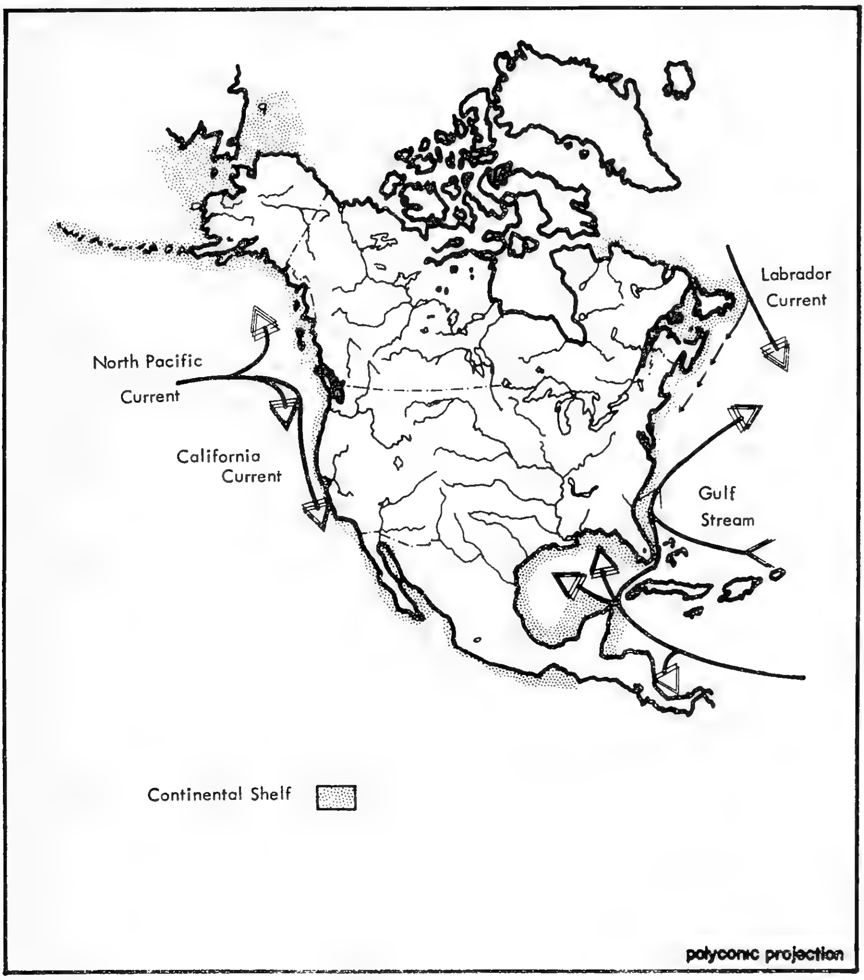
#### DOMINATING ENVIRONMENTAL FACTORS

The natural estuarine environment is based on the conversion of radiant solar energy into other forms of energy with the assistance of the mechanical effects of gravitational energy. This conversion is accomplished by an intricate array of prey—predator relationships among living organisms, from the microscopic living creatures which convert solar energy directly and are eaten by other organisms, to the fish and wildlife which are the ultimate life forms in the manless estuarine environment.

Solar radiation and gravitational forces control the natural environment through a complex series of mechanisms. In the estuarine zone this control exhibits itself through seven major environmental factors that exist throughout the estaurine zone.

(1) *Continental Shelf.*—The submerged land next to the continent slopes gently to a depth of about 600 feet, then it drops more rapidly to form the deep ocean basins. This fringe of slightly sloping submerged land, which along much of the Atlantic and Gulf coasts would appear quite flat to the naked eye, is called the Continental Shelf; its width and general configuration along the U.S. coastline affects the force with which ocean waves strike the shore and consequently the manner and degree of shoreline erosion and accretion (fig. IV. 1.1).

FIGURE IV.1.1 MAJOR OCEAN CURRENTS AFFECTING THE UNITED STATES



(2) *Ocean Currents.*—The major ocean currents passing near or impinging on the continent exert strong, if subtle, effects on the estuarine zone through their temperatures, which affect continental land temperatures, and through their nutrients, which govern the nature and productivity of offshore and estuarine fisheries. The cold Labrador Current water from Maine to Virginia, warm Gulf Stream water along the South Atlantic and gulf coasts, and the California Current along the Pacific coast all have noticeable effects on coastal land and water (fig. IV.1.1).

(3) *Coastline Slope.*—The configuration of the coastline itself, even though subject to additional molding by the flow of rivers to the sea, is closely related to the shape and structure of the Continental Shelf. A wide continental shelf is generally associated with lowland next to the coast, while a narrow shelf is associated with mountainous terrain. These associations throughout the estuarine zone of the United States have produced estuarine systems characteristic of particular regions. Glaciation in New England, Washington, and Alaska; old mountain ranges and a sedimentary coastal plain from New Jersey to Texas; and the young, steep ranges of the Pacific coast are all continental features having different impacts on the estuarine zone.

(4) *River Flow.*—The estuarine zone is also shaped through erosion and sediment transport by fresh water making its way to the sea. All along the coastlines are streams and rivers carrying water from land runoff to the sea. These waterways range from the Mississippi River, which drains 41 percent of the conterminous land mass of the United States, down to tiny trickles across a beach. The volumes of water and sediment moved reflect not only the total amount of precipitation and its annual cycle, but also the sizes and slopes of drainage basins and the types of soil over which the rivers flow.

(5) *Sedimentation.*—The general outlines of many estuaries, lagoons, and embayments in the estuarine zone were formed by erosion from land runoff during the last ice age when sea levels were much lower than they are now. As the sea level rose, the drowned river mouths became zones of mixing, sediment deposition, and erosion where the rivers and tidal currents met. These erosions and sedimentation processes molded the estuarine zone into its present shape and continue to change it.

(6) *Climate.*—Solar energy striking the earth sets up complex cycles of water and energy flow from the oceans to the sky and the land and back again. That part of the energy cycle occurring in the atmosphere gives rise to the various combinations of weather phenomena which make up local climates. Land, sea, and sky are mutually dependent in producing specific climates, and the great ocean currents play their indirect roles in modifying the climates of the estuarine zone.

(7) *Tide.*—The tide stands alone as a controlling force and symbol of the estuarine environment. The combination of tidal action and river flow gives rise to that unique phenomenon called an "estuarine circulation pattern," which means the fresh water flows in one direction in one layer and the salt water flows in the opposite direction in another layer with various degrees of mixing at the interface between them. This type of circulation pattern is of great importance in some of the estuaries along the Atlantic and Gulf coasts, and to a large extent governs the capacity of such estuaries to rid themselves of waste materials.

THE BIOPHYSICAL ESTUARINE REGIONS

Each estuarine system along the coastline is affected to some extent by all of these dominating environmental factors. In some cases the dominance of one particular factor is readily apparent. It is much more often the case that the competing environmental factors are so evenly balanced that none can be said to dominate and the estuarine zone appears to be composed of a bewildering variety of unique systems.

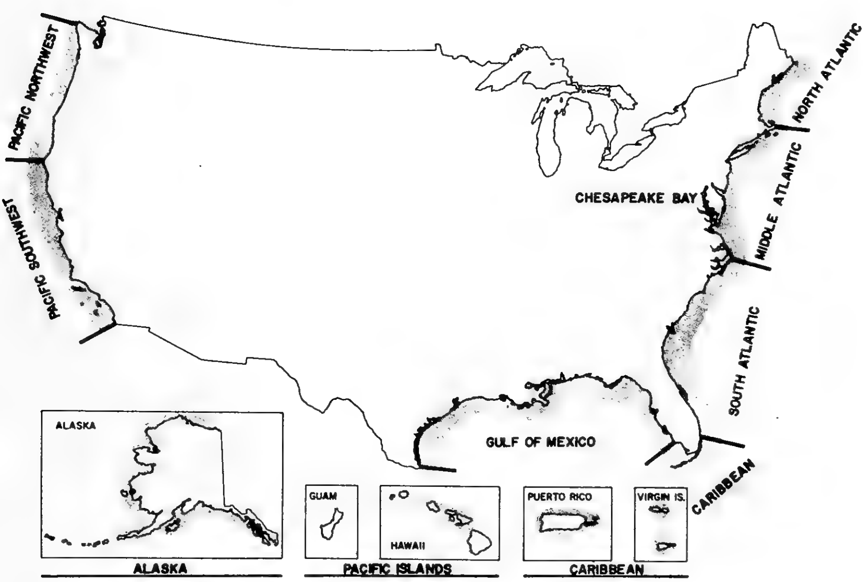
Yet, the dominating environmental factors listed above form a set of natural guiding principles which govern the general characteristics of the estuarine zone of the United States, and the occurrence of various combinations of these environmental factors permits the grouping of the national estuarine system into 10 geographical zones, each governed by a different combination of environmental conditions (figure IV. 1.19).

### *Characteristics of the Biophysical Regions*

#### *North Atlantic estuarine region: Canadian border to Cape Cod*

Cool, fertile waters with a large tidal range strike a steep, indented coast with deep water close inshore, but protected from the full force of the ocean waves by a wide continental shelf. Moderate precipitation with heavy snowfall leads to heavy spring river runoff which dominates local circulation. Natural erosion and sedimentation are not severe problems, and the evolution of drowned river valley estuaries is in an early stage in this region.

Figure IV.1.19
BIOPHYSICAL REGIONS OF THE UNITED STATES



*Middle Atlantic estuarine region: Cape Cod to Cape Hatteras, exclusive of Chesapeake Bay*

A wide, gently sloping continental shelf with a smooth shoreline is cut by the entrances of several major river systems carrying moderate amounts of sediments. The same cool, fertile waters as in the North Atlantic estuarine region wash this coastline but with a smaller tidal range. The evolution of drowned river valleys into coastal marshes is in a secondary stage in the larger estuarine systems, with sand spits and barrier islands forming.

*Chesapeake Bay estuarine region: All of the Chesapeake Bay system from Cape Charles and Cape Henry Island*

Isolation from direct oceanic effects in much of the greatly branched systems, the many subsystems with major river flows, and the reduced concentration of the ocean salt throughout the bay and its tributaries make this a unique estuarine system. This is a drowned river valley with numerous similar tributary systems in various stages of evolution.

*South Atlantic estuarine region: Cape Hatteras to Fort Lauderdale, Fla. (about 26° north latitude)*

The generally wide Continental Shelf is brushed by the warm waters of the well-defined Gulf Stream. The low-lying Coastal Plain terminates in barrier islands and marshes in which large amounts of sediments are being continually deposited by moderate-sized rivers fed by heavy summer rainfall. Many of the drowned river valley estuaries have evolved all the way to coastal marshes. Tidal ranges are small to moderate, depending on local conditions.

*Caribbean estuarine region: Fort Lauderdale to Cape Romano (the Florida peninsula south of 26° north latitude), plus Puerto Rico and the Virgin Islands*

High temperatures, heavy rainfall, and warm ocean currents along practically nonexistent continental shelves result in tropical estuarine environments throughout this region. Coral reefs and mangrove swamps are the typical coastal features of south Florida, while the islands are mountainous and are fringed with coral reefs and beaches. Tidal ranges are small.

*Gulf Coast estuarine region: Cape Romano to the Mexican border*

A wide Continental Shelf extends all the way around this large embayment, in which warm tropical waters are moved gently by weak currents and small tidal ranges. Heavy rainfall over most of the area brings sediments from the broad coastal plain to be deposited in the estaurine zone. Most of the drowned river valleys have evolved to a point intermediate between those of the Middle and South Atlantic regions—barrier islands are extensive and have large shallow bays behind them.

The Mississippi, carrying drainage from 41 percent of the coterminous land mass of the United States, forms one of the major deltas of the world and is unique among the estuarine systems of the United States, both in its size and in the extent to which it has built out over the Continental Shelf.

*Pacific Southwest estuarine region: Mexican border to Cape Mendocino*

Because of the narrow Continental Shelf, periodic upwelling of deep water close inshore as winds force the California current offshore brings cool, fertile water near the coast for several months of the year. The coastline has a typical beach and bluff configuration with only a few shallow embayments and the unique earthquake-born valley of San Francisco Bay, which, in the delta formed by the confluence of the San Joaquin and Sacramento Rivers, shows what erosion and sedimentation might have done along the southwest coast if rainfall were greater in that area of easily erodable mountains.

*Pacific Northwest estuarine region: Cape Mendocino to the Canadian border*

The Continental Shelf and coastal configurations are similar to those of the Pacific Southwest, but ocean water temperatures are lower here; the movement of the California current away from the coast is not as pronounced, and heavier rainfall has resulted in some major rivers cutting through the coastal mountains to form deeply embayed estuarine systems. Extensive erosion and sedimentation have caused wide tidal flats, bars, and shoals to be typical of these systems.

The Straits of Juan de Fuca and Puget Sound,which were glacier formed, do not have as severe sedimentation as exists along the ocean coast, and have retained much of their original configuration.

*Alaska estuarine region: All of Alaska including the Aleutian and Bering Sea Islands*

The dominant factors in this region are temperature and precipitation. Water temperatures are near freezing, and much of the precipitation falls as snow. The Continental Shelf is wide all through the region, and tide ranges are very large. The southeast and south coasts have active glaciation and consist primarily of glacier-cut embayments and fjords; the west and north coasts are much flatter and have been modified to some extent by sediments eroded from the interior, including glacial silt, and by the grinding action of pack ice during winter.

*Pacific Islands estuarine region: The Hawaiian Islands, American Samoa, and Guam*

This region consists of tropical ocean islands of volcanic origin. Dominating factors are lack of a continental shelf, full exposure to oceanic conditions, and pleasantly warm temperatures. Coral reefs and beach and bluff configurations are typical.

## THE LAND AND THE WATER

Within the general domination of broad-scale environmental factors are smaller scale governing conditions that, through their effects on water movement and circulation, determine what kind of local environment can exist in a particular estuarine system.

*The land*

The shape of the land along the land-sea interface goes far toward determining what water movement and circulation patterns exist in particular local areas and, consequently, how fast a particular estuarine system will rid itself of pollutants. Within the general compass of the estuarine regions discussed in the preceding section there are different structural types which define patterns of water movement typical of particular structures, no matter what the external environment may be.

Alaska presents the greatest variety of estuarine form and structure of any of the estuarine regions. Nearly all kinds of systems typical of other regions are found there. In addition, Alaska has the only glaciated coast and most of the fjords found in the United States.

Characteristic of the North Atlantic region is a very irregular, hilly coastline with deep water close inshore and long, narrow embayments with open access to the sea. Estuarine systems within the Chesapeake Bay region consist of a group of branched rivers entering the Chesapeake Bay itself, which is in turn the former valley of the Suequehanna River.

In the Middle Atlantic region the estuarine zone consists primarily of a few large drowned river valley embayments (for example, New York Harbor, Delaware Bay, Narragansett Bay) and some small marsh and barrier beach systems receiving only coastal fresh-water runoff. The estuarine zone of the Gulf region, on the other hand, consists mainly of moderate-sized embayments with barrier beaches and extensive marshes, but receiving river flow from upland drainage areas and representing an intermediate state in the evolution of drowned river valleys into coastal marshes.

The South Atlantic region has two dominant types of estuarine structure. From Cape Hatteras to about Jacksonville, Fla., there is a general input of upland river drainage to the estuarine zone and the estuarine systems are typical drowned river valleys in the later stages of evolution represented by barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville fresh-water runoff comes primarily from local coastal drainage, and there are uniform and extensive barrier island beaches with long narrow embayments behind them having continuous but generally narrow strips of marsh along the embayments. This structure fades into the extensive swamplands of the Everglades farther down the Florida Peninsula.

Both the Pacific Northwest and Pacific Southwest regions have few estuaries. The estuarine systems of the Northwest Pacific region tend to be the mouths of rivers which have cut their way through coastal mountain ranges, either of their own accord or aided by glaciers as in the case of Puget Sound. Shallow coastal embayments with little and sporadic river flow are characteristic of the few estuarine systems of the Southwest, except for San Francisco Bay, which receives fresh water runoff from much of central California.

Estuarine systems of the islands, both Atlantic and Pacific, are few and consist mostly of embayments without major river inflows.

The estuarine zone can be classified according to its local morphology into 10 major categories, several of which exist in each of the estuarine biophysical regions. Within each of these categories, the similarities in structure reflect similarities in water movement, water quality, and ecology which make it possible to apply lessons learned in managing an estuarine system in one region to similar estuarine systems in other regions. The morphological categories are:

1.1 Smooth shoreline without inlets
1.2 Smooth shoreline with inlets
1.3 Smooth shoreline with small embayments
2.1 Indented shoreline without islands
2.2 Indented shoreline with islands
3 Marshy shoreline
4 Unrestricted river entrance
5.1 Embayment with only coastal drainage
5.2 Embayment with continuous upland river inflow
6 Fjord

Unrestricted river entrances and embayments dominate the estuarine zone and are rather evenly distributed throughout all the regions, with the common type of estuarine system being a coastal embayment with drainage from only the local coastal area. Many of these latter embayments have large marsh areas, but the Middle Atlantic, South Atlantic, and Gulf are the regions in which marshes are the predominant feature in some parts of the estuarine zone.

*The water*

The unique nature of water movement and circulation patterns in the estuarine zone are the result of the meeting and mixing of fresh river and salty ocean water of slightly greater density under the oscillating influence of the tide. There may be additional complicating factors such as temperature and wind action, but the resulting circulation nearly always reflects the interaction of river flow and estuary shape with the tidal flow of the ocean water. General water movement patterns are predictable for each category of estuarine shape.

It is where moderately larger rivers and streams meet the sea that the unique estuarine circulation patterns occur most frequently. Large fresh water flows in well-defined channels tend to slide over the top of the denser sea water without rapid mixing. Water movement in such cases exhibits various degrees of stratification.

With wider channels, smaller river flows, and greater tidal ranges more mixing occurs and other forces come into play. Embayment shape, bottom configuration and material, and the effects of the earth's rotation all may play a role. In some estuarine systems of this type, the degree of stratification may change with changes in river flow, temperature, wind, or other transient conditions.

Estuarine water quality is the product of both land and water. From the land, erosion and solution in river water bring suspended and dissolved minerals, while decaying vegetation adds dissolved salts, but negligible quantities of organic matter.

In the estuarine zone these two different solutions meet and mix. Salt concentrations range from those of the oceans to the almost unmeasurable amounts present in some rivers. Where little stratification exists, sea salt dominates mineral concentrations in estuarine waters; in stratified systems, however, the small amounts of minerals entering in the fresh water may be as important in some parts of the estuarine zone as the much larger concentrations from the sea are in others.

### THE LIFE

The governance of the dominating environmental factors, as modified by estuarine shape and water quality, result in an input of energy into individual estuarine systems, and it is in the variety and diversity of estuarine life that the input of energy to the estuarine zone finds ultimate expression. Whether energy comes directly, as in solar radiation stimulating photosynthesis, or whether it comes indirectly, as with tidal flows or wind and rain pounding on the shoreline, its absorption and conversion to other forms of energy (such as food) are essential steps in the continuation of life in the water, in the mashes, and on the land.

Energy input from gravitational forces, as illustrated by tidal action and river flow, depends primarily on local or regional conditions, but direct energy input from solar radiation depends largely on latitude, the tropics receiving much more energy per acre than the arctic. The relative amounts of energy entering an estuarine system govern the kinds of life found there, and natural ecosystems show systematic variations related to the sources and amounts of energy received.

Estuarine zones with strong mechanical energy inputs from waves, currents, tides, or river flows develop similar ecosystems no matter whether in the tropics or the arctic. Where, however, such energy inputs do not dominate the input of radiant solar energy, natural communities develop compositions typical of tropical, temperate, or arctic latitudes.

Tropical systems are subject to unvarying warm temperatures; light energy input is both greater and more regular than in other latitudes. Within this general group there are the sparse populations along coasts with deep clear water close inshore; the teeming and colorful populations of coral reefs; and the mangroves and the submerged grasslands associated with shallow, nutrient-laden water. Only the southern part of Florida and the islands are of this type.

Arctic systems are subject to wide fluctuations of sunlight and temperature but ice is the key factor. Ecological systems develop in, on, and under the ice and in the fjords associated with glaciers. Only a small part of Alaska includes estuarine systems of this type.

Temperature systems are subject to moderate solar energy inputs, temperatures which change regularly with the seasons, and generally larger tide ranges and more wave action than either tropic or arctic systems. Most of the estuarine systems of the United States lie in the temperate zone, and the balancing of solar energy input against mechanical energy input in this zone leads to a great variety of ecosystem types, even within small geographic areas.

The grouping of ecosystems outlined here describes a limited range of recurring variation of chemical and physical properties to which certain forms of life have adapted and on which they are now dependent.

The basic environmental needs for all living plants and animals in such zones are zones of salinity consistently fluctuating over a limited range of concentration; solar energy; water temperature variation; water quality and nutrients favorable to their propagation, growth, and survival; and, for some life forms, bottom conditions suitable to their unique needs.

The dependence of fish and shellfish on the estuarine zone is governed by particular environmental requirements for reproduction, protection, food supply, or a combination of these. Estuarine-dependent species are of three types:

*1. Species restricted to estuaries*

Among the relatively few species of fish and shellfish that complete their entire life cycle in the estuarine zone is the Atlantic (American) oyster. It will die after long exposure to fresh water although it can stand limited periods of such exposure and can thrive in relatively high salinity water. The spotted sea trout occupies the estuary for all its life purposes and only occasionally leaves the estuary under unusual extremes of salinity and temperature.

*2. Anadromous and catadromous species*

Anadromous species pass through the estuarine zone on their journey from the sea to the freshwater environment where they spawn. Some species, such as the Pacific salmon, die after spawning and others, such as the striped bass, live to return to the estuarine zone and the sea. The young of all anadromous species spend varying periods of time in the freshwater areas where they were spawned, but all eventually migrate to the estuaries and then the sea.

There are few truly catadromous species that mature in the fresh or brackish water environments, and then migrate to higher salinity waters of the estuary of the adjacent sea to spawn. The American eel and the blue crab are examples of this type.

*3. Migratory estuarine species*

The great majority of estuarine dependent species fall under this classification. Some use the brackish and freshwater areas of the estuarine zone for reproduction; some as a source of food; some for shelter, either as adults or young; and some for all these reasons. They all have in common the basic need for both estuarine and ocean environments at some point in their life cycle. This group includes the great majority of fish and shellfish of direct importance to man, such as shrimp, menhadden, flounders, and red drum (fig. IV. 1.38).

Estuarine wildlife can be classified into four categories: (1) fur bearing animals, (2) game waterfowl, (3) ornamental shore birds, and (4) the common wildlife that can tolerate human presence.

The primary fur bearers are the fur seal in Alaska, nutria in the South Atlantic and Gulf States, the common eastern muskrat in New Jersey, the Virginia muskrat in the Central Atlantic States, and the Louisiana muskrat in Alabama, Mississippi, Louisiana, and Texas. Secondary in importance are the racoon, mink, and otter.

The dependence of waterfowl on the estuarine zone is both complex and incompletely understood. The primary sport species, such as mallards and canvasbacks, have been successfully adapted to manmade changes in their environment, particularly those changes not affecting the nesting sites.

The ornamental shore and sea birds are a particularly esthetic attraction among the national fauna. These birds are generally more dependent upon estuarine conditions than the more mobile waterfowl and, in addition, have demonstrated a considerably greater sensitivity to the overall encroachment of man. These birds include whooping cranes, pelicans, bald eagles, egrets, ibis, and many others.

### GOVERNING SUBDIVISIONS OF THE BIOPHYSICAL ENVIRONMENT

Solar energy and gravitational energy are the basis for everything that happens naturally in the estaurine zone. This discussion of the biophysical environment has been concerned primarily with the environmental conditions surrounding the transformation of these energies into forms useful in living processes and exploitable by man. Three different sets of subdivisions of the biophysical environment were used in this discussion.

Differences in the external environment divided the estuarine zone of the United States naturally into 10 geographic regions, each subject to a particular governing combination of the external influences of tide, ocean currents, wave action, sedimentation, and climate. This subdivision into estuarine biophysical regions gave broad ranges of conditions in each region, but the importance of local coastal conditions in governing energy flows via water movement paved the way for a subdivision of the estuarine zone according to 10 morphological groups having similarities in water movement, circulation, and the ability to rid themselves of wastes.

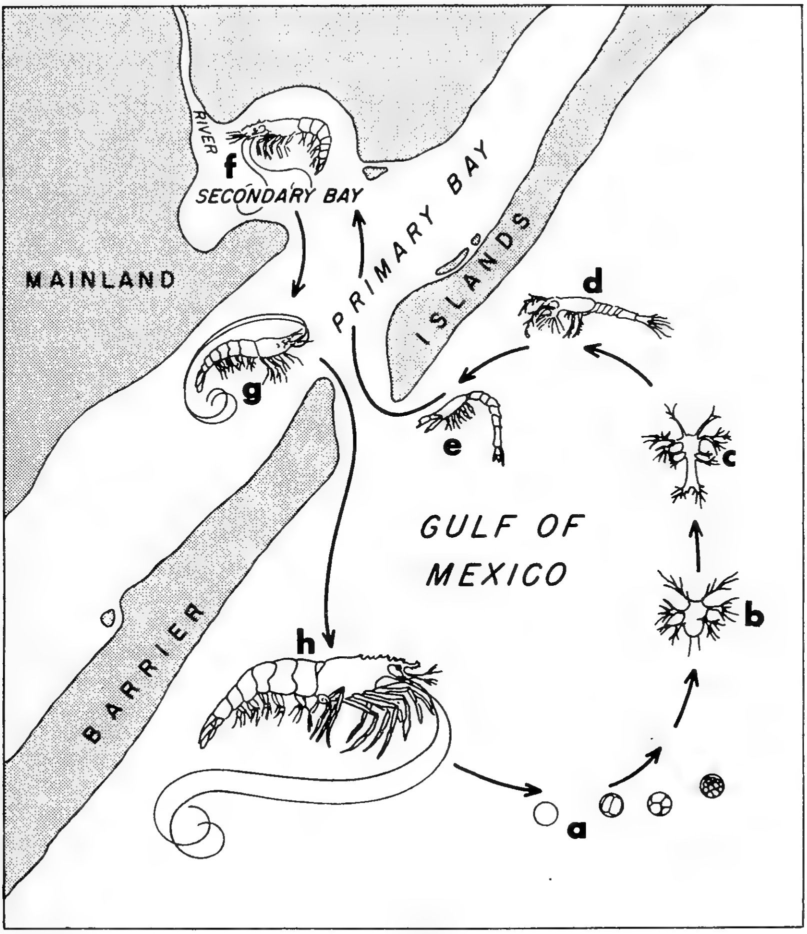
A subdivision according to ecological communities was also based primarily on geographical location, but again coastal conditions made it necessary to identify small ecosystems governed by specific local conditions within each of the major groupings.

## The Socioeconomic Environment

The socioeconomic environment of the estuarine zone is the direct result of its value as a means of sustenance, a place to live, a source of enjoyment, and a route of transportation. The laws regulating man's activities in this zone are historically intended to protect and serve individual and group interest in dealing with each other. Only recently has it become apparent that the laws protecting man from

## Figure IV.I.38

### TYPICAL LIFE HISTORY OF THE GULF OF MEXICO SHRIMP




Source: W.C. Guest, The Texas Shrimp Fishery, 1958.

| | | | | | |
|---|---|---|---|---|---|
| a | Shrimp Eggs | d | Mysis | g | Adolescent Shrimp |
| b | Nauplius Larva | e | Postmysis | h | Adult Shrimp |
| c | Protozoa | f | Juvenile Shrimp | | |

himself must be extended to protect the natural environment from man.

This extension of the institutional environment must recognize not only the realities of how the biophysical environment operates, but it must also recognize the need of human society for the estuarine zone and its value to civilization both as an essential part of his ecosystem and as an exploitable resource.

## POPULATION AND INDUSTRIAL DEVELOPMENT IN THE ESTUARINE ZONE

The importance of the estuarine zone of the United States to the national community is shown most clearly by the numbers of people that use it. Population concentration in the coastal counties began when the first European colonist arrived. This concentration brought about the development of a corresponding amount of manufacturing industry in the estuarine zone, while the great harbors gave the estuarine zone its dominating position as the commercial center of the Nation.

Long before the settlement of Plymouth, British, French, and Spanish fishermen were exploring the North Atlantic fishery resources including those in the Gulf of Maine and along Georges Bank; after colonization of New England, the fisheries were the sustaining industry that provided the economic foundation for growth and development. The estuaries were also the entry portal for the immigrants that came to this Nation looking for the land of opportunity.

As the population grew, the relative importance of the fishery progressively declined as economic growth in other industries outstripped the demand for seafood as a staple diet item. The growth of industrial and population centers in the estuarine zone closely paralleled the growth of the rest of the Nation, with the estuarine zone becoming relatively more important in international commerce and less important in agricultural food production than the interior of the country.

The coastal counties contain only 15 percent of the land area of the United States, but within this area is concentrated 33 percent of the Nation's population, with about four-fifths of it living in primarily urban areas which form about 10 percent of the total estuarine zone area. Another 13 percent of the estuarine land area is farmland, but this accounts for only 4 percent of the total agricultural land of the Nation. The estuarine zone, then, is nearly twice as densely populated as the rest of the country, and supports only one-fourth as much agriculture per unit area.

In those regions lying between Cape Hatteras, N.C., and Canada as well as in the Pacific Southwest, over 90 percent of the population lives in urban areas; over much of the Atlantic estuarine zone stretches the great northeastern megalopolis with population densities averaging over 1,000 persons per square mile. The remainder of the estuarine zone of the United States exhibits a pattern of major centers of population clustered around natural harbors and separated by stretches of coastline which are either empty and inaccessible or beginning to be sprinkled with private residences and resort communities in the vicinities of population centers.

The coastal counties have within their borders 40 percent of all manufacturing plants in the United States. The mixture of manufacturing types in the estuarine zone is the same as the national composition with only minor exceptions, such as the concentration of the apparel manufacturing industry in the Middle Atlantic region, particularly in the New York area. Distribution of manufacturing types among the biophysical regions shows regional differences related to historical development as well as raw material and market availability.

Over half of all plants in the coastal counties and one-fifth of all manufacturing plants in the United States are located in the Middle Atlantic biophysical region, which was the historical center of the Nation's industrial growth and is still one of the major market areas. The Pacific Southwest is the major industrial center of the Pacific coast and is developed as intensively as the Middle Atlantic region. Some industrial development in other regions tends to follow historical or present raw-material availability. Leather-product plants are clustered in the North Atlantic region, and lumber manufacturing plants are most plentiful in the Pacific Northwest. Food processing plants, however, follow closely the distribution of population.

While much of the industrial development located in coastal counties affects the estuarine zone indirectly through use of adjacent land, some of the water-using industries have an impact on the estuarine zone far beyond their numbers. The paper, chemical, petroleum, and primary metals industries are the major water users among manufacturing establishments and are distributed universally throughout the estuarine zone.

## USE OF THE ESTUARINE ZONE

Many of the uses catalogued in this report occur only because the historical growth of the country makes the estuarine zone the place where the people and the industry are. Only commercial navigation and commercial fishing are uses which are primarily associated with the estuarine zone rather than other parts of man's environment. Uses such as water supply, waste disposal, and recreation are associated with civilization wherever it exists; in the estuarine zone they may have different values, different emphasis, or different impact on the biophysical environment.

The great unique use of the estuarine zone, which makes it of primary importance to man and his civilization, is its place in the life cycle of many animals which aid in converting solar energy into more usable forms. While no life form can be singled out as irreplaceable, the kinds of life which need the estuarine zone to survive represent essential links in the energy conversion chain upon which man depends for survival. Many of the human uses of the estuarine zone depend directly or indirectly on the existence of the estuarine zone as a healthy habitat.

### *Fishing*

The important fish species are those sought by either the sports fisherman or the commercial fisherman. Practically all of the sports fish species are dependent upon the estuarine zone for one or more phases of their life development, and approximately 65 percent of all commercial fish species are estuarine-dependent.

In 1967 U.S. fishermen received $438 million for approximately 4.06 billion pounds of commercial fish and shellfish. It has been estimated that two-thirds of the total value, or approximately $300 million, can be considered for estuarine-dependent species. This is a conservative estimate of the direct value derived from the estuarine fishery for it does not include the value of fish harvested by foreign vessels off the U.S. coast. Five of the six leading species by weight, representing over one-half of the U.S. commercial fish tonnage in 1967, are estuarine-dependent.

*Recreation*

The demand for outdoor recreation has increased significantly over the past decade. The trend toward higher personal income and more leisure time has made it possible for a greater precentage of the populace to seek new outlets. Companies manufacturing equipment for outdoor recreation have sprung up by the hundreds.

The advertising industry has campaigned vigorously to sell the public on the need for recreation, and service facilities to support the recreationalist are blossoming in all parts of the country.

There are a wide variety of land and water recreational activities available in the estuarine zone and many estuarine systems are intensively used for recreational pursuits. The unique combination of available resources in close proximity to large population centers offers an unparalleled recreational opportunity for many people who could not afford to travel far from their homes.

Each type of recreational activity has a certain sensitivity to the quality of the environment in which the activity takes place. Clusters of activities that require similar environmental conditions but differ in environmental quality needs can be grouped as follows: (1) swimming and associated shore activities, including picnicing and camping; (2) sports fishing from shore or small boats; (3) boat-centered activities, such as cruising or water skiing; and (4) aesthetic appreciation of the total environment.

*Transportation and National defense*

The Nation's estuaries provide the physical, social, and economic conditions required for an effective system of water terminals serving international trade and coastal shipping. According to a 1966 inventory of ports and terminals by the Maritime Administration, there were 1,626 marine terminal facilities providing deep water berths in 132 ports on the Atlantic, Gulf, and Pacific coasts. The significance of these ports and terminal facilities is indicated by the 1965 statistics which show that these ports handled 346,315,000 tons of foreign trade cargo which was 78 percent of the U.S. foreign trade total. In addition, the port facilities handled 332.1 million tons in coastal cargo and 288.2 million tons in local shipping.

The estuarine ports also serve as essential elements of the national defense system. The deep water terminals exert a significant influence on the location of defense installations as well as of the industrial complexes necessary for logistical support of the defense effort. A direct indication of the use of estuaries by naval vessels is the total number of ships in commission. During the fiscal year 1967 this number was 931 with a planned increase to 960 in the fiscal year 1969.

The use of the harbors for waterborne transportation is competitive in that it may cause other uses to be foregone. Heavy ship traffic interferes with pleasure boating and related activities. Maintenance of the ship channels may alter the ecology and the surface area occupied by the large vessels may well interfere with safe pleasure boating.

Water transportation is not the only type of transportation consideration for estuaries. Since a major percentage of large cities are located on estuarine systems, there is considerable pressure to develop fill areas for airports which then utilize the long overwater approaches to keep the jet noise away from developed areas. The water areas offer a barrier to land travel that must be overcome with causeways or bridge type structures which can interfere with navigation or cause habitat damage. On the other hand, peripheral roads offer some of the more scenic routes available and are frequently the only undeveloped area on which roads can be built.

*Municipal and industrial water supply*

The water in the estuary can serve as a source of both domestic and industrial water supply; but utilization of estuarine water for domestic supply is very limited at the present time. Normally the brackish water is unpotable and treatment costs to render it potable are extremely high. The brackish estuarine water is also a poor source for industrial process water. Here again a high degree of purity is normally required in the process water and the cost of removing the dissolved salts is prohibitive.

Estuarine waters are used extensively, however, as a source of industrial cooling water. For this use the most important considerations are the quantity and the ambient temperature. Water temperatures are generally well below the maximum for economical cooling, and since the ocean is connected to one side of the estuary, the quantity is no problem. Cooling water is required by both the manufacturing industry and electric power generation plants; the greatest use is in the thermal electric plants.

The distribution of cooling water use parallels population and industrial development in the coastal counties, even though electrical power can be transported economically over many miles. The greatest concentrations of cooling water use are in the middle Atlantic and Pacific southwest regions; fortunately these regions both have moderate water temperatures which make possible efficient use of the available cooling water.

There are, however, 47 nuclear powerplants built or scheduled for completion by 1976. All of these are in the megawatt range, with a combined capacity of nearly 35,000 megawatts of electrical power. While the bulk of these will be in the cooler parts of the Nation, 12 will be in the South Atlantic, Gulf, and Caribbean regions where water temperatures are high, greater volumes must be used to achieve proper cooling, and the increase in water temperature through the powerplant may be sufficient to cause environmental damage.

*Waste disposal*

The concentration of population and industrial development in the estuarine zone has led naturally to the use of estuarine waters for removal of the waste materials of man's civilization from his immediate vicinity. It is unlikely that cities were built on the coastline with any conscious consideration of the use of the estuarine environment for waste disposal, yet it has happened that this use has become one of the major uses of estuarine waters and the associated land. Virtually all

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of the cities and industries in the coastal counties dispose of wastes either directly or indirectly into the estuarine zone.

Liquid waste discharges to estuarine systems include domestic waste products, industrial waste materials of all degrees of chemical complexity and sophistication, used cooling water with its thermal load, and storm runoff. These wastes affect the estuarine environment in different ways and can eliminate other uses.

Liquid wastes are not the only concern. The use of the estuarine shoreline for refuse dumps and land fills results in considerable debris getting into the water; water leaching through these dumps has a pollutional impact on the estuarine water. Spoil disposal from dredging activities is another form of solid waste material that contributes to estuarine degradation, and solid materials entering the estuary in the form of debris from storm runoff can be significant in terms of damaging beneficial uses.

Waste disposal is a highly significant and universal use of the estuarine resource and it is likely to remain so. Along with the many other socioeconomic uses of the estuarine environment, it must be managed so that it does not damage the biophysical environment.

*Exploitation of mineral resources*

Minerals within the water, on the bottom, and under the bottom are a valuable part of the estuarine resource and are being exploited widely.

Subbottom mining operations are limited to the recovery of sulfur, petroleum, and natural gas, with the major operations occurring in Louisiana, Texas, California, and Alaska. These operations exist both in the estuaries and out on the continental shelves with the governing criterion for locating being the location of reserves.

Recovery of minerals from submerged estuarine zone bottoms by surface mining, i.e., dredging, is primarily directed toward sand, gravel, and oyster shell production. Sand and gravel operations are universal throughout coastal areas wherever suitable deposits and a market exist.

Oyster shell is an extremely useful construction material in the Gulf of Mexico biophysical region. Twenty of the 22 million tons of annual U.S. production are in the Gulf States with Texas and Louisiana producing the vast majority of it.

Phosphate rock is an important estuarine mineral resource; about 75 percent of the total U.S. production is in the estuarine zone of Florida and North Carolina, particularly around Tampa Bay and Pamlico Sound.

*Aquaculture*

The great fish and shellfish resources of U.S. coastal waters have adequately supplied the seafood demands of the increasing population for over 300 years. Now, however, the demands for some products is so great that the normal fishing grounds and fisheries are in great danger of being exhausted, both from overfishing and from the indirect effects of man's enroachment into the estuarine environment. To supply future needs of some fish products new approaches toward commercial fishing are needed, both in harvesting the natural growth and in controlling the entire fishery. Aquaculture is defined as the rearing of aquatic organisms, both plants and animals, under controlled conditions using the techniques of plant and animal husbandry. It involves a variety of operations, some that are highly sophisticated where man exercises control over the principal environmental factors affecting the cultured species, and others that are very simple with only minimal control or manipulation of the habitat and the cultured animal.

*Shoreline development*

The use or development of estuarine water either governs or depends on land or shoreline use.

Commercial development of the shoreline includes loading terminals, docks and shipyards, airports, industrial plants, and the smaller municipal and local piers. Recreational facilities include marinas, beaches, parks, fishing piers, and vacation cottages, motels and hotels. Although the motels and hotels are a commercial venture, their prime purpose is to support the recreationist. Residential development of waterfront property in many communities places on the shoreline intensive housing development accompanied by boat docks, fishing and swimming piers, and private beaches. Commercial and personal transportation requires airports, highways, and commercial port facilities.

Structures built to protect or conserve the shoreline include bulkheads to hold the shore in place, dikes to prevent flooding and to extend reclaimed land, jetties to provide a protective barrier between the sea and ship channels, and groins along beach areas to control sand movement.

## THE SOCIAL AND ECONOMIC VALUES OF ESTUARINE USE

All uses have value, both individually and as part of the development and use of the entire estuarine resource for the benefit of the present and future national community. The importance and total value of any estuarine system lay not in the measure of economic value for any particular use, but in multiplicity of use related to the needs of people who live there or otherwise depend on the estuarine resource.

*Fish and wildlife habitat*

The value of the estuarine zone as fish and wildlife habitat both depends on and augments its value for other uses, particularly recreation and commercial fishing.

There is, in addition to these, the basic incalculable value of the estuarine habitat as a link in the essential energy-conversion chain which permits man to survive at all.

The trapping of fur bearers in the marshes of the gulf and Atlantic represents one of the few economic values directly attributable to estuarine habitat. Louisiana is the major producer; in the 1965–66 season total sales were $4.6 million out of the Nation's $6 million total.

*Commercial fishing*

An entire complex of commerce and industry can rest upon one primary producing industry such as commercial fishing. Each time the basic product changes hands it generates economic activity and gains in value until by the time it reaches the ultimate consumer, its price may be many times what the fisherman was paid for it. The effect of such value multiplier factors will be such as to make the actual values of specific commercial fisheries several times the landed values.

Thus, the $438 million received by U.S. fisherman in 1967 probably represents a total input to estuarine zone economic activity of over $1 billion; exactly how much it is impossible to say. Case studies assign multiplier values of about three and four to commercial fishery landing values, but the magnitudes of such multipliers depend on the structure of the local economy as well as on other factors and generalities are likely to be misleading.

The relationship of the estuarine zone and commercial fishing cannot be expressed by any simple economic index. The importance of commercial fishing in the estuarine zone is related economically not only to estuarine habitat, but also to transportation, commerce, food processing, and aquaculture.

*Recreation*

Each kind of recreational use has its own economic impact. Recreational boating supports a large boatbuilding, marina, and boat repair industry. Sport fishing supports not only a certain part of the boating industries, but also a very specialized industry manufacturing and selling fishing tackle. For example, the 1965 survey of fishing and hunting shows that salt water anglers spent $800 million in that year. Sightseeing and swimming support motel and restaurant services in the favored areas, as do other overnight recreational activities.

Attempts at the quantification of overall recreational economic values are not yet well-developed. The user-day recreation benefits approach has been used in some Federal waterway and reservoir projects, but has been used in the estuarine system only in an analysis of fisheries and recreation in San Francisco Bay. Net benefits for general recreation activities, by this method, range from $0.50 to $1.50 per day. Specific forms of recreation may have higher values.

Applying such a figure to the population of the coastal counties suggests that the value of the recreational resource of the estuarine zone is about $300 million if each person has about 5 days of recreational use. Such an estimate would include only local use and no multiplier values and might therefore be regarded as minimum value of the entire value of the entire estuarine recreation resource.

The major problems in defining the economic values of recreation in the estuarine zone lie in the facts that recreation itself is not an easily defined commodity nor can it be isolated from other economic activities such as transportation, food and lodging services, and equipment manufacturing.

*Commercial navigation and national defense*

Estimates of the economic value of commercial navigation are based on the direct revenue to the port of handling a ton of cargo, generally $16 to $20. Such estimates lead to a total value of the estuarine resource of $4.7 billion annually for cargo revenues alone, without multiplier values. An additional economic value of $10 billion annually in salaries and wages has been estimated for 11 major ports.

These estimates do not show the impact of commercial navigation on land transportation, shoreline development, or the manufacturing industries. Without the deep, safe harbors commercial navigation could not exist on a large scale, and without commercial navigation the great cities around these harbors would not have developed.

Deepwater harbors are essential elements of the national defense system. Furthermore, the location of these deepwater ports has influenced the location of other defense installations as well as the industrial complexes necessary for the logistical support of the defense effort.

The cost of the national defense effort in the estuarine zone for 1967 is estimated at about $900 million, exclusive of pay and allowances for shore-based Navy and Marine Corps personnel. The economic impact of national defense activity overlaps into all other estuarine zone uses because of the massive payrolls associated with it. This impact is centered in the areas with major defense installations.

*Waste disposal*

The waters of the estuarine zone have received wastes from the people and industries on their shores ever since the first cities were founded. The economic benefit in the use of estuarine waters for waste disposal has been fully utilized by nearly all industries and communities in the estuarine zone, and only the tremendous capacity of estuarine waters to absorb and remove waste materials has kept the estuarine zone from suffering severe damage from such waste discharges.

No overall estimate of the value of this use of the estuarine resource is possible because the level of treatment necessary in any particular case depends on many local factors.

While the use of estuarine waters for waste disposal may not be esthetically appealing it is an existing estuarine use with which other uses must compete, and it should be considered along with them in the overall economic evaluation of estuarine uses.

*Examples of socioeconomic environments in the estuarine zone*

Almost all estuarine systems have either a multiplicity of uses at the present time or such uses are available in the system. Estuaries presently support such varied uses as military berthing and associated activities, commercial port facilities, shipping channels, industrial uses, commercial fisheries, sport fishing, recreation, wildlife habitat, and purely esthetic purposes. In most estuaries one or two of the uses predominate while the others take minor roles.

Narragansett Bay is an ideal example of an estuary that has developed in an unbalanced fashion. That is, the economic value of the estuary at the present time is largely associated with the industrial, military, and transportation uses of its waters. Other uses are, of course, made of the estuary but their economic significance is dwarfed by the tremendous magnitude of the military and commercial uses. However, it must be remembered that this economic measure is merely an indicator of the value of the waters and is not in any way related to the right or necessity of polluting such waters in the process of achieving this value. In fact, the only time that such an economic measure would be used would be for comparing one total use of the estuary to another total use. Of course, it is seldom that questions are so broad as to cover either/or propositions for the entire activity. Rather, the questions usually revolve around such things as the benefits to be derived from reducing pollution caused by users of the estuary compared with the costs of achieving the reduction in pollution.

Franklin County, Fla., is dependent upon pollution-free waters in Apalachicola Bay for its economic existence. The unpolluted waters of the bay provide the seafood caught by local commercial fishermen and processed at shore-based installations. Additional income for the area results from tourism engendered by the bay's waters.

Both tourism and commercial fishing are prime potential sources of income to any estuarine system. In the case of Apalachicola Bay, these happen to be the major sources of income because of the nature of the estuary and its location which prevent its development as a commercial shipping facility.

The San Diego economy, although heavily dependent upon the military and shipping activities in the bay, has diversified to the extent that it is no longer completely dependent upon such uses of the bay. At the same time there has been a growing demand for recreational uses of the bay. Evidence of the local residents' interest in the bay for recreation, tourism, and commercial uses can be found in their willingness to invest substantial sums of money in facilities to prevent pollution of the bay by municipal wastes.

Mission Bay, a separate estuary in the San Diego area, is an example of the recreational potential to be found in an estuarine system. However, this special study points up the fact that the best use of an estuary may not come about naturally. Rather, it shows that a planned development program with adequate investments are necessary to achieve optimal use of an estuary.

*Measures of overall value and importance*

The discussions of values of individual uses and the case studies of specific estuarine systems present a confusing picture of the relationship of estuarine uses to economic indicators.

Estimates of the direct economic benefit of the estuarine zone to the residents of the coastal counties can be made. The estimates of economic activity generated by the presence of Narragansett Bay in Rhode Island give a conservative annual economic benefit of $920 per capita, $420 of which is personal income. Average personal income for all of the coastal counties is, according to Bureau of the Census figures, $500 per capita greater than the average for the remainder of the country. The total economic activity generated by this additional personal income then amounts to about $1,100 per person, using the Narragansett Bay multiplier values.

The total direct economic benefit of the estuarine zone to the residents of the coastal counties is then about $60 billion in terms of additional economic activity stimulated by the presence of estuarine systems. This is not a measure of the total economic activity of the estuarine zone, but only of the "value added" to the total economic activity of the coastal counties by the presence of the estuarine zone.

Such gross means can give only an order-of-magnitude estimate of even the direct economic value of the estuarine zone and cannot possibly reflect either indirect benefits or the social importance of the estuarine zone, much less its ecological value.

Valid criteria for evaluating the importance of the estuarine environment or the value of individual estuarine uses, to a community must, however, go beyond the reach of economic approximation and recognize the fundamental relationship between man and his environment. Wherever there are people the environment will be exploited to satisfy the needs and desires of man and his civilization.

Increasing environmental pressures from demographic and commercial development are paralleled in the same community by the increasing desire for greater recreational use. That these can be compatible is clearly shown by the San Diego Bay example. Such community reactions as in San Diego and in San Francisco demonstrate that, while people need commercial development and use, they want a safe and enjoyable environment at the same time.

### SOCIAL AND ECONOMIC TRENDS IN THE ESTUARINE ZONE

At the present time, the major uses of estuaries, in terms of gross monetary return are: military use, shipping, and industrial activities. These uses are, of course, historical and do not necessarily reflect the uses that would be made of the estuary under today's conditions or future conditions, if each use were to compete for the water use at the same time. In other words, historical use has brought about the present use imbalance in many estuarine systems. However, given the opportunity to develop, other uses might attain equal importance economically while contributing important social benefits.

Estuaries at the present time represent underdeveloped natural resources that are important to the social as well as the economic well-being of the Nation. Based on present trends and demands, there is little doubt that there will be a tremendous need for estuarine uses other than for military, shipping, and industrial uses. That is, if the facilities are available for recreation, sports, or esthetic enjoyment, they will be used and used to great advantage from an economic standpoint as well as a social standpoint.

If normal circumstances prevail, the Nation's population and general high standard of living will continue to increase in the coming decades. A moderate estimate projects a doubling of the national population by the turn of the century, with a significant proportion of that growth occurring in urban areas.

The population will be made up of a large proportion of youth and young persons of working ages, with only a moderate increase in the elderly through the end of the century. Personal income will rise dramatically. Estimates of leisure time vary considerably, but all authorities agree that the workweek will shorten, from a conservative estimate of 35 hours a week to as little as 20 hours per week. The National Planning Association has projected that in 1990, 10 percent, and in 2000, 20 percent of the men between the ages of 25 and 54 will be granted a 1-year leave every 7 years.

Urban, and particularly suburban growth, will expand greatly both to accommodate the growing population and to provide amenities that it increasingly demands: single-family dwellings, recreational areas, transportation facilities, industrial developments, and so on. These demands will place rapidly increasing burdens on the Nation's resources and its environment. These burdens, in turn, will tax the ability of decisionmakers and the Nation's population to cope with the complexity and insistence of the problems generated by a postindustrial, urbanized society.

Information provided by this analysis of national population and economic trends gives only the grossest indication of the activities and expected pressures of population and economic activity on all of the Nation's environment. Analysis of these indicators can only provide a general indication of the magnitude of the demands which will be generated by these forces in the near future on the estuarine zone.

## Pollution: The Impact of Human Society on the Estuarine Environment

Man has always used the biophysical environment as he needed it for survival and thrown back into it his waste products and anything else he did not need. As long as civilization was limited to small towns and villages the impact of such treatment on the estuarine environment was not noticeable and apparently insignificant. With the development of a civilization based on a complex socioeconomic environment, however, his impact on the natural environment has increased until now the most accurate term to express the relationship of man to his biophysical environment is pollution.

Pollution is the degradation of the biophysical environment by man's activities; it is no longer limited to the discharge of sewage and industrial wastes, but now includes direct or indirect damage to the environment by physical, chemical, or biological modification.

Environmental degradation is the result of often minute changes in water quality, water circulation, or other conditions which are part of the biophysical estuarine environment. There are brightly colored or otherwise visible waste materials which have obvious pollutional implications, but by far the deadliest pollutants are those which are invisible and often unsuspected until the damage is done. These pollutants can be found only by the most delicate and sensitive tests and, even then, the presence of some highly dangerous materials or conditions can only be inferred by indirect evidence.

### MATERIALS AND CONDITIONS WHICH DEGRADE THE ENVIRONMENT

One of the major constituents of municipal and many industrial wastes is *decomposable organic material.* Such materials consist primarily of carbohydrates from plants and paper, proteins from animal matter, and miscellaneous fats and oils. The decomposable organics are not necessarily detrimental by themselves but exert a secondary effect by reducing dissolved oxygen in the water. The level of dissolved oxygen is one direct index of the healthiness of the system. High levels are generally indicative of a healthy system which will support a diverse biota and multiple use. The lower the concentration of dissolved oxygen becomes, the sicker the system is, and the less desirable it is for habitat or use.

Another class of materials, primarily organic, that can have considerable impact on the estuarine ecosystem are the *flesh-tainting substances.* Generally these materials are contained in industrial waste effluents and they result in offensive tastes, odors, and colors of fish and shellfish.

The salts of *heavy metals* are fairly soluble and stable in solution. Consequently, they will persist for extended lengths of time. Many of these are highly toxic to the aquatic biota, and since many marine organisms exhibit the ability to accumulate and concentrate substances within their cell structure, the presence of these metals in small concentrations can have deleterious effects.

Aquatic life forms require trace amounts of some minerals and vitamins for growth and reproduction. Elimination of such materials from the environment or their reduction below minimum levels can limit the growth and reproduction of some biota. Conversely, an oversupply of all necessary trace *mineral salts* and vitamins can stimulate growth, providing satisfactory conditions of temperature, salinity, and dissolved oxygen also exist. An oversupply of inorganic nutrient salts, such as those of nitrogen and phosphorus, may be associated with drastic shifts in the composition of the aquatic community.

One of the many unfavorable effects of municipal and some industrial wastes is the contamination of the receiving environment with bacteria, viruses, and other organisms of public health significance. *Pathogenic organisms*, especially those from the intestines of warm-blooded animals frequently persist for sufficient periods of time and distance to pose a threat to the health and well being of unsuspecting water users. Secondary chances of exposure to these organisms exist through the contamination of shellfish which can be harvested for food.

Among the waste products that are frequently introduced into the estuarine environment are some directly toxic to marine organisms. *Toxic materials* may exhibit a short catastrophic impact or a more subtle long-term interference with growth and reproduction processes. The end result is to create a biological desert in which no organism can survive. The pesticide group is of particular concern in the estuarine zone. Estuaries are the terminus for most of the major river systems, and as such they tend to concentrate the waterbone materials carried in by the large terrestrial drainage systems. The biological magnification capability of estuarine animals significantly increases the hazard and destructive potential of any contributed pesticides. The ultimate damage is to stress or eliminate parts of the energy conversion chain in the estuarine environment.

The addition of large quantities of heat from industrial cooling water constitutes a form of pollution which must be considered. The entire ecosystem may be stressed by *thermal pollution.* The amount of damage is dependent on the resulting temperature of the environment and the species composition of the biotic community. The total range of detriments should be carefully considered on an individual case basis before heat is released to the environment. Heat affects the physical properties of water, the rates at which chemical and biological reactions progress, and can kill living organisms.

Man's activities may affect the rate of *sediment* inflow, deposition, and outflow by purposely or inadvertently upsetting the natural balance. If upstream erosion is increased due to poor land management practices, the load carried in will increase. Conversely, activities along the coast can result in increased shore erosion, removing more sediment than is contributed. The primary pollutional problem from sediment, however, is from increased influx and accelerated deposition. The detrimental effects of sedimentation are reflected in an impairment of uses such as navigation, recreation, and fish propagation.

One of the greatest threats to the estuarine ecosystem is the ever-present chance for a *catastrophic spill* of oil or other hazardous materials. The large volumes of petroleum and chemical products transported through the estuarine zone by ships, barges, pipelines, tracks, and railroads present a continuing opportunity for accidental bulk spills. The consequences of these spills depend on the amount and type of material released and the characteristics of the receiving water. They may range in magnitude from tragic loss of life to little more than economic loss for the transporter.

The effect any pollutant has on an estuarine environment depends on where it goes, how strong it is, and how rapidly it is assimilated or flushed out of the environment. All of these conditions depend on water movement and circulation patterns which are in turn governed by the relationship of tide and riverflow to estuarine shape and size. *Physical modifications* such as the dredging of new or deeper navigation channels, building of causeways or jetties, and even construction of pier bridges can cause subtle changes in water movement that can change the balance of environmental conditions in an estuarine system and result in gradual undesirable changes in the ecosystem in addition to direct habitat damage.

### SOURCES OF POLLUTION

Nearly all of man's activities can result in environmental degradation. Pollutants and polluting conditions are very rarely unique to a particular use or specific activity, but may result from man's existence in the estuarine zone as well as his use of it. The major sources of pollution are these:

(1) Those sources associated with the extent of development of the estuarine zone, including waste discharges from municipalities and industries, and land runoff from these as well as agriculture;

(2) Those sources associated with particular activities of great pollutional significance, specifically dredging and filling, watercraft operation, underwater mining, and heated effluent discharges;

(3) External sources having impact derived through flow regulation and upstream water quality.

Over 8 billion gallons of *municipal wastes* are discharged daily into the waters of the estuarine zone. While most of this volume is domestic sewage, many municipal waste discharges also contain significant amounts of industrial wastes, which may add to the variability and complexity of the wastes discharged. Municipal waste discharges have four important effects on receiving water quality: depletion of dissolved oxygen, and introduction of pathogenic organisms, settleable material, and inorganic nutrients.

Sewage treatment reduces and alters the impact of municipal waste on the environment. Primary treatment with chlorination will remove part of the decomposable organic material, nearly all of the settleable and suspended solids, and almost eliminate the possibility of pathogens in the effluent. Secondary treatment can almost eliminate decomposable organic material, and some special processes can eliminate certain kinds of dissolved salts. About one-half the municipal wastes discharged to estuarine waters receive secondary treatment, with the most extensive use of secondary treatment being in the Chesapeake Bay estuarine region.

Associated with the major metropolitan developments are large numbers of industrial complexes with their attendant waste products. Many of these *industrial wastes*, especially from the chemical industry, are of such a complicated nature that it is difficult both to identify them and to assess their effects on the receiving streams. Only 4,000 of the more than 200,000 manufacturing plants in the coastal States account for 97 percent of the total liquid wastes discharged. Of the nearly 22 billion gallons of industrial wastes discharged only 29 percent receive any kind of waste treatment.

Intensification of use of the estuarine zone has resulted in many artificial changes being made in the physical structure. Shoreline areas have been filled to create more land area for residential and commercial use; channels have been dredged and maintained to permit safer and better navigation; and harbor facilities have been dredged and bridges and causeways have been built. All of this activity has had impact on the coastal zone ecosystem, but the activities having the most impact on water quality are *dredging and filling*. The potential for pollution of the system exists in both filling and dredging; both can introduce foreign materials into the water, destroy aquatic habitat, and alter physical circulation patterns.

The primary source of *thermal pollution* is from industrial cooling water effluents. Powerplants are the major users of cooling water in the estuarine zone, and power generation capacity has approximately doubled each decade during this century. The impact of this growth on the estuarine areas is evidenced by the fact that, in 1950, 22 percent of the powerplants were in the coastal zone; it is anticipated that over 30 percent of the plants will be located there in the late 1970's.

Estuarine areas are also very important highways of commerce, and thousands of commercial vessels, foreign and domestic, from ocean liners to barges, traverse the coastal waterways each year. Added to this are many of the 1,500 Federal vessels and many nearly 8 million recreational vessels. All of these watercraft carry people and/or cargo, and are a real or potential pollution source.

*Mining* from the estuary floor causes alteration of the estuarine shape and water circulation characteristics, with a secondary effect being the turbidity problems associated with material removal. Mining of sand and gravel from the estuarine floor are universal while oyster shell dredging in any great quantity is restricted to the Gulf Coast. These operations remove part of the estuarine floor with a concomitant destruction of habitat and life. There are also great amounts of suspended and settleable solids frequently released into the water, from which they are redeposited in other places.

The water quality of estuarine areas is dependent not only on direct waste sources but also on the quality of the *inflowing streams* and runoff entering the system. Tributary influent quality is generally a good index of the type and intensity of land use surrounding and upstream from estuarine systems, and can be a major cause of ecological stress within the system. The complex interactions between fresh and salt water may magnify the effects of pollutants carried into the tidal regime, resulting in quality anomalies completely alien to either fresh or oceanic environments.

## EXTENT OF POLLUTION EFFECTS

Environmental damage from human activities manifests itself in changes in water quality and in changes in the living communities. Either or both may be caused by any of the kinds of pollution or sources of pollution mentioned earlier. One key to the degree of environmental impact is measurement of alteration in water quality. Extensive data have been collected on a few of the estuaries with the most severe problems, and limited information is available on other estuarine systems to outline the emergence, or document the existence, of water quality problems.

Examples of estuarine systems that show definite documented water quality degradation as a result of human activities are these: Penobscot Bay, Boston Harbor, Moriches Bay, New York Harbor, Raritan Bay, Delaware Estuary, Baltimore Harbor, Potomac River, James River, Charleston Harbor, Savannah River, Biscayne Bay, San Juan Harbor (P.R.), Tampa Bay, Pensacola Bay, Mississippi River, Galveston Bay, Laguna Madre, San Diego Bay, Los Angeles Harbor, San Francisco Bay, Columbia River, Puget Sound, Silver Bay (Alaska), and Hilo Harbor (Hawaii).

Pollutional damage to estuarine ecosystems may be sudden and dramatic as fish or other aquatic life forms suddenly dying, or it may be so gradual as not to be noticed for many years. Many studies of different aspects of estuarine biology have been made, but there are only a few cases in which comprehensive ecological studies have been made of pollutional effects.

All of the 25 estuarine systems listed above also show some ecological damage, but in 38 percent of the estuarine systems of the United States there is not sufficent information to decide whether there is no ecological damage, or whether there is just no easily identifiable pollution problem present.

The complex nature of pollution in the estuarine zone prevents the separation of sources of pollution, kinds of pollution, and types of environmental damage into neat compartments of cause and effect. All of human activities in the estuarine zone can damage the environment and most of them do.

Wherever people live, work, and play in the estuarine zone the demands of their social and ecomonic activities place stresses on the biophysical environment. These stresses frequently result in degradation of the environment, perhaps not immediately or even in a few years, but nonetheless certain in its devasting final impact.

## USE CONFLICTS AND DAMAGES: MAN'S BATTLE WITH HIMSELF AND NATURE

The consequence of damage to the biophysical environment is loss of use either immediately or at some time in the future. Loss of use, however, may also be associated with the appropriation of part of the estuarine resource for one exclusive use even when no damage to the environment itself occurs.

Institutional management must cope with the problems of responsibility and authority in achieving maximum multiple use of the estuarine resource. Within this comprehensive framework technical management must resolve the problems surrounding conflicts of use, competition for the resources of the estuarine zone, and environmental damage. The primary objective of technical management is to achieve the best possible combination of uses to serve the needs of society while protecting, preserving, and enhancing the biophysical environment for the continuing benefit of present and future generations.

The uses of the estuarine zone grew and changed in consonance with population growth and industrial development. Not until recent years was a concerted attempt made to understand and resolve the conflicts that arose in the competition to use and exploit these land and water resources. During the past 300 years of growth and industrial expansion with its emphasis on economic growth and direct monetary gain, large parts of the estuarine zone were preempted or usurped to serve the individual needs of commercial enterprises. The net result has been less a conflict in existing uses than an exclusion of some uses.

Nearly all estuarine uses involve both land and water, either directly or indirectly. For example, the construction of a manufacturing plant on the shore of an estuarine system may not involve any direct use of the water (even for waste disposal), yet it limits access by its occupation of the shoreline and so may interfere with other uses. Conversely, the disposal of liquid wastes into the water may not use any appreciable space but may make the shoreline unusable for recreation as well as making the water itself unsafe.

The impact of one estuarine use on another may be either "prohibitive" or "restrictive" depending on the kind of use and sometimes on the manner in which it is carried out.

Prohibitive impacts involve permanent changes in the environment and thereby prohibit all uses unable to cope with such changes. The geographical range of such impacts may be from the limited area in which they occur to an entire estuarine system, depending on the nature and size of the change. The impact may be temporary, if it is possible to return the environment to its original form, or it may be permanent.

Any use or activity requiring physical modification of the shoreline, marshes, or bottom of an estuarine system may have a prohibitive impact. Modification of water circulation also tends to be prohibitive when it has any conflicting impact. Examples of estuarine uses and activities generally having prohibitive impacts are navigation dredging, other dredging and filling, solid waste disposal, construction of bridges, dikes, jetties, and other structures, shoreline development, mining from the estuarine bottom, and flow regulation.

Some estuarine uses may restrict estuarine use for other purposes but do not automatically exclude other uses. These are those activities which do not require a permanent modification of the estuarine system; they generally include those uses directly involved with the estuarine waters and other renewable resources.

Restrictive impacts may involve damage to water quality, living organisms, or aesthetic quality; such impacts may also result from the exclusive appropriation of space. The key feature of uses which cause restrictive impacts is that they may, with proper management, be carried out simultaneously with other uses.

Any kind of municipal or industrial waste discharge may have a restrictive impact and often does. Commercial fishing, recreation, and water supply are the major uses restricted by pollution from liquid waste discharges.

Some kinds of commercial fishing require the use of trawls or the setting of traps or nets that must be left for some time. The use of such devices restricts other uses while the devices are in place, but there is no permanent appropriation of estuarine waters or space. The major conflict is with recreation in that recreational boating must be excluded from areas where fishing gear is near the surface.

Where there is conflict, the scene is set for trade-off, i.e., a willing substitution of one activity for another. The scene is equally set for uncompensated damage where one user group precludes the activities of a second unrelated user group but does not reimburse them for damage. Actual documented examples of use damages are difficult to find. One major reason is the basic fact that has permeated much of the discussion of economic and social values: many estuarine values are not quantifiable. While damages to a commercial enterprise, such as commercial fishing, can be quantified in terms of the economic loss, the essentially intangible values of recreation and estuarine habitat are difficult to measure.

Recreational loss would have to be measured in terms of how many people *don't* swim or go boating in the Potomac River because it is polluted. It is far easier to find out how many people *do* go there even if it is polluted; even these values are hard to find.

The value of estuarine habitat is just as difficult to establish. There are now about 5.5 million acres of important estuarine marsh and wetland habitat remaining in the estuarine zone of the United States. Perhaps each acre is not valuable by itself, but the total habitat is irreplaceable.

Use damage is not a necessary feature of civilization in the estuarine zone, but use conflicts will continue to exist as more and more demands are made on the natural environment. The ability of any management authority to prevent use damage and to resolve use conflicts depends not only upon its institutional composition and legal authority, but also upon the social, economic, and biophysical characteristics of the estuarine management unit within which its authority is exercised.

The analyses of social and economic values of the estuarine zone examined concurrently with the similar analyses of use conflicts, pollutional effects, and use damages form the basis for resolving use conflicts through the application of technical knowledge, i.e., technical management.

The primary objective of technical management is to accommodate the needed and desired uses of any estuarine management unit within that system without overall damage to the biophysical environment. The ability to achieve this objective depends on the boundaries of the management unit and upon the means available for resolving both prohibitive use conflicts and restrictive use conflicts.

The impact of the social and economic requirements of civilization on the natural estuarine environment is the technical problem with which management must deal, and effective control of this impact can be maintained only if both the major sources of damage and the geographic range of their influence are subject to unified control.

An estuarine management unit, therefore, should consist not only of the estuarine waters, bottoms, and associated marshlands; but it should also include all the shoreline surrounding the estuarine waters themselves and as much of the adjoining land as is necessary to regulate the discharge of wastes into estuarine waters.

Allocation of part of the estuarine resource for an exclusive single-purpose use is a necessary fact of estuarine management. The shoreline is a necessary location for shipping docks and for swimming beaches, but they cannot both occupy the same place on the shoreline. Similarly, frequently dredged channels and oyster beds cannot occupy the same space at the same time. Resolution of such conflicts can be achieved by allocation of adequate space to each use through whatever institutional mechanism is established.

The evaluation of the effects of prohibitive uses on the estuarine environment is probably the most difficult problem currently facing technical management. The immediate and obvious effects of the habitat loss associated with such uses can be measured and described fairly easily, but the ultimate results of the modification of water movement patterns and flushing characteristics can only be estimated in general terms.

In nearly every problem associated with prohibitive use conflicts, however, the area of primary concern is the effect on the estuarine ecosystem of any physical modifications proposed; the limitations of knowledge mentioned above, therefore, present a critical problem in present efforts to resolve prohibitive use conflicts.

A more difficult problem arises where there is involved a massive dredge or fill operation with its concomitant immediate effect on the ecosystem. When such modifications are a necessary or desirable development of the environment it may be necessary to forego the habitat use; however, in many cases it may be possible to create new, equivalent habitat in a different part of the management unit, or it might be possible to restore part of the damaged environment.

While the resolution of prohibitive use conflicts requires the abandoning of one use in favor of another, the potential for carrying out any modifications necessary so as to increase habitat value as well as economic value should be a key factor in the resolution of such problems.

Disposal of liquid wastes to the estuarine environment is the major restrictive use impact of the socioeconomic environment. This use conflict can be resolved completely either by treating all wastes to such an extent that they do not interfere with any other uses or else removing them entirely from the environment.

Technology exists to provide thorough treatment for nearly every kind of municipal and industrial waste, and there is no reason not to provide treatment sufficient to protect the environment from damage and to permit other uses. Treatment requirements for different wastes may vary from place to place according to local conditions, but damage to the environment and restriction of other uses can be prevented.

Water quality standards have been set and are now being implemented in all the coastal States. These standards are the foundation upon which the effective control of estuarine pollution rests, and they provide the framework within which technical management can effectively operate.

Estuarine waters even in busy harbors are used for recreational purposes by those who cannot afford to go elsewhere, regardless of whether the waters are safe for body contact or not. Also the role of the estuarine zone as a nursery for some fish, passage for others, and a residence for still more is readily apparent although its full implications in the energy conversion chain are not understood. For these reasons the long-range achievable water quality goal of estuarine management should be to keep all waters safe for direct contact by humans and also usable as a fish and wildlife habitat.

## Management and Knowledge

A great deal of technical and socioeconomic knowledge is necessary to support a comprehensive program of estuarine management. This knowledge must be supplied through multidisciplinary efforts. The knowledge thus developed must include: (1) Knowledge and understanding of the biological, physical, and chemical factors of the estuarine zone, (2) knowledge of the institutional framework governing each portion of the estuarine zone, (3) knowledge of the demographic, social, and economic factors and their trends, (4) establishment of goals and uses so that future studies can be relevantly oriented, and (5) an augmentation and synthesis of all this knowledge.

The available pertinent information on these subjects has been gathered, organized, and coordinated into the National Estuarine Inventory. This compilation revealed many areas in which information is poor or is lacking; some can be obtained by careful, routine monitoring of the estuarine environment. The acquisition of other knowledge requires an integrated, multidisciplinary research and study program.

The most important knowledge to be gained is an understanding of the estuarine environment adequate to permit the recognition and interpretation of interrelatonships which, in turn, provides the capability to predict the effects of natural and human activities in the estuarine zone. The research and study programs which will yield this information are in the categories of:

(1) Ecology, taken to include base line information, broad ecological studies, biology, water quality, natural variability, and interface factors.

(2) Toxicity, taken to include bioassay needs and methodology, sublethal effects, and mortality phenomena.

(3) Microbiology, taken to include the regeneration of plant nutrients, biodegradation of organic wastes, eutrophication, and pathogens.

(4) Physics and mathematics, taken to include hydraulics, sedimentation, effects of structures and physical modifications, and physical and mathematical modeling.

(5) Planning, taken to include economics, law, social and demographic factors and trends, resource evaluation and allocation, and the role of technical research and study in supporting a comprehensive management program.

(6) Needs of researchers, taken to include environmental modeling, methodology (both laboratory and field techniques), data processing, training needs, and estuarine zone laboratories.

The various agencies and institutions working in estuaries should coordinate their activities; results of research should be widely disseminated. The national program for estuarine study should be developed with strong regional emphasis based on ecology, geography, and a commonality of problems and objectives. Planning for estuarine use and development must be based on broad public benefits rather than narrow private interests. A system of criteria by which to gauge estuarine quality is necessary. Key management roles require adequately trained people in ecology, engineering, economics, planning, and law. Finally, the public must be informed of its stake in the estuary.

The Federal and State roles in estuarine monitoring, research, and study should be a joint one with their respective actions complementary. The State role is basically to manage its estuarine and coastal zone resources, coordinate the research activities of its appropriate agencies and institutions, and to augment and encourage the development of new knowledge applicable to its estuaries and coastal area. The Federal role, a residual one, is primarily to assist the States through such means as: grants to States and to academic institutions, organizations, and individuals to support needed investigations; perform broad studies not of a local nature; participate in State and local studies; coordinate Federal estaurine and coastal zone research and study activities; and organize and coordinate its laboratory resources so as to cooperate with and assist States, localities, and academic institutions supporting and using research in the estuarine and coastal zones.

## Conclusions

The ever-increasing and often conflicting social and economic demands of modern human civilization are placing significant pressures on the limited estuarine resources of the United States. The delicately balanced natural ecology of the estuarine zone has been subjected to over 300 years of exploitation and alteration; objective analysis of the results of this use and misuse shows that positive action is needed now to preserve, conserve, and enhance the finite resources of the coastal zone.

Natural estuarine ecosystems are communities of living organisms existing in reasonably delicate balances determined by definable but poorly understood external environmental conditions. These systems exist only in the geographically and physically limited narrow interface where the land meets the sea; where over one-third of this Nation's present population and industry is concentrated into 15 percent of the land area.

This society uses the resources of the estuarine zone and coastal zone to serve not only those social and economic purposes for which the zone is uniquely valuable, such as recreation, fishing, and navigation, but also to satisfy other requirements of civilization wherever organized human society exists. These uses include industrial, residential, and commercial land development, exploitation of mineral resources and fossil fuels, water supply, and a place to dispose of the wastes from all of these activities. The economic pressures of these diverse and often conflicting uses have often resulted in a preemption of the estuarine resources for individually profitable uses to the limitation or exclusion of other valuable, but much less quantifiable, uses.

The natural aesthetic and habitat qualities of the estuarine and coastal environment enhance its value for many economic uses and also make it a recreational resource of great commercial, as well as social value. It is the value of the estuarine zone as a fish and wildlife habitat, a recreational resource, and an aesthetic attraction that make the estuarine zone a unique feature of the human environment, yet it is these very values that have been generally ignored in satisfying the immediate social and economic needs of civilization. The overall value of the estuarine zone for commerce, navigation, and transportation has been detailed in this report to the extent that definitive economic data are available. The values of the estuarine zone as a fish and wildlife habitat, as a recreational facility, and as an aesthetic experience are probably greater than they are for commercial exploitation but, unfortunately, we have not yet developed the ability to adequately express these social and humanistic values in quantitative terms.

The pressures of population growth and economic development associated with increasing urbanization and industrialization in the estuarine zone have permitted and, indeed, encouraged dredging and filling operations, resulting in the destruction of many valuable areas of estuarine marsh and wetlands. The complete and irreversible loss of this habitat eradicates not only the resident and transient wildfowl dependent upon it, but also the life support system of the bulk of the Nation's sport and commercial fish. True, we cannot now establish a direct quantifiable relationship describing the acreages of wetland, marsh, or estuary necessary to support our coastal fisheries, but we do know that this relationship does exist and that the necessary habitat must be protected. Activities generated by these same social and economic pressures have degraded estuarine waters, severely damaging not only the estuarine ecosystem, but also the other essential human uses of the estuarine resource.

The value of the estuarine resources to the Nation lies more in the multiple purposes it can serve than in the economic worth of a single use, and it is this overriding national value which has been minimized or ignored. Population and economic development pressures are increasing more rapidly now than they have in the past, and continuation of present attitudes and approaches toward use of the estuarine and coastal zone can bring only an increasing rate of damage to its ecology and to the resources it supplies.

Properly supported and managed research and studies to increase present knowledge and information can contribute greatly to effective technical management of the estuaries and coastal areas.

Over and above this, though, must be added a stronger and better institutional environment to provide the umbrella for the integrated and comprehensive planning needed to convert the processes of loss and damage to actions leading to enhanced and broadened values. The program for accomplishing this is presented in Part III.

# PART III. RECOMMENDATIONS—THE PROPOSED PROGRAM

## Introduction

At present, planning and development in the estuarine zone is done on an independent, piecemeal basis. The resultant losses to fish and wildlife resources, the habitat upon which they depend, and the impact on recreational, scenic, esthetic qualities, and water quality itself appear to be proceeding at an increasingly rapid rate. Whole sectors of the public object, but economic and political pressures, particularly at the local level, seem to win out and the irreparable damages to estuarine and coastal regions continue.

It is thus evident that a higher order of planning and evalution is needed. The planning must be both integrated and comprehensive and in the concurrent evaluation, involve all the use of the waters and the adjacent lands. The impact on the total environment must be considered and be paramount to single-purpose aspects.

It is the purpose of this part of the study to recommend the program that will provide for the necessary planning and its implementation at the various levels of government. This was directed in the words of Congress as follows:

> Recommendations for a comprehensive national program for the preservation, study, use, and development of estuaries of the Nation, and the respective responsibilities which should be assumed by Federal, State, and local governments and by public and private interests.

As the study proceeded it was determined quite early that the direct relationship of the coastal areas to the estuaries made it impractical to attempt to consider them separately. This was true because of their close proximity, their continuous influence upon each other, and because both are affected by the same economic and social pressures; thus the recommendations that follow apply equally to the estuarine areas proper and to the entire coastal zone, that overall area where the continent and the islands meet the sea.

A comprehensive program for the management of the estuarine and coastal zones of the Nation, must have as its primary concern the institutional environment, that is, the framework which includes the forms of law, political institutions, and organizational mechanisms, that man must use to provide himself the capability to control, develop, and use these zones. Once this framework is established it becomes more easily possible to conduct activities designed to improve the biophysical environment and the socioeconomic environment.

What is proposed is a program that recognizes the primary responsibilities of the States in a management program for their estuarine and coastal areas, and on the Federal side provides for the coordination of Federal activities in these areas and for assistance to the States in their management activities.

Any comprehensive national program for the estuarine and coastal zones must provide flexibility in many ways to fit regional and local conditions and situations, but regardless of variables it must establish a guiding policy and a set of objectives. Regardless of variables, in order to be effective the program must provide for: (1) planning and implementation; (2) active administration in terms of regulation, control, coordination, and financing; and (3) the development of the knowledge and data necessary as a basis for all action.

This report does not recommend any particular type of organization at the State level but only what it must accomplish. The particular organization, it is felt, will vary to fit the situation. Also, there is awareness that some States have established estuarine and coastal management programs and that others have them in the planning stage. These programs, where known, have been studied, and their ideas included herein.

## The Elements of a Comprehensive National Program

It follows, therefore, that any program of management must contain at least the following elements:

(1) Mutually agreed-upon policy, objectives, and functions.

(2) Legislative authorization to carry out the program's functional activities.

(3) Development of the basic knowledge necessary for effective management.

(4) Provisions for planning and implementation.

(5) Active administration in terms of regulation, control, and coordination.

(6) Financial and manpower resources.

(7) Public awareness and acceptance.

The mutually agreed-upon policy and objectives are the basis and the reason for this study, and is described below, as a *national policy*, not a *Federal policy*.

The remaining elements are contained in the roles and recommended responsibilities to be assumed at the various levels of government. For most activities required, there is a continuous series of concurrent Federal, State, and local jurisdictions. This is present now under current law, and it must be assumed that the situation will continue to exist, as many functions must be carried out at each level of government. There is also that essential element of public awareness, the nongovernmental public and private interests, whose support of a national program through political and social processes can bring much progress toward better management.

It must be kept in mind that the importance of the estuarine and coastal areas is not limited to the coastal States and communities. The economic, social, and environmental use and well-being of the estuarine and coastal zones of the Nation are of vital interest to the inland States as well. It is for these reasons that there must be a national program that gives adequate consideration to this breadth of interest and which embraces well-defined roles for the Federal, State, and local levels of government as well as for public and private interests.

Any recommended national policy must reflect the fact that there is strong national interest in the effective management and protection of the estuarine and coastal zone for the following reasons:

(1) The pressures of population growth and economic development, including requirements for industrial, commercial, residential development, recreation, exploitation of mineral resources and fossil fuels, transportation and other navigation, waste disposal, and exploitation of fish and other living marine resources, impose an increasing number of conflicting demands upon the finite resources of the coastal zone.

(2) Estuaries, marshlands, and other parts of the coastal zone contain extremely valuable habitat for fish and wildlife which move beyond State boundaries; such areas are vital to the life support of a major part of the Nation's commercial and sport fisheries harvest; such areas, particularly the estuaries, constitute ecological systems which are susceptible to destruction and disruption by man.

(3) Continued unplanned or uncoordinated development activities in the coastal zone pose an immediate threat of irreversible harm to the coastal zone and its resources and a loss of the benefits it offers.

(4) The coastal zone is a valuable area for multiple economic, recreational, and resource uses.

(5) The interest in the coastal zone extends to the citizens of all the States, and is not limited to the citizens in the coastal States.

## POLICY AND OBJECTIVES OF A COMPREHENSIVE NATIONAL ESTUARINE AND COASTAL ZONE MANAGEMENT PROGRAM

### *The Recommended National Policy*

Achievement of the best use of the values of the estuarine and coastal zones through a balance between: (a) multipurpose development; (b) conservation; and (c) preservation over both the short and long range. Priority consideration should be given to those resources that are nonrenewable and to maintaining those resources and uses which are estuarine-dependent. It shall also recognize that the primary responsibility for management of the estuarine and coastal zones rests with the States.

This recommended national policy recognizes the vital need in present and future programs to:

Encourage urban and industrial growth and the resulting land use in a manner to preserve the maximum of the estuarine and coastal zone resources and to insure the greatest number of beneficial uses.

Recognize that estuarine-dependent land uses require preference and that some uses such as residential and some industrial uses do not need shoreline locations.

Conserve the estuarine and coastal environment to sustain and enhance its nursery value, its wildlife habitat value, and its commercial fisheries value.

Develop and make accessible the many forms of outdoor recreation and the aesthetic values offered by the estuaries and coastal areas.

Reduce to an acceptable minimum the adverse effect of man's use of the estuaries and coastal areas and accept preservation as one means of reasonably guarantying the opportunity to exercise future options.

The recommended national policy will put in effect a comprehensive national program for the effective management, beneficial use, protection, and development of the estuarine and coastal zone of the Nation involving Federal, State, and local governments, and public and private interests in an appropriate manner. It will permit the optimum use of this vital resource by recognizing the existence of competing uses and accommodating them through appropriate management and, further, conserve these resources in such a manner as to keep open the options for various uses in the future and not foreclose them. This management system will recognize the primary and constitutional role of the States in managing their resources as well as the role of the Federal Government in protecting the wider national interest. The principal goal of the national program is the use of the estuarine and coastal zone for as many beneficial purposes as possible and, where some uses are precluded, to achieve that mix of uses which society, based on both short- and long-range considerations, deems most beneficial.

## The Objectives of a National Program of Management

Without attempting to assign responsibilities of functions to the various levels of government at this point, the objectives of a comprehensive management plan are listed below. These objectives also constitute a reasonably thorough set of guidelines for an acceptable management plan.

(1) Equitable consideration in management decisions of the views of all public and private interests concerned with the use and preservation of estuarine and coastal resources.

(2) Adequate planning, that is, the preparation and adoption by the appropriate government, of plans governing the balanced development, conservation, and preservation of coastal and estuarine resources. Elements of such a plan may vary but ordinarily should include determinations of immediate and long-range needs and objectives, water quality standards, zoning of land use, and any public or private facilities, sites, et cetera. What is needed is the construction of an optimum resource utilization profile for each estuary and coastal area based on an objective means of value identification and appraisal. Specific uses for various parts of an estuary or coastal area must be determined and comparative values placed on these uses in terms of the accepted national policy. Specific uses are:

Industrial and commercial location and use;

Recreation and scenic enjoyment;

Preservation of fish and wildlife and their habitat;

Residential—both urban and suburban development;

The exploitation of mineral resources including oil, gas, sulfur, sand and gravel, and others;

Generation of electrical power;

Water supply;

Exploitation of living resources including fish, shellfish, other wildlife, and the pursuit of aquaculture;

Transportation;
National defense;
Waste disposal; and
Scientific research.

In placing a value on the above uses, consideration must be given to the following criteria:

(*a*) Multipurpose use;
(*b*) Preservation of the estuarine habitat essential to living
(*c*) Use for estuarine dependent activities; and
resources;
(*d*) Conservation of nonrenewable resources.

(3) Implementation, that is, the making and execution by government of decisions as to which alternative plan will achieve for all concerned the best use of the resource. The three broad forms of governmental regulation include:

(*a*) The establishment and enforcement of policies controlling use and/or modification of estuarine and coastal resources by public authorities through:

[1] Water quality and other standards, zoning of land use, and official use and management plans.

[2] Permits, licenses, et cetera, governing permissible uses and/or modification of estuarine and coastal resources.

(*b*) Promotion of established plans and policies through various forms of incentives and assistance.

(*c*) Control of use by selected acquisition, development and/or administration by government itself.

(4) Service activities to assist planning, regulation, and the use of estuarine and coastal resources including:

(*a*) Funding, through grants, credit, subsidies, or other financial inducements;
(*b*) Technical assistance;
(*c*) Research, studies, and inventories; and
(*d*) Information and educational programs to improve public awareness and manpower development programs to provide trained personnel.

(5) Participation in management by all levels of government, with the primary management responsibility of the States preserved and enhanced, and with existing management authority and programs retained where these contribute to achieving the other objectives.

## Responsibilities and Recommended Role of the States in the Comprehensive National Estuarine and Coastal Management Program

The States, in our Federal system of government, occupy a strategic position in the management of the Nation's estuarine and coastal resources. As holders of residual sovereignty, they possess ample authority to manage these resources as they see fit, subject only to limitations imposed upon them by the Constitution, by the Congress acting pursuant to constitutionally authorized powers, and by their own constitutions. Moreover, even in those areas in which the Federal Government exercises exclusive or primary authority, the nature of our political process gives State officials substantial power to influence the objectives and exercise of Federal policies.

The strategic State position is also a direct result of the on-scene nature of the State function—the interface between the forces of politics, business, and people and their respective ambitions for putting to use the storehouse of available estuarine and coastal resources. It is in the State Capitols that many of the major decisions will be made that will determine the success of a national estuarine and coastal management program.

### THE STATE RESPONSIBILITIES

Seven aspects of the States' possession of this residual sovereignty which relate more specifically to the management of estuarine and coastal resources, help underscore the States' strategic and primary responsibility. First, although the Federal role has expanded in recent years, the States retain primary authority and responsibility for the prevention and control of water pollution. Second, they hold title to wholly or partially submerged lands and mineral resources in the estuarine and coastal zone and are responsible for administering these, through retention by the State or through their disposal or lease, in the public interest. Third, the States possess primary authority to decide, either directly or through their local subdivisions, how the shoreline and related uplands in the estuarine and coastal zones are to be used for various purposes, that is, trade and commerce, industry, parks, recreation, et cetera. Fourth, the authority of local governments generally in managing the water and land resources in estuaries is determined by the States. Fifth, the exploitation of the fisheries and other living estuarine and coastal resources is under State control to the seaward boundary of U.S. territorial seas. Sixth, the nature and forms of interstate cooperation in managing the Nation's estuaries is a matter which the States largely decide. And, finally, each State presides over the common law which governs private relations in the development and use of estuarine and coastal resources, and resolves the conflicting rights, interests, and privileges of its citizens in using these resources.

### THE RECOMMENDED STATE ROLE

Clearly, therefore, it is upon the States that the Nation must place its major reliance in achieving that reasonable compromise between private rights and expectations, on the one hand, and the collective or public interest, on the other. It is also upon the States that the Nation must rely primarily for the integration of Federal service functions into State programs and, even more important, for the development of suggested reconciliations where the regulatory or service programs of different Federal agencies in a specific estuary are in conflict. These are the heart of this study's recommendations for sound management of the estuarine and coastal resources.

Responsibilities inherent in this strategic and primary role of the States in improving management of the Nation's coastal resources are both immediate and of a more long-range nature. The immediate role to be played by the States includes:

(1) Vigorous implementation of water quality standards established for each State's estuarine and coastal waters.

(2) Maximum use of the States' available existing authority

to halt or minimize further undesirable physical modification of estuaries through dredging, filling, and drainage.

(3) Immediately establishing and maintaining, if presently lacking, effective interstate, interagency, and State-local coordination of estuarine and coastal management programs.

(4) Conducting an early evaluation of the impact on the estuaries as a result of upstream water and related land resource development and the occurrence and growth of upstream waste discharges, taking into account the interstate nature of particular interstate streams.

(5) Making an immediate review of the jurisdictional relationship between the States and the subordinate units of government in matters dealing with the establishment and enforcement of land-use plans, and the importance of the relationship between land use and the quality of the estuarine and coastal environments.

(6) Undertaking a thorough review of the present estuarine and coastal management capabilities of the State and its subordinate governmental units for the purpose of identifying steps needed to strengthen the State's long-range management effectiveness.

(7) Formulating and putting into operation a comprehensive statewide program for the management of its estuarine and coastal resources.

## Recommendations for New State Programs and Organizations

Effective discharge by the States of the all-important role which they occupy in achieving comprehensive and sound management of estuarine and coastal resources will in many instances require legislation establishing new management authority and organization.

The exact form such new authority and organization should take may well vary from State to State. Each State's action in this regard will, as it should, reflect its own special political and governmental traditions, the present organization of the State government, and the current division of authority and responsibility between the State and its local governmental units. Moreover, the estuaries themselves vary in their nature and the uses for which each is most suited, the degree to which the estuarine and coastal zone has been developed for various purposes, and the dimensions and complexity of their management problems. These differences, too, suggest that, as they seek more effectively to manage estuarine and coastal resources, the response from the States need not, and should not, be rigidly uniform.

Indeed the innovations and experiments which the States' responses can be expected to produce are regarded as a positive good and are therefore encouraged. The recommendations which follow should be viewed in that light and also as reflecting and drawing upon the significant improvements which some States already have instituted in their estuarine and coastal management programs.

*It is recommended that each State, if it has not already done so, take action along the following lines to improve its estuarine and coastal management capability and effectiveness:*

(1) There is a primary need to provide organizational arrangements in the State governmental structure with the authority and

resources to administer State-level estuarine and coastal management functions, or, alternatively, to coordinate State-level management activities in the estuaries, including State-local, interstate, and State-Federal relations. Such organizational arrangements should be facilitated by the proposed new program of Federal grants (outlined under "Federal Role") for the administration of the State estuarine and coastal management programs. The State should coordinate its own programs with the appropriate part of Federal programs.

(2) Improve the States' long-range management capability through such other measures as:

(*a*) Preparation of an official use and management plan for each of the States estuaries and coastal zones, either by the State or by general or special purpose subdivisions with State participation and assistance and through the use of public hearings at critical stages in the development process. This plan should be appropriately coordinated with Federal agencies, State agencies, local governments, and other interests; and with plans for managing the land and water resources in the estuary's tributary streams, metropolitan area plans, economic development plans, and so forth.

(*b*) Instituting State-level permit requirements for dredging, filling, or other modification of wetlands and other estuarine and coastal resources in areas not subject to exclusive Federal regulation.

(*c*) Requiring all State and local agencies engaged in activities which may physically or otherwise modify estuarine or coastal resources, either directly or through issuance of permits, licenses, leases, and so forth, to comply with the approved use and management plan for the estuary in question. In the absence of such plan, the agency should be required to:

[1] Give notice of the intended action and hold a public hearing before acting, if another governmental agency gives notice that a substantial adverse effect on estuarine or coastal resources or their use is a likely result.

[2] Minimize adverse effects on estuarine and coastal resources and their use. Provisions for such requirements also should authorize denial of such permits, licenses, and so forth, based the possibility of such adverse effects.

(*d*) Where necessary, initiate legislative and judicial proceedings to resolve problems in establishing the States title to tidal lands, wetlands, and so forth, and in regulating use of estuarine and coastal lands under private ownership.

(*e*) Strengthening selective land acquisition and development programs for recreation and conservation purposes.

(*f*) Instituting State-level authority to review land use, zoning, and other action by local governments and to veto if inconsistent with the State-adopted management plan for that estuary.

(*g*) Augmented funding of all components of the States comprehensive management programs.

(*h*) Developing interstate agreements for the conduct of joint or coordinated planning or other management functions in interstate estuaries.

(*i*) Establishing appropriate intrastate regional managegement organizations or special districts to provide effective local implementation of the use and management plans for intrastate estuarine and coastal zones.

(*j*) Authorizing local governments to exercise tax policies designed to facilitate the preservation of estuarine and coastal sites which should be preserved and used in their natural state.

## Responsibilities and Recommended Role of Local Government in the Comprehensive Estuarine and Coastal Management Program

The local governments of this country are subdivisions of the States and are created by the States for a wide variety of purposes. These purposes may range from specific functions such as water supply, sewage collection and treatment, port development and operation, etc., to general-purpose units of government such as counties, cities, and towns.

### RESPONSIBILITIES OF LOCAL GOVERNMENT

It is with the general purpose units of government that the responsibility rests for many of the day-to-day decisions that have impact on the quality of the estuarine and coastal environment. The responsibility to control the character and location of shoreline developments through land use planning and zoning and the enforcement of zoning requirements resides with the local governments. The responsibility to control waste discharges and land drainage exists largely with local governments. The interface between people and government takes place largely at the local level. Because of these responsibilities and relationships it is important that we be aware of the extent to which the local governments have been effective in influencing the balance between the destruction or misuse of the estuarine and coastal resources, and the development of plans for their effective comprehensive management. For the most part local governments have not made a significant contribution toward bringing about balanced use of the estuaries and their related land resources.

While the States have retained control of the uses of estuarine waters, local governments have been delegated the prime responsibility for managing the adjacent land areas, which in many cases has included much of the marsh and wetland resources. The local governments, inadequately staffed and frequently too small to encompass an entire estuarine or coastal area, lacking funds and receiving little guidance, coordination, and supervision from the States, often have been subjected to severe economic and policital pressures to proceed with unplanned or limited purpose development without an adequate appraisal of the long-range adverse impacts on the estuarine and coastal environment. As a result all too many valuable estuarine and coastal resources continue to be destroyed or greatly diminished in their usefulness.

## THE RECOMMENDED ROLE OF LOCAL GOVERNMENT

Despite this rather unhappy picture, the role of local government in the management of the estuarine and coastal zones is a crucial one because it is "on scene" and directly concerned with the people, industry, the land, and water.

This singularly important role in estuarine and coastal management includes such things as waste collection, treatment and disposal, land use planning and control, and the development of estuarine and coastal areas for commerce, transportation, recreation, et cetera. It also includes the development of support for regional programs for estuarine and coastal management and the crucial function of explaining to its citizenry the importance and impact of local governmental activities upon estuarine and coastal resources and their use.

With increased attention to coordinated planning of the estuarine zone and its related land resources and with increased assistance and improved supervision from the State level much more can be accomplished at the local level of government. As this takes place there should be an expanded and increasingly effective role for the local government to play.

*This expanded role should provide for:*

(1) Improvement in the collection, treatment, and disposal of wastes.

(2) Development of local laws and ordinances for estuarine and coastal zone preservation and management, including control over shoreline construction activities.

(3) Effective enforcement of local laws and regulations.

(4) Comprehensive surveys of ownership, land claims, and leases through title checks and an updated land register to clarify land ownership.

(5) Sounder land and water use planning and zoning practices, including the development of more flexible and imaginative approaches, such as planned unit development, cluster zoning, and subdivision control.

(6) Use of tax assessment and land valuation policies to induce sound conservation and development practices through such means as preferential assessment and deferred taxation.

(7) Providing public ownership or access to selected estuarine and coastal areas for whatever purposes that are necessary for sound management of estuarine and coastal zones and related land resources.

(8) Active participation in State and Federal estuarine and coastal management programs.

(9) Active participation in appropriate regional management organizations, which would cover the entire estuarine and coastal zone problem area. These organizations may be multifunctional, and in urban areas, metropolitan in character, dealing with such problems as water pollution control, port development, transportation, hurricane, flood and erosion control, architectural preservation, recreation, and so forth. The regional management organization may have limited purpose or broad management responsibility, including regulatory power over dredging and filling, zoning,

land-water use, eminent domain and revenue-raising power, and so forth.

(10) Development of public education, information programs, including cooperative efforts with private groups in order to encourage local initiative and support for balanced use of estuarine and coastal zones.

(11) Development of local professional and technical training programs for employees of Governmental agencies and private industry to foster understanding of and capability to resolve problems and carry out functions related to the estuarine and coastal management program.

## The Responsibilities of Public and Private Interests

If the Nation is to achieve a sound balance between the development of its estuarine and coastal resources for all beneficial purposes and their conservation and preservation for future use, it is essential that public and private interests in the nongovernmental sector of our society meet their responsibilities for achieving that goal. It is also essential that the public and private interests have an opportunity to exercise their responsibilities against the backdrop of an announced national policy and in terms of announced plans for estuarine and coastal zone management toward which they have made a constructive contribution.

Many of this Nation's estuarine and coastal resources continue to be endangered because of a failure to achieve in governmental programs a proper balance between the development of these resources for all beneficial purposes and their preservation and conservation. The responsibility for this dire condition ultimately rests with the public and private forces within American society that thus far have controlled the use and management of these resources.

This means too that the reversal of shortsighted policies now in force will not occur until there emerge within our society new conceptions of what constitute the real public and private interest in the use of these resources. Only as these expressions of desirable new goals and values evolve, and receive strong and effective articulation by public and private interests within the nongovernmental sector, will our management of estuarine and coastal resources, both in the private sector and by governments responding to social and political pressure, be redirected toward sounder use and management objectives.

### RESPONSIBILITIES OF PUBLIC INTERESTS

From public interests—citizen groups, conservation organizations, professional societies, the Nation's educational institutions, and others—there is need for continuing action in three broad areas. The first is educational activity which is the prerequisite to the successful reversal of present shortsighted estuarine and coastal management policies; and, further, through active and vigorous participation in the political and governmental processes, to work for the implementation of sound estuarine and coastal zone programs at all levels of government and in the private sector.

A second broad area of responsibility is the support of research programs of governmental bodies through nongovernmental studies leading to improved understanding of the nature and behavior of estuarine and coastal resources, their interrelationship, and so forth. Continuing studies directed toward appraising and improving Federal, State, and local management of the estuaries and coastal areas also are a critical need and a special responsibility of groups outside government.

The third broad area of responsibility is to support the objectives of the national policy through public, but nongovernmental, acquisition of estuarine and coastal sites which should be preserved in their natural state and to demonstrate new ways of achieving balanced development, conservation, and preservation of estuarine and coastal resources.

### RESPONSIBILITIES OF PRIVATE INTERESTS

From private interests—ranging from the largest national industrial corporations to the local individuals developing real estate in the estuarine and coastal zone—there is an equally important need for action in four broad areas. These are, first, to recognize that the pubic interest often is identical with the true private interest, particularly if the latter is viewed in the perspective that includes all other private interests and the long run; and further, to recognize that where such is not the case, the private interest must be subordinated to the larger public interest.

A second responsibility, and one private interests share with governmental and other public entities, is to consider in advance the effects of proposed actions in the estuarine and coastal zone on other uses of estuarine and coastal resources and to minimize, wherever possible, the adverse effects upon these other uses.

Third, as special beneficiaries of the development and use of estuarine and coastal resources for their own private purposes, private interests have the responsibility of joining in research and educational programs aimed at broadening and improving the general public's understanding of the importance and nature of estuarine and coastal resources. To make this possible there is need for support for research institutions affiliated with academic institutions to provide to governments at the Federal, State, and local level the knowledge necessary for management. There should be governmental and private participation in such institutions and part of the States' goals should be the training of both professional and technical personnel in the problems of the estuarine and coastal zone.

Finally, it is the responsibility of the private sector to participate in political and governmental processes so as to insure the proper recognition, both in the national program and in use and management plans for specific estuarine and coastal areas, of legitimate private interests.

## RESPONSIBILITIES AND RECOMMENDED ROLE OF THE FEDERAL GOVERNMENT IN THE COMPREHENSIVE NATIONAL ESTUARINE AND COASTAL ZONE MANAGEMENT PROGRAM

The responsibility for leadership in defining the policy and objectives of a national program for the comprehensive management of the estuarine and coastal zones of the United States rests with the Federal Government. It is also the responsibility of the Federal Government to implement its portion of the announced national program; to coordinate the activities of its respective departments and agencies; to define the Federal role to be established and maintained with State, interstate, and local governments as well as with a wide variety of public and private interests; to identify Federal jurisdictions in the estuarine and coastal zones, and to relate these jurisdictions to those of State, interstate, and local governments to exercise its jurisdictional responsibilities to prevent the destruction and misuse of the resources of the estuarine and coastal zones; to evaluate the impact of Federal and federally supported water and related land resource projects upon the downstream estuaries and coastal areas, especially for interstate and international river basins; to perform the functions that are exclusively Federal in nature in such a manner as to establish a leadership example for other governmental, public, and private interests.

### NATIONAL INTERESTS

These responsibilities coupled with the role that follows make up a rather thorough and detailed picture of the *national interest* in the estuarine and coastal zones.

### THE RECOMMENDED FEDERAL ROLE

The role described herein includes what is now being carried out by Federal agencies and that which must be done, in addition, to discharge Federal responsibility in achieving comprehensive and effective management of the Nation's estuaries and coastal areas. It is important to stress that the Federal role is not the primary one in this regard, let alone the exclusive one. It is rather one of sharing authority over resources over which the States exercise *primary* jurisdiction. Nor is the Federal role, in general, new, much of it having developed through the years.

What is increasingly evident, however, is that the national program directed toward achieving the best use of estuarine and coastal resources requires also a strengthening of the role of the Federal Government in that program.

Viewed against that backdrop, the Federal role should be to:

(1) Provide the impetus for the initial establishment, and progressive improvement, of the national program by the enactment of Federal legislation enunciating a national policy and providing grants to States for the development and implementation of comprehensive estuarine and coastal zone management plans.

(2) Provide continuing support and guidance to the States through:

(a) Grants to State, interstate, and local programs for the purposes of:

[1] Development of use and management plans for specific estuaries and coastal areas.

[2] Selective acquisition and development of estuarine and coastal sites for recreation and preservation purposes.

[3] Research, study, and training in estuarine and coastal problems.

[4] Inventory activities in the States' estuarine and coastal zones.

[5] Administration of State (including special intrastate districts created by the State) and interstate

management programs to implement State-approved management plans.

[6] Waste collection and treatment facilities.

[7] Support of estuarine and coastal zone laboratories.

(b) Cooperative activities to prepare estuarine and coastal management plans initiated either by the States or by a Federal agency pursuant to established authority.

(c) Technical advice and assistance.

(d) Provision of services such as navigation channels; flood control and protective works, beach restoration, aids to navigation, and environmental prediction, including weather, tides, etc.

(e) Promotion of, and guidance and support to, cooperation among the States in managing interstate estuaries.

(f) Recommendations and advice to the States and interstate agencies concerning their estuarine and coastal zones management policies.

(g) Provision of information and education to the public concerning estuarine and coastal resources, programs, and problems.

(3) Complete and maintain the broad national inventory of the estuaries and coastal areas and their resources initiated by the National Estuarine Pollution Study and the Inventory directed by the National Estuary Protection Act (Public Law 90–454).

(4) Continue broad estuarine and coastal studies not of a local nature. Examples are the National Estuarine Pollution Study by the Department of the Interior; the same agency's study under the National Estuary Protection Act of the feasibility and desirability of establishing a nationwide system of estuarine preserves; the comprehensive study by the Corps of Engineers of Chesapeake Bay, authorized in 1965; and the survey, authorized in 1968, by the Corps of national shoreline erosion problems.

Additional broad scientific studies in hydrology, living resources, and ecology are needed; and, in particular, a study of the means of establishing values associated with the various uses of the estuarine and coastal zones.

(5) Participate in local and regional studies where appropriate to assist local and regional management.

(6) Assure appropriate Federal performance under regional and international obligations for the management of flyways, fisheries resources, etc.

(7) Exercise regulatory authority, presently assigned and proposed in S. 7 and H.R. 4148 (if enacted), in the following areas:

(a) Enforcement of water quality standards, as necessary, and various other controls over pollution including:

[1] Oil, thermal, and radioactive pollution;

[2] Disposal of vessel wastes;

[3] Disposal of solid wastes and other refuse, dredged fill, et cetera, in navigable waters;

[4] Treatment of wastes at Federal installations.

(b) Issuance of permits, licenses, or other controls governing certain permissible uses or modification of estuarine and coastal resources including:

[1] Permits for structures over and in navigable waters;

[2] Regulations establishing harbor lines;

[3] Regulations restricting use of navigable waters for various purposes (danger zones, fishing grounds, et cetera); and

[4] Licenses regulating the construction and operation of non-Federal hydroelectric and nuclear facilities for generating electric power.

(8) Coordinate Federal estuarine and coastal management activities and provide means for coordinating these activities with those of the States, their subdivisions, and interstate agencies.

(9) In cooperation with the States, continuously monitor developments and conditions in estuaries and coastal areas and evaluate the effectiveness of the national program.

(10) Provide adequate investigation and consideration for the protection of estuarine values in the formulation of comprehensive river basin development programs under the aegis of the Water Resources Council by assuring cooperative State-Federal recognition of the impacts of upstream water quality and hydrology and related land resources development upon the resources of the estuaries.

Before leaving the recommended Federal role it is important to note that several of the above items are already the subject of legislation currently being considered by Congress.

## Recommendations Concerning New Legislation at the Federal Level

If the Federal role in the national estuarine and coastal zone management program is to be carried out successfully, critical needs are new legislation authorizing a Federal program directed specifically to the problems of the estuarine and coastal zone and provisions for coordination of that new program with existing programs directly or indirectly affecting those zones.

Accordingly, *it is first recommended that there be:* The enactment of legislation establishing the comprehensive national management program. Among its purposes, this legislation should:

(1) Specify the national policy, its broad objectives and guidelines.

(2) Establish and fund two new programs of grants as follows:

(a) Matching program development grants to a State for the purpose of assisting the State in preparing a comprehensive State program for the management of its estuarine and coastal zones. To be eligible for such grants the State must demonstrate that the grant will be used to develop a comprehensive management program meeting the requirements set forth in the following section on operating grants.

(b) Upon approval of the State's comprehensive management program, annual operating grants to the State to assist in the administration of the State program for comprehensive management of its estuarine and coastal zones.

In the administration of such operating grants it shall be insured that the coastal State is organized to implement the comprehensive management plan.

It shall also be insured that the State has at least certain specific authorities as follow:

(1) Permit authorities to control dredge, fill, and alteration of the lands and waters below the mean highwater marks.

(2) Zoning authority, or authority to require local zoning to conform with the State management plan.

(3) The power of eminent domain as necessary for implementation of the plan.

The comprehensive plan of management shall be consistent with the policy and objectives of the national estuarine and coastal zone management program and shall include the following:

(1) A feasible land and water use plan consistent with existing water quality standards.

(2) Recognition of the national interests and State and local interests in the preservation, use, and development of the estuarine and coastal zone.

(3) Appropriate consideration of other resources use and management plans bearing on the use, conservation, and management of the estuarine and coastal zones.

The plan should be adopted only after public hearings and consultation with all appropriate interested parties and shall contain in addition to the above the following:

(1) A description of the coastal State's current programs.

(2) A program for regular review and updating of the management plan, with procedures for modification of it that include public hearings.

(3) Provision for adequate review of State, local, and private projects for consistency with the plan and for advice regarding the consistency of Federal and federally assisted projects with the plan.

(4) An identification of the boundaries of the portions of the coastal State subject to the management plan.

(c) With the approval of the Secretary, the Governors of the respective States may designate an existing interstate agency to receive a portion of both the planning and operating grant to the individual States.

(d) Provide that operating grant support shall be withdrawn when there is failure to adhere to a comprehensive plan of management.

(3) Authorize the Secretary of the Interior to:

(a) Administer the proposed new program of Federal grants to States and interstate agencies.

(b) Develop after appropriate consultation and review the necessary rules and regulations needed to administer the proposed new program.

(c) Conduct a continuing review of State programs for the development, conservation, and use of the Nation's estuaries and coastal areas:

(d) Establish advisory bodies in the Department of the Interior to advise, consult with, and make recommendations to the Secretary on matters of policy in the national estuarine and coastal zone management program.

(e) Cooperate with other Federal departments concerned with the comprehensive management of the estuarine and coastal zone and to establish the mechanisms necessary for such cooperation.

(f) The Secretary should not approve State plans until he has solicited the views of Federal agencies principally affected by such plans or has evidence that such views were provided the State in the development of the plan.

(4) All Federal agencies conducting or supporting activities in the coastal area should seek to make such activities consistent with the approved plan for the area. States and local governments submitting applications for Federal assistance in coastal areas should indicate the views of the appropriate State or local agency as to the relationship of such activities to the approved plan for the coastal area. Federal agencies should not approve proposed projects that are inconsistent with the plan without making investigation and finding that the proposal is, on balance, sound. The Secretary should be advised by the heads of other agencies of such problems and be provided an opportunity to participate in any investigation.

THE NATIONAL ESTUARINE POLLUTION STUDY

VOLUME II

[illegible]

# PART IV. IMPORTANCE OF THE ESTUARINE ZONE

## Introduction

The comprehensive management program presented in part III establishes a framework to regulate man's activities in the estuarine zone to preserve and develop the estuarine resource while achieving full use of it. Effective management, however, must be firmly based on an understanding of what the estuarine resource is, what use it has to man, and what impact man's activities have on it.

The comprehensive management program is in essence a working relationship among the institutional, biophysical, and socioeconomic environments in the estuarine zone. This part of the report deals with the existing relationship between the biophysical environment and the socioeconomic environment. It describes first the estuarine zone without man; then it considers how man uses the estuarine zone and how these activities affect the land, the water, and the life. Finally, it seeks to show what will happen to the estuarine zone unless man controls his impact on this part of his environment.

The biophysical environment divides naturally into 10 geographical regions, each dominated by a different combination of environmental conditions. The discussion revolves about these biophysical regions as the primary subdivisions of the natural environment of the estuarine zone. Because of the similarity of environmental conditions within it, each region has estuarine systems, uses, and problems which are typical of the region, if not unique to it.

The use of the biophysical regions as the basic units for discussion illustrates regional similarities and differences. These serve not only to point out the essential unity of the estuarine zone as a unique resource, but also to emphasize how an effective national management program can use knowledge gained in one region to solve problems in another.

Certain photographs of a purely illustrative nature, and not essential to the continuity of the text, have been omitted in this part of the report as presently duplicated.

# CHAPTER 1. THE ESTUARINE SYSTEM OF THE UNITED STATES

Man uses and is influenced by the whole world ocean, but that narrow zone where the land containing his civilization meets the sea is unique. This is the point where man, the sea—his immemorial ally and adversary—and the land meet and challenge each other. That narrow zone is the subject of this chapter (IV–1–1).

The estuarine zone has many forms; nearly all are represented along the coastline of the United States. These include the classic drowned river mouth, exemplified by Delaware Bay and in greater variety by its neighbor, Chesapeake Bay. There are the entrance cuts and deltas of great rivers such as the Columbia and the Mississippi; there are the marshlands of Georgia and the barrier island systems of North Carolina. There are the coral formations of the Florida Keys and the fjords of Alaska and Washington; there are the rocky coast of Maine, the bluffs of California, and the sandy shores of Texas. There is infinite variety but there is also the common theme of the sea, the land, and—along much of the U.S. coastline—man.

The estuarine zone of the United States was the gateway to a continent. The many deep, natural harbors of the Atlantic and the gulf coasts provided safe anchorages for the ships which brought the first colonists to these shores and which carried the produce of the land to distant markets. The teeming coastal waters provided a never-failing supply of food to vary and supplement the results of farming and hunting.

The great population and industrial centers which developed around these seaports served as supply bases and takeoff points for those who moved west, north, and east to settle the enormous heartland of North America, leaving the estuarine zone and its problems far behind, but still using this zone to send their produce across the sea.

This zone between land and sea is a unique environment deriving its properties from both land and sea, but having characteristics resulting from the existence of the interfacial zone itself and from the interaction of land and sea upon each other.

## Section 1. General Description

The estuarine zone is best characterized as a region of constantly recurring change. The constancy of change and the dynamic equilibrium associated with the changes comprise the visible features of the estuarine environment. The obvious complexity of structure, movement, and life in the estuarine zone hides the inherently simply basic causes of the existence and character of the estuarine environment.

All life is dominated by gravity and by the sun's radiant energy, but the effects of these are especially apparent in the estuarine zone. The earth's gravity pulls the rivers down to the sea; at sea level the gravitational attraction of the earth itself reaches a dynamic balance with the gravitational attraction of the sun and the moon. The results of this are the unique estuarine water movement patterns caused by the differences in density between fresh river water and salt ocean water, and the tidal ebb and flow which is noticeable only in the estuarine zone.

All forms of life on earth depend on the sun as their ultimate source of energy. This energy is incorporated into plant material which in turn supports all animal life. Plants need water and light to grow. There is a profusion of both in the estuarine zone together with a plentiful supply of dissolved nutrients derived from both land and sea. These conditions make coastal areas the most productive environments in the world, and as a result very specialized biological communities have developed in the estuarine zone. Such communities cannot only tolerate the dynamic balance of conditions but actually depend on the constantly recurring environmental variations to sustain themselves.

The wide range of interaction of the two basic driving forces of gravity and solar energy brings about a bewildering variety of individual environments in the estuarine zone, each being dominated and controlled by a different combination of factors. Some may be dominated by tidal range, some by river flow, some by geometry of the coastline, some by climate, some by the sediments deposited, and some by combinations of these. The variety is infinite.

Yet, within this variety, there is order which lends itself to measurement and through measurement to management of the estuarine zone to preserve it for continuing multiple use. The purpose of this discussion is not to present a detailed analysis of the differences among the parts of the estuarine zone, but rather to outline what these differences are, why they exist, and what must be measured to establish a basis for sound technical management within the overall framework of wise institutional management.

It would be convenient if the state of knowledge were such that the estuarine environment and its variety could be described in terms of the primary forces which control it; then it would be possible to manage each estuarine system efficiently and exactly for optimum use.

Unfortunately, the present extremely limited state of knowledge requires the measurement of a wide variety of attributes, and management must be derived through the pragmatic application of knowledge gained from such measurement.

There are six different kinds of characteristics that should be understood to make a rational effort at sound technical management:

*Shape and size.*—Fresh water carries sediments eroded from the land to the coast where they are deposited and molded along with the original shoreline by the energy of ocean waves and currents. Shape and size go far toward determining water movement, the life forms present, and the speed with which pollutants can be absorbed or passed through the estuarine zone. These are characterized by length of shoreline, water and marsh area, and water volume.

*Water movement.*—The slight difference in density between fresh water and ocean, combined with tidal, weather, and shape effects, causes diversity of water movement patterns in the estuarine zone. These patterns are important in pollution control and in determining the ecological balance. Parameters of water movement are river inflow, tidal range, currents, density difference, and volume of tidal inflow.

*Life forms.*—The estuarine zone is recognized as the most productive part of the natural environment. The many forms of life include animals and plants which live in the bottom, on the bottom, in the water, on the water, and in the marshes which border much of the coast. The various communities in the estuarine zone are characterized by measuring the identity, distribution, and abundance of the species present, ranging from bacteria and the minute phytoplankton which are the primary users of solar energy to the fish, shellfish, and other wildlife which are the final steps in the food chain concentrating solar energy for man's use.

*Water quality.*—Even raw domestic sewage is over 99 percent pure water, but the infinitesimal amount of dissolved and suspended material has effects far out of proportion to its magnitude. While ocean water contains dissolved solids measured in concentrations of parts per thousand, water quality measurements, except for temperature, are couched in terms of parts per million and parts per billion whether they are measurements of dissolved oxygen, plant nutrients, organic pollutants, toxic chemicals, or any of the other parameters by which pollutional levels are characterized.

Upon the very delicate tests by which such minute concentrations are measured depends the quantitative knowledge of pollution and how to control it.

*Nature of the bottom.*—The land under the water in the estuarine zone can tell much of the history of water flowing over it. Solids are deposited from the water on the bottom, and creatures and plants living on and in the bottom draw their nourishment from the water itself. Estuarine bottoms are characterized by the kind and amount of sediments, vegetation, and animal life found there, both near the surface and much deeper.

*Esthetic appeal.*—Not all people enjoy the same things; the bustle of the Port of Baltimore might not be appreciated by a salmon fisherman from Alaska, for example, nor might a shrimp fisherman from the marshes of Louisiana appreciate the bluffs along the California coast. Yet an estuary which has no debris along its edge or floating in it, no smell of oil, or chemicals, or sewage, no dead fish, no floating mats of algae, and no peculiar color is pleasing to all. These things are generally subjective, and since they do not lend themselves to quantitative measurement, are sometimes overlooked in evaluating the quality of the estuarine environment.

Through measurement of these six kinds of characteristics, the dominating environmental factor in the estuarine zone can be understood and made to work for the ultimate benefit of mankind.

## Section 2. The Dominating Environmental Factors

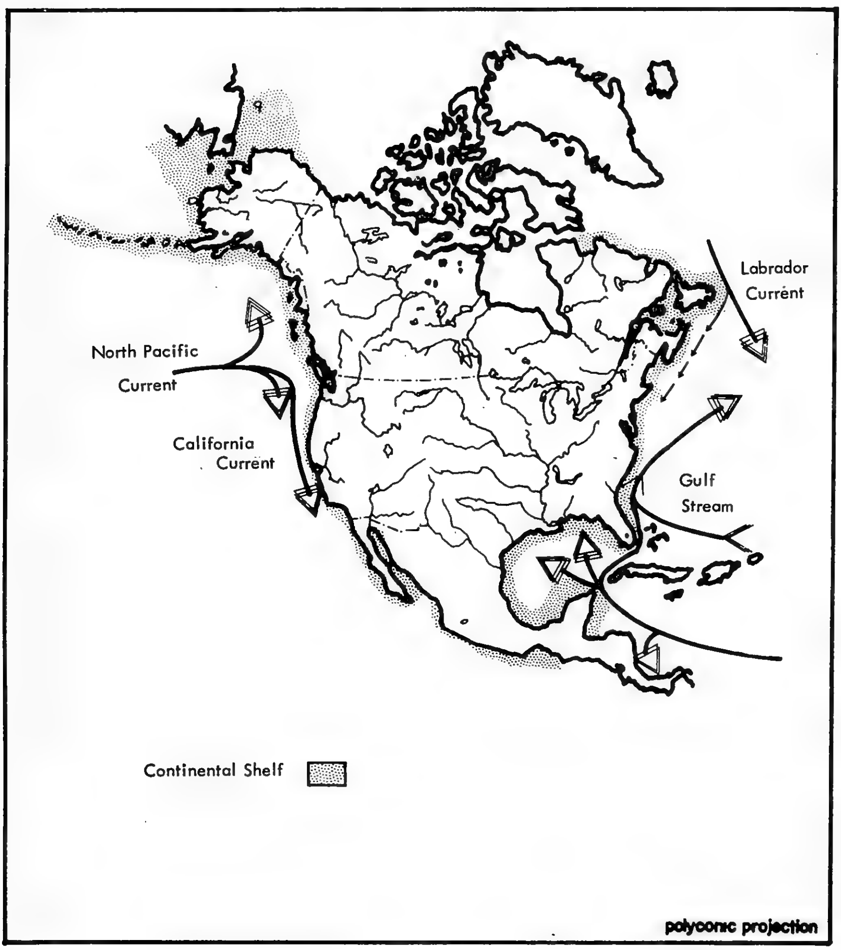
The diversity of the estuaries, bays, inlets, lagoons, marshes, and other features which make up the estuarine zone presents a disconcerting picture of apparent individual uniqueness and complexity without evident unifying principles for technical and political management. Such unifying principles do exist, however, and the estuarine zone as an environment is governed by a small number of often competing dominating factors, having interrelationships which determine the nature of each individual estuarine system. Similarities and contrasts among estuarine areas in different parts of the coastline point out the limitations of technical management in the various portions of the estuarine zone, and show the realities of nature within which the managing political entities must work.

## CONTINENTAL SHELF

The submerged land next to the continent slopes gently to a depth of about 600 feet, then it drops more rapidly to form the deep ocean basins (see fig. IV.1.1). This fringe of slightly sloping submerged land, which along much of the Atlantic and gulf coasts would appear quite flat to the naked eye, is called the Continental Shelf, and its width and general configuration along the coastline of the United States is one of the offshore conditions affecting the estuarine environment.

The large ocean waves lose much of their energy in the relatively

FIGURE IV.1.1 MAJOR OCEAN CURRENTS AFFECTING THE UNITED STATES



shallow water depths over the continental shelves, thus reducing the force with which they strike the shore (fig. IV.1.2). Where the Continental Shelf is wide, waves reach the shore with greatly decreased power and tend to move existing sediments around rather than cutting the shoreline to produce new ones.

Along the Atlantic and gulf coasts of the continental United States the Continental Shelf is generally about 50 to 100 miles wide and terminates at depths ranging from 300 to 900 feet. Within this regime four significant differences in conditions on the shelf are reflected in the estuarine zone:

(1) The Gulf of Maine forms an embayment between Cape Cod and Nova Scotia, and the general configuration of deep basins close to shore with broad banks seaward of them is unique to this part of the coast (fig. IV.1.3). While the shoal waters on the shelf serve to protect the New England coast from the full force of the ocean swells, the deep embayment near shore and the narrow trough which connects it to the ocean cause the great tide ranges and strong currents characteristic of the region. These currents tend to reduce deposition of sediments close inshore, particularly along the Maine coast where the tide range is greatest and the currents strongest.

(2) Cape Hatteras is a region where the deposition of sediments on the wide shelf at the meeting place of two major ocean currents has resulted in the building of a series of barrier islands out over the shelf and the formation of a wide shallow embayment (Pamlico Sound) behind them (fig. IV.1.4). This sedimentation process has reduced the width of the Continental Shelf to less than 20 miles at this point and created the infamous Diamond Shoals seaward of the barrier islands.

(3) South Florida, from Miami to beyond the Florida Keys, has virtually no Continental Shelf; this is probably related to the passage of the Gulf Stream through the narrow channel between the Bahama Islands, Cuba, and Florida (fig. IV.1.5). These same islands, however, serve to protect the southern part of Florida from heavy ocean swells, while the steady current keeps sediments from depositing on the offshore coral formations of the Florida Keys and tends to spread coral growth northward along the Florida Coast.

(4) The Mississippi River, draining about 41 percent of the continental United States, has built a delta entirely across the Continental Shelf and now deposits most of its sediments on the slope beyond (fig. IV.1.6). The generally enclosed nature of the embayment forming the Gulf of Mexico has permitted the formation of this delta and its associated channels and marshlands, as well as the combination of barrier island and coastal marshland formation which makes up the majority of the Gulf of Mexico estuarine systems.

On the Pacific coast of the continental United States, the Continental Shelf is 2 to 20 miles wide and terminates at depths of 300 to 600 feet. Pouring over this narrow, steep shelf is the full force of the Pacific Ocean swell; this makes for excellent surfing, but it also leads to considerable erosion of the shoreline. Shoreline erosion by wave action with the development of a beach and bluff configuration is typical of this part of the coastline (fig. IV.1.2). Strong currents and turbulent waters near the shore tend to remove eroded material rapidly, and extensive shoal areas rarely occur.

The Continental Shelf along all the coasts of Alaska is wide; in the Bering Sea it averages 400 miles. The Bering Sea shelf is the flattest area of this size on the face of the earth, primarily because of the fine silt deposited on an irregular rocky platform by glacier-fed rivers.

### OCEAN CURRENTS

The major ocean currents impinging on or passing close to the continent exert strong, if subtle, effects on the estuarine zone; see figure IV.1.1.

The best known of these is the Gulf Stream which moves northward along the South Atlantic coast from Florida to Cape Hatteras, where it turns east out across the Atlantic. Between Cape Hatteras and Newfoundland, water from the Labrador Current moves slowly southward between the Gulf Stream and the coast.

The Labrador Current, a cold water mass with abundant plant nutrients, makes the Grand Banks off Newfoundland one of the most productive fisheries of the world. While much of the Labrador Current mixes with the Gulf Stream, some of its water enters the Gulf of Maine as part of the strong tidal and wave-driven flow, and still more drifts down the Middle Atlantic coast from Massachusetts to North Carolina.

The Gulf Stream is very warm water from subtropical latitudes, and carries with it subtropical life forms as well as heat. Its warming effect on the land can be seen in the difference in vegetation above and below Cape Hatteras, as well as in differences in kinds of aquatic life (fig. IV.1.7).

A major part of the Gulf Stream emerges from the warm, subtropical Gulf of Mexico and flows around the tip of Florida. These waters nurture the great shrimp fishery and warm the coasts of northern Europe as well as those of the southeastern United States.

Along the west coast of North America the eastward-flowing warm current of the Pacific Ocean (the North Pacific Current) splits at about the latitude of the United States-Canadian border; the portion moving south is called the California current, while that moving north into the Gulf of Alaska is called the Alaska Current.

The California Current exerts a moderating effect on continental temperatures as it moves southward; the major effect, however, occurs during the spring and early summer when the winds are such that in some places the California Current moves away from the coast and cold, nutrient-laden deep water comes to the surface near the shore. Two major zones of this "upwelling" are off Santa Barbara and off Cape Mendocino, near the northern part of California. During other seasons a complex series of eddies and countercurrents develops, all of which tends to make the nearshore areas very productive.

The Alaska Current exerts a warming effect on the southern part of Alaska, similar to that of the Gulf Stream in northern Europe. The Bering Sea, which receives some water from the Pacific Subarctic Current, is the birthplace of the cold deep currents of the northern Pacific, and the waters within the Bering Sea are very cold and rich in nutrients.

None of the effects of Continental Shelf and ocean current structure are clearly visible and dramatic. They are a matter of slight differences in degrees of temperature, of concentrations of certain chemical compounds, or of speed of motion. Yet they help to explain why lobsters grow in Maine and not along the coast of South Carolina, and they form one basis for regarding the national estuarine system as a unified whole, not as a group of unique coastal systems.

### STRUCTURE OF THE COASTLINE

The configuration of the coastline itself, even though subject to additional molding by the flow of rivers to the sea, is closely related to the shape and structure of the Continental Shelf. A wide Continental Shelf is generally associated with lowland next to the coast, while a narrow shelf is associated with mountainous terrain. These associations throughout the estuarine zone of the United States have produced estuarine systems characteristic of particular regions.

The northern part of the North American Continent was once covered by an ice sheet of continental dimensions, which left its impress on the estuarine zone as far south as New York City on the Atlantic coast and Puget Sound on the Pacific coast. These massive glacial rivers, sometimes over 1 mile thick, cut their way to the ocean, terminating somewhere in the vicinity of the edge of the Continental Shelf on both coasts (fig. IV.1.8).

The result of their passage is the sharply sculptured and generally steep shoreline associated with the New England, Puget Sound, and southeast Alaska regions. The submarine topography of these regions is similar to that above the water, except where earth and rock have eroded from the land above the water and been deposited on the land under the water. The estuarine zone along formerly glaciated coasts is a region of deep, heavily indented embayments, many islands, steep rocky shores, predominantly evergreen forests reaching nearly to the water, irregular bottom topography, and vistas of great scenic beauty (fig. IV.1.9).

The unglaciated parts of the Atlantic coast and of the gulf coast consist of relatively flat terrain in which coastal embayments and marshes are the predominant estuarine features. These are coasts formed primarily of sediments eroded from ancient mountains, and along which the embayments and marshes form traps for sediments the rivers bring down to the sea.

The estuarine zones along these coasts may be of many forms, but the general impression is one of great expanses of shallow water and aquatic vegetation, extensive sand dunes and sandy ocean beachfront, and narrow and carefully maintained navigation channels with port facilities well inland (fig. IV.1.10).

The Pacific coast of the conterminous United States is actively being eroded by wave action against the exposed shoreline. The major coastal feature is narrow beach or rocks at the base of steep bluffs. Deep embayments behind headlands or shallow indentations in the coast are typical of the estuarine zone.

The southern coast of Alaska is the only part of the United States with glaciers existing in the estuarine zone. Glacier-fed estuaries have much floating ice, usually in the form of small icebergs, and very steep sides. The water is icy cold and often milky with sediment from earth and rock ground to a fine flour by the movement of the ice across the land (fig. IV.1.11).

## RIVER FLOW

The estuarine zone is also shaped through erosion and sediment transport by fresh water making its way to the sea. Along the coastlines of the Continental Shelf of the United States are streams and rivers carrying water from land runoff to the sea. These waterways range from the Mississippi River down to the tiniest stream trickling across the sands of a beach.

Figure IV.1.12 illustrates typical seasonal variation in river flow into the estuarine zones of the United States. Everywhere there is a pronounced annual cycle; peaking sharply in the spring in Alaska and New England, peaking from early summer to early fall along the Atlantic and gulf coasts, and reaching a maximum in late winter along the Pacific coast.

Annual cycles of river flow depend on the annual variation of temperature as well as of precipitation, and the total volumes of water and sediment moved reflect not only the total amount of precipitation, but also the sizes and slopes of drainage basins and the types of soil over which the rivers flow in their fall to the sea.

All river flows begin as either rain, snow, or ice. While rain moves almost immediately into the hydrologic system as ground water and as surface runoff, snow and ice may remain for several months on the ground until they melt under the warmer temperatures of spring. This sudden influx of several months' precipitation into the hydrologic system frequently results in severe erosion and flooding with heavy transport of sediment into the estuarine zone.

River basin drainages unaffected by winter freezeup conditions, such as most of those on the southeast Atlantic and gulf coast, also erode and carry sediment loads, but their effects are distributed more equally around the year. Coasts with low-lying drainage basins tend to have marshes which trap sediments, reducing erosion in coastal areas.

TABLE IV.1.1.—RIVER FLOW IN THE ESTUARINE ZONE OF THE UNITED STATES

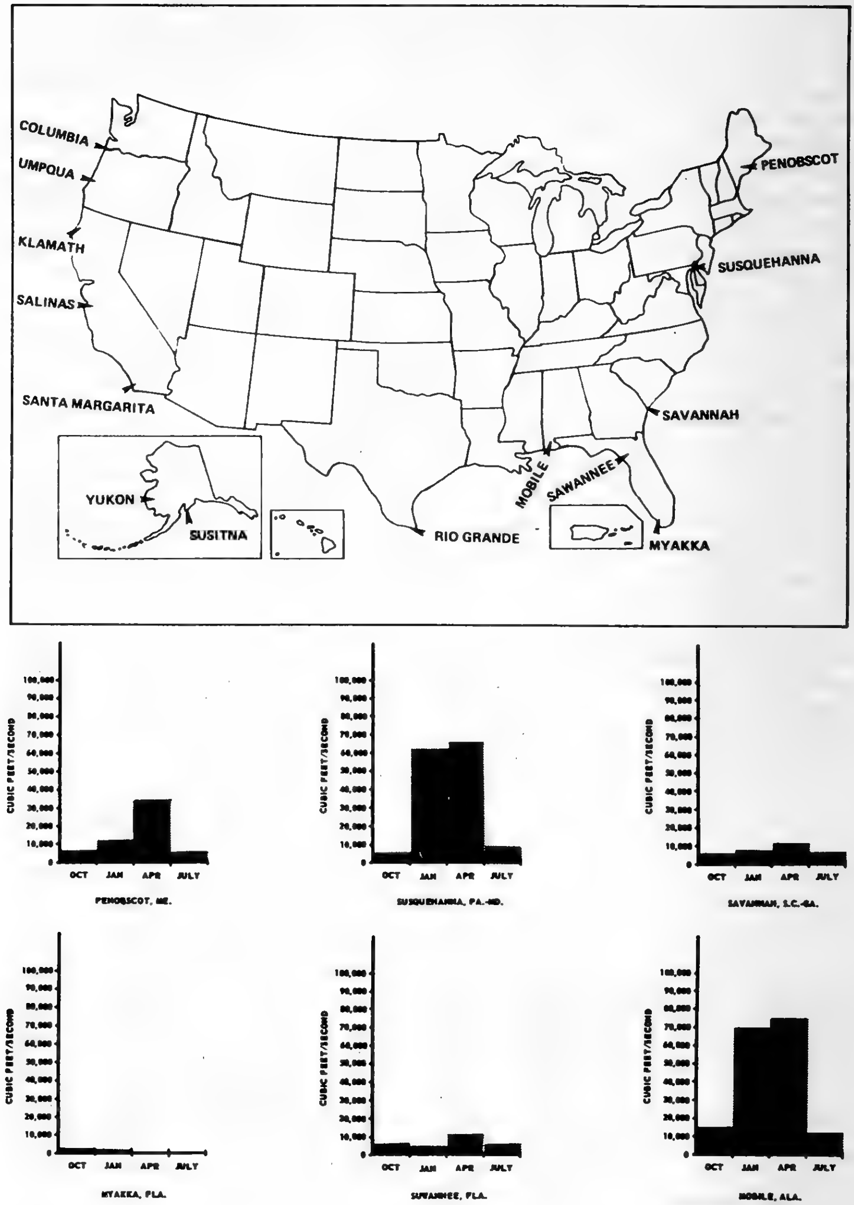
| | | | | | Major river basins (more than 1,000 square miles drainage) | | |
|---|---|---|---|---|---|---|---|
| Biophysical region | Drainage area (square miles) | Total freshwater runoff (cubic feet per second) | Drainage area per mile of ocean coastline | Runoff per mile of total tidal shoreline | Number of rivers | Total gaged drainage area (square miles) | Average annual runoff (cubic feet per second) |
| North Atlantic | 40,700 | 72,000 | 30 | 16 | 5 | 18,600 | 30,900 |
| Middle Atlantic | 69,700 | 106,000 | 54 | 15 | 6 | 35,300 | 51,400 |
| Chesapeake | 66,500 | 79,800 | ---------- | 15 | 6 | 47,100 | 55,600 |
| South Atlantic | 149,500 | 154,000 | 182 | 16 | 12 | 68,600 | 70,200 |
| Caribbean | 10,400 | 11,500 | 7 | 3 | 0 | 0 | 0 |
| Gulf (total) | 1,704,000 | 799,000 | 750 | 52 | 21 | 1,394,000 | 706,000 |
| Excluding Mississippi | 464,000 | 249,000 | 274 | 19 | 20 | 249,000 | 156,000 |
| Southwest Pacific | 94,300 | 83,400 | 79 | 27 | 8 | 49,000 | 30,500 |
| Northwest Pacific (total) | 314,000 | 368,000 | 469 | 77 | 9 | 275,000 | 293,000 |
| Excluding Columbia | 56,000 | 133,000 | 84 | 28 | 8 | 38,000 | 98,000 |
| Alaska (total) | 700,000 | [1] | 47 | ---------- | 16 | 345,000 | 351,000 |
| Excluding Yukon | 340,000 | [1] | 22 | ---------- | 15 | 86,000 | 176,000 |
| Pacific islands | 6,710 | [1] | 6 | ---------- | 0 | 0 | 0 |
| Total (including Alaska and Pacific islands) | 3,116,800 | 2,000,000 | 124 | ---------- | 83 | 2,232,600 | 1,588,600 |
| Total (excluding Alaska and Pacific islands) | 2,410,100 | 1,568,700 | 264 | 29 | 67 | 1,978,600 | 1,237,600 |
| Total (excluding Alaska, Pacific islands, Mississippi River and Columbia River) | 912,000 | 784,000 | 106 | 18 | 65 | 596,000 | 492,600 |

[1] Not available.

Reference: The National Estuarine Inventory.

Data sources: U.S. Geological Survey, U.S. Coast and Geodetic Survey.

## FIGURE IV.1.12 EXAMPLES OF VARIATION IN RIVER FLOW



## FIGURE IV.1.12 EXAMPLES OF VARIATION IN RIVER FLOW (continued)

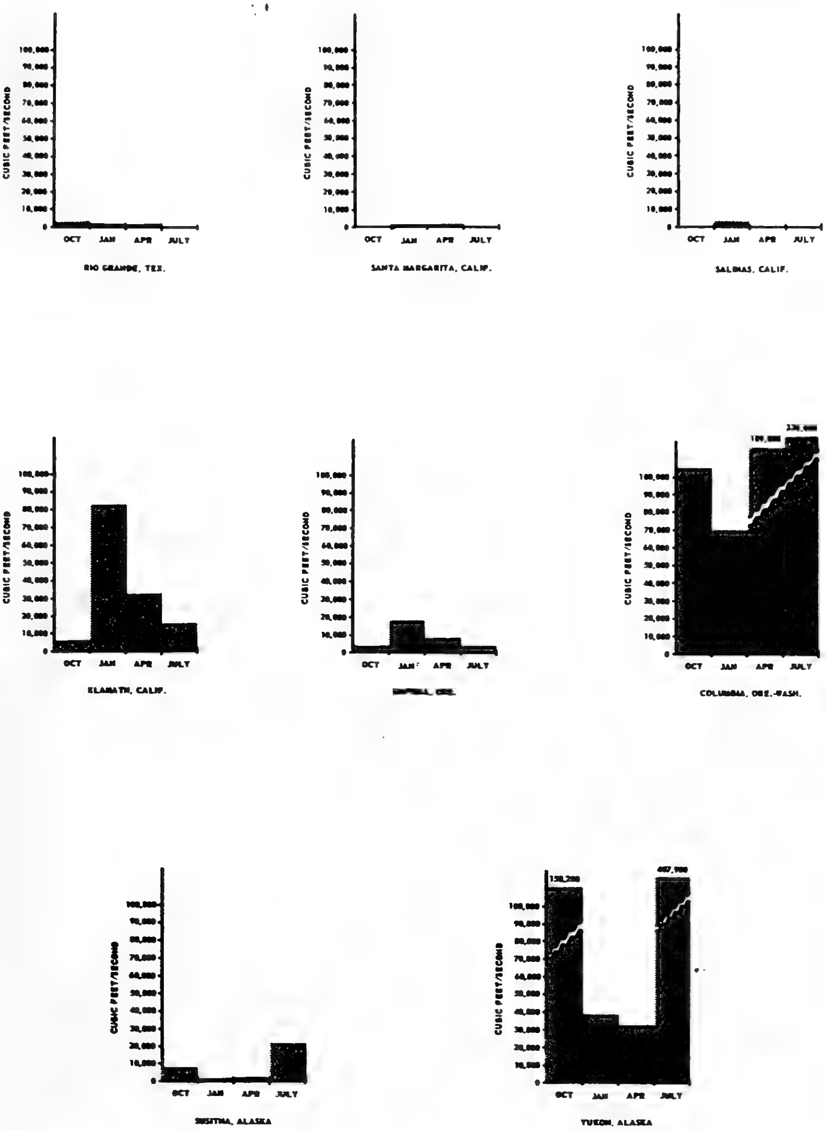


Table IV.1.1 shows the magnitude and distribution or river flows entering the estuarine zone of the United States. Two river systems, those of the Mississippi and the Columbia, drain 62 percent of the land area of the conterminous United States and account for 50 percent of the land runoff passing through the estuarine zone. The Yukon has a drainage area of about 360,000 square miles in Alaska and Canada, about one-third that of the Mississippi, and ranks between the Mississippi and Columbia as one of the three major river systems of the Nation.

The mouths of these three rivers form estuarine systems unique in the estuarine zone of the United States. The tremendous volumes of water discharged [1] by each of these is the dominating environmental factor where the river enters the sea.

The Mississippi and Yukon reach the ocean after passing through many hundreds of miles of low-lying, easily erodable land. Immense deltas formed at the mouth of each river as the great volumes of suspended material accumulated in this passage were deposited at the place where the river currents were slowed down by the sea (fig. IV.1.12A and fig. IV.1.6). The Columbia collects relatively little sediment in its passage over rocky terrain, and is confined near its mouth to a narrow channel where it has cut its way to the ocean through coastal mountain ranges. The deposited sediments form only an offshore bar which is continually cut away and reestablished by the ocean swells and currents sweeping in over the narrow Continental Shelf (fig. IV.1.12B).

There are 80 other river basins in the United States having drainage areas of over 1,000 square miles; these, with the three river systems already mentioned, account for land runoff from 85 percent of the entire land area draining to the estuarine zone. Over half of these are in the Gulf, Alaska, and South Atlantic biophysical regions. There are none in the Caribbean and Pacific islands regions.

The ratio of drainage basin size to miles of ocean coastline in each region, as shown in table IV.1.1, is an index of the relative importance of upland runoff conditions to the estuarine zone. In the North Atlantic biophysical region, for example, runoff comes on the average only from a distance of 30 miles inland. In the South Atlantic region, however, runoff comes from an average distance of 182 miles, thus indicating that large river basins are far more important to the estuarine zone in the South Atlantic region than in the North Atlantic.

The ratio of runoff to total miles of tidal shoreline is an index of the importance of land runoff in estuarine stratification and water movement patterns. A low ratio means there is little runoff in proportion to the size of the estuarine zone, as in the Caribbean region, and water stratification generally is not significant in this region; while high ratios, as in the two Pacific regions, indicate high proportionate land runoff and stratification-dominated estuaries.

Regional averages like those in table IV.1.1 are important in that they show that there are general unifying criteria through which lessons learned in one part of the national estuarine system can be applied to other parts of the estuarine zone.

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[1] In a little over an hour on an average day, the Mississippi discharges into the Gulf of Mexico enough water to supply the domestic water needs of the entire present population of the United States.

## SEDIMENTATION

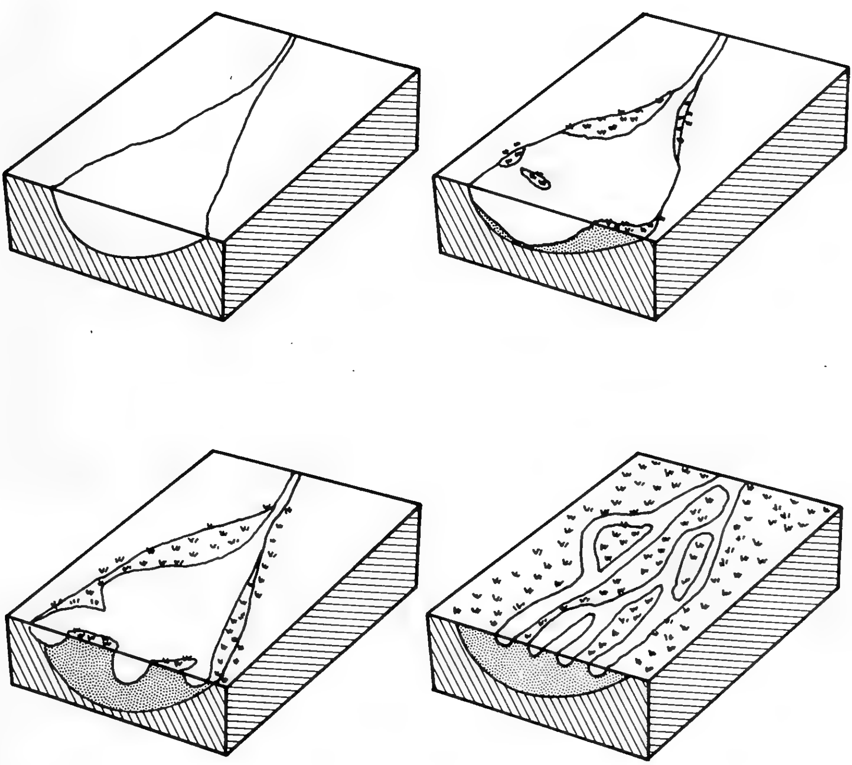
The general outlines of the estuaries, lagoons, and embayments in the estuarine zone of the United States were formed by erosion from land runoff during the last ice age when sea levels were much lower than they are now. As the sea level rose, the drowned river mouths became zones of mixing, sediment deposition, and erosion where the rivers and tidal currents met. These erosion and sedimentation processes molded the estuarine zone into its present shape and continue to change it.

The greatest changes occurred in those regions where the surface soils and clay on wide, gently sloping coastal plains rapidly eroded from the land and came to rest in the estuarine zone or farther out on the continental shelf. Least change occurred where coastal plains and continental shelves are narrow or consist mostly of resistant rock.

Figure IV.1.13 illustrates the evolution of an estuary from a drowned river valley to a coastal marsh. The estuarine zone of the United States from New York to Texas abounds with examples of this evolutionary process (fig. IV.1.14). Delaware Bay has not yet

Figure IV.1.13

STAGES IN ESTUARINE SYSTEM MODIFICATION DUE TO SEDIMENTATION



been cut off from the sea by barrier islands, Mobile Bay illustrates the initial formation of offshore bars, Matagorda Bay shows the full development of barrier islands, and the marshes around the mouth of the Satilla River represent the ultimate stage in the filling of an estuary.

The great ice sheet which once covered the estuarine zones of New England, northwest Washington, and southeast Alaska scoured off much of the readily erodable surface material in the coastal watersheds, thus, natural sedimentation has been a relatively minor factor in modifying estuaries in these areas. Narragansett Bay and Puget Sound, among many others, still maintain the great depths typical of glacially formed embayments.

Near the edge of the ice sheet, however, where the scoured-off earth and rock carried along under and in the ice finally stopped as the glaciers met the sea and melted, small, shallow bays formed in the glacial debris and subsequently developed offshore sand spits and barrier islands as illustrated by Moriches Bay (fig. IV.1.15) on the south side of Long Island, which is formed of such glacial debris.

Abundant sediment eroded from the coastal ranges along the Pacific coast of the continental United States has nearly filled several estuaries, and wide tidal flats are common in the few estuaries along these coasts (fig. IV.1.16). The Columbia, however, collects a proportionately less suspended load of sediment as it comes down through the less-erodable volcanic mountains and plateaus of the Pacific Northwest.

TABLE IV.1.2.—CHARACTERISTICS OF SEDIMENT LOADS ENTERING AND SEDIMENTS RESIDENT IN THE ESTUARINE ZONE

| Biophysical region | Average annual suspended sediment load: Tons per square mile | Average annual suspended sediment load: Tons | Number of rivers sampled | Kinds of sediments in the estuarine zone |
|---|---|---|---|---|
| North Atlantic | (1) | (1) | 0 | Glacial debris—Little input from rivers; clay silt in deep areas; sand, gravel around edges. |
| Middle Atlantic | 220.0 | 15,300,000 | 5 | Silt, clay in deep areas; fine sand elsewhere. |
| Chesapeake Bay | 130.0 | 8,640,000 | 3 | Do. |
| South Atlantic | 389.0 | 58,100,000 | 1 | Fine sand predominates; organic silt in rivers and swamps. |
| Caribbean | (1) | (1) | 0 | Fine sand, except for coral reefs and mangroves. |
| Gulf: | | | | |
| (1) Excluding Mississippi. | 124.0 | 57,600,000 | 7 | (1) Silts and clays with sands abundant around margins only. |
| (2) Mississippi | 244.0 | 305,000,000 | 1 | (2) Fine silts and clays, covered by fine sand where delta-making is inactive. |
| Pacific Southwest: | | | | |
| Pacific slopes | 398.0 | 21,000,000 | 2 | Fine sand in channels, silts and clays around edges and on tidal flats. |
| Central Valley | 71.4 | 3,000,000 | 2 | |
| Pacific Northwest: | | | | |
| Pacific slopes | 3,610.0 | 98,000,000 | 3 | Do. |
| Columbia | 112.0 | 29,000,000 | 2 | |
| Alaska | (1) | (1) | 0 | Mixture of gravel, silt, and general glacial debris on southeast, south. Extremely fine "flour" on some parts of south and southwest. |
| Pacific Islands | (1) | (1) | 0 | Sand, coral, slight amounts of silt near rivers. |

[1] Not available.

Reference: The National Estuarine Inventory.
Data sources: U.S. Geological Survey.

The southern part of the Florida peninsula is far from the sources of coastal plain sediment which has filled estuaries immediately to the north. Locally derived sediments, combined with the results of plant and animal activity, are the great estuarine modifiers in this region. Mangrove swamps on the southwest coast and coral reefs on the southeast (fig. IV.1.17) are typical coastal formations.

Table IV.1.2 gives estimated total quantities of suspended sediments entering the estuarine zone and shows the kinds of sediments typical of each region. The data leading to this table include the effects of human activity as well as natural sedimentation. The most significant thing about this table is the paucity of data leading to these estimates. The sediments carried by only 26 of the rivers entering the estuarine zone have been measured sufficiently well to permit even these estimates (IV–1–2).

The great volume of sediments carried by the Mississippi, as contrasted to the quantity carried by the Columbia, illustrates one of the major differences between a river forming a delta and one not forming a delta. The contrast between the sediment loads being carried by the rivers of the middle Atlantic and Chesapeake regions and those of the south Atlantic and gulf also illustrate why the evolution of drowned river valleys has progressed farther in the latter regions.

The two Pacific coast regions are striking in that rivers with drainage only from the coastal mountain ranges carry much greater sediment loads than those which drain the interior ranges.

## CLIMATE

Solar energy striking the earth sets up complex cycles of water and energy flow from the oceans to the sky and the land and back again. That part of the energy cycle occurring in the atmosphere gives rise to the various combinations of weather phenomena which make up local climates. Land, sea, and sky are mutually dependent in producing specific climates, and the great ocean currents play their indirect roles in modifying the climates of the estuarine zone in addition to their direct effects discussed earlier.

The annual distributions of temperature, precipitation, sunlight, and prevailing winds as well as the total amounts of each are of the greatest significance. Table IV.1.3 and figure IV.1.18 summarize the major climate characteristics in the estuarine zone of the United States.

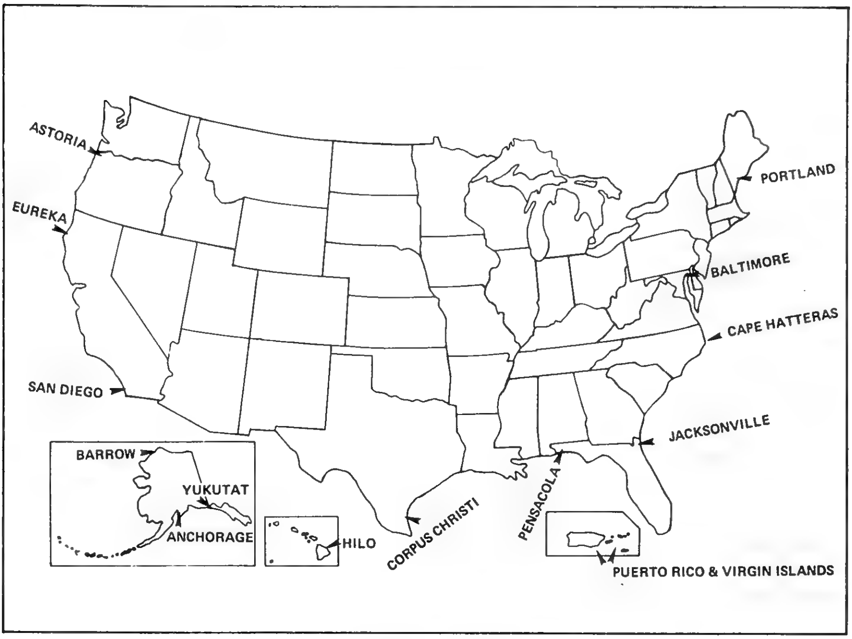
Precipitation may fall as rain, snow, or other forms of ice, depending on temperature; the form of precipitation has not only local impact, but also affects annual patterns of river flow in rivers draining to the coast. There is a tendency for precipitation along the northern Atlantic coast to be heaviest during the cooler months and for much of it to fall as snow; the Pacific coast, except for Alaska, has a similar precipitation pattern with much less snowfall. The southern Atlantic, Gulf, and Alaskan coasts receive their heaviest precipitation in the summer and fall, as do Puerto Rico and the Virgin Islands.

TABLE IV.1.3—CLIMATOLOGICAL CHARACTERISTICS

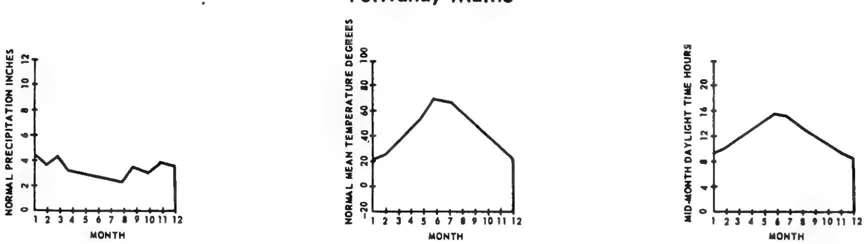
| Biophysical region | Mean temperatures (deg. F.) Annual | Jan. | Apr. | July | Oct. | Precip. (in.) Norm total | Snow, sleet, norm, total | Hum. (%) annual AM | PM | Prevailing wind (knots, direction) Jan. | Apr. | July | Oct. | Solar radiation hrs. (per day and percent of possible) Jan. | Apr. | July | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Atlantic: Portland, Maine | 45.0 | 21.8 | 42.5 | 68.1 | 48.6 | 42.9 | 71.7 | 81 | 60 | 8N | 9S | 7S | 8N | 9.3/54 | 13.4/56 | 15.1/67 | 11.1/59 |
| Middle Atlantic: | | | | | | | | | | | | | | | | | |
| Nantucket, Mass | 49.1 | 32.5 | 43.8 | 67.5 | 53.8 | 43.7 | 33.9 | 82 | 71 | 13NW | 13SW | 10SW | 11SW | 9.5/40 | 13.3/55 | 14.9/63 | 11.1/58 |
| New York, N.Y | 54.5 | 33.2 | 51.4 | 76.8 | 58.3 | 42.4 | 29.7 | 72 | 57 | 10NW | NW | 7SW | 8SW | .6/50 | 13.3/5 | 14.8/66 | 11.1/61 |
| Cape Hatteras, N.C | 62.2 | 46.6 | 59.3 | 78.0 | 65.4 | 54.5 | 2.9 | 82 | 67 | 10NE | 12SW | 9SW | 10NE | 10.0/62 | 13.1/67 | 14.3/70 | 11.3/71 |
| Chesapeake Bay: Baltimore, Md | 57.6 | 37.3 | 55.7 | 79.1 | 60.0 | 44.2 | 22.7 | 71 | 54 | 9SW | 10SW | 8SW | 8SW | 9.7/48 | 13.2/59 | 14.7/65 | 11.2/63 |
| South Atlantic: | | | | | | | | | | | | | | | | | |
| Charleston, S.C | 65.0 | 50.3 | 64.3 | 80.1 | 66.2 | 49.2 | .1 | 87 | 56 | 8SW | 9SW | 7SW | 7NE | 10.2/62 | 13.0/75 | 14.1/69 | 11.4/71 |
| Jacksonville, Fla | 69.5 | 55.9 | 68.7 | 82.6 | 71.0 | 53.4 | .1 | 87 | 54 | 7NW | 8SE | 7SW | 8NE | 10.4/57 | 12.9/70 | 13.9/59 | 11.5/56 |
| Miami, Fla | 75.1 | 66.9 | 74.2 | 81.8 | 77.8 | 46.3 | .0 | 85 | 60 | 8NW | 9SE | 7SE | 8NE | 10.7/68 | 12.8/72 | 13.6/62 | 11.6/59 |
| Caribbean: | | | | | | | | | | | | | | | | | |
| Key West, Fla | 76.8 | 69.6 | 75.8 | 83.3 | 79.0 | 40.0 | .0 | 80 | 67 | 11NE | 11SE | 9SE | 10NE | 71 | 80 | 69 | 67 |
| San Juan, P.R | 78.0 | 74.4 | 76.6 | 80.4 | 80.0 | 64.2 | .0 | 83 | 66 | 7NE | 8NE | 8NE | 6NE | 11.1/66 | 12.6/66 | 13.1/64 | 11.7/62 |
| Gulf: | | | | | | | | | | | | | | | | | |
| Tampa, Fla | 72.2 | 61.2 | 71.4 | 81.6 | 74.7 | 51.6 | Trace | 88 | 57 | 8N | 9NE | 7E | 8NE | 10.6/67 | 12.8/72 | 13.8/60 | 11.5/65 |
| Port Arthur, Tex | 68.5 | 53.6 | 68.2 | 81.9 | 70.3 | 53.1 | .6 | 91 | 62 | 10N | 11S | 7S | 8N | 10.5/44 | 12.9/51 | 13.9/66 | 11.5/68 |
| Brownsville, Tex | 73.7 | 61.4 | 73.9 | 84.0 | 75.9 | 26.8 | Trace | 90 | 61 | 10SE | 13SE | 10SE | 9SE | 10.7/47 | 12.8/54 | 13.6/81 | 11.6/67 |
| Pacific Southwest: | | | | | | | | | | | | | | | | | |
| San Diego, Calif | 62.4 | 54.9 | 60.5 | 69.3 | 65.0 | 10.9 | Trace | 61 | 61 | 5NE | 6NW | 6NW | 5NW | 10.2/68 | 13.0/61 | 14.1/67 | 11.4/66 |
| San Francisco, Calif | 55.6 | 47.9 | 54.1 | 60.4 | 59.4 | 17.4 | Trace | 71 | 67 | 6NW | 10NW | 12NW | 8NW | 9.9 | 13.2 | 14.5 | 11.3 |
| Pacific Northwest: | | | | | | | | | | | | | | | | | |
| Astoria, Oreg | 51.4 | 40.1 | 49.7 | 60.8 | 54.1 | 76.0 | 3.7 | 78 | 73 | 7E | 7NW | 7NW | 6SE | 9.0 | 13.5 | 15.4 | 11.0 |
| Seattle, Wash | 53.2 | 40.7 | 51.8 | 65.6 | 54.4 | 31.9 | 8.4 | 72 | 60 | 7S | 7S | 6NW | 6SE | 8.9/28 | 13.6/47 | 15.6/63 | 10.9/36 |
| Pacific Islands: Honolulu, H.I | 75.2 | 72.0 | 73.3 | 77.9 | 77.5 | 23.9 | .0 | 73 | 58 | 9NE | 11NE | 12NE | 10NE | 11.0/66 | 12.6/73 | 13.3/77 | 11.7/72 |
| Alaska: | | | | | | | | | | | | | | | | | |
| Juneau, Alaska | 40.6 | 26.2 | 39.5 | 54.7 | 41.9 | 56.9 | 90.5 | 72 | 82 | 7N | 8SE | 7N | 8SE | 7.1/29 | 14.4/37 | 17.6/27 | 10.3/17 |
| Anchorage, Alaska | 35.3 | 13.0 | 35.4 | 57.3 | 36.0 | 14.3 | 80.4 | 70 | 62 | 5NE | 6N | 6S | 5N | 6.4/38 | 14.7/58 | 18.5/42 | 10.1/41 |
| Nome, Alaska | 26.3 | 5.6 | 21.0 | 49.6 | 30.3 | 18.7 | 60.5 | 81 | 77 | 10E | 9E | 9SW | 10N | 42 | 52 | 60 | 34 |
| Barrow, Alaska | 10.1 | −15.1 | 20.2 | 39.7 | 17.1 | 4.1 | 27.0 | 79 | 77 | 10SE | 10NE | 10E | 12E | 0.0 | 16.5 | 24.0 | 8.8 |

Reference: The National Estuarine Inventory. Data source: U.S. Weather Bureau.

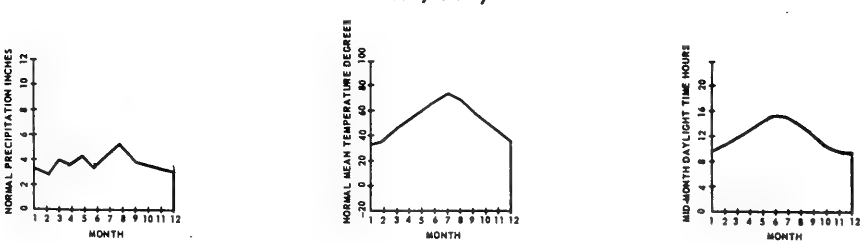
## FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE




### Portland, Maine

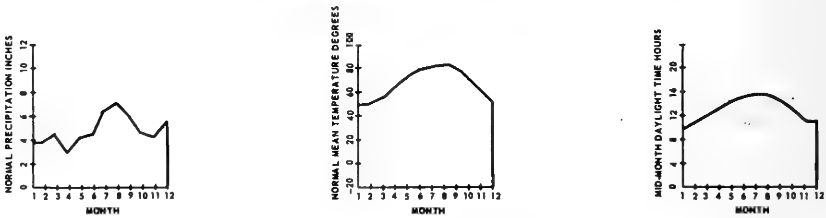



### Baltimore, Maryland

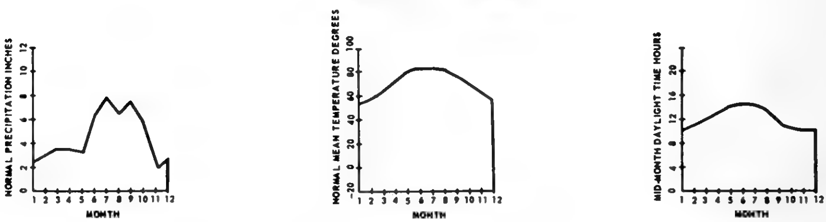


## FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE (continued)

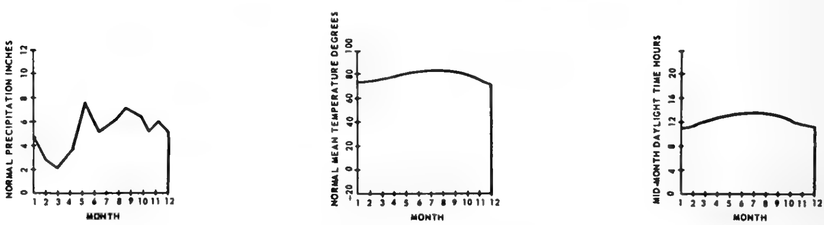
### Cape Hatteras, North Carolina



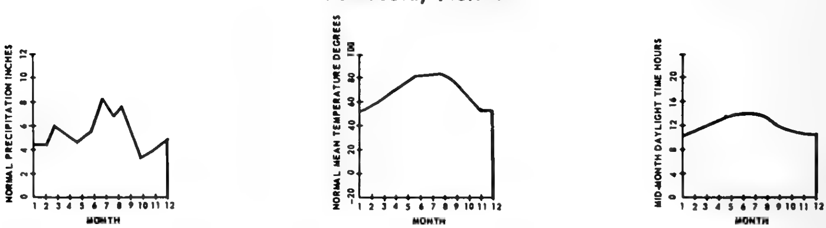

### Jacksonville, Florida




### Puerto Rico & Virgin Islands

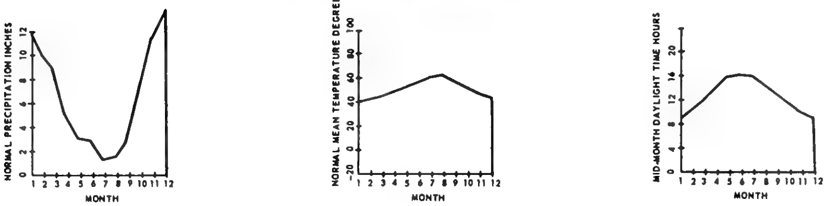



### Pensacola, Florida

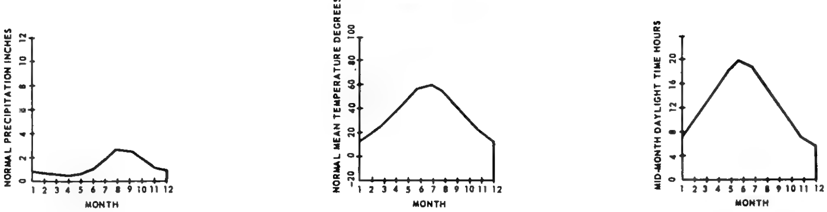


## FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE (continued)

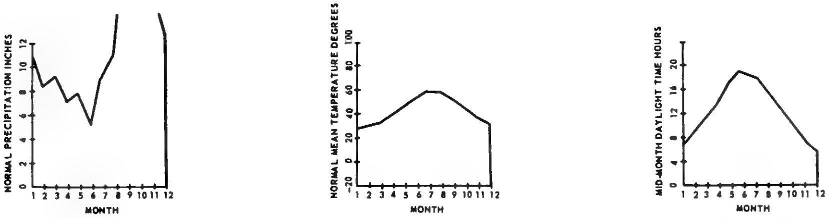
### Astoria, Oregon



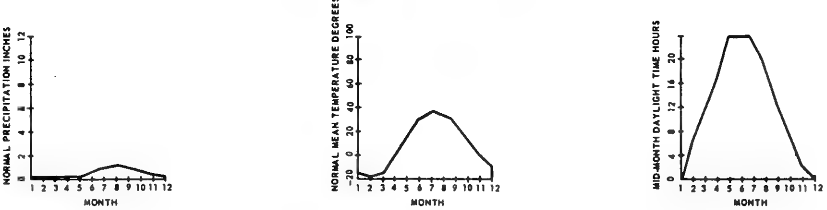

### Anchorage, Alaska




### Yukutat, Alaska

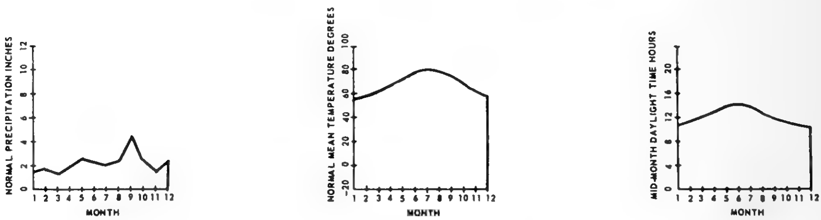



### Barrow, Alaska

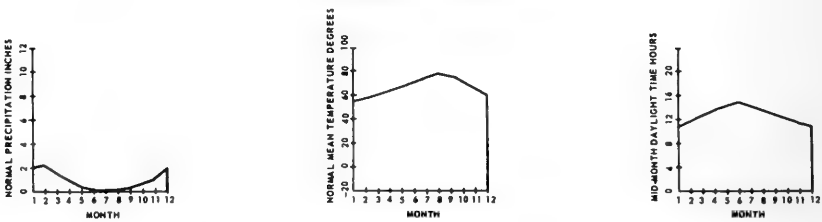


## FIGURE IV.1.18 SEASONAL VARIATION IN CLIMATE AROUND THE ESTUARINE ZONE (continued)

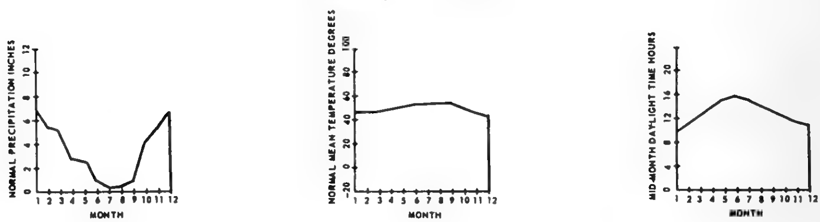
### Corpus Christi, Texas



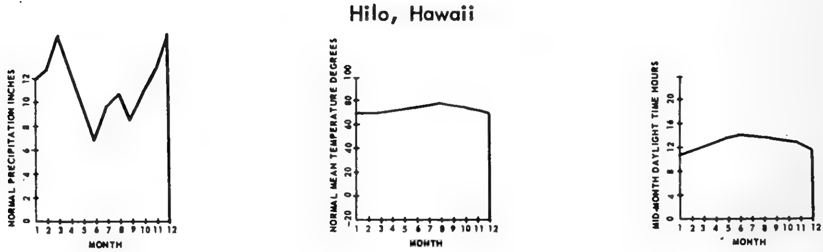

### San Diego, California




### Eureka, California




### Hilo, Hawaii



Local air, water, and ground temperatures, which govern the form in which precipitation occurs, are primarily a matter of solar radiation, which becomes more intense in latitudes nearer the equator. Local temperatures are, however, greatly moderated by local precipitation, cloud cover, nearby ocean conditions, and prevailing winds. Two examples serve to illustrate this point:

(1) Key West, Fla., on an island in the warm waters of the Gulf of Mexico, has an average temperature of 77° F.; Brownsville, Tex., in about the same latitude but on the mainland, has an average temperature of 74° F. At Key West annual temperatures, moderated by the marine environment, range over only 49 degrees, whereas the range at Brownsville is 85 degrees.

(2) Astoria, Oreg., at the mouth of the Columbia River, and Portland, Me., are both in the same latitude in zones of prevailing westerly winds. At Astoria, where the winds are blowing off the Pacific Ocean, there are 76 inches of precipitation, including 4 inches of snow. At Portland the prevailing winds blow off the continental land mass and there are 43 inches of precipitation, but 72 inches of snow.

### TIDE

The tide stands alone as a controlling force in the estuarine environment. The ebb and flow of the tide are the great facts of the estuarine zone, and have determined much of man's history from the time Julius Caesar lost a fleet because of the tides in the English channel to the time of D–Day in 1944, which was set because of the right combination of tide and moon.

Tides are easily understood. The Sun, the Moon, and the Earth mutually attract each other, according to Newton's law of gravitation;[2] the great masses of fluid in the ocean, being more sensitive to tiny changes in gravitation force than the solid land, are pulled about rather freely in a predictable fashion based on the relative positions of Sun, Moon, and Earth. They are predictable to such an extent that tables of accurate predictions of tidal height are published for each day of each year for each major port of the world. Such predictions are valuable both to the captain trying to dock a large oil tanker and to the fisherman who is trying to find where the big ones are biting.

Perhaps because tides are so easily understood and predicted, and are so easily observable everywhere, their importance in the estaurine zone has been largely overlooked.

Table IV.1.4 gives typical tidal characteristics in several estuaries of the United States. It is immediately apparent that tides on each coast of the United States are different. Along the Atlantic and Pacific coasts there are semidiurnal tides, i.e., two complete tides in a little over one day, but the Atlantic tides are equal and the Pacific tides are unequal. In the Gulf of Mexico most places have one tide a day, i.e., diurnal, but some places such as Tampa Bay exhibit both kinds of tides at different times of the month.

[2] It is interesting to note that observations of the rhythmic rise and fall of the tide led to the mathematical concepts through which the law was formulated.

TABLE IV.1.4.—TYPICAL TIDAL CHARACTERISTICS OF THE ESTUARINE ZONE OF THE UNITED STATES

| Biophysical region | Type of tide | Tidal range (feet) Mean | Spring | Diurnal[1] | Maximum tidal flood | Current velocity ebb |
|---|---|---|---|---|---|---|
| North Atlantic: | | | | | | |
| Eastport, Maine (Bay of Fundy) | Equal semidiurnal | 18.2 | 20.7 | | 3.5 | 3.5 |
| Isle de Haut, Maine; (Penobscot Bay) | do | 9.3 | 10.7 | | 1.6 | 1.7 |
| Portsmouth Harbor, N.H | do | 8.7 | 10.0 | | 1.4 | 2.1 |
| Boston Harbor, Mass | do | 9.5 | 11.0 | | 2.0 | 1.5 |
| Middle Atlantic: | | | | | | |
| Dumpling Rocks (Buzzard Bay) | do | 3.7 | 4.6 | | .9 | 1.3 |
| The Narrows (New York Harbor) | do | 4.5 | 5.5 | | 2.0 | 2.3 |
| Cape May Harbor, N.J | do | 4.4 | 5.3 | | 2.1 | 2.5 |
| Virginia Beach, Va | do | 3.4 | .1 | | 1.3 | .9 |
| Chesapeake Bay: | | | | | | |
| Wolf Trap Light (lower bay) | do | 1.0 | 1.2 | | 1.8 | 2.2 |
| Point No Point (midbay) | do | 1.3 | 1.5 | | .5 | .7 |
| Chesapeake Bay Bridge, Maryland | do | .8 | .9 | | .8 | 1.0 |
| Washington, D.C. (Potomac River) | do | 2.9 | 3.3 | | .7 | .3 |
| South Atlantic: | | | | | | |
| Wilmington, N.C. (Cape Fear River) | do | 3.6 | 3.9 | | 2.0 | 1.7 |
| Savannah River entrance, Georgia | do | 6.9 | 8.1 | | 1.8 | 3.0 |
| Mayport, Fla. (St. Johns River) | do | 4.5 | 5.3 | | 2.5 | 3.5 |
| Fort Pierce Inlet, Fla | do | 2.6 | 3.0 | | 3.0 | 3.5 |
| Caribbean: | | | | | | |
| Miami Harbor, Fla | do | 2.5 | 3.0 | | 2.2 | 2.4 |
| Key West, Fla | do | 1.3 | 1.6 | | 1.2 | 2.0 |
| San Juan, P.R | do | 1.1 | 1.3 | | (2) | (2) |
| Christiansted, St. Croix | Diurnal | | | 0.8 | (2) | (2) |
| Gulf of Mexico: | | | | | | |
| St. Petersburg, Fla. (Tampa Bay) | do | | | 2.3 | .3 | .3 |
| Pensacola Bay entrance, Florida | do | | | 1.1 | 1.8 | 2.1 |
| Barataria Bay, La | do | | | .9 | 1.7 | 1.7 |
| Aransas Pass, Tex | do | | | 1.7 | 1.6 | 1.0 |
| Pacific Southwest: | | | | | | |
| Sen Diego Bay entrance, California | Unequal semidiurnal | 3.9 | | 5.6 | 1.2 | 1.4 |
| Monterey Bay, Calif | do | 3.5 | | 5.3 | (2) | (2) |
| San Francisco Bay entrance, California. | do | 4.0 | | 5.7 | 3.3 | 3.9 |
| Point Arena, Calif | do | 4.0 | | 5.8 | 1.3 | 1.3 |
| Pacific Northwest: | | | | | | |
| Humboldt Bay entrance, California | do | 4.5 | | 6.4 | 1.8 | 2.3 |
| Yaquina Bay entrance, Oregon | do | 5.9 | | 7.9 | 2.8 | 2.6 |
| Grays Harbor entrance, Washington | do | 6.9 | | 9.0 | 2.5 | 2.2 |
| Puget Sound (Elliott Bay), Wash | do | 7.6 | | 11.3 | (2) | (2) |
| Alaska: | | | | | | |
| Juneau (Gastineau Channel) | do | 13.8 | | 16.4 | 2.3 | 2.3 |
| Anchorage (Cook Inlet) | do | 25.1 | | 28.1 | 3.3 | 3.3 |
| Goodnews Bay (Kuskokwim Bay) | do | 6.2 | | 8.9 | 2.6 | 2.4 |
| Point Barrow | do | .3 | | .4 | (2) | (2) |
| Pacific Islands: | | | | | | |
| Honolulu, Hawaii (Oahu) | do | 1.2 | | 1.9 | (3) | (3) |
| Hilo, Hawaii (Hawaii) | do | 1.6 | | 2.4 | (3) | (3) |
| Apra Harbor, Guam | do | (3) | | (3) | 1.7 | 3.4 |
| Pago Pago Harbor, American Samoa | do | 2.5 | | 4.0 | (3) | (3) |

[1] For an unequal semidiurnal tide, the diurnal range is the extreme range over the 2 sequential tides in slightly over 1 day.
[2] Weak and variable.
[3] No data.

Reference: The National Estuarine Inventory.

Deta source: U.S. Coast and Geodetic Survey.

Tide ranges, i.e., the difference between high water and low water, are not so uniform. These are largely a matter of shape, size, and bottom material in individual estuarine areas. Ranges vary from the barely noticeable rises and falls of some lagoons along the Gulf of Mexico to the tremendous 28-foot range in Alaska's Cook Inlet.[3]

Even with small tidal ranges and small estuaries, the volumes of water being moved by tidal flow are fantastic. At Charleston, for example, in 6.5 hours 25 billion cubic feet of water move into or out of the harbor in one tidal cycle (IV–1–3). This is more than enough volume of water to supply the entire population of the United States with water for 1 day. The volume of water flowing into or out of Great South Bay on Long Island in one tidal cycle is adequate in volume to supply the city of New York for 1 week.

The combination of tidal action and river flow gives rise to that unique phenomenon called an "estuarine circulation pattern," which usually means that fresh water flows in one direction in one layer and salt water flows in the opposite direction in another layer with various degrees of mixing at the interface between them. This type of circulation pattern is of great importance in some of the estuaries along the Atlantic and gulf coasts, and to a large extent governs the capacity of such estuaries to rid themselves of waste materials.

## Section 3. The Biophysical Estuarine Regions

Each estuarine system along the coastline is affected to some extent by all of these dominating environmental factors. In some cases, as in the example already given, the dominance of one particular factor is readily apparent. It is much more often the case that the competing environmental factors are so evenly balanced that none can be said to dominate and the estuarine zone appears to be composed of a bewildering variety of unique systems.

Yet, as an individual person can be identified as a member of the human species by general common characteristics and as a member of particular race by more specific characteristics, so can individual estuarine systems be recognized as belonging to regional and national groupings.

Table IV.1.5 summarizes the dominating environmental factors in the estuarine zone of the United States. Combinations of environmental conditions characteristic of various parts of the coastline permit the grouping of the national estuarine system into ten biophysical

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[3] A tidal bore, a single breaking wave bringing in the flood tide, is characteristic of Turnagain Arm of Cook Inlet at certain times. This is the only tidal bore in the United States.

TABLE IV.1.5.—DOMINATING ENVIRONMENTAL FACTORS OF THE ESTUARINE ZONE OF THE UNITED STATES

| Environmental factor | North Atlantic | Middle Atlantic | Chesapeake Bay | South Atlantic | Caribbean |
|---|---|---|---|---|---|
| Continental Shelf width range (statute miles), bottom type | 150–250, irregular, rocky | 50–100, smoothly sloping, lagoon off major river. | Not applicable | 30–70, smoothly sloping | 3–10 E< Florida, Puerto Rico, Virgin Islands—190–North of Florida Keys. |
| Ocean currents [1] influenced by | Labrador Current | Labrador Current | None | Gulf Stream | Gulf Stream. |
| Temperature (F.): | | | | | |
| Mean | 46 | 54 | 59 | 72 | 80. |
| Summer | 65 | 73 | 80 | 87 | 87. |
| Winter | 32 | 36 | 38 | 50 | 71. |
| Salinity (percent): | | | | | |
| Mean | 3.03 | 3.15 | 1.37 | 3.55 | 3.57. |
| Dry season | 3.1 | 3.18 | 1.60 | 3.60 | 3.63. |
| Wet season | 2.9 | 3.13 | 1.10 | 3.25 | 3.49. |
| Coastline structure | Rocky, very irregular, many embayments. | Smooth, many large embayments. | Very irregular, extensive marshes on east side. | Smooth, low lying, extensive marshes. | Irregular, mangroves, coral and rocks. |
| River flow: | | | | | |
| Runoff per mile of tidal shoreline (CFS) | 16 | 15 | 15 | 16 | 3. |
| Number of major river basins | 5 | 6 | 6 | 12 | 0. |
| Total runoff (CFS) | 72,000 | 106,000 | 79,800 | 154,000 | 11,500. |
| Sedimentation quantity of suspended load (1,000 tons/yr.). | No data: sedimentation not severe problem, great amount of rock. | 15,300 | 8,640 | 58,100 | No data. |
| Climate: [2] | | | | | |
| Temperature (F.): | | | | | |
| Mean | 45 | 54 | 58 | 66 | 76. |
| Summer | 80 | 84 | 87 | 92 | 89. |
| Winter | 12 | 25 | 30 | 40 | 64. |
| Precipitation (in.): | | | | | |
| Total | 43 | 42 | 44 | 50 | 46. |
| Snow, ice | 72 | 16 | 23 | 0 | 0. |
| Tide: [2] Type | Equal, semidiurnal | Equal, semidiurnal | Equal, semidiurnal | Equal, semidiurnal | Equal, semidiurnal. |
| Mean range (ft.) | 10 | 5 | 2 | 5 | 2. |

| Environmental factor | Gulf of Mexico | Pacific Southwest | Pacific Northwest | Alaska [3] | Pacific Island |
|---|---|---|---|---|---|
| Continental Shelf width range (statute miles), bottom type. | 65–140, smoothly sloping | 2–20, average about 10 | 9–38, with indentations on the outer edge. | 30–150 on southeast and south coast, 400 on west coast. | 0, volcanic island rising from south. |
| Ocean currents [1] influenced by | Water forming Gulf Stream | California Current | California-Aleutian Current | Alaska Current | Mid-Pacific circulation. |
| Temperature (F.): | | | | | |
| Mean | 73 | 60 | 51 | 42 | 77. |
| Summer | 87 | 69 | 56 | 55 | 81. |
| Winter | 54 | 56 | 45 | 30 | 73. |
| Salinity (percent): | | | | | |
| Mean | 3.23 | 3.36 | 30.8 | 3.19 | 3. |
| Dry season | 3.70 | 3.38 | 3.25 | 3.21 | 3. |
| Dry season | 3.03 | 3.33 | 2.85 | 3.12 | 3. |
| Coastline structure | Smooth, low lying with barrier Islands, marshes. | High land close to shore, bluffs and beaches. | High land close to shore, bluffs and beaches. | All glaciated, irregular except in Northwest. | Steep, irregular with beaches. |
| River flow: | | | | | |
| Runoff per mile of tidal shoreline (CFS) | 52 | 27 | 77 | No data | No data. |
| Number of major river basins | 21 | 8 | 9 | 16 | 0. |
| Total runoff (CFS) | 799,000 | 83,400 | 368,000 | No data | No data. |
| Sedimentation quantity of suspended load (1,000 tons/yr.) | 362,600 | 24,000 | 127,000 | No data | No data. |
| Climate: [2] | | | | | |
| Temperature (F.): | | | | | |
| Mean | 69 | 61 | 55 | 40 | 75. |
| Summer | 91 | 76 | 79 | 64 | 33. |
| Winter | 45 | 43 | 35 | 5 | 67. |
| Precipitation (in.): | | | | | |
| Total | 55 | 12 | 40 | 56 | 24–14. |
| Snow, ice | 0 | 0 | 9 | 90 | 0. |
| Tide: [2] Type | Diurnal | Unequal semidiurnal | Unequal semidiurnal | Unequal semidiurnal | Unequal semidiurnal. |
| Mean range (ft.) | 2 | 5 | 7 | 20 | 2. |

[1] Data are typical near-coastal values for the region, except for Chesapeake Bay, where data are for the middle of the bay.
[2] Data are for a point typical of the region.
[3] Data given are for southeast and south coasts only.

Reference: The National Estuarine Inventory.
Data sources: U.S. Coast and Geodetic Survey, U.S. Geological Survey, U.S. Weather Bureau.

estuarine regions of dissimilar Environmental characteristics (fig. IV.1.19).

CHARACTERISTICS OF THE BIOPHYSICAL REGIONS

*North Atlantic estuarine region.*—Canadian border to Cape Cod.

Cool, fertile waters with a large tidal range strike a steep, indented coast with deep water close inshore, but protected from the full force of the ocean waves by a wide continental shelf. Moderate precipitation with heavy snowfall leads to heavy spring river runoff which dominates local circulation. Natural erosion and sedimentation are not severe problems, and the evolution of drowned river valley estuaries is in an early stage in this region.

*Middle Atlantic estuarine region.*—Cape Cod to Cape Hatteras, exclusive of Chesapeake Bay.

A wide, gently sloping continental shelf with a smooth shoreline is cut by the entrances of several major river systems carrying moderate amounts of sediments. The same cool, fertile waters as in the North Atlantic estuarine region wash this coastline but with a smaller tidal range. The evolution of drowned river valleys into coastal marshes is in a secondary stage in the larger estuarine systems, with sand spits and barrier islands forming.

*Chesapeake Bay estuarine region.*—All of the Chesapeake Bay system from Cape Charles and Cape Henry inland.

Isolation from direct oceanic effects in much of the greatly branched system, the many subsystems with major river flows, and the reduced concentration of the ocean salt throughout the bay and its tributaries make this a unique estuarine system. This is a drowned river valley with numerous similar tributary systems in various stages of evolution.

*South Atlantic estuarine region.*—Cape Hatteras to Fort Lauderdale, Fla. (about 26° north latitude).

The generally wide continental shelf is brushed by the warm waters of the well-defined Gulf Stream. The low-lying coastal plain terminates in barrier islands and marshes in which large amounts of sediments are being continually deposited by moderate sized rivers fed by heavy summer rainfall. Many of the drowned river valley estuaries have evolved all the way to coastal marshes. Tidal ranges are small to moderate, depending on local conditions.

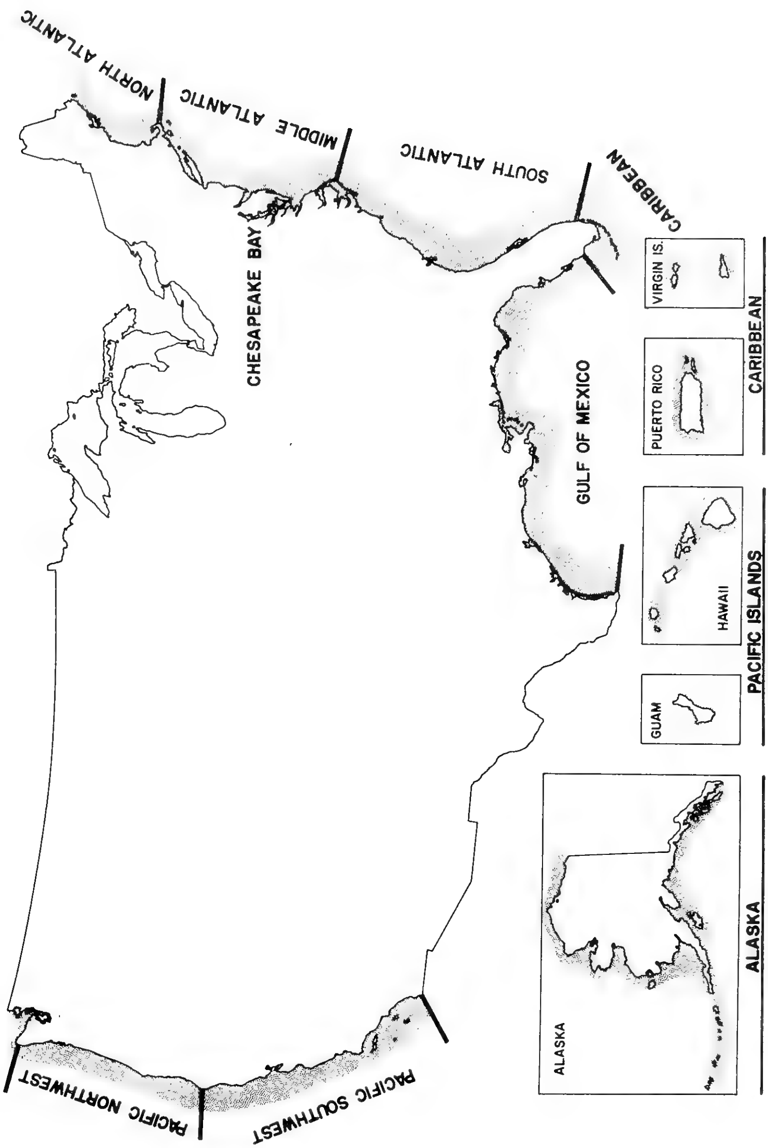
*Caribbean estuarine region.*—Fort Lauderdale to Cape Romano (the Florida peninsula south of 26° north latitude), plus Puerto Rico and the Virgin Islands.

High temperatures, heavy rainfall, and warm ocean currents along practically nonexistent continental shelves result in tropical estuarine environments throughout this region. Coral reefs and mangrove swamps are the typical coastal features of south Florida, while the islands are mountainous and are fringed with coral reefs and beaches. Tidal ranges are small.

*Gulf estuarine region.*—Cape Romano to the Mexican border.

A wide continental shelf extends all the way around this large embayment, in which warm tropical waters are moved gently by weak currents and small tidal ranges. Heavy rainfall over most of the area brings sediments from the broad coastal plain to be deposited in the estuarine zone. Most of the drowned river valleys have evolved to a point intermediate between those of the Middle and South Atlantic regions—barrier islands are extensive and have large shallow bays behind them.

Figure IV.I.19
BIOPHYSICAL REGIONS OF THE UNITED STATES



The Mississippi forms one of the major deltas of the world. This delta is unique among the estuarine systems of the United States, both in its size and in the extent to which it has built out over the continental shelf.

*Pacific Southwest estuarine region.*—Mexican border to Cape Mendocino.

Because of the narrow continental shelf, periodic upwelling of deep water close inshore as winds force the California Current offshore brings cool, fertile water near the coast for several months of the year. The coastline has a typical beach and bluff configuration with only a few shallow embayments and the unique earthquake-born valley of San Francisco Bay which, in the delta formed by the confluence of the San Joaquin and Sacramento Rivers, show what erosion and sedimentation might have done along the southwest coast if rainfall were greater in that area (fig. IV.1.20) of easily erodable mountains.

*Pacific Northwest estuarine region.*—Cape Mendocino to the Canadian border.

The continental shelf and coastal configurations are similar to those of the Pacific Southwest, but ocean water temperatures are lower here; the movement of the California Current away from the coast is not as pronounced, and heavier rainfall has resulted in some major rivers cutting through the coastal mountains to form deeply embayed estuarine systems. See figure IV.1.21. Extensive erosion and sedimentation have caused wide tidal flats, bars, and shoals to be typical of these systems.

The straits of Juan de Fuca and Puget Sound, which were glacier-formed, do not have as severe sedimentation as exists along the ocean coast, and have retained much of their original configuration.

*Alaska estuarine region.*—All of Alaska including the Aleutian and Bering Sea Islands.

The dominant factors in this region are temperature and precipitation. Water temperatures are near freezing, and much of the precipitation falls as snow. The continental shelf is wide all through the region, and tide ranges are very large. The southeast and south coasts have active glaciation and consist primarily of glacier-cut embayments and fjords; the west and north coasts are much flatter and have been modified to some extent by sediments eroded from the interior, including glacial silt, and by the grinding action of pack ice during winter.

*Pacific Islands estuarine region.*—The Hawaiian Islands, American Samoa, Guam.

This region consists of tropical ocean islands of volcanic origin. Dominating factors are lack of a continental shelf, full exposure to oceanic conditions, and pleasantly warm temperatures. Coral reefs and beach and bluff configurations are typical (fig. IV.1.22).

## MANAGEMENT AND THE BIOPHYSICAL REGIONS

The environmental factors upon which this subdivision of the national estuarine system is made all represent transport of solar or gravitational energy to the estuarine zone. Inherent in this subdivision is acceptance of the fact that the input of energy—upon which all life is based—differs in quantity and type in the several regions of the estuarine zone.

In managing estuaries for human benefit, these regional differences in energy form and quantity represent the environmental realities within which management must operate. In the fullness of time and with greater understanding of the world it may be possible to modify the environmental conditions to some extent, but for the present the existing environmental limitations must be accepted.[1]

This discussion has so far considered only those environmental factors which dominate the estuarine environment, not the environment itself. Management's fundamental concerns, however, are with the appearance and quality of the individual environment and with the variety and usefulness of the life forms a particular environment will support.

There are many life forms which exist throughout the estuarine zone, most of them being particularly adaptable forms of plankton, crustaceans, and fish. In addition to these, however, there are some less adaptable life forms which require a limited range of conditions to survive and yet others which need a very specific environment to reproduce.

Maine lobsters, for example, are numerous in the North Atlantic estuarine region, scattered in the Middle Atlantic, and cannot be found in other regions. The commercial shrimp, on the other hand, are abundant throughout the Gulf, Caribbean, and South Atlantic regions, but sparse beyond this range. Maine lobsters thrive in the cold Labrador Current waters, while the major commercial species of shrimp need warm waters like those of the Gulf Stream to reproduce.

Within the general range of the regional estuarine environment are specific local conditions with which management in particular estuarine systems must deal. The next part of this discussion considers local conditions of land and water interaction and their relationship to the living communities present.

## Section 4. The Land and the Water

Nowhere on the earth's surface are land and water as intimately related as in the estuarine zone, and nowhere are their interactions so significant in the ultimate effect on man's environment.

Concern with the quality of the environment is couched ultimately in terms of its effect on life forms—whether it is safe for human beings to be near, whether it looks clean, and whether desirable aquatic life forms can live and reproduce in it. These conditions are measured in terms of the magnitudes of water quality parameters which tell indirectly what the water quality is. These magnitudes depend not only upon the character and concentrations of waste materials, but also upon the rapidity with which a particular system can purge itself of damaging agents.

The shape of land along the land-sea interface goes far toward determining what water movement and circulation patterns exist in particular local areas, and, consequently, how fast a particular estuarine system will rid itself of pollutants. Within the estaurine regions discussed in the preceding section, different structural types define patterns of water movement typical of particular structures, no matter what the external environment may be.

[1] One environmental factor, river flow, is already being freely modified—sometimes with less understanding than may be desirable. A case study on damages associated with river flow modification in Charleston Harbor is presented in chapter 5 (IV–1–3).

## MORPHOLOGY OF THE ESTUARINE ZONE

Those characteristics shown in table IV.1.6 describe differences in structure and form of the estuarine zone among the estuarine regions. The descriptive ratios presented in this table result from combining areas and distances characteristic of the estuarine zone of each region. Such ratios are numerical indices of the relative sizes of the estuarine zone in each region and also give quantitative measures of its relative composition among regions. Their greatest value, however, is in comparing individual estuarine systems so as to apply the lessons learned in one estuary to the problems of another.

Alaska has by far the longest general coastline and tidal shoreline as well as the greatest estuarine water area of any estuarine region, but the Chesapeake Bay region has a much greater proportion of estarine shoreline and area for its size than any of the other regions. Esturine systems within the Chesapeake Bay region consist of a group of branched rivers entering the Chesapeake Bay itself, which is in turn the former valley of the Susquehanna River. The estuarine systems on the western side of the bay tend to be surrounded with somewhat hillier land and less extensive marsh areas than those on the eastern shore, though nearly all systems tributary to the bay are drowned river valleys.

The Middle Atlantic and Gulf estuarine regions have about equal amounts of tidal shoreline and estuarine water areas per mile of ocean coastline, but in the Middle Atlantic region the estaurine zone consists primarily of a few large drowned river valley embayments (e.g. New York Harbor, Delaware Bay, and Narragansett Bay) and some small marsh and barrier beach systems receiving only coastal fresh water runoff. The estaurine zone of the Gulf region on the other hand consists mainly of moderate sized embayments with barrier beaches and extensive marshes, but receiving river flow from upland drainage areas and representing an intermediate state in the evolution of drowned river valleys into coastal marshes in the gulf region.

The North Atlantic is unlike any of the other regions in overall structure, but is similar to Puget Sound and southeast Alaska. Characteristic of the North Atlantic region are very irregular, hilly coastlines with deep water close inshore and long, narrow embayments with open access to the sea.

The South Atlantic region has two dominant types of estuarine structure. From Cape Hatteras to about Jacksonville, there is a general input of upland river drainage to the estuarine zone and the estuarine systems are typical drowned river valleys in the later stages of evolution represented by barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville fresh water runoff comes primarily from local coastal drainage, and there are uniform and extensive barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville freshwater runoff comes primarily from local coastal drainage, and there are uniform and extensive barrier island beaches with long narrow embayments behind them. Continuous but generally narrow strips of marsh lie along the embayments. This structure fades into the extensive swamplands of the Everglades farther down the Florida peninsula.

Both the Pacific Northwest and Pacific Southwest regions have few estuaries. The estuarine systems of the Northwest Pacific region tend

TABLE IV. 1.6—SIZE AND SHAPE COMPARISONS AMONG BIOPHYSICAL REGIONS

| | North Atlantic | Middle Atlantic | Chesapeake Bay | South Atlantic | Caribbean | Gulf of Mexico | Pacific Southwest | Pacific Northwest | Alaska | Pacific Islands | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ocean coastline (miles) | 1,358 | 1,286 | 11.3 | 817 | 1,542 | 2,270 | 1,194 | 669 | 14,899 | 1,194 | 25,230 |
| Tidal shoreline (miles) | 4,419 | 7,992 | 5,469 | 9,793 | 3,437 | 15,476 | 3,060 | 4,793 | 33,904 | 1,328 | 89,571 |
| Estuarine water area (square miles) | 3,401 | 5,130 | 4,554 | 3,973 | 717 | 10,944 | 799 | 1,946 | 14,353 | 15 | 45,832 |
| Marsh area (square miles) | 97.6 | 603.1 | 595 | 2,267 | 616.4 | 8,427 | 191 | 44.5 | (1) | 15 | 12,841 |
| Coastal counties area (square miles) | 11,177 | 19,237 | 13,859 | 24,839 | 9,869 | 48,151 | 31,168 | 42,768 | 334,413 | 6,703 | 552,184 |
| Descriptive ratios: | | | | | | | | | | | |
| Tidal shoreline/ocean coastline | 3.3 | 6.2 | 408.0 | 12.0 | 2.2 | 6.8 | 2.6 | 7.2 | 2.3 | 1.1 | 3.6 |
| Estuarine water area/ocean coastline | 2.5 | 4.0 | 400.0 | 4.9 | .46 | 4.8 | .67 | 2.9 | .96 | .01 | 1.8 |
| Estuarine water area/tidal shoreline | .77 | .64 | .83 | .41 | .21 | .71 | .26 | .41 | .42 | .01 | .5 |
| Marsh area/ocean coastline | .07 | .47 | 53.0 | 2.8 | .40 | 3.7 | .16 | .07 | | .01 | .5 |
| Marsh area/tidal shoreline | .02 | .08 | .11 | .23 | .18 | .54 | .06 | .01 | | .01 | .1 |

Reference: National Estuarine Inventory.
Data sources: U.S. Coast and Geodetic Survey, Bureau of the Census.

[1] No data.

to be the mouths of rivers which have cut their way through coastal mountain ranges, either of their own accord or aided by glaciers as in the case of Puget Sound. Shallow coastal embayments with little and sporadic river flow are characteristic of the few estuarine systems of the Southwest, except for San Francisco Bay, which receives fresh water runoff from much of central California.

Alaska presents the greatest variety in estuarine form and structure of any of the estuarine regions. Nearly all kinds of systems typical of other regions are found there. In addition, Alaska has the only glaciated coast and most of the fjords found in the United States.

The rivers entering the estuarine zone drain nearly 90 percent of the U.S. land area. They carry to the sea sediments eroded from this vast expanse and deposit much of it in the narrow band of 274 counties which comprise the basic political subdivisions of the estuarine zone. These coastal counties form a strip of land averaging about 50 miles wide along the coast, except where the large embayments of the Chesapeake Bay and Puget Sound make this strip reach more 100 miles from the ocean.

The total area of the coastal counties is 552,000 square miles with the bulk of this in the Alaskan estuarine region and the smallest part in the Pacific Island estaurine region. In the Middle Atlantic, South Atlantic, and Gulf regions, the coastal strip is low-lying plain composed of easily erodable materials which tend to be deposited in the estuarine zone and moved about by waves and currents. The ocean coast is mostly sand throughout these regions, overlain near river mouths by some mud and clay. The Mississippi delta is entirely mud, clay, silt, and sand washed down from the heartland of the continent. Sand, mud, and clay predominate in the embayments, with sand characteristic of open waters and mud common in marshes.

Rock, gravel, and sand are the common bottom materials along the North Atlantic coast, with the rock overlain by fine mud and silt in confined areas and sand common in the offshore areas.

The Pacific coast counties form mountainous strips along the coast. Sediments reaching the ocean in this region tend to be deposited in broad tidal flats or bars where currents permit, or washed off into the ocean where wind and waves motion is sufficiently vigorous. Bottom sediments are rock and clay covered in some places with fine mud.

The characteristic sediment of the Alaskan estuarine region is glacial flour, that extremely fine material ground from the land and carried along by glaciers. Many of the estuaries and much of the continental shelf off the western Alaskan coast are covered with this material.

Coral reefs, sand, and rocks are typical of estuarine bottoms in the Pacific and Atlantic Islands. Except in extremely sheltered areas, sediments are rare because of the continuous wind and wave action.

## A MORPHOLOGICAL CLASSIFICATION OF THE ESTUARINE ZONE

The estuarine zone can be classified according to its local morphology into major categories, several of which exist in each of the estuarine biophysical regions. Within each of these categories, the similarities in structure reflect similarities in water movement, water quality, and ecology which make it possible to apply lessons learned in managing an estuarine system in one region to similar estuarine systems in other regions.

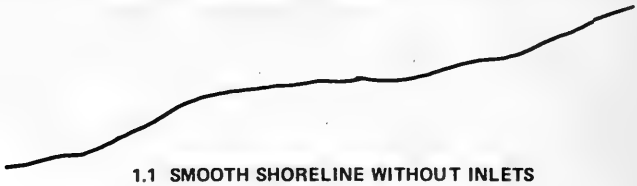
TABLE IV-1-7.—A MORPHOLOGICAL CLASSIFICATION OF THE NATIONAL ESTUARINE ZONE BY DOMINATING CHARACTERISTIC

[Numbers of types in each biophysical region]

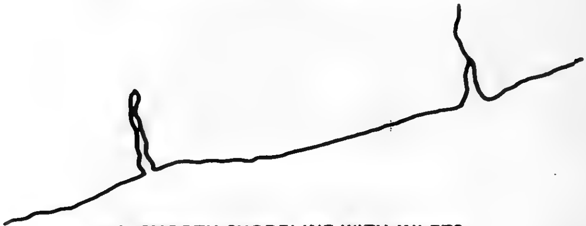
| Classification type | North Atlantic | Middle Atlantic | Chesapeake Bay | South Atlantic | Caribbean | Gulf of Mexico | Pacific Southwest | Pacific Northwest | Alaska | Pacific islands | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Smooth shoreline: | | | | | | | | | | | |
| Without inlets | 1 | 2 | | | 1 | 1 | 9 | | | 11 | 25 |
| With inlets | 2 | 7 | | 7 | | 1 | | 5 | 2 | | 24 |
| With small embayments | 3 | 8 | | 9 | | 11 | 6 | 7 | 6 | 14 | 64 |
| Indented shoreline: | | | | | | | | | | | |
| Without islands | 10 | 4 | | | 16 | 1 | | | 10 | 2 | 43 |
| With islands | 15 | 5 | | 2 | 2 | 1 | 1 | 1 | 33 | | 60 |
| Marshy shoreline | | 3 | 1 | 6 | 1 | 13 | | | | | 24 |
| Unrestricted river entrance | 7 | 7 | 7 | 8 | | 34 | 8 | 21 | 2 | | 94 |
| Embayment: | | | | | | | | | | | |
| With only coastal drainage | 8 | 24 | 136 | 41 | 4 | 91 | 21 | 3 | 12 | 9 | 349 |
| With upland river inflow | 17 | 23 | 18 | 12 | 2 | 54 | 19 | 27 | 23 | | 195 |
| Fjord | | | | | | | | 2 | 4 | | 6 |
| Total | 63 | 83 | 162 | 85 | 26 | 207 | 64 | 66 | 92 | 36 | 884 |

Reference: The National Estuarine Inventory.
Data source: FWPCA.

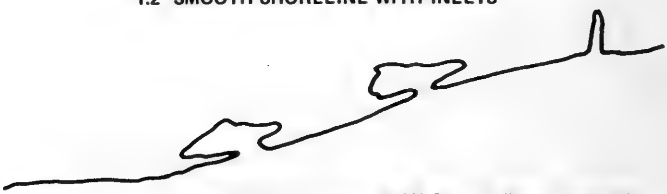
FIGURE IV.1.23 MORPHOLOGICAL CLASSIFICATION OF ESTUARIES AND ESTUARINE ZONES



1.1 SMOOTH SHORELINE WITHOUT INLETS

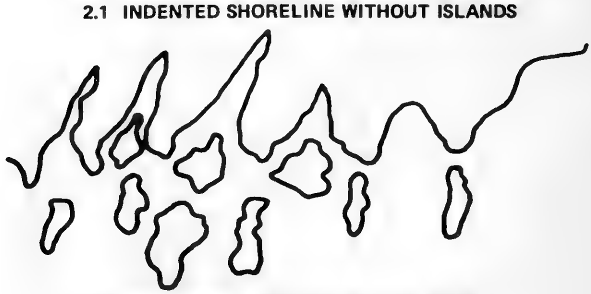


1.2 SMOOTH SHORELINE WITH INLETS



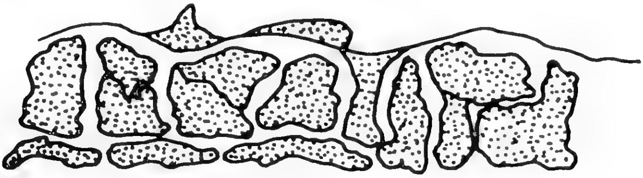
1.3 SMOOTH SHORELINE WITH SMALL EMBAYMENTS

2.1 INDENTED SHORELINE WITHOUT ISLANDS

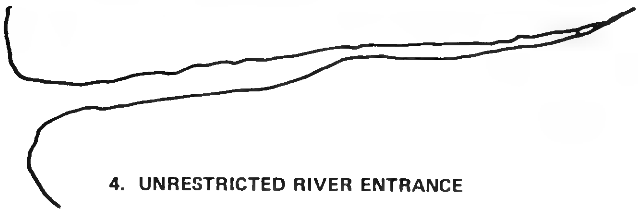


2.2 INDENTED SHORELINE WITH ISLANDS

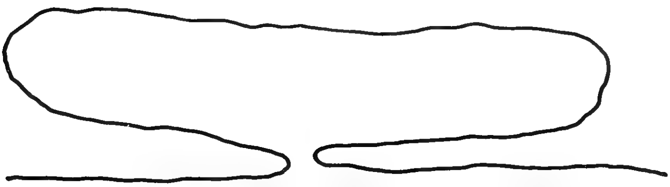
FIGURE IV.1.23 MORPHOLOGICAL CLASSIFICATION OF ESTUARIES AND ESTUARINE ZONES (continued)



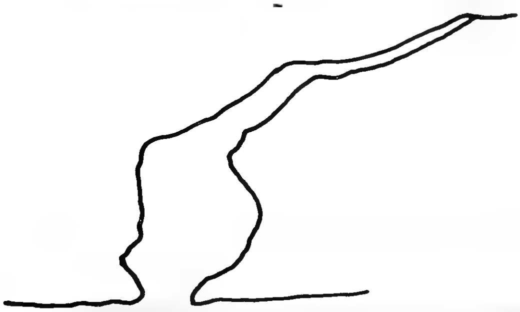
3. MARSHY SHORELINE



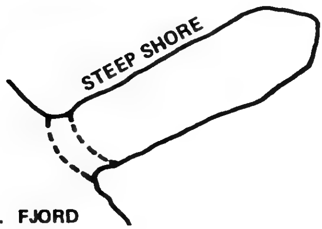
4. UNRESTRICTED RIVER ENTRANCE



5.1 EMBAYMENT WITH ONLY COASTAL DRAINAGE



5.2 EMBAYMENT WITH CONTINUOUS UPLAND RIVER INFLOW




6. FJORD

Figure IV.1.23 illustrates each category. Table IV.1.7 shows the numbers of different kinds of estuarine systems in each estuarine biophysical region. Unrestricted river entrances and embayments dominate and are rather evenly distributed throughout all the regions, with the common type of estuarine system being a coastal embayment with drainage from only the local coastal area. Many of these latter embayments have large marsh areas, but the Middle Atlantic, South Atlantic, and Gulf are the regions in which marshes are the predominant feature in some parts of the estuarine zone.

### WATER MOVEMENT IN THE ESTUARINE ZONE

The unique nature of water movement and circulation patterns in the estuarine zone is the result of the meeting and mixing of fresh river water and salty ocean water of slightly greater density under the oscillating influence of the tide. There may be additional complicating factors such as temperature and wind action, but the resulting circulation nearly always reflects the interaction of river flow and estuary shape with the tidal flow of the ocean water.

General water movement patterns are predictable for each category of estuarine shape. Where there is little or no fresh water inflow, water moves toward and away from the shore, being reflected into currents paralleling the shore in some cases. On ocean beaches, this parallel type of water movement builds sandspits and barrier islands to begin the transformation of drowned river valleys into embayments and coastal marshes, as illustrated by figure IV.1.24.

Where fresh water runoff reaches the sea as a series of small streams or as seepage across the surface, coastal marshes often form and circulation patterns are weak and undefined. This situation may exist where local coastal drainage runs off to the sea, where a drowned river valley has filled in so much that the river channel is no longer defined, or where sediment deposition at the mouth of a large river forms a delta (fig. IV.1.6).

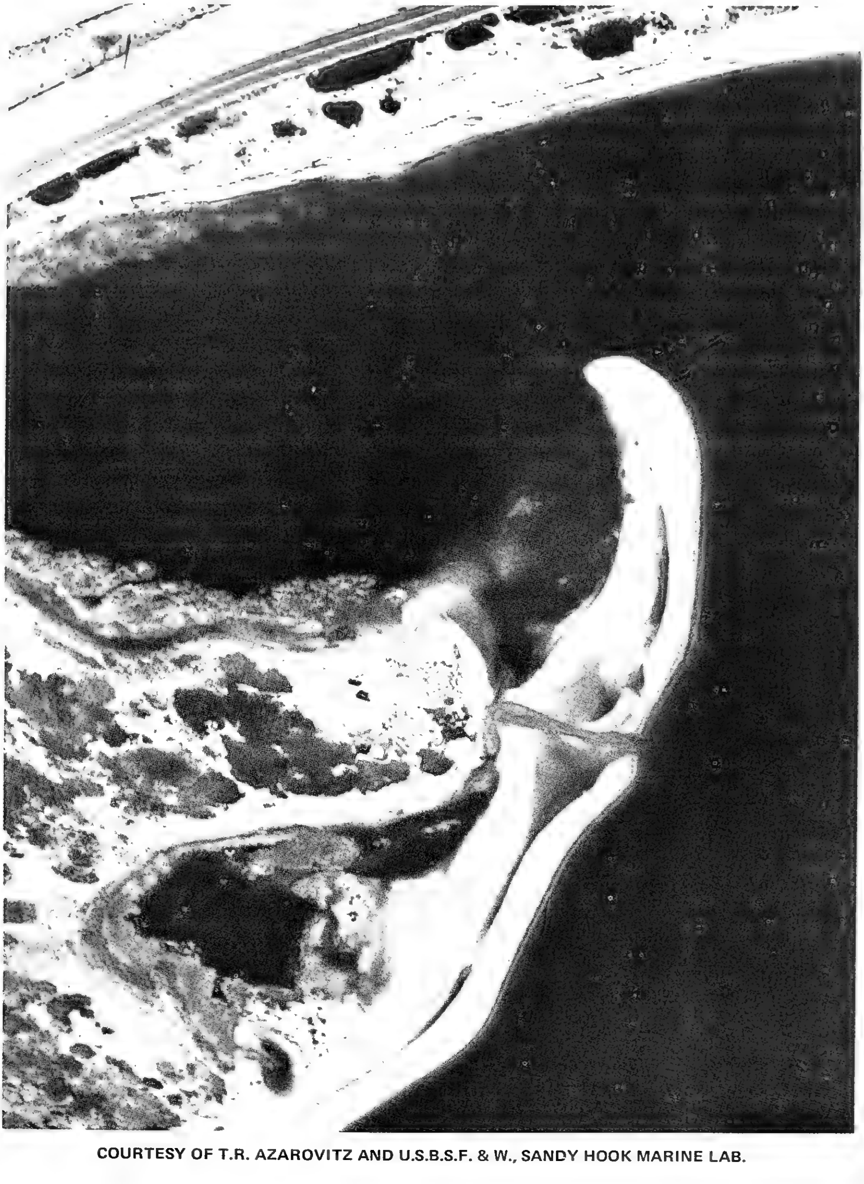
Fiords are formed where a glacier, having gouged out a deep embayment, melts as it reaches the sea and deposits the entrained dirt and rock as a shallow sill across the entrance of the embayment (fig. IV.1.25). This sill isolates the lower water of the fjord from the sea; the only significant water movement is in the layers above the sill level.

It is where moderately large rivers and streams meet the sea that the unique estuarine circulation patterns occur mostly frequently. Large fresh water flows in well-defined channels tend to slide over the top of denser sea water without rapid mixing. Water movement in such cases exhibits various degrees of stratification.

Narrow channels and high fresh water flows result in a well-defined sea water layer moving upstream along the bottom of the channel and a nearly fresh layer moving toward the sea along the surface (fig. IV.1.25).

The Mississippi and Savannah Rivers are classic examples of this "salt-wedge" circulation pattern. With this type of water movement, salt and water from the bottom layer mix constantly into the top layer, and more salt water flows in from the sea to replace it so that the total amount of water in motion may be many times the river flow

FIGURE IV.1.24 SAND SPIT BUILDUP (SANDY HOOK BAY, N.J.)



COURTESY OF T.R. AZAROVITZ AND U.S.B.S.F. & W., SANDY HOOK MARINE LAB.

Figure IV.1.25

CIRCULATION IN A TYPICAL FJORD

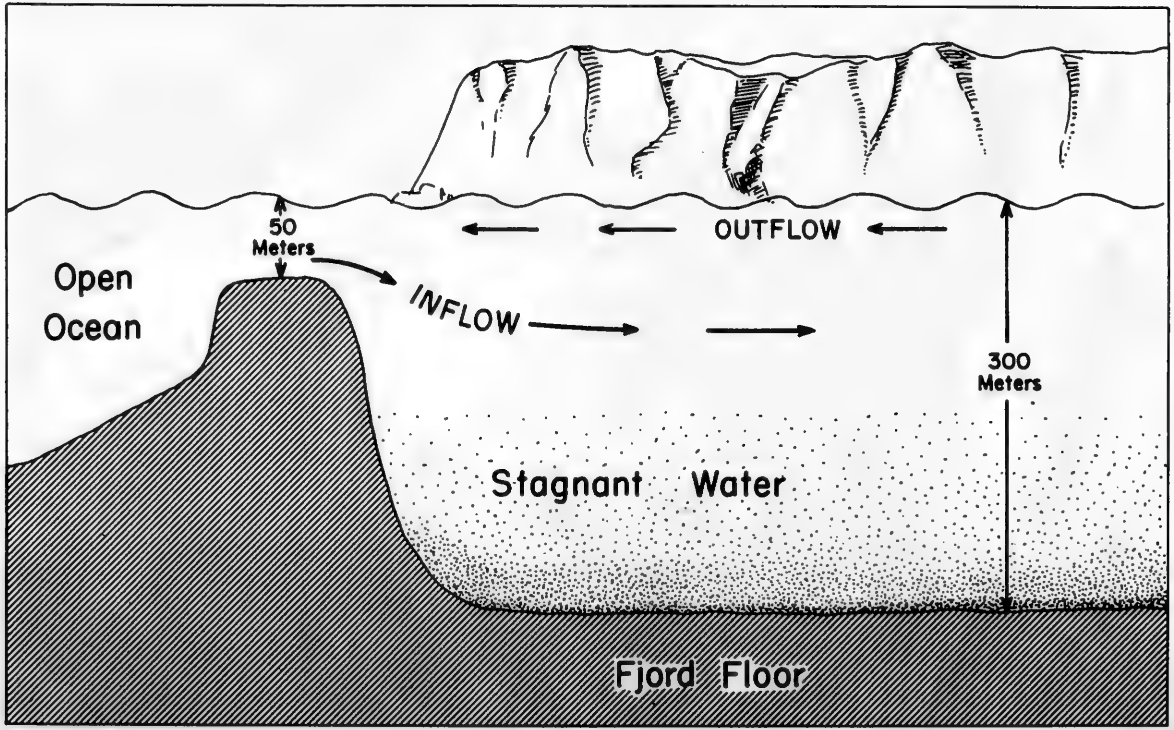
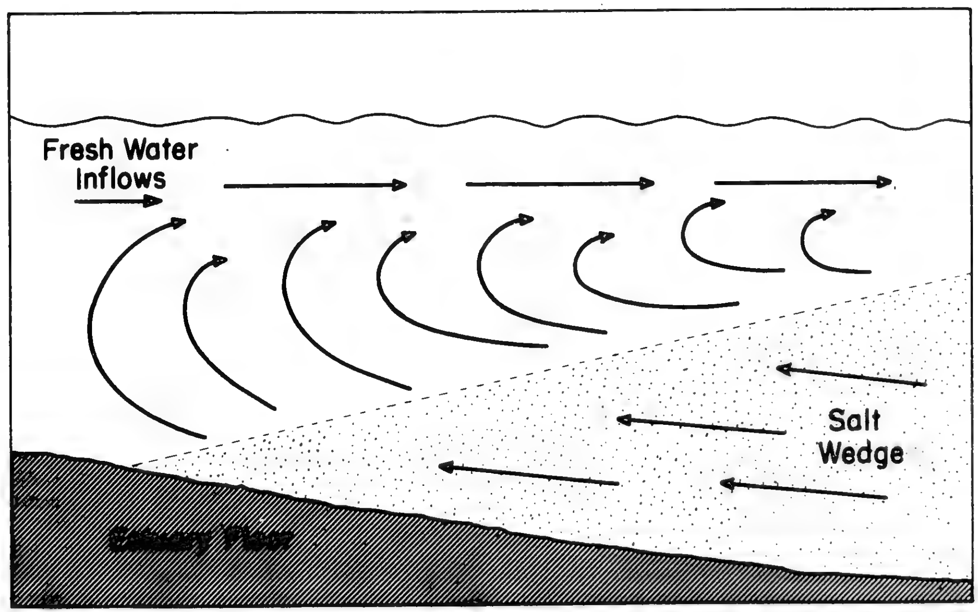


Figure IV.I.26

TYPICAL SALT WATER WEDGE CIRCULATION PATTERN



plus the tidal flow. Such estuarine systems purge themselves very rapidly of waste discharges.

With wider channels, smaller river flows, and greater tidal ranges more mixing occurs and other forces come into play. Embayment shape, bottom configuration and material, and the effects of the earth's rotation all may play a role. In some estuarine systems of this type, the degree of stratification may change with changes in river flow, temperature, wind, or other transient conditions.

The James River is a drowned river valley in the Chesapeake Bay estuarine region (fig. IV.1.27). Its length of tidal influence is great in proportion to its width, and it exhibits some vertical stratification. Delaware Bay is much wider than the James and is stratified laterally (fig. IV.1.28); that is, salt content along the eastern shore tends to be higher than that along the western shore. This phenomenon probably results from forces, associated with the earth's rotation, which in large bodies of water tend to cause lateral stratification as a result of the different rates of slipping of salt and fresh water on the spinning earth's surface.

Hillsborough Bay, an arm of Tampa Bay, is nearly unstratified and quite salty during much of the year. During high flows, however, the Hillsborough River pushes the salt out of the upper part of the bay and often kills heavy growths of a salt water plant which is not tolerant of fresh water.

Some very large embayments with small ocean entrances such as Pamilco Sound have very small tidal ranges, very little stratification, and throughout most of their area, very weak currents (fig. IV.1.4). Only at the channels to the ocean are currents strong, and there they are often extremely violent and dangerous. Wastes discharged into such embayments tend to remain for long periods and exert their effects in the estuary rather than moving out to sea.

### NATURAL WATER QUALITY IN THE ESTUARINE ZONE

Estuarine water quality is the product of both land and water. From the land, erosion and solution in river water bring suspended and dissolved minerals, while decaying vegetation adds dissolved organic material. Sea water itself contains three percent dissolved salts, but negligible quantities of organic matter.

In the estuarine zone these two different solutions meet and mix. Salt concentrations range from that of the oceans to the almost unmeasurable amounts present in some rivers. Where little stratification exists, sea salt dominates mineral concentrations in estuarine waters; in stratified systems, however, the small amounts of minerals entering in the fresh water may be as important in some parts of the estuarine zone as the much larger concentrations from the sea are in others. The interface between fresh and salt water is a region of complex chemistry where some material may be precipitated out or otherwise changed, much as lye soap used to be "salted out" when soap was made by boiling lard with wood ash extract in the backyard. Organic matter from decaying vegetation is particularly susceptible to this type of chemical effect.

Climate also plays a direct role in determining estuarine water quality. Excessive evaporation can drive salinities far above those of ocean

TABLE IV. 1.8.—NATURAL OCEAN AND RIVER WATER QUALITY TYPICAL OF THE ESTUARINE ZONE

| Biophysical region | Ocean water quality | | | | | | River water quality | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature (degrees Fahrenheit) | Disolved oxygen (P.P.M.) | Ph | Salinity (Cl—) (P.P.M.) | Phosphate, phosphorus (P.P.M.) | Nitrate, nitrogen (P.P.M.) | Temperature (degrees Fahrenheit) | Disolved oxygen (P.P.M.) | Ph | Salinity (Cl—) (P.P.M.) | Phosphate, phosphorus (P.P.M.) | Nitrate, nitrogen (P.P.M.) |
| North Atlantic: | | | | | | | | | | | | |
| Summer | 65 | 7.93 | 8.15 | 17,989 | 0.124 | … | 72 | 7.51 | 6.3 | 1.0 | 0.05 | 0.7 |
| Winter | 32 | 8.22 | 8.15 | 17,989 | … | … | 32 | 12.43 | 6.7 | 3.0 | .06 | .2 |
| Middle Atlantic: | | | | | | | | | | | | |
| Summer | 73 | 6.34 | 7.62 | 17,385 | 1.053 | 0.280 | 71 | 7.60 | 7.6 | 9.5 | .21 | 4.6 |
| Winter | 36 | 7.17 | (1) | 14,022 | … | … | 35 | 11.99 | 7.1 | 12.0 | .03 | 1.1 |
| Chesapeake Bay: | | | | | | | | | | | | |
| Summer | 80 | 6.60 | 7.66 | 10,266 | 1.425 | .056 | 80 | 6.94 | 7.0 | 9.5 | … | .6 |
| Winter | 38 | 8.13 | 7.53 | 7,922 | .712 | … | 40 | 11.00 | 6.9 | 11.0 | … | 3.4 |
| South Atlantic: | | | | | | | | | | | | |
| Summer | 87 | 6.66 | 8.17 | 19,723 | .434 | … | 76 | 7.18 | 7.0 | 5.0 | .14 | 1.5 |
| Winter | 50 | 6.74 | 8.00 | 19,839 | 1.084 | … | 55 | 9.16 | 4.9 | 6.2 | .25 | .5 |
| Caribbean: | | | | | | | | | | | | |
| Summer | 87 | 6.70 | 8.10 | 19,723 | .341 | … | 83 | 6.65 | 7.4 | 44.0 | .12 | … |
| Winter | 71 | 6.33 | 7.99 | 19,906 | .434 | … | 61 | 8.30 | 8.2 | 60.0 | … | .7 |
| Gulf of Mexico: | | | | | | | | | | | | |
| Summer | 87 | 6.52 | 8.03 | 19,424 | .712 | … | 78 | 5.80 | 7.7 | 5.0 | .00 | .6 |
| Winter | 54 | 7.39 | 8.24 | 19,945 | .372 | … | 57 | 8.99 | 6.8 | 6.0 | … | 1.2 |
| Pacific Southwest: | | | | | | | | | | | | |
| Summer | 69 | 8.20 | 8.05 | 18,504 | 2.571 | … | 68 | 7.79 | 8.0 | 6.7 | … | 1.4 |
| Winter | 56 | 7.90 | 8.20 | 18,499 | 2.292 | … | 46 | 10.29 | 8.1 | 4.8 | … | .9 |
| Pacific Northwest: | | | | | | | | | | | | |
| Summer | 56 | 8.02 | 7.56 | 16,017 | 5.049 | .812 | 74 | 7.29 | 7.5 | 3.0 | .26 | .3 |
| Winter | 45 | 8.76 | 8.33 | 14,770 | 6.721 | … | 46 | 10.29 | 7.9 | 2.0 | .11 | .3 |
| Alaska: | | | | | | | | | | | | |
| Summer | 55 | 10.09 | 7.31 | 17,596 | 2.013 | .042 | 52 | 9.23 | 7.5 | 3.2 | … | .5 |
| Winter | 30 | 3.84 | 7.81 | 17,706 | … | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Pacific Islands: | | | | | | | | | | | | |
| Summer | 81 | 6.90 | 8.24 | 19,307 | .898 | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| Winter | 73 | 6.97 | 8.23 | 19,396 | .558 | (2) | (2) | (2) | (2) | (2) | (2) | (2) |

[1] No winter data available.
[2] No data available.

Note: Values estimated at 85 percent saturation.

Reference: The National Estuarine Inventory.

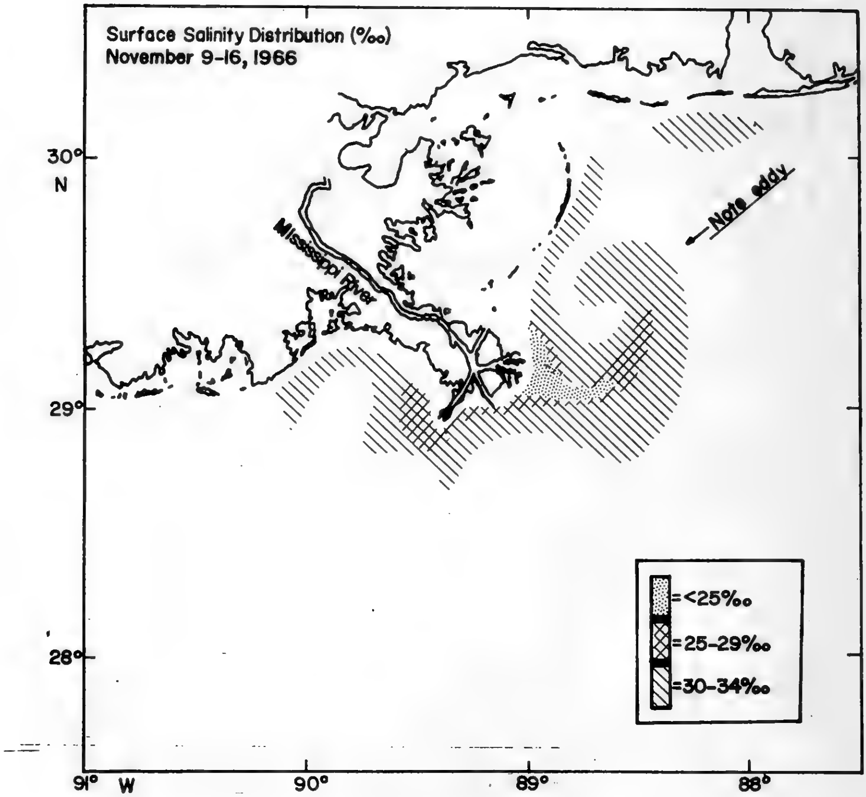
Data Sources: National Oceanographic Data Center and FWPCA.

water, as in Laguna Madre, and create an inverse estuarine system. Sunlight beating down on shallow embayments may raise temperatures so high that use of the estuarine waters for cooling may be seriously impaired.

Table IV.1.8 summarizes ocean and river water quality in each of the estuarine regions. Ocean water quality itself varies in different areas off the coast, generally reflecting ocean currents and climate as discussed earlier. Ocean temperatures reflect not only the variation in latitude, but also the temperature differences of the cold and warm currents around the coast. The temperature difference north and south of Cape Hatteras is particularly striking, because the Gulf Stream and Labrador Current water each dominate on one side of the Cape.

Nearshore ocean surface salinities are strongly influenced by river runoff and local precipitation. The effects of the Mississippi on the Gulf of Mexico are shown in figure IV.1.29. Less dramatic but nonetheless significant, are the effects of the Hudson on the Atlantic and of the Columbia on the Pacific.

FIGURE IV.1.29 SURFACE SALINITY DISTRIBUTION AROUND THE MISSISSIPPI DELTA




SOURCE: Bureau of Commercial Fisheries, Galveston, Texas

The turbidity of ocean water is generally low except where it meets the shore; there the amount of turbidity is a direct reflection of the intensity of wave action and the nature of bottom material.

Dissolved oxygen is essential for all aquatic life. The amount of dissolved oxygen present in surface ocean water is very close to the total amounts the water can contain. Since this saturation concentration depends on both temperature and salt concentration, the warm, saline waters, of the Gulf contain far less oxygen than the cold, relatively fresh waters off the Alaskan coast.

The natural quality of water free from human impact in the rivers entering the estuarine zone depends primarily on the nature of the ground over which they flow. Minerals enter the water by dissolving from soil and rock as the water flows over it or carries it along. Water flowing over limestone or other sedimentary material usually has greater concentrations of dissolved minerals than water flowing over volcanic rock and sand. Insoluble minerals are carried along as sediments, some dissolving slightly and others settling out in quiet reaches of the rivers or in the estuarine zone.

Decaying plant and animal materials also dissolve into the flowing streams. These materials use oxygen in the decaying process and in some streams, particularly in swampy areas, very low-dissolved oxygen concentrations are normal. Dissolved organic material frequently has a very intense yellow-black color which may make a water body appear jet black. This condition is common in the estuarine zones of the south Atlantic and Gulf regions.

Variable as estuarine water quality and water circulation are, estuarine waters in each of the estuarine regions have typical characteristics for different morphological categories. Table IV.1.9 outlines such typical natural estuarine zone conditions.

## Section 5. The Life Energy and Life in the Estuarine Zone

It is in the variety and diversity of estuarine life that the input of energy to the estuarine zone finds ultimate expression. Whether energy comes directly, as in the solar radiation stimulating photosynthesis, or whether it comes indirectly, as with tidal flows or wind and rain pounding on the shoreline, its absorption and conversion to other forms of energy (such as food) are essential steps in the continuation of life in the water, in the marshes, and on the land.

Energy input from gravitational forces, as illustrated by tidal action and river flow, depends primarily on local or regional conditions, but direct energy input from solar radiation depends largely on the latitude, the tropics receiving more energy per acre than the Arctic. The relative amounts of energy entering an estuarine system govern the kinds of life found there, and natural ecosystems show systematic variations related to the sources and amounts of energy received.

Estuarine zones with strong mechanical energy inputs from waves, currents, tides, or river flows develop similar ecosystems no matter whether in the tropics or the Arctic. Exposed ocean beaches at all latitudes have communities of burrowing animals such as snails, worms, clams, and crabs. Rocky sea fronts develop communities of attached algae and mollusks (fig. IV.1.30). Channels with strong

TABLE IV.1.9—CHARACTERISTIC NATURAL ESTUARINE ZONE CIRCULATION AND WATER QUALITY CONDITIONS

| Biophysical region | Smooth shoreline (1) | Indented shoreline (2) | Marshy shoreline (3) | Unrestricted river entrance (4) | Embayment, coastal drainage only (5) | Embayment, continuous upland river flow (6) | Fjord (7) |
|---|---|---|---|---|---|---|---|
| North Atlantic | Deep near shore, oceanic water, longshore currents, some suspended sand and clay. | Deep near shore, oceanic water, erratic tidal currents; eddies and tidal pools. | Strong currents in many small channels through marsh, some turbidity, high oxygen. | Highly stratified, some turbidity, high oxygen, temperatures warmer in summer, colder in winter than ocean. | Little turbidity, water of oceanic character; strong tidal currents through inlets. | Little turbidity, high oxygen, may be stratified, upper layer fresh, with temperatures warmer in summer, colder in winter than the ocean. | |
| Middle Atlantic | Oceanic water, longshore currents; suspended mud, clay silt. | Generally shallow, suspended mud and sand, oceanic water. | Moderate currents in well-defined channels, high dissolved oxyganic material, little turbidity, high oxygen. | Moderate stratification, suspended mud and silt, high oxygen, strong currents. | Generally shallow, small tides, clear water with lowered salinity, high oxygen. | Variable stratification, suspended mud and silt, high oxygen, small amounts of organic material. | |
| Chesapeake | Longshore tidal currents highly variable salinities, small amounts of organic material. | Moderate tidal currents, highly variable salinities, some turbidity. | Poorly defined channels, small currents, dissolved organic material, moderately fluctuating oxygen. | Moderate stratification, suspended mud and silt, high oxygen, strong currents. | Generally shallow, small tides, clear water with lowered salinity, high oxygen. | Variable stratification, suspended mud and silt, high oxygen, small amounts of organic material. | |
| South Atlantic | Primarily tidal and wave induced currents, oceanic water with mud, clay and silt. | Moderate tidal currents, highly variable salinities, some turbidity. | Small currents, high color, dissolved organics, highly variable oxygen, sometimes low, high temperatures. | Strong stratification, high suspended mud and clay, strong currents, dissolved organics, moderate oxygen. | Some color, small currents, generally shallow, high dissolved organics, highly fluctuating oxygen. | Slight and variable stratification, river water cooler than ocean, slight color, some oxygen fluctuation. | |
| Caribbean | Clear ocean water, gentle currents, warm temperatures throughout the year. | Clear ocean water, gentle currents, eddies, warmer than ocean. | High dissolved organics, color, suspended mud, very small currents, hot. | Slightly turbid, strong currents, river cooler than ocean water. | Very small currents, generally shallow, quite warm, clear ocean water. | Slightly turbid, eddying currents, slight stratification, high oxygen. | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gulf of Mexico | Clear, generally warm ocean water, longshore currents. | Very small currents, ocean water with slight turbidity, warmer than ocean. | High dissolved organics, color, very small currents, slightly turbid, very warm. | Slightly turbid, strong currents, river cooler than ocean water. | Very small currents except in inlet, shallow, warm, slight turbidity from sand and silt, highly fluctuating oxygen. | Slight and variable stratification, river water cooler than ocean some oxygen fluctuation. | |
| Southwest Pacific | Strong wave action, cool oceanic water, some silt and clay turbidity. | Moderate suspended solids, erratic currents, high oxygen, cool. | High suspended solids, erratic tidal currents, warmer than ocean and rivers. | Strong stratification, offshore bar formation, cool, high oxygen. | Some suspended silt, erratic currents, cool, high oxygen. | Moderate to strong stratification, high suspended silt, strong currents, high oxygen, cool. | |
| Northwest Pacific | Strong wave action, cold ocean water, some silt and clay turbidity. | Moderate suspended solids, erratic currents, high oxygen, cold. | High suspended solids, erratic tidal currents, warmer than ocean and rivers. | Strong stratification, offshore bar formation, cold, high oxygen. | Some suspended silt erratic currents, cold, high oxygen. | Moderate to strong stratification, high suspended silt, strong currents, high oxygen, cold. | |
| Alaska | Very cold oceanic water, usually ice, salinities slightly depressed. | Very cold oceanic water, overlain by some fresh water, high oxygen. | Very cold water, variable salinity, much fine silt, debris from freezing. | Strong currents,high suspended solids frequently glacial in origin, very cold. | Very cold oceanic water, much ice, surface layer of fresh water, high oxygen. | High turbidity with glacial debris, seasonal freezeups, strong currents during runoffs. | Stagnant below silt depth, very little oxygen, high salinity, hydrogen sulfide. |
| Pacific Islands | Clear warm ocean water, strong wave action. | Clear ocean water, gentle currents, eddies, warmer than ocean. | High dissolved organics, color, suspended mud, very small currents, hot. | Slightly turbid, strong currents, river cooler than ocean water. | Very small currents, generally shallow, quite warm, clear ocean water. | Slightly turbid, eddying currents, slight stratification, high oxygen. | |

References: (1) U.S. Coast and Geodetic Survey, Coast Pilots, Tidal Current Tables. (2) U.S. Army Project and Study Reports. (3) FWPCA Reports and unpublished data. (4) National Estuarine Inventory.

currents develop firmly attached communities where bottoms are hard, and only microbial life where sediments are constantly in motion or being deposited. Where, however, such energy inputs do not dominate the input of radiation solar energy, natural communities develop compositions typical of Tropical, Temperate, or Arctic latitudes.

Tropical systems (fig. IV.1.31) are subject to only slightly varying warm temperatures; light energy input is both greater and more regular than in other latitudes. Within this general group there are the sparse populations along coasts with deep clear water close inshore; the teeming and colorful populations of coral reefs; and the mangroves and the submerged grasslands associated with shallow, nutrient-laden water. Only the southern part of Florida and the islands are of this type.

Arctic systems are subject to wide fluctuation of sunlight and temperature but ice is the key factor. Ecological systems develop in, on and under the ice and in the fiords associated with glaciers. (Fig. IV.1.32.) Only a small part of Alaska includes estuarine systems of this type.

Temperature systems are subject to moderate solar energy inputs, temperatures that change regularly with the seasons, and generally larger tide ranges and more wave action than either tropic or arctic systems. Most of the estuarine systems of the United States lie in the temperate zone, and the balancing of solar energy input against mechanical energy input in this zone leads to a great variety of ecosystem types, even within small geographic areas

The tropical coral reefs have their counterparts in oyster reefs where hard surfaces and constant currents exists, and where there is sufficient particulate food in the water. The mangroves and submerged grasslands also have their counterparts in extensive marshes and submerged algae and grass beds which are among the most productive parts of the estuarine zone (fig. IV.1.33).

There are also intertidal ecosystems of burrowing animals, such as clams, where bottoms are soft (fig. IV.1.16) and of attached animals and plants where they are not (fig. IV.1.34). The predominant influence of great amounts of river flow and the associated rapid salinity changes and stratification also result in ecosystems specific for different salinity zones or types of stratification. Where there is little river runoff, characteristic plankton and attached algae communities develop (fig. IV.1.35).

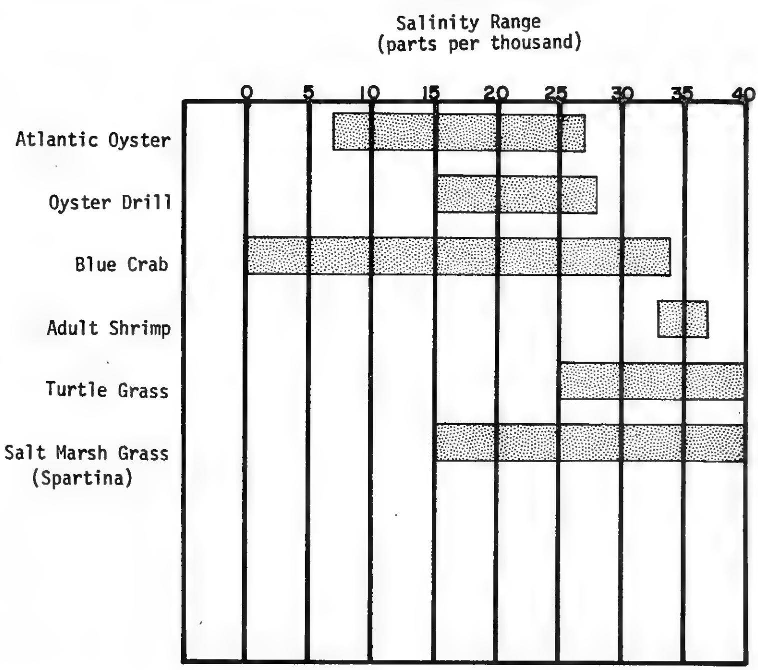
The ecosystems described relate primarily to organisms that tend to stay in one place or move only short distances during their life. Of these, the oyster, the clam, the crab, and the lobster are the only economically significant animals. The great importance of such ecosystems, however, lies in the fact that these communities form intermediate steps in the conversion of solar and gravitational energy to forms useful to mankind; upon them depend the great pelagic fisheries which the estuarine zone nurtures. Without these communities mankind would be without shrimp, salmon, and menhaden, as well as the oysters, crabs, and lobsters which spend all of their lives there.

The grouping of ecosystems outlined here describes a limited range of recurring variation of chemical and physical properties to which certain forms of life have adapted and on which they are now dependent. The basic environmental needs for all living plants and animals in such zones are zones of salinity consistently fluctuating over a limited range of concentration; solar energy; water temperature variation; water quality and nutrients favorable to their propagation, growth, and survival; and, for some life forms, bottom conditions suitable to their unique needs.

Many forms of plant and animal life can tolerate salinity ranging from ocean concentrations (35 parts per thousand) to practically zero. Other life forms must have a much narrower salinity range in which to live and reproduce. There are animals which require different salinities at different parts of their life cycle and which migrate to find it. Figure IV.1.36 shows the range of salinity tolerance of some characteristic estuarine plants and animals. Most of those with a limited salinity tolerance can also withstand temporary exposure to salinities outside that range.

Solar radiation governs the photosynthetic process by which plants manufacture the basic food upon which all life ultimately depends. The primary producers of food in the aquatic environment are the microscopic plants upon which the succession of more advanced life forms feed. Planktonic communities exist in all ranges of salinity and temperature, but their composition may vary even with constant temperature and salinity. The rate of input of solar radiation is greater

**FIGURE IV.1.36 COMMON SALINITY RANGES OF OCCURENCE FOR SOME ESTUARINE-DEPENDENT PLANTS & ANIMALS**




Source: Odum, H. T., op. cit.

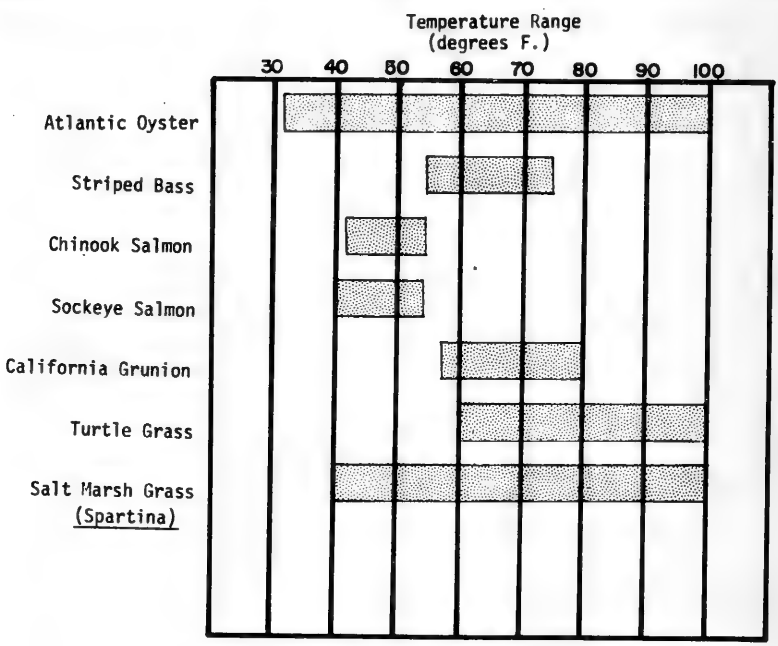
in the tropics than in Arctic, and life in tropical environments is more prolific than in the Arctic.

Although water temperatures in the estuarine zone are closely related to the input of solar radiation, they are also greatly influenced by the temperatures of nearby cold or warm ocean currents. Many plant and animal species tolerate a wide enough temperature range to survive in considerable stretches of the estuarine zone from north to south.

There are a considerable number of plants and animals that have adapted to temperature ranges in the colder estuarine zone; others have adapted to temperature ranges occurring in the warmer temperate and subtropic waters of the estuarine zone; and there are some that have adapted to the colder waters of the northern estuaries. the warmer waters of the southern estuarine zone, and the gradations in between. Figure IV.1.37 shows the temperature ranges tolerated by some characteristic estuarine organisms.

The quality of water in the estuarine zone has sometimes dramatic, sometimes subtle, effects on estuarine life. The disolved and particulate nutrients so plentiful in the coastal zone make this area very productive compared to other parts of man's environment. The coral reef communities of the tropics, where energy conversion is primarily a

**FIGURE IV.1.37 COMMON TEMPERATURE RANGES OF OCCURENCE OF SOME ESTUARINE-DEPENDENT PLANTS & ANIMALS**




Sources: Odum, H. T., op. cit.
"Industrial Waste Guide on Thermal Pollution," FWPCA, p. 40-42 (1968)

matter of photosynthesis, are nowhere near as productive as the oyster reefs and marshlands of the temperate zone, where particulate organic foods as well as solar energy are converted into plant and animal tissue for use by animals higher in the food chain.

### DEPENDENCE OF FISH AND SHELLFISH ON THE ESTUARINE ZONE

Dependency is governed by particular environmental requirements for reproduction, protection, food supply, or a combination of these. Estuarine dependent species are of three types:

(*1*) *Species restricted to estuaries.*

Among the relatively few species of fish and shellfish that complete their entire life cycle in the estuarine zone is the Atlantic oyster. It will die after long exposure to freshwater although it can stand limited periods of such exposure and can thrive in relatively high salinity water. The spotted sea trout occupies the estuary for all its life purposes and only occasionally leaves the estuary under unusual extremes of salinity and temperature.

(*2*) *Anadromous and catadromous species*

Anadromous species pass through the estuarine zone on their journey from the sea to the freshwater environment where they spawn. Some species, such as the Pacific salmon, die after spawing and others, such as the striped bass, live to return to the estuarine zone and the sea. The young of all anadromous species spend varying periods of time in the freshwater areas where they were spawned, but all eventually migrate to the estuaries and then the sea.

There are few truly catadromous species that mature in the fresh or brackish water environments, and then migrate to higher salinity waters of the estuary of the adjacent sea to spawn. The American eel and the blue crab are examples of this type.

(*3*) *Migratory estuarine species*

The great majority of estuarine dependent species fall under this classification. Some use the brackish and freshwater areas of the estuarine zone for reproduction; some as a source of food; some for shelter, either as adults or young; and some for all these reasons. They all have in common the basic need for both estuarine and ocean environments at some point in their life cycle. This group includes the great majority of fish and shellfish of direct importance to man, such as shrimp, menhaden, flounders, and red drum.

Various types of dependency are illustrated by several examples.

### SHRIMP

The commercially important shrimp are of three kinds: brown, white, and pink. These species are concentrated along the South Atlantic and Gulf coast of the United States. The pink shrimp spawns in offshore waters at depths of 100 to 150 feet, salinity between 3.61 and 3.77 percent, and temperatures between 64° and 77° F. After 13 or 14 hours, the eggs hatch and the larval shrimp begin to pass through a series of developmental stages, at the same time beginning to move or drift towards the Florida mainland about 100 miles distant (fig. IV.1.38).

Movement to the estuary probably takes from 3 to 5 weeks and, despite the large numbers of postlarvae entering the estuary, only an estimated five out of every hundred eggs produce shrimp that survive to this stage.

By the time the estuary is entered, the postlarvae have developed from planktonic to benthic feeders and have developed a wide tolerance to varying salinity and temperature conditions. From about 2 to 4 months the juvenile shrimp grow rapidly from perhaps one-half inch in length to commercial size before returning to the sea and completing the life cycle.

The life cycle of the three primary commercial species are similar but the species differ in their penetration of the estuary and their utilization of the estuarine environment after the adult stage is attained. The brown shrimp spawns in waters 150 to 230 feet in depth and remains a relatively short time in the estuary. The white shrimp rarely is found in waters deeper than 100 feet and possesses a greater affinity for fresh water than do the others.

The estuary fulfills two primary functions: (1) Provision of adequate nourishment during a period of rapid physical growth and (2) protection from predators. A large proportion of the shrimp's diet appears to consists of small, invertebrate animals, such as worms, mollusk larvae, and small crustaceans, as well as fish larvae and nematodes.

Shrimp is a primary food item for various estuarine animals, including red drum, spotted seatrout, snook, and gray snapper; but the estuary undoubtedly provides more vegetation and debris for protection than open waters, and sufficient alternative foods exist in the estuaries to move some of the pressure from the shrimp.

### MENHADEN

Spawning occurs at sea along the continental shelf, and the eggs hatch in the ocean after about 2 days. Larvae move into the estuaries as far as the freshwater interface. A transformation of physical characteristics accompanies the entrance into the estuaries as larvae grow and shift from being selective, particulate feeders to being nonselective, filter-feeding juvenile menhaden which can tolerate wide variations in both salinity and temperature.

The menhaden population of a particular estuarine system seems to be determined by the number of larvae entering the waters, food, oxygen, competition, and predators. Because they are primary consumers, feeding directly upon the natural vegetation, menhaden represent the base of the food chain for many predators, such as the bluefish, striped bass, and sharks.

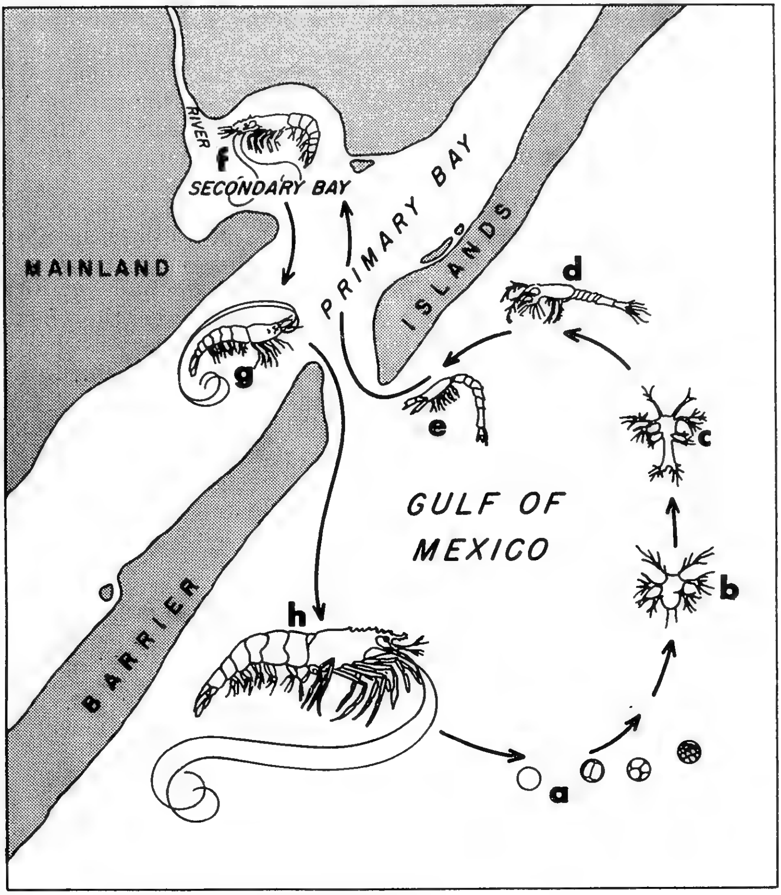
### SALMON

There are today only token runs of Atlantic salmon into a few rivers in Maine to spawn, although in colonial times this species was extremely abundant from the Housatonic River to the St. Croix River.

In the shallow estuarine areas of the Bay of Fundy and the coastal bays and sounds of Maine they are frequently caught in herring weirs

Figure IV.I.38

TYPICAL LIFE HISTORY
OF THE GULF OF MEXICO SHRIMP




Source: W.C. Guest, The Texas Shrimp Fishery, 1958.

| | | | | | |
|---|---|---|---|---|---|
| a | Shrimp Eggs | d | Mysis | g | Adolescent Shrimp |
| b | Nauplius Larva | e | Postmysis | h | Adult Shrimp |
| c | Protozoa | f | Juvenile Shrimp | | |

set in shallow water. The waters in these estuaries provide an abundance of food for the salmon in the form of the young sea herring and euphausiid shrimp.

All five species of salmon on the west coast have one basic difference from the Atlantic salmon. They die subsequent to spawning. The total spawning range of these species is from Monterey Bay, Calif., to the northwest tip of Alaska. Only the King salmon occupies the spawning streams of the full range. The Silver salmon has the next longest range along the coast extending from the Sacramento River to the Bering Strait. The Red, Pink, and Chum salmon range from Washington State to the Bering Sea, and are rarely found south of this.

The distance upstream that the Pacific salmon migrates to spawn varies from species to species, as well as within species, varying from the extreme headwaters 1,500 miles from the estuarine zone to within a few miles of the estuary. Both the young and adult salmon of all species pass through the estuarine zone, either to reach the spawning ground in fresh water or to reach the sea. During the passage through the brackish estuary the adult ceases feeding, whereas the young of all species utilize the food available in the estuarine zone as they pass through to reach the sea. Young Silver salmon are known to remain within the estuarine portions of their natal stream, growing rapidly on the abundant food supply in this highly productive environment. Adult Silver salmon are caught throughout the year within the estuarine zone. The Pink salmon fry enter the brackish estuarine waters soon after hatching in the Spring, and are known to remain there until August.

### OYSTERS

The Atlantic oyster has evolved into an animal of broad adaptability relative to salinity, temperature, and food requirements, as indicated by its range, on the Atlantic and gulf coasts of North America from the Gulf of St. Lawrence to the Mexican coast.

The Atlantic oyster is most abundant in estuarine systems characterized by considerable inflows of fresh water, with constant water movement, and fluctuating local salinities. The currents bring food to these fixed animals and distribute the larvae. Two of the most productive areas for the Atlantic oyster are the Chesapeake Bay and the Louisiana bays and sounds affected by the great flow of the Mississippi River.

The salinity range most favorable to the Atlantic oyster lies between five and 30 parts per thousand. Below five little or no reproduction takes place and the feeding ability is affected. Oysters occupying areas with salinities exceeding 15 parts per thousand are subject to a number of predators such as the oyster drill.

The Atlantic oyster has adapted to wide ranges of temperatures. It survives in temperatures of around 34°F. and in temperatures of up to 90°F. Intertidal oysters in the warm climate of Texas survive a number of hours out of the water with internal temperatures of as much as 120°F. This oyster ceases feeding when temperatures fall below 43°F. or rise above 107°F. Oysters spawn only when the temperature of the water rises above 68°F., whether in Long Island Sound or Apalachicola Bay. In its southern range the oyster has a much longer spawning period and feeds all year long.

## Section 6. Energy and Management in the Biophysical Environment

Solar energy and gravitational energy are the basis for everything that happens naturally in the estuarine zone. This discussion of the biophysical environment has been concerned primarily with the transformation of these energies into forms useful in living processes and exploitable by man. Three different sets of subdivisions of the biophysical environment were used in this discussion (fig. IV.1.39).

Differences in the external environment divide the estuarine zone of the United States naturally into 10 geographic regions, each subject to a particular combination of the external influences of tide, ocean currents, wave action, sedimentation, and climate. This subdivision into estuarine biophysical regions gave broad ranges of conditions in each region, but the importance of local coastal conditions in determining energy flows via water movement paved the way for a subdivision of the estuarine zone according to 11 morphological groups having similarities in water movement, circulation, and the ability to rid themselves of wastes.

A subdivision according to ecological communities is also based primarily on geographical location, but again local coastal conditions make it necessary to identify small ecosystems within each major grouping. This subdivision rests not only on the shape and form of coastal areas, but also on the composition of the estuarine bottom.

As an illustration of the relationships of these groupings, consider the ways to classify a group composed of all the deliverymen in the United States. They work in 50 States (the biophysical regions); they work in cities, towns, and rural areas (the morphological classification); they deliver different kinds of things, such as groceries, clothes, furniture, and hardware (the ecosystems).

Each of these different groupings of the estuarine zones is significant to management. The biophysical regions are contiguous geographic zones with similar general environmental conditions that would be appropriate for an institutional management unit. The morphological grouping can serve as a guide to useful physical modification and necessary waste treatment, while the ecological grouping tells what can and can't be done with the living resource.

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IV–1–1 The material presented in this chapter was distilled from a number of sources. While individual citations are given in some cases, the complexity of the source information precludes detailed references. The more informative general references are these:

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# CHAPTER 2. USE OF THE ESTUARINE ZONE

The predominant uses of any particular estuarine area depend on historical and economic development, population pressures, and the kinds of natural resources available for exploitation. The socio-economic environment of the estuarine zone is the direct result of the value of the estuarine zone as a means of sustenance, a place to live and work, a source of enjoyment, and a means of transportation. This chapter describes that environment in terms of how the biophysical environment is exploited to serve man's needs and shows conceptually how valuable it is to his society (IV–2–1).

The major values of the estuarine zone to society form the framework for discusing the relationships of individual uses, their compatibility with other uses, and the physical modification that has taken place to support these uses.

## Section 1. Sustenance: Use as a Fish and Wildlife Habitat

### FISH

Estuarine dependence is a convenient term for describing a normally complex biological interrelationship between the estuarine environment and an aquatic organism. This dependence includes a vast spectrum of biological relationships. Practically all of the sports fish species are dependent upon the estuarine zone for one or more phases of their life development, and approximately 65 percent of all commercial fish species are estuarine-dependent. The discussion in chapter 1 concerning life in the estuarine zone described the nature of estuarine dependence and gave examples of several estuarine-dependent species important to human society.

Many fish species live their entire lives in the estuarine zone and are well-adapted to this type of environment. The oyster, for example, has lived in the estuary for millions of years, as evidenced by the huge deposits of shell on the bottoms of bays. The shallow water, salty substrate, and intermediate salinities are ideal for oyster culture.

Other species may use the estuary only as a passage zone on their way to freshwater streams or to the open ocean. However, in doing so, they also utilize the high production of food that is characteristic of estuaries. Even some continental shelf species, such as bluefish, and most marine predators (including tuna), can be considered dependent upon the estuary as an ultimate source of most of their food.

The economically important fish species are those sought by either the sports fisherman or the commercial fisherman; however, the sports fishes are usually taken by hook or with hand-held equipment. Table IV.2.1 lists some of the more important estuarine-dependent species of sports and commercial fish and shellfish. It also shows the type of dependency of each.

TABLE IV.2.1.—ESTUARINE DEPENDENCE OF IMPORTANT SPORT AND COMMERCIAL FISH

| Biophysical region | Sports fish: Type of dependence | | |
|---|---|---|---|
| | Permanent residence | Passage zone | Nursery zone |
| North Atlantic | Croaker, Atlantic mackerel, bluefish. | Atlantic salmon, shad | Striped bass. |
| Middle Atlantic | Croaker, drums, Atlantic mackerel, spot, bluefish. | Shad | Do. |
| Chesapeake | Crabs, croaker, drums, spot, bluefish. | do | Do. |
| South Atlantic | Crabs, croaker, drums, spotted sea trout, spot, bluefish. | do | Do. |
| Caribbean | Spotted sea trout, spot, bluefish | | |
| Gulf of Mexico | Crabs, croaker, drums, spotted sea trout, spot, bluefish. | Shad | Striped bass. |
| Pacific Southwest | Abalone, rockfish, barracuda | | |
| Pacific Northwest | Abalone, rockfish | Salmon (chum, coho, king, red). | Pink salmon. |
| Alaska | Crabs | do | Do. |
| Pacific Islands | Barracuda | | |

| Biophysical region | Commercial fish: Type of dependence | | |
|---|---|---|---|
| | Permanent residence | Passage zone | Nursery zone |
| North Atlantic | Oysters, clams, croaker, flatfish | Atlantic salmon, eel | Menhaden, lobsters. |
| Middle Atlantic | do | Eel | Menhaden. |
| Chesapeake | Oysters, clams, crabs, croaker, flatfish. | do | Do. |
| South Atlantic | Oysters, crabs, croaker, flatfish | do | Shrimp, menhaden. |
| Caribbean | Flatfish | | Lobsters. |
| Gulf of Mexico | Oysters, crabs, croaker, flatfish | | Shrimp, menhaden. |
| Pacific Southwest | Clams, abalone, flatfish | | |
| Pacific Northwest | Oysters, abalone, crabs, flatfish | Salmon (chum, coho, king, red). | Pink salmon. |
| Alaska | Crabs, flatfish | do | Shrimp, pink salmon. |
| Pacific islands | Oysters, flatfish | | Lobsters. |

Figure IV.2.1 illustrates the geographic ranges of some of the estuarine-dependent sport and commercial fish throughout the United States, and many of these different kinds of sports fish can be caught as one goes from salt water to fresh water within an estuary (fig. IV.2.2). Fishermen have nearly as much variety as the fish they catch, as figure IV.2.3 demonstrates. Even the ocean fisheries are to some extent related to the estuarine zone, because most fishing and the most productive fishing grounds are close to continents. Latitudinal ranges of some major commercial fish off U.S. coasts are shown in figure IV.2.4.

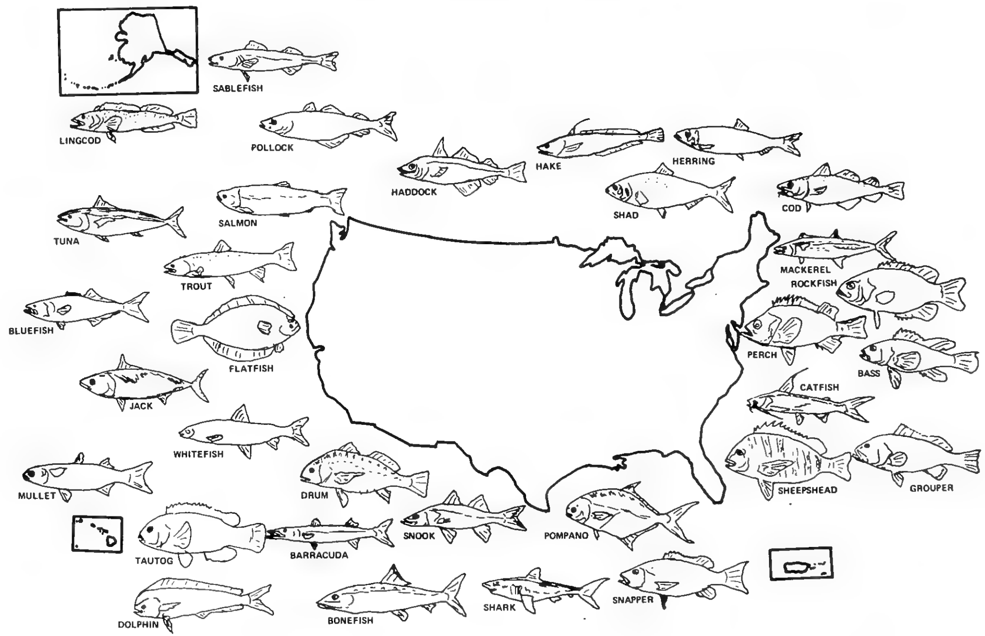
## WILDLIFE

Estuarine wildlife can be classified into four categories with differing economic significance: (1) fur bearing mammals, (2) game waterfowl, (3) ornamental shore birds, and (4) the common wildlife that can tolerate human presence. The relative abundance of some characteristic species in the biophysical regions is discussed below.

### *Fur bearers*

The primary estuarine fur bearers are the fur seal in Alaska, nutria in the South Atlantic and Gulf States, the common eastern muskrat in New Jersey, the Virginia muskrat in the Central Atlantic States, and the Louisiana muskrat in Alabama, Mississippi, Louisiana, and Texas. Secondary in importance are the raccoon, mink, and otter.

FIGURE IV.2.1 SPORTS FISH OF IMPORTANCE TO ESTUARINE FISHERMEN* **




SOURCES: 1965 Salt Water Angling Survey, BSF&W
Fishery Statistics of the United States, BCF

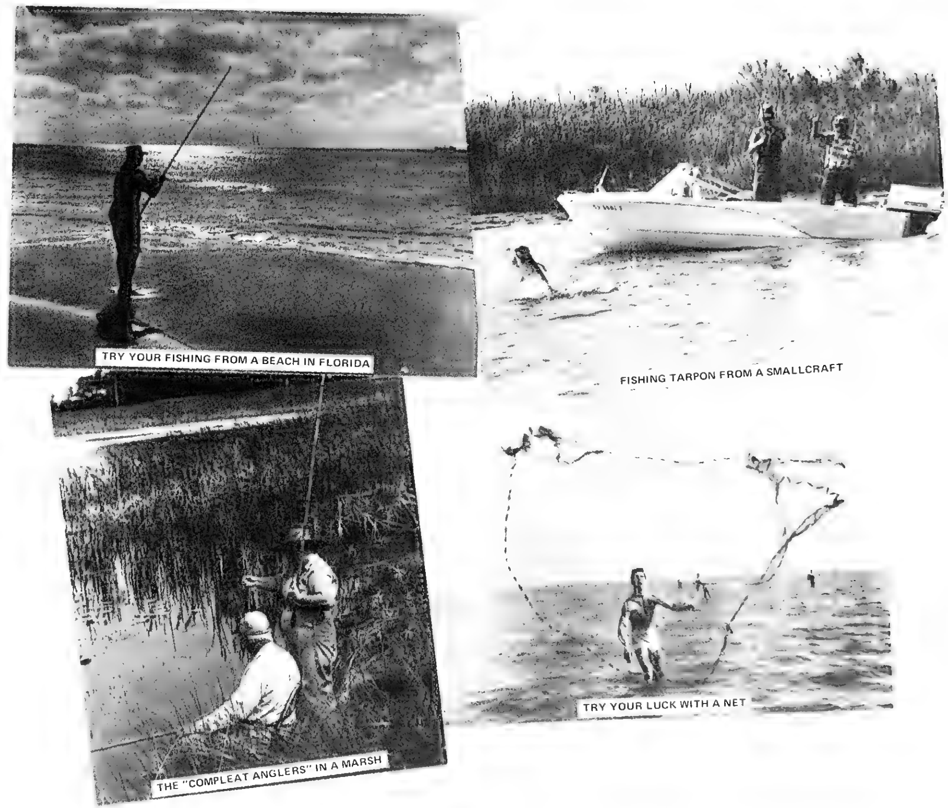
*Generally, distributed latudinally, that is, similar species are found on both coasts, usually by different names.

**Ranges of all types vary widely

FIGURE IV.2.3a A YOUNG SALT-WATER FISHERMAN GETS HIS START IN THE BAYOUS OF LOUISANA

COURTESY LOUISIANA WILD LIFE AND FISHERIES COMM. PHOTO BY J.H. BRITT

FIGURE IV.2.3b



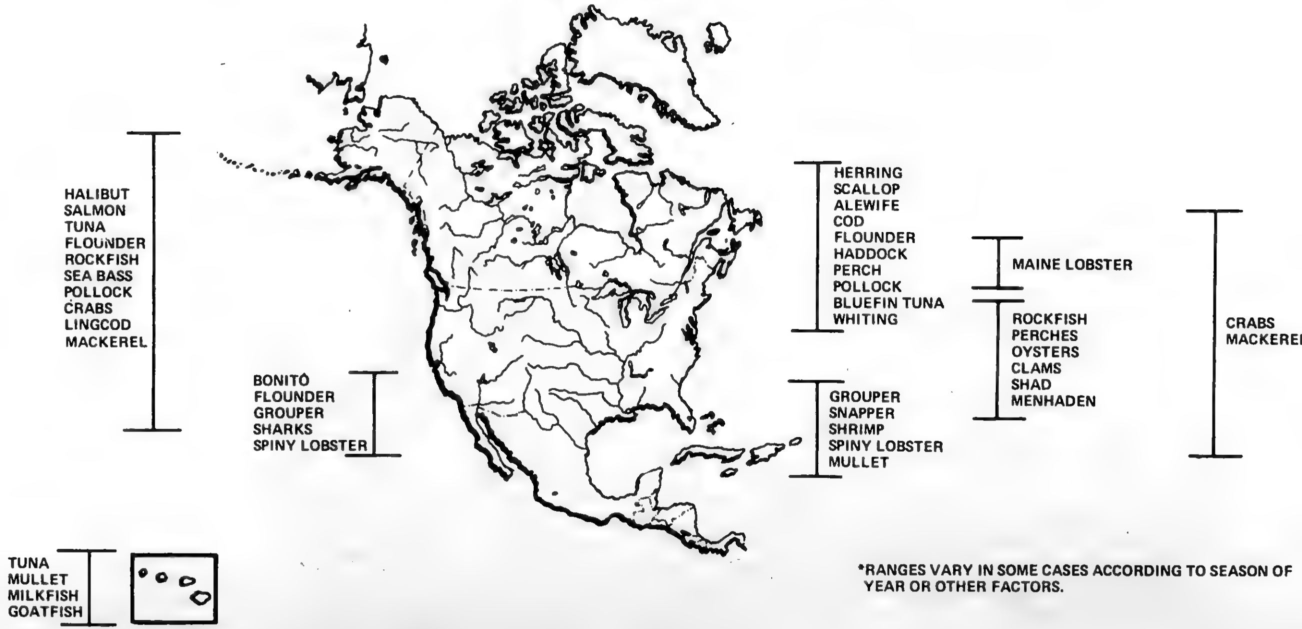
TRY YOUR FISHING FROM A BEACH IN FLORIDA

FISHING TARPON FROM A SMALLCRAFT

THE "COMPLEAT ANGLERS" IN A MARSH

TRY YOUR LUCK WITH A NET

FIGURE IV.2.4. LATITUDE RANGES OF SOME COMMERCIAL FISH *




*RANGES VARY IN SOME CASES ACCORDING TO SEASON OF YEAR OR OTHER FACTORS.

Foxes, weasels, opossum, and bobcats are not sought for their fur but may occasionally be trapped (fig. IV.2.5).

For economic levels of fur production, the marshes must be managed specifically for the fur bearers. This means control of undesirable plants, prevention of excessive populations and, in some cases, control of predators. The primary food plants are threesquare and cattails; these, however, are easily supplanted by invading needleruch, cordgrass, sawgrass, and other undesirable plants. Hence, the marshes are burned annually, usually in the fall, and are subsequently flooded to eradicate the pest plants and enhance growth of threesquare (fig. IV.2.6). Dikes or other water control devices are used to help minimize the intrusion of salt water into the fresh or brackish water of the producing marshes. Thus, the marshes managed for fur production are not normally available for other valuable aquatic species, especially shrimp and estuarine-dependent fish (fig. IV.2.7).

*Game waterfowl*

The dependence of waterfowl on the estuarine zone is both complex and not completely understood. The primary sport species, such as mallards and canvasbacks, have been successfully adapted to man-made changes in their environment, particularly those which do not affect the nesting sites. In some cases, the construction of roads, drainage canals, and other works have enhanced nesting areas by stabilizing water levels, providing flood-proof nesting sites and drought-proof rearing ponds. Furthermore, most species do not appear particularly dependent on any aspect of the estuarine zone, being able to use freshwater marshes, lakes, and ponds with equal ease. This ambivalence has been sharply enhanced in the gulf area by extensive rice cultivation and cattle farming which enable many species, such as the white-fronted geese, to shift habitats away from estuarine marshes. Other species, such as Canada geese and mallards, have demonstrated even more adaptability, many remaining the entire winter in the freshwater bodies of the Midwest (fig. IV.2.8). Many sea ducks feed upon small crustaceans, fish, and insects that are estuarine-dependent. These ducks have not learned to feed on agricultural lands, and tend to migrate to deeper saltwater environments during the winter.

In summary, while game waterfowl are frequently observed in the estuarine areas, they do not appear dependent upon specific estuarine conditions. There are some exceptions, such as the American brant, but research has not determined the relationship between altered habitat and declining numbers.

*Ornamental birds*

Shore and sea birds are a particularly aesthetic attraction among the national fauna. However, they rarely have a direct tangible economic value, except as a component of the natural ecosystem. These birds are generally more dependent upon estuarine conditions than the more mobile waterfowl, and have demonstrated a greater sensitivity to the overall encroachment of man. The saga of the virtually extinct whooping crane is well known and documented; and the trials of several other groups, such as the egrets, have received periodic publicity. Among the bird life most threatened by changing environmental conditions, especially in the estuaries, are the larger fish-eaters of the Nation's coast.

The brown pelican has already disappeared from the gulf coast of Alabama, Mississippi, Louisiana, and Texas, where it was a common sight prior to 1960. This disappearance coincided with the heavy fish kills of 1960–64 in the lower Mississippi River, which were caused by excessive residues of pesticides. One theory proposed that the dead and dying pelicans observed during that period had accumulated lethal dosages (fig. IV.2.9). This assumption, however, was not verified and another theory used to explain the lack of any recovery was the destruction of nesting grounds in black mangroves by the severe cold.

The 80 species of waders, which include the egrets, storks, herons, ibis, and spoonbills, are predominantly residents of the southern United States, particularly in Florida. The recent drought and manmade changes in the Everglades have drastically reduced the number of these species in Florida. For some species, this represents a serious setback in their gradual recovery from near extinction at the hands of the plume hunters. Waders elsewhere on the southern coast have also diminished in numbers, apparently because of irresponsible shooting and manmade environmental changes.

## AQUACULTURE

The great fish and shellfish resources of United States coastal waters have adequately supplied the seafood demands of the increasing population for over 300 years. Now, however, the demand for some products is so large that the normal fishing grounds and fisheries are in great danger of being exhausted, both from overfishing and from the indirect effects of man's encroachment into the esuarine environment. To supply future needs of some fish products new approaches toward commercial fishing are needed, both in harvesting the natural growth and in controlling the entire fishery.

Aquaculture is defined as the rearing of aquatic organisms, both plants and animals, under controlled conditions using the techniques of plant and animal husbandry. It involves a variety of operations: some are highly sophisticated where man exercises control over the principal environmental factors affecting the cultured species, and others are very simple with only minimal control or manipulation of the habitat and the cultural animal.

The following examples illustrate the variety of aquacultural activities that are now practiced:

(1) Rearing aquatic species from selectively bred strains to commercial size under controlled conditions where the optimum requirements for food, temperature, salinity, and other physiological and environmental needs are provided; predators and competitors are eliminated and diseases controlled, and highly mechanized methods are used to reduce labor costs. This is the ultimate in aquacultural operations and has been achieved only for a few species (e.g., carp).

(2) Rearing aquatic species in natural or artificial enclosures to commercial size, with or without supplemental feeding, predator control, environmental adjustment, and selective breeding. Enclosures may be man-made tanks, natural or artificial ponds, or enclosed areas of the sea. Such techniques are now used for the production of oysters, clams, shrimp, catfish, carp, and baitfish. (fig. IV.2.10).

(3) Rearing aquatic species in hatcheries through the juvenile stages, the period of greatest natural mortality, to stock natural areas.

FIGURE IV.2.9.

ONE LESS BROWN PELICAN IN THE SOUTHEAST.

ONE OF OUR MORE SERIOUSLY THREATENED SPECIES AFFECTED BY DDT.

This effort may be used to replenish stock reduced by natural or artificial changes in the environment, overfishing or other factors, or to introduce new species into an environment. Such methods are being used to maintain salmon and trout fisheries and to provide sportfish in areas of heavy fishing pressure.

(4) Transplanting wild stocks as eggs, young, or spawning adults from one natural area to another to provide more suitable habitat for spawning, growth, or survival, and to introduce species into new environments. This method has been the backbone of present day oyster culture on leased grounds. This method was also used to introduce striped bass and shad from the east coast to west coast waters. Widespread transplants of salmon have also been made with varying success.

(5) A variety of other techniques have been developed to increase abundance and survival of commercially valuable species, e.g., cultching oyster beds with shell to increase setting; suspending shell strings from floats or piling to catch larval oysters and grow the adults using the total water column (fig. IV.2.11); moving oysters to predator or disease-free areas; construction of artificial reefs to provide more suitable habitat for oysters, lobsters, and fish (fig. IV.2.12); and opening or closing breaches in barrier islands to improve environmental conditions of essential lagoons.

(6) Aquaculture is also practiced in the experimental rearing of larval fish and shellfish to study the importance of environmental factors on survival and to determine causes of the marked variation in year-class size.

Aquaculture, with a few minor exceptions, appears to be today where agriculture was 50 or more years ago. True farming of the sea is still in its infancy. At the present time almost all of the oysters produced on the west coast of the United States have at least one manipulation by man before they are harvested; on the Atlantic seaboard approximately 50 percent are manipulated at least once before harvest. Other than oysters, there are no known enterprises in marine aquaculture that are expecting a significant profit. Many ventures are presently underway to develop pilot plants for commercial farming in the future.

Table IV.2.2 lists the range of species that are presently being studied for marine aquaculture. Research is at private, university, State government, and Federal Government laboratories.

*Table IV.2.2.—Species under marine aquaculture research*

| Organism: | *State* |
|---|---|
| Algae | Florida. |
| Shrimp | Alabama, Florida, Texas, Louisiana, South Carolina, California. |
| Crabs | California, Maryland, Oregon. |
| Lobsters | Maine, Florida, California, Massachusetts. |
| Crayfish | Louisiana. |
| Freshwater Shrimp | Florida, Alabama, Hawaii. |
| Mussel | California, Oregon. |

*Table IV.2.2.—Species under marine aquaculture research*—Continued

| Organism—Continued | *State* |
|---|---|
| Oyster | North Carolina, Delaware, Virginia, Connecticut, New York, California, Texas, Louisiana, Alabama, Mississippi, Massachusetts, Washington, Oregon, Rhode Island, Florida, Georgia. |
| Scallops | New York, Florida. |
| Clam | New York, Oregon. |
| Marine Worms | Maine, Florida. |
| Alligators | Louisiana. |
| Freshwater Catfish (brackish water) | Louisiana. |
| Spot | Louisiana. |
| Croaker | Louisiana. |
| Mullet | Louisiana, Hawaii. |
| Pompano | Florida, Louisiana, Texas, South Carolina, Alabama. |
| Sea Trout | Florida. |
| Abalone | Oregon, California. |

## Section 2. Enjoyment: Use for Recreation

The demand for outdoor recreation has increased significantly over the past decade. The trend toward higher personal income and more leisure time has made it possible for a greater percentage of the populace to seek new outlets. The advertising industry has campaigned vigorously to sell the public on the need for recreation. Companies manufacturing equipment for outdoor recreation, and service facilities to support the "recreationalist" are blossoming in all parts of the country. In addition, the unique availability of resources, in close proximity to large population centers, offers an unparalled recreational opportunity for many who previously could not afford to travel far from their homes.

Since there is this wide variety of land and water recreational activities available in the estuarine zone, many estuarine systems are intensively used for these pursuits. This is primarily because people rarely have a single activity as the sole objective of a recreational outing. Clusters of activities that require similar environmental conditions, but differ in environmental quality needs, can be grouped as follows: (1) Swimming and associated shore activities, which include picnicking and camping; (2) sports fishing from the shore or a small boat; (3) boating which is one of the most popular water-based activities, and boat-centered activties, such as fishing, water skiing, cruising, hunting, and even traveling or socializing; and (4) aesthetic appreciation of the total environment.

Based on attendance, the most heavily used beaches in the United States are Long Island in New York and the coastal beaches of Maryland, Virginia, Massachusetts, Florida, and California. The majority of these beaches face the open sea rather than an estuary or coastal sound. It is estimated that less than 10 percent of the entire coastal swimming activity, or less than 3 percent of all swimming participation, occurs inside embayments.This apparent lack of utilization of swimming is based on several factors varying from personal preference to environmental quality. The most significant reasons are these:

(1) There is a lack of large sandy beaches, surf, and expansive seascapes.

(2) Public access is limited because of marshy terrain and private development along the shoreline. (For example, of all Maryland's 41 State parks, including those authorized or under construction, only five are on the estuaries. In Connecticut only five of the 82 State parks are located on the coast, despite a recreation shoreline of 162 miles).

(3) Swimming is often prohibited or is disagreeable in embayments because of low water quality.

The fishing aspects have been discussed previously, but are mentioned again because of the relationship between sport fishing and recreation, especially as an associated activity. Pleasure boating and shoreline activities are frequently extensions of sport fishing trips or vice versa.

Boating is a major recreational use of the estuarine system. On a per capita basis however, the coastal States do not have a high propensity towards boating activities. While representing 61.5 percent of the Nation's population in 1966, the coastal States accounted for only 55.4 percent of the total sales in outboard motors. Only about 25 percent of all pleasure boating is estimated to occur in the coastal waters, most of which is in protected areas.

Aesthetic enjoyment is probably the most widespread use of the estaurine environment today. Tourists from the interior States are always eager to view such sights as ships coming under the Golden Gate Bridge into San Francisco Bay, the lonely solitude of Fort Sumter as it rests seemingly impregnable in Charleston Harbor, and the parade of ships in and out of New York Harbor. The attractive scenic vistas are not for the tourists alone, but hold a certain magnetism for residents of the coastal cities as well. One has only to scan the real estate advertisements to realize the premium value on waterfront or waterview lots.

Many of the coastal cities have had the foresight to reserve the estuarine shoreline for parks and scenic parkways. The George Washington Memorial Parkway in Virginia is a good example, for it allows unparalleled view of the historic Potomac River near the Nation's capital.

Aesthetic appreciation of the estuarine zone is not limited to the enjoyment of the scenic grandeur, but also includes observation of its wide variety of wildlife. This includes birds of all types, the fascinating creatures of the tide pools, and playful porpoises cavorting in the water with an enviable freedom.

A portion of the estuarine wildlife also serves another recreational use—hunting. Some of the estuarine marsh areas offer unexcelled waterfowl hunting opportunities. To a lesser degree the estuarine areas in certain sections of the country offer other types of hunting opportunities, such as coastal deer in South Carolina and Florida and big game in Alaska.

There are certain ancillary facilities and services necessary to realize the full potential of estuarine recreation. First and foremost is adequate access to the reserved areas such as parks, wildlife refuges, beaches and roadways, waterways, and paths. The Chesapeake Bay is an excellent example of a large estuarine system with limited public access; most of the access sites available to the public are privately controlled and charge user fees.

Additional support services and facilities may range from nothing but access trails for wilderness areas to expensive resort type communities with shopping, hotel or motel accommodations, and restaurants.

The activity on which the recreation area is based generally determines the minimum support facility and service needs. Swimming requires, in addition to beach, sanitary facilities and life guards, as well as such items as food shops and beach equipment rental booths. If the beach is extremely popular, motels, specialty shops, and a whole spectrum of commercial enterprises will develop. If boating is the prime activity, launching ramps, marinas, and repair shops will be needed in addition to basic sanitary facilities. If fishing is the prime activity, bait and tackle shops are needed. It is evident that the extent of development of support service is almost unlimited, depending on the popularity of the recreational area (fig. IV.2.13).

Just how the popularity or importance of a particular recreational activity or area is measured presents another problem. Ideally, the importance could be defined as the sum of all the individual users' values. Since this figure is difficult if not impossible to obtain, some index of use must be developed. Table IV.2.3 shows some possible indices of use and some of their characteristics.

TABLE IV.2.3.—INDICES OF RECREATIONAL USE OF ESTUARINE AREAS

| Index factor | Advantages | Disadvantages |
|---|---|---|
| Number of visitors | Direct indication of popularity | May have to be estimated; does not indicate type of activity. Difficult to evaluate economically. |
| Duck stamps sold | Readily available from records; gives a partial dollar value. | Does not relate to estuarine area alone; not always an indicator of use. |
| Hunting licenses sold | do | Do. |
| Fishing licenses sold | do | Many States do not require licenses for salt water fishing. |
| Fishing participation days | An indicator of one specific type of recreational use; shows pressure on a particular area. | No records to furnish figures; no indicator of fisherman success. No monetary values attached. |
| Yacht club memberships | Records available to supply information | May not be true indicator of participation in use. Applies to only a small segment of total user group. |
| Marina slips | Information readily available; indicates a capacity figure; gives indication of value. | Not a true indicator of boating activity because of the mobility of transient boats. |
| Parking area at launching ramps | Indicates estimated use importance of popularity. | Does not reflect actual use; no indication of number of people or size of boats or type of use. |
| Boat registrations | Available from records | Not all boats required to be registered. Trailer boats are extremely mobile and registrations do not show area of use. |
| Charter boats operating including tours and passenger spaceavailable. | May be indicative of potential traffic from given location or of desirability of an area for fishing or sightseeing. | Could be difficult to obtain. Does not reflect actual use, only capacity. |
| Nonresident hunting and fishing licenses. | Information readily available from records. Indicates interest by out-of-State residents. | Not necessarily specific to estuarine zone; fishing licenses may not be required in salt water areas. |

The relative intensity of recreational use of the estuarine zone varies in different sections of the country. Data pertaining specifically to the estuaries are not available; however, some information on the importance of recreation in the coastal area, which serves as an index to estuary potential, is given in table IV.2.4. This table presents a breakdown of recreation shoreline by shore type, ownership, and degree of development. The recreation shoreline is defined according to accessibility and usefulness for recreational pursuits. It comprises about one-third of the entire tidal shoreline of the United States.

TABLE IV.2.4.—ESTIMATED MILEAGE OF THE U.S. RECREATION SHORELINE (STATUTE MILES)

| | | | | | | Ownership | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Public | | |
| | | | Type of shoreline | | | | | |
| Biophysical region | Total shoreline | Extent of development | Beach | Bluff | Marsh | Recreation areas | Restricted areas | Privately owned |
| North Atlantic | 2,983 | High | 158 | 2,683 | 142 | 43 | 3 | 2,937 |
| Middle Atlantic[1] | 2,929 | do | 742 | 1,146 | 1,041 | 147 | 66 | 2,717 |
| Chesapeake Bay | 1,798 | Low | 157 | 941 | 699 | 5 | 125 | 1,667 |
| South Atlantic | 2,517 | Moderate | 746 | 283 | 1,489 | 149 | 72 | 2,295 |
| Caribbean (Florida only) | 809 | Low | 328 | 124 | 357 | 49 | 37 | 722 |
| Gulf of Mexico | 3,642 | do | 1,247 | 586 | 1,809 | 81 | 94 | 3,469 |
| Pacific Southwest | 1,136 | Moderate | 253 | 788 | 95 | 133 | 89 | 913 |
| Pacific Northwest | 2,039 | do | 284 | 1,570 | 185 | 163 | 38 | 1,839 |
| Alaska | | (2) | (2) | (2) | | | | |
| Pacific Islands | | (2) | (2) | (2) | | | | |
| Total | 17,853 | | 3,915 | 8,121 | 5,817 | 770 | 524 | 16,559 |

[1] Middle Atlantic region mileages include New York Great Lakes frontage and excludes all Pennsylvania frontage.
[2] No data available.

Reference: Outdoor Recreation Resources Review Commission, Rept. No. 4.

Analysis of the data in the table shows the differences in shoreline development in various sections of the country. The heavily populated northeast section of the country, including the North Atlantic and Middle Atlantic regions, has a fairly well-developed coastal area. Of the total 5,912 recreation shoreline miles (including the Great Lakes portion of New York) there are 5,654 miles under private or restricted public ownership, meaning that 97 percent of the shore is inaccessible to the general public (fig. IV.2.14). In the Chesapeake and South Atlantic regions the state of shoreline development is low to moderate. Of the total 4,315 miles of recreation shoreline for the two regions, only 154 miles are public recreational areas, a mere 4 percent of the total. The level of development of the gulf coast is relatively low. Out of a total 3,642 miles of recreation shoreline only 81 are dedicated to public recreational areas, a total of only about 2 percent. The Pacific coast, which is composed of 75 percent bluff type shoreline, in areas suitable for recreation provides 10 percent of this length for recreation, or almost 300 out of 3,000 miles.

That so much of the recreation shoreline is in private ownership indicates the high value placed on waterfront property and the desire to own it, either for passive enjoyment or for more active recreational pursuits.

## Section 3. Use for Transportation

The Nation's estuaries provide the physical, social, and economic conditions required for an effective system of: Water terminals serving international trade and coastal shipping; essential elements of the national defense system; areas used for airport development; and land transport.

According to a 1966 inventory of ports and terminals by the Maritime Aministration, there were 1,626 marine terminal facilities providing deep water berths in 132 ports on the Atlantic, Gulf and Pacific Coasts. Table IV.2.5 shows the distribution of estuarine ports. The significance of these ports and terminal facilities is indicated by the 1965 statistics which show that they handled 78 percent of the U.S. foreign trade total, or 346,315,000 tons of foreign trade cargo. In addition, the port facilities handled 332.1 million tons in coastal cargo and 288.8 million tons in local shipping.

FIGURE IV.2.14. EXTENSIVE SHORELINE DEVELOPMENT ALONG A BAYOU IN LOUISIANA

PHOTO BY: ROBERT N. DENNIE, COURTESY OF LOUISIANA WILD LIFE AND FISHERIES COMMISSION.

Table IV.2.5 also shows arrivals and departures for the major U.S. ports for 1964. The traffic indicated by these statisics demonstrates the competition for water surface and navigation channels. In New York, for example, there are between two and three arrivals or departures every hour. Portland, the 11th ranking port in the estuarine zone, has an arrival or departure every 2 hours. There is very little information giving a breakdown in vessel types. Statistics for the year 1964 for the port of New York show 18,682 dry cargo or passenger arrivals and departures and 5,098 tankers.

TABLE IV.2.5.—ESTUARINE USE BY WATERBORNE COMMERCE, 1964

| Biophysical region | Number of ports | Number of terminals | Major port | Combined arrivals and departures | Estimated numbers of watercraft |
|---|---|---|---|---|---|
| North Atlantic | 10 | 100 | Boston | 4,168 | 2,084 |
| Middle Atlantic | 19 | 419 | New York | 24,580 | 12,290 |
| | | | Philadelphia | 13,791 | 6,895 |
| Chesapeake Bay | 5 | 157 | Hampton Roads | 11,353 | 5,676 |
| | | | Baltimore | 10,734 | 5,367 |
| South Atlantic | 12 | 105 | Charleston | | |
| | | | Savannah | | |
| | | | Jacksonville | | |
| Caribbean | 1 | 8 | Miami | | |
| | | | San Juan | | |
| Gulf of Mexico | 24 | 353 | New Orleans | 10,400 | 5,200 |
| | | | Houston | 8,372 | 4,186 |
| Pacific Southwest | 19 | 222 | Los Angeles-Long Beach | 9,467 | 4,733 |
| | | | San Francisco | 9,081 | 4,540 |
| Pacific Northwest | 19 | 200 | Seattle | 4,171 | 2,085 |
| | | | Portland | 4,081 | 2,040 |
| Alaska | 15 | 29 | Anchorage | | |
| Pacific islands | 9 | 41 | Honolulu | | |
| Total | 133 | 1,634 | | | |

Reference: The National Estuarine Inventory.
Data Source: Maritime Administration and U.S. Army Corps of Engineers.

The estuarine ports also serve as essential elements of the national defense system. The deep water terminals exert a significant influence on the location of defense installations, as well as of the industrial complexes necessary for logistical support of the defense effort. A direct indication of the use of estuaries by the naval vesels is the total number of ships in commission. During the fiscal year 1967 this number was 931 with a planned increase to 960 in the fiscal year 1969.

In addition to those commissioned ships, in fiscal year 1967 there were 1,071 merchant ships in the National Defense Reserve Fleet. These ships are stored in the estuarine areas as shown in table IV.2.6.

Waterborne transportation in the estuaries is not a completely free

TABLE IV.2.6.—FISCAL YEAR 1967, NATIONAL DEFENSE RESERVE FLEET (MERCHANT SHIPS)

| Location | Ships not maintained | Ships maintained in retention status | Total |
|---|---|---|---|
| Hudson River | 69 | 68 | 137 |
| James River | 164 | 122 | 286 |
| Mobile | 65 | 100 | 165 |
| Beaumont | 25 | 100 | 125 |
| Suisun Bay | 99 | 128 | 227 |
| Olympia | 21 | 110 | 131 |
| Total | 443 | 628 | 1,071 |

gift. In all cases a large investment is required to support and sustain this activity. Adequate channels must be provided to carry the ship traffic. In almost all estuaries this involves maintenance dredging to provide sufficient water depth to float deep draft vessels (fig. IV.2.15). These channels must be marked with navigation aids to prevent the ships from inadvertently straying into shallow water. Terminal facilities are necessary for loading, unloading, and storing cargo. There must also be shipyards with all the equipment and facilities necessary to repair, maintain, and fuel the large ships (fig. IV.2.16).

Besides the physical facilities needed, there are certain environmental considerations. Already mentioned is sufficient water depth to keep the ships afloat. Since dock facilities and berthing space are expensive and cannot be monopolized for long periods of time by single ships, there must be safe anchorage areas where ships can await their turn at the piers. These anchorage areas also provide temporary safety during stormy weather and must, therefore, be sheltered from the direct force of the wind and waves. The whole concept of a harbor is a port of safety out of harm's way.

The advent of nuclear powered ships has presented additional problems. The harbor areas must be protected from every possibility of environmental contamination by radioactive substances, and these ships must have easy access to the sea.

The use of the harbors for waterborne transportation is competitive in that it may cause other uses to be foregone. Heavy ship traffic interferes with pleasure boating and related activities (fig. IV.2.17). Maintenance of the ship channels may alter the ecology and the surface area occupied by the large vessels may well interfere with safe pleasure boating.

Transportation in estuaries is not limited to waterborne traffic. Since a major percentage of large cities are located on estuarine systems, there is considerable pressure to develop fill areas for airports which then utilize the long overwater approaches to keep the jet noise away from developed areas. San Francisco International Airport is a good example, and in Washington, D.C., National Airport uses fill areas and overwater approaches (fig. IV.2.18).

As the airplanes get bigger and the air traffic gets heavier, it appears that more cities will try to develop isolated airport facilities. The planning of the Miami Jetport in the Big Cypress Swamp is a good example. In cities where estuarine areas are available a similar trend will probably develop. The last aspect of transportation to be considered is that of land transport. A dichotomy exists here. The water areas offer a barrier to land travel that must be overcome with causeways or bridge type structures which can interfere with navigation or cause habitat damage. On the other hand, peripheral roads offer some of the more scenic routes available and are frequently the only undeveloped area on which roads can be built. Examples of these peripheral roads are Bayshore Drive in Tampa, Fla.; Bayshore Freeway south of San Francisco; and Harbor Drive in San Diego (fig. IV.2.19).

### Section 4. Use as a Human Habitat

These are the uses that occur wherever people live and work in civilized communities. They represent uses not unique to coastal areas, although the estuarine zone places restrictions on some uses and offers advantages in other activities.

## MUNICIPAL AND INDUSTRIAL WATER SUPPLY

The water in the estuary can serve as a source of both domestic and industrial water supply, but its utilization for domestic supply is very limited at the present time. Normally the brackish water is unpotable and treatment costs to render it potable are extremely high; however, where the upstream freshwater inflow is sufficient to repel salinity intrusion from portions of the tidal area, the water is used for a domestic and agricultural water supply source. The San Francisco Bay Delta area is an excellent example of this, although there are a few others.

The brackish estuarine water is also a poor source for industrial process water. Here again a high degree of purity is normally required in the process water and the cost of removing the dissolved salts is prohibitive.

Estuarine waters are used extensively, however, as a source of industrial cooling water. For this use the most important considerations are ambient temperature and quantity. Water temperatures are generally well below the maximum for economical cooling, and since the ocean is connected to one side of the estuary, the quantity is no problem. Cooling water is required by both the manufacturing industry and electric power generation plants; the greatest use is in the thermal electric plants. Table IV.2.7 shows cooling water withdrawals in the coastal counties. Not all of the amounts shown are taken from estuarine waters, but almost all of these quantities find their way back into estuarine waters.

The distribution of cooling water uses parallels population and industrial development in the coastal counties, even though electrical power can be transported economically over many miles. The greatest concentrations of cooling water use are in the Middle Atlantic and Pacific Southwest regions; these regions both have moderate water temperatures which make possible efficient use of the available cooling water.

Table IV.2.7 also shows, however, that there are 47 nuclear powerplants built or scheduled for completion by 1976. All of these are in the

TABLE IV.2.7.—ESTIMATED COOLING WATER USE IN THE COASTAL COUNTIES, 1963

[Water use in million gallons per day]

| Biophysical region | Total cooling water use | Power generating plant use | Manufacturing industrial use | Existing or planned nuclear powerplants (number) |
|---|---|---|---|---|
| North Atlantic | 1,480 | 1,200 | 280 | 3 |
| Middle Atlantic | 11,030 | 9,000 | 2,030 | 20 |
| Chesapeake Bay | 1,040 | 850 | 190 | 5 |
| South Atlantic | 350 | 290 | 60 | 8 |
| Caribbean | 330 | 270 | 60 | 3 |
| Gulf of Mexico | 1,020 | 830 | 190 | 1 |
| Pacific Southwest | 3,850 | 3,150 | 700 | 5 |
| Pacific Northwest | 900 | 730 | 170 | 2 |
| Alaska | (1) | (1) | (1) | (1) |
| Pacific Islands | 100 | 80 | 20 | (1) |
| Total, estuarine zone | 20,100 | 16,400 | 3,700 | 47 |

1 No data.

Reference: National Estuarine Inventory.
Data source: U.S. Department of Commerce, Bureau of the Census, Census of Manufactures 1963.

megawatt range, with a combined capacity of nearly 35,000 megawatts of electrical power. While the bulk of these will be in the cooler parts of the Nation, 12 will be in the South Atlantic, Gulf, and Caribbean regions. In these regions water temperatures are high, greater volumes must be used to achieve proper cooling, and the increase in water temperature through the powerplant may be sufficient to cause environmental damage.

In addition to water temperature, there are other environmental requirements and problems associated with the use of estuarine waters for cooling. The potential user must have access to the water, and the water ideally should have a low suspended load to reduce maintenance on the cooling system. A major problem is that use of the brackish waters can be accompanied by large growth of mollusks and other clogging organisms which can result in costly maintenance and repairs.

## WATER POWER GENERATION

Many schemes have been promulgated to harness the energy of the tides for the generation of electric power. In the Passamaquoddy arm of the Bay of Fundy and in some parts of Cook Inlet, Alaska, the tide range is in excess of 25 feet. If the vast amount of energy involved in the water movement could be harnessed, a tremendous power source would become available. Unfortunately, tidal electric plants cannot compete economically with the fossil-fueled or nuclear thermoelectric plants. Even more important, power generation peaks would vary with tide fluctations, not consumer demands. It appears there is very little potential for economic development of tidal power.

## WASTE DISPOSAL

The concentration of population and industrial development in the estuarine zone has led naturally to the use of estuarine waters for removal of the waste materials of man's civilization from his immediate vicinity. It is unlikely that cities were built on the coastline with any conscious consideration of the use of the estuarine environment for waste disposal, yet it has happened that this use has become one of the major uses of estuarine waters and the associated land. Virtually all of the cities and industries in the coastal counties dispose of wastes either directly or indirectly into the estuarine zone.

Liquid waste discharges to estuarine systems include domestic waste products, industrial waste materials of all degrees of chemical complexity and sophistication, used cooling water with its thermal load, and storm runoff. These wastes affect the estuarine environment in different ways and can eliminate other benefical uses (fig. IV.2.20).

Liquid wastes are not the only concern. The use of the estuarine shoreline for refuse dumps and land fills results in considerable debris getting into the water (fig. IV.2.21). Water leaching through these dumps has a pollutional impact on the estuarine water. Spoil disposal from dredging activities is another form of solid waste material that contributes to estuarine degradation (fig. IV.2.22). Solid materials entering the estuary in the form of debris from storm runoff can be significant in terms of damaging beneficial uses.

The impact of waste disposal on the estuarine environment will be discussed in part IV, chapter 5. In the context of estuarine uses it is important to recognize, however, that waste disposal is a highly significant and universal use of the estuarine resource and that it is likely to remain so. Along with the many other socioeconomic uses of the estuarine environment, it must be managed so that it does not damage the biophysical environment.

### EXPLOITATION OF MINERAL RESOURCES

Minerals within the water, on the bottom, and under the bottom are a valuable part of the estuarine resource and are being exploited widely. Table IV.2.8 shows the extent of such exploitation in the estuarine zone.

Subbottom mining operations are limited to the recovery of sulphur, petroleum, and natural gas, with the major operations occurring in Louisiana, Texas, California, and Alaska (fig. IV.2.23). These operations exist both in the estuaries and out on the continental shelves with the governing criterion for location being the location of reserves; the carrying out of such operations does not require an extensive amount of local installation or development after drilling is finished.

Avery Island, La., for example, has over 100 oil wells in active pro-

TABLE IV.2.8.—MAJOR EXPLOITATION OF COASTAL MINERAL RESOURCES, 1967

| Biophysical region [1] and commodity [2] | Number of operations | Quantity produced [3] Amount | Units | Value |
|---|---|---|---|---|
| North Atlantic: | | | | |
| Metals | 45 | 1,668,058 | Tons | $7,251,772 |
| Sand and gravel | 116 | 10,068,000 | Tons | 10,611,000 |
| Clay | 7 | 34 | Tons | 99 |
| Middle Atlantic: | | | | |
| Metals | 73 | 8,085,909 | Tons | 15,878,611 |
| Sand and gravel | 232 | 12,299,000 | Tons | 20,193,000 |
| Clay | 24 | 419,549 | Tons | 1,149,331 |
| Chesapeake Bay: | | | | |
| Metals | 26 | 4,415,357 | Tons | 11,351,502 |
| Lime | 3 | 6,034 | Tons | 114,580 |
| Sand and gravel | 140 | 3,451,000 | Tons | 3,511,000 |
| Clay | 16 | 103,500 | Tons | 207,000 |
| South Atlantic: Sand and gravel | 6 | 137,000 | | 89,000 |
| Gulf of Mexico: | | | | |
| Petroleum | 311 | 775,970 | Barrels | 92,138,579 |
| Natural gas | 830 | 12,977,008 | Cu. ft | 22,540,516 |
| Natural gas liquids | 138 | 3,321,951 | MG | 64,513,281 |
| Metals | 14 | 37,946 | Tons | 21,081 |
| Lime | 2 | 3,057,318 | Tons | 23,413,877 |
| Sand and gravel | 29 | 3,848,950 | Tons | 6,991,125 |
| Clay | 5 | 6,724,608 | Tons | 36,036,697 |
| Salt | 1 | 2,743,450 | Tons | 21,337,860 |
| Sulfur | 4 | 16,569 | Tons | 528,590 |
| Other nonmetals | 42 | 16,261,084 | Tons | 32,316,421 |
| Nonmetals | 14 | 4,315,639 | Tons | 12,516,395 |
| Pacific Southwest: | | | | |
| Undistributed | 23 | 1,009,793 | Tons | 55,997,873 |
| Other mineral fuels | 334 | 3,127,128 | MG | 40,160,352 |
| Petroleum | 465 | 214,807 | Barrels | 582,000 |
| Sand and gravel | 216 | 64,696,906 | Tons | 73,307,506 |
| Other nonmetals | 182 | 11,474,022 | Tons | 43,205,436 |
| Pacific Northwest: | | | | |
| Other mineral fuels | 1 | 107,736 | MG | 898,430 |
| Sand and gravel | 155 | 26,750,606 | Tons | 34,447,779 |
| Other nonmetals | 127 | 7,856,956 | Tons | 13,721,602 |

[1] Data are not available for the Caribbean, Alaska, and Pacific islands regions.
[2] Commodity classifications from U.S. Bureau of Mines, "Minerals Yearbook."
[3] Quantities and values of some commodities are withheld to avoid disclosure of individual operations.

Data source: U.S. Bureau of Mines.

duction as well as some new drilling. Yet, the company exploiting the oil reserves has restored all abandoned well sites and taken special efforts to make their facilities blend into the natural environment (fig. IV.2.24). This example is an exception to general practice, but nevertheless points out the resource exploitation is not necessarily synonomous with environmental destruction.

Recovery of minerals from submerged estuarine zone bottoms by surface mining, that is, dredging, is primarily directed toward sand, gravel, and oyster shell production. Sand and gravel operations are prevalent throughout coastal areas wherever suitable deposits and a market exist. Most sand and gravel dredging operations supply nearby users; therefore, they tend to be distributed in relationship to construction and to population.

The concentration of population and industrial development in the estuarine zone, the accessibility of estuarine areas for sand and gravel dredging, and the efficiency of barge transport to coastal construction areas all tend to increase the pressure on submerged estuarine sand and gravel deposits, particularly as coastal shore deposits are exhausted. While no data are available on the present relative importance of shore and submerged deposits in the various biophysical regions, it is certain that all available sources of sand and gravel deposits will be exploited intensively.

Oyster shell production is an extremely useful construction material in the Gulf of Mexico biophysical region. Twenty of the 22 million tons of annual U.S. production are in the Gulf States with Texas and Louisiana producing the vast majority of it. The major oyster shell deposits are in shallow embayments such as Galveston Bay, Tex., and Mobile Bay, Ala.

Phosphate rock is an important estuarine mineral resource; about 75 percent of the total U.S. production is in the estuarine zone of Florida and North Carolina, particularly around Tampa Bay and Pamlico Sound. Considerable deposits of phosphate rock underlie much of the South Atlantic biophysical region, and these may be subject to future exploitation.

Ocean water is a great reservoir of dissolved minerals, some of which are extracted commercially. Installations in the estuarine zone in California, New Jersey, Texas, and Florida extract magnesium compounds from coastal ocean water and supply the bulk of U.S. production. Large ponds are used in California for the evaporation of saline water to produce commercial salt; many of these have been built in marshes or shallow estuarine waters.

## SHORELINE DEVELOPMENT

The use or development of estuarine water either depends upon, or governs, land or shoreline use. Examination of some of the purposes of shoreline development illustrates this relationship.

Recreational shoreline development is based on potential water use. Recreational facilities included: Marinas which support boating activities; beaches which are necessary for the swimmers; parks that cater to those seeking aesthetic enjoyment of the water; fishing piers and vacation cottages, motels, and hotels (fig. IV.2.13). Although

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the motels and hotels are a commercial venture, their prime purpose is to support the recreationalist. Finally, recreation sites provide the access needed to enjoy the water.

Residential developments breed water use because of the proximity of the water. In many communities the development of waterfront property subjects the shoreline to intensive housing development. This, in turn, is accompanied by a buildup of boat docks, fishing and swimming piers, and private beaches which are represenative of the owner's affluence (fig. IV.2.14). Whether or not the water use is the primary motivation for the owner is not significant.

Commercial development of the shoreline includes docks and shipyards, loading terminals, the smaller municipal and local piers, industrial plants, and airports. These are all built to furnish a service and a profit return for the investors (fig. IV.2.16).

Transportation, both commercial and personal, is common to all other activities. In addition it requires highways, commercial port facilities, and airports (fig. IV.2.18). The land-water relationship of airports has been discussed previously. Highways are not directly related to water use but are an integrated part of land-water schemes. Highways along the shoreline usually involve the development of bridges and fills which provide a ready access to the water for aesthetic appreciation and for fisherman. In addition, their protective facilities preserve the shoreline and make it available for use. This aspect is impotrant because if the shoreline is not protected adequately, development uses must be foregone and the water becomes inaccessible.

Other structures built to protect the shoreline include bulkheads to hold the shore in place; dikes to prevent flooding and extend reclaimed land, jetties to provide a protective barrier between the sea and ship channels; and groins along beach areas to control sand movement (fig. IV.2.25).

## Section 5. Deliberate Modification of the Estuarine Zone

Deliberate modification programs are developed to intensify and support major uses. In the past many of these programs resulted in use damages far beyond the intended benefits, but the trends in present practice include attempts to predict unsought consequences. The overall impact of any modification scheme depends on the type and extent of the project.

The most common forms of modification are channel dredging for maintenance of navigation: construction of barriers to reduce damage from storm waves and tsunamis; the construction of dikes, jetties, and groins for navigation, storm protection, erosion control, and land reclamation purposes; wetland filling through dredging spoil disposal, land fill operations, and solid waste disposal; regulation of fresh water inflow for upstream water use or flood protection; and the construction of highway fills, causeways, bridges for land transportation. These modification activities may occur singly or in combination, but in general the result is the same. The estuarine zone form, structure, shape, salinity, and water movement patterns are affected to some degree.

The greatest percentage of deliberate modification of the estuarine zone is for the protection and maintenance of navigation. Almost every harbor area in the United States requires some form of dredging maintenance to maintain access and berthing space. This may take the form of a channel six feet deep or one forty deep, depending upon the ship traffic. Table IV.2.9 shows the amount of dredging required by the Corps of Engineers to maintain the harbors of U.S. Ports.

Jetties are a less common item on the coastal scene. These structures are generally placed where it is necessary to protect a channel and are usually built only where narrow harbor entrances are subjected to shoaling and wave action. On the west coast of the United States jetties are often used to form harbor enclosures as in Los Angeles Harbor and Halfmoon Bay (figure IV.2.25).

Groins are not too frequently used in the estuarine environment. Normally they are built along sandy coastal beaches to help control beach erosion. The groins effectively interfere with the littoral transport phenomena by trapping materials that would be carried away; they are used extensively along the east coast and in southern California.

TABLE IV.2.9.—ANNUAL HARBOR AND CHANNEL DREDGING AND MAINTENANCE COSTS

| Biophysical region | Volume dredged (cubic yards) | Cost, dollars | Number of years of record |
|---|---|---|---|
| North Atlantic | 751,000 | 1,959,000 | 17 |
| Middle Atlantic | 5,241,000 | 5,542,000 | 18 |
| Chesapeake Bay | 6,123,000 | 3,140,000 | 18 |
| South Atlantic | 5,668,000 | 1,488,000 | 18 |
| Caribbean | 123,000 | 41,000 | 18 |
| Gulf of Mexico | 30,880,000 | 4,840,000 | 18 |
| Pacific Southwest | 166,200 | 156,000 | 18 |
| Pacific Northwest | 992,000 | 507,500 | 17 |
| Alaska | 6,900 | 5,400 | 19 |
| Pacific Islands | 74,200 | 157,400 | 18 |

Reference: The National Estuarine Inventory.

Source: U.S. Army Corps of Engineers.

Utilizing barriers to protect the land from the fury of storms at sea is a procedure that has been frequently proposed but little used. There are two examples of hurricane barriers along the east coast, in New Bedford, Mass., and Providence, R.I. Schemes have been developed for other hurricane barriers in Narragansett Bay and Tampa Bay but have not materialized. Feasibility investigations of a tsunami barrier for Hilo Bay in Hawaii were conducted by the Corps of Engineers but no construction has taken place.

Major modifications of estuarine areas by land fill or marsh and wetland reclamation have occurred throughout the Nation. The area reclaimed is generally the highly productive tidal marsh which is so important to estuarine ecology. As an example, 80 percent of the 300 square miles of wetlands that originally surrounded San Francisco Bay have been filled. San Francisco Bay is not unique. Table IV.2.10 lists areas of basic marsh and wetland habitat filled in the past 20 years (figure IV.2.26). Expanding residential and commercial needs for more shoreline land and navigation spoil disposal requirements are the major causes of dredging and filling operations.

Two-thirds of the total marsh and wetland areas are important fish and wildlife habitat. Since the late 1940's, 7 percent of the important habitat has been lost; the largest single block of this has been in the San Francisco Bay system, where much of the tidal marsh and shallow waters no longer exist.

The patterns of filling estuarine marsh and shallow water areas closely parallel population and industrial development within the estuarine zone. In North Atlantic and Middle Atlantic regions commercial development has been the major cause of the filling of estuarine areas; in Florida (which has parts in three biophysical regions) residential development has been the major reason for filling; in both Louisiana and Texas dredging and filling associated with oil and gas exploration has been the major cause for estuarine physical modification.

TABLE IV.2.10.—ESTUARINE HABITAT REMOVED BY DREDGING AND FILLING OPERATIONS

| Biophysical region | Available habitat in 1955 (acres): Area of total marsh and wetland | Available habitat in 1955 (acres): Area of important wildlife habitat | Habitat lost, 1947–67: Area dredged and/or filled | Habitat lost, 1947–67: Percent of habitat lost |
|---|---|---|---|---|
| North Atlantic | 168,000 | 167,000 | 4,000 | 7.0 |
| Middle Atlantic | 424,000 | 424,000 | 89,000 | 8.6 |
| Chesapeake Bay | 441,000 | 428,000 | 3,000 | .5 |
| South Atlantic | 1,551,000 | 797,000 | 25,000 | 2.3 |
| Caribbean (Florida only) | 469,000 | 99,000 | 15,000 | 7.5 |
| Gulf of Mexico | 6,000,000 | 3,426,000 | 167,000 | 4.8 |
| Pacific Southwest | 165,000 | 162,000 | 256,000 | 67.0 |
| Pacific Northwest | 174,000 | 98,000 | 5,000 | 4.0 |
| Alaska | (1) | (1) | 1,100 | .2 |
| Pacific Islands | 10 | | | |
| Total | 9,392,000 | 6,175,000 | 565,100 | 7.0 |

[1] Insufficient data.

References: USDI, Fish and Wildlife circular 39, "Wetalnds of the United States," 1956. USDI, Fish and Wildlife Service data presented in congressional hearings, "Estuarine areas," House serial No. 90–3.

Estuarine modifications due to control and regulation of tributary freshwater streams may be unsought consequences rather than deliberate developmental schemes. Many of the Nation's major river basins have been subjected to some type of major waste resource development, as shown in table IV.2.11. These include flood control, public water supply, power generation, or navigation projects. Generally, the more densely populated and the more arid States have accomplished, out of necessity, greater control of the surface water resources.

California is investing over $2 billion to conserve the surplus water in the northern half of the State and transport it to the southern half. This great effort requires interbasin diversions from coastal basins and results in much different fresh water inflow patterns in the estuarine areas. Texas is also developing its water resources according to a carefully developed plan. Florida has built numerous flood control works which have affected the drainage from Lake Okeechobee into the Everglades and have altered the estuarine environment. The Savannah River in Georgia is fairly well-regulated by two upstream reservoirs. The Roanoke River in Virginia and North Carolina is regulated, as is the Susquehanna in Maryland and Pennsylvania. There are numerous control structures on small coastal streams in New Hampshire and Oregon.

TABLE IV.2.11.—MAJOR FLOW REGULATION STRUCTURES ON ESTUARINE-TERMINATING STREAMS

| State and River name | Purpose | Active storage volume |
|---|---|---|
| NORTH ATLANTIC | | |
| Maine: | | |
| St. Croix | Log driving, power | 187,100 |
| Grand Lake Stream | Power | 161,000 |
| Sebec | do | 57,400 |
| West Branch Penobscot | Log driving, power | 344,000 |
| East branch Penobscot | do | 41,000 |
| Webster Brook | do | 116,000 |
| Kennebec | Power | 60,000 |
| Do | Log driving, power | 544,900 |
| Ossipec | Power, recreation | 23,000 |
| Massachusetts: | | |
| Nashua | Municipal, power | 171,800 |
| Cohas | do | 16,600 |
| Merrimac | Flood control | 153,700 |
| Winnepesakee | Power, recreation | 38,000 |
| MIDDLE ATLANTIC | | |
| Connecticut: | | |
| Natchang | Flood control, recreation | 52,000 |
| East branch Farmington | Municipal | 68,710 |
| West branch Farmington | do | 20,000 |
| Swift-Westfield | Municipal, power | 1,236,000 |
| Little | do | 70,000 |
| Naugatuck | Flood control, recreation | 42,000 |
| Saugatuck | Municipal | 15,600 |
| New Jersey: Esopus | Municipal, recreation | 392,378 |
| New Jersey, Delaware: East branch Delaware, Pennsylvania. | Municipal, power, recreation | 453,880 |
| CHESAPEAKE BAY | | |
| Maryland: | | |
| Susquehanna | Municipal, power | 70,000 |
| Patuxent | Municipal, recreation | 18,100 |
| North Branch, Patapsco | Municipal | 129,115 |
| Gunpowder | do | 72,520 |
| SOUTH ATLANTIC | | |
| North Carolina: Roanoke | Flood control, industry, power, recreation, low flow augmentation. | 2,110,500 |
| South Carolina: | | |
| Santee | Navigation, power | 1,099,900 |
| Cooper | do | 761,500 |
| Georgia: Savannah | Flood control, navigation, power | 1,730,000 |
| GULF | | |
| Florida: Apalachicola | Navigation, power, recreation | 425,900 |
| Alabama: | | |
| Tallapoosa | Power | 1,375,000 |
| Tombigbee | Navigation | 117,000 |
| Texas: | | |
| Nueces | Irrigation, municipal, recreation, industrial | 185,800 |
| Medina | Irrigation | 254,000 |
| Colorado | Flood control, irrigation, municipal, power, recreation, industrial. | 1,922,000 |
| Rio Grande | Irrigation, flood control | 4,081,000 |
| Louisiana: Buffalo Bayou | Flood control | 127,900 |
| PACIFIC SOUTHWEST | | |
| California: | | |
| Calaveras | Municipal | 968,000 |
| Sacramento | Flood control, power, irrigation | 4,377,000 |
| Cache | Irrigation, recreation | 319,000 |
| San Jacinto | Irrigation | 12,000 |
| Santa Ana | Flood control | 217,000 |
| Tujunge | do | 32,000 |
| San Gabriel | do | 33,400 |
| Los Angeles | do | 17,300 |
| Cottonwood | Municipal | 44,040 |
| Sweetwater Creek | Irrigation, municipal | 27,690 |

TABLE IV.2.11.—MAJOR FLOW REGULATION STRUCTURES ON ESTUARINE-TERMINATING STREAMS—Continued

| State and River name | Purpose | Active storage volume |
|---|---|---|
| PACIFIC NORTHWEST | | |
| Oregon: | | |
| Columbia-Dam and locks | Navigation, power | 87,000 |
| Willamette, locks | Navigation | (1) |
| Washington: | | |
| White | Flood control | 106,000 |
| Baker | Power | 142,370 |
| Washington, Canada: Whatcom | Municipal | 26,400 |
| ALASKA | | |
| Alaska: | | |
| Sour Mill Creek | Desilting, industrial | 150,000 |
| Purple Lake | Power | 25,000 |
| Annex Creek | do | 23,360 |
| Cooper Creek | do | 108,000 |
| Eklutna | Power, recreation | 163,300 |
| PACIFIC ISLANDS | | |
| Hawaii: Fresh water holding ditches | Water supply retention | (1) |

[1] No information available on volume.

Reference: The National Estuarine Inventory.
Data source: U.S. Geological Survey, U.S. Army Corps of Engineers.

The Columbia River in Washington and Oregon is one of the most fully developed large rivers in the country. This flow regulation has had an impact on estuarine ecology, especially the anadromous fish runs. There has been considerable modification in the estuarine systems from freshwater flow regulation. Modification of the estuary was not the primary objective of the regulatory projects but occurred as an unsought consequence. Future water resource development schemes will have to consider the estuarine impact to insure that detrimental effects are kept at a minimum.

## Section 6. Summary

The single great unique feature of the estuarine zone, which makes it of primary importance to man and his civilization, is its role in the life cycle of many animals which aid in converting solar energy into more usable forms. While no life form can be singled out as irreplaceable, the kinds of life which need the estuarine zone to survive represent essential links in the energy conversion chain upon which man depends for survival.

Many of the uses cataloged in this chapter occur only because the historical growth of the country makes the estuarine zone the place where people and industry are. Only commercial navigation, naval use, and commercial fishing are uses which are primarily associated with the estuarine zone, rather than other parts of man's environment. Uses such as water supply, waste disposal, and recreation are associated with civilization wherever it exists; in the estuarine zone they may have different values, different emphasis, or different impact on the biophysical environment.

This chapter points out the intrinsic importance of the estuarine zone as a feature of the human environment. The mere cataloging of uses gives no measure of the total value of the estuarine environment to man and his civilization, because each identifiable use is merely a single example of how man has found a way to exploit an estuarine resource for his benefit.

Very rarely does an individual or an organization use an estuarine area for only one purpose. Tourists may come for recreation, but they also dispose of their wastes in the estuarine zone. An industry may use an estuary for shipping and for waste disposal, but many of its employees will be sport fishermen or boating enthusiasts who use the estuary for recreation. The fishermen and oystermen who harvest the living resources still need navigation channels and docks for their boats.

The value and the importance of the estuarine zone lie in the great number of ways in which it can serve human society. Multiple use of the estuarine resource is an intrinsic feature of the socioeconomic environment of the estuarine zone, and those estuarine systems which can be used intensively for many purposes are the most valuable components of the national estuarine system.

REFERENCES

IV–2–1 Battelle Memorial Institute, The Economic and Social Importance of Estuaries (a report prepared under contract No. 14–12–115 with FWPCA, as part of the National Estuarine Pollution Study), Columbus, Ohio, Battelle Memorial Institute, 1968.

# CHAPTER 3.—THE SOCIAL AND ECONOMIC VALUES OF ESTUARINE USE

Chapter 2 described the most important uses of the estuarine zone. There are a variety of uses associated with demographic and industrial development in the coastal counties; each biophysical region has very similar kinds of uses to the others, but there are differences in intensity of certain kinds of use in different biophysical regions, and also in individual areas within regions.

Such differences tend to be related to the availability for exploitation of a particular kind of resource; such as sunshine and beaches in Florida, oil in Texas and Louisiana, deep safe harbors at New York and San Francisco, salmon runs in Washington and Alaska. Each of these stimulates emphasis in estuarine exploitation for a particular kind of use, sometimes to the extent of excluding all other uses either by expropriating all available space or damaging the environment for other uses.

Estuarine use is a complex assortment of interlocking and overlapping types of estuarine resource exploitation.

All of such uses have value, both individually and as part of the development and use of the entire estuarine resource for the benefit of the present and future national community. The mission of this chapter is to show that the importance and total value of any estuarine system lie not in the measure of economic value for any particular use, but in multiplicity of use related to the needs of people who live there or otherwise depend on the estuarine resource.

The approach used is twofold. First, the overall economic development of the estuarine zone and the economic values of several individual uses show the relationship of one use to other uses. Then the balance of uses in several estuarine systems shows the relationship of community needs to estuarine uses.

The common denominator in this discussion is people; their economic needs combined with their social desires and values are what determines the socioeconomic demands on the biophysical estuarine environment.

## SECTION 1. ECONOMIC DEVELOPMENT OF THE ESTUARINE ZONE

Estuarine areas have been a key factor in the development of our Nation. Long before the settlement of Plymouth, British, French, and Spanish fishermen were exploring the North Atlantic fishery resources including those in the Gulf of Maine and along Georges Bank. The need for shore bases to support the cod fishery of the New England coast was a significant factor in stimulating exploration and settlement.

After colonization of New England, the fisheries were the sustaining industry that provided the economic foundation for growth and development. The role of the estuarine zone in supporting the fishery operations was extensive: By necessity most of the inhabitants settled near the natural harbors; fish was the main food staple and the main export; the harbors were the focal point for incoming ships and served as the only commercial centers. The resources of the sea and waterborne commerce were the economic mainstay of the developing Nation; much of the development of California was dependent on ships sailing around the tip of Cape Horn, South America, and this development of trade centered on the west coast opened up new vistas for commercial activity.

The estuaries were also the entry portal for the immigrants that came to this Nation looking for the land of opportunity. It is little wonder that most of the major cities of the United States are positioned on a natural estuarine harbor.

As the population grew, the relative importance of the fishery progressively declined as economic growth in other industries outstripped the demand for seafood as a staple diet item. The growth of industrial and population centers in the estuarine zone closely paralleled the growth of the rest of the Nation, with the estuarine zone becoming relatively more important in international commerce and less important in agricultural food production than the interior of the country.

## URBAN AND AGRICULTURAL DEVELOPMENT

Table IV.3.1 shows present population and agricultural development in the estuarine zone.[1] This table illustrates very clearly the existence of several distinct environments in the estuarine zone. Population and agricultural data exist in political subdivision groupings, while the Standard Metropolitan Statistical Areas (SMSA) cross State and county boundaries to present unified economic groupings. It happens that the classification by biophysical regions cuts across the boundaries of some political subdivisions, but is compatible with the SMSA economic units.

The differences in boundaries of these environments is one of the key problems with which estuarine zone management must deal; in the present discussion the primary concern is with the biophysical environment of the esturaine zone, and the regions describing this environment are the basic unit for analysis. Where necessary political subdivisions have been broken at county boundaries as required to present a consistent analysis.

The coastal counties contain only 15 percent of the land area of the United States, but within this area is concentrated 33 percent of the Nation's population, with about four-fifths of it living in primarily urban areas which form about ten percent of the total estuarine zone area. Another 13 percent of the estuarine land area is farmland, but this accounts for only four percent of the total agricultural land

[1] In this, as in many other tables requiring nationwide socioeconomic statistics, 1960 is the last year for which consistent data are available to support regional comparisons.

TABLE IV.3.1—POPULATION AND AGRICULTURE IN THE ESTUARINE ZONE, 1960

| Biophysical regions and States | State population density (persons per square mile) | Coastal counties population | Coastal[1] urban areas population | Coastal counties population density (persons per square mile) | Coastal county land in farms (percent) | Coastal county tidal shoreline density: Population density (persons per square mile) | Coastal county tidal shoreline density: Farmland (square mile/mile) | Population in SMSA'S (percent) | Total coastal counties population (percent) |
|---|---|---|---|---|---|---|---|---|---|
| North Atlantic | | 3,258,798 | 3,541,000 | 292 | 17.6 | 740 | 0.45 | 109 | 5.6 |
| Maine | 31 | | | 61 | 21.6 | | | | |
| New Hampshire | 67 | | | 149 | 22.7 | | | | |
| Massachusetts[2] | 657 | | | 897 | 10.7 | | | | |
| Middle Atlantic | | 22,387,123 | 20,852,000 | 1,165 | 28.1 | 2,800 | .68 | 93 | 38.1 |
| Massachusetts[2] | 657 | | | 719 | 16.2 | | | | |
| Rhode Island | 816 | | | 816 | 17.9 | | | | |
| Connecticut | 521 | | | 699 | 17.0 | | | | |
| New York | 351 | | | 5,009 | 4.5 | | | | |
| New Jersey | 806 | | | 962 | 17.1 | | | | |
| Pennsylvania | 251 | | | 2,091 | 26.4 | | | | |
| Delaware | 225 | | | 225 | 54.8 | | | | |
| Maryland[2] | 314 | | | 50 | 45.2 | | | | |
| Virginia[2] | 100 | | | 332 | | | | | |
| North Carolina[2] | 93 | | | 40 | 38.6 | | | | |
| Chesapeake Bay | | 5,127,824 | 4,956,000 | 370 | 38.0 | 940 | .96 | 97 | 8.8 |
| Maryland[2] | 314 | | | 397 | 51.5 | | | | |
| Virginia[2] | 100 | | | 258 | 32.6 | | | | |
| District of Columbia | 12,442 | | | 12,442 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| South Atlantic | | 2,202,669 | 1,659,000 | 89 | 31.5 | 225 | .80 | 75 | 3.8 |
| North Carolina [2] | 93 | | | 40 | 27.5 | | | | |
| South Carolina | 79 | | | 68 | 30.6 | | | | |
| Georgia | 68 | | | 92 | 15.9 | | | | |
| Florida [2] | 92 | | | 128 | 42.6 | | | | |
| Caribbean | | 3,682,667 | 935,000 | | | 1,070 | | 25 | 6.3 |
| Florida [2] | 92 | | | 211 | 11.7 | | | | |
| Puerto Rico | 687 | | | 687 | | | | | |
| Virgin Islands | 133 | | | 133 | 52.2 | | | | |
| Gulf of Mexico | | 5,833,149 | 3,109,000 | 121 | 49.1 | 380 | 1.53 | 53 | 10.0 |
| Florida [2] | 92 | | | 96 | 34.8 | | | | |
| Alabama | 64 | | | 129 | | | | | |
| Mississippi | 46 | | | 105 | | | | | |
| Louisana | 72 | | | 119 | | | | | |
| Texas | 36 | | | 146 | | | | | |
| Pacific Southwest | | 12,198,082 | 10,991,000 | 391 | 48.1 | 3,980 | 4.90 | 90 | 20.7 |
| California [2] | 100 | | | 391 | 48.1 | | | | |
| Pacific Northwest | | 3,126,000 | 2,414,000 | 30 | 15.1 | 650 | 1.35 | 77 | 5.3 |
| California [2] | 100 | | | 27 | 20.0 | | | | |
| Oregon | 18 | | | 58 | 18.5 | | | | |
| Washington | 43 | | | 97 | 15.5 | | | | |
| Alaska | 0.4 | 168,721 | 85,531 | 0.5 | <1.0 | 5 | .07 | 50 | .3 |
| Pacific Islands | | 632,772 | 500,000 | | 64.7 | 480 | 3.37 | 79 | 1.1 |
| Hawaii | 99 | | | 99 | 64.7 | | | | |
| Guam | 316 | | | 316 | 24.0 | | | | |
| American Samoa | 264 | | | 264 | | | | | |

[1] Based on standard metropolitan statistical areas (SMSA), except for Alaska, which are those communities with a population density of over 1,000 persons per square mile.
[2] States with area in more than 1 biophysical region.

Reference: The National Estuarine Inventory.

Source: U.S. Department. of Commerce, Bureau of the Census, U.S. Coast and Geodetic Survey.

of the Nation. The estuarine zone, then, is nearly twice as densely populated as the rest of the country, and supports only one-fourth as much agriculture per unit area.

The magnitude of population and agricultural development in the estuarine zone is shown in table IV.3.1 by densities in terms of tidal shoreline. The few estuarine areas in the Pacific Southwest show the greatest shoreline development for both living and farming as shown by population density of 3,980 persons per mile of tidal shoreline and a farmland density of 4.9 acres per mile. The Middle Atlantic region, in contrast, has a very high population density and a low farmland density, showing how in this region the estuarine zone developed as a center of population while agriculture developed elsewhere.

The difference in estuarine land use development between these two regions probably results from the difference in rainfall. The low rainfall in the Pacific Southwest required the intensive use for farming of all land amenable to irrigation, of which a major part was that near the mouths of the major rivers. The plentiful rainfall in the Middle Atlantic region, however, permitted the use of much land away from the estuarine zone for farming, so that the intensive estuarine land use pattern of the Pacific Southwest did not develop.

In those regions lying between Cape Hatteras and Canada, as well as in the Pacific Southwest, over 90 percent of the population lives in urban areas; over much of the Atlantic estuarine zone stretches the great Northeastern megalopolis with population densities averaging over 1,000 persons per square mile. The remainder of the estuarine zone of the United States exhibits a pattern of major centers of population clustered around natural harbors and separated by stretches of coastline which are either empty and inaccessible or beginning to be sprinkled with private residences and resort communities in the vicinities of population centers.

Agriculture in the estuarine zone itself tends to follow the crop patterns typical of neighboring inland areas, although there are some important crops which require special conditions of humidity or soil dampness most easily found in the estuarine zone, if not directly associated with estuarine waters themselves. Cranberries in New Jersey and Massachusetts, rice in Texas and Louisiana, and sugarcane in Hawaii, Louisiana, Florida, and Puerto Rico are examples.

### INDUSTRIAL DEVELOPMENT

Table IV.3.2 gives a general picture of the extent of industrial development in the estuarine zone. The coastal counties have within their borders 40 percent of all manufacturing plants in the United States, thus closely paralleling population concentration into the estuarine zone. The mixture of manufacturing types in the estuarine zone is the same as the national composition with only minor exceptions, such as the concentration of the apparel manufacturing industry in the

Middle Atlantic region, particularly in the New York area. Distribution of manufacturing types among the biophysical regions shows regional differences related to historical development as well as raw material and market availability.

Over half of all plants in the coastal counties and one-fifth of all manufacturing plants in the United States are located in the Middle Atlantic biophysical region, which was the historical center of the Nation's industrial growth and is still one of the major market areas. The Pacific Southwest is the major industrial center of the Pacific coast, and its tidal shoreline now has the same intensity of development as that of the Middle Atlantic region. Some industrial development in other regions tends to follow historical or present raw material availability. Leather product plants are clustered in the North Atlantic region, and lumber manufacturing plants are most plentiful in the Pacific Northwest. Food processing plants, however, follow closely the distribution of population.

While much of the industrial development located in coastal counties affects the estuarine zone indirectly through use of adjacent land, some of the water-using industries have an impact on the estuarine zone far beyond their numbers. The paper, chemical, petroleum, and primary metals industries are the major water users among manufacturing establishments; these are listed separately in table IV.3.2 to show how universally these industries are distributed throughout the estuarine zone. The brackish estuarine waters may become an increasingly important source of water supply for industries, and for municipalities as desalting technology improves.

### LAND OWNERSHIP

Out of the millions of acres of land contiguous to the estuarine zone, only a relatively small amount is relegated to urban development and farmland. A considerable portion is in the form of unused or undeveloped land, the ownership of which has an important bearing on future use of the estuarine environment. Privately owned land is subject to possible industrial or real estate development which could add significantly to water quality problems. Publicly owned land, on the other hand, represents the potential for development of a broad-based public use with proper controls. It also indicates the potential for public access to the water. Table IV.3.3 summarizes land ownership in the coastal counties within each biophysical estuarine region. Except for Alaska, the great preponderance of estuarine zone land is in private ownership. The North Atlantic, Middle Atlantic, and Chesapeake Bay regions in particular have little land in these counties still remaining under public ownership. Detailed information on actual or potential use of these privately owned lands is not available; it is certain, however, that some commercial or residential use exists or is intended in most cases.

TABLE IV.3.2.—EXTENT OF INDUSTRIAL DEVELOPMENT IN THE ESTUARINE ZONE

| Biophysical regions | Total number of plants | Number of plants with >20 employees: Total | Major water use industries: Paper and allied products | Major water use industries: Chemical and allied products | Major water use industries: Petroleum and allied products | Primary metals industries | Major industries in region (plants with >20 employees): Industry group | Number of plants | Percent of total plants in region | Percent of total industry group in estuarine zone | Density of industrial development (number of plants per mile of tidal shore line) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| North Atlantic | 8,617 | 2,933 | 132 | 88 | 13 | 60 | Apparel, other textile products | 368 | 12.5 | 4.4 | 0.7 |
| | | | | | | | Leather and leather products | 342 | 11.7 | 34.0 | |
| | | | | | | | Fabricated metal products | 225 | 7.8 | 6.7 | |
| | | | | | | | Machinery and electrical equipment | 483 | 16.5 | 10.0 | |
| | | | | | | | Food and kindred products | 375 | 11.1 | 7.8 | |
| Middle Atlantic | 65,000 | 21,847 | 761 | 840 | 78 | 532 | Apparel, other textile products | 6,547 | 30.0 | 79.4 | 2.7 |
| | | | | | | | Printing and publishing | 1,701 | 7.8 | 56.5 | |
| | | | | | | | Fabricated metal products | 1,677 | 7.7 | 49.6 | |
| | | | | | | | Machinery and electrical equipment | 2,353 | 10.8 | 48.1 | |
| | | | | | | | Textile mill products | 1,280 | 5.9 | 79.4 | |
| | | | | | | | Food and kindred products | 1,413 | 6.5 | 33.2 | |
| Chesapeake Bay | 5,186 | 2,064 | 86 | 127 | 13 | 41 | do | 510 | 24.7 | 12.1 | .4 |
| | | | | | | | Printing and publishing | 240 | 11.6 | 8.0 | |
| | | | | | | | Fabricated metal products | 158 | 7.7 | 4.7 | |
| | | | | | | | Apparel and other textile products | 191 | 9.3 | 2.3 | |
| | | | | | | | Lumber and wood products | 142 | 6.9 | 8.7 | |
| | | | | | | | Stone, clay, and glass products | 133 | 6.4 | 9.8 | |
| South Atlantic | 2,695 | 693 | 40 | 59 | 12 | 10 | Food and kindred products | 164 | 23.7 | 3.9 | .07 |
| | | | | | | | Lumber and wood products | 97 | 14.0 | 6.0 | |
| | | | | | | | Stone, glass, and clay products | 67 | 9.7 | 4.9 | |
| | | | | | | | Chemicals and allied products [1] | 59 | 8.5 | 3.4 | |
| | | | | | | | Printing and publishing | 51 | 7.4 | 1.7 | |
| Caribbean | 2,554 | 654 | 18 | 16 | 5 | 9 | Apparel and other textile products | 123 | 18.8 | 1.5 | .2 |
| | | | | | | | Fabricated metal products | 75 | 11.5 | 2.2 | |
| | | | | | | | Furniture and fixtures | 55 | 8.6 | 4.8 | |
| | | | | | | | Printing and publishing | 54 | 8.3 | 1.8 | |
| | | | | | | | Food and kindred products | 81 | 12.4 | 1.9 | |
| Gulf of Mexico | 6,980 | 2,013 | 70 | 192 | 62 | 61 | do | 493 | 24.5 | 11.7 | .1 |
| | | | | | | | Fabricated metal products | 216 | 10.7 | 6.4 | |
| | | | | | | | Chemicals and allied products [1] | 192 | 9.5 | 11.2 | |
| | | | | | | | Machinery, except electrical | 161 | 8.0 | 6.5 | |
| | | | | | | | Stone, clay, and glass products | 168 | 8.3 | 12.3 | |
| | | | | | | | Lumber and wood products | 123 | 6.1 | 7.6 | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pacific Southwest | 27,508 | 7,633 | 240 | 332 | 54 | 286 | Food and kindred products | 845 | 11.1 | 20.1 | 2.5 |
| | | | | | | | Apparel and other textile products | 846 | 11.1 | 10.3 | |
| | | | | | | | Printing and publishing | 545 | 7.1 | 18.1 | |
| | | | | | | | Electrical equipment | 664 | 8.7 | 28.9 | |
| | | | | | | | Fabricated metal products | 867 | 11.4 | 25.6 | |
| | | | | | | | Transportation equipment | 429 | 5.6 | 39.1 | |
| Pacific Northwest | 7,584 | 1,804 | 76 | 55 | 14 | 47 | Food and kindred products | 292 | 16.2 | 40.8 | .4 |
| | | | | | | | Lumber and wood products | 662 | 36.7 | 40.8 | |
| | | | | | | | Fabricated metal products | 115 | 6.4 | 3.4 | |
| | | | | | | | Machinery, except electrical | 97 | 5.4 | 3.9 | |
| | | | | | | | Printing and publishing | 93 | 5.2 | 3.1 | |
| | | | | | | | Paper and allied products [1] | 76 | 4.2 | 5.2 | |
| Alaska [2] | 303 | | | | | | | | | | |
| Pacific Islands | 672 | 194 | 26 | 8 | (3) | (3) | Food and kindred products | 75 | 37.8 | 1.8 | .1 |
| | | | | | | | Textile mill products | 37 | 19.1 | 2.3 | |
| | | | | | | | Paper and allied products [1] | 26 | 13.4 | 1.8 | |
| | | | | | | | Lumber and wood products | 19 | 9.8 | 1.2 | |
| Total estuarine zone | 126,796 | 39,835 | 1,449 | 1,717 | 251 | 1,046 | Apparel and other textile products | 8,239 | 20.7 | | |
| | | | | | | | Food and kindred products | 4,199 | 10.5 | | |
| | | | | | | | Fabricated metal products | 3,381 | 8.5 | | |
| | | | | | | | Printing and publishing | 3,011 | 7.6 | | |
| | | | | | | | Machinery, except electrical | 2,476 | 6.2 | | |
| | | | | | | | Electrical equipment | 2,315 | 5.8 | | |
| | | | | | | | Chemicals and allied products [1] | 1,717 | 4.3 | | |
| | | | | | | | Lumber and allied products | 1,623 | 4.1 | | |
| | | | | | | | Textile mill products | 1,613 | 4.0 | | |
| | | | | | | | Paper and allied products [1] | 1,449 | 3.6 | | |
| | | | | | | | Stone, clay, and glass products | 1,361 | 3.4 | | |
| | | | | | | | Furniture and fixtures | 1,175 | 2.9 | | |
| Total United States | 306,619 | 99,355 | 3,552 | 3,985 | 689 | 3,585 | Food and kindred products | 14,113 | 14.1 | | |
| | | | | | | | Apparel and other textile products | 13,011 | 13.0 | | |
| | | | | | | | Fabricated metal products | 212 | 9.2 | | |
| | | | | | | | Machinery, except electrical | 8,426 | 8.4 | | |
| | | | | | | | Printing and publishing | 7,215 | 7.2 | | |
| | | | | | | | Lumber and wood products | 5,765 | 5.8 | | |
| | | | | | | | Electrical equipment | 4,722 | 4.7 | | |
| | | | | | | | Stone, clay, and glass products | 4,655 | 4.7 | | |
| | | | | | | | Textile mill products | 4,367 | 4.4 | | |
| | | | | | | | Chemicals and allied products [1] | 3,985 | 4.0 | | |
| | | | | | | | Primary metal industries [1] | 3,585 | 3.6 | | |
| | | | | | | | Paper and allied products [1] | 3,552 | 3.6 | | |

[1] Major water use industries.
[2] Data not available for coastal area only.
[3] No data.

Reference: National Estuarine Inventory
Data source: Census of Manufactures, 1964.

TABLE IV.3.3.—LAND USE DISTRIBUTION IN THE ESTUARINE ZONE

| Biophysical region | Area (square miles) incorporated in— Metropolitan areas | Farms | Parks, recreation areas, refuges, forests, etc. | National defense installations [1] | Remainder of area in coastal counties |
|---|---|---|---|---|---|
| North Atlantic | 1,744 | 1,965 | 347 | 16 | 7,121 |
| Middle Atlantic | 10,374 | 5,403 | 1,172 | 51 | 2,288 |
| Chesapeake Bay | 5,401 | 5,272 | 662 | 52 | 2,524 |
| South Atlantic | 7,569 | 7,840 | 2,919 | 26 | 6,511 |
| Caribbean (Florida only) | 2,042 | 778 | 2,370 | 3 | 3,931 |
| Gulf of Mexico | 11,929 | 23,620 | 6,275 | 21 | 6,327 |
| Pacific Southwest | 16,192 | 15,210 | 7,324 | 59 | (2) |
| Pacific Northwest | 14,117 | 6,440 | 18,734 | 18 | 3,477 |
| Alaska (total State) | 100 | 3,060 | 20,626 | 5 | 323,787 |
| Pacific Islands | 598 | 3,677 | 38,170 | 14 | 3,240 |

[1] Number of installations only. Areas classified.
[2] Much farmland is within SMSA boundaries, distorting totals.

Reference: National Estuarine Inventory.

Sources: U.S. Departments of Housing and Urban Development, Agriculture, Commerce, Defense, and Interior.

## Section 2. The Values of Individual Uses

### FISH AND WILDLIFE HABITAT

The value of the estuarine zone as fish and wildlife habitat both depends on and augments its values for other uses, particularly recreation and commercial fishing.

There is, in addition to these, the basic incalculable value of the estuarine habitat as a link in the essential energy-conversion chain which permits man to survive at all.

The trapping of fur bearers in the marshes of the Gulf and Atlantic represents one of the few economic values directly attributable to estuarine habitat. Louisiana is the major producer; in the 1965–66 season total sales were $4.6 million out of the Nation's $6 million total. These included the pelts and some meat from nutria, muskrat, raccoons, mink, and otter, with much of the harvest coming from marshes managed specifically for that purpose.

The management of marshes for fur bearers requires periodic burning over, means of controlling predators, and the control of saline water intrusion. This makes the marshes so managed unsuitable for some other forms of estuarine-dependent life such as shrimp; so against the economic value of marsh management for commercial trapping must be set the unknown cost of the loss of habitat for other forms of life.

The harvesting of pelts in the estuarine zone is of small economic value even when the $4 million per year fur seal harvest of the Pribiloff Islands is included. As a measure of the full value of estuarine habitat this annual value is an excellent indicator of how the measurable economic worth of an estuarine use my reflect very little of its actual importance.

### COMMERCIAL FISHING

The economic value of the estuarine zone to even such an obviously estuarine-dependent industry as commercial fishing can be established only with numerous assumptions and approximations. Not only is the existence of much of the harvestable crop dependent on the estuarine habitat, but the estuarine zone also provides the safe harbors without which the ocean fisheries could not exist. In addition, the seafood processing plants which supply the entire Nation are nearly all located in the estuarine zone and derive economic benefit from the existence of the commercial fishing industry.

In 1967 U.S. fishermen received $438 million for approximately 4.06 billion pounds of commercial fish and shellfish. It has been estimated that two-thirds of the total value, or approximately $300 million, can be considered for estuarine-dependent species. This is a conservative estimate of the direct value derived from the estuarine fishery for it does not include the value of fish harvested by foreign vessels off the U.S. coast. Five of the six leading species by weight, representing over one-half of the U.S. commercial fish tonnage in 1967 are estuarine dependent (table IV.3.4).

Table IV.3.5 shows the weight and values of the major estuarine-dependent commercial fish landings by biophysical region. The Gulf of Mexico region fishery has by far the greatest volume and value, primarily due to landings of shrimp and menhadden, which use the estuarine zone as a nursery area. The anadromous salmon fisheries of Alaska and the Pacific Northwest rank second, and the fisheries of estuarine-resident oysters in the Chesapeake are third in the Nation among the estuarine-dependent species.

TABLE IV.3.4.—RANKING OF THE 10 MOST IMPORTANT COMMERCIAL FISHERIES IN THE UNITED STATES, 1965

| By weight (thousand pounds) | | | By value (thousand dollars) | | |
|---|---|---|---|---|---|
| Rank | Kind | Weight | Rank | Kind | Value |
| 1 | Menhaden | 1,726,104 | 1 | Shrimp | 82,409 |
| 2 | Crabs | 334,599 | 2 | Salmon | 65,123 |
| 3 | Salmon | 326,806 | 3 | Tuna | 41,734 |
| 4 | Tuna | 318,895 | 4 | Crabs | 30,745 |
| 5 | Shrimp | 234,644 | 5 | Oysters | 27,867 |
| 6 | Flounders | 180,121 | 6 | Menhaden | 27,073 |
| 7 | Haddock | 133,892 | 7 | Lobsters | 25,584 |
| 8 | Sea Herring | 110,293 | 8 | Flounders | 17,948 |
| 9 | Ocean Perch | 83,608 | 9 | Clams | 16,000 |
| 10 | Whiting | 82,574 | 10 | Haddock | 13,630 |
| | Total | 3,540,536 | | Total | 348,113 |
| | | 1967 | | | |
| 1 | Menhaden | 1,165,800 | 1 | Shrimp | 103,100 |
| 2 | Tuna | 329,000 | 2 | Salmon | 48,600 |
| 3 | Crabs [1] | 316,000 | 3 | Tuna | 44,514 |
| 4 | Shrimp | 312,200 | 4 | Oysters | 31,600 |
| 5 | Salmon | 206,400 | 5 | Crabs | 27,100 |
| 6 | Flatfish | 110,900 | 6 | Lobsters | 24,100 |
| 7 | Haddock | 98,500 | 7 | Clams | 19,000 |
| 8 | Sea Herring | 85,100 | 8 | Menhaden | 15,200 |
| 9 | Ocean Perch | 71,500 | 9 | Flatfish | 13,600 |
| 10 | Anchovies | 69,600 | 10 | Haddock | 10,500 |
| | Total | 2,765,000 | | Total | 337,314 |

[1] The crab landings include the king crab, which is not an estuarine-dependent species.

Sources: Charles H. Lyles, "Fisheries of the United States * * * 1965," Stat. Dig, 59 (April 1966), p. 4. Charles H. Lyles, "Fisheries of the United States * * * 1967," C.F.S. No. 4700 (April 1968), p. 4.

An entire complex of commerce and industry can rest upon one primary producing industry such as commercial fishing, and figure IV.3.1 illustrates in a very simple fashion some of the more direct impacts of commercial fishing on the economy. Each time the basic product changes hands it generates economic activity and gains in value until by the time it reaches the ultimate consumer, its price may be many times what the fisherman was paid for it.

The effect of such value multiplier factors will be such as to make the actual values of specific commercial fisheries several times the landed values such as those given in table IV.3.4 and table IV.3.5.

Thus, the $438 million received by U.S. fishermen in 1967 probably represents a total input to estuarine zone economic activity of over $1 billion; exactly how much it is impossible to say. Case studies discussed later in this chapter assign multiplier values of about three and four to commercial fishery landing values, but the magnitudes of such multipliers depend on the structure of the local economy as well as on other factors and generalities are likely to be misleading.

Consumption of both edible and industrial fish products continues to increase, but the part of the consumption supplied by domestic fishermen continues to decrease. Imports represented 82 percent of the industrial fish supply and 53 percent of the edible fish supply in 1967. A primary cause of this loss of market is the inability to compete economically with foreign fishing fleets using the most advanced technology. Aquaculture is a potential means for correcting this condition, and, as such, represents a potential estuarine use of large but indeterminate value.

The relationship of the estuarine zone and commercial fishing cannot be expressed by any simple economic index. This brief discussion shows that the importance of commercial fishing in the estuarine zone is related economically not only to estuarine habitat, but also to transportation, commerce, food processing, and aquaculture.

## RECREATION

Recreation is the one major estuarine use that is directly and irretrievably related to individual people. It is a pursuit carried out strictly on an individual choice basis and has as much variety as individuals themselves have. Every estuarine system where there are people is subject to recreational use, whether it is of recreational quality or not.

When an estuarine system is of poor recreational quality, only those people who cannot afford to go elsewhere will use it. When a system is of acceptable quality, many local people will use it and it may even attract some tourists from less-favored areas. When an estuarine system is not only of acceptable quality but has other attractions such as beautiful scenery or pleasant weather, recreation and tourism become major commercial enterprises.

Each kind of recreational use has its own economic impact. Recreational boating supports a large boatbuilding, marina, and boat repair industry. Sport fishing supports not only a certain part of the boating industries, but also a very specialized industry manufacturing and selling fishing tackle. For example, the 1965 Survey of Fishing and Hunting shows that salt water anglers spent $800 million in that year. Sightseeing and swimming support motel and restaurant services

FIGURE IV.3.1 EXAMPLE OF ECONOMIC ACTIVITIES RELATED TO ESTUARINE RESOURCES

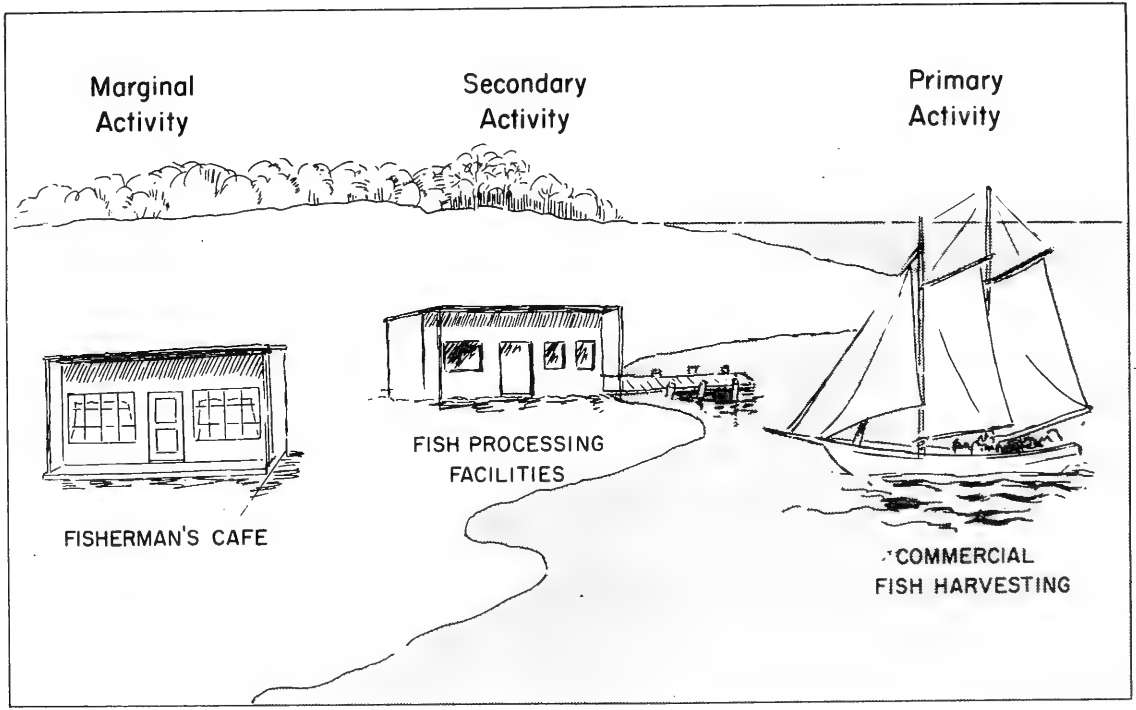


TABLE IV.3.5.—COMMERCIAL LANDINGS OF MAJOR ESTUARINE-DEPENDENT FISH AND SHELLFISH, 1965

[Weight in thousand pounds; value in thousand dollars]

| Name | Biophysical region | | | | | | | | | | Total, United States |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Atlantic | Middle Atlantic | Chesapeake Bay | South Atlantic | Caribbean [1] | Gulf of Mexico | Pacific Southwest | Pacific Northwest | Alaska | Pacific Islands [2] | |
| Shrimp: | | | | | | | | | | | |
| Weight | 2,093 | 76 | 26,120 | 14,870 | 180,394 | 264,400 | 264 | 3,007 | 16,819 | | 243.6 |
| Value | 245 | 28 | 10,137 | 4,755 | 66,160 | 66,160 | 28 | 298 | 757 | | 82.4 |
| Salmon: | | | | | | | | | | | |
| Weight | 208 | | | | | | 4,254 | 47,708 | 274,844 | | 326.8 |
| Value | 161 | | | | | | 2,374 | 14,475 | 48,274 | | 65.1 |
| Oysters: | | | | | | | | | | | |
| Weight | 57 | 1,348 | 20,889 | 4,075 | <1 | 19,154 | 376 | 8,788 | 2 | | 54.6 |
| Value | 114 | 2,055 | 16,249 | 1,508 | <1 | 5,711 | 105 | 2,123 | 2 | | 27.8 |
| Crabs: | | | | | | | | | | | |
| Weight | 2,043 | 11,507 | 84,416 | 37,608 | 700 | 37,385 | 897 | 19,449 | 140,566 | 28 | 334.5 |
| Value | 89 | 794 | 7,436 | 2,061 | 324 | 2,566 | 231 | 3,500 | 13,729 | 16 | 30.7 |
| Lobsters: | | | | | | | | | | | |
| Weight | 23,842 | 6,359 | 44 | 196 | 5,547 | 6 | 480 | | | 8 | 36.4 |
| Value | 17,943 | 3,997 | 17 | 107 | 3,125 | 3 | 385 | | | 7 | 25.5 |
| Clams: | | | | | | | | | | | |
| Weight | 3,557 | 55,748 | 10,351 | 404 | | 114 | <1 | 588 | 89 | 1 | 70.8 |
| Value | 2,036 | 11,185 | 2,929 | 170 | | 42 | <1 | 329 | 41 | 1 | 16.0 |
| Menhaden: | | | | | | | | | | | |
| Weight | 9 | 152,216 | 358,768 | 192,373 | | 1,002,837 | | | | | 1,726.1 |
| Value | | 2,285 | 5,385 | 2,502 | | 16,902 | | | | | 27.0 |
| Total: | | | | | | | | | | | |
| Weight | 31,602 | 227,254 | 474,468 | 260,676 | 21,118 | 1,259,890 | 6,271 | 79,540 | 432,320 | 37 | 2,793.1 |
| Value | 20,427 | 20,344 | 32,015 | 16,486 | 8,203 | 91,383 | 3,123 | 20,725 | 62,803 | 24 | 275.5 |

[1] Caribbean, Florida only.
[2] Pacific islands, Hawaii only.

Reference: National Estuarine Inventory.
Source: U.S. Department of the Interior, Bureau of Commercial Fisheries.

in the favored areas, as do other overnight recreational activities. Table IV.2.3 gives the advantages and disadvantages of several indices of recreational economic impact; as this table shows, there is no single satisfactory index for showing the importance of the estuarine zone in recreation, or vice versa.

In many cases the economic value of recreation may depend upon the total economic structure of a particular estuarine system. For example, the Biscayne Bay area in Florida is oriented toward the recreational pursuits of the vacationing tourist; the useful indexes of recreational activity here would be motel, hotel, charter boat, and marina revenues. The shoreline of the Chesapeake Bay in Maryland, in contrast, is almost entirely oriented toward private residences or commercial marinas catering to the regional resident, who needs permanent boat mooring facilities.

The significant indexes of recreational activity here would be boat sales and repairs, marina revenues, and waterfront property values.

Attempts at the quantification of overall recreational economic values are not yet well-developed. The user-day recreation benefits approach has been used in some Federal waterway and reservoir projects, but has been used in the estuarine system only in an analysis of fisheries and recreation in San Francisco Bay. Net benefits for general recreation activities, by this method, range from 50 cents to $1.50 per day. Specific forms of recreation may have higher values.

Applying such a figure to the population of the coastal counties suggests that the value of the recreational resource of the estuarine zone is about $300 million if each person has about 5 days of recreational use. Such an estimate would include only local use and no multiplier values and might therefore be regarded as minimum value of the entire value of the entire estuarine recreation resource.

The major problems in defining the economic values of recreation in the estuarine zone lie in the facts that recreation itself is not an easily defined commodity nor can it be isolated from other economic activities such as transportation, food and lodging services, and equipment manufacturing.

## COMMERCIAL NAVIGATION AND NATIONAL DEFENSE

The economic value of commercial navigation is easier to establish than the value of any other activity. Even here, however, there is impact of this use on other estuarine uses, and the estimates of economic value are not complete. Estimates of the economic value of commercial navigation are based on the direct revenue to the port of handling a ton of cargo, generally $16 to $20. Such estimates lead to a total value of the estuarine resource of $4.7 billion annually for cargo revenues alone, without multiplier values. An additional economic value of $10 billion annually in salaries and wages has been estimated for the 11 major ports listed in table IV.2.5.

These estimates do not show the impact of commercial navigation on land transportation, shoreline development, or the manufacturing industries. Without the deep, safe harbors commercial navigation could not exist on a large scale, and without commercial navigation the great cities around these harbors would not have developed.

Deep-water harbors are essential elements of the national defense system. Furthermore, the location of these deep-water ports has influenced the location of other defense installations as well as the industrial complexes necessary for the logistical support of the defense effort.

The cost of the national defense effort in the estuarine zone for 1967 is estimated at about $900 million, exclusive of pay and allowances for shore-based Navy and Marine Corps personnel. The economic impact of national defense activity overlaps into all other estuarine zone uses because of the massive payrolls associated with it. This impact is centered in the areas with major defense installations, as will be shown in the case studies presented later in this chapter.

### WASTE DISPOSAL

The waters of the estuarine zone have received wastes from the people and industries on their shores ever since the first cities were founded. The economic benefit in the use of estuarine waters for waste disposal has been fully utilized by nearly all industries and communities in the estuarine zone, and only the tremendous capacity of estuarine waters to absorb and remove waste materials has kept the estuarine zone from suffering severe damage from such waste discharges.

All other uses of the estuarine zone result in the need to dispose of some waste products, and the general practice has been merely to dump them into the water and forget them. Chapter 5 discusses the sources and nature of pollutional materials and activities, and how this use of estuarine zone waters can affect other uses.

The economic benefit of this estuarine use is a real one and it must be considered along with other established uses of the estuarine zone. This benefit can be calculated in terms of the difference between the cost of an advanced degree of waste treatment needed when the waste assimilation capacity of the estuarine system is fully utilized.

No overall estimate of the value of this use of the estuarine resource is possible because the level of treatment necessary in any particular case depends on many local factors.

While the use of estuarine waters for waste disposal may not be esthetically appealing, it is an existing estuarine use with which other uses must compete, and it should be considered along with them in the overall economic evaluation of estuarine uses.

## SECTION 3. REVIEWS OF CASE STUDIES OF USES OF THE ESTUARINE ENVIRONMENT

The preceding section discussed separately some important estuarine uses and showed how the calculable economic estimates fell short of showing the actual value of each use. This section describes several estuarine systems as socioeconomic environments to show how the use balance in each may differ from the others and how one use may dominate all others.

Almost all estuarine systems have either a multiplicity of uses at the present time or such uses are available in the system. Estuaries presently support such varied uses as military berthing and associated activities, commercial port facilities, shipping channels, industrial uses, commercial fisheries, sport fishing, recreation, wildlife habitat, and purely aesthetic purposes. In most estuaries one or two of the uses predominate while the others take minor roles.

It is, however, important to understand that estuarine uses are not mutually exclusive and that with sufficient planning and caution, these uses can exist in harmony with one another. In fact, in order to receive the maximum return from a natural resource such as an estuary, all of the uses of the specialized environment should be developed to the maximum with the detrimental uses minimized.

Minimizing detrimental uses does not, in most cases, mean that the major activity must be stopped. Rather, it means that for most uses only the harmful extent of such uses must be stopped or restricted. For example, sanitary wastes discharged from ships may be a harmful side effect of shipping that must be curtained. There is no need to conclude, however, that shipping must be stopped. Similarly, water skiing or boat racing may be harmful to sport fishing. However, a simple zoning of certain areas for use of sport fishermen and not for high speed boating or water skiing allows the use of an estuary for all these pursuits.

At the present time, the major uses of estuaries, in terms of gross monetary return are: military use, shipping, and industrial activities. These uses are, of course, historical and do not necessarily reflect the uses that would be made of the estuary under today's conditions or future conditions, if each use were to compete for the water use at the same time. In other words, historical use has brought about the present use imbalance in many estuarine systems. However, given the opportunity to develop, other uses might attain equal importance economically while contributing important social benefits.

Estuaries at the present time represent underdeveloped natural resources that are important to the social as well as the economic well-being of the Nation. Although lack of understanding of the dynamics of an estuary and the inability to foresee the coming of age of an industrial economy, with its resultant increase in leisure time, may have combined to allow undesirable exploitation of certain estuaries, such exploitation need not be allowed to continue.

Based on present trends and demands, there is little doubt that there will be a tremendous need for estuarine uses other than for military, shipping, and industrial uses. That is, if the facilities are available for recreation, sports, or aesthetic enjoyment, they will be used and used to great advantage from an economic standpoint as well as a social standpoint. Also, some commercial fishery ventures may again become not only feasible but profitable if the detrimental uses of estuaries are curtailed.

### NARRAGANSETT BAY
(IV–3–1)

The Narragansett Bay system in Rhode Island and Massachusetts is an estuary of approximately 170 square miles with a total shoreline of approximately 240 miles. Except for normal shoaling towards shore, there are only very limited areas where the water depth is less than 6 feet at mean low tide. Passages between the islands have sufficient depths for large ships—channels need only be dredged where they enter the Taunton and Providence Rivers. Because of the islands in the bay and the irregular coast, Narragansett Bay has a long shoreline with coves and embayments that are protected from the wave effects of major storms. The tidal range is a moderate 3 to 4 feet but a favorable cross section to length ratio of the basin helps to ensure reasonably good flushing. Figure IV.3.2 (on p. 159) is a map of the bay.

The population of Rhode Island is mainly clustered about the shores of Narragansett Bay. A special census in 1965 enumerated the total at 892,709 of which some 69 percent resided in towns and cities touching the bay. The long term migration of the population appears in a gradual movement from the upper bay towns to the lower bay towns. In the total bay area, there are 69,160 areas of developed land and 115,039 areas of land with development potential. Table IV.3.6 shows the distribution of developed land.

TABLE IV.3.6.—PERCENT OF USE BY CATEGORY OF DEVELOPED LAND, NARRAGANSETT BAY, R.I.

| Use | Proportion in percent of developed land | |
|---|---|---|
| | Urban | Rural |
| Residential | 41.2 | 42.4 |
| Industrial-commercial | 12.3 | 9.8 |
| Governments, institutions, or public utilities | 15.4 | 20.8 |
| Recreational | 9.9 | 9.3 |
| Roads and highways | 21.2 | 17.7 |

From colonial times, when perhaps the more important economic activities were purely bay oriented (e.g., fishing and foreign trade), industry and trade has clustered about the bay and its tributaries following the growth of population in these areas and the concurrent growth of a pool of skilled labor. Within the total socioeconomic environment of the area, seven estuarine-dependent product-producing areas are examined to show some of the methods involved in deriving a value for a given use. The categories include commercial fisheries, defense establishments, recreation, bay transportation, marine-oriented industry and commerce, research and education, and waste disposal.

Table IV.3.7 shows the production, value and productivity of the Narragansett Bay fisheries for 1939 and 1965. In order to illustrate the former importance of a species, the oyster is included although it is no longer commercially important.

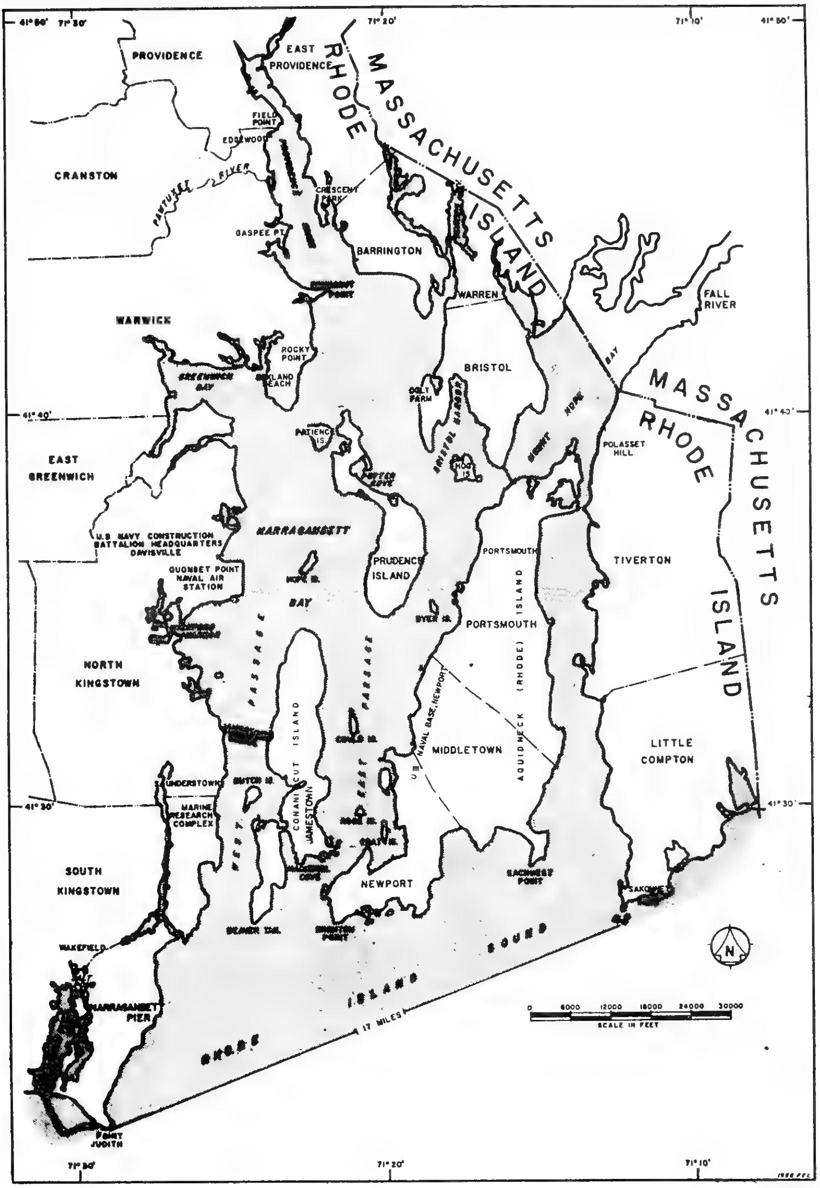
There has been a reversal in the relative importance of the finfisheries and shellfisheries over the 25-year period due partially to the decline in the oyster fishery resulting from the disappearance of the wild oyster from Narragansett Bay for unknown reasons. Improvement in finfishing methods together with a lack of improvement in shellfishing methods have also contributed to this reversal.

TABLE IV.3.7.—COMMERCIAL FISHERIES OF NARRAGANSETT BAY

| | Finfish | Shellfish [1] | | |
|---|---|---|---|---|
| | | Oysters | Clams | Total |
| **1939** | | | | |
| Fishermen | 101 | | | 924 |
| Catch (pounds) | 4,022,900 | 2,313,500 | 2,197,900 | 5,147,200 |
| Catch | $122,808 | $399,100 | $250,600 | $774,134 |
| Catch per fisherman (pounds) | 38,830 | | | 5,571 |
| Gross value per fisherman | $1,216 | | | $838 |
| Average annual price (per pound) | $0.035 | | | $0.15 |
| **1965** | | | | |
| Fishermen | 116 | | | 1,437 |
| Catch (pounds) | 9,809,700 | 11,500 | 2,297,300 | 2,695,000 |
| Catch | $835,202 | $14,100 | $1,062,700 | $1,372,653 |
| Catch per fisherman (pounds) | 85,302 | | | 1,875 |
| Gross value per fisherman | $7,263 | | | $0.955 |
| Average annual price (per pound) | $.085 | | | $0.509 |

[1] Meat weight only, except for lobsters which are live weight.

FIGURE IV.3.2 NARRAGANSET BAY AND VICINITY



One of the most significant features shown in this table is that earnings per fisherman from shellfish changed only slightly from 1939 to 1965, while earnings from finfish increased six times, all during a period when shellfish prices increased much more than finfish prices. This suggests that the shellfishery in Narragansett Bay is unable to compete economically with the finfishery and that it may be declining as a significant resource use.

### DEFENSE ESTABLISHMENTS

One of the oldest uses of Narragansett Bay, and certainly the most important today from the point of expenditures, is the role of the bay in the National Military Establishments. The strategic location and excellent harbor led to its early use as a base for naval operations, and, with accommodation to the changes and innovations of modern warfare, so it remains today. Located at Newport, where important fleet units and academic activities are based, and at Quonset Point (North Kingstown), the U.S. Navy in Rhode Island is the largest single employer in the State and produces the highest level of dollar output directly attributable to the bay.

About 90 percent of the U.S. Navy expenditures in the Narragansett Bay area are paid as wages and salaries to civilian and military personnel. Substantial sums are also expended annually on contract construction, maintenance and repair, utilities and purchases from local merchants. Finally, direct payments are made by the Federal Government (in lieu of taxes) to school districts enrolling children of military personnel.

Table IV.3.8 shows the contribution of the Naval Establishment to the bay economy and the growth of this contribution between 1963 and 1967.

In spite of the size of the Navy operation, there are only two areas of conflict between the military and other bay uses. These are problems created by sewage disposal and problems from oil pollution. The shore installations of the Navy in Narragansett Bay are either served by sewage disposal facilities on a par with those in the surrounding communities or share, on a user-charge basis, with surrounding communities in disposal facilities which meet the approval of the Rhode Island State Board of Health. The sewage pollution problems that do exist are associated with the discharge of untreated wastes from oceangoing vessels. The bay is home port for about 70 oceangoing vessels and numerous other smaller craft. Few vessels have sewage treatment facilities abroad.

TABLE IV.3.8.—SPENDING BY THE U.S. NAVY IN THE NARRAGANSETT BAY, RHODE ISLAND AREA, 1963–67

| Item | Years | |
|---|---|---|
| | 1963 | 1967 |
| Wages and salaries to civilian and military personnel [1] | | $197,274,605 |
| Local purchases of goods and services [2] | | 10,516,557 |
| Contractual construction | | 5,163,502 |
| Maintenance and repair and utilities [3] | | |
| Federal aid to impacted school districts in Rhode Island [4] | | 2,853,720 |
| Total | $124,240,000 | 215,808,384 |

[1] May be somewhat inflated because 1967 report does not separate fleet military personnel who may have been paid elsewhere. Sum also includes allowance to dependents.
[2] Includes only those sums specifically mentioned as being spent locally.
[3] Based on contracts awarded during the year, estimating most or all small maintenance and report contracts. All assumed to be with local contractors.
[4] School year 1967–68.

RECREATION

Six categories of activity are considered: swimming, boating, sport-fishing, waterfowl hunting, scuba and skin diving, and summer residences.

*Swimming*

There are State, municipal, and private beaches on the 31 miles of sandy beach in Narragansett Bay. Table IV.3.9 shows the estimated maintenance costs and intensity of use for each kind of beach.

TABLE IV.3.9.—SWIMMING BEACH USE IN NARRAGANSETT BAY, 1967

| | State | Municipal | Private [1] | Total |
|---|---|---|---|---|
| Length of beach (feet) | 3,829 | 16,150 | | 19,979 |
| Annual expenditure by owner | $100,741 | $164,979 | $119,574 | $385,294 |
| User-days | 624,000 | 642,000 | 465,000 | 1,731,000 |
| Expenditure per user-day | $0.16 | $0.26 | | $0.22 |
| User-days per foot of beach | 163 | 40 | | 87 |

[1] Value estimated from municipal.

The estimated annual maintenance cost of $385,000 is the only economic indicator available to show the value of this type of recreational use.

Public beach use in Narragansett Bay appears to be heavily concentrated in a few State beaches, and other beaches seem to have adequate space to support the swimming demand.

*Boating*

Estuaries favor recreational boating because of the relatively protected waters and variety of activities possible. Narragansett Bay, with its deep embayment and many protected waterways has been a historically prominent recreational boating area. Not all boats are registered, so that the total numbers of boats actually using the estuarine system cannot be obtained directly. In 1965, however, 10,175 recreational boats were registered in the State of Rhode Island. In addition many out-of-State boats use the Bay.

Surveys of boat owners as well as boatyard and marina operators give an estimate of annual expenditures for boating of $5.2 million based on boat operating and maintenance costs. Table IV.3.10 shows the estimated participation in boating in Narragansett Bay. This number of user-days appears excessive since it would require 25 trips of each 15,000 boats with at least five persons on each trip; it is included to show the difficulties of assembling data to establish economic values for recreational pursuits.

TABLE IV.3.10.—ESTIMATED PARTICIPATION IN BOATING, NARRAGANSETT BAY, 1965

| | Percent | Persons | Days per person | User-days |
|---|---|---|---|---|
| Boating | 28 | 168,000 | 9.5 | 1,596,000 |
| Sailing | 5 | 30,000 | 11.5 | 345,000 |
| Total | 33 | 198,000 | | 1,941,000 |

Based on estimates of a 600,000 population over 12 years of age in Rhode Island.

Source: "The 1965 Survey of Outdoor Recreation," Bureau of Outdoor Recreation, U.S. Department of the Interior, October 1967, pp. 45–52.

*Sport fishing*

Saltwater sport fishing is an extremely popular use of Narragansett Bay and adjacent waters. About 38 percent of boating time on Narragansett Bay and adjacent waters is allocated to sport fishing, and there is considerable fishing from shore. This takes place primarily in four types of areas: From bridges that cross streams feeding into the Bay or connecting the Bay with other smaller estuaries; from the breakwaters on piers that jut out into Bay; along the rocky shoreline in the southern part of the Bay; and the sandy beaches at the end of the swimming season which coincides with the fall runs of bluefish and striped bass.

It is not possible to estimate the total expenditures for sport fishermen in Rhode Island, for no reliable data are available from which to estimate their number. What is significant, however, is that a great many people engage in it, and that it is a relatively low-cost outdoors activity within the means of many.

*Waterfowl hunting*

In addition to commercial fisheries, Narragansett Bay is an important feeding and resting area for migratory waterfowl. The Bay is considered to be a relatively large unit of high quality migration and wintering habitat. The major species using the area include many highly desirable game birds.

No formal data are available on the number of hunting trips that were made annually by each purchaser of waterfowl stamps. Based on data from other Northeastern States and considering the waterfowl counts and hunting regulations, it is estimated that each hunter made about 3.5 trips per year on the average. Bag checks by Rhode Island conservation officers indicate an average kill of 0.56 birds per trip. For 1968 it is calculated that 2,507 hunters making 8,774 trips shot a total of 4,900 birds.

*Skin and scuba diving*

The popularity of this activity in Narragensett Bay has been greatly enhanced by the natural advantages which are not present in the adjacent coastal areas. The Bay's ocean front shoreline has some access ways which permit diving and spearfishing directly from shore without a boat. Most sport diving is conducted in waters shallower than 100 feet, and much of this area is within swimming distance of the shore. The Bay also attracts many sport divers from outside the State.

*Seasonal residences*

The last category of recreational use is that of seasonal residences. Seasonal residences are defined as those houses occupied generally for recreational purposes for a part of the year. In Rhode Island, most, if not all, seasonal residences are summer residences. Based on building permits for 1961–65, it is estimated that in property tax revenue alone, summer property approaches an annual value of $1 million. Although the presence of summer residents increases the municipal service loads, a significant absence here is provision for educational services, which generally comprise about 70 percent of municipal costs. Also the expenditures of the part-time residences stimulate employment and income of these towns. Accordingly, the total income resulting from the inflow of persons in seasonal residences in the bay area during the summer months is much greater than the costs incurred by municipalities in providing services to such seasonal residences. If it is assumed that 5 percent of the investment in property is expended annually to cover repairs, maintenance, and insurance, and if it is further assumed that the total assessed value of the bay summer property represents 70 percent of the actual investment, then the total assessment of $27,418,059 would represent an investment of $39,168,600 with annual expenses of $1,958,430. Adding the expenses to the tax revenues gives an estimated annual net addition to the area of $2,870,875.

### BAY TRANSPORTATION

Narragansett Bay is both an obstacle to and an avenue of commerce. The transstate movement of people and goods is blocked by the same body of water that serves as a natural well-sheltered roadway for waterborne commerce. However, the income, employment, and expenditures generated in construction, operation, and maintenance of ocean port facilities, bridges, and ferry facilities justify the inclusion of transportation as an economic factor.

The Port of Providence is Rhode Island's major port and ranks third in overall importance for the New England States. The economic impact of the port can be measured through all three categories of activities—primary, secondary, and marginal (see fig. IV.3.1). Table IV.3.11 shows estimates of economic impact of various commodities passing through the port and multiplier factors from a nationwide study of the Maritime Administration.

TABLE IV.3.11.—ESTIMATES OF ECONOMIC IMPACT OF VARIOUS COMMODITY TYPES PASSING THROUGH THE PORT OF PROVIDENCE, R.I., 1968

| Type of cargo | Volume [1] (short tons) | Income production [2] per ton | Total impact |
|---|---|---|---|
| General | [3] 509,353 | $18.46 | $9,402,656 |
| Tanker (crude or refined) | 8,280,954 | 4.38 | 36,270,579 |
| Coal | 416,391 | 3.02 | 1,257,501 |
| Total economic impact | | | 46,930,736 |

[1] Waterborne Commerce of the United States, calendar year 1966, Op. Cit., p. 26.
[2] From correspondence with Chief, Division of Ports and Systems, Office of Maritime Promotion, Maritime Administration, U.S. Department of Commerce, dated Sept. 27, 1968.
[3] Includes: 156,611 short tons of iron and steel scrap; 183,506 short tons of building cement.

Table IV.3.12 shows the construction of the port in terms of marine-related employment. This table emphasizes the importance of the marginal activities.

The value of port improvement in facilities and navigational aids must also be considered. Where cargo facilities are concerned, past expenditures in the Port of Providence may be considered normal, given the size of the port and the complex of facilities for general or specialized cargo handling. Based on an estimated straight line depreciation over a 17-year period, the average addition to the value of the port is approximately $235,000 annually.

The value of channel improvements is more difficult to assess. With expenditures totaling only 4 million over the lifetime of the various rivers and harbors projects up to 1963, this amount may largely be written off. In essence, this assumes the income effects of these expenditures do not significantly add to the value of the port. On the other hand, the much greater amount of investment in 1967, a $14.3 million dredging project over a shorter period of time, will affect the economy of the port community. Since this dredging is to enable the port to handle the newer deeper draft vessels, it is necessary to prevent port obsolescence. Again, using a 50-year straight-line depreciation an average annual charge would amount to $268,000.

TABLE IV.3.12.—NUMBER OF FIRMS, AVERAGE ANNUAL EMPLOYMENT, AND TOTAL WAGES AND SALARIES FOR 1965 MARINE RELATED OCCUPATIONS IN RHODE ISLAND (COVERED EMPLOYMENT)

| | Number of firms | Average employment | Total wages |
|---|---|---|---|
| Deep sea, foreign transportation | 2 | 3 | $5,252 |
| Deep sea, domestic transportation | 1 | 7 | 65,184 |
| Local water transportation (ferries, lighterage, towing, and tugboat service, other not elsewhere classified) | 4 | [1] 41 | 481,880 |
| Services incidental to water transportation (piers and docks, stevedoring, water transportation services, not elsewhere classified) | 36 | 248 | 1,183,772 |
| Total | 43 | 299 | 1,736,088 |

[1] Includes Jamestown Ferry operation (approximately 30 employees $400,000 annual wages).

Source: Records of the Rhode Island Department of Employment Security.

In addition to the commercial shipping aspects of transportation, the impact of toll bridges must be considered. There are three toll bridges, the Jamestown Bridge from North Kingston to Connecticut Island, the Mount Hope Bridge from Bristol to Portsmouth, and the Newport-Jamestown Bridge, which will replace the ferryboats. The Jamestown Bridge will become toll free in 1969 when its bonds are redeemed. The Mount Hope was built in 1929 and its outstanding bonds were retired in 1964. Tolls will continue to be collected until the Newport-Jamestown Bridge is paid off. The Newport-Jamestown Bridge is scheduled to open in 1969. The bridge is being built at an estimated cost of $60 million.

Table IV.3.13 shows a résumé of the value of transportation to the Narragansett Bay area.

TABLE IV.3.13—*Annual dollar impact of transportation, Narragansett Bay*

| *Item* | *Impact* |
|---|---|
| Port of Providence | $47,200,000 |
| Jamestown Ferry | [1] 740,000 |
| The Bridges: | |
| Jamestown-North Kingston | 233,000 |
| Mount Hope | 190,000 |
| Newport-Jamestown | [2] 1,200,000 |
| Total impact | 49,563,000 |

[1] Discontinued after 1969.
[2] Based on straight line depreciation of 50-year amortization period.

*Marine-oriented industry and commerce*

A survey conducted in 1965–66 showed 75 marine-oriented firms located around Narragansett Bay in addition to marinas and boatyards. The firms are involved in such activities as ship and boat building, marine electronics, sail making, and fishnet construction. At the time of the survey, these firms employed 4,251 people and had annual cash flows of $60,006,000. The revenue breakdown is shown in table IV.3.14.

TABLE IV.3.14.—*Cash flow for marine-oriented industry and commerce, Narragansett Bay, 1965–66*

| *Item* | *Amount* |
|---|---|
| Purchases from local marine firms | $1, 289, 229 |
| Purchases from local nonmarine firms | 4, 742, 454 |
| Wages, salaries, interest, profit, and rent | 39, 031, 502 |
| Local taxes | 210, 921 |
| Federal taxes and purchases outside area | 14, 731, 894 |
| Total | 60, 006, 000 |

*Research and education*

The area around Narragansett Bay is the base for considerable research and education in the marine sciences. These are primarily State and Federal programs even though some education and research activity take place in marine-oriented commercial firms. The investment in and expenditure for marine-oriented educational activities in the bay area is steadily expanding. On a dollar ranking basis, the Navy is first with various programs at the University of Rhode Island closely following. For research the same situation exists insofar as growth and dollar ranking. Table IV.3.15 gives a summary of estimated expenditures on research and education.

TABLE IV.3.15.—*Estimates for expenditures for research and education on or connected with Narragansett Bay, Rhode Island, 1967–68*

| *Activity* | *Research and education* |
|---|---|
| U.S. Navy: | |
| Naval Schools Command | $17, 328, 879 (Naval Schools Command, Naval Destroyer School, Naval War College combined) |
| Naval Destroyer School | |
| Naval War College | |
| Naval Underwater Weapons Research and Engineering Station | 13, 146, 662 |
| U.R.I.: | |
| Graduate School of Oceanography | 2, 322, 000 |
| Department of Fisheries and Marine Technology | 150, 000 |
| Other U.R.I.[1] | 513, 000 |
| Department of Ocean Engineering | 375, 000 |
| Miscellaneous: | |
| Narragansett Marine Gamefish Laboratory (USDI) | 120, 600 |
| Northeast Marine Health Sciences Laboratory (USPHS) | 560, 000 |
| National Marine Water Quality Laboratory (USDI) | 786, 000 |
| R.I. State Atomic Reactor | 222, 694 |
| R.I. Marine Fisheries Station | 186, 000 |
| Total | 35, 710, 835 |

[1] I ncludes expenditures under the Sea-Grant Program and marine activities not elsewhere classified

Marine-oriented research and educational activities on the Narragansett Bay area have little conflict with other uses of the bay. They exact no particular social costs in the form of unfavorable effects on the bay environment and are income producing. Areas of greatest economic impact are under supervision of the Military Establishment and are subject to the changing dictates of national military policies.

*Waste disposal*

It is estimated that approximately 150 million gallons per day (m.g.d.) of liquid wastes flow into Narragansett Bay through municipal sewer systems or treatment plants. At the beginning of 1969, 20 percent of these wastes received primary treatment, 70 percent received secondary, and 1 percent received tertiary treatment. The remaining undetermined amount of wastes are either discharged untreated into the bay or to individual treatment systems such as septic tanks where the effluent may eventually seep or leak into the bay.

The tidal action in the bay and the bay itself are in fact part of the waste disposal process. With two exceptions—harvesting of shellfish and to a lesser degree contact recreation—this use of the bay for waste assimilation is compatible with other uses at the existing levels of waste treatment.

The capability of the bay to assimilate waste products is a valuable economic asset. Its worth can be estimated either in terms of the increased value of the system for other uses or in terms of increased costs for waste treatment if the bay could not be used for this purpose.

The only real economic damage to bay resources by waste disposal is the prohibition of shellfish harvesting in certain areas. This is a damage to the commercial shellfish industry rather than to the shellfish themselves since the closures are a matter of public health considerations and not habitat damage. If the areas presently barred to commercial shellfishing were opened, the value of the current commercial crop might increase by as much as $1 million, assuming that there is this much additional economic demand for the product.

If the bay could not be used for disposal of partly treated wastes it would be necessary to dispose of them to the ocean or else provide advanced waste treatment. Based on the alternative costs of these two disposal methods, the waste assimilation capacity of Narragansett Bay has an annual economic value of $6 to $8 million.

*Total economic value of Narragansett Bay*

Table IV.3.16 summarizes annual economic activity caused by Narragansett Bay, R.I.

The accounting is incomplete in the sense that no attempt has been made to include imputed "values" or expenditures per user-days for various recreational activities, notably swimming, hunting, skindiving, and spearfishing. The expenditures incurred in these activities were not included, for in none of the four cases were not included, for in none of the four cases were both expenditures per participant and the numbers of participants known. Also it was not possible to derive adequate estimates of the value the bay contributes to the people of Rhode Island through its effect on environmental quality. This includes air temperature modification, open scenic space, and open space for low land aircraft approach and take off. These features, which have been omitted from the calculations, are unquestionably very valuable.

TABLE IV.3.16.—ESTIMATED ECONOMIC ACTIVITY AND PERSONAL INCOME GENERATED BY PRIMARY EXPENDITURES ASSOCIATED WITH NARRAGANSETT BAY, RHODE ISLAND 1967–68[1]

| Activity | Primary expenditures[3] | Economic Activity Generated[1] Multiplier | Total | Multiplier | Personal income |
|---|---|---|---|---|---|
| U.S. Navy | $215,808,384 | 2.73 | $589,156,888 | 1.22 | $263,286,228 |
| Marine industry | 60,006,000 | 2.37 | 142,214,220 | .95 | 57,005,700 |
| Transportation | 49,563,000 | 1.00 | [2] 49,563,000 | .64 | 31,720,320 |
| Waste disposal | 6,200,000 | 1.69 | 10,478,000 | 1.29 | 7,998,000 |
| Research and education | 5,235,294 | 1.95 | 10,208,823 | .62 | 3,245,882 |
| Boating (services) | 3,815,788 | 2.76 | 10,531,574 | .94 | 3,586,840 |
| Summer housing | 2,870,875 | 2.35 | 6,746,556 | .78 | 2,239,282 |
| Commercial fishing | 2,207,855 | 2.96 | 6,535,250 | 1.18 | 2,605,268 |
| Swimming | 385,294 | 2.68 | 1,032,587 | .96 | 369,882 |
| Total | 346,092,490 | | 826,466,898 | | 372,057,402 |

[1] For multipliers see: Rorholm, Lampe, Marshall, and Ferrell "Economic Impact of Marine Oriented Activities—A Study of the Southern New England Marine Region." Economics of Marine Resources No. 7, University of Rhode Island, Kingston (1967).

[2] The "primary" figure here is based on a multiplier value, hence no additional multiplier effect is present.

[3] The "primary expenditure" here is actually an opportunity cost (see the appropriate section). The multiplier that has been used is that computed for "Households" since the saving occurrs in household expenditures.

Spending generates income and further spending. Multipliers developed in an earlier study have been used to estimate the extent to which the $346 million primary expenditure generates further economic activity and personal income in the area. It is estimated that primary expenditures generate a total transaction of $826,466,898 of which over $372 million is personal income in the form of wages, salaries, profit, interest, and rent. The latter figure may also be thought of as the local value added. The total transactions generated are about 23 percent of the gross State product for Rhode Island which was estimated at about $3.5 billion in 1964. The $372 million personal income is about 13 percent of total personal income in the State in 1967 which was estimated at $2.9 billion.

Narragansett Bay gives an example of an estuarine-oriented economy which has grown up in an unorganized fashion as economic and social pressures dictated. The major contributing monetary factor is the expenditures of the U.S. Navy, which account for nearly two-thirds of the economic activity generated in the Narragansett Bay area. The least significant economic use is commercial fishing, accounting for less than 1 percent of the economic activity.

An estuary such as Narragansett Bay, through its effect on the physical environment of the surrounding area, bestows a certain value on this area. This is the only "output" of the bay which does not require combinations of labor and capital added to the bay itself. To be sure, it may be possible to increase this output or effect by certain man-made modifications, but since the evaluation of our environment is to a large extent subjective, one cannot always be sure that net results of man-made modifications are, in fact, positive.

There are two kinds of specific environmental effects involved:

(1) Climatic effects. Weather data indicate that the bay lowers the mean maximum summer temperature in Providence as much as 4 degrees through the way the bay channels the afternoon sea breezes inland from the ocean. Similarly the water gives off its stored heat at a slower rate than does the land resulting in some modification of mean low winter temperatures. This can be ob-

served on numerous occasions when the coast will experience sleet or rain while it will be snowing and drifting some miles inland.

(2) Open space. Open space serves a number of purposes in and around urban areas, all of which are difficult to quantify. There is no doubt, however, that the upper bay and Providence River north of Conimicut Point, as well as the Barrington and Warren Rivers, provide the surrounding communities with open space which they otherwise would have had to provide in the form of parks or other open areas in order to keep the kind of environmental quality now given free by these waters. The open space provided by the bay also serves as low-level flight space for approach and takeoff at the Quonset Point Naval Air Station, saving the community a great deal of noise pollution and a resultant drop in property values.

The general effect of open space on residence values has been observed frequently. It is commonly accepted that property values increase markedly as a park or other open area is approached. The same is the case as one approaches the shoreline, even if the water itself is not usable at that particular location. If higher prices are paid for property on a shore which is not suitable for either boating or swimming, then this value must be caused by the marine environment in general.

The discussion of Narragansett Bay has been almost entirely from an economic viewpoint. Such discussions are necessarily limited to calculations based on individual values, and cannot consider the value of the general marine environment. This can be established only from the attitudes of an entire community to the estuarine resource.

### APALACHICOLA BAY (IV–3–2)

Apalachicola Bay, located in Florida off the Gulf of Mexico, provides a direct contrast with Narragansett Bay. This is important not only in illustrating the diversity of uses to which estuaries currently are put, but also inproviding a basis for evaluating an estuary's socioeconomic situation on a different, and possibly more meaningful, basis.

Apalachicola Bay, unlike Narragansett Bay, is not a berthing place for military vessels and, accordingly, does not have the type of economy which is a significant military complex engenders. Nor is the coastal estuary a commercial port of importance. Rather, studies have shown the present and potential importance of commercial fishing, recreation, and tourism to this estuary.

*Commercial fisheries*

The economic base of Franklin County, Fla., the land area upon which the bay is located, is unusually narrow. Dependence on commercial fishing and on the processing and export of seafood from the county is so great that serious pollution would be disastrous to its inhabitants. In November 1963, for example, about 62 percent of the employment in Franklin County was related directly or indirectly to the oyster industry. Direct employment is made up of jobs as tongers and workers in shore installations, while indirect employment consists of a variety of middleman functions related to the industry. This is only a partial view, however, of the importance of unpolluted water to the economy of Franklin County. Employment, direct and indirect, associated with other types of seafood—to the extent that the catch is made in the bay or outside if the bay was the "nursery"—and much of the employment based on tourism is attributable to adequate pollution control.

As an initial step in determining the economic value of Apalachicola Bay, value and qantity statistics have been assembled for finfish and shellfish landings.

Table IV.3.17 summarizes these figures for the 4 years, 1964 through 1967, for which complete data are available. Separate statistics are presented for oysters, shrimp, crabs, and finfish. Some shellfish are included with the finfish but in no year do they amount to more than 1 percent of the total quantity or value figures for finfish.

TABLE IV.3.17.—FISH AND SHELLFISH LANDINGS AND VALUES, APALACHICOLA BAY, 1964–67

| Species | 1964 | | 1965 | | 1966 | | 1967 | |
|---|---|---|---|---|---|---|---|---|
| | Catch (pounds) | Value (dollars) | Catch (pounds) | Value (dollars) | Catch (pounds) | Value (dollars) | Catch (pounds) | Value (dollars) |
| Oysters [1] | 1,415,600 | 396,368 | 1,380,500 | 463,301 | 2,191,100 | 673,562 | 2,404,800 | 730,578 |
| Shrimp [2] | 704,100 | 129,861 | 202,500 | 52,396 | 271,800 | 75,143 | 138,000 | 35,501 |
| Crabs [3] | 552,500 | 38,078 | 935,700 | 51,082 | 610,100 | 30,501 | 675,400 | 36,668 |
| Finfish | 1,887,300 | 134,713 | 1,614,100 | 129,372 | 937,600 | 82,571 | 432,600 | 58,159 |
| All species (total) | 4,559,500 | 699,020 | 4,132,800 | 696,151 | 4,010,500 | 861,777 | 3,650,800 | 860,906 |

[1] Shucked weight.
[2] "Heads-off" weight.
[3] Live weight.

Source: Apalachicola Office, Fish and Wildlife Service, U.S. Department of the Interior.

The 4-year totals show a total catch of 16,353,600 pounds, valued at $3,117,854, for Apalachicola Bay. During the period, there was a significant increase in oyster landings and value accompanied, conversely, by a large decrease in shrimp catch over the period.

It should be recognized that the landings (fisherman's) value represented only a part of the total value of the fishing industry. For Franklin County (Apalachicola) oysters for example, the final value averaged four times the amount paid to the fisherman (and dependent upon the final form in which the oysters were sold, this multiple could exceed seven times the fisherman's value).

In 1967, wholesale prices of oysters fluctuated between $4.50 and $6.50 (per gallon, shucked) for standard oysters and between $5.50 and $7.50 for select oysters. The markup to truckers ranged from $1.75 to $2.00 per gallon during the year averaging $1.50 per gallon to dealers. All of the available information lends support to the conclusion that the final value of the oyster industry is about four times the fishermen's value. For 1967, this total amount would be $5,098,860.

The total value of shrimp landings in Franklin County in 1967 was $431,018. However, all the landings were not directly related to the Apalachicola River and Bay. Significantly, the shrimp caught in the gulf areas nearest the Apalachicola River and Bay are more closely related to the estuary and it has been estimated by oceanographers that approximately 90 percent of all of the shrimp caught in areas close to the bay were originally inhabitants of the estuary which served as a "nursery" for these shrimp, a reflection of the economic value of estuaries which is not always recognized.

To illustrate the commercial fishery value of the estuaries further, shrimp prices (with head off) averaged $0.92 per pound in 1967. Of the final retail average of $1.30 per pound, 5 cents per pound represented the wholesaler's markup with the remaining 33 cents being received by the retailer. With the conversion factors provided by the price data it can be estimated that the total retail value of the shrimp landings attributable to the Apalachicola estuary is approximately $471,260.

Table IV.3.18 contains the projects of the annual fishery landings values attributable to the estuary. Projects are made for the years 1975, 1980, and 2000. Because oysters and shrimp are highly income elastic products, the value of their production should increase at a rate at least equal to that of the national income. This of course assumes no unusually extreme shifts in supply. A rate of 4 percent has been compounded to the base years to approximate the future values of oyster and shrimp landings.

Finfish and, to a lesser extent, crabs have a much lower income elasticity. Thus, a growth rate of only 2 percent has been used in extending their values forward to the years cited in the table. Again supply variation and/or changes in processing methods can affect estimates. For example, an increased use of fishery products as a source of protein for underdeveloped countries would have an impact on the demand side.

This material reinforces the contention that simple values of fishery landings are a totally inadequate measure of the "true value" of the fishery resources involved. Only by studying both the values added in production and the income generated by the income multiplier can a realistic estimate be made.

TABLE IV.3.18.—PROJECTIONS OF THE ANNUAL VALUE OF APALACHICOLA ESTUARINE RELATED LANDINGS [1]

| Species | 1967 | 1975 | 1980 | 2000 |
|---|---|---|---|---|
| Oysters | $5,098,860 | $6,975,240 | $8,489,602 | $18,600,641 |
| Shrimp | 471,260 | 644,633 | 784,648 | 1,719,156 |
| Crabs | 285,452 | 334,264 | 369,089 | 548,639 |
| Finfish | 576,981 | 675,645 | 746,036 | 1,108,957 |
| All species | 6,432,553 | 8,629,832 | 10,389,375 | 21,977,393 |

[1] Values are in terms of final retail values.

*Value of tourism and recreation*

A great deal of the economic value of clean water in Apalachicola Bay derives from its attraction to tourists. Salt and fresh water fishing, swimming, water skiing, surf boarding, boating, sunbathing, and gathering oysters along the shore are among the water-related tourist activities. Tourists from Alabama, Georgia, and north Florida are usually interested in water-related activities while residents of the South and other regions are more likely only to be passing through Franklin County. In order to estimate the proportion of water-related tourist stops on the mainland side of Apalachicola Bay, the economics department of Florida State University asked owners of the three largest motels in Apalachicola and Eastpoint to have all guests during July 1968 fill out a questionnaire. A total of 173 "families" comprising

480 persons filled out the questionnaire. A summary of results is shown in table IV.3.19.

TABLE IV.3.19.—REASONS GIVEN FOR TOURIST INTEREST IN FRANKLIN COUNTY, JULY 1968

| Home | Families | | |
|---|---|---|---|
| | Water-related interest | Passing through | Other |
| North Florida | 9 | 8 | 9 |
| Other Florida | 7 | 15 | 11 |
| Alabama-Georgia | 27 | 6 | 8 |
| Other South | 9 | 21 | 10 |
| Non-South | 3 | 25 | 5 |
| Total | 55 | 75 | 43 |

Table IV.3.19 pertains only to travelers stopping on the mainland. It is reasonable to assume that virtually all of the visitors to the offshore islands are there for "water-related" purposes and that the same is true for residents of cottages built alongside the gulf (such as the 150 rooms in the Wilson's Beach cottages). According to the Florida Hotel and Restaurant Commission there were 248 rooms in 18 motels and 249 rooms in the rental cottages within the county. Using the results of table IV.3.19 for the motels, and assuming that all of the guests at the cottages are "water-related" it appears for Franklin County as a whole that about two-thirds of the tourist business is related to the estuary.

The 1967 Florida Tourist Study published by the Florida Development Commission shows 5,046 automobile tourists from out of state with Franklin County as their destination. If arrivals by private planes, boats, and buses are added the figure might be in the neighborhood of 5,200. Adding the estimated number that came from Florida brings the 1967 total to 7,800 of which an estimated 5,200 are "water related." The Florida Development Commission shows the average tourist stay to be 14.8 days and the average expenditure per person per day to be $17.20. Because of the lower than average prices of accommodations in Franklin County, average expenditures of $14 per day and an average stay of 15 days appear reasonable. For 1967 this would yield a total estimate of $1,092,000. This source of income may be expected to continue in the future at least commensurate with national or regional population increases as well as other factors. It has been projected to increase to $3,571,600 in 1975; to $5,077,020 by 1980; and to $13,377,000 by the year 2000.

*Effect on local residents*

Table IV.3.20 summarizes projections discussed earlier of the actual and potential economic benefits which may be expected with proper pollution control efforts in the Apalachicola Estuary. The main source of income in 1967 was derived from the commercial fishing industry—$4,868,118—compared with $2,799,629 accruing to total incomes of fish industry sources out of Franklin County and $1,463,280 for tourism in Franklin County for a grand total of $9,131,027. With the maintenance of satisfactory conditions in the estuary's waters, by the year 2000 it is anticipated that income from tourism will increase by several magnitudes and that a grand total in excess of $44 million will be generated.

TABLE IV.3.20.—ESTIMATED ACTUAL AND POTENTIAL INCOME GENERATED NATIONALLY BY CLEAN WATER IN APALACHICOLA ESTUARY

| Source of income | 1967 | 1975 | 1980 | 2000 |
|---|---|---|---|---|
| Local income generated: | | | | |
| Seafood | $4,868,118 | $6,493,489 | $7,781,773 | $16,303,655 |
| Tourism | 1,463,280 | 4,785,944 | 6,803,207 | 17,925,180 |
| Total | 6,331,398 | 11,279,433 | 14,584,980 | 34,228,835 |
| Value added out of county: | | | | |
| Oysters | 2,549,430 | 3,487,620 | 4,244,801 | 9,300,321 |
| Shrimp | 16,967 | 23,211 | 28,250 | 61,896 |
| Crab | 95,151 | 111,422 | 123,030 | 182,880 |
| Finfish | 138,081 | 161,693 | 178,538 | 265,391 |
| Total | 2,799,629 | 3,783,946 | 4,574,619 | 9,810,488 |
| Total national contribution of Apalachicola estuary | 9,131,027 | 15,063,379 | 19,159,598 | 44,039,323 |

Estimates of economic benefits to local residents indicated in table IV.3.20 are of particular importance to the area because its present relatively low economic status indicates the local population is unable to better itself economically from pursuits other than those related to the estuary. However, in addition to the economic improvement which may be anticipated locally, consideration also should be given to the recreational advantages afforded by the estuary to local citizens. It is reasonable to expect that a direct relationship exists between socioeconomic level and the distance which the members of the population will travel to fill their recreational needs; that is, the lower a person's income the shorter distance he is likely to travel for purposes of recreation. Therefore, even with the increasing mobility which Americans have experienced in the last several decades, there is no question but that availability of adequate water recreational facilities near the local population is of incalculable benefit to those local citizens. These benefits can be expected to increase with the shortened workweek predicted for the future as well as the increase in economic well-being projected for the population with ready access to the Apalachicola Estuary.

### SAN DIEGO BAY (IV-3-3)

The San Diego area is an example of the multiple uses and development of an estuarine system. The basic development and growth of San Diego is attributable to the military uses of its deepwater estuary. However, later diversification of the economy into areas of manufacturing, trade, tourism, and education has made the area less dependent upon a single use of the estuary. In fact the relative value of the estuary to the entire population is shifting toward recreation and aesthetic values. Indications of the value of these recreational pursuits and aesthetic pleasures to the general populace can be found in the estimated over $2 million they are willing to spend annually to prevent pollution of the bay by municipal sources.

The San Diego study does not provide a complete economic accounting analysis of the estuary's total value but it does give some estimates of the various components of the area's economy. Also, there are estimates of the costs of abating bay pollution from municipal sources and estimates of the monetary benefits resulting from such pollution abatement.

*Description of the study area*

*Statistical study areas*

For purposes of the technical analysis, bay-related land has been divided into three geographic areas. Study area I consists of virtually all land immediately adjacent to and surrounding the bay extending approximately 4 to 8 miles inland from the Pacific Ocean. Study area II lies immediately adjacent to area I and extends approximately 15 additional miles inland. Study area III includes the balance of the county.

*General description—San Diego County*

San Diego Bay lies in the southwestern corner of the United States. It is the prime economic factor in the development of San Diego County which surrounds it. The county, which corresponds to the San Diego Standard Metropolitan Statistical Area, is bordered on the south by Mexico, on the east by Imperial County, on the north by Riverside and Orange Counties, and on the west by 70 miles of Pacific Ocean shoreline. It is approximately 80 miles wide and encompasses 4,258 square miles (fig. IV.3.3 on p. 174).

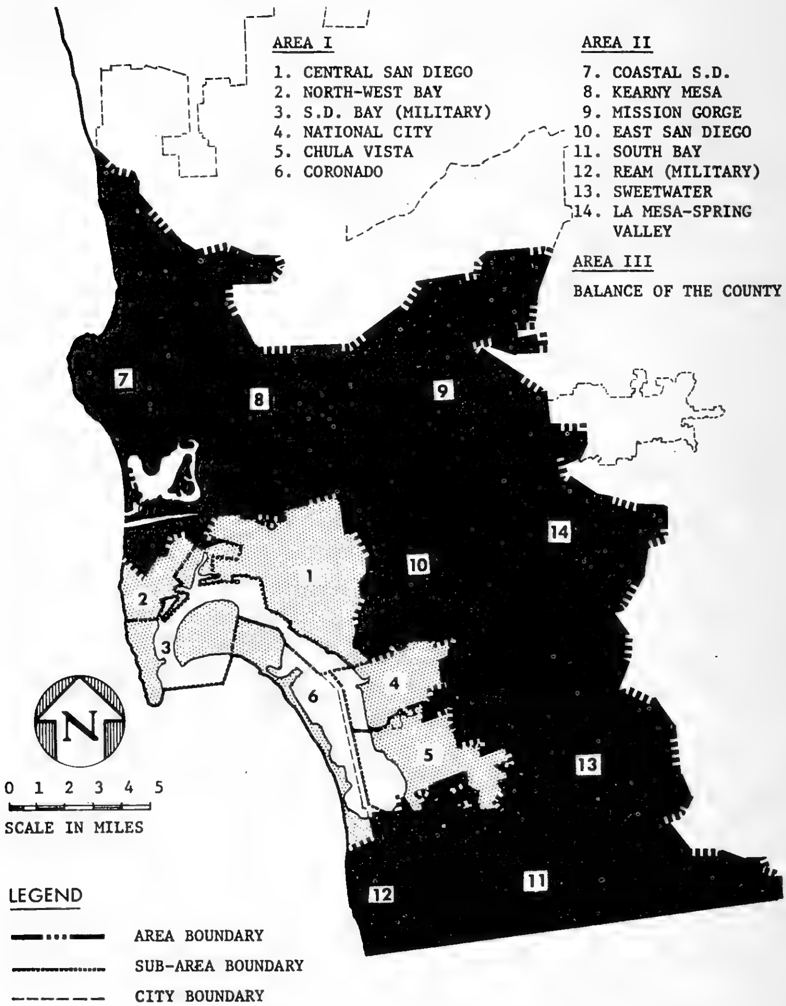
The entire San Diego area has many valuable natural features, but the one of greatest influence and value is San Diego Bay. The bay is crescent shaped, approximately 15 miles in length, varies in width from one-quarter to 2½ miles, and has a surface area of approximately 18.5 square miles. It is protected on the west by the high ground of Point Loma and is separated from the Pacific Ocean by a narrow sand spit called the Silver Strand. North Island, once an actual island, forms the northern end of the Silver Strand.

San Diego Bay is one of the great natural harbors of the world. Four cities and three naval military facilities line its shoreline: the city of San Diego in the north, east, and south; National City and Chula Vista on the eastern shore south of San Diego; Coronado along the western edge of the bay; North Island Naval Station occupying the western half of North Island; the Marine Corps Depot across the bay to the north; and San Diego Naval Station along the northeastern shore of the bay. The city of Imperial Beach lies just south of the bay on the Pacific coast, 3 miles north of San Diego Bay and on the coast is Mission Bay, 22 years ago, Mission Bay was a tidal mudflat. Extensive development, which is still continuing, has converted it into an attractive recreational waterland.

Approximately 369,000 civilians are gainfully employed in San Diego County. The county's economy, which once depended primarily on the military and the aircraft-aerospace industries, has experienced considerable diversification. Today, other major contributors to the economy are shipbuilding, manufacturing, tourism, education, agriculture, and construction.

Government agencies comprise the largest civilian employment category in San Diego County. In 1967, 83,500 persons were in Government services. This is an increase of over 47.7 percent since 1960. There was a similar increase in the number of persons employed in service industries. Public employment other than in the defense sector is expected to increase in proportion to the increase in the population of the county.

FIGURE IV.3.3 SAN DIEGO BAY STUDY AREAS AND SUB-AREAS



Today the U.S. Navy has modern facilities, equipment, training camps, research laboratories, and a total naval personnel of approximately 170,000 persons. An estimated 215,000 dependents of these 170,000 naval men live in San Diego County. The majority of the 100,000 shore-based military personnel are based at San Diego installations or Camp Pendleton. Additional naval personnel are based at the Ream and Miramar Naval Air Stations.

*Density*

Approximately 73 percent of the county's civilian population lives within 20 miles of San Diego Bay. Study area I, adjacent to the bay, and with less than 1 percent of the county's total land area, has approximately 19 percent of the civilian population; Study area II, immediately adjacent to study area I with 6.9 percent of the county's nonmilitary land area, has 52 percent of the civilian population. In other words, the population is more concentrated towards the bay, and population density is inversely proportional to the distance from the bay. Figure IV.3.4 on page 176 shows the anticipated population growth of the three areas.

*Municipal wastes*

By the mid-1950's wastes discharges into San Diego Bay began to exceed the assimilative capacity of the waters. In late 1960 local voters passed a $42.5 million bond issue for the construction of new waste treatment facilities. As a result of the new facilities, no domestic wastes have been discharged to San Diego Bay since 1964. All sewage is now collected and pumped to the treatment plant from which it is discharged into the Pacific Ocean.

Table IV.3.21 shows the estimated annual dollar costs and benefits involved in the bay cleanup. Annual costs of debt service, and operation and maintenance of the facilities range from $2.3 million in fiscal year 1967–68 to a projected $3.3 million in the year 2000. These estimated costs have been adjusted to exclude costs not borne by the local residents or those costs not exclusively associated with bay cleanup. In other words, debt service costs associated with the Federal contribution for construction have been excluded along with those costs required whether the wastes are disposed of in the bay or in the ocean.

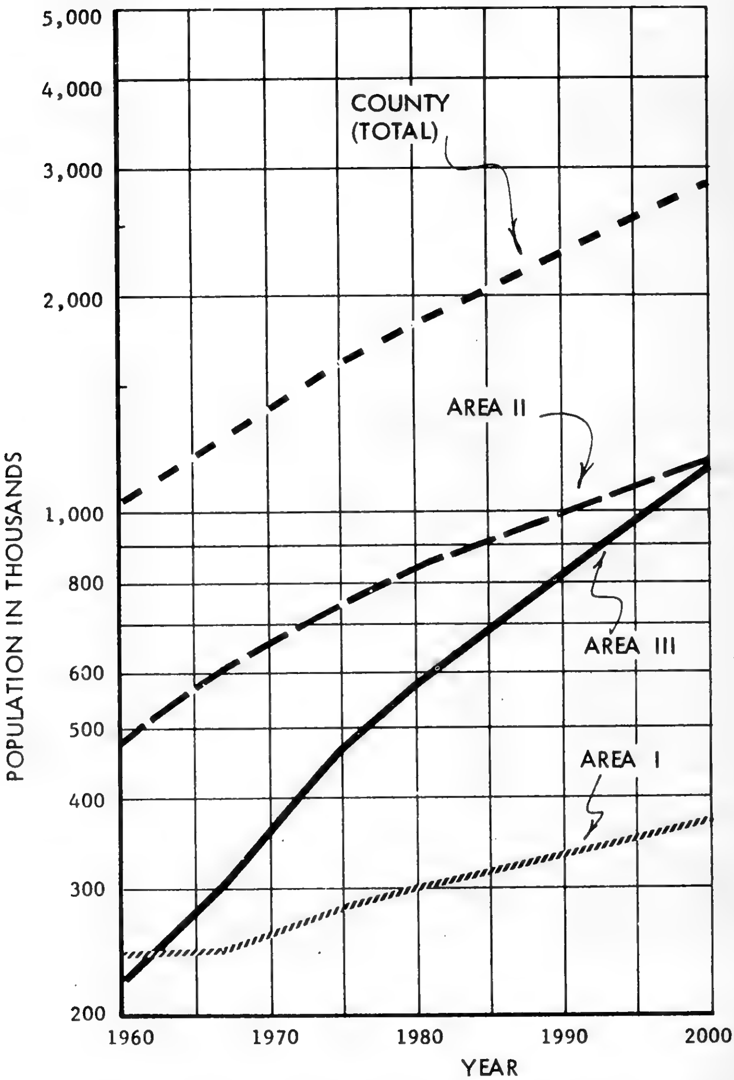
TABLE IV 3.21.—ANNUAL COSTS[1] OF AND DIRECT RECREATIONAL BENEFITS RESULTING FROM ABATEMENT OF MUNICIPAL POLLUTION SAN DIEGO BAY CLEAN-UP

[Amounts in dollars]

| | Fiscal year 1967–68 | 1975 | 1980 | 2000 |
|---|---|---|---|---|
| Bay cleanup costs | 2,312,000 | 2,613,000 | 2,848,000 | 3,296,000 |
| Recreational benefits: | | | | |
| Beach activities/swimming | 2,294,000 | 2,837,000 | 3,225,000 | 4,776,000 |
| Water skiing | 387,000 | 484,000 | 553,000 | 830,000 |
| Sailing and canoeing | 155,000 | 194,000 | 222,000 | 333,000 |
| Power boating | 2,165,000 | 2,763,000 | 3,190,000 | 4,899,000 |
| Fishing and wildlife sports | 1,000,000 | 1,160,000 | 1,274,000 | 1,729,000 |
| Naval use (amphibious and other water contact training) | (2) | (2) | (2) | (2) |
| Total | 6,001,000 | 7,438,000 | 8,464,000 | 12,567,000 |

[1] Includes debt service, operation, and maintenance. Excludes construction costs required whether wastes are discharged into the bay or the ocean, also excluded debt service costs on Federal share of construction costs.
[2] None available.

**FIGURE IV.3.4 SAN DIEGO COUNTY POPULATION GROWTH BY STATISTICAL AREA**




PRIMARY SOURCE: REGIONAL GENERAL PLAN, SAN DIEGO COUNTY 1990.

Benefits shown in table IV.3.21 are those directly attributable to water related recreational activities. Estimated direct recreation benefits range from $6 million in 1967–68, to $12.0 million in the year 2000. These benefits are restricted to recreational aspects only and do not include the impact of money spent for recreation on the associated parts of the economic system.

*Economy*

*Military*

The U.S. Navy and Marine Corps contributed $1.2 billion to the economy of San Diego County in 1967. This was an increase of 17 percent over 1966. Major factors in the increase were greater military construction, the Vietnam war buildup, and an increasing number of dependents and retired military men moving into the county. As described previously, an estimated 170,000 naval men and Marines are stationed at military facilities in San Diego County. An estimated 173 Navy ships are based in San Diego. On an average, 90 Navy ships operate out of San Diego harbor every day. The Navy spends approximately $300 million to support these ships and the several other naval commands in the community. For utilities (gas, electricity, water, phone) alone, the Navy spends more than $7 million every year. The Navy also employs civilian, civil service employees, and blue collar workers who received compensation of $201.8 million in 1967. Military construction in San Diego County averages more than $20 million annually.

*Commercial/industrial*

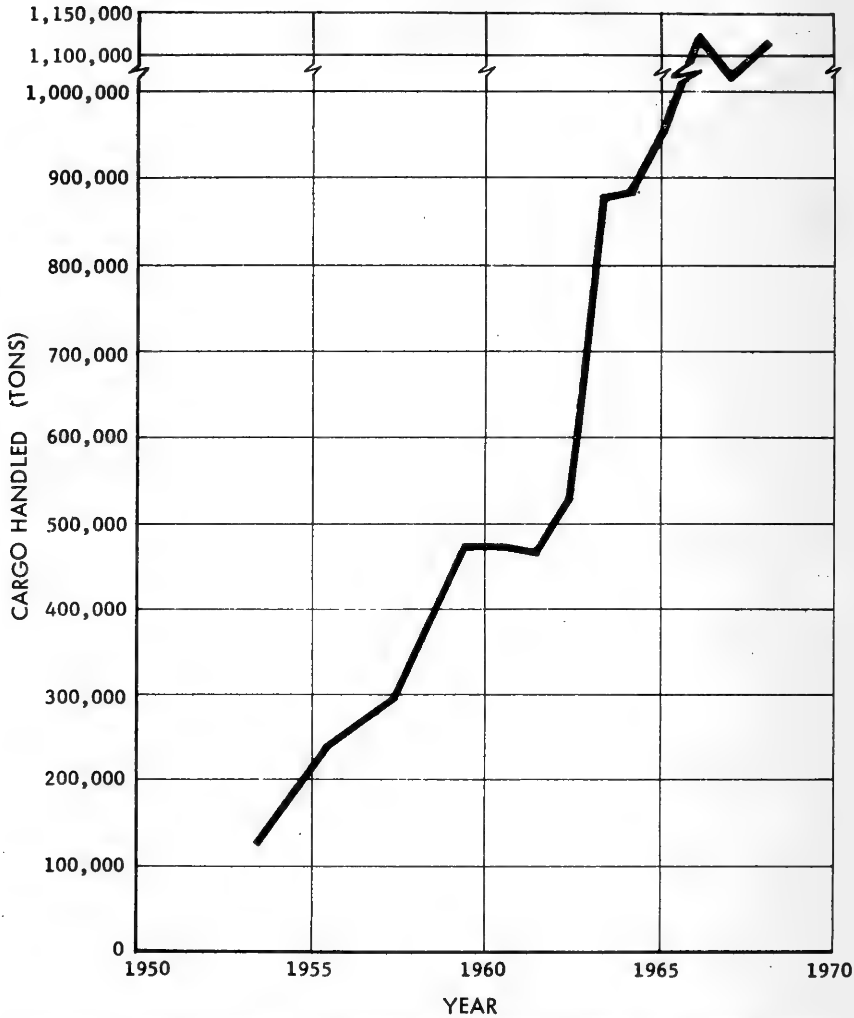
*Maritime commerce.*—The continually expanding growth (figure IV.3.5, p. 178) of the maritime industry's use of San Diego as a harbor necessitates the construction of a new terminal every 10 years.

For fiscal year 1967–68, Marine terminals reported a total revenue tonnage via port of San Diego of 1,107,060 tons. The total value of cargo was $269.3 million, including bunker fuels. Inbound cargo was valued at $203.3 million, and outbound at $65.6 million. The largest single import category was toys and novelties with a value of $38.3 million; second largest item imported was textile and clothing valued at $30.2 million. The largest export category was household goods with a value of $15.2 million; the second largest category among export goods was transportation equipment and machines valued at $13.1 million. In terms of tonnage, however, lumber had the greatest import tonnage, and potash the greatest export tonnage.

*Shipbuilding.*—The shipbuilding industry provides employment for five times as many workers today as it did less than 20 years ago. The current labor force of almost 4,000 workers is expected to increase to 6,750 by the year 1990. This increase would, however, represent no change in the industry's percentage of the total San Diego County labor force, and is expected to remain constant at 1 percent. The economic value of shipbuilding has grown from $6.5 million in 1950 to $91.7 million in 1967.

Some 20 shipbuilding and repair firms scattered throughout the bay conduct operations ranging from the construction and repair of large vessels to alterations on small fishing boats. Commercial shipbuilding and repair operations have increased as the result of the clos-

FIGURE IV.3.5 TONNAGE SERVICED BY THE SAN DIEGO PORT




SOURCE: SAN DIEGO BAY, CALIFORNIA. A REVIEW, BENEFICIAL USES, WASTE DISPOSAL PRACTICES, WATER QUALITY; IRVING TERZICH, 1965.

ing of the U.S. naval repair facility in 1964. The building and repair of naval vessels is now a major industry using the bay as a resource.

*Fishing.*—San Diego Bay services the world's largest annual tuna catch. It is estimated to represent approximately 45 percent of the total world catch and to have a value of $21.7 million. The number of persons annually employed in fishing in the San Diego area has decreased by almost half since 1950, from 2,050 to 1,100. This is expected to remain stable at approximately 1,300 for the projected years of 1975, 1980, and 1990. The fishing industry now provides about 0.2 percent of the county's employment.

Fish canneries in the San Diego Bay area are primarily engaged in the processing of tuna caught by a 100-boat fleet operating out of the bay. More than 4 million cases are processed annually by the five canneries located in the area. Thawing and fluming of fish is done on the bay shore.

San Diego Bay serves as a refuge, feeding, and nursery area for fish. As such, it effectively influences the fishery resources of the surrounding ocean. Approximately 100,000 persons, 80 percent from out of town, fish from commercial fishing boats which operate out of San Diego Bay.

*Fish and animal reduction.*—In fish and animal reduction, solid and liquid wastes from fish canneries and solid wastes of animal origin are processed for oil and grease. The remaining solids are dried and converted to chicken feed.

Animal entrails originally washed with bay water are now flushed with fresh water; however, a cooker and drier fumes washer is operated with water from San Diego Bay.

*Kelp.*—There is an abundant supply of kelp in Pacific Ocean offshore waters. Its chief value is as a source of iodine. The San Diego Bay area is a natural location for the kelp-processing industry.

*Chemical industry.*—The San Diego unified port district operated an oil separation unit at its 10th Avenue marine terminal for processing ballast and bilge water of ships using district facilities. The unit has a capacity of 1 million gallons per day, but has been used intermittently and far below its capacity.

*Manufacturing.*—Manufacturing is the largest civilian, nongovernmental component of the economy of San Diego County. It is largely dependent on aircraft and ordnance production. In 1967, 32,200 of the county's 61,700 manufacturing employees (or slightly over 50 percent) were in aircraft and ordnance. The total manufacturing payroll for 1967 was over $496 million.

*Trade (wholesale and retail).*—In 1967, total annual wages in the trade-industrial category were approximately $339 million, or 24 percent of the total San Diego County civilian payroll. From 1960 to 1967, the wholesale-retail trade payroll increased 151 percent, with the greatest increase occurring between 1965 and 1967. Trade represents the second largest civilian payroll category in San Diego County.

*Tourism.*—The third largest industry in San Diego is tourism. Estimated total visitor expenditures have increased approximately 50 percent between 1960 and 1967, with the sharpest rise occurring during the 1965 to 1967 period. In addition to bay cleanup, opening of the San Diego Convention Center in 1965 undoubtedly influenced this increase.

In 1967, 446 conventions met in San Diego and contributed approximately $42.5 million to the area's economy. It has been estimated that each delegate remained an average of 4.18 days and spent about $35.50 per day. San Diego County's 1967 hotel-motel occupancy rate of 75 percent ranks among the highest in the Nation.

*Education.*—As previously mentioned, San Diego's public and private schools employed 33,900 or 8.9 percent of all civilian employed persons in 1967. During the last 5 years, 11,500 persons were added to the education payrolls, an increase of 49.1 percent.

*Federal civil service.*—The number of Federal civilian government employees in 1967 was 83,500. This was 47 percent higher than the 56,550 employed in 1960. The total wages paid to Federal civilian employees in 1967 was about $225.6 million.

*Recreation*

San Diego County is fortunate in having an abundant supply of mountains, beaches, and other places of recreational value. In 1965, according to the county planning department, a total of 17,157 acres of land was used for recreational purposes:

| Study area: | *Acres* |
|---|---|
| I | 1,868 |
| II | 9,427 |
| III | 5,862 |
| Total (county) | 17,157 |

*Beaches.*—Existing ocean beaches in the county are a major recreational attraction for both residents and tourists. Of the 70 miles of ocean shoreline, exclusive of bays and inlets, about 24 miles are suitable for swimming activity, and half of this is accessible to the public. The following future county beach area requirements have been projected based on standards developed by the California Public Outdoor Recreation Plan Committee Report, part II, 1960:

| Year: | *Acres* |
|---|---|
| 1968 | 225 |
| 1975 | 259 |
| 1980 | 291 |
| 2000 | 366 |

Current beach area capacity would therefore appear to be adequate, although it may be necessary to develop access roads to those beach areas which are now inaccessible to the general public.

*Boating.*—The number of registered pleasure crafts using San Diego Bay was approximately 4,000 in 1955; 20,000 in 1965; and more than 24,000 in June of 1968. San Diego Bay's permanent mooring facilities can currently accommodate 2,404 boats, and there are an additional 611 dry storage spaces. Plans are underway to almost double the mooring facilities by provisions at Shelter and Harbor Islands.

Approximately 50,000 trailered pleasure craft use the waters of San Diego Bay annually. Total investment in all pleasure craft using the bay has been estimated at $35 million. The full economic impact of boating would also include fuel, boat maintenance, visitor spending (food, hotels, entertainment, etc.), and rentals for boats and their berths. A private developer in the Imperial Beach area is planning a residential community of 3,500 units, each with its own boat slip, to be constructed over a 10-year period.

*Swimming and beach use*

According to the California Department of Parks and Recreation, Planning Monograph No. 4, the most popular summer outdoor recreational activity in the San Diego metropolitan district is swimming, with 84,000 participants; driving for pleasure is second, with 54,000 participants; and walking for pleasure is third, with 49,000 participants. For persons of 12 years and older, the age group of 12 to 17 years has the greatest number of outdoor recreation participation days. Where available, beaches would therefore seem to be the most useful summer recreational resource for the population as a whole, and especially for the teenage population. The requirement for swimming facilities is expected to more than double by 1980 when a demand of 184,000 participants is projected for the county.

*Recreation outlook*

According to outdoor recreation outlook to 1980 by the California State Department of Parks and Recreation, population in the San Diego area is expected to increase from 1,049,000 to 1,800,100 between 1960 and 1980, or 71.6 percent. The number of recreation participation days is projected to increase from 107,300,000 to 212 million, an increase of 97.5 percent based on population and participation days data.

The total recreational benefit in 1970 is projected to be over $135 million. Of this, $40 million is related to water-oriented sports such as swimming, boating, et cetera. An unknown percentage of the approximately $80 million relating to walking, driving, sightseeing, picnicking, et cetera is attributable to the presence of San Diego Bay. Total recreational economic benefits have been projected as almost $280 million for 1980, a more than threefold increase in comparison with the estimated $91 million for 1960.

## MISSION BAY
## (IV–3–3)

The preceding presentation primarily reflected the situation in San Diego County and reviewed that situation in light of the economic base supplied by the bay estuary. However, another very important part of the San Diego scene is Mission Bay. This particular bay is an excellent example of recreational possibilities available in an estuarine system.

Mission Bay was formerly no more than a mudflat in a tidal area. However, its development is comparable to the possibilities of any large estuarine situation where a portion of the system can be devoted to special recreational pursuits. The particular value in such a situation is that the use of special areas need not interfere with the major uses of the estuary, although the amount of pollution in the estuary must be limited so as not to preclude use of the recreational portion.

The following summary of the Mission Bay experience points up the multitude of possibilities that are available for recreational and economic development in an estuary given some initial investment of time and money.

Mission Bay Park is the Nation's largest municipally owned aquatic park and provides for public recreation in conjunction with land reclamation, water conservation, and commercial enterprise. It was dredged out of the large tidal mudflat located about 2 miles north of the northwest section of San Diego Bay, and lies entirely within the city of San Diego.

Development of the 4,600-acre aquatic playground was initiated in 1946 when the voters of the city of San Diego authorized a $2 million bond issue to finance it. Shortly thereafter, the U.S. Army Corps of Engineers established a floodway separating the San Diego River from Mission Bay. Subsequent dredging operation by both the Corps and the city of San Diego opened up the entire bay and created the many coves and islands which form its land masses.

By the end of 1966, the city had invested a total of $14.5 million in the development of Mission Bay: $9 million from three bond issues, and $5.5 million in capital outlay funds. The State of California contributed 2,900 acres of tidelands, and $3.5 million for the realinement of public utilities and the construction of new bridges. By the time of its anticipated completion it has been estimated that a total of approximately $56 million in public funds, and $50 million in private funds, will have been invested in Mission Bay. In short, many public agencies and private groups have been and will continue to be, instrumental in the development of the $106 million water playground known as Mission Bay.

The park is a multiple-use project covering 2,500 acres of water and 2,100 acres of land area. Most of the bay has a depth ranging from 6 to 12 feet at mean lower low water. The park includes six islands, 10 peninsulas, two small craft basins, 10 covers, the entrance channel from the Pacific Ocean, two large open water areas, and Vacation Isle. Figure IV.3.6 shows the location of the park complex's various recreational facilities.

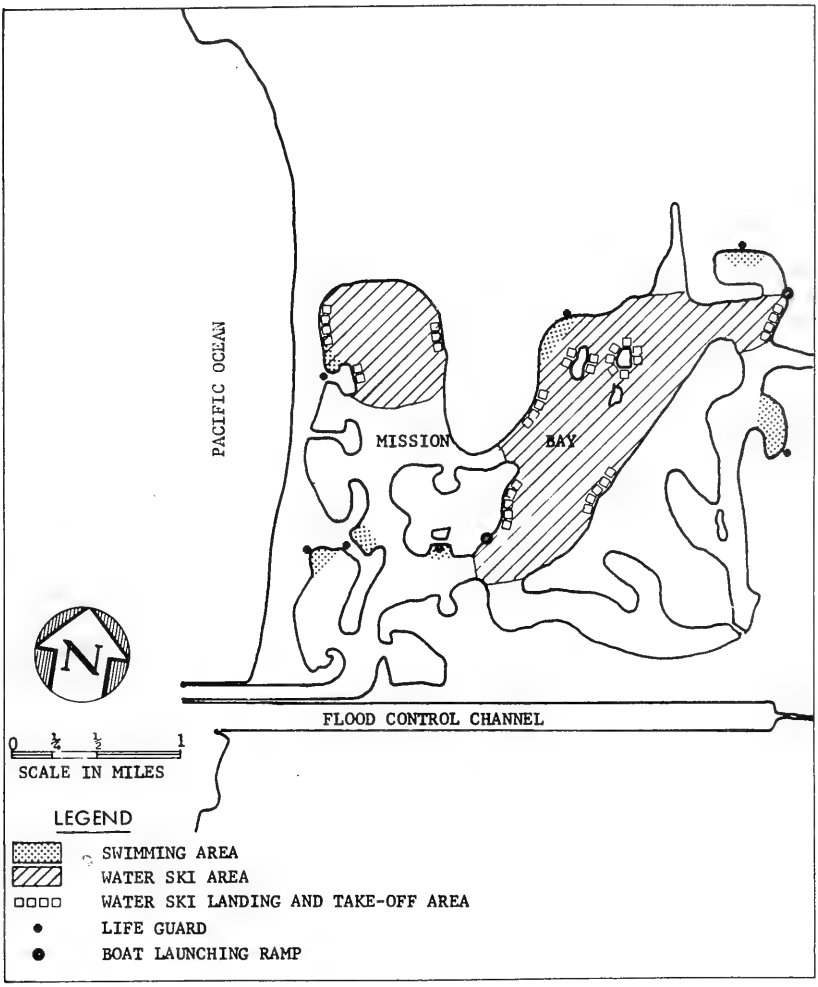
There are approximately 27 miles of beaches at Mission Bay with supervised swimming in seven areas. During the 1965–66 fiscal year, the total recorded attendance was 484,702 persons exclusive of the low-attendance winter months.

There is no charge for the use of the concrete launching ramps which the city provides in designated sections of the bay. An estimated average of 200 boats are launched on weekdays, 600 over weekends. A special area is set aside for sailboating and controlled-speed boating activities. Four large marinas—with slips for 1,200 boats and dry storage accommodations for 250 boats—serve the larger powerboats and sailboats using the bay and the ocean beyond. Ultimately, it is planned to construct slips for a total of 12,000 boats. Powerboat racing on Mission Bay has attracted wide interest. Fiesta Bay can accommodate all classes of racing inboards including unlimited hydros.

Sport fishing is permitted anywhere in the bay except for official swimming areas and those designated for water ski landing and takeoffs. Anglers from the Metropolitan San Diego area make extensive use of Mission Bay waters where the following may be caught: Bonito, barracuda, spotfin, and yellowfin croakers, rubberlip and shiner surfperch, California halibut, jacksmelt, and topsmelt. It is anticipated that good fishing conditions will continue as long as the waters remain free from pollution.

The University of California maintains a small wildlife preserve near Rose Creek Inlet which is used primarily for bird watching and

FIGURE IV.3.6 EXISTING WATER RECREATION AREA MISSION BAY




SOURCE: CITY OF SAN DIEGO - RECREATION DEPARTMENT, AQUATIC DIVISION bird study of waterfowl, gull, and shorebirds. Because it is illegal to discharge firearms within the city of San Diego, there is no waterfowl hunting on the bay.

The quality of Mission Bay waters depends primarily on the physical characteristics of the bay. The temperature, clarity, and dissolved oxygen concentration in the entrance channel tends to approximate that of the adjacent ocean. Atlhough dissolved oxygen nitrates and phosphates are low, the presence of phytoplankton and suspension of bottom materials caused by water motion contribute to turbidity. As measured by coliform indicators, the bacterial quality of Mission Bay is excellent.

There is virtually no direct discharge of waste to Mission Bay except for overflow from Sea World's display tanks, and infrequent overflows from the municipal sewerage system and boats. The use of marine heads in the bay is discouraged. There are drying beds for liquid digested sludge on Fiesta Island. Their use conforms to the requirements of the San Diego Regional Water Quality Control Board, and their presence has created no known problems.

Sea World Aquatic Park is a unique, privately owned marine exhibit located in Mission Bay Park. After filtering to improve clarity, bay waters are used in the exhibit and performance tanks.

There is a heavy demand for the 1,000 rooms offered by resort hotels in or adjacent to Mission Bay Park. These are largely classified as luxury accommodations. In addition, there are trailer park accommodations of 653 spaces. Facilities for tourist accommodations are expected to increase, and one hotel is planning to provide an additional 127 rooms for visitors as well as additional convention rooms.

## SUMMARY OF CASE STUDY REVIEWS

Narragansett Bay is an ideal example of an estuary that has developed in an unbalanced fashion. That is, the economic value of the estuary at the present time is largely associated with the industrial, military, and transportation uses of its waters. Other uses are, of course, made of the estuary but their economic significance is dwarfed by the tremendous magnitude of the military and commercial uses. However, it must be remembered that this economic measure is merely an indicator of the value of the waters and is not in any way related to the right or necessity of polluting such waters in the process of achieving this value. In fact, the only time that such an economic measure would be used would be for comparing one total use of the estuary to another total use. Of course, it is seldom that questions are so broad as to cover either/or propositions for the entire activity. Rather, the questions usually revolve around such things as the benefits to be derived from reducing pollution caused by users of the estuary compared with the costs of achieving the reduction in pollution.

Franklin County, Fla., is dependent upon pollution-free waters in Apalachicola Bay for its economic existence. The unpolluted waters of the bay provide the seafood caught by local commercial fishermen and processed at shore-based installations. Additional income for the area results from tourism engendered by the bay's waters.

Both tourism and commercial fishing are prime potential sources of income to any estuarine system. In the case of Apalachicola Bay, these happen to be the major sources of income because of the nature of the estuary and its location which prevent its development as a commercial shipping facility.

The San Diego economy, although heavily dependent upon the military and shipping activities in the bay, has diversified to the extent that it is no longer completely dependent upon such uses of the bay. At the same time there has been a growing demand for recreational uses of the bay. Evidence of the local residents' interest in the bay for recreation, tourism, and commercial uses can be found in their willingness to invest substantial sums of money in facilities to prevent pollution of the bay by municipal wastes.

Mission Bay, a separate estuary in the San Diego area, is an example of the recreational potential to be found in an estuarine system. However, this special study points up the fact that the best use of an estuary may not come about naturally. Rather, it shows that a planned development program with adequate investments are necessary to achieve optimal use of an estuary.

In summary, then, it can be seen that the major uses of estuaries vary from one estuary to another, depending upon historical development and suitability for specific uses. However, the primary points indicated by these various estuary reviews are: (1) estuaries are adaptable to several different uses; (2) current use of any given estuary is not the sole indicator of the estuary's value; and (3) with adequate effort the recreational and social aspects of an estuary can become vital parts of that estuarine system.

## Section 4. Measures of Value and Importance of the Estuarine Zone

The discussions of values of individual uses and the case studies of specific estuarine systems present a confusing picture of the relationship of estuarine uses to economic indicators.

Estimates of the direct gross economic benefit of the estuarine zone to the residents of the coastal counties can be made. The estimates of economic activity generated by the presence of Narragansett Bay in Rhode Island give a conservative annual economic benefit of $920 per capita, $420 of this in personal income. Average personal income for all of the coastal counties is, according to Bureau of the Census figures, $500 per capita greater than the average for the remainder of the country. The total economic activity generated by this additional personal income then amounts to about $1,100 per person, using the Narragansett Bay multiplier values.

The total direct economic benefit of the estuarine zone to the residents of the coastal counties is then about $60 billion in terms of additional economic activity stimulated by the presence of estuarine systems. This is not a measure of the total economic activity of the estuarine zone, but only of the "value added" to the total economic activity of the coastal counties by the presence of the estuarine zone.

Such gross means can give only an order-of-magnitude estimate of even the direct economic value of the estuarine zone and cannot possibly reflect either indirect benefits or the social importance of the estuarine zone, much less its ecological value.

Valid criteria for evaluating the importance of the estuarine environment or the value of individual estuarine uses, to a community must, however, go beyond the reach of economic approximation and recognize the fundamental relationship between man and his environment. Wherever there are people the environment will be exploited to satisfy the needs and desires of man and his civilization.

Increasing environmental pressures from demographic and commercial development are paralleled in the same community by the increasing desire for greater recreational use. That these can be compatible is clearly shown by the San Diego Bay example. Such community reactions as in San Diego and in San Francisco demonstrate that, while people need commercial development and use, they want a safe and enjoyable environment at the same time. Effective management, therefore, should direct its efforts not toward excluding some uses, but toward accommodating all uses without environmental damage.

With such an objective, economic criteria of use importance are of little value. Guidelines for estuarine management should recognize man's relationship to his environment and express his determination that it shall be preserved.

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# CHAPTER 4. SOCIAL AND ECONOMIC TRENDS

This part of the report emphasizes the complex interaction among the biophysical and socioeconomic environments within the estuarine zone. The existing socioeconomic environment is the subject of the preceding chapter; this chapter deals with trends associated with the social and economic environment.

The availability of certain resources in or near estuaries has strongly influenced patterns of population growth and economic activity. Once initiated, these changing economic and demographic patterns alter the nature of the estuaries themselves. For example, the presence of plentiful timber resources was a factor in the development of many coastal towns and cities. Long after the depletion of the timber resource, the deep deposits of sediments carried down from the scarred land to the estuary bottom altered the biophysical system. Similarly, new sets of economic activity such as transportation, manufacturing, and commerce replaced the initial extractive lumbering activity and in turn affected the biophysical environment.

Other trends, stemming from pressures wholly or partially external to the estuarine environment, may also have profound influence. For instance, the changing economic demands of a dynamic society affect the location and composition of economic activity and populations in the estuarine zone. Thus, changes in labor markets, location of raw materials, and prices determined to a large degree the shift of textile manufacturing from the New England coast to the South.

Barring catastrophes or other unforeseen developments, certain trends are expected to continue in the country at large. Rapid population growth and continued development of urban-suburban areas are notable among the demographic projections, while the economy is expected to show continued diversification, technological change, and expansion.

To assess the impact of these trends on the estuarine zone, the reasons for the distribution of future population and economic growth must be understood; and an understanding of past and present trends indicates in a general way what may be expected.

The discussions in this chapter provide a basis for projecting the changes that may be brought about by man's continuing activities in the estuarine zone.

This chapter was summarized from the report "Social and Economic Trends associated with the Nation's Estuarine Region," prepared by Harold F. Wise & Assoc. under contract with FWPCA as part of the National Estuarine Pollution Study. The report is now being prepared for publication.

## Section 1. National Population and Economic Trends

### NATIONAL POPULATION GROWTH

America has experienced a continually high rate of population growth. Today there are six times as many Americans as there were 100 years ago, and more than twice as many as there were 50 years ago. This growth is expected to continue in the future, though likely at a slower rate.

Figure IV.4.1 provides clear evidence of the "population explosion" which took place in the United States in the years following World War II. In the decade 1950–60, the total U.S. population increased by nearly 28 million persons, a growth rate of 15.6 percent for the decade, or an annual population growth rate of nearly 1.6 percent. That growth is expected to continue at a rate of approximately 1.3 percent annually with the total population of the United States increasing from a little over 205 million persons in 1970 to about 400 million in 2020.

Figure IV.4.2 shows recent population increases and decreases throughout the Nation. Population decreases have occurred almost uniformly in the period 1940 to 1960 in the predominantly agricultural counties of the Midwest, the South, the Southwest, and Appalachia. In contrast, those counties in which metropolitan development has occurred generally show steady increase during these years. Perhaps the most striking growth record in this period appears in what may generally be designated as the coastal zone, where only a handful of some 274 coastal counties experienced any population decline during either of the 10-year periods between 1940 and 1960.

### URBAN-RURAL SHIFTS

The growth of population in urban areas and relative decline in rural areas has been a steady trend in America since the first census was taken. As figure IV.4.3 shows, the 1920 census marked a symbolic turning point, with urban citizens outnumbering rural ones for the first time. Metropolitanism is fast becoming central to consideration of all aspects of American life. In 1965, 67 percent of the country's population lived in the 212 SMSA's identified by the Bureau of the Budget.

### AGE COMPOSITION

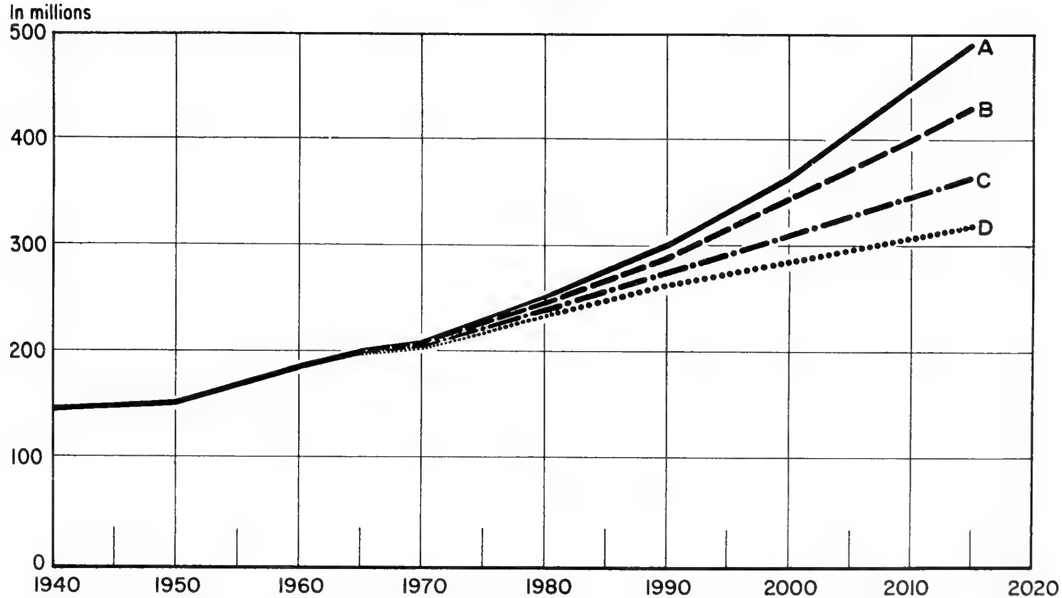
The age composition of the population will also change in ensuing years. Of particular significance is the expected rise in the main working age population (ages 25–64) from 86.4 million in 1966 to about 90.1 million in 1970 and 123.9 million in 1990. From 1975 on, the younger portion of this age group is expected to increase rapidly, while the number of elderly citizens shows only a slight increase.

### NATIONAL ECONOMIC GROWTH

The amount of personal income generated in the economy indicates the general capacity to purchase goods, services, and amenities.

**Figure IV.4.1**

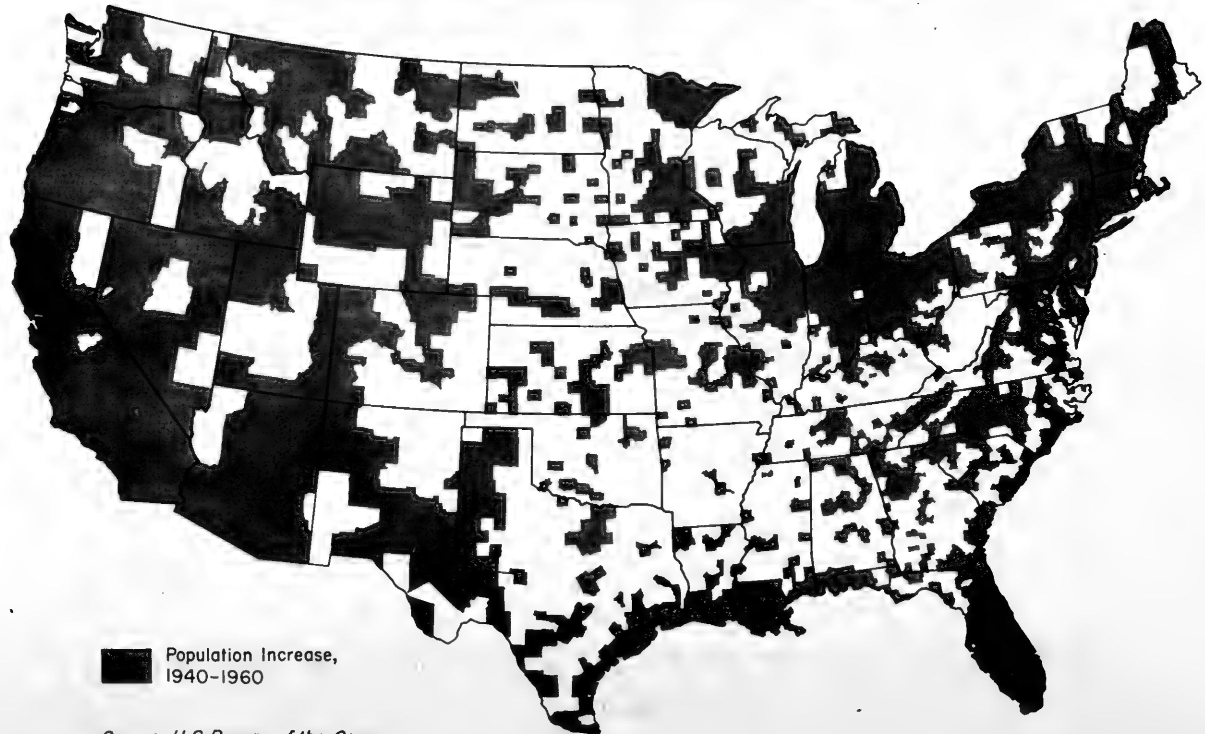
ESTIMATES AND PROJECTIONS OF THE POPULATION OF THE UNITED STATES, 1940-2015




*Source: U.S. Bureau of the Census.*

Figure IV.4.2

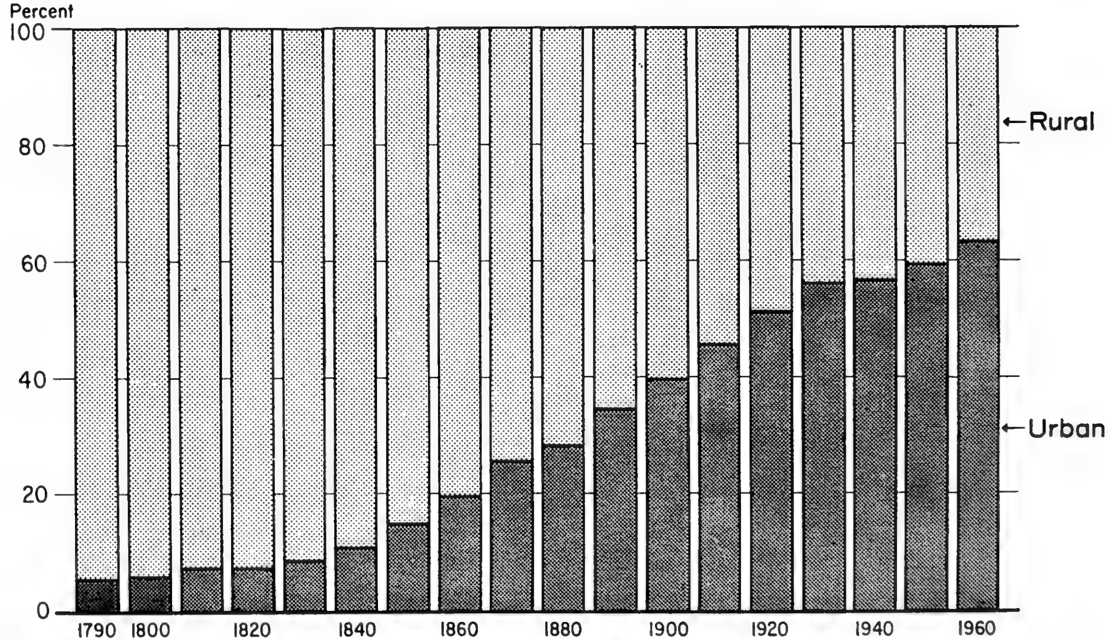
POPULATION TRENDS IN U.S. COUNTIES, 1940–1960




Source: U.S. Bureau of the Census.

**Figure IV.4.3**

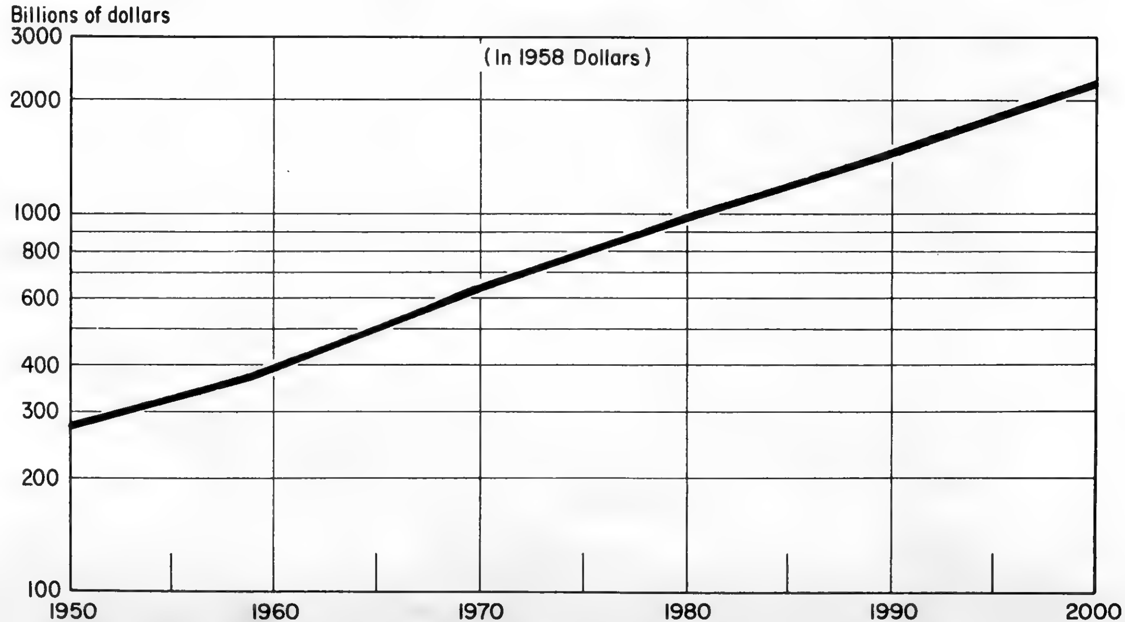
URBAN AND RURAL COMPONENTS OF TOTAL UNITED STATES POPULATION, 1790-1960




*Source: U. S. Bureau of the Census.*

**Figure IV.4.4**

ESTIMATED AND PROJECTED TOTAL PERSONAL INCOME IN THE UNITED STATES, 1950-2000




*Source: U.S. Department of Commerce, Office of Business Economics, Regional Economics Division.*

Figure IV.4.4 shows a steadily rising trend and projection of U.S. personal income. Total personal income is expected to rise at a 5.1 percent annual rate of growth from 1970 to 2020. In terms of constant 1958 dollars, this represents an increase from about $615 billion to nearly $5 trillion in 2020. Similarly, per-worker earnings will increase substantially, rising from $6,000 in 1920 to $23,000 by 2020 as figure IV.4.5 on page 194 shows.

Within the economy, considerable variation in the rates of growth of various sectors is expected. "Goods-producing" industries such as agriculture, mining, and manufacturing will decrease in relative importance, while those which are "service-producing" (e.g., contract construction, trade and finance, and government) will increase. This changing pattern of employment is exhibited in figure IV.4.6 on page 195. This figure gives a detailed account of percentages of national employment by broad industrial category.

The fact that employment in agriculture, forestry, and fisheries is expected to show a steady decline from 12.5 percent of total national employment in 1950 to 1.2 percent in 2020 is worthy of special attention, for combining all three of these categories masks the changes that are actually taking place. A Bureau of Labor Statistics study which treats each of the three categories separately for the years 1960–1975 anticipates:

(1) 1,978,000 fewer agricultural workers in 1975 than in 1960 (a percentage drop from 8.6 percent to 4.2 percent);

(2) an increase in forestry employment from 48,000 to 70,000;

(3) growth in fisheries employment from 45,000 to 60,000.

Both forestry and fisheries maintain constant shares of national employment of .7 percent and .6 percent respectively.

Employment in the service-producing sector should exhibit the greatest proportional increase in the foreseeable future. The services group will surpass both manufacturing and wholesale-retail trade in percent of national employment by 1980.

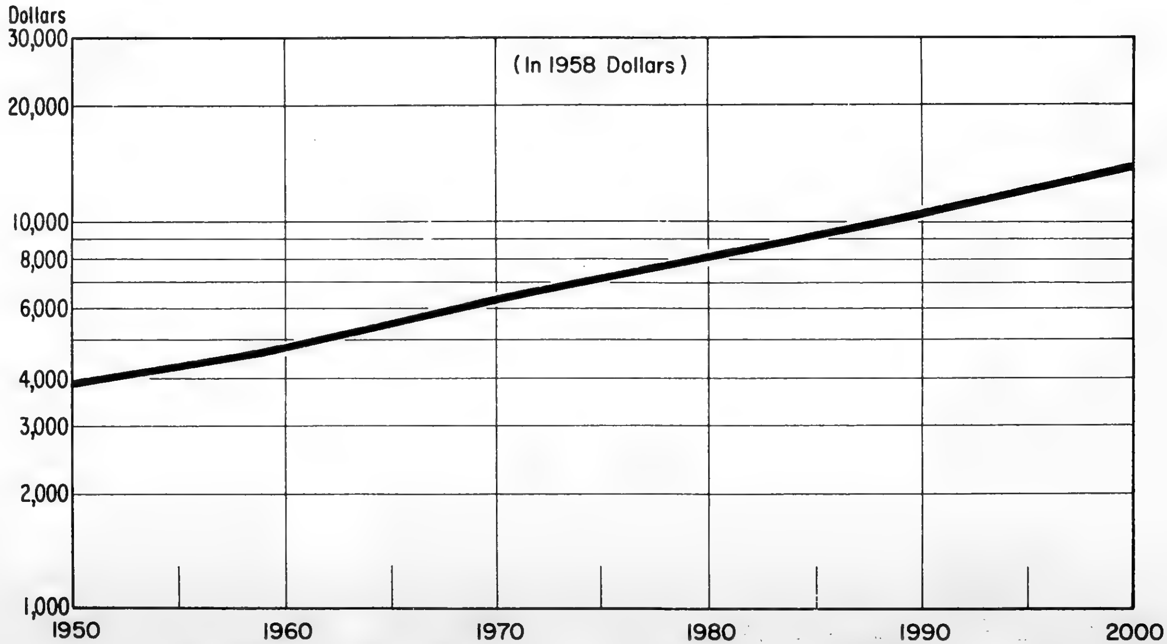
## IMPLICATIONS OF THE NATIONAL PICTURE

If normal circumstances prevail, the Nation's population and general high standard of living will continue to increase in the coming decades. A moderate estimate projects a doubling of the national population by the turn of the century, with a significant proportion of that growth occurring in urban areas.

The population will be made up of a large proportion of youth and young persons of working ages, with only a moderate increase in the elderly through the end of the century. Personal income will rise dramatically. Estimates of leisure time vary considerably, but all authorities agree that the workweek will shorten, from a conservative estimate of 35 hours a week to as little as 20 hours per week. The National Planning Association has projected that in 1990, 10 percent, and in 2000, 20 percent of the men between the ages of 25 and 54 will be granted a 1-year leave every 7 years. Urban and particularly suburban growth will expand greatly both to accommodate the growing population and to provide amenities that it increasingly demands: single-family dwellings, recreational areas, transportation facilities, industrial developments, and so on. These demands will place rapidly

**Figure IV.4.5**

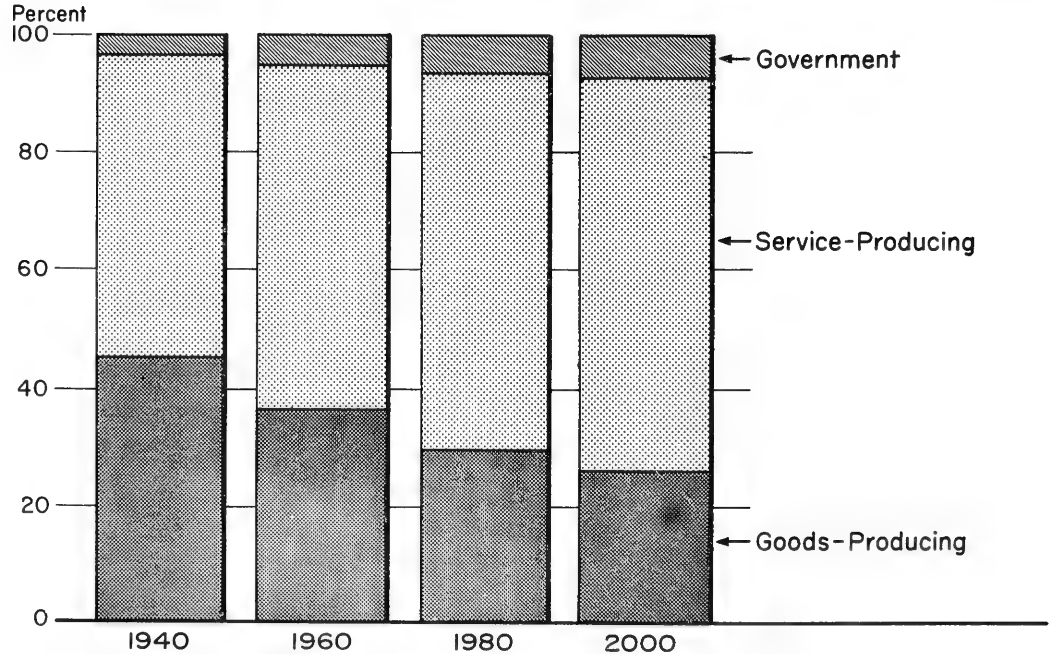
ESTIMATED AND PROJECTED PER-WORKER EARNINGS IN THE UNITED STATES, 1950-2000




*Source: U.S. Department of Commerce, Office of Business Economics, Regional Economics Division.*

**Figure IV.4.6**

PERCENT OF TOTAL CIVILIAN EMPLOYMENT IN THE UNITED STATES
Represented by "Goods-Producing," "Service-Producing," and "Government" Sectors, 1940–2000



increasing burdens on the Nation's resources and its environment. These burdens, in turn, will tax the ability of decisionmakers and the Nation's population to cope with the complexity and insistence of the problems generated by a post-industrial, urbanized society.

## SECTION 2. TRENDS IN THE ESTUARINE ZONE POPULATION AND ECONOMY

### FUTURE POPULATION GROWTH IN THE ESTUARINE ZONE

The estuarine zone economic region includes the coastal counties plus a few noncoastal counties included as part of estuarine zone SMSA's.[1] The overall recent population growth rate in the estuarine zone economic region has exceeded that of the Nation as a whole. From 1930 through 1960, the population of the coastal counties and SMSA's increased 78 percent, compared to a national growth rate of 46 percent. Future population growth is projected to continue above the national average, but at a somewhat lower rate. Estuarine zone population is expected to more than double between 1960 and 2020 from 60 million to 139 million persons. Approximately 35 percent of the Nation's total population will then be located on the land area encompassed by the national estuarine economic region.

This report focuses on the characteristics of the major urban regions presented in figure IV.4.7. Three of the four major urban regions anticipated by the year 2000 front on the coastal zone: the Atlantic seaboard region, the Florida Peninsula urban region, and the California "megalopolis." The Lower Great Lakes urban region does not border the marine coastal zone but is contiguous to the Great Lakes.

Major characteristics of the three coastal-related major urban regions are set out below:

(1) The Atlantic seaboard region extended from Augusta, Maine to Prince William County, Va., in 1960, covering 50,553 square miles with a total population of 37.5 million. By the year 2000 it will increase in size to 64,000 square miles and will contain 78 million persons. It will then extend south to Hampton Roads, Va. and increase in density from 741 persons per square mile to 1,050.

(2) The Florida Peninsula urban region included 11,300 square miles in 1960 and contained 3.3 million persons. By the year 2000 the region is expected to cover 20,000 square miles and contain nearly 14 million people.

(3) The California "megalopolis" will close the gap between the two major urban areas existing in California in 1960, the southern California urban region which extends from the Mexican border in the south to San Maria on the north and has a population of 8.9 million, and the bay area-central California region, extending from southern Monterey County to Sonoma County in the north and inland to Modesto with a population of 4.9 million. In 2000 it will be an agglomeration of urban and metropolitan zones 600 miles in length with a population of 44.5 million people.

Graphic presentation of the growth of these major regions is presented in figures IV.4.8, IV.4.9, and IV.4.10.

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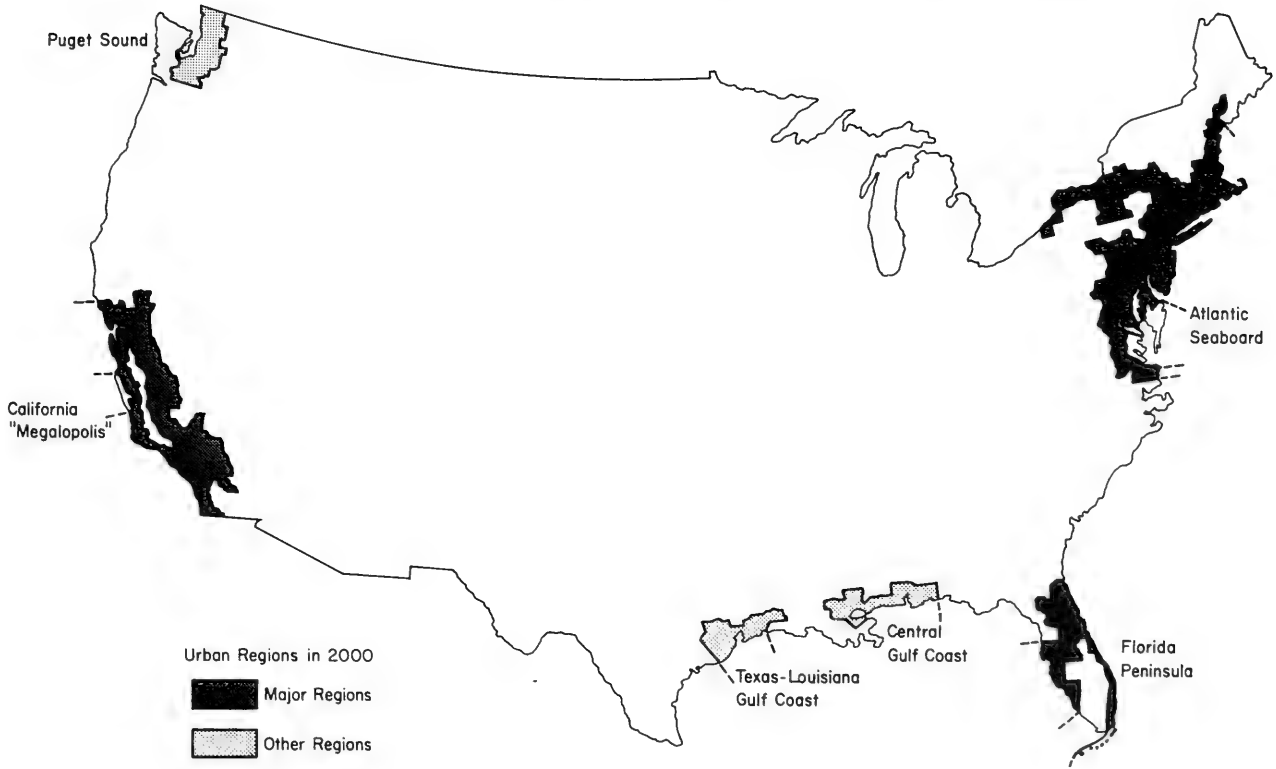
[1] SMSA's are Standard Metropolitan Statistical Areas.

**Figure IV.4.7**

## Urban Regions in the Estuarine Zones in the Year 2000



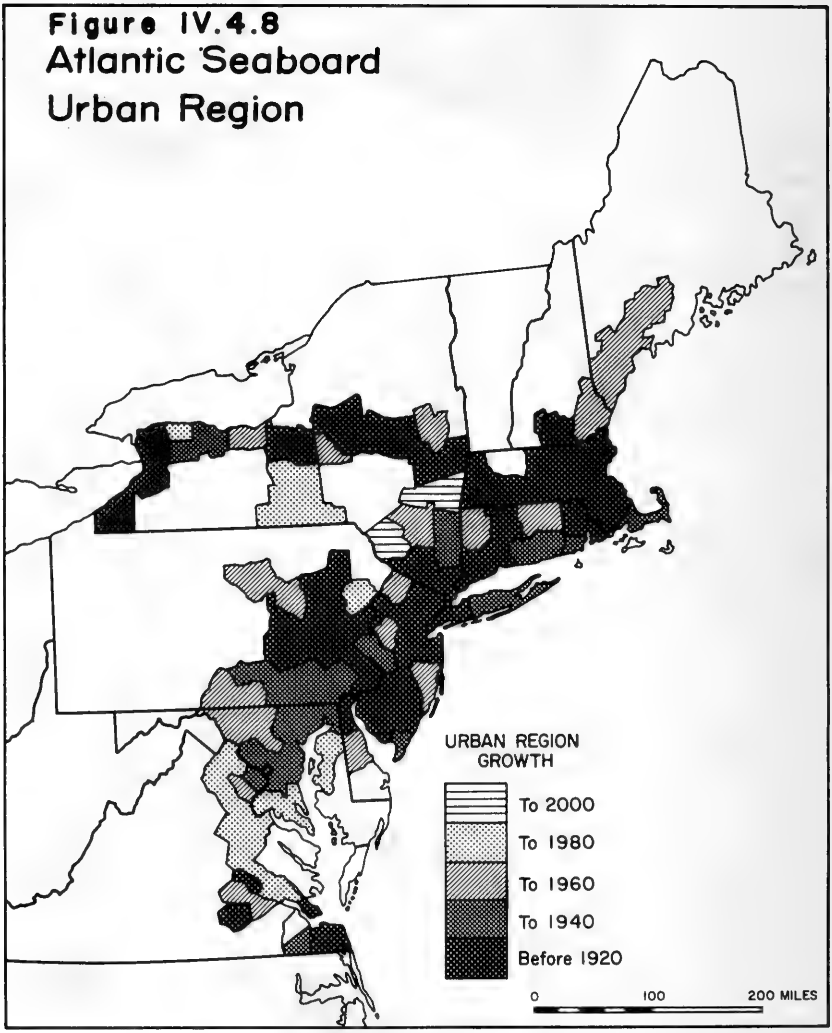
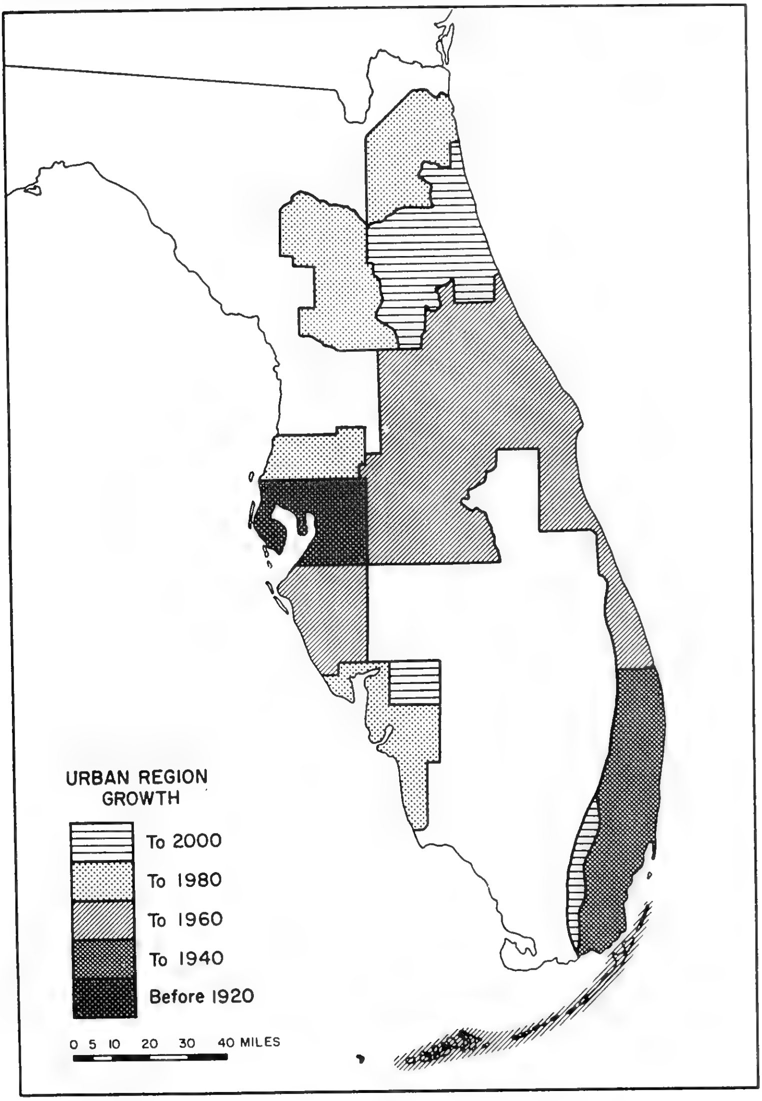


Figure IV.4.8
Atlantic Seaboard
Urban Region
URBAN REGION
GROWTH
To 2000
To 1980
To 1960
To 1940
Before 1920
0
100
200 MILES

**Figure IV.4.9**

## Florida Peninsula Urban Region



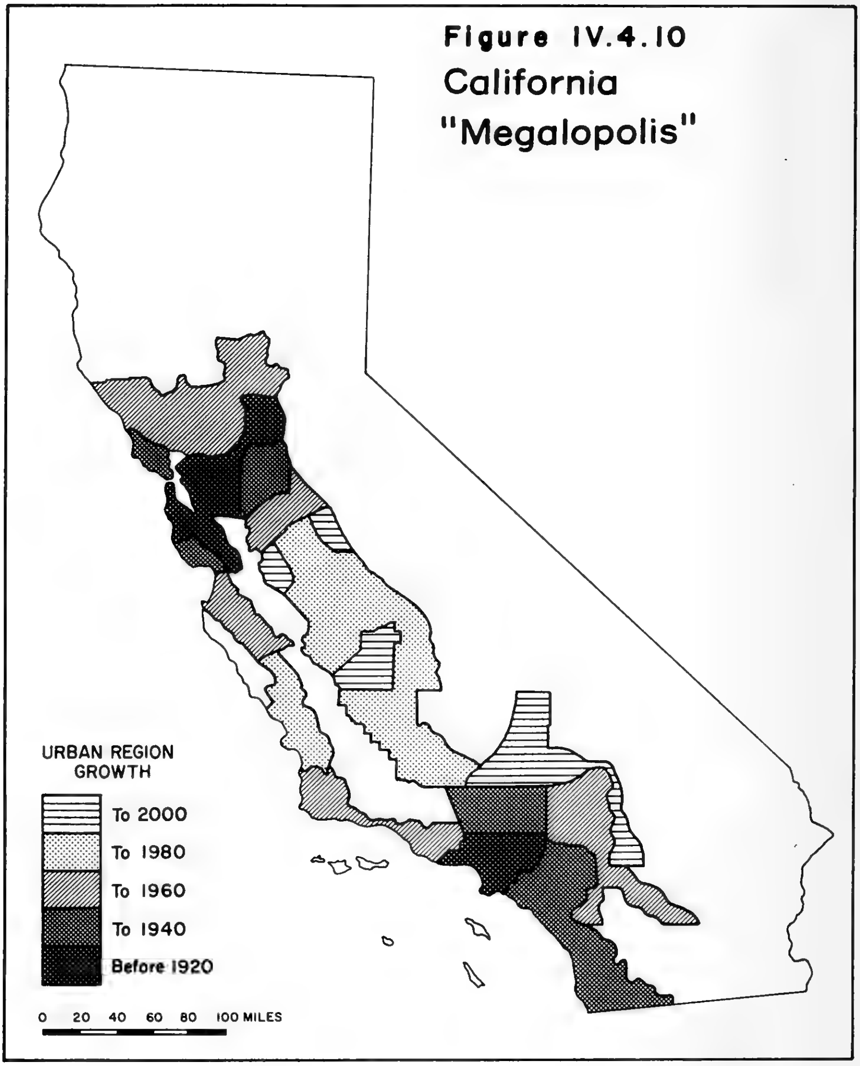


Figure IV.4.10
California
"Megalopolis"
URBAN REGION
GROWTH
To 2000
To 1980
To 1960
To 1940
Before 1920
0 20 40 60 80 100 MILES

The three other urban regions which are expected to develop in the estuarine regions by the year 2000 are described below:

(1) The central gulf coast is expected to have a population of 2.1 million by 1980. By 2000 the region is projected to reach from Baton Rouge, La., to Pensacola, Fla. and contain 4.7 million people.

(2) The Texas-Louisiana gulf coast roughly parallels the coast and has experienced substantial growth in recent decades. The region extends from Houston to Lake Charles, La., and is expected to grow in population from 1.8 million in 1960 to 5 million in 2000.

(3) The Puget Sound which will expand its area to include additional population to the Canadian border, will increase in population from 2.5 million persons in 1980 to 3.6 million in 2000.

Urban growth has both a direct physical impact on estuarine resources in the usurpation of land for development purposes, and an indirect impact in increased runoff, changed water composition, and increased demand for water supplies.

Other implications are also important. By and large, urban populations are those which most strongly feel the effects—good and bad—of increased per capita income, leisure time, and mobility. There are, speaking very generally, three segments of the urban population affected by these forces, and they react differently in terms of the estuarine environment. The groups and the implications are:

(1) High income: Urban residents with high income place pressure on the estuarine environment some distance from their place of residence. They are able to afford either second homes or extended stays at vacation resorts. Much of the total national demand expressed by that segment of the population in the upper middle and high income brackets falls on the nonurban portions of the coastal-estuarine zone.

(2) Middle income: Those persons with middle range incomes either opt for new housing in the suburban ring surrounding the central city or choose to remain within the central city. In either case, their mobility is increased by their ability to afford leisure time activities removed from their place of residence. The pressure is likely to fall on public areas in the coastal-estuarine zone.

(3) Low income: Residents of the central city with low incomes are not able to leave the confines of the central city. Their enjoyment of the coastal-estuarine zone resources is tied tightly to the quality of the coastal-estuarine interface within the central city itself.

## FUTURE DISTRIBUTION OF POPULATION GROWTH IN THE BIOPHYSICAL REGIONS

Table IV.4.1 gives a comparative breakdown of population growth rates in the estuarine economic areas defined by the Office of Business Economics (OBE) compared to national growth. Individual areas showing a population growth rate lower than the Nation's during the 1930–60 period are clustered in the north and middle Atlantic biophysical regions and include the Maine coast, Massachusetts-Rhode

Island coast, New York and northeast New Jersey coast and the Philadelphia-New Jersey-Delaware areas. These areas, with the possible exception of the Maine coast, are mature areas which experienced an early growth in population and reached a large population density relatively quickly. They are now growing comparatively slowly. Highest relative growth between 1930 and 1960 (more than 100 percent above the national average) took place in four areas: Florida, the Mississippi-Alabama-west Florida coast, Texas, and California. These areas are expected to experience extensive short- and long-term growth in the future. Significantly, these areas also reflect a change in life style toward a suburban, leisure-centered existence with its attendant demands for land- and water-related activities.

TABLE IV.4.1.—POPULATION GROWTH RATES IN OBE ESTUARINE ECONOMIC AREAS COMPARED TO NATIONAL GROWTH, 1930–60

| Individual estuary economic areas | Growth rate (percent) | Difference from national growth (percent) |
|---|---|---|
| 1. Maine coast | 26 | −20 |
| 2. Massachusetts-Rhode Island coast | 22 | −24 |
| 3. Connecticut coast | 48 | +2 |
| 4. New York-northeast New Jersey | 38 | −8 |
| 5. Philadelphia-New Jersey-Delaware | 44 | −2 |
| 6. Maryland-Virginia coast | 103 | +57 |
| 7. North Carolina coast | 45 | −1 |
| 8. South Carolina coast | 79 | +33 |
| 9. Georgia-eastern Florida coast | 312 | +266 |
| 10. Southern Florida gulf coast | 261 | +215 |
| 11. Central Florida gulf coast | 75 | +29 |
| 12. Mississippi-Alabama-west Florida coast | 174 | +128 |
| 13. Louisiana coast | 79 | +33 |
| 14. Texas north gulf coast | 178 | +132 |
| 15. Texas south gulf coast | 153 | +107 |
| 16. Southern California coast | 206 | +160 |
| 17. Central California coast | 135 | +89 |
| 18. Northern California coast | 156 | +110 |
| 19. Oregon coast | 93 | +47 |
| 20. Washington coast | 87 | +41 |

Note: National population growth rate, 46 percent; total estuary economic region growth rate, 78 percent; difference, plus 32 percent.

Actual trends and projections of numbers of persons by OBE estuarine economic area are given in table IV.4.2. Table IV.4.3 demonstrates population pressure on the available coastline and associated estuaries. That pressure can be summarized as follows:

(1) The New York-northeast New Jersey coast area, OBE area 4 with a population density of nearly 4,000 persons per square mile in 1970 (more than twice as high as the next most densely populated area projected for 2000), will continue to be the most populous area in the United States and exert the most concentrated pressure on remaining coastal open space and water quality from municipal and other wastes;

(2) The southern North Atlantic and Middle Atlantic biophysical region, OBE areas 2 through 6, will continue to experience the greatest concentration of population of economic activity;

(3) The distribution of major population densities will change from a heavy preponderance located in the North Atlantic and Middle Atlantic region, to a more even distribution including

TABLE IV.4.2.—POPULATION DENSITY IN THE ESTUARINE ECONOMIC REGION AND INDIVIDUAL AREAS 1950–2000

| | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|---|
| Estuarine economic region population total | [1] 219.1 | 280.2 | 330.7 | 384.9 | 449.4 | 516.9 |
| Estuarine economic area (population total): | | | | | | |
| 1 | 57.7 | 61.2 | 65.1 | 70.6 | 77.6 | 84.3 |
| 2 | 827.7 | 911.1 | 987.1 | 1,088.8 | 1,214.5 | 1,341.4 |
| 3 | 463.0 | 568.7 | 642.9 | 720.7 | 817.5 | 907.7 |
| 4 | 3,054.7 | 3,506.4 | 3,904.8 | 4,295.4 | 4,732.8 | 5,173.6 |
| 5 | 533.8 | 645.6 | 720.8 | 808.3 | 918.2 | 1,032.1 |
| 6 | 242.7 | 311.4 | 369.6 | 435.3 | 519.4 | 606.1 |
| 7 | 43.0 | 49.3 | 50.9 | 52.6 | 56.1 | 60.0 |
| 8 | 54.6 | 67.9 | 73.3 | 78.5 | 86.8 | 96.5 |
| 9 | 92.5 | 170.3 | 238.7 | 303.3 | 371.3 | 448.0 |
| 10 | 69.3 | 133.9 | 173.1 | 210.3 | 244.2 | 291.1 |
| 11 | 16.7 | 21.5 | 22.8 | 25.5 | 29.1 | 33.7 |
| 12 | 71.9 | 104.5 | 124.7 | 144.9 | 174.0 | 204.7 |
| 13 | 93.3 | 121.6 | 143.7 | 156.4 | 171.8 | 189.3 |
| 14 | 137.4 | 194.6 | 225.9 | 277.4 | 338.2 | 412.1 |
| 15 | 54.7 | 69.8 | 78.7 | 87.2 | 98.1 | 108.7 |
| 16 | 309.7 | 486.7 | 640.7 | 804.1 | 1,003.7 | 1,206.1 |
| 17 | 207.0 | 279.3 | 357.4 | 441.5 | 541.1 | 643.2 |
| 18 | 17.0 | 26.7 | 32.9 | 41.0 | 50.1 | 59.6 |
| 19 | 56.2 | 65.7 | 71.5 | 82.5 | 95.2 | 107.5 |
| 20 | 72.4 | 89.0 | 104.9 | 122.9 | 144.1 | 166.9 |

[1] Densities are expressed in persons per square mile.

Source: Computed from Office of Business Economics population projections and Department of Commerce county land area measurements.

TABLE IV.4.3.—ESTIMATES AND PROJECTIONS OF POPULATION IN THE ESTUARINE ECONOMIC REGION AND INDIVIDUAL AREAS

[In thousands]

| | 1950 | 1960 [1] | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|---|
| Estuarine economic region total population | 45,302.1 | 57,946.2 | 68,396.9 | 76,606.7 | 92,940.0 | 106,900.3 |
| Estuarine economic area population total: | | | | | | |
| 1 | 471.7 | 499.7 | 531.5 | 576.7 | 633.6 | 688.2 |
| 2 | 4,355.4 | 4.794.3 | 5,194.3 | 5,729.2 | 6,390.6 | 7,958.2 |
| 3 | 761.2 | 934.9 | 1,057.0 | 1,184.8 | 1,343.9 | 1,492.2 |
| 4 | 13,593.6 | 15,603.5 | 17,376.5 | 19,114.4 | 21,061.0 | 23,022.3 |
| 5 | 4,399.3 | 5,320.8 | 5,939.9 | 6,661.5 | 7,567.1 | 8,505.8 |
| 6 | 4,473.0 | 5,739.5 | 6,812.8 | 8,023.3 | 9,573.3 | 11,172.1 |
| 7 | 447.1 | 511.7 | 529.0 | 546.1 | 582.7 | 623.0 |
| 8 | 374.8 | 466.2 | 503.2 | 539.0 | 595.7 | 662.2 |
| 9 | 1,432.5 | 2,637.8 | 3,698.7 | 4,699.3 | 5,752.5 | 6,941.1 |
| 10 | 547.7 | 1,058.7 | 1,369.0 | 1,663.1 | 1,931.0 | 2,302.7 |
| 11 | 98.0 | 126.5 | 134.2 | 150.2 | 171.0 | 198.1 |
| 12 | 563.0 | 818.5 | 977.0 | 1,135.3 | 1,363.3 | 1,603.2 |
| 13 | 1,177.8 | 1,535.3 | 1,814.7 | 1,974.4 | 2,168.6 | 2,930.0 |
| 14 | 1,324.7 | 1,900.8 | 1,206.7 | 2,710.4 | 3,304.1 | 4,026.1 |
| 15 | 441.5 | 563.8 | 635.6 | 704.1 | 792.3 | 878.2 |
| 16 | 5,233.5 | 8,224.9 | 10,826.2 | 13,586.9 | 16,906.1 | 20,381.0 |
| 17 | 2,944.2 | 3,972.6 | 5,084.6 | 6,280.3 | 7,696.9 | 9,150.2 |
| 18 | 78.0 | 122.7 | 151.0 | 188.1 | 230.1 | 273.8 |
| 19 | 1,091.4 | 1,276.8 | 1,389.3 | 1,602.7 | 1,849.6 | 2,087.7 |
| 20 | 1,493.7 | 1,837.3 | 2,165.5 | 2,536.8 | 2,972.6 | 3,444.1 |

[1] For purposes of uniformity, 1960 data is taken from April enumeration.

Source Office of Business Economics, Regional Economics Division.

Florida, Texas, and California in the South Atlantic, Gulf, and Pacific regions. Examples of this shift in population concentration are found in the central California coast, which is expected to grow from a population density of a little more than 350 persons per square mile in 1970 to nearly 600 in 2000, and in the Texas north gulf coast which will experience a population density growth from 225 persons per square mile in 1970 to over 400 per square mile in that same 30-year period;

(4) Although some areas in the United States will remain relatively lightly populated, the pressures of increased population will be felt in even the most remote coastal areas, if not by local population growth, then by increasing demands of more urbanized populations for the amenities of the coastal zone; often expressed in terms of seasonal influxes;

(5) The effects of increased population density will vary according to a number of considerations such as the employment structure, distribution of the population within the area, the biophysical environment, institutional constraints, and so on;

(6) Finally, many of the conflicts generated by competing demands on the estuarine resource, which are most visible in today's metropolitan areas, will intensify in those areas in the future and extend to estuarine areas which are now relatively unmodified and free of intense competitive demands.

## FUTURE ECONOMIC ACTIVITY IN THE ESTUARINE ZONE

The estuarine economic region in recent decades exhibits a rate of economic growth slightly greater than the national average. Personal income in constant dollars expanded 177 percent from 1929 to 1962, while national personal income rose 170 percent. Nearly all parts of the region are expected to either maintain positions of relative wealth in the future or to increase their relative wealth.

Manufacturing is the principal export activity of the region, and the significance of the region as a focus for industry is shown by the level of concentration of employment. In 1960, about one-half of the manufacturing industries had a level of concentration greater than the national level. Significant degrees of overall specialization in the region are indicated in transportation equipment excluding motor vehicles, petroluem refining, apparel, and in both printing and publishing and chemicals.

Certain industries of minor importance to the overall estuarine zone economy assume great importance in smaller areas. The pulp and paper and lumber and furniture industries, for example, play central roles in such estuarine economic areas as the Maine coast, the North Carolina coast, and the northern California coast. In the Central Florida gulf coast and the Texas south gulf coast forestry and fisheries predominate. Many of these economic activities locate in various estuarine areas to take advantage of the unique natural resources of the estuarine environment found there. These activities are discussed in the next part of this chapter.

The overall economic growth of the estuarine zone will continue at a high rate in future decades. Significant concentrations of industry will continue in the relatively mature Middle Atlantic biophysical region, while significant expansion will occur in the Gulf of Mexico and Pacific biophysical regions. Marked differences will occur, however, in the smaller areas making up these biophysical regions, both in economic activity and population distribution.

### FUTURE DISTRIBUTION OF ECONOMIC ACTIVITY IN THE BIOPHYSICAL REGIONS

Economic activities vary greatly throughout the estuarine zone. The principal determinants of economic activity have been the location of natural resources historic circumstances, availability of substantial markets, and changes in technology.

*The North Atlantic and Middle Atlantic biophysical regions*

The New England marine States saw the country's first economic development. Basic resources defined the parameters of activity—forests, fish, fur, and farmlands. Shipbuilding and trade flourished around major centers of oceangoing transportation. The major metropolitan areas of Boston, New York, and Philadelphia developed around those endeavors. Their presence led to further expansion from Massachusetts to New Jersey. Today four of the five OBE economic areas fronting on the North and Middle Atlantic biophysical regions (with the exception of the Maine coast) have become considerably less dependent on the forests and fisheries and have developed into diversified, mature economies, increasingly service providing rather than goods producing in character.

Maine's continuing dependence on the natural resources of fisheries and forests, and on its location in the coastal zone, is indicated by high relative concentrations of transportation equipment manufacturing excluding motor vehicles (mainly shipbuilding), paper and allied products industries, and forestry and fisheries activities. These concentrations are noticeably higher in the Maine coastal area than in the other four associated areas in the North and Middle Atlantic biophysical regions.

The other OBE estuarine economic areas in the North and Middle Atlantic biophysical regions exhibit economic activity that is more closely related to supplying the sophisticated and diverse demands of urban markets. All economic areas in these regions, however, are highly dependent on the estuaries for port facilities to move the goods produced within their boundaries. In the case of the Philadelphia-New Jersey-Delaware coast, the combination of large nearby markets and adequate port facilities has combined to stimulate a large petroleum refining and chemicals industry, even through the raw materials for those manufactures must be imported.

*The Chesapeake Bay biophysical region*

The OBE economic area of the Maryland-Virginia coast corresponds to the Chesapeake Bay biophysical region. Although some of the earliest settlements occurred adjacent to the bay and its related rivers, the area's economy has developed later than those located in the North and Middle Atlantic regions. However, the area has followed the pattern of beginning with extractive industries built upon the coastal natural resources of agriculture, forests and fisheries, and then proceeding to develop a diversified economy. In recent decades, this area has grown faster than the national average, with civilian and military government located primarily in the Washington Metropolitan Area and Hampton Roads, Newport News, respectively, providing the impetus for more of the growth. The Chesapeake Bay continues to provide an important fisheries input to the regional economy, but its importance relative to other, sometimes competing, economic activities such as primary metals, transportation services, and shipbuilding has declined and is projected to continue to decline in the future.

The existence of a large steel-producing plant at Sparrows Point in the Chesapeake Bay is a further example of the development of an industry highly dependent on the estuarine environment for transport by ship, but not for other natural resources.

*The South Atlantic biophysical region*

This region includes the OBE estuarine economic areas of the North and South Carolina coast and the Georgia-eastern Florida coast. The economic areas in the region have traditionally been producers of raw materials in the form of agricultural products (particularly tobacco and cotton and more recently soybeans), finfish and shellfish, and forestry products. The North Carolina coast, and to a somewhat lesser degree, the South Carolina coast, continue to exhibit significant concentrations of economic activity in these areas. National defense activities dominate both of these areas, with Charleston being the focus for considerable naval activity. Recreation and tourist activities dominate portions of the North and South Carolina coastal areas, notably the Cape Hatteras, N.C., and Myrtle Beach, S.C., resort areas.

The Georgia-eastern Florida coast area is not as dependent on the natural resources of forests and fisheries as North or South Carolina, although Savannah, for instance, is a major center for the manufacturing of paper and allied products. The importance of the land-water interface, particularly in the Florida portion of this area, is centered on its value as a retirement and recreation area. The total economy of the area has thus moved increasingly to a service-producing economy with significant growth in professional services, contract construction, amusements, and similar activities.

*The Gulf of Mexico biophysical region*

This region extends from the southern Florida gulf coast economic area to the southern Texas gulf coast. Economic activities within this region are extremely diverse, ranging from a high dependence on agriculture, forestry and fisheries in the central Florida gulf coast area to the highly industralized petrochemical and manufacturing economy located in the north Texas gulf coast and centered on the Houston-Galveston complex.

The southern Florida gulf coast contains many service industries drawn to the Tampa-St. Petersburg retirement and recreation area. A high degree of specialization in contract construction in the area attests to the tremendous growth of the housing and building industry to accommodate the vast in-migration of recent years. Although forestry and fisheries is declining in this area's economy, there is a continuing relative concentration of these activities in the southern Florida gulf coast area.

Central gulf coast area economic activity presents a picture of relatively slow growth and one which has traditionally taken advantage of the natural resources of timber, agricultural land, and marine fish which occur in the area. Forestry and fisheries are very highly concentrated into this area.

The Mississippi-Alabama-west Florida coast area economy is highly dependent on the Federal military, especially in Pensacola, Fla.

However, the area shows great internal diversity. Mobile Bay is the center of increasing manufacturing activity and shipping. Textiles play an increasing role in this economy as well as the more traditional shipbuilding activity and fisheries centered in the Mobile Bay area. Harrison County, Miss., is the focus of a growing petrochemical complex and other heavy industry dependent on availability of crude oil, increasing developing of the inland waterway, and artificial ship-channel construction.

The Louisiana and Texas north and south gulf coast areas have all experienced greater-than-national-average growth in the recent past and are projected to continue this growth in the future. Much of this growth is attributable to the discovery and extraction of the coastal shelf petroleum deposits through the use of new technologies. All three economic areas show significantly high concentrations in the extractive phase of petroleum recovery (mining), the processing phase (refining), and in the production of secondary products (chemical and allied products). In contrast, the traditional importance of agriculture, forestry, and fisheries, particularly in the Louisiana and Texas south gulf coasts, has declined.

It is interesting to note that the impact of the new petrochemical-based economy differs markedly among these areas. The Louisiana coast experiences ample rainfall and abundant inflows of fresh water provided mostly by the Mississippi River and its tributaries. In contrast, the Texas coastal areas experience considerably less rainfall and fresh water inflow, particularly as one moves south along the coastline. The availability of fresh and brackish water for increasing upstream agricultural irrigation, domestic, and industrial uses will therefore be considerably different in the two coastal areas of Louisiana and Texas. This, in turn, will affect the desired quality and quantity of water, and increase the management problems faced by local, State, and Federal Governments.

*The Pacific Southwest biophysical region*

Two of the three California OBE coastal economic areas located in the Southwest biophysical region have sustained phenomenal growth, both in population and economic activity. The manufacturing activities of both the southern California and central California coasts are well diversified and expanding. Most of these developments are dependent on estuarine natural resources, primarily for port facilities and for some oil extraction in the southern California coast. However, tremendous pressure on remaining coastal open space for housing and development already exists and will inevitably increase in the future.

The southern California coast area is water scarce and dependent for its supply on sources outside the area. Central California's major estuary, San Francisco Bay, will be affected by these southern California water demands. The California water plan, which calls for significant diversion of fresh water inflow, presents major problems of water quality management for this area.

*The Pacific Northwest biophysical region*

This region includes the northern California coast, the Oregon coast and the Washington coast areas. These coastal areas are relatively undeveloped except for the Portland and Seattle metropolitan areas. All three areas remain specialized in economic activities related to the ample forest and fisheries resources of this region. This region is expected to show moderate growth rates in the future, with much of this growth occurring in the two metropolitan areas of major importance. The concentration of both population and economic growth in the Portland and Seattle areas will place heavy demands on the Columbia River and Puget Sound estuarine areas, particularly as demand grows for increased port facilities and associated industry, pulp and paper manufacturing, and the processing of food and kindred products.

Table IV.4.4 summarizes in some detail the major economic indicators of individual OBE estuarine economic areas. The areas are grouped roughly by biophysical regions.

The analysis of high-water-use industries conducted by the Bureau of the Census provides a framework for analysis of the impact of present and future economic activities on the Nation's estuarine zone. In 1964, the census of manufactures showed that the five major water-use industries in the United States, in order of magnitude of gross water intake, were the following: primary metal industries, chemicals and allied products, paper and allied products, petroleum and coal products, and food and kindred products.

Ranked in order of brackish water use (which may include use of estuarine water), chemicals and allied products were overwhelmingly the highest water user, nearly equaling the totals of the other four highest users, which were the following: petroleum and coal products, primary metal industries, paper and allied products, and food and kindred products. The two industries that exhibited significant increases in brackish water use between 1954 and 1964 were chemicals and allied products, and primary metals.

TABLE IV.4.4—SUMMARY OF ECONOMIC INDICATORS IN THE ESTUARINE ECONOMIC AREAS, SET OUT BY BIOPHYSICAL REGIONS

| Coastal-Estuary economic area | SMSA's in the area | Economic growth rate | Projected growth rate | Concentration and growth of major industries in the area (with location quotients of over 1.0, the national average) | Significant high water use industries |
|---|---|---|---|---|---|
| 1. North Atlantic: | | | | | |
| Maine coast | Portland | Less than national average (from a low comparative base level of economic activity). | Moderate increase, reaching national average. | Miscellaneous manufacturing (2.2); +transportation equipment, excluding motor vehicles (3.3); food and kindred products (1.2); paper and allied products (3.6); −textiles (2.0); −lumber and furniture (1.6.) (*forestry and fisheries (10.6).) | Paper and allied products. |
| Massachusetts-Rhode Island coast. | Boston, Lawrence-Haverhill, Lowell, Brockton, New Bedford, Fall River, and Providence-Pawtucket-Warwick. | Less than national average (from a high comparative base level of economic activity). | Slightly declining but continuing above the national average. | Miscellaneous manufacturing (2.4); +electrical equipment (2.3); −textiles (2.3); apparel (1.5); +food; +nonelectrical machinery (*forestry and fisheries (1.8)). | Total manufacturing; textiles (though the importance of this industry is declining sharply). |
| 2. Middle Atlantic: | | | | | |
| Connecticut coast. | New London-Groton-Norwich, Meriden, New Haven, and Waterbury. | Less than national average (from a high comparaive base level of economic activity). | Slightly declining but continuing above the national average. | +Miscellaneous manufacturing (2.6); +fabricated metals and ordnance (3.3); +transportation equipment, excluding motor vehicles (3.7); nonelectrical machinery (1.4) (*primary metals (1.8); paper (1.4); chemicals (1.3)). | Total manufacturing; chemical; paper; primary metals. |
| New York northeast New Jersey. | Bridgeport, Norwalk, and Stamford, Conn., and New York, New York and Jersey City, Newark and Paterson-Clifton-Passaic, N.J. | Less than national average (from a high comparative base level of economic activity). | Slightly declining, but likely to remain as the focal point of American economic activity in the future. | Apparel (2.9); + miscellaneous manufacturing (1.4); + electrical equipment (1.4); − printing and publishing (1.7); food; (*+ chemicals (1.5); + other transportation services (2.2)). | Chemicals; textile mill products. |
| Philadelphia, New Jersey-Delaware coast. | Philadelphia, Wilmington, Delaware and Atlantic City, N.J. | Less than national average (from a high comparative base level of economic activity). | Slightly declining, but continuing above the national average. | +Miscellaneous manufacturing (1+); +electrical equipment (1+); +chemicals (2.9); −apparel (1+); +food (1+) (+petroleum refining (2.6); other transportation services (1+)). | Total manufacturing; food; chemicals; paper and allied products, and petroleum refining. |
| 3. Chesapeake bay: Maryland-Virginia coast. | Baltimore, Washington, D.C., and Richmond, Newport News-Hampton Roads, and Norfolk-Portsmouth, Va. | Greater than national average. | Moderate increase, maintaining relative position of wealth versus the national average. | +Government, public administration (2.9); Armed Forces (3.2); +food; +transportation equipment, excluding motor vehicles (1.5); +printing and publishing (1.2); primary metals (*−forestry and fisheries (2.2); other transportation services (1.3)). | Primary metals. |

See footnotes at end of table.

TABLE IV.4.4—SUMMARY OF ECONOMIC INDICATORS IN THE ESTUARINE ECONOMIC AREAS, SET OUT BY BIOPHYSICAL REGIONS—continued

| Coastal-Estuary economic area | SMSA's in the area | Economic growth rate | Projected growth rate | Concentration and growth of major industries in the area (with location quotients of over 1.0, the national average) | Significant high water use industries |
|---|---|---|---|---|---|
| 4. South Atlantic: | | | | | |
| North Carolina coast. | Wilmington, N.C. | Slightly greater than average (from a low base level of economic activity). | Moderate increase, but continuing below the national average. | Armed Forces; −agriculture; −lumber and furniture (2.7); food; −apparel; −textiles (forestry and fisheries (8.1)). | Food; textiles, paper and paper products. |
| South Carolina coast. | Charleston, S.C. | Greater than average (from a low base level of economic activity). | do | Armed Forces; −agriculture; +transporation equipment, excluding motor vehicles (3.3); −lumber and furniture (2.0); paper and allied products (2.8) (+forestry and fisheries (3.4)). | Paper and paper products. |
| Georgia-eastern Florida coast. | Savannah, Ga., Jacksonville, West Palm Beach, Ft. Lauderdale-Hollywood and Miami, Fla. | Considerably greater than the national average. | Considerable increase, maintaining wealth position equal to that of the nation. | +Services; food; miscellaneous manufacturing; paper (1.4) (forestry and fisheries (1.6)). | Do. |
| 5. Gulf of Mexico: | | | | | |
| Southern Florida gulf coast. | Tampa-St. Petersburg | Considerably greater than average. | Considerable increase, maintaining a wealth position somewhat less than that of the Nation. | +Services, contract construction (1.5); miscellaneous manufacturing; +food (1.1); −forestry and fisheries (3.4). | Food and kindred products |
| Central Florida gulf coast. | | Greater than national average (from a low comparative base level of economic activity). | Considerable increase, but remaining below the national average. | Government, armed services (5.2); +paper and paper products (7.6); −lumber and furniture (2.3); food and kindred products; −forestry and fisheries (18.8); −agriculture. | Paper and paper products; food and kindred products. |
| Mississippi-Alabama-west Florida coast. | Pensacola, Fla., and Mobile, Ala. | do | Moderate increase, increasing to national average. | +Government, Armed Forces; +paper and paper products (4.1); +transportation equipment, excluding motor vehicles (1.9); −food and kindred products; +textiles (1.3); forestry and fisheries (5.2). | Paper and paper products; textiles. |
| Louisiana coast. | New Orleans, Lafayette, and Lake Charles. | Greater than national average (from a relatively high comparative base level of economic activity). | Relatively stable, maintaining a level somewhat less than that of the Nation. | Food and kindred products (1.5); +petroleum refining (4.3); +chemicals (1.1); transportation equipment, excluding motor vehicles; +mining; −forestry and fisheries (4.5); −agriculture; +other transportation services (3.6). | Petroleum refining: chemicals; food and kindred products. |

| | | | | | |
|---|---|---|---|---|---|
| Texas north gulf coast. | Houston, Beaumont-Port Arthur-Orange, Galveston–Texas City. | Considerably greater than the national average (a comparatively recent phenomenon). | Considerably greater than the national average space (a comparatively recent phenomenon). | +Mining (mainly petroleum) (2.9); +petroleum refining (13.0); +chemicals (3.1); +nonelectrical machinery (1.3) (other transportation services (1.9)). | Petroleum refining; chemicals and allied products; primary metals. |
| Texas south gulf coast. | Corpus Christi, Brownsville–Harlingen–San Benito. | Considerably greater than the national average (from a low comparative base level of economic activity). | Moderate increase, but continuing below the national average. | −Agriculture; food (1.1); +primary metals (1.1); +chemicals (1.5); +petroleum refining (3.0) (−forestry and fisheries (5.6); +mining (3.4)). | Chemicals and allied products; petroleum refining: primary metals. |
| 6. Pacific Southwest: | | | | | |
| Southern California coast. | Los Angeles–Long Beach, San Diego, Santa Barbara, Oxnard, Ventura and Anaheim–Santa Ana–Garden Grove. | Considerably greater than national average (from a relatively high base level of economic activity). | Moderate increase, maintaining a position of wealth relative to the Nation. | +Transportation equipment, excluding motor vehicles (4.0); +fabricated metals and ordnance (1.8); +electrical equipment (1.5); +miscellaneous manufacturing; +nonelectrical machinery; +food and kindred products; +services (+petroleum refining (1.5)). | Total manufacturing activity; food and kindred products; petroleum refining. |
| Central California coast. | San Francisco-Oakland, Vallejo-Napa, Salinas-Monterey, and San Jose. | Greater than national average (from a relatively high base level of economic activity). | do | +Government; +services; food (1.3); +fabricated metals and ordnance (1.3); electrical equipment; printing and publishing (1.1) (+other transportation services (1.9); petroleum refining (1.8)). | Food and kindred products. |
| Northern California coast. | | Greater than the national average. | Moderate increase, maintaining relative wealth of the area versus the national average. | Lumber and furniture (19.8); food and kindred products (forestry and fisheries (11.6)). | |
| Oregon coast | Portland, Eugene | Somewhat greater than the national average. | Moderate increase, equal to that of the national average. | Lumber and furniture (7.0); food and kindred products; +paper (2.7) (forestry and fisheries (4.2); other transportation services (1.4)). | Paper and allied products. |
| Washington coast. | Seattle-Everett, Tacoma | do | Moderate increase, maintaining relative wealth of the area versus the national average. | +Transportation equipment, excluding motor vehicles (6.7); −lumber and furniture (3.0); food and kindred products; printing and publishing; paper and allied products (1.7) (forestry and fisheries (3.7); other transportation services (1.8)). | Do. |

* Indicates those economic activities listed in parentheses are concentrated in the area, but are not major contributors to area employment.

\+ Indicates fast growth industries.
− Indicates slow growth or declining in regional importance.

## Section 3. Trends in Selected Activities Associated With the Estuarine Zone

The discussions in the preceding sections give some indication of the pressures placed on the estuarine resources in recent years and those that may be expected in the future. This section presents the discernible trends of some specific activities associated with the estuaries. Where possible, projections are made of the likely results of these trends.

For convenience of presentation and examination, different activities are discussed separately; however, it must be emphasized that these activities are closely interrelated and often place additive and conflicting demands on the estuarine environment. In short, because these activities all take place in the limited area of the landwater interface, and affect the land frontage, water, and biota of the zone, problems of management are inescapable.

The activities selected for detailed attention are those which have a particularly close relationship to the resources that occur in the estuaries, open coastline, and near-shore waters. Other activities that are found in the estuarine zone, but are not directly tied to the natural resources existing there, are given less attention. The concepts of primary, secondary, and marginal activities (fig. IV.3.1) are used with these definitions:

(1) Primary activities are those uses which by their nature are locationally tied to the estuarine zone;

(2) Secondary activities are those uses that are closely associated with primary activities and as a consequence have a significant tendency to locate in the estuarine zone; and

(3) Marginal activities are those uses which are not directly tied to the estuary zone, but which tend to be found in areas of urban-surburban development.

Harvesting finfish and shellfish for food and other uses is an example of primary activity associated with the estuary zone, while plants constructed to process the catch denote secondary activities. Marine waterborne commerce is directly tied to the estuary port system and is thus considered a primary activity. The naval arm of the national defense capability is likewise firmly linked to existing ports and harbors and is thus a primary activity. Specialized facilities and provision of logistical support for these primary commercial shipping and naval activities are secondary activities. Industries which require frontage on navigable waters to receive or distribute bulk raw materials and/or processed goods by ship are primary activities. Examples of this type of industry are petroleum transportation (often closely tied to secondary processing activities), export of bulk commodities such as lumber and grain products, some primary metal refining, and shipbuilding.

Many other activities compete for locations in the estuary zone, drawn by the inflow of raw materials, by extensive markets, or by the availability of transportation networks in significant portions of the zone. Examples of secondary activities which are located in the estuarine zone are pulp and paper mills, fossil or nuclear power plants—where location must be balanced with the distance to consumers of energy—chemical and food processors, and primary metals refineries.

Despite the fact that the estuarine environment supplies relatively unique resources which attract many primary and secondary activities, the greater part of economic activity, particularly in the relatively mature economies of the Northeast, Middle Atlantic, and west coasts, is not directly dependent on the natural resources of the estuarine environment. The service sectors of the economy dominate most of these marginal activities and range from garbage collection to construction of office buildings. Many other marginal activities are drawn to the land-water interface for esthetic reasons, such as restaurants, hotels, and specialty shops. The resulting mix of many economic activities, with significant variations in proportional makeup of primary, secondary, and marginal activity, characterize the dominant urban-suburban environment which exists and will increase in the estuarine zone and coastline of the Nation.

Trends and projections for marine fisheries, transportation and national defense, marine mining and processing, recreation, and waste discharge are presented here. Where appropriate, the discussion of these subjects is related to the biophysical regions and OBE estuarine economic areas.

### MARINE FISHERIES

The Nation's fishing industry has been widely characterized as relatively undeveloped in management and operation, inferior to the competing fishing fleets of other nations in technology, under-capitalized, and relatively weak in respect to both the national economy and to foreign competition. This consensus of opinion is supported by numerous comparative statistics.

The industry has grown relatively slowly in productivity over the years. From 1925 through 1966, the quantity of catch increased by only 60 percent. During the same period, the rise in the amount paid to fishermen for their catch was only slightly higher, increasing something less than 100 percent. In fact, the average annual catch per fisherman has remained below the 1957–59 average since 1964.

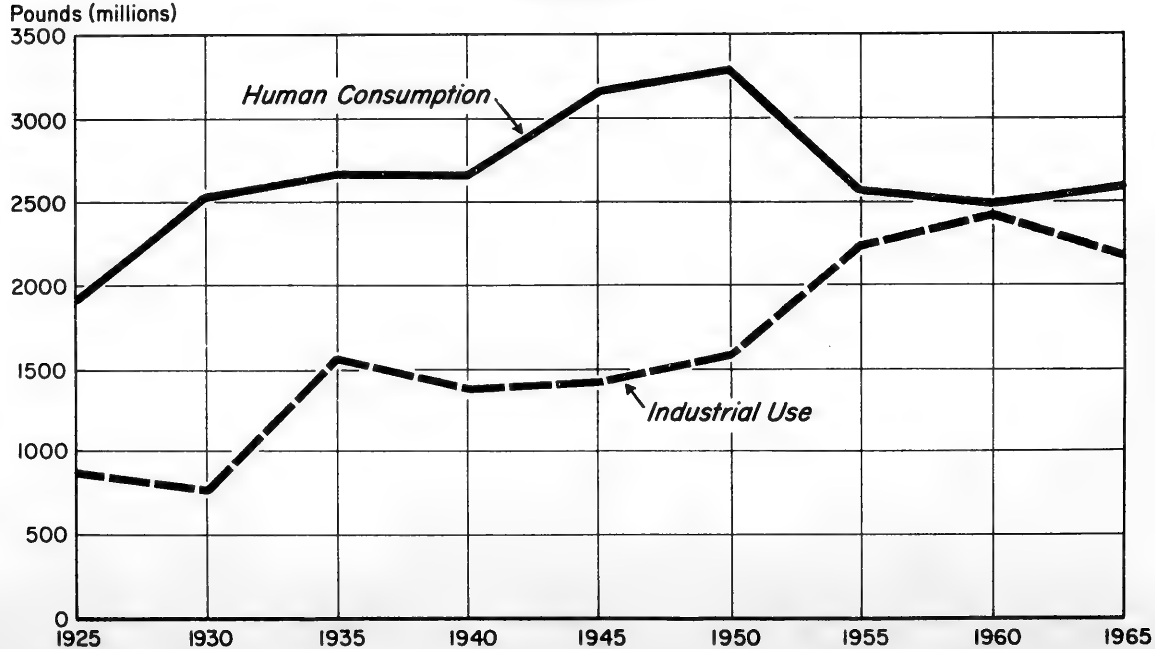
*The industrial fishery*

Industrial uses of commercial fish, rather than human consumptive uses have accounted for most of the increase in tonnage in the recent past, as indicated in figure IV.4.11. This trend is particularly evident in the more recent period between 1961 and 1966. Industrial uses of marine fish are primarily for fish oils, fish solubles, and fish meal. These basic products are used mainly for industrial processing, pet food, agricultural feed (particularly for chickens), and fertilizers.

The primary species caught for industrial use is the menhaden, an estuarine-dependent fish. Productive areas for this fish have been the Middle Atlantic, Chesapeake, South Atlantic, and Gulf of Mexico biophysical regions. Production in the Middle Atlantic region has decreased markedly in recent years, and the catch in the Chesapeake Bay has fluctuated. Fishing pressure for menhaden in all regions has intensified, and may have reached the point of overharvest in some localized areas. This pressure has continued despite declines in the wholesale price for fishmeal partly brought on by foreign competition, particularly from anchovies from the Humboldt Current grounds off Peru. Figure IV.4.12 indicates the growing foreign share of the industrial fish catch.

**Figure IV.4.11**

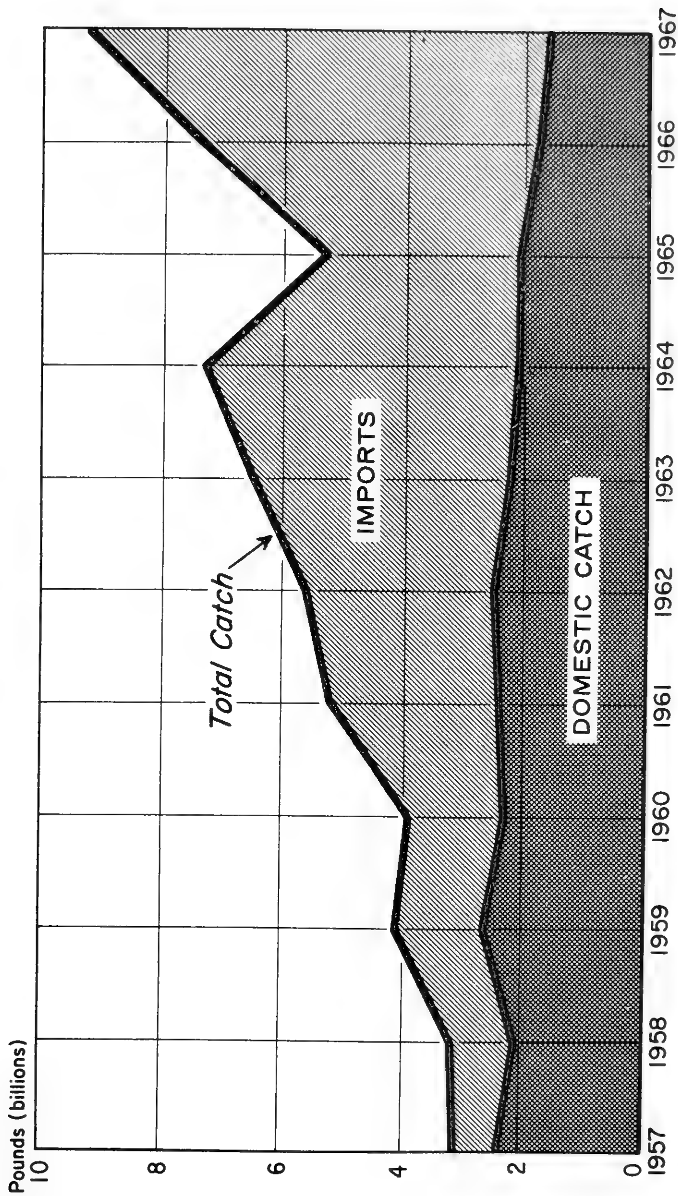
HUMAN CONSUMPTION AND INDUSTRIAL USE OF DOMESTIC FISH CATCH, 1925-1965




*Source: Bureau of Commercial Fisheries.*

**Figure IV.4.12**

**FOREIGN AND DOMESTIC SHARES OF TOTAL INDUSTRIAL FISH CATCH, 1957-1967**



In 1958, imports of industrial fishery products accounted for 35 percent of the total U.S. supply; in 1967, imports accounted for 82 percent of the total. This increasing share of imported industrial fish products contributes to the balance-of-payments problem in the national economy as well as directly affecting the economic base of the domestic fishing industry.

It must be noted, however, that increased harvesting of industrial fish is ultimately dependent on existing renewable supplies of the resource. Although some sizable stocks of underutilized species exist, such as the thread herring in the Gulf of Mexico, other stocks may be overfished, now or in the future. Further degradation or destruction of the estuarine nursery grounds for menhaden could well reduce or eliminate this major domestic source of industrial fish.

*The edible commercial fishery*

Despite the growth of the industrial fish sector, edible fish continue to dominate the overall fisheries market in terms of value, as table IV.3.4 indicates.

*Shrimp*

Penaeidean shrimp, the most valuable commercial fish resource, are dependent upon the estuary for nursery grounds and are then harvested in coastal shelf waters. Almost all domestic harvesting of this shellfish occurs in the southern South Atlantic and Gulf of Mexico biophysical regions. Particular estuarine economic areas that support this fishery and allied processing are the Georgia-eastern Florida coast, the Louisiana coast, the Mississippi-Alabama-west Florida coast and the Texas north and south gulf coasts.

Recent and projected trends show a strong and increasing demand for shrimp although prices have increased rapidly. The ability to supply these increasing demands in the future is dependent, to a great extent, on the continuing supply of domestic shrimp. It is estimated that the shallow water shrimp fishery is already fully utilized and perhaps over-fished in the traditional south Atlantic and Gulf of Mexico grounds. While the deep water shrimp supplies are estimated to be large and are relatively untapped, there are considerable technological problems in locating and harvesting these shrimp.

The continued existence of domestic shrimp to meet rising market demands is uncertain. Recent declines in shrimp landings have been noted in estuarine areas of relatively little industrial and population pressure and in areas of considerable economic and population concentration. For example, in Florida's Apalachicola Bay, the shrimp fishery experienced a dramatic decrease in the short period between 1964 and 1967. The 1967 catch was less than 17 percent of the 1964 landings. Nearby St. George Sound experienced a similar decline during the same period. The decline in local supplies of shrimp forced Apalachicola fishermen to extend their operations to the Tortugas area of Florida, which not only increased their operating costs, but—more significantly—added to the heavy pressure already applied to the Tortugas shrimp fishery.

Galveston Bay, a steadily growing population and industrial center, has been a prime nursery ground for shrimp and a major area of shrimp harvesting and processing. These primary and secondary fishery activities are threatened by the degradation of the Galveston estuarine environment by industrial and municipal pollution, by dredging and filling, and by decreases in the quantity and quality of freshwater inflows. Although market demand and prices rose steadily from 1962 through 1966, and fishing pressure increased, the total Galveston catch declined drastically from 4,192,900 pounds in 1962 to 1,941,000 in 1966. Although a direct causal relationship between estuary degradation and this decline in catch cannot be demonstrated at this time, it is reasonable to conclude that the cumulative effect of degradation acts to reduce available supplies of shrimp.

*Oysters*

The record of the oyster industry in the United States is a continuing story of depletion in absolute quantity and decline in the usefulness of remaining beds. Declines have taken place in nearly all estuary areas that naturally supported oyster populations. Depletion has occurred for many reasons, both natural and man-induced.

Natural catastrophes have depleted the oyster beds over time. The hurricane of 1954 in Narragansett Bay, for example, is considered the prime factor in the destruction of beds and the decline of the secondary processing industry in that location. By 1956 the oyster harvest from Narragansett Bay had declined to 31,000 pounds, from 252,000 pounds in 1953. In 1957, the last remaining oyster dealer went out of business.

Most of the reduction in domestic oyster production, however, can be attributed to man's activities in the estuaries. Examples of the diminution or extinction of this resource are many. New Jersey's Raritan Bay, an outstanding producer of oysters for the New York market in the 19th century, is now almost barren of this shellfish, mainly due to municipal and industrial waste discharge. A study in Shelton, Wash., indicated that sulphite waste discharge from paper pulp manufacturing almost surely brought about a serious decline in the oyster population.

Many areas of oyster production for human consumption are closed because municipal wastes contaminate oysters with bacterial matter.

Silting due to dredge operations has appreciably diminished the quality of many former oyster-producing areas. The silt may actually smother the beds, or may so seriously disturb the estuary floor as to cause deleterious effects from lowered amounts of dissolved oxygen. This process, which has been observed in parts of Galveston Bay, produces hydrogen sulfide and releases concentrated amounts of toxic chemicals in bottom sediments.

The decrease in production and consumption of oysters due to natural or man-induced causes is exacerbated by changes in consumer preference, lack of mechanized shucking and packaging procedures, and increasing labor costs. Perhaps the most difficult problem is presented by the legal labyrinth surrounding ownership and use of oyster beds. Management and sound overall economic use of the oyster resource is almost impossible under present institutional constraints which range from public ownership in Massachusetts to a tangle of leasing and private ownership in such areas as Georgia, the Chesapeake Bay, and James River estuaries.

The future of a viable oyster industry, and the continued availability of a delicate and nutritious food, is thus linked not only to the quality of the biophysical environment, but to the workings of the economic and institutional environment as well.

*Anadromous fish*

Landings of anadromous fish, particularly those of economic importance such as the salmon and shad, have declined in numbers, while retail markets have generally shown a steady improvement.

The diminution of the continental salmon fishery provides a classic example of the damage inflicted on fisheries by biophysical modification. As dam-building, lumbering, and other kinds of man's activities increased, the once-abundant salmon catches declined. The Atlantic salmon has almost completely disappeared from the east coast. On the west coast, reduction in the quality and quantity of freshwater, sedimentation in spawning areas, pollution of the transitional zones in estuaries, and heavy fishing pressure by both sport and commercial fishermen have combined to reduce the once-flourishing salmon industry.

Most of the domestic catch now comes from salmon dependent on the streams, rivers and estuaries of Alaska, since that State is for the most part free of the physical and biological modifications made by man in the other Pacific coast States. Growth of logging, oil, natural gas, and hydroelectric activities may alter this situation drastically in coming decades. Even without these modifications, which have little-known effects on the possible sustained yield of Alaskan salmon, this fishery faces serious economic and institutional problems. Fishing pressure is rising significantly because of increased numbers of fishermen and improved harvesting technology, while catch per fisherman has declined greatly. Increases in market price sustained this odd circumstance, as figure IV.4.13 shows.

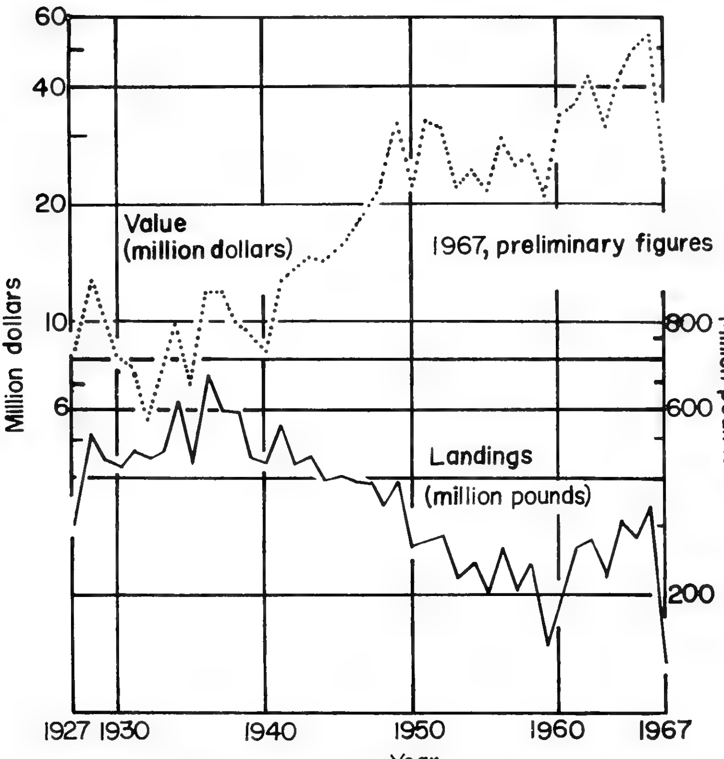
*Future prospects*

Examples of the historical decline and projected pressures on the domestic commercial fishery could be multiplied many times. The market demand for fishery products is growing and is projected to rise sharply in the near future, but the amount of that market which will be supplied by imports is not yet clear.

It is the conclusion of many experts in the field that a harsh choice must be made in the near future: either the management of the Nation's estuarine resources will be substantially strengthened, institutional constraints relieved, and the trend toward degradation of the estuarine environment stemmed, or the supply of commercially valuable finfish and shellfish to meet rising demands will diminish.

Mariculture, the manipulation of the estuarine or marine environment to increase production of commercial species, is often cited as a method to overcome the depletion of natural stocks and fill increasing market demands for fish products. The ability of artificial culture to significantly increase yields has been proven in countries such as Japan where shrimp, oyster, and certain finfish are raised on a profitable basis. However, the economic use of mariculture is in its infancy in the United States. Although the ultimate impact of aquaculture practices would appear great, increasing yields from five to as much as 20 times, the present economic and social climate would seem to indicate that the impact of mariculture will be relatively slight in immediate future decades. When other ancillary values are added, it would appear that proper management of the natural estuarine en-

FIGURE IV.4.13 TOTAL ALASKA SALMON CATCH (POUNDS & VALUE), 1927-67




Source: Bureau of Commercial Fisheries

vironment is a preferable course of action both to preserve and perhaps enhance the production of fish and maintain the quality of this unique environmental resource.

### COMMERCIAL AND NATIONAL DEFENSE TRANSPORTATION

*Commercial*

An environment favorable to transportation has been one of the most significant historical factors in coastal and estuarine development. Settlements originated at the sites of coastal harbors and at the mouths of rivers because of the accessibility of these areas to trading vessels. The commerce which passed through these centers encouraged further growth and development. The coastal and estuarine areas also saw rapid development of air, rail, and highway systems because the main demand was located there and the terrain presented few obstacles. Connecting links were needed between the coastal trade centers and the hinterlands, and the level land available along the coasts, bays and rivers was the natural location for railroads and highways for both engineering and economic reasons. Airports also require large tracts of level land, and a waterside location affords the benefits of unobstructed and unpopulated approach zones. This concentration in coastal and estuarine centers has continued as these areas have maintained their growth and thereby further simulated the maximum utilization and expansion of transport facilities.

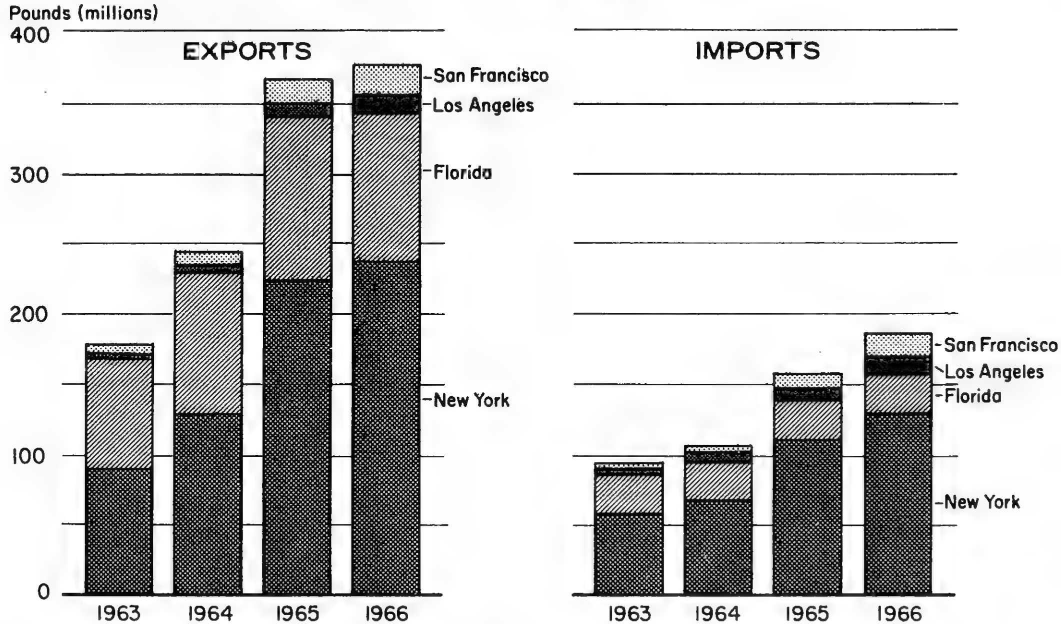
Airborne commerce has experienced considerable growth. Some statistics are available to relate it to estuarine locations. Figure IV.4.14 gives some historical data on airborne import and export commerce by coastal customs districts. Airport location on or near an expanse of water is desirable because it affords unobstructed approaches and reduces noise problems. Airports are presently located in estuarine areas in Boston, New York (both Kennedy and La Guardia), Washington, Norfolk, San Diego, San Francisco and Oakland.

A further element which will almost certainly affect the estuarine zone is the development of new ports. For example, if the proposed free port in Maine becomes a reality there will be a rapid proliferation of all types of commercial transportation to service that port area and to provide a network for distribution. Since major refinery operations are part of the proposed plans, this development will include pipelines and associated petro-chemical facilities, and other modes of land transport. Such a free port could have far-reaching effects on the present distribution of cargo tonnages at east coast ports as well as develop an estuarine area which is now relatively pristine.

Another factor which could significantly affect the trade distribution of all ports is the development of the super-tankers and larger dry cargo vessels. These carriers require up to 60-foot channel and berthing depths. This will call for an enormous dredging operation in most ports, where maximum dredged channel depth now is around 40 feet. Some places, like New York, have already been dredged to bedrock level, so blasting would be necessary to go deeper. An alternative solution is to establish offshore docking facilities for the super-ships and bring their cargoes ashore through pipelines or in lighter-type ships. The bottom clearance requirements of these ships are considerably smaller, which would mean far less dredging for channel maintenance. How-

**Figure IV.4.14**

AIRBORNE EXPORTS AND IMPORTS AT COASTAL CUSTOMS DISTRICTS, 1963-1966




*Source: Department of Commerce, Statistical Abstract of the United States; 1966 and 1967.*

ever, the current world merchant fleet will no doubt continue to operate for at least another 20 years, which means that channels would have to be maintained at least until this generation of ships has been phased out.

It has also been suggested that a decrease in the number of ports might prove more economical in the handling of the super fleet because of its enormous cargo capacity. Improved off-loading technology and larger warehouses will be necessary to handle the increased tonnage, and it would be inefficient to develop a whole network of these facilities, some of which might lie idle part of the time. Furthermore, many smaller ports probably could not generate demand to warrant development of super ship capabilities.

The expansion of land transportation can be expected to parallel port development in the future as it has in the past. Pipeline construction will develop concurrently with oil production—probably at a rapid rate since the demand for natural gas and petroleum products is expected to triple over the next 30 years. The future of rail transport is difficult to assess, no so much because of demand factors but because the roads (particularly in the east) are undergoing a period of administrative restructuring and a consolidation of service.

The Houston-Galveston Bay complex demonstrates how a good harbor can encourage the growth and development of an area and begin a demand spiral that leads to more intensive utilization of the harbor and the development of other transport facilities. The Port of Houston is now the third largest U.S. seaport in terms of total tonnage moved. In 1963, approximately one-third of Houston's economy was linked to the ship channel, the port and the resultant industry. Total investment flowing from the port facilities and related industries exceeded $2.5 billion that year. The dredging of the Houston ship channel and the development of cargo facilities has thus been of major consequence in the development of this area.

Table IV.4.5 shows the significance of transportation and its concomitant, wholesale trade, for the Houston-Galveston Bay area for the years 1956 and 1967. The Port of Houston is served by six trunkline railroads, 38 motor freight carriers, 8 barge lines, 11 export packers, 35 freight forwarders, 19 stevedoring companies, and a large number of marine outfitters and ship chandlers. More than 100 steamship lines offer service to all free-world ports. Future demand for all types of transportation is expected to increase as the population grows and industry expands.

The San Francisco Bay Conservation and Development Commission has done an excellent case study of the transportation pressures being exercised in its estuarine area. San Francisco was founded as a port city, and shipping is still of primary importance to the entire economy of the bay area. In addition to the economic impact of the shipping industry itself, there are many other businesses and industries that have been drawn to the region because of the availability of water transport. In 1965, Checchi & Co. estimated that 50,000 jobs were attributable to general-cargo shipping and industries dependent on shipping. This represented a payroll of about $820 million.

TABLE IV.4.5.—TRANSPORTATION-WHOLESALE TRADE INDUSTRIES, BAY AREA, 1956–67

| | 1956 | 1967 |
|---|---|---|
| Employment: | | |
| Total in study area | 384,891 | 608,865 |
| Total in transportation-wholesale trade | 62,790 | 96,550 |
| Transportation-wholesale trade as percentage of total | 16.3 | 15.9 |
| Taxable payrolls (millions): | | |
| Total in study area | $1,535.6 | $3,053.6 |
| Total in transportation-wholesale trade | 255.6 | 637.2 |
| Transportation-wholesale trade as percentage of total | 16.7 | 18.2 |
| Number of firms: | | |
| Total in study area | 25,465 | 34,187 |
| Total in transportation-wholesale trade | 2,977 | 4,269 |
| Transportation-wholesale trade as percentage of total | 11.7 | 12.5 |

Source: County Business Patterns, 1956, 1967.

By tonnage, the principal cargo passing through the San Francisco Bay is petroleum. This tonnage is expected to increase significantly in the future, and bring with it deep draft tankers with drafts as much as 60 feet. At this time, however, there are no reliable estimates of the impact of this future increase in San Francisco port traffic, nor are there reliable methods to measure the conflicting values and costs presented by this phenomenon.

## NATIONAL DEFENSE

The use of estuarine and coastal ports has always been an essential need of the national defense system for the movement of weapons, troops, and supplies to and from overseas bases and operations zones. Table IV.4.6 itemizes amounts of military cargo and passengers transshipped by area for 2 recent years. Tons and dollar value of cargo went up appreciably from fiscal year 1966 to fiscal year 1967, while numbers of passengers decreased. The impact of the Vietnam war can be seen in the comparison of figures for the Eastern and Western areas for the 2 years. However, it is a primary item of Defense policy that facilities be available for use in all coastal areas to meet particular military logistics requirements at any time.

Future demands for the use of estuarine and coastal areas by the Department of Defense are difficult to project since they will vary greatly according to the state of international affairs and the impact of technological developments. The Office of Business Economics has regarded military employment as a constant after the year 1980 because of this lack of predictability. The examples given in chapter 3 of the impact of Naval activity on Narragansett Bay and San Diego Bay give at least a general idea of the magnitude of present and future military activities in the Nation's estuaries.

TABLE IV.4.6.—MILITARY CARGO AND PASSENGERS TRANSHIPPED THROUGH CONTINENTAL U.S. WATER PORTS[1]

| Part I, cargo areas | Fiscal year 1966 | | Fiscal year 1967 | |
|---|---|---|---|---|
| | Measurement ton [2] (thousands) | Dollars (millions) | Measurement ton [2] (thousands) | Dollars (millions) |
| Total, all areas | 5,965.4 | 134.0 | 20,835.5 | 184.6 |
| Eastern area | 7,777.3 | 52.0 | 8,973.5 | 66.8 |
| Atlantic ports | 5,723.5 | 39.9 | 6,243.3 | 49.1 |
| Gulf ports | 2,030.0 | 12.0 | 2,635.5 | 17.0 |
| Western area | 8,188.1 | 82.0 | 11,862.0 | 117.8 |
| North Pacific coast (Washington-Oregon) | 1,625.2 | 14.5 | 3,275.5 | 29.1 |
| South Pacific coast | 6,562.9 | 67.5 | 8,586.5 | 88.7 |

| Part II, passenger | Fiscal year 1966 | | Fiscal year 1967 | |
|---|---|---|---|---|
| | Passengers (thousands) | Dollars (thousands) | Passengers (thousands) | Dollars[3] (thousands) |
| Total, all areas | 213.7 | 880.5 | 120.5 | 366.6 |
| Eastern area | 121.2 | 365.9 | 28.6 | 171.8 |
| Atlantic ports | 120.0 | 361.2 | 27.8 | 166.4 |
| Gulf ports | 1.2 | 4.7 | 0.8 | 5.4 |
| Western area | 92.5 | 114.6 | 92.2 | 194.8 |
| North Pacific coast (Washington-Oregon) | (4) | (4) | 10.2 | 21.6 |
| South Pacific coast | 92.5 | 114.6 | 82.0 | 173.2 |

[1] With the exception of the Great Lakes.
[2] 1 measurement ton equals 40 cubic feet.
[3] Dollar amounts represent cost, not revenue, which is computed on predetermined billing rates.
[4] No movement reported.

Source: Quarterly progress report. 4th quarter fiscal year 1967, RCSDD–IL (Q) 493, Military Traffic Management and Terminal Service, Washington, D.C.

## ESTUARINE MINING AND PROCESSING

Actual extraction of both hard and soft minerals from the estuaries is presently limited. By far the most valuable and potentially profitable mining activities in the estuary areas are petroleum extraction, gas and sulphur recovery, and sand, gravel, and shell dredging. It is important to note that the primary activity of extraction, with the exception of sand and gravel dredging, has had relatively little effect on the estuarine environment. Such secondary activities as petroleum refining, transport by pipeline or ship, and petrochemical processing have had much greater impact. Finally, the marginal activities which grow up to support the populations drawn to areas of heavy petroleum extraction and secondary industry also place a heavy burden on the quality of the estuarine zone.

Petroleum (oil and gas) dominates present and projected mining activity in the offshore regions of the United States, accounting for over 84 percent of offshore mineral production in 1966. Offshore sources supply a relatively small, but rapidly increasing, share of the total domestic oil output.

As table IV.4.7 illustrates, offshore production of petroleum has grown steadily in the past decade, rising from less than 3 percent of total production in 1958 to nearly 10 percent in 1967. If exploration, technologies of recovery, and demands advance at expected rates, it is projected that 20 percent of total domestic production in 1980—about 1 billion barrels—may come from the offshore marine region.

TABLE IV.4.7.—CRUDE OIL PRODUCTION FROM THE CONTINENTAL SHELF[1]

[Millions of barrels]

| Year | Location | | | Total on shelf | Percent of total production terrestrial and marine |
|---|---|---|---|---|---|
| | California | Louisiana | Alaska (Cook Inlet) | | |
| 1948 | 14.4 | | | 14.4 | 0.72 |
| 1953 | 14.8 | 3.0 | | 17.8 | .75 |
| 1956 | 16.5 | 11.0 | | 27.5 | 1.05 |
| 1958 | 15.8 | 55.1 | | 70.9 | 2.90 |
| 1960 | 15.2 | 84.2 | 0.6 | 100.0 | 3.92 |
| 1962 | 17.8 | 126.9 | 10.3 | 145.0 | 5.45 |
| 1964 | 20.9 | 163.3 | 11.1 | 195.3 | 7.00 |
| 1965 | (2) | 197.3 | 11.1 | 208.4 | 7.25 |
| 1966 | (2) | 243.1 | 14.4 | 257.5 | 8.50 |
| 1967 | (2) | 291.3 | 20.3 | 320.6 | 9.85 |

[1] It should be noted that totals from Texas are not included in this summary. It is thus a conservative picture of offshore oil production.
[2] Not available.

Source: National Council on Marine Resources and Engineering Development, "The Economic Potential of the Mineral and Botanical Resources of the U.S. Continental Shelf and Slope," report by Economic Associates, Inc., p. 226, 1968.

Nearly one-quarter of present U.S. reserves are found on the Continental Shelf. Those reserves found under water depths of 200 feet or less are of particular importance to the estuarine zone; major areas identified as having significant crude oil deposits in near-shore water are listed in table IV.4.8.

Sulphur mining is another major estuarine activity. Presently, most of the subsurface extraction is concentrated in three mines: two located on the Continental Shelf several miles off the Louisiana coast and the third in a coastal bay off the same State. By 1970, these three mines are projected to supply about 2.5 million tons of Frasch sulphur, or about one-fourth of total projected domestic demand.

Significant expansion of this industry in the estuarine zone seems unlikely in the near future, since there are large and economically competitive land-based sulphur sources in western Texas, as well as competition from gypsum byproducts and from probable byproduct recovery under new air pollution restrictions.

*Table IV.4.8—U.S. areas with significant crude oil deposits—Estimated ultimate reserves of offshore crude oil*

[Billions of barrels]

| Region: | |
|---|---|
| Atlantic seaboard (excluding Florida) | 1.0 |
| Florida, Northern Gulf Coast | 3.2 |
| Mississippi and Alabama | 2.9 |
| Louisiana | 17.9 |
| Texas | 7.0 |
| Southern California | 1.3 |
| Alaska, Pacific Coast, and Gulf of Alaska | 24.0 |
| Total | 57.0 |

Source: The Economic Potential of the Mineral and Botanical Resources of the U.S. Continental Shelf and Slope, op. cit., p. 221.

These figures reinforce those already cited and identify the Gulf of Mexico biophysical region as the probable future focus of continental U.S. petroleum recovery and secondary processing growth. Alaska, perhaps including the Bering Sea and Arctic margins, is also certain to be an area of increasing exploration, recovery, and refining.

The mining of sand and gravel from the estuary floor does not compare in economic importance to the extraction and processing of petroleum and sulphur. The present value of sand and gravel produced in coastal bays and estuaries is estimated to be between $18 and $30 million a year. Marine shell deposits, particularly oyster shell, have been harvested for years, mainly in the Gulf of Mexico and San Francisco Bay. Production of shell was estimated to be about 21 million tons in 1966, with a value of approximately $33 million.

Yet, the mining of sand, gravel, and shell has a significant impact on estuarine conditions wherever it is practiced. Unlike petroleum, the mining of these aggregates is not the spur for industrial and population expansion. The reverse is true. Demand for coastal and estuarine deposits of aggregates is the direct result of metropolitan growth and related urban demands for cheap construction material in the form of concrete and other building products.

Since suitable construction aggregates are found nearly universally on the Atlantic, gulf, and Pacific coasts, and transportation of these materials often makes up one-half or more of the costs to the consumer, present and future growth of this industry in the coastal-estuary zone will be dependent on increasing urban developments, and the availability of competing deposits on the land surface. Thus, projections of growth of coastal-estuarine extraction of aggregates are difficult due to the fact that local demand-and-supply conditions are now and will continue to be the major determining factor in decisions to exploit marine aggregate resources.

Sources of aggregate extracted from supplies in coastal rivers and estuaries already provide the principal source of sand and gravel for such metropolitan areas as New York, Philadelphia, Baltimore, Washington, D.C., Norfolk, Mobile, and New Orleans. Oyster shell is a major source of cement and associated lime requirements in Galveston Bay, Tex. Significant quantities are also mined in the San Francisco Bay. It seems reasonable to conclude that as urban areas continue to grow through suburban expansion, as land values rise and as zoning restrictions are tightened, that the demand for estuary reserves of sand, gravel, and shell will grow. Offshore dredging on a massive scale is presently precluded due to the high cost of building suitable dredges, technological difficulties of deep-water recovery, and competing resources on land and the estuaries.

Salt is an obvious yet relatively insignificant product extracted from estuarine water. Only three of over 100 salt-producing operations are located in estuarine areas. Their total production in 1967, valued at $17 million, was about 7 percent of the total U.S. production. Such activity in estuarine areas is bound to decline as pressure is exerted by more competitive uses of estuarine land.

Current interest in exploiting phosphorite and manganese nodules and contiguous deposits of nickel, cobalt, and copper is limited by available technology. Gold and platinum metals exist in submerged beach and placer deposits off Alaska, California, and Oregon but it is unlikely that mining will be undertaken for them in the near future. Diamonds, gold, and zircon have also been identified in the estuarine sands of various States, but extraction appears unlikely.

Magnesium metal, magnesium oxide, and bromine are all extracted from sea water and plants are presently located mainly in the estuarine zones of Texas and California. Production is adequate for projected demand and little expansion is anticipated, at least within the estuarine area. Relatively little modification of the estuarine environment results from these activities.

In review, the future of mining in the estuarine zone and near coastal waters will center on two categories of minerals that may give rise to serious and increasing pressures on that environment: petroleum, gas, and sulphur, and sand, gravel, and shell. Improved management of estuarine resources must take these primary and the associated secondary and marginal activities into account in any rational scheme to balance and optimize the values of the Nation's coastal resources.

## OUTDOOR RECREATION

### *Historical trends*

Outdoor recreation awareness has existed since the establishment of the first communities in the United States with their typical commons and public parks. Parks and their value to an urban society were reemphasized by the great city planning movement of the latter decades of the 19th century. This revival was accompanied by an awareness on the part of urban scholars that natural resources were not inexhaustible and should receive a measure of protection. The effect, of course, was the establishment of the national park and national forest systems largely centered in the Western States and areas of very light population. The advent of the State park movement in the 1920's was augmented by a variety of national initiatives during the 1930's which tended to establish some balance in the distribution of land areas managed by public agencies for a variety of public purposes, including outdoor recreation. The objectives were largely resource-protection oriented and the facility development which took place during the 1930's was directed far more at providing employment than meeting, in a planned fashion, identified outdoor recreation needs.

The years of World War II and a suddenly released affluence during the decade following the cessation of hostilities combined to produce an enormous awareness on the part of a rapidly changing society that the opportunities afforded by the public stock of resource areas was inadequate to meet their needs. A variety of landmark investigations into the status of outdoor recreation were undertaken and published during that decade. Principal among them were: intensive studies of the shorelines of the United States by the National Park Service, and a preparation of Operations Outdoors program by the U.S. Forest Service. These investigations culminated in the establishment of a California Outdoor Recreation Study Committee and the National Outdoor Recreation Resources Review Commission.

*Measures of demand*

Both these studies for the first time demonstrated the basic causal factors in outdoor recreation demand. In effect, they found that adequate planning for outdoor recreation required larger concerns than the biophysical environment; that the economic environment—expressing the preference of society for goods and services—and the institutional environment—decisions about the focus and characteristics of agencies charged with the protection of resources and the provision of outdoor recreation facilities—were equally important.

The principal causal factors noted and documented by the Outdoor Recreation Resources Review Commission reports were:

(1) Growth in total population;

(2) Growth in leisure time;

(3) Increased mobility of the total population, including transportation;

(4) Changing population characteristics of the total population; and

(5) Concentration of population in urban or metropolitan centers.

It was concluded that, as the levels of these factors rose, the growth of outdoor recreation demand for specific activities or opportunities would accelerate faster than the net increase in total population. Sections 1 and 2 showed that these principal factors in the growth of outdoor recreation demand will exhibit sustained growth both nationally and within the estuarine zone. Therefore, although no specific quantification is presently available to project actual recreational demands on and uses of the Nation's estuarine resources, they will certainly increase at substantial rates in the future. It is uncertain whether the supply of recreation resources will in fact be sufficient to meet this large, if unquantified, demand. Continued degradation and restriction of recreation resources, particularly those in the estuarine zone, may well mean that some of the potential demand will be canceled by overcrowded, unattractive areas already much in evidence.

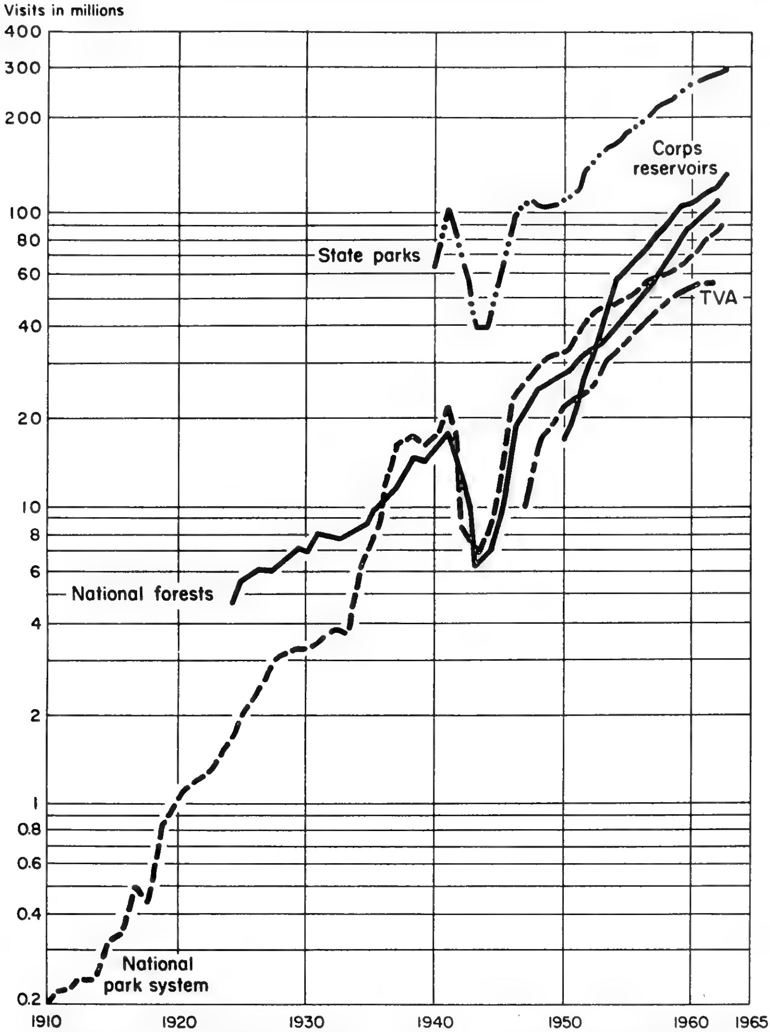
Although specific estuarine projections are not available, it has been generally concluded by experts in the field that one indicator—attendance in public parks—has risen by about 10 percent annually for many years. This is a rate more than five times the rate of the "population explosion" noted in section 1. There are indications that this comparative rate of growth for the outdoor recreation experience in public park areas must level off, but the immediate future would seem to maintain the trend toward more overcrowding and use, and the modifying pressures these entail, as figure IV.4.15 indicates.

Recreation demands are expressions of desire for certain activities and thus are difficult to translate into requirements for particular quantities of bay shoreline, acres of marsh, and so on. Thus the magnitude of future demands and the consequent requirements for associated estuarine resources are extremely difficult to pinpoint.

Perhaps the most common indicator of recreation growth is expressed by "user days" of some particular activity. An example of this is provided by the national trends and projections developed by the Bureau of Outdoor Recreation. Figure IV.4.16 indicates the projections for five outdoor recreation activities that occur in the estuarine

## Figure IV.4.15

### ATTENDANCE AT MAJOR TYPES OF OUTDOOR RECREATION AREAS

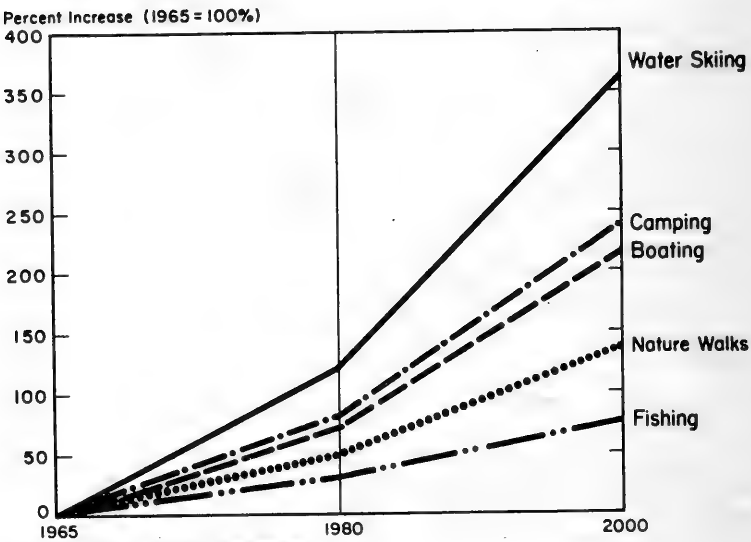



Source: Marion Clawson and Jack L. Kultsch, Economics of Outdoor Recreation (Baltimore: John Hopkins Press, 1966), P. 44.

environment although, obviously, they can be accommodated in other areas as well. Numerous other inventories indicate similar exponential projections of recreation activity in coming decades. Of particular note here are the inescapable conflicts generated among recreation users themselves, and on the finite land and water resources of the Nation. For example, the tremendous rise in water skiing and high-speed motorboating directly conflicts with the more quiet pursuit of sport fishing which is increasing simultaneously.

**Figure IV.4.16**

**PERCENT INCREASES IN SELECTED OUTDOOR RECREATION AREAS**




Source: Bureau of Outdoor Recreation

It is necessary to distinguish between actual demands and potential demands. The actual demands for certain recreation activities such as hunting, sightseeing, and boating can be, in a general way, obtained from areas in which these activities are well-established and monitored. However, in many areas the potential for certain recreational activities is much higher than indicated by present use. For example, the Delaware estuary comprehensive study—1966—estimated that the upper Delaware estuary alone had a capacity of over 8 million activity days for boating, while only 1,800,000 activity days are currently being used, which amounts to a utilization of the boating potential of only 23 percent. Similarly, only 8 percent of the sport fishing capacity in the upper Delaware estuary appeared to be realized. Even though the definition of "capacity" used in this and similar studies is open to serious question, future demands will place great pressures even on those areas which appear to be underutilized today.

On the other hand, it is known that the hunting opportunities in State and Federal reserves are not as good as they are on carefully managed private areas. This is due to the special characteristics of waterfowl, their sensitivity to overhunting, and the necessary latitudes of hunting pressures on publicly managed lands. It appears unlikely, however, that privately owned and managed lands, particularly those fronting on the estuaries, can maintain sufficient opportunities for future outdoor recreation let alone expand them.

This points out that, while there may be ample present opportunities for some recreation activities in certain areas, on others the system and use demands impose severe limitations. It must be one of the prime concerns of the management of the estuarine resources that, while they will be used increasingly for all purposes, the resource base that satisfies recreation demands must be retained. Destruction of the resource base would constitute the final absurdity of destroying the objects of increasing demand for the satisfactions of this environment.

*User groups*

The recreation pressures on estuarine resources are generated by three basic user groups. They are:

(1) Periodic: Those who either reside in the estuarine zone or within short travel distance from the estuarine zone, and who travel from their place of residence to the estuary resources, participate in outdoor recreation activities and return to their place of residence within a single day.

(2) Seasonal: Seasonal recreation users are those who maintain residences at another place but who spend more than 1 day at a time in the estuarine zone. These users may range from those who spend a single weekend to those who spend 1 or 2 weeks or several months in some form of residence—that is, campground, hotel-motel, or cottage in the estuarine zone.

(3) Permanent: Those who maintain permanent recreation residences in the estuarine zone.

The demands for, and use of, the recreation resources in the estuarine zone by all three user groups will increase substantially in the future. Periodic users already overburden recreation facilities near metropolitan areas as anyone who attempts to reach near-shore areas on weekends is well aware. With the growth of megalopoli from Maine to Virginia, both coasts of Florida, northern Texas and California in the near future, pressures from day-use participants is certain to rise.

In addition, both the periodic and seasonal user groups concentrate the bulk of their pressures on the estuarine and coastal environment in the short summer-months span. Thus, the greatest use is made

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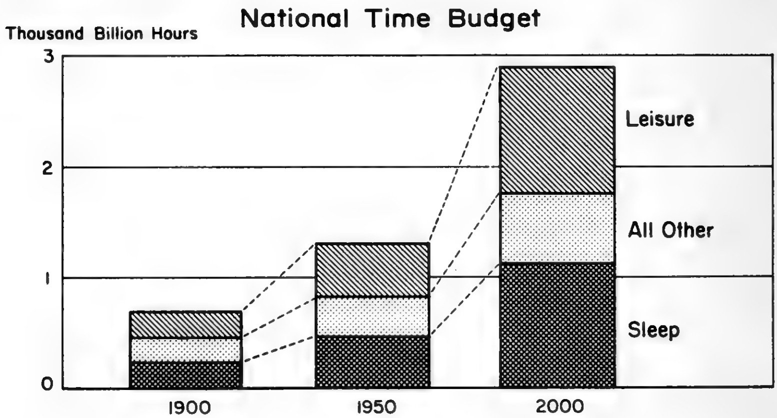
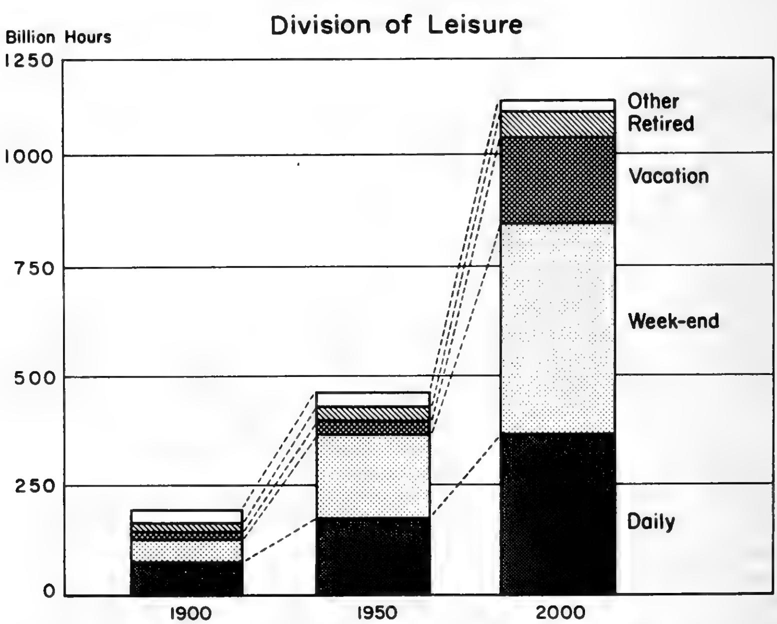
## Figure IV.4.17

### NATIONAL TIME BUDGET AND TIME DIVISION OF LEISURE, 1900, 1950, AND 2000




Source: Marion Clawson, How Much Leisure: Now and in the Future, (Washington, D.C.: Resources for the Future, Inc., 1964), P. 11.

of the shoreline and water in the period of maximum vegetal growth, and often the time when supplies of fresh water for all purposes such as drinking, carrying municipal wastes, et cetera, are least available. Instructive in this regard is the growth of resort communities, such as Ocean City, Md., from sleepy towns of 25,000 persons in April, to "cities" of 350,000 on weekends in the summer months.

Perhaps the greatest recent change in user group pressure results from the tremendous growth of permanent residences constructed in coastal and estuarine locations. Recreation amenities provided by these areas is a prime factor in this trend. Although growth figures are not uniformly available, the growth of permanent and "second" homes appears to be general throughout the Nation, particularly in outlying "suburbs" tied to metropolitan job centers by expanding transportation networks. This growth of permanent users of the estuarine zone is further increased by the phenomenal expansion of retirement communities in such areas as Florida, Texas, and California.

Figure IV.4.17 summarizes the projections of leisure time which contribute heavily to the pressures discussed above.

## Section 4. Future Waste Discharge Impacts

The amounts and impact of wastes generated by man's activities are a function of population growth, urbanization, industrial and commercial development, changing technologies, and consumption of goods and services—even those associated with leisure-time activities. The following discussion defines trends and the probable future course of events related to waste discharge affecting the estuarine zone. However, in most cases, only an indication of the magnitude of the problem can be set out here due to the lack of comparable long-term data, the complexity of the waste discharge assimilation process, and the unknown quantity and composition of future waste discharges.

The emphasis in the following discussion is on those trends in waste discharge that most directly affect water quality, although it must be recognized that the problems associated with wastes affect the total environment, and extend well beyond the defined area of the estuarine zone, both landward and seaward.

### LIQUID WASTES

#### *Fresh water inflows*

Many of the sources that determine estuarine water quality are and will be external to the estuarine zone. The quantity, as well as quality, of fresh water inflows to the estuaries is largely determined by upstream water use. Water diversion for irrigation, impoundment for flood control, and a host of other uses tend to cut the natural streamflow necessary to the successful assimilation and diffusion of both natural and manmade wastes. An example of upstream diversion of water is provided by the Texas Water Plan, which is projected to alter streamflows radically into such productive estuaries as Galveston Bay and those situated in the southern Texas coast. Even if a tremendous planned diversion from the Mississippi River for fresh water inflows to the estuaries is completed on a timely basis, these estuarine systems are projected to face overall reduction of fresh water supply and the accompanying stresses both on the natural assimilative capacities of these estuaries and the biotic communities presently existing there.

Pressures for increased upstream diversion and use of fresh water are certain to increase in all biophysical regions, but the relatively arid and high-growth western gulf and the Southwest Pacific coasts are projected to experience the greatest pressures on present estuarine systems for at least three main reasons:

(1) Much of the upstream water is used to support irrigation with accompanying actual loss of water to the inflow systems by evaporation, transpiration, and absorption, as well as mineralization through leaching.

(2) The amount of rainfall and snow pack is highly variable and often results in extended periods of flooding and drought in these regions.

(3) Consumption of water other than for irrigation is bound to increase at a high rate in response to expected population growth considerably above the national average.

It should be noted, however, that these diversion projects may also allow increased control of water inflows that could be beneficial to maintenance of existing estuarine productivity. Furthermore, some proposed projects may merely shift the major portion of existing inflows from one area to another as in the case of the proposed diversion of Delaware River inflow from Delaware Bay, through the Hudson River, to Raritan Bay, and New York Harbor.

*Municipal wastes*

Municipal waste water disposal is the most frequently cited example of water quality degradation. The major impact of municipal waste water discharge is calculated on the basis of the amount of biological oxygen demand (BOD), bacterial indicator organisms, generally coliforms, and suspended and dissolved solids reaching both fresh and estuarine water. The magnitude of the future extent of the water pollution problem is indicated by the projection that, even if secondary treatment were provided for all urban and sewered population in the United States by 1980, the amount of residual wastes reaching the Nation's waters would be about the same as today when much of this population is not served by secondary treatment facilities. From approximate coefficients developed by the Federal Water Pollution Control Administration for municipal wastes generated by man in areas served by sewers, a rough estimate of the overall yearly municipal sewered waste loads may be computed for the estuarine zone as shown in table IV.4.9.

TABLE IV.4.9.—APPROXIMATE MUNICIPAL WASTES GENERATED YEARLY BY THE ESTUARINE ZONE POPULATION, 1960–80

| | | 1960 | 1970 | 1980 | Numerical increase, 1960–80 |
|---|---|---|---|---|---|
| Waste water | billions of gallons | 1,611.7 | 1,902.3 | 2,130.7 | 519 |
| Standard BOD | millions of pounds | 2,229.5 | 2,631.5 | 2,947.4 | 718 |
| Settleable and suspended solids | do | 2,686.1 | 3,170.5 | 3,551.1 | 865 |

Note: These projections are based on formulae found in the FWPCA publication, The Cost of Clean Water, Vol. II, "Detailed Analysis" (Washington, D.C.: U.S. Government Printing Office, 1968), p. 68.

Although these figures are approximate, and understate the magnitude of the municipal waste load in the estuarine zone, they indicate the tremendous pressure increasing population itself will place on the water quality of the estuarine zone in the future. It does not take into account the increasing use of high-water-use appliances such as washing machines, dishwashers, and garbage disposals, which will contribute significantly to higher per capita water wastes in the future.

These figures are reasonable statements of pressures from urban populations, but the exterior suburban and rural populations presently not served by sewers will undoubtedly contribute further significant liquid-bearing wastes to the estuaries. For example, beach-front and estuarine communities, particularly resort-oriented developments, have traditionally and continue to depend in large degree on septic tank disposal of municipal wastes. Problems of waste seepage from septic treatment have been noted in such places as the north and south shores of Long Island, Florida resort and retirement communities, and the Delaware-Maryland-Virginia shoreline. Furthermore, many coastal communities were originally sewered with primary treatment facilities. These facilities, often discharging directly into shallow back bays, are no longer adequate to meet increased development, density pressures, and the longer duration of stays caused by burgeoning "second home" markets. The communities, limited to residential tax bases, are hard pressed to finance facilities adequate to handle peak loads reached for relatively short periods in the critical summer months.

TABLE IV.4.10.—CAPITAL OUTLAYS NEEDED TO OBTAIN ADEQUATE MUNICIPAL WASTE TREATMENT FOR URBAN POPULATIONS IN MARINE COASTAL STATES AND ESTIMATES FOR ESTUARINE-ASSOCIATED PORTIONS OF THOSE STATES, 1969-73

[In millions]

| State | Entire State | Estuarine portions of States |
|---|---|---|
| Alabama | $137.0 | $15.2 |
| Alaska | 14.5 | Unknown |
| California | 732.2 | 574.0 |
| Connecticut | 188.3 | 118.0 |
| Delaware | 31.5 | 31.5 |
| District of Columbia | 23.0 | 23.0 |
| Florida | 369.6 | 286.3 |
| Georgia | 223.1 | 15.1 |
| Hawaii | 40.1 | 40.1 |
| Louisiana | 195.0 | 91.1 |
| Maine | 47.0 | 21.3 |
| Maryland | 136.1 | 124.4 |
| Massachusetts | 200.0 | 149.0 |
| Mississippi | 57.0 | 4.9 |
| New Hampshire | 35.0 | 9.2 |
| New Jersey | 561.1 | 507.7 |
| New York | 1070.1 | 682.0 |
| North Carolina | 101.5 | 11.4 |
| Oregon | 145.3 | 92.1 |
| Pennsylvania | 331.6 | 105.2 |
| Rhode Island | 41.5 | 41.5 |
| South Carolina | 100.0 | 19.6 |
| Texas | 342.5 | 88.1 |
| Virginia | 206.6 | 114.1 |
| Washington | 173.3 | 121.0 |
| Total | 5,503.0 | [1] 3,285.8 |

[1] 60 percent.

Source: Computed from table 1-3A in The Cost of Clean Water, op. cit., p. 13.

A final indicator of the magnitude of the municipal waste problem is provided by table IV.4.10. The marine coastal States are projected to require an outlay of \$5½ billion between 1969 and 1973 to adequately treat municipal wastes during that period. This represents 63 percent of the national total of \$8.693 billion projected for 1969 through 1973. The estuarine portions of the marine States (basically the coastal counties) are estimated to require 60 percent of the marine States' total outlay, or something over \$2¼ billion during the same period.

As one might expect, the heavily populated estuarine-associated States such as California, New York, New Jersey, and Florida will require bulk of expenditures in the near future (nearly two-thirds of the total). Similarly, the estuarine portions of the marine States located in the Middle Atlantic biophysical region (New York to Delaware) will account for nearly 44 percent of the national total for these areas. These and other urban-dominated areas will require the fullest possible resources, technology, and planning of private, local, State, and Federal establishment if estuarine water quality is to be maintained, and perhaps enhanced.

*Industrial wastes*

Although municipal wastes are shown to be a major and projected source of pollution, both nationally and associated with the estuarine zone, manufacturing is the principal source of controllable waterborne wastes.

In terms of the generally quoted measurements of strength and volume, the FWPCA estimates that manufacturing establishments are responsible for about three times as great a loading as that caused by the Nation's population. Moreover, the volume of industrial production, which gives rise to industrial wastes, is increasing at about 4.5 percent a year, or three times as fast as the population growth rate.

Approximately 85 percent of the 14.2 trillion gallons of water used by manufacturing plants in 1964 was accounted for by four major industry groups; namely: Primary metal industries, chemical and allied products, paper and allied products, and petroleum and allied products. Most of the growth in manufacturing water demands between 1954 and 1964 may be attributed to these four industry groups. This may be expected to continue in at least the near future. Blast furnaces and steel mills alone accounted for 27 percent of the total; industrial chemicals for about 21 percent of the total. Relatively large industry units account for nearly all measured industrial uses; 3 percent of the firms inventoried by the census of manufactures made up 97 percent of the total industrial water used for the Nation.

Estuarine economic areas identified as having significant concentrations of high water use industries are:

(1) Chemicals and allied products: New York-northeast New Jersey, Philadelphia-New Jersey-Delaware coast and the Texas north gulf coast.

(2) Petroleum refining: Philadelphia-New Jersey-Delaware coast, Louisiana coast, Texas north gulf coast and Texas south gulf coast, and California coast.

(3) Paper and allied products: Marine coast, South Carolina

coast, Georgia-eastern Florida coast, central Florida gulf coast, Mississippi-Alabama-west Florida coast, Oregon coast, and Washington coast.

All of these industries have high growth potential and may be expected to intensify their activities in the future.

Other high-water-use industries of importance to individual estuarine areas are:

(1) Textiles: Massachusetts-Rhode Island coast, New York-northeast New Jersey coast, North Carolina coast, and Mississippi-Alabama-west Florida coast.

(2) Primary metals: Connecticut coast, Maryland-Virginia coast, and the Texas north and south gulf coasts.

(3) Food and kindred products: Philadelphia-New Jersey-Delaware coast, North Carolina coast, southern Florida gulf coast, central Florida gulf coast, Louisiana coast, the California coasts, and the Oregon and Washington coasts.

*Thermal wastes*

Although heated effluents may come from a variety of sources, electric power generation is estimated to produce 81 percent of the total heat discharged to the Nation's waters. Demand and production of electric power in this country has doubled every 10 years during this century, with most of the increase coming through use of thermal-generating methods. Power requirements of electrical systems in 1980 will be three times what they were in 1963.

TABLE IV.4.11.—ELECTRICAL GENERATING CAPACITY IN THE UNITED STATES; IN AREAS ASSOCIATED WITH THE ESTUARINE ZONE, 1959–80

[In electrical megawatts]

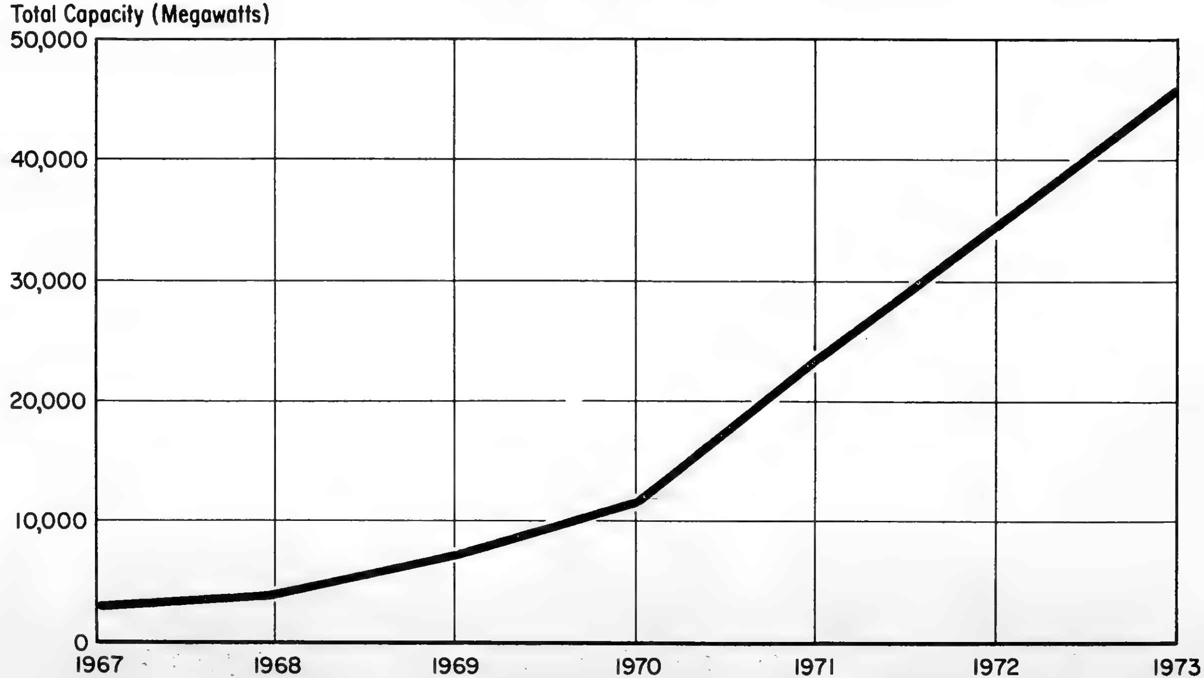
| Power supply area | Total installed at end of 1959 | Additions installed in 1960 through 1966 | Additions expected for 1967 through 1973 | Additions forecast for 1974 through 1980 | Average percent increase per year |
|---|---|---|---|---|---|
| New England (PSA 1 and 2) | 6,700 | 2,300 | 5,500 | 6,900 | 5.7 |
| New York (PSA 3 and 4) | 11,600 | 5,800 | 6,100 | 9,900 | 5.2 |
| New Jersey, Delaware, most of Pennsylvania and Maryland, District of Columbia (PSA 5 and 6) | 12,800 | 6,000 | 11,200 | 15,900 | 6.3 |
| Most of Virginia, North Carolina, South Carolina (PSA 18 and 21) | 8,400 | 5,300 | 7,900 | 13,000 | 7.0 |
| Most of Florida (PSA 24) | 3,300 | 4,300 | 6,700 | 15,400 | 11.1 |
| Northwestern Florida, Georgia, most of Alabama and Mississippi, Louisiana, western Arkansas (PSA 22, 23, and part of 25, 33, and 35) | 8,300 | 5,900 | 10,900 | 18,600 | 8.2 |
| Oklahoma, Texas, New Mexico (PSA 36–39, and rest of 33 and 35) | 11,700 | 8,100 | 15,600 | 26,100 | 8.2 |
| Washington, rest of Idaho and Oregon (PSA 42–45) | 9,300 | 4,500 | 9,300 | 13,300 | 6.7 |
| California (rest of PSA 46–48) | 12,800 | 8,500 | 9,200 | 16,500 | 6.4 |
| Alaska | 200 | | | | |
| Hawaii | 500 | | 200 | 200 | 2.8 |
| Puerto Rico | 400 | 200 | 600 | 900 | 8.2 |
| Total for United States | 158,000 | 75,000 | 139,000 | 207,000 | 6.3 |

Source: U.S. Atomic Energy Commission, "Forecast of Growth of Nuclear Power."

As table IV.4.11 indicates, overall expansion of electric generating capacity for the Nation will average about 6 percent annually during the period 1959–1980. Areas of particularly rapid growth include Florida, parts of the gulf coast, Texas, and Puerto Rico.

**Figure IV.4.18**

TOTAL NUCLEAR-FUELED GENERATING CAPACITY OPERATIONAL IN YEARS
1967-1973



Modern plants being installed presently, and in the near future, will be larger in unit size, thereby increasing plant efficiency, but concentrating heat effects to a significant degree. Hydroelectric power generation, with the exception of the Pacific Northwest, is projected to decline in importance. Fossil, and particularly nuclear, power generation will expand tremendously to meet expected demands. It is estimated, for example, that by 1975 about half of the generation capacity will be nuclear fueled.

The growth of nuclear power is significant, not only because of the large unit size (800 megawatts or larger), but because they must presently operate at lower, and therefore less efficient, temperatures. In sum, it will take more heat to generate a given amount of electrical energy in the future, and more of that heat will have to be dissipated somehow into cooling waters. Figure IV.4.18 gives an indication of the growth of new nuclear generating plants to 1973.

Although the actual future number of fossil and nuclear plants located on the coasts and estuaries of the United States is unknown, an indication of future thermal alteration potential is provided by future operation of the following plants affecting coastal waters:

TABLE IV.4.12.—EXPANDED OR PROJECTED POWER PLANTS AFFECTING ESTUARINE WATERS

| Project | Megawatts | First electricity |
|---|---|---|
| Maine Yankee Atomic Powerplant, Lincoln, Maine | 790 | 1972–73 |
| Pilgrim Station, Plymouth, Mass | 625 | 1971 |
| Connecticut Yankee Atomic Powerplant, Haddam Neck, Conn | 462 | 1967 |
| Indian Point Station—Unit 1, Buchanan, N.Y | 265 | 1962 |
| Indian Point Station—Unit 2, Buchanan, N.Y | 873 | 1970 |
| Oyster Creek Nuclear Powerplant Oyster Creek, N.J | 515 | 1969 |
| Oyster Creek Nuclear Power Unit No. 2, Oyster Creek, N.J | 815 | 1972 |
| Peach Bottom Atomic Power Station Unit No. 1, Philadelphia, Pa | 40 | 1967 |
| Peach Bottom Atomic Power Station Unit No. 2, Philadelphia, Pa | 1,065 | 1971 |
| Peach Bottom Atomic Power Station Unit No. 3, Philadelphia, Pa | 1,065 | 1973 |
| Surry Power Station Unit No. 1, Surry County, Va | 783 | 1971 |
| Calvert Cliffs Nuclear Powerplant Unit No. 1, Maryland | 800 | 1973 |
| Calvert Cliffs Nuclear Powerplant Unit No. 2, Maryland | 800 | 1973 |
| Brunswick Steam Electric Plant Unit No. 1, Brunswick County, N.C | 821 | 1976 |
| Brunswick Steam Electric Plant Unit No. 2, Brunswick County, N.C | 821 | |
| Crystal River Plant Unit No. 3, Crystal River, Fla | 825 | 1972 |
| Humbolt Bay Powerplant, San Onofre, Calif | 430 | 1967 |
| Malibu Nuclear Plant Unit No. 1, California | 462 | 1973 |
| Rancho Seco Nuclear Generating Station, California | 800 | 1973 |
| Diablo Canyon Nuclear Powerplant Unit No. 1, San Luis Obispo, Calif | 1,060 | 1971 |
| Diablo Canyon Nuclear Powerplant, San Luis Obispo, Calif | 1,070 | 1974 |

## SOLID WASTES

Solid wastes, particularly those associated with urban areas and concentrations of industry, must be recognized as major hazards to the maintenance of a desirable estuarine environment. The problem of disposal of solid wastes becomes particularly acute as available land surrounding central cities is built up. Traditionally, wetlands have been considered convenient sites for the disposal of all types of unwanted material, from demolition wastes to tricycles. It is estimated that the amount of land necessary to store and/or process solid wastes for ultimate disposal will nearly double from 1966 to 1976.

A recent report conducted for the Regional Plan Association studied the New York metropolitan area generation and handling of wastes. The study found that in 1965 the residential solid wastes generated per capita per year averaged from about a half a ton to nearly two-thirds of a tone. Thus, nearly 11 million tons of residential solid wastes were generated in the New York metropolitan area in 1965. By the year 2000, it is estimated that residential solid wastes may triple.

Solid waste by business was also found to be significant. An estimated 6½ million tons were generated in the study area in 1965 and the high projection for 2000 indicates a solid waste load for that year of over 22 million tons.

Within comparative limits, the New York example is being repeated throughout the Nation, and particularly in metropolitan areas associated with the estuaries.

Factors affecting the extent of the solid waste disposal problem, including internal processing techniques and external changes arising from social, economic, marketing, and consumption trends, indicate that solid wastes will expand at a rate substantially exceeding population growth in the foreseeable future and radically change both in volume and character. This projected situation is graphically highlighted by figure IV.4.19. It should be noted that the gross amounts of nondegradable packaging materials such as plastics will also greatly expand, and the trend toward disposable containers will also contribute to the solid waste that must be accommodated by the environment.

This brief review of the future of the estuarine zone as a receptacle for man-caused wastes leads to the conclusion that the continuation of current trends will ultimately bring about the destruction of much of the estuarine system as we know it. A great commitment of money, manpower, and technology will clearly be required to alleviate the ill effects of current practices and to prevent damages in the future.

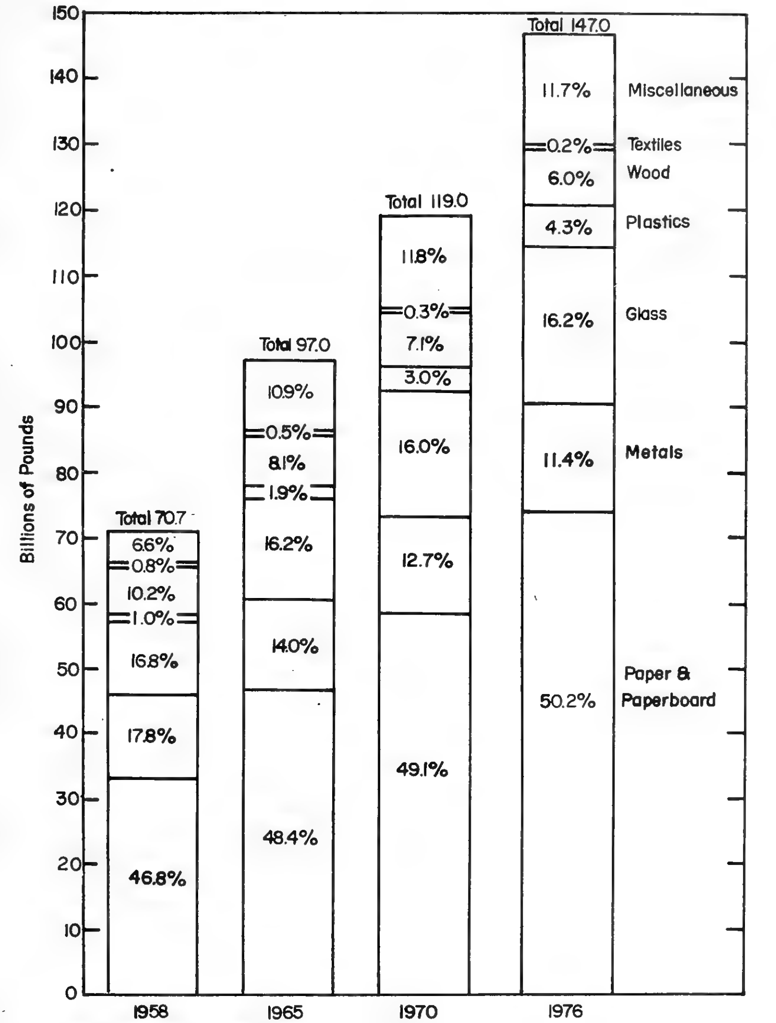
## SUMMARY

The anticipated continuing increase in population and industrial development in the estuarine zone will increase the strong pressures presently existing on the estuarine biophysical environment. The economic pressures will lead as coastal resources are exploited in more ways and more intensively, and as commercial exploitation of the deep ocean makes itself felt through use of the estuarine zone as a staging area.

As the economic pressures increase, more and more estuarine areas will be preempted for commercial purposes, to the detriment of the intrinsic social value of the estuarine zone. The anticipated great increase in recreational need will tend to follow economic development; therefore, recreational use may very well be relegated to small areas useless for other purposes unless effective overall management of the entire resource can be established and maintained.

The great projected increases in waste discharges from all sources may do far more than usurp other uses—these wastes can destroy part of the environment itself and thereby damage the very ecosystem of which man is an integral part and from which his sustenance comes.

FIGURE IV.4.19 CONSUMPTION OF PACKAGING MATERIALS BY WEIGHT 1958-1976 (BILLIONS OF POUNDS)




Source: Midwest Research Institute

# CHAPTER 5. POLLUTION IN THE ESTUARINE ZONE

Man has always used the biophysical environment as he needed it for survival and thrown back into it his waste products and anything else he did not need. As long as civilization was limited to small towns and villages the impact of such treatment on the environment was not noticeable and apparently insignificant. With the development of a civilization based on a complex socioeconomic environment, however, his impact on the estuarine environment has increased until now the most accurate term to express the relationship of man to the biophysical environment is "pollution."

Pollution is the degradation of the biophysical environment by man's activities; it is no longer limited to the discharge of sewage and industrial wastes, but now includes direct or indirect damage to the environment by physical, chemical, or biological modification.

This chapter shows the relationship between man's presence in, and use of, the estuarine environment and its degradation. The kinds of materials and types of changes that tend to degrade the environment are the first topics of discussion, then the relationship of pollutional conditions to the various socioeconomic activities are described. The chapter concludes with a description of the impact of the socioeconomic environment on the biophysical environment and specific examples of pollutional effects.

## Section 1. Materials and Conditions That Degrade the Environment

Environmental degradation is the result of often-minute changes in water quality, water circulation, or other conditions which are part of the biophysical estuarine environment. Brightly colored or otherwise visible waste materials (fig. IV.5.1) have obvious pollutional implications, but by far the deadliest pollutants are those that are invisible and often unsuspected until the damage is done. These pollutants can be found only by the most delicate and sensitive tests; even then, the presence of some highly dangerous materials or conditions can only be inferred from indirect evidence.

### DECOMPOSABLE ORGANIC MATERIALS

One major constituent of municipal and many industrial wastes is decomposable organic material. Such materials consist primarily of carbohydrates from plants and paper, proteins from animal matter, and miscellaneous fats and oils (fig. IV.5.2). The decomposable organics are not necessarily detrimental by themselves, but they exert a secondary effect by reducing dissolved oxygen in the water. This oxygen resource depletion results from the biochemical reactions involved in microbial utilization of organics for food.

The biochemical oxygen demand (BOD) is the standard test for this component. It is an index of the availability of organic matter for biological food and the amount of oxygen utilized by organisms in the metabolism of this food. BOD is generally expressed as milligrams per liter of 5-day BOD at 68° F. While natural waters have values around 1, untreated domestic sewage may average around 300.

The flow of oxygen resources in an estuary is analogous to the flow of money in a bank if the estuarine system is viewed as a dissolved oxygen bank. There is a certain amount of oxygen in the system just as there are certain assets in a bank; the oxygen is invested in supporting and renewing the biota, while the bank assets are invested to earn money. There is a constant flow of oxygen into and out of the estuarine system, both to and from the atmosphere and the ocean. In the bank there is a cash flow to and from the depositors. Large waste discharges may exert an abnormal demand on the oxygen resources such as an embezzler exerts on the cash resources of a bank. If enough dissolved oxygen is utilized in stabilizing wastes the system goes bankrupt.

The amount of organic wastes that can be assimilated in the estuarine system without stressing the biota is dependent on the oxygen balance or the flow of oxygen in the system. The rate of oxygen renewal is dependent on the tidal driving force causing new oceanic water to flood into the system, the fresh water inflow, the wind, the surface area, and the amount of turbulence generated by the fresh-oceanic water mixing. The more turbulent the system the greater opportunity for atmospheric exchange with the attendant ability to assimilate more waste (fig. IV.5.3). Severely depressed dissolved oxygen levels, which result from an excess of oxygen-consuming organic wastes, affect many categories of beneficial uses. With aquatic habitat damage, pollution-tolerant plants and animals replace the more sensitive types. Desirable game and food fish may be completely eliminated; areas of low dissolved oxygen may block the passage of anadromous fish, thereby affecting the reproduction cycle. If oxygen is totally depleted, noxious odors may develop, completely eliminating such uses as boating, swimming, and esthetic appreciation.

The level of dissolved oxygen in the water is one direct index of the healthiness of the system. High levels generally indicate a healthy system which will support a diverse biota and multiple use. The lower the concentration of dissolved oxygen becomes, the sicker the system is, and the less desirable it is for habitat or use.

### FLESH-TAINTING SUBSTANCES

Another class of materials, primarily organic, which can have considerable impact on the estuarine ecosystem, are the flesh-tainting substances. Generally these materials are contained in industrial waste effluents and they result in offensive tastes, odors, and colors of fish and shellfish. The most common culprits are the oils or petroleum products. These materials in slight amounts will impart an oil or kerosene flavor to a wide variety of fish and shellfish, including mullet, mackerel, oysters, clams, and mussels (fig. IV.5.4).

Another source of tainting substances directly related to organic waste discharges can develop when some areas receiving waters

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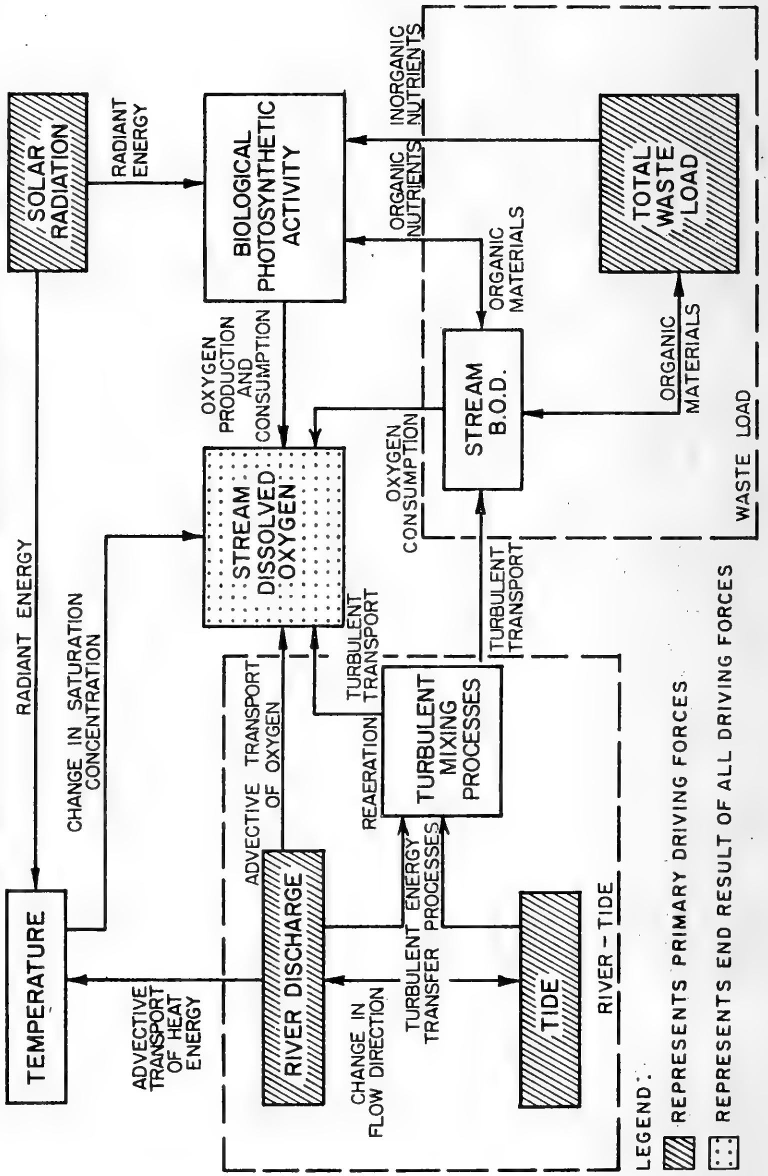
FIGURE IV.5.3

FACTORS AFFECTING ESTUARINE DISSOLVED OXYGEN CONCENTRATION



reach septicity; i.e., all of the dissolved oxygen is depleted. Under such anaerobic conditions the decay of the benthic sludge deposits can result in the production of hydrogen sulfide, which has a very strong "rotten egg" odor. This gas, highly soluble in water, causes a black discoloration of bivalve shells and imparts an offensive taste and odor to their flesh when water carrying it moves across shellfish beds.

### HEAVY METALS

The heavy metal salts are fairly soluble and stable in solution. Consequently, they will persist for extended lengths of time. Many of these are highly toxic to the aquatic biota. Since many marine organisms accumulate and concentrate substances within their cell structure, the presence of these metals in small concentrations can have deleterious effects. Table IV.5.1 lists the more common metals that are of environmental concern (IV–5–1).

TABLE IV.5.1.—CHARACTERISTICS OF COMMON METALS OF CONCERN IN THE ESTUARINE ENVIRONMENT

| Metal | Chemical symbol | Natural concentration in sea water (mg./l) | Concentrations in marine organisms: Plants (mg./l) | Concentrations in marine organisms: Animals (mg./l) | Range of concentrations that have toxic effects on marine life (mg./l) |
|---|---|---|---|---|---|
| Silver | Ag | 0.0003 | 0.25 | 1 to 3 | Highly toxic. |
| Arsenic | As | .003 | 30.0 | 0.005 to 0.3 | 2. |
| Cadmium | Cd | .08 | .4 | 0.15 to 3 | 0.01 to 10. |
| Chromium | Cr | .00005 | 1.0 | 0.2 to 1.0 | 1.0. |
| Copper | Cu | .003 | 11.0 | 4 to 50 | 0.1. |
| Mercury | Hq | .00003 | .03 | | 0.1. |
| Lead | Pb | .00003 | 8.4 | 0.5 | 0.1. |
| Nickel | Ni | .0054 | 3.0 | 0.4 | 0.1. |
| Zinc | Zn | .01 | 150.0 | 6 to 1,500 | 10.0. |

The toxic concentrations listed in the table represent the lowest values for the particular species tested and not absolute minimums. Also, these toxic levels do not consider the synergistic effect that may occur with the presence of other metals. For example, the toxic effects of mercuric salts are accentuated by the presence of trace amounts of copper. The table does indicate the minute quantities of metal *salts* that can damage an estuarine system.

### INORGANIC NUTRIENT SALTS

Aquatic life forms require trace amounts of some minerals and vitamins for growth and reproduction. Elimination of such materials from the environment or their reduction below minimum levels can limit the growth and reproduction of some biota. Conversely, an oversupply of all necessary trace mineral salts and vitamins can retard growth or stimulate it; providing satisfactory conditions of temperature, salinity, and dissolved oxygen also exist. An oversupply of inorganic nutrient salts, such as those of nitrogen and phosphorus, may be associated with drastic shifts in the composition of the aquatic community.

There may be shifts in population as the growth of one kind of life is stimulated more than that of others by additional nutrients, there may be increases in the general productivity of the entire ecosystem, or there may be no changes at all if one necessary factor is missing. When there is excessive growth with associated changes in distribution patterns and predator-prey relationships, some organisms may reach a state of "nuisance growths." This condition is defined as a density of growth that interferes with a desirable water use or the growth and reproduction of organisms desirable to man. Examples of these situations are: (1) excessive drifting plant growths that make bathing beaches unattractive, produce unpleasant odors, foul the bottoms of boats, and spoil the esthetic appearance, and (2) dense populations of rooted aquatics which interfere with the movement and reproduction of fish (fig. IV.5.5).

In any case it must be stressed that some other environmental condition, and not nutrients alone, may be the controlling factor in such growths. The estuarine ecosystem is highly complex; its composition is dependent on a large number of variables, many of which are as yet not understood.

### PATHOGENIC ORGANISMS

One unfavorable consequence of municipal and some industrial wastes is the contamination of the receiving environment with bacteria, viruses, and other pathogens with public health significance. The organisms, especially those from the intestines of warmblooded animals, frequently persist for sufficient periods of time and distance to pose a threat to the health and well-being of unsuspecting water users. Secondary channels of exposure to these organisms exist through the contamination of shellfish which can be harvested for food.

Multiple use of any estuarine zone requires careful consideration of the potential for contact with disease-producing agents. The problem of finding pathogenic organisms in water is difficult. The methods available for determining the numbers of these micro-organisms in sewage and receiving water are not practical for routine use; nor is it possible to decide which organisms should be included in the testing procedures.

Evaluation of the micro-organism density in water receiving waste discharges is based on the test for the total number of viable coliform bacteria present. This test procedure may be further extended to differentiate between the total numbers and those of probable fecal origin. The coliform bacteria in this instance are used strictly as indicator organisms. Although the coliform organism has been associated with infant diarrhea, it is generally considered as nonpathogenic in water. The organism is present in fecal material in large numbers, is highly viable in water, and is relatively easy to identify. The use of an indicator organism is justified on the premise that, if coliforms of fecal origin are present, other pathogens of fecal origin probably are present also.

Although most human enteric pathogens do not survive for extended periods outside the host's body, evidence indicates that they may remain sufficiently viable in all types of aquatic environment to reinfect healthy individuals. Although considerable investigative work has been done on fresh water and on oceanic water, many questions are yet to be answered where the two meet in the estuarine zone.

Some of the factors affecting the survival of pathogenic organisms are—

(1) Environmental conditions such as salinity, temperature, amount of sunlight, and degree of dilution.

(2) Biological agents antagonistic to the survival of the waste-borne organisms.

(3) Bacteriophages or viruses.

(4) Protozoan and other lower animals which consume pathogens for survival.

(5) Sedimentation and adsorption of pathogens with and by particulate matter in the receiving water.

(6) The amount of nutrient material available to support or stimulate multiplication of the organisms.

The presence of the coliform organisms, especially the fecal coliform, is an index to the degree of public health hazard. The two main avenues of exposure for humans in the estaurine environment are through body contact during recreation and through ingestion of contaminated food harvested from the estuary. In the former, the problem becomes one of balancing reasonable safeguards for public health and well-being against undue restrictions on the availability of waters for contact recreation. In estuarine recreation water, this problem is complicated by the lack of definitive epidemiological studies correlating the incidence of waterborne disease with degrees of bacterial pollution. To develop rational bacterial standards for contact recreation, the most promising approach appears to be through intensive monitoring of indicator organisms coupled with salinity studies.

Shellfish contamination presents another problem in that the major concern is the ingestion and harboring of pathogenic enterovirus and bacteria by the organism. These viruses can then be passed on to a human host, especially if the shellfish are eaten raw. The relationship between the densities of coliform indicator organisms and the presence of enteroviruses is still ill-defined and needs further definitive investigation to assure the adoption of rational public health protecting criteria. At present shellfish closures are based on very stringent coliform bacteria concentration standards designed to provide a safety factor to insure public health.

## TOXIC MATERIALS

Among the waste products frequently introduced into the estuarine environment are some directly toxic to marine organisms. Toxic materials may exhibit a short catastrophic impact or a more subtle long-term interference with growth and reproduction processes. The end result is the creation of a biological desert in which no organism can survive.

The short-term catastrophic type of toxicity usually results from an accidental spill or slug discharge of materials into the water. The impact is immediate and the results are dramatic.

The long-term type of toxicity is manifested through the gradual destruction of the natural biota. The effects of sublethal concentrations of toxic mateirials are amplified through biological magnification. Many animals, especially shellfish, can remove these materials from the environment and store them in their tissues. This magnification phenomenon has been documented with such pollutants as pesticides, heavy metals, and radionuclides. The body concentration of the toxicant may reach such a level that death results in the host organism when the material is released to the blood stream by physiological activity. Any higher carnivore consuming an organism with high tissue concentrations of toxic materials may be subject to acute or fatal poisoning. Table IV.5.2 lists the biological magnification factors of five mollusks for specific pesticides (IV–5–2).

The pesticide group is of particular concern in the estuarine zone. Estuaries are the terminus for most of the major river systems, and as such they tend to concentrate the waterborne materials carried in by the large terrestrial drainage systems. The biological magnification capability of estuarine animals significantly increases the hazard and destructive potential of any contributed pesticides. Table IV.5.3 shows the concentration of selected pesticides that will kill 50 percent of exposed shrimp within 48 hours. Shrimp are one of the most sensitive groups of marine organisms (IV–5–1).

TABLE IV.5.2—MAGNIFICATION FACTORS OF FIVE SELECTED MOLLUSKS [1]

| Pesticide: | Magnification range |
|---|---|
| Lindane | 10– 250 |
| Endrin | 500–1, 250 |
| Methoxychlor | 300–1, 500 |
| Dieldrin | 700–1, 500 |
| Heptachlor | 250–2, 500 |
| Aldrin | 350–4, 500 |
| DDT | 1, 200–9, 000 |

[1] Mention of any trade name in this report does not constitute endorsement of the product by the Federal Government.

TABLE IV.5.3.—THE 48-HOUR TLm [1] FOR SHRIMP FOR SELECTED PESTICIDES (IN MICROGRAMS/LITER)

| | | | |
|---|---|---|---|
| Organochloride Pesticides: | | Organochloride Pesticides: | |
| Aldrin | 0. 04 | Dieldrin | 0. 6 |
| BHC | 2. 0 | Endosulfan | 0. 3 |
| Chlordane | 2. 0 | Methoxychlor | 4. 0 |
| Endrin | 0. 2 | Perthane | 3. 0 |
| Heptachlor | 0. 2 | TDE | 3. 0 |
| Lindane | 0. 2 | Toxaphene | 3. 0 |
| DDT | 0. 6 | | |
| Organophosphorous Pesticides: | | Organopohosphorous Pesticides: | |
| Coumaphos | 2. 0 | Naled | 3. 0 |
| Dursban | 3. 3 | Parathion | 1. 0 |
| Fenthion | 0. 00 | Ronnel | 5. 0 |

[1] TLm=concentration which will kill 50 percent of exposed animals.

Many other materials have a toxic effect on estuarine biota. These materials may be present in various industrial wastes or be byproducts of interaction within the estuary. Examples are cyanides from metal-plating wastes and sulfides from the anaerobic decomposition of sewages and industrial wastes.

Wastes from the chemical industry are highly variable and potentially toxic. Ever-changing chemical technology leads to many new products, each creating a new, complex, waste-disposal problem.

Included in the consideration of toxic materials are radionuclides discharged to the estuarine waters. Ionizing radiation, when absorbed in living tissue in quantities substantially above that of natural background, is recognized as injurious (IV.5.1). Since some isotopes may be extremely long-lived, and radionuclides may be cycled through the food chain or recycled to the environment if the host expires, the biological magnification factor is important. The potential consequences of each particular radioisotope discharge must be evaluated individually. The best rule is to minimize the amount of these materials cycling in the environment.

Toxic materials directly kill the biota, interact in the food chain, or deleteriously affect the reproduction or growth processes. The ultimate damage is to stress or eliminate parts of the energy-conversion chain in the estuarine environment (fig. IV.5.6).

## HEAT

The preceding discussion emphasized the many environmental factors affecting the impact of various types of wastes on the estuarine environment. Water temperature was mentioned in almost every instance. Thus the addition of large quantities of heat from industrial cooling water constitutes a form of pollution which must be considered (fig. IV.5.7).

The impact of heat pollution on the environment appears in several different ways:

(1) Heat affects the physical properties of water such as density, viscosity, vapor pressure, and solubility of dissolved gases. Consequently, such processes as the settling of particulate matter, stratification, circulation, and evaporation can be influenced by changes in temperature. Since the solubility of oxygen in water decreases as temperature increases, thermal pollution reduces the oxygen resources. Most aquatic organisms depend on dissolved oxygen to maintain growth and reproduction.

(2) Heat affects the rate at which chemical reactions progress, and it can speed up the formation of undesirable compounds or change dynamic chemical equilibria. It also affects biochemical reactions and can result in a more rapid depletion of the oxygen resources. If sufficient heat is added, temperatures can be elevated enough to sterilize the environment by killing all living organisms.

(3) Environmental temperatures are important to the living resources. Physiological processes such as reproduction, development, and metabolism are temperature dependent. The range of many species of fishes and the species composition of communities are governed to a great extent by the environmental temperature. Temperature anomalies also can block the passage of anadromous fish, greatly reducing future populations.

(4) An increase in temperature can result in synergistic action; that is, the simultaneous effects of separate agents is greater than the total sum of individual effects. Prime examples are increased toxicity of some materials, increases in susceptibility of fish to diseases, and increased virulence of fish pathogens.

(5) Thermal pollution affects other aquatic organisms such as the aquatic plants, the benthos, and the bacterial populations. Increased temperatures may reduce the numbers of species in the

community and stimulate excessive populations of individual species to nuisance conditions.

The entire ecosystem may be stressed by thermal pollution. The amount of damage is dependent on the resulting temperature of the environment and the species composition of the biotic community. The total range of detriments should be carefully considered on an individual case basis before heat is released to the environment.

### SEDIMENTATION

The estuarine zone serves as a repository for the suspended material carried by the Nation's rivers. From a pure mass standpoint, a significant percentage of these materials is comprised of the sediment load which is measured in billions of tons annually. For example, a conservative estimate of the sediment from the Mississippi River through its delta complex is 500 million tons annually.

Man's activities may purposely or inadvertently upset the natural balance of inflow, deposition, and outflow. If upstream erosion is increased due to poor land-management practices, the load carried in suspension will increase. Conversely, activities along the coast can result in increased shore erosion, removing more sediment than is contributed. The primary pollutional problem from sediment, however, results from increased influx and accelerated deposition.

The detrimental effects of sedimentation are reflected in an impairment of uses such as navigation, recreation, water supply, and fish propagation. Navigational interests are damaged by the accretion of materials in ship channels and near docking facilities; millions of dollars are expended each year in channel dredging to maintain navigation. Recreational interests suffer from the loss of safe boating water, increased maintenance of marinas, and from the loss of fishing areas (fig. IV.5.8). The cost of diversion and use for water supply purposes may be significantly increased because of the need to remove excess sediment.

Fishery loss stems from the destruction of suitable habitat. This damage results from loss of suitable breeding areas, loss of food chain organisms because of change in benthic characteristics, and fish kills from excessive turbidity.

Channel maintenance adds to the sedimentation problem. The cost of dredging is greatly influenced by the selection of spoil areas; if the spoil is redeposited in the water environment, changes in bottom characteristics are transferred to other areas, thus expanding the scope of impact. Dredging spoil disposal results in increased turbidities as well as changing bottom configuration. Both occurrences can adversely affect the aquatic habitat. Natural sedimentation is an integral part of the estuarine environment. Manmade sedimentation problem is a form of pollution that is significant in terms of dollar damages and must be considered in the overall management scheme.

### CATASTROPHIC ACCIDENTS

One great threat to the estuarine ecosystem is the ever-present chance of a catastrophic spill of oil or other hazardous materials. The large volumes of petroleum and chemical products transported through the estuarine zone by ships, barges, pipelines, trucks, and railroads present a continuing opportunity for accidental bulk spills. The consequences of these spills depend on the amount and type of material released and the characteristics of the receiving water. They may range in magnitude from tragic loss of human life to little more than economic loss for the transporter (fig. IV.5.9).

When a significant spill occurs, the results can be dramatic. A large quantity of material is suddenly disgorged into the system; the fate of this material depends on its miscibility with water, its solubility in water, and its density, stability, and volatility. The fate of the environment depends on what segments contact the material and the inherent toxicity of the material.

The potential magnitude of the problem is staggering. The quantities and varieties of oils and other hazardous materials transported or stored are reflected in the following statistics:

(1) Almost 4 billion barrels of petroleum and natural gas liquids are used annually in the United States.

(2) Twenty-five billion pounds of animal and vegetable oils are consumed or exported annually.

(3) Almost 80 billion pounds of synthetic organic chemicals are produced annually by some 12,000 chemical companies. These chemicals, many of which are toxic or have unknown effects on aquatic or human life, range from everyday food flavorings to lethal pesticides.

The damage to water uses can be demonstrated by consideration of a catastrophic oil spill. Water birds are attracted by the slick on the surface. Once they contact the oil, their feathers become matted and oil soaked. The birds either drown, are killed by toxicosis from ingested oils or by exposure from the loss of body insulation, starve to death from inability to fly and search for food, or are eaten by predators (fig. IV.5.10).

Fish become coated with oil and their gills become clogged, resulting in death. If the exposure is sublethal, their flesh becomes tainted rendering them unfit for human consumption for a considerable time. Toxic oil fractions in the water can kill the larval and adult forms of invertebrate marine life necessary for a balanced ecosystem. Aquatic vegetation is destroyed. An extreme fire hazard can exist, depending on the type and extent of the oil blanket. Recreational use of the water is impaired. Swimmers become coated with oil which is difficult to remove; boat hulls are stained; beaches with oil deposits become virtually unusable. Apart from the physical damage, there is also an esthetic damage. Noxious odors may permeate the shoreline areas; and waterfront properties are despoiled (fig. IV.5.11).

The direct damage is not the total economic impact. The cost of cleanup must be added and is considerable. The ever-present threat of a catastrophic spill places the estuarine treasure house of resources in jeopardy.

### DELIBERATE PHYSICAL MODIFICATION

Building a bridge, dredging a channel, and filling land for a housing development are not ordinarily regarded as forms of pollution, yet they can cause damage to the biophysical environment far more devastating than the most potent industrial or municipal waste.

Physical modification is permanent; once an estuarine habitat is destroyed by dredging or filling, it is gone forever. No waste treatment can correct or even minimize the damage. The destruction of a marsh or part of the estuarine shallows has an obvious effect on habitat value, but equally severe damages can be associated with apparently minor physical alterations.

The effect any pollutant has on an estuarine environment depends on where it goes, how strong it is, and how rapidly it is assimilated or flushed out of the environment. These conditions depend on water movement and circulation patterns, which are in turn governed by the relationship of tide and river flow to estuarine shape and size. Dredging of new or deeper navigation channels, building of causeways or jetties, and even construction of bridge piers can cause subtle changes in water movement that can alter the balance of environmental conditions in an estuarine system and result in gradual undesirable changes in the ecosystem.

Table IV.2.10 shows the amount of estuarine habitat lost by filling; table IV.2.11 lists the major river flow regulation structures affecting rivers in the estuarine zone; table IV.5.4 gives a general idea of the numbers of miscellaneous structures in the estuarine zone. These three tables indicate only the extent of modification, not of its effects. While destruction of habitat by filling is measurable, the environmental changes wrought in an estuarine system by external flow regulation or by internal structures are so closely associated with its morphology that generalization is impossible. Table IV.5.4 shows that there are in the estuarine zone 752 jetties, dikes, and breakwaters averaging nearly 1,000 feet in length. These are all solid structures specifically designed and placed to modify flow patterns. While habitat damage may have been considered in the design of many of these, it is unlikely that effects on the estuarine environment were considered seriously in the placement of many of the 989 causeways and pier bridges within the estuarine system.

TABLE IV.5.4.—ARTIFICIAL MODIFYING STRUCTURES

| Biophysicial region | Jetties, dikes, and breakwaters: Number | Jetties, dikes, and breakwaters: Length (average, feet) | Causeways: Number | Pier bridges: Number | Dredged channels: Number | Dredged channels: Length[1] (feet) | Total structures (excluding channels) |
|---|---|---|---|---|---|---|---|
| North Atlantic | 60 | 2,600 | 48 | 48 | 146 | 48,640 | 156 |
| Middle Atlantic | 171 | 160 | 53 | 58 | 269 | 18,340 | 282 |
| Chesapeake Bay | 63 | (2) | 19 | 37 | 37 | 99,724 | 119 |
| South Atlantic | 44 | 1,130 | 43 | 46 | 68 | 40,746 | 133 |
| Caribbean | 31 | 960 | 32 | 34 | 43 | 18,500 | 97 |
| Gulf of Mexico | 196 | 260 | 146 | 170 | 308 | 22,702 | 512 |
| Pacific Southwest | 37 | 1,100 | 22 | 30 | 55 | 12,820 | 89 |
| Pacific Northwest | 51 | 60 | 30 | 37 | 91 | 8,800 | 118 |
| Alaska | 62 | 930 | 44 | 41 | 73 | 0 | 147 |
| Pacific Islands | 37 | 1,140 | 27 | 24 | 75 | 13,000 | 88 |
| Total | 752 | 930 | 464 | 525 | 1,165 | 283,272 | 1,741 |

[1] For depths greater than 35 feet.
[2] Not available.

Reference: National Estuarine Inventory.

Source: U.S. Army Corps of Engineers.

Physical modification of estuarine systems may enhance the usefulness of the biophysical environment. In fact, many modifications are made deliberately to improve or protect an estuary for a specific use, but often without consideration of the effects on other uses. The side effects of such modifications may be good or bad, depending on local conditions. For example, the piers and abutments that support bridges are frequently excellent fishing grounds, yet the same piers can have adverse effects on water movement.

A Public Health Service study of Great South Bay on Long Island, N.Y., in 1961 found that water circulation west of the Bay Bridge was greatly restricted, dye tracers showed that the bridge piers acted as a partial barrier to water movement. Figure IV.5.12 (see p. 254) shows the Bay Bridge and schematically illustrates the movement of dye near the bridge. This study concluded that the restricted circulation west of the Bay Bridge was a contributing factor to the degradation of water quality in this area (IV–5–3).

The insidious nature of environmental damage associated with physical modification makes it difficult to assess and predict the effects of specific physical changes on the estuarine environment. Three examples of the results of physical modification illustrate how flow regulation can damage an estuary, what the results of progressive filling can do, and how physical modification can improve the environment.

*Charleston Harbor, South Carolina*

As part of the national plan to minimize unemployment during the depression of the 1930's, the South Carolina Public Service Authority was formed. Its purpose was to build a large dam, water supply, flood control, navigation, and recreation complex that would generate employment opportunity. This complex, called the Santee-Cooper project, involved the diversion of the Santee River into the Cooper River through Lake Marion and Lake Moultrie. The outflow from Lake Moultrie would go through a hydroelectric plant into the Cooper River. In addition to the creation of large recreation lakes the project would open a navigation channel to Columbia, S.C. It was felt the increased flow in the Cooper River would benefit Charleston Harbor, because it would help flush pollutants from the harbor and improve water quality (fig. IV.5.13).

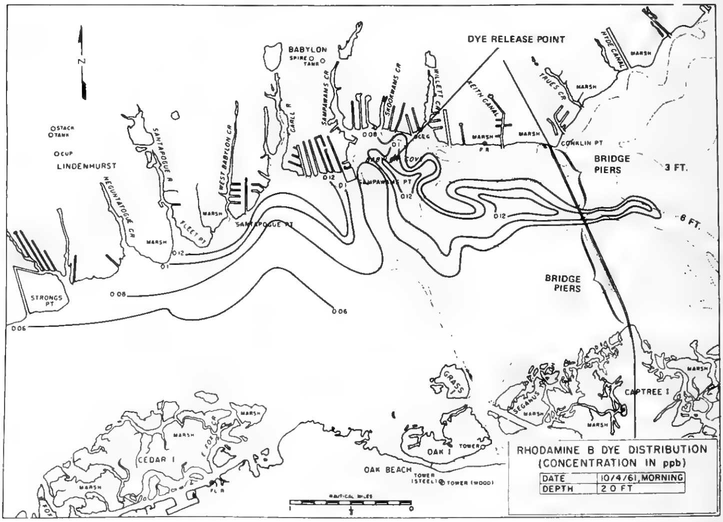
The project was completed and placed in operation in 1942. By 1947, shoaling rates in the harbor had increased to the point where dredging was a full-time operation. Hydraulic model studies found the answer to the increased channel maintenance: the higher fresh water inflow had markedly increased salinity stratification and resulted in the formation of a salt wedge. Particles were entrapped in the wedge, and deposition of sediments increased.

The intended modification changed the circulation patterns and, instead of improving conditions in the harbor, created more serious problems. There is now a recommendation to divert the flow back into the Santee. The net longrun effect, regardless of the outcome of this recommendation, will be the complete alteration of two estuarine systems with an unknown total effect on the ecosystem (IV–5–4).

*San Francisco Bay, Calif.*

San Francisco Bay is the largest of all natural harbors on the Pacific coast south of Puget Sound (fig. IV.5.14). The fresh water inflow to

FIGURE IV.5.12 WATER MOVEMENT NEAR A PIER BRIDGE, GREAT SOUTH BAY, LONG ISLAND, N.Y.




TOP: DYE MOVEMENT THROUGH THE BAY BRIDGE ON A WINDLESS EBB TIDE. GREATEST WATER DEPTH NEAR THE BRIDGE WAS 9 FEET.

BOTTOM: RECENT PHOTOGRAPH OF BAY BRIDGE. NOTE THAT DYE MOVEMENT WAS DIRECTLY TOWARD THE OPEN PART OF THE BRIDGE. (SECOND BRIDGE WAS BUILT AFTER THE 1961 DYE STUDY).

San Francisco Bay is primarily the drainage from the Central Valley of California; the Sacramento River from the north and the San Joaquin from the south form a huge rich delta which is connected to the bay. The overall size not including the tidal delta area is about 435 square miles at mean high water.

In 1850, when California was admitted to the Union, San Francisco Bay was even larger than it is today. More than 300 square miles of marshlands along its shores gave it the appearance of being extraordinarily vast, particularly during maximum spring tides when the bay waters flooded far inland, drowning all but the tips of reeds and marsh grasses. Since those early days more than 240 square miles of the salt marshes have been reclaimed, chiefly for agriculture and salt ponds. In addition, approximately 17 square miles of tidal and submerged lands have been filled, mostly along the waterfronts of San Francisco, Oakland, and Richmond; in Richardson and San Rafael Bays in Marin County; and along the northern bayshore of San Mateo County. And yet the bay still seems so immense that it intrigues many minds with the possibilities of reclaiming additional square miles for industrial and residential developments, recreation areas, airports, highways, and commercial establishments.

The bay presents few obstacles to reclamation through land fill. It is shallow throughout much of its area, with 80 percent of the water less than 30 feet deep and 70 percent less than 18 feet deep at low-tide references. About 248 square miles of tidal and submerged lands in the bay are still susceptible to reclamation. If these areas were filled and used for urban purposes, only 187 square miles of the bay would remain as deepwater channels for ships and many portions of the bay would be reduced almost to rivers.

This example shows the magnitude of reclamation that can occur without consideration of future consequences. A total damage assessment has not been made, but there has been a drastic decline or elimination of clam and shrimp fishing within the bay. When nursery areas of the size of San Francisco Bay are damaged this damage must be reflected in the life of the adjacent coastal waters (IV–5–5).

*Mission Bay, San Diego, Calif.*

Mission Bay in California is one of the better examples of deliberate modification to intensify use. In fact, this unique case demonstrates what can be accomplished through coordinated Federal, State, and local planning and construction. The end result has added considerable value to the community and has preserved a portion of the estuarine environment in a metropolitan area (fig. IV.5.15).

Mission Bay and San Diego Bay lie in the delta of the San Diego River. Prior to about 1825 the river would switch channels and flow into one or the other, depending on the whims of nature. Between 1825 and 1877, history shows the San Diego River channel emptying into San Diego Bay. Since San Diego Bay was one of the best natural harbors on the Pacific coast, the shipping interests became very concerned over the sediment load deposited in the harbor. It was felt that, if this sedimentation process were not controlled, the bay would become too shallow for navigation.

Consequently, in 1877 the San Diego River was permanently diverted into Mission Bay. The period from 1900 to 1950 was one of exceptional growth for southern California. Private and Federal developments in the San Diego Bay portion of the delta were of sufficient magnitude to warrant flood control works on the river. Subsequently, a separate flood control channel, which empties into the ocean, was built for the San Diego River, and some navigation dredging was done in Mission Bay.

During the same period of time (1900–1959), changes were occurring in Mission Bay. In 1929, California incorporated Mission Bay into its State park system. In 1945, title to the tidelands and submerged lands was granted to the city of San Diego. The city passed a $2 million bond issue for improvement of Mission Bay. It also cooperated with the Corps of Engineers, complying with all conditions necessary to obtain a multipurpose flood control and navigation project for the San Diego River and Mission Bay.

Since 1946, the venture has accomplished a completely separate flood channel for the San Diego River, a superbly planned recreational development in Mission Bay including private investments totaling over $22,500,000 for support and service facilities, an orderly preservation of habitat necessary for coastal fisheries, and open-water recreation areas with water quality sufficiently high for all water-contact sports. The bay has been zoned for various activities, banks have been stabilized, and beaches have been created. All of this area is just a few minutes drive from the center of San Diego.

The total dredging effort in Mission Bay since 1946 has cost over $6,500,000 and over 9,500,000 cubic yards of material have been removed. Mission Bay stands today as a shining example of what determined community effort can achieve (IV–5–6, IV–5–7).

## Section 2. Sources of Pollution

Nearly all of man's activities can result in environmental degradation. The pollutants and polluting conditions outlined in the preceding section are rarely unique to a particular use or specific activity, but they result from man's existence in the estuarine zone as well as his use of it. The major sources of pollution described in this section fall into three broad categories:

(1) Those sources associated with the extent of development of the estuarine zone, including waste discharges from municipalities and industries, and land runoff from urban and agricultural land.

(2) Those sources associated with particular activities of great pollutional significance, specifically dredging and filling, watercraft operation, underwater mining, and heated effluent discharges.

(3) External sources having impact derived through flow regulation and upstream water quality.

### MUNICIPAL WASTES

Over 8 billion gallons of municipal wastes are discharged daily into the waters of the estuarine zone. While most of this volume is domestic sewage, many municipal waste discharges also contain significant amounts of industrial wastes, which may add to their variability and complexity.

Municipal waste discharge have four important effects on receiving-water quality:

(1) The decomposable organic matter of municipal waste discharge exerts a demand on the oxygen resources of the receiving water. This demand can result in depletion of dissolved oxygen to the point where desirable biota cannot tolerate the environment; they disappear or are killed. Complete depletion can result in noxious odors with destruction of esthetic values.

(2) Municipal wastes may contain pathogenic organisms dangerous to human beings. The coliform bacteria measurement is an index of the possible presence of pathogens. The basic premise is that if fecal indicator organisms are present, there is a high probability of pathogens being present; this condition is a public health hazard for anyone ingesting or contacting the water. There are many documented cases of waterborne epidemics and water-transmitted diseases to support the health hazard premise.

(3) The settleable material in municipal wastes may be deposited on the bottom, resulting in large sludge banks of organic content. These sludge banks can also deplete the oxygen resources through biochemical reactions. The suspended materials, if sufficient in quantity, can reduce the depth to which sunlight penetrates, altering that portion of the ecosystem dependent upon photosynthetic activity.

(4) Dissolved salts can make the water less desirable for other uses and the fertilizer or nutrient portions are sometimes implicated in stimulating nuisance growths of algae and other aquatic plants. These aquatic growths in an enriched stream can cause severe fluctuations in dissolved oxygen concentrations and can interfere with other legitimate uses.

Table IV.5.5 summarizes municipal waste discharge volumes into the biophysical regions. While the Middle Atlantic region has by far the largest volume of municipal waste discharge, the potential impact on the estuarine zone is greatest in both the Pacific Southwest and in the Pacific islands because of the small estuarine water areas in these two regions. This potential impact is lessened by the ability to use deep ocean outfalls, an approach made practicable by the narrow Continental Shelf in these regions.

TABLE IV.5.5.—MUNICIPAL WASTE DISCHARGES IN THE ESTUARINE ZONE

| Biophysical region | Total volume of municipal wastes [1] | Percent of sewered population with secondary treatment, 1968 [2] | Volume per square mile of estuarine area (gals./day) |
|---|---|---|---|
| North Atlantic | 550 | 25 | 160,000 |
| Middle Atlantic | 3,500 | 60 | 680,000 |
| Chesapeake Bay | 640 | 90 | 140,000 |
| South Atlantic | 270 | 75 | 70,000 |
| Caribbean | 160 | (3) | 220,000 |
| Gulf of Mexico | 760 | 75 | 70,000 |
| Pacific Southwest | 1,900 | 30 | 2,380,000 |
| Pacific Northwest | 390 | 50 | 200,000 |
| Alaska | 13 | 25 | 1,000 |
| Pacific Islands (Hawaii only) | 85 | 25 | 5,700,000 |
| Total | 8,300 | 50 | 180,000 |

[1] Based on 150 gallons per capita per day of total population in standard metropolitan statistical areas, 1965.
[2] Data from USDI, FWPCA, "Cost of Clean Water, 1969."
[3] Not available.

Sewage treatment reduces and alters the impact of municipal waste on the environment. Primary treatment with chlorination removes part of the decomposable organic material, removes nearly all of the settleable and suspended solids, and almost eliminates the possibility of pathogens in the effluent. Secondary treatment can almost eliminate decomposable organic material, and some special processes can eliminate certain dissolved salts. About half the municipal wastes discharged to estuarine waters receives secondary treatment, with the most extensive use of secondary treatment being in the Chesapeake Bay estuarine region.

### INDUSTRIAL WASTES

Associated with the major metropolitan developments are large numbers of industrial complexes with their attendant waste products. Many of these wastes, especially from the chemical and petroleum industries, are so complicated that it is difficult both to identify them and to assess their effects on the receiving streams.

Table IV.3.2 gives a summary of the major manufacturing industries in the estuarine zone. Table IV.5.6 presents the basic characteristics of wastes from each major industrial category. Table IV.5.7 and table IV.5.8 show the waste discharges and levels of waste treatment associated with this industrial development.

TABLE IV.5.6.—*Pollution characteristics of industrial waste*

| *Type of industry* | *Origin of major wastes* |
|---|---|
| Ordnance and accessories | Powerplant, stack washing, leaching from ashes, lubrication and hydraulic oil spillage, surface cleaning, treating and painting, plating operations, trimming and buffing operations, milling with cutting oils. Repair and rework operations. |
| Food and kindred products | Washing of raw products, slaughtering, separation of skins, peels, pits, scales, feathers and other inedible fractions of crude products, rendering of fats, blanching, cooking operation, curing and pickling operations, byproducts of too little value to market, spills, floor and equipment cleaning, diffusion extraction operation, wet grinding operations, steep tank liquors, still bottoms and cooling water. |
| Tobacco manufactures | Mainly dry operations, some incidental cleanup operations. |
| Textile mill products | Wool scouring, desizing operations, cleaning, dyeing and bleaching. |
| Apparel and other finished products made from fabrics and similar materials. | Dry operations. |
| Lumber and wood products, except furniture. | Leaching of logs being floated to mills and held in ponds for milling. Sawdust is potentially a heavy polluting agent if disposed so that it is washed into surface waters by storm runoff or if stored so that leachate reaches surface waters. Preservatives and glues. |
| Furniture and fixtures | Water curtain utilized to pick up waste from varnishing, painting, and finishing operations. |

TABLE IV.5.6.—*Pollution characteristics of industrial waste*—Continued

| *Type of industry* | *Origin of major wastes* |
|---|---|
| Paper and allied products | Pulping operations, including leaching of logs and chips, chemical pulping treatments, and bleaching operations. Debarking processes. Condensate from reagent recovery evaporators. Disposed fibers from papermaking. Glue, ink, and coloring agent spills. Heavy contamination from production of naval stores. |
| Printing, publishing, and allied industries. | Mainly dry operation. Some waste from glueing and preparation of plates. |
| Chemicals and allied products | Bleeding of recycle streams to avoid buildup of impurities, wet scrubbing of stacks and condenser exhausts, side reactions in many processes, acid, alkaline and organic extraction agents, impurities in raw materials, catalysts, unreacted monomers and other feed reagents, stabilizers, contaminated cooling water, dispersing agents, spent culture media, cleanup, and spills. |
| Petroleum refining and related industries. | Crude oil and process brines, cooling water from heat exchangers. Leaky heat exchange equipment. Side reaction products from cracking and synthesizing operations. Fractions that escape collection by distillation columns. Stack washing, storage tank drainoff and spills. |
| Rubber and miscellaneous plastic products. | Most processes dry. Cooling water used in considerable quantity. Acid or alkali digestion of reclaimed rubber and washing of digested product. Acid, salt, and alcohol coagulants for latex processes. Wash water for latex processes. Lubricating and hydraulic oil spills. Reagent spills and cleanup operations. Latex and reclaim processes greatest polluters. |
| Leather and leather products | Wastes occur almost exclusively in tanning and finishing operation. Salting of hides, leachate and scraping from hides, green fleshing, unhairng, bating, pickling, degreasing and tanning. |
| Stone, clay, glass, and concrete products. | Grading of sand, clay and other mined components is ma,or waste-water contamination source. |
| Primary metal industries | Cleaning and pickling acids. Various cleaning solutions and detergents. Oils for forming operations. Coke quenching and stack washing water, cooling water, molding and ore sands, machining operations. Leaching agents for ores, flotation process, ore purifying. |
| Fabricated metal products, except ordnance, machinery, and transportation equipment. | Lubricating and hydraulic oil spills from processing equipment. Machining operations, flue gas washing, metal cleaning operations, paint spraying operation, electroplating anodizing. |
| Machinery except electrical | Water wash of stacks, blowdown of boiler, cooling tower residues, ion exchange wastes, drainage from cinder and ash dumps, cutting oils, lubricating compound spills and rinse, hydraulic oil leaks, sand blast dusts, dispersions, metal chips, metal surface cleaners, corrosion prevention reagents, painting and plating operations. |

TABLE IV.5.6.—*Pollution characteristics of industrial waste*—Continued

| *Type of industry* | *Origin of major wastes* |
|---|---|
| Machinery, equipment, and supplies. | Metal forming operations, metal cleaning, plating and painting operations. Cutting and drilling of insulators. |
| Transportation equipment | Stack washing, cutting oils, spills of lubricating oils and hydraulic oils, pickling and cleaning operations, plating operations, cooling water, blowdown of boilers, corrosion protection, painting operations, and sanding. |

| *Major wastes characteristics* | *Treatment* |
|---|---|
| Suspended solids as fly ash, metal powder, paint solids, domestic wastes and miscellaneous cleanup solids. Cutting, lubricating and hydraulic oils. Detergents and organic cleaning agents. Cyanide and heavy metals. | Plant control. Oil separators, flocculation and sediment action. Cooling systems. Buffer lagoons. Aerobic biological treatment. Use of municipal system. |
| Heat, high BOD and suspended solids, detergents, nitrogenous substances, fat, organic acids, salts, large operations cause severe nuisance growth; animal pathogenic hazard. | Process control, keeping water use at a minimum and exclusion from wastewater screens, fat separators, sedimentation, biological treatment and municipal plants, separation of solids for landfill or barging to sea, disinfection. |
| Minor problem | Municipal plants. |
| High BOD, heat and suspended solids, acids, bases, bleaching agents, detergents and dyes with high coloring activity. Many waste components have biocidal action. | Process control, physical, chemical biological, particularly activated sludge and aerated lagoon. Municipal plants. |
| Very little water pollution | Municipal plants. |
| Large amount of BOD in leachate from logs and from sawdust. Some biocidal continiminant in leachate and in preservative spills. | Process control. |
| Solvents, pigment, varnish solids. High BOD and biocidal components. | Process control chemical, sedimentation, boi-oxidative, municipal plants. |
| very high suspended solids, BOD, heat, oil, acid, alkali, color and biocidal component problem. The volume is large and treatment difficult. | Process control, chemical precipitation, neutralization, sedimentation and centrifugation. All types of biological treatment. Lagoons, landfill and irrigation. Controlled discharge on outgoing tides. |
| Some BOD glueing and acidic metal solutions from plate preparation. Very limited source of cyanide from plating operations. | Process control, chemical, physical, municipal plants. |
| Acids, alkalies, salts, flammable and biocidal organic compounds in great variety, suspended solids, oils, phosphorous, sulfides, cyanides, heavy metals detergents, elastomer dispersions and fluorides. High BOD loads. | Process control, chemical, neutralization, oxidation, precipitation, sedimentation, oil separation, bio-oxidative treatment with adapted systems, particularly activated sludged and aerated lagoons. Many wastes require isolation and special treatment. Buffer lagoons help handle difficult loads. Buring of separated solids or oils. |

TABLE IV.5.6.—*Pollution characteristics of industrial waste*—Continued

| *Major wastes characteristics* | *Treatment* |
|---|---|
| Various oily components. Phenolic compounds. Sour waters containing sulfides and mercaptans. Ammonia. Cyanide. Pyridine. Spent caustic solutions. Various detergents. Hot streams. Various sludge components. Chromates. Biocidal agents. Chemicals that cause fish flavors, a major wastewater problem. | Physical, chemical, oxidation, cooling, neutralization, oil separation, sedimentation, bio-oxidation in adapted systems, particularly activated sludge and aerated lagoons. Flotation, electrostatic separators and centrifugation. |
| Large quantity of hot water. Sulfur zinc compounds and wide variety of biocidal organic compounds. Organic acids and BOD components. Discoloration from carbon black. Detergents and suspended solids. | Process control, physical, acclimated bio-oxidative system. |
| Salt, animal fluids, proteinaceous compounds, fat, suspended flesh, sulfide and ammonium salts, detergents, organic solvents, vegetable and chrome tanning agents. Very high BOD and nusiance promotion components. Components with biocidal action. | Process control, chemical coagulation, sedimentation, bio-oxidative treatments. |
| Suspended solids from mineral grading in large quantity, when mining associated with manufacture. Small amount of suspended solids from grinding and cutting operations. | Sedimentation. |
| Fly ash, metal chips and powder, iron salt solutions, acids, bases, chromium, variety of organic chemicals, cyanide, oils, detergents, sulfides, ammonia, fluorides and heat. Volume hugh. | Process control, chemical, physical neutralization, precipitation, oil separation, flotation, magnetic separation, acclimated bio-oxidative systems particularly activated sludge and aerated lagoons. High speed mills and deteriorating ore quality leading to more waste. Deep wells. No separation of fluorides. |
| Oils, metals powder and chips, detergents, paint solvent and solids, chromic acid, phosphoric acid, cyanide and heavy metals. | Process control, chemical, sedimentation, oil separation, bio-oxidation, municipal plants. |
| Suspended solids, oils, detergents, acidic metal salts, organic solvents, cyanide, ammonia, fluoride, phenolic compounds, phosphoric and chromic acids. Many substances unfavorable to aquatic organisms. | Process control, chemical, oil separation, sedimentation, bio-oxidation, municipal plant. |
| Metal chips and powder, other suspended solids, oils, acides, detergents, cyanide, heavy metals, paint solvents and solids. These industries are not regarded as heavy polluters but carry on operations that consistently lead to polluted water. Plating baths are a serious hazard and demand close control. | Process control, double tanking of cyanide baths, chemical, oil separation, sedimentation, bio-oxidation and municipal plants. |

TABLE IV.5.6.—*Pollution characteristics of industrial waste*—Continued

| *Ma or wastes characteristic* | *Treatment* |
|---|---|
| Oils, metal chips, detergents, acids, iron salts, cyanide, heavy metals, fly ash, paint solvent and solids and alkaline waste. Many components with biocidal activity. | Process control, chemical, physical sedimentation, oil emulsion, breaking and separation, special isolation and destruction of cyanide wastes. Bio-oxidative treatment with acclimated systems. |

TABLE IV.5.7.—INDUSTRIAL WASTE DISCHARGES IN COASTAL STATES, 1963

| State | Total waste discharge | | Treated waste discharge | | Untreated waste discharge | | Total wastes treated (percent) |
|---|---|---|---|---|---|---|---|
| | Number plants | Volume (m.g.d.) | Number plants | Volume (m.g.d.) | Number plants | Volume (m.g.d.) | |
| Maine | 64 | 447 | 21 | 55 | 43 | 392 | 12 |
| New Hampshire | 40 | 96 | 12 | 14 | 28 | 82 | 15 |
| Massachusetts | 304 | 395 | 78 | 44 | 226 | 351 | 11 |
| Rhode Island | 67 | 44 | 11 | 8 | 56 | 36 | 18 |
| Connecticut | 209 | 319 | 65 | 25 | 144 | 294 | 8 |
| New York [1] | 565 | 1,559 | 176 | 578 | 389 | 981 | 37 |
| New Jersey | 421 | 1,082 | 148 | 361 | 273 | 721 | 33 |
| Pennsylvania [1] | (2) | 4,041 | 10 | 1,008 | (2) | 3,033 | 25 |
| Delaware | 45 | 499 | 21 | 318 | 24 | 131 | 71 |
| Maryland | 143 | 1,099 | 48 | 258 | 95 | 841 | 23 |
| Virginia | 147 | 753 | 69 | 189 | 78 | 564 | 25 |
| District of Columbia | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| North Carolina | 238 | 400 | 86 | 151 | 152 | 249 | 38 |
| South Carolina | 158 | 277 | 60 | 38 | 98 | 239 | 14 |
| Georgia | 200 | 584 | 58 | 208 | 142 | 376 | 36 |
| Florida | 116 | 630 | 59 | 219 | 57 | 411 | 35 |
| Alabama | 154 | 663 | 44 | 249 | 110 | 414 | 38 |
| Mississippi | 71 | 178 | 23 | 66 | 48 | 112 | 37 |
| Texas | 343 | 3,986 | 169 | 737 | 174 | 3,249 | 18 |
| Louisiana | 171 | 2,310 | 68 | 819 | 103 | 1,491 | 35 |
| California | 578 | 857 | 230 | 526 | 348 | 331 | 61 |
| Oregon | (2) | 414 | 49 | 93 | (2) | 321 | 22 |
| Washington | (2) | 934 | (2) | 296 | 80 | 638 | 32 |
| Alaska | (2) | 83 | (2) | 11 | (2) | 72 | 13 |
| Hawaii | (2) | 279 | (2) | 41 | (2) | 238 | 15 |
| Total | 4,034 | 21,879 | 1,505 | 6,312 | 2,668 | 15,567 | 29 |

[1] Includes some discharge to the Great Lakes and the Ohio River.
[2] No data av. ilable.
Reference: National Estuarine inventory.

Source: U.S. Dept of Commerce, Bureau of the Census.

Note: The establishments included in this table are those having water use of 20,000,000 gallons or more annually. This represents 97 percent of total industrial manufacturing water use.

TABLE IV.5.8.—WASTE DISCHARGES OF MAJOR WATER USE INDUSTRIES IN THE COASTAL STATES [1] (VOLUME IN M.G.D.) 1963

| State | Food and kindred products | | | Paper and allied products | | | Chemicals and allied products | | | Petroleum and coal products | | | Primary metals industries | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Treated | Untreated | Total | Treated | Untreated | Total | Treated | Untreated | Total | Treated | Untreated | Total | Treated | Untreated |
| Maine | 3 | (2) | 3 | 395 | 25 | 370 | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| New Hampshire | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| Massachusetts | 30 | (2) | 30 | 123 | 30 | 93 | 45 | 15 | 30 | (2) | (2) | (2) | 30 | (2) | 30 |
| Rhode Island | 5 | (2) | 5 | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | 11 | (2) | 11 |
| Connecticut | 3 | (2) | 3 | 17 | 14 | 3 | 25 | (2) | 25 | (2) | (2) | (2) | 63 | (2) | 63 |
| New York | 87 | 5 | 82 | 348 | 41 | 307 | 348 | 132 | 216 | (2) | (2) | (2) | 485 | 263 | 222 |
| New Jersey | 41 | 11 | 30 | 66 | 30 | 36 | 192 | 22 | 170 | 359 | 88 | 271 | 85 | 3 | 82 |
| Pennsylvania | 80 | 3 | 77 | 187 | 88 | 99 | 414 | 19 | 395 | 301 | 268 | 33 | 2,811 | 597 | 2,214 |
| Delaware | 6 | 3 | 3 | 11 | 11 | (2) | 115 | 8 | 107 | (2) | (2) | (2) | (2) | (2) | (2) |
| Maryland | 36 | 3 | 33 | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| Virginia | 6 | 3 | 3 | 175 | 63 | (2) | 438 | 49 | 389 | (2) | (2) | (2) | 3 | (2) | 3 |
| District of Columbia | (2) | (2) | (2) | (2) | (2) | 112 | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| North Carolina | 11 | 3 | 8 | 178 | 110 | 68 | 33 | 11 | 22 | (2) | (2) | (2) | 1 | (2) | 1 |
| South Carolina | 3 | (2) | 3 | (2) | (2) | (2) | 91 | 3 | 88 | (2) | (2) | (2) | (2) | (2) | (2) |
| Georgia | 24 | 5 | 19 | 422 | 156 | 266 | 74 | 27 | 47 | (2) | (2) | (2) | (2) | (2) | (2) |
| Florida | 57 | 5 | 52 | 359 | 167 | 192 | 206 | 44 | 162 | (2) | (2) | (2) | (2) | (2) | (2) |
| Alabama | 5 | (2) | 5 | 307 | 162 | 145 | 178 | 11 | 167 | (2) | (2) | (2) | 128 | 60 | 68 |
| Mississippi | 6 | 3 | 3 | (2) | (2) | (2) | 49 | (2) | 49 | (2) | (2) | (2) | (2) | (2) | (2) |
| Texas | 19 | 5 | 14 | 76 | 60 | 16 | 2,852 | 68 | 2,784 | 595 | 518 | 79 | (2) | (2) | (2) |
| Louisiana | 30 | 30 | (2) | 154 | 129 | 25 | 931 | 52 | 879 | 663 | 608 | 55 | (2) | (2) | (2) |
| California | 148 | 36 | 112 | 66 | 47 | 19 | 85 | 38 | 47 | 378 | 307 | 71 | 28 | 25 | 3 |
| Oregon | 24 | 5 | 19 | 194 | 52 | 142 | (2) | (2) | | (2) | (2) | (2) | 30 | 11 | 19 |
| Washington | 33 | 11 | 22 | 646 | 178 | 468 | 77 | 44 | 33 | 5 | 5 | (2) | 71 | 41 | 30 |
| Alaska | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| Hawaii | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) | (2) |
| Total | 657 | 131 | 526 | 3,724 | 1,363 | 2,361 | 6,153 | 543 | 5,610 | 2,303 | 1,794 | 509 | 3,746 | 1,000 | 2,746 |
| Percent of total treated | (3) | 20 | (3) | (3) | 37 | (3) | (3) | 9 | (3) | (3) | 78 | (3) | (3) | 27 | (3) |

[1] Includes some discharges to the great lakes and the Ohio River.
[2] No date available.
[3] Total unavailable.

Note: The establishments included in this table are those having water use of 20,000,000 gallons or more annually. This represents 97 percent of total industrial manufacturing water use.

Reference: National Estuarine Inventory.

Source: U.S. Department of Commerce, Bureau of the Census.

These tables show industrial water use for the coastal States, not for the coastal counties only, but nearly all wastes discharged into the waters of these States ultimately reach estuarine waters. Only 4,000 of the more than 200,000 manufacturing plants in the coastal States account for 97 percent of the total liquid wastes discharged. Of the nearly 22 billion gallons of industrial wastes discharged daily, only 29 percent receive any waste treatment. The Pacific Southwest biophysical region has the greatest percentage of industrial wastes treated, while the North Atlantic biophysical region has the least.

Of the major water use industries shown in table IV.5.8. the petroleum and coal products industries have the highest percentage of wastes treated and the chemical industries have the least. These five industrial groupings are responsible for 76 percent of the total volume of industrial wastes discharged in the coastal States.

The primary metals and petroleum and coal products industries are centralized in the Middle Atlantic, Gulf, Pacific Southwest, and Pacific Northwest regions, but the other major water use industries are distributed throughout all regions. The kinds of wastes associated with food, paper, and chemical manufactures are therefore universal problems, while the other major industrial waste types concern only particular estuarine environments.

This discussion considers only the volumes of wastes either treated or not treated; it does not consider the level of treatment provided. Some industrial wastes, including those from all major water use industries, require extensive treatment before disposal to the environment. Others do not require anything other than settling and clarification. The percentages of wastes treated, however, do give an idea of relative concern for the environment expressed in action by the industrial and institutional communities.

Desalination operations and the ever-growing nuclear power facilities are new kinds of industry representing potential environmental problems. Salt water conversion plants remove dissolved materials from water to make it fit for municipal consumption and industrial process use. In the case of sea water, where salt concentrations are as high as 33,000 mg/1, the purification of each million gallons of water results in a waste containing almost 300 pounds of impure salts. Nuclear operations present a completely different problem—that of protecting the environment from exposure to harmful ionizing radiation. Since environmental exposure must be held to a minimum, careful control and monitoring of existing and potential radiological waste sources are essential.

### DREDGING AND FILLING

Intensification of use of the estuarine zone has resulted in many artificial changes being made in its physical structure. Shoreline areas have been filled to create more land area for residential and commercial use; channels have been dredged and maintained to permit safer and better navigation; harbor facilities have been dredged; bridges and causeways have been built. All of these activities have impact on the coastal zone ecosystem, but the activities having the most impact on water quality are dredging and filling. The potential for pollution of the system exists in both filling and dredging; both can introduce foreign materials into the water, destroy aquatic habitat, and alter physical circulation patterns. In the case of dredging, exposed bottom materials, if sufficiently high in organic content, can adversely affect oxygen resources. Disposal of dredged materials often creates another problem—unless the materials are used for land fill, dredged material creates water quality problems in the disposal area.

The general magnitudes of dredging and filling activities are shown in tables IV.2.9 and IV.2.10. These generalities hide the slow attrition of estuarine areas by the small bulkheading, filling, and dredging activities associated with statistically small operations such as those associated with improvement of numerous private residences. Probably few such operations create noticeable habitat damage, but the total effect in local areas may be severe over an extended period.

### HEATED WASTE DISCHARGES

Waste heat is another type of pollutant that is discharged to the water environment as an expediency. Heat energy can be equally as dangerous to aquatic environment as the other more obvious forms of pollution. The primary source of heat energy is from industrial cooling water effluents. Table IV.5.9 is a summary of the cooling water use by industry for the United States. Power plants are the major users of cooling water in the estuarine zone as shown in table IV.2.7.

Power generation capacity has approximately doubled each decade during this century. The impact of this growth on the estuarine areas is evidenced by the fact that in 1950 22 percent of the powerplants were in the coastal zone; it is anticipated that over 30 percent of the plants will be located there in the late 1970's.

The existing cooling water use and waste heat discharges are summarized in table IV.2.7. The contrasts among the various regions are related to differences in factors such as the degree of urbanization and industrialization and the availability of hydroelectric power.

TABLE IV.5.9.—INDUSTRIAL USE OF COOLING WATER DURING 1964[1]

| Industry | Cooling water intake (billions of gallons) | Percent of total |
|---|---|---|
| Electric power | 40,680 | 81.3 |
| Primary metals | 3,387 | 6.8 |
| Chemicals and allied products | 3,120 | 6.2 |
| Petroleum and coal products | 1,212 | 2.4 |
| Paper and allied products | 607 | 1.2 |
| Food and kindred products | 392 | .8 |
| Machinery | 164 | .3 |
| Rubber and plastics | 128 | .3 |
| Transportation equipment | 102 | .2 |
| All other | 273 | .5 |
| Total | 50,065 | 100.0 |

[1] Data from U.S. Dept. of Commerce, Bureau of the Census, "Census of Manufactures, Industrial Water Use," 1964.

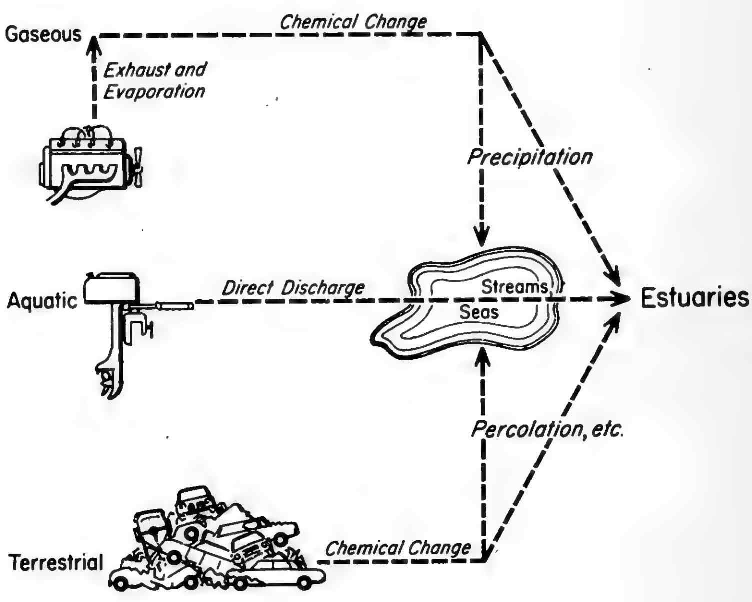
### WATERCRAFT OPERATION

Estuarine areas are important highways of commerce; thousands of commercial vessels, foreign and domestic, from oceanliners to barges, traverse the coastal waterways each year. Added to this traffic are many of the 1,500 Federal vessels and many of nearly 8 million recreational vessels. All of these watercraft carry people and/or cargo, and they are a real or potential pollution source. Just based on an occupancy rate alone, the waterways of this Nation received untreated wastes from vessels equivalent to a city of 500,000. Added to these wastes are the many gallons of oils, bilge water, ballast water, wash water, chemicals, and accidental cargo spills.

Recreational boat usage creates a somewhat different waste impact from that of commercial traffic. These craft are generally congregated near large population centers, and boat usage is most intense on the weekends when the boatowners have free time. In addition to the human waste and garbage, there are large quantities of unburnt fuel products exhausted from boats, particularly from the two-stroke cycle outboard motors (fig. IV.5.16).

**Figure IV.5.16**

INFLUENCE OF THE USE OF THE INTERNAL COMBUSTION ENGINE ON DIFFERENT MEDIA AND ON THE ESTUARIES



## MINERAL EXPLOITATION

Commercial exploitation of the mineral resources in estuarine areas is another potentially significant waste source. Three types of extractive activities exist in the estuarine zone: (1) sub-bottom mining of sulfur and petroleum, (2) mining of materials such as sand, gravel, and oyster shell from the estuarine bottom, and (3) mineral extraction directly from the water. Each creates a different water-quality problem.

The sub-bottom operations, especially for petroleum, interfere with the aquatic habitat in several ways. In the exploration phase, the use of seismic explosions can be detrimental to the biota in the immediate vicinity. Drilling activities always present the potental threat of a blowout or rupture resulting in a wild well (fig. IV.5.17). Potential problems in the production phase include the possibility of collision or storm damage to the rig and the disposal of the oil well brine. Transportation of oil whether by ship or pipeline poses an additional pollution threat.

In sulfur mining, the Frasch process is generally used; superheated water (325° F.) is pumped into the sulfur formation and molten sulfur is pumped out. The bleedoff waters must be vented from the deposit, and these waters are highly saline with a rather high hydrogen sulfide content (fig. IV.5.18).

Both petroleum and sulfur mining cause a secondary impact due to the shoreline support facilities that accompany their development.

The shoreline development creates problems similar to those discussed under municipal and industrial waste sources.

Mining from the estuary floor causes alteration of the estuarine shape and water circulation characteristics. A secondary effect is the turbidity problem associated with material removal. Mining of sand and gravel from the estuarine floor is universal, while oyster shell dredging in any great quantity is restricted to the gulf coast. These operations remove part of the estuarine floor with a concomitant destruction of habitat and life. There are also great amounts of suspended and settleable solids frequently released in the water, from which they are redeposited in other places. Phosphate mining, common in North Carolina and Florida, may introduce nutrient phosphates and toxic fluorides into the water.

Extraction of minerals from sea or estuarine water is the third type of mining activity. Minerals extracted include common salt, magnesium oxide, magnesium metal and bromine. Available information indicates that the pollutional impact of the water extraction process is insignificant.

The extent of estuarine mining activities is shown in table IV.2.8. On a nationwide basis the subbottom mining industry is restricted to the Gulf coast of Texas and Louisiana, and the coasts of California and Alaska. Isolated areas of the other types of mining activity also are shown in the table. The economics of bottom mining and of water extraction compared to the availability of materials from other sources seems to preclude extensive development, except for materials such as sand and gravel.

FRESH WATER INFLOWS

The quality of estuarine areas is dependent not only on direct waste sources but also on the quality of the streams and runoff entering the system. Tributary influent quality is generally a good index of the type and intensity of land use in the surrounding area and upstream from an estuarine system, and it can be a major cause of ecological stress within the system. The complex interactions between fresh and salt water may magnify the effects of pollutants carried into the tidal regime, resulting in quality anomalies completely alien to either fresh or oceanic environments. It is, therefore, imperative to examine the secondary or relatively uncontrollable pollutant source of tributary inflow.

The first item to be considered is the quality of major rivers and streams entering the estuarine area. Many streams are subjected to various uses and abuses in their upstream reaches; by the time they reach the coastal area the full cumulative effects of pollution are exerted. If no regulatory actions were taken, there probably would be severe quality deterioration throughout the coastal regions of the country. However, the implementation of the water quality standards program through joint Federal-State effort has provided a two-pronged attack on pollution with two levels of regulatory power. Rigid enforcement of this program should result in a steady improvement of the quality of water entering the estuary systems. Table IV.5.10 summarizes the tributary inflow quality from upstream pollution for selected streams entering the estuarine zone. These data are for the first station above tidal influence and show the baseline for management planning. These data may be contrasted with natural river water quality shown in table IV.1.8.

TABLE IV.5.10.—EXAMPLES OF RIVER WATER QUALITY AS STREAMS ENTER THE ESTUARINE ZONE

| Biophysical region | River | Typical observed water quality conditions in inflowing river |
|---|---|---|
| North Atlantic | Merrimack | Bacterial counts (MPN) above 1,000,000; dissolved oxygen (DO) below 50 percent saturation. |
| Middle Atlantic | Connecticut | MPN above 10,000; DO near saturation. |
| Chesapeake | Potomac | MPN less than 1,000; DO near saturation; high turbidity during moderate to high flows. |
| South Atlantic | Savannah | High turbidity during moderate to high flows; high natural dissolved organic load, low DO. |
| Caribbean | Canals from Everglades | High natural dissolved organic load; low DO. |
| Gulf of Mexico | Mobile | MPN above 10,000. |
| | Pascagoula | MPN above 10,000. |
| | Pearl | High natural dissolved organic load, low DO. |
| Pacific Southwest | Russian | MPN above 5,000. |
| Pacific Northwest | Willamette | MPN above 10,000. |
| Alaska | Yukon | Very high turbidity. |

The second item to consider is the quality of the inflow from land runoff. The pollutional potential of this source is dependent on land-use patterns, the rainfall-land runoff relationship, and rainfall intensity. If the land is essentially natural marshland or covered by natural vegetation, runoff does not pose a serious water quality problem. Runoff from agricultural land, however, can be a threat, depending upon the amount of chemical fertilizers and pesticides used and the degree to which the land can be eroded. If the land is urbanized with large paved areas, the runoff can be up to twice as strong as normal domestic sewage because of the oil and other materials carried from the streets and yards (fig. IV.5.18).

Figure IV.1.18 shows the seasonal variation in precipitation for selected coastal stations. This figure shows a rather varied distribution of precipitation throughout the national coastal areas and indicates the seasons when runoff could present problems.

In addition to the pollutants carried in the runoff, the fresh water itself may stress the ecosystem through dilution of the salinity to concentrations lower than those necessary to support some life forms. A case in point is the annual killing of aquatic vegetation in Tampa Bay with the onset of summer rains (fig. IV.5.19).

Last in runoff consideration is the degree of flow regulation or water resource development upstream from the tidal environment. These upstream impoundments, with the attendant flow regulation, may have both beneficial and detrimental effects. The reservoirs can serve as equalizing basins, providing a rather constant quality of estuarine fresh water inflow. The difference between regulated flows and natural flows however, may cause ecological stress through alteration of the salinity regime or the circulation patterns. Table IV.2.11 is a compilation of flow regulation structures on major estuarine streams.

## Section 3. Extent of Pollution Effects

Environmental damage from human activities manifests itself in changes in water quality and in changes in living communities. Either or both may be caused by any of the kinds of pollution or sources of pollution already discussed.

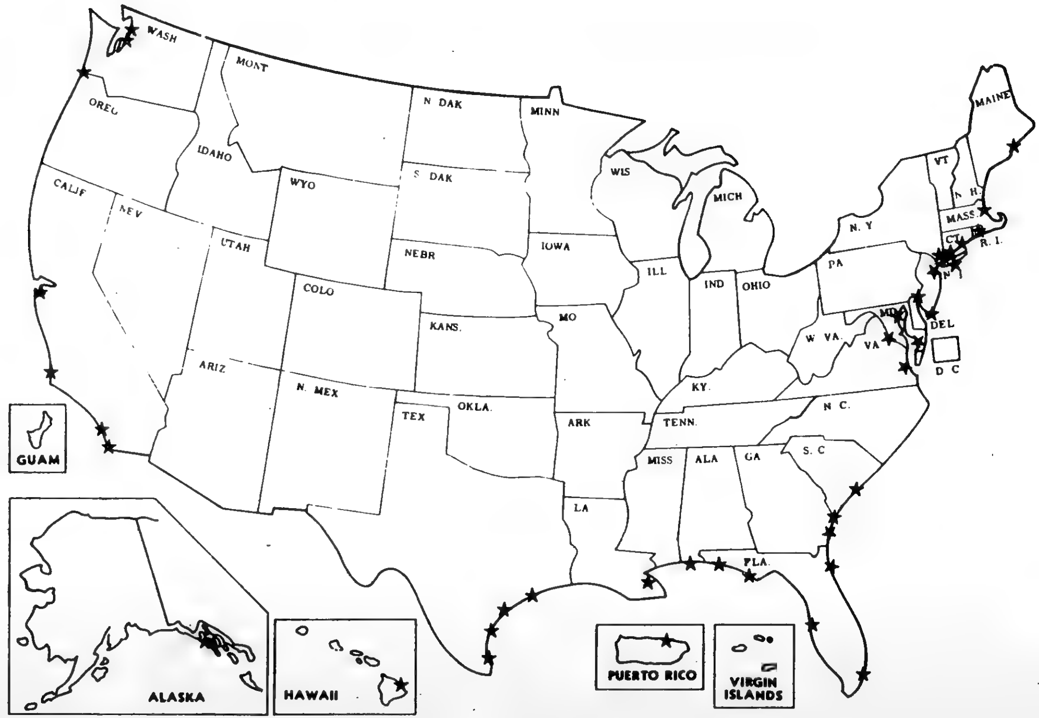
This section contains separate discussions of degradation of water quality and damage to living communities, but water quality is an integral part of estuarine ecosystems and changes in one are usually reflected in the other. An accurate and thorough analysis of the relationship of pollution to environmental damage must recognize these related factors. The compartmentation of discussion in this section is necessary because water quality studies and ecological studies are rarely conducted simultaneously in the same system. This situation, indeed, is one major existing deficiency in the present approach toward study of the estuarine environment.

### DEGRADATION OF WATER QUALITY

One key to the degree of environmental impact is measurement of alteration in water quality. Extensive data have been collected on a few of the estuaries with the most severe problems, and limited information is available on other estuarine systems to outline the emergence, or document the existence, of water quality problems. For the majority of the Nation's estuarine systems, however, there are little or no data to describe existing water quality conditions.

The northeastern coast of the United States is the most intensively used and the best studied part of the estuarine resource (fig. IV.5.21). From the Virginia-North Carolina border to the tip of Maine there are 10 Coastal States encompassing 15 major estuarine systems and harboring an estimated 1966 population of 45,416,000. Economic development includes a wide variety of commercial, industrial, and governmental activities. Nearly all waste products from this all-

FIGURE IV.5.21
DISTRIBUTION OF SOME ESTUARIES WITH DEGRADED WATER QUALITY



encompassing megalopolis are discharged to the estuarine systems. The Chesapeake Bay system, which is one of the largest estuarine complexes in the country, has many areas of water quality impact. The problems in the Potomac River downstream from the Nation's Capital are documented by numerous scientific studies. Pollution in Baltimore Harbor and noxious conditions in the James River have been recorded in detail. (IV–5–10)

The Delaware River and Bay system has been the subject of considerable study for the development of a water quality restoration program. Likewise Boston Harbor, Penobscot Bay, New York Harbor, and Narragansett Bay have been studied in detail to quantify water quality changes and to provide a technical base for developing remedial measures.

The estuarine zones along the coast from North Carolina to southern Florida have not been studied as extensively as those in the northeast (fig. IV.5.21). Except for Charleston Harbor and the Savannah River, little concerted effort has been expended in documenting quality changes. The rapid growth of the Miami area is focusing attention on the estuarine waters of southern Florida. The water quality of estuaries of the U.S. Gulf coast is well-defined by field investigation only in several critical problem areas. Tampa Bay, the Mississippi Delta to a lesser extent, the Houston ship channel, and parts of Laguna Madre in Texas, have been investigated from the water quality standpoint.

The geomorphology of the Pacific coast is different from that of the Atlantic and Gulf (fig. IV.5.21). The coast, for the most part, is composed of steep rocky bluffs with little or no beach. The estuaries are natural watercourses cut through bluffs and are generally enclosed to some degree by an oceanward sandbar. Because of this rugged coastline, intense urbanization has occurred only near the major estuarine systems that form natural harbors. This unique settlement pattern has been reflected in the concentration of estuarine water quality work along the Pacific coast. Systems such as San Diego Bay, San Pedro Bay, Santa Monica Bay, Monterey Bay, San Francisco Bay, and Puget Sound have been studied rather intensely, to either define localized problems, or to reflect long term degradation. Examples are the studies of San Diego Bay that led to the construction of a metro-sewage system with disposal through a deep ocean outfall; investigations of pulp and paper industrial pollution of Puget Sound; studies of the effects on the Columbia River of radioactive wastes from Hanford, Wash.; and the effect of agricultural drainage from the Central Valley of California on San Francisco Bay.

Most of the estuarine zones of Alaska are still unknown quantities from the water quality standpoint (fig. IV.5.24). Pollution has made some impact on isolated areas but the degree of damage is not well-documented. In Hawaii the situation is very similar. Except for Pearl Harbor and Kaneohe Bay there is an extreme paucity of data on the estuarine areas. Guam, Samoa, and the Virgin Islands have not yet felt intense development. The potential of these areas is still to be explored. The scope of existing water quality problems as well as extent of water quality change is not known. Puerto Rico has development concentrated in separated coastal areas. San Juan Harbor has been studied rather extensively and is in poor water quality condition (fig. IV.5.21). Pollution surveys have also been carried out in the estuaries serving other coastal cities such as Ponce, Mayagüez, Arecibo, Fajardo, and Aguadilla which all have sufficient populations to create estuarine pollution problems.

The great variety of kinds of pollution and the different ways in which the many components of waste materials interact with the estuarine environment to damage water quality preclude the choice of a single parameter to define the overall extent of water quality degradation. Damage to water quality can be a direct and obvious thing such as paper and solids from a sewage discharge (fig. IV.5.25) or as subtle and invisible as the pathogenic organisms which may accompany it.

Table IV.5.11 lists some estuarine systems with severely degraded water quality. While not exhaustive, this list shows the extent of water quality degradation in many of the estuarine systems of the United States, and it gives a general appreciation of the kinds of water quality damage that now exist. The data in this table show only that water quality degradation exists in the estuarine systems listed. In many cases the data available are not sufficient to determine specific sources of the pollution or how to correct it.

### DAMAGE TO ESTUARINE ECOSYSTEMS

Pollutional damage to estuarine ecosystems may be sudden and dramatic as fish or other aquatic life forms suddenly dying, or it may be so gradual as not to be noticed for many years.

Fish kills such as those shown in figure IV.5.26 are readily apparent even to the casual observer; their causes are sometimes not so easy to determine. Industrial wastes appear to be responsible for the majority of fish kills in 1966, the last year for which data are available, with food processing being the most common industrial activity responsible. The estuarine brackish and salt waters, however, had less than 1 percent of the fish casualties reported; probably one reason is the enormous volume of waters available for dilution of waste discharges (IV–5–11).

The effects of physical destruction of habitat are also easy to assess, at least in terms of the immediate damage caused. The more subtle related effects of damage to organisms dependent indirectly on the habitat for food supply are more difficult, sometimes impossible, to determine.

Many studies of different aspects of estuarine biology have been made, but there are only a very few cases in which comprehensive ecological studies have been made of pollutional effects. The available information on the extent of ecological damage is summarized in table IV.5.12. The information base for this table is exceedingly sparse; most studies were done when there was apparently some damage or other kind of ecological problem. Therefore, it is not possible to say whether 38 percent of the Nation's estuarine systems are undamaged or merely present no identifiable problems at this time (IV–5–10).

The estuarine systems of the Middle Atlantic biophysical region have suffered the most damage; 83 percent exhibit some ecological damage, but only in a few cases is the extent known in any quantifiable sense. The Chesapeake Bay and Gulf of Mexico regions have the largest numbers of heavily damaged systems, probably because of the intensity of use of the estuarine systems in these regions. Forty percent

FIGURE IV.5.26 FISH KILL

COURTESY LOUISIANA WILD LIFE & FISHERIES COMM. PHOTO BY ROBERT N. DENNIE.

of the estuaries of the Pacific southwest region are heavily damaged; this reflects the intensive development of the relatively few estuarine systems of this region.

TABLE IV.5.11.—SOME ESTUARINE SYSTEMS WITH DEGRADED WATER QUALITY[1]

| Biophysical region | Major source of water quality degradation[2] | | |
|---|---|---|---|
| | Low dissolved oxygen (under 50-percent saturation) | Bacterial contamination (over 1,000 m.p.n. total) | Other |
| North Atlantic: | | | |
| Penobscot Bay | X | X | Toxic materials. |
| Salem, Marblehead, Nahant Bays | X | X | |
| Boston Harbor | X | X | |
| Middle Atlantic: | | | |
| Providence River | X | X | |
| Connecticut River | | X | |
| Port Chester, Stamford | X | X | |
| Moriches Bay | | X | Excess nutrients. |
| New York Harbor | X | X | |
| Raritan Bay | | X | |
| Cape May Inlet | X | | |
| Delaware River | X | X | |
| Chesapeake Bay: | | | |
| James River | X | | |
| Potomac River | X | X | |
| Baltimore Harbor | X | X | |
| Choptank River | X | X | |
| South Atlantic: | | | |
| Cooper River (Charleston, S.C.) | X | | Sedimentation. |
| Savannah River | X | X | |
| Altamaha River | | X | |
| St. Johns River | X | X | |
| Caribbean: | | | |
| Upper Biscayne Bay | X | X | |
| San Juan Harbor | X | X | |
| Gulf of Mexico: | | | |
| Tampa Bay | X | X | |
| St. Joseph Bay | X | X | |
| Pensacola Bay | X | | |
| Mobile Bay | X | X | |
| Mississippi River | | X | |
| Galveston Bay | X | X | |
| Matagorda Bay | | X | |
| Corpus Christi Bay | | X | |
| Laguna Madre | X | | |
| Pacific Southwest: | | | |
| San Francisco Bay | | X | |
| Monterey Harbor | | X | |
| Los Angeles Harbor | X | X | |
| San Diego Bay | | X | |
| Pacific Northwest: | | | |
| Columbia River | | X | |
| Elliot-Bellingham Bays (Puget Sound) | X | | Toxic materials. |
| Alaska: Silver Bay | X | | |
| Pacific Islands: Hilo Harbor | | X | Sugarcane debris. |

[1] Inclusion in this table means only that there are zones within this system where water quality is degraded in the manner shown. It does not mean that the entire estuarine system is of degraded quality. The evaluations presented are based on water quality data in the National Estuarine Inventory and on additional reported data.

[2] The most obvious and severe type or types of degradation are indicated; other forms of pollution may be present.

TABLE IV.5.12.—ECOLOGICAL DAMAGE IN THE ESTUARINE ZONE[1]

| Biophysical region | Extent of damage: Heavy Number | Heavy Percent | Moderate Number | Moderate Percent | No damage or no information Number | No damage or no information Percent | Total |
|---|---|---|---|---|---|---|---|
| North Atlantic | 5 | 8 | 34 | 56 | 22 | 36 | 61 |
| Middle Atlantic | 23 | 21 | 68 | 62 | 19 | 17 | 110 |
| Chesapeake Bay | 40 | 25 | 61 | 39 | 57 | 36 | 158 |
| South Atlantic | 11 | 14 | 35 | 44 | 34 | 42 | 80 |
| Caribbean | 1 | 4 | 18 | 72 | 6 | 24 | 25 |
| Gulf of Mexico | 65 | 30 | 102 | 48 | 47 | 22 | 214 |
| Pacific Southwest | 22 | 40 | 13 | 24 | 20 | 36 | 55 |
| Pacific Northwest | 6 | 10 | 24 | 40 | 30 | 50 | 60 |
| Alaska | 2 | 2 | 5 | 6 | 79 | 92 | 86 |
| Pacific Islands | 4 | 12 | 5 | 16 | 23 | 72 | 32 |
| Total | 179 | 20 | 365 | 42 | 337 | 38 | 881 |

[1] Data from Reference IV.5.10.

## Section 4. Examples of Estuarine Systems Damaged by Pollution

Even though water quality damage and ecological damage are difficult to quantify in terms of exactly how much damage has been done and what was its cause, many estuarine systems have felt the deleterious impact of human exploitation. Examples showing the impact of one particular source of pollution or of one kind of pollutant are rare, because use of the estuarine resource is seldom confined to a single type of activity. The estuarine systems discussed here were chosen because one particular kind of pollutional situation or effect seems to dominate the environment; but, nevertheless many other conditions contribute to the total environmental damage in each case.

### MUNICIPAL WASTES

*Raritan Bay*

Raritan Bay between New York and New Jersey is a prime example of a polluted estuary surrounded by an intensively developed area (figure IV.5.27). The Raritan system, which is composed of the bay itself, the Raritan River, the Arthur Kill, and the Narrows receives approximately 1,500 million gallons of wastes per day which contain over 1,300,000 pounds of BOD. Although 75 percent of the waste volume is from industry, the major impact on the estuary is from the nutrient and bacteriological content of the municipal sewage. The densities of bacteriological indicator organisms along the shorelines of the bay and in the confluences of the tributary systems indicate gross contamination with human wastes, and the nutrient materials contributed by municipal sewage systems have been sufficient to upset the ecological balance in the system.

In some portions of Arthur Kill and the Raritan River dissolved oxygen values reach zero in summer conditions, and the western part of Raritan Bay also has depleted dissolved oxygen. High photosynthetic production by algae counteract these effects in the larger part of the bay itself.

Coliform bacteria counts are high throughout much of the bay and have forced the closing of some public bathing beaches; dye tracer studies showed that unchlorinated human waste discharges from the upper bay (New York Harbor) reached beaches on Staten Island within six hours. In 1961 an outbreak of infectious hepatitis was traced to raw shellfish taken from Raritan Bay in the areas within influence of these human wastes.

The investigations of the Raritan system have been in progress for a sufficient length of time to document both the polluted conditions and the beginning of recovery due to the construction of pollution abatement facilites. Bacterial contamination still exists but the biological community is recovering to form a more diversified and stable aquatic population (IV–5–8).

*Potomac River, D.C., Md., Va.*

The head of the Potomac estuary near Washington, D.C., is severely polluted by the municipal wastes of the Washington metropolitan area. Nowhere is there such a clear example of the effects of massive municipal waste discharges on an estuary. During the low flow periods of the warm summer months, dissolved oxygen levels approach zero in some reaches, being kept from total depletion by heavy production from large algae growths. The effects of these waste discharges are measurable along 20 miles of the river (IV–5–9).

*James River, Va.*

Another example of sewage wastes in an estuarine system is the James River in Virginia (figure IV.5.28). The James River is the most southerly major tributary of the Chesapeake Bay. It is approximately 400 miles in length and varies in width from 5 miles at the mouth to less than 0.1 mile in its upper extremities. The river is tidal from its mouth to the city of Richmond, a distance of 90 nautical miles. The freshwater-saltwater interface migrates between river mile 24 and 60, depending on tide and river flow conditions.

Richmond, Va., is the major waste source on the upper James. Wastes from this city have caused an over enrichment of the upper river section which has resulted in nuisance growths of algae typical of polluted water. The saline sections of the river have not reflected hyperfertilization and are in the transitional stages.

However, brief flareups of nuisance biological growths have occurred and its appears that these nuisance conditions will remain for longer periods of time until a noxious stability is reached (IV–5–10).

*Upper Biscayne Bay, Fla.*

This is one of the man bays on the Florida coast in which the shallow depths allow light penetration sufficient for the growth of submerged vegetation (such as grasses) and algae. Among the impacts of raw sewage discharges into such systems are the limitation of light penetration due to suspended solids and the settling of organic material to the bottom. Both of these impacts affect the submerged vegetation and algae.

Upper Biscayne Bay is located between Miami and Miami Beach. It is nonuniform in width (2 to 4 nautical miles) and is approximately 6 nautical miles in length. The Miami River enters the southwest portion of the bay (fig. IV.5.29). The total number sewage outfalls entering upper Biscayne Bay was 70. The Miami River, carrying the sewage from 29 outfalls, was the major pollutant source. It is estimated that 30 to 50 million gallons per day raw sewage flows into the bay.

Kinds of fixed vegetation divided the bay into two major zones.

Along the Miami shoreline was a zone of red algae, which can survive in low light intensities, and most of the surrounding bay was a zone of grasses and other vegetation requiring much sunlight. No life was found at locations above the Miami River mouth in areas near sewage outfalls, and there was a zone in midbay containing no fixed vegetation.

The softest sediments were found along the Miami shoreline just north of the Miami River mouth. Soft sediments also occurred in midbay with harder sediments along the shores of Miami and Miami Beach where the currents are stronger.

The oxygen consumption of the sediments was highest in the softest sediments just north of the Miami River mouth, in the northwestern portion of the bay, and in the deep water south of the Miami River mouth. These zones were relatively deep, had poor bottom circulation, and were zones of major deposition of organic-rich material.

Both harmful and fertilizing effects were observed in Biscayne Bay. The harmful effects were indicated by the absence of life. These areas were within 200 yards of sewage outfalls, were greater than average depth and had soft, sticky mud with high amounts of oxidizable organic matter. The fertilizing effects were most pronounced in areas 200–600 yards from outfalls in shallow water with good tidal circulation in firm sandy mud. Species associations within definite communities were found to be indicative of both the harmful and fertilizing effects (IV–5–10).

## INDUSTRIAL WASTES

*Los Angeles Harbor, Calif.*

The Los Angeles Harbor portion of San Pedro Bay, Calif., provides an example of an estuarine system receiving oil refinery wastes. These wastes were discharged into enclosed basins or slips which had very limited tidal circulation and flushing. The effects on the receiving system were reflected in progressive studies of the benthic bilogical community. Initial investigations showed the bottom to be composed of black oily material with the odor of hydrogen sulfied, a characteristic of anaerobic conditions. The receiving area was subsequently bridged, and a diverse population of bottom organisms began to populate the area. The continuous discharge of the refinery waste, however, eliminated the biota after a relatively short time. This example demonstrates the ability to recover if proper management techniques are utilized (IV–5–10).

*Silver Bay, Alaska*

Another example of the water quality changes caused by industrial wastes is the Silver Bay system of Alaska. A paper pulp mill located on the bay discharges sulfite waste liquor to the waste surface. Water quality sampling of the bay demonstrated extensive degradation of the surface water stratum as indicated by depressed dissolved oxygen concentrations, changes in pH (hydrogen ion concentration), and increase in turbidity. Vertical profiles of these water quality parameters indicated that the waste materials remained on or near the surface in a low-density layer. The concentrations of the sulfite waste liquor were sufficient to be toxic to many of the natural food chain organisms and to cause abnormalities to oyster larvae and fish eggs (IV–5–10).

*Honokaa, Hawaii*

Located on the north coast of the island of Hawaii (largest of the Hawaiian Islands) is a complex of six sugarcane processing plants. These mills are remotely situated along an inaccessible shoreline characterized by steep cliffs 100 to 200 feet high. The alongshore currents push the wastes long distances along the shore and then out into the ocean.

The main effects of the sugarcane wastes have been the shading of coral by the highly turbid waters, the occurrence of high phosphorus and coliform concentrations, and the lowering of fish diversity and productivity. The slope of the ocean floor near shore is steep and great depths are reached in a short distance. Thus, the mixing and dilution capacity of the deep water minimizes the effects within a short distance offshore, while some wastes drift alongshore with the currents.

With the mixing and current structure of the steeply sloping ocean bottom, the effects of the sugarcane mill wastes on the hydrography of the area are negligible. There is no significant difference in the oxygen concentration, temperature, or salinity in the outfall area. The color of the waste from the sugar mill is that of the soil carried with the cane from the fields (the common mode of harvesting sugarcane is with the aid of a bulldozer and considerable soil is scraped up with the cane and hauled to the processing mill). The soil is a bright red-brown color, and this color, plus the turbidity produced by washing the cane before crushing, is discharged into the ocean producing a vivid contrast to the surrounding blue water. The alongshore currents carry this turbidity great distances along the shore instead of allowing it to be diluted further out at sea.

One of the more distinguishing characteristics of a tropical coast is the large quantity of coral. In the sugar mill waste disposal area at Honokaa, the coral has been completely covered with sludge (composed mainly of bagasse and settleable solids) within a radius of one-quarter mile from the outfall. For the next quarter mile on either side of the sludge deposit, the coral coverage has been reduced to about 10 percent total coverage. For the third quarter mile downcurrent from the outfall, the coral coverage is between 10 and 55 percent. The coral coverage on the downcurrent side of the outfall does not reach normal density until about three-fourths of a mile from the outfall, where coverage is about 55 percent (considered normal for comparable areas). There is little doubt that the reduced coral density is a result of the increased turbidity, since coral relies upon light penetration for its formation and maintenance.

At many sugarcane mills, the normal procedure is to combine human sewage with the sugarcane wastes. This practice results in very high concentrations of coliform bacteria, because the bacteria in the warm sugar-laden waste multiply rapidly. At the outfall of the Honokaa mill, the coliform count was 100,000 per 100 milliliters. The coliform concentration was still as high as 1,000 per 100 milliliters at a distance of 1 mile downcurrent from the outfall.

Many tropical fish are dependent upon the coral reef structure for protection from predators and on the organisms symbiont with coral reefs for food. Since the coral in the Honokaa sugar mill outfall area was destroyed, it is reasonable to expect that the fish population also deteriorated. The diversity of fishes in the outfall area decreased to 16, as compared to a normal 60 found 2 miles away. The biomass of fish was also reduced near the waste disposal area; 160 pounds per acre during the sugarcane grinding season, compared to 600 pounds per acre 2 miles away (IV–5–10).

### DREDGING AND FILLING OPERATIONS

*Laguna Madre*

One good example of water quality changes from dredging and filling operations is South Bay of the Laguna Madre system in Texas (Figure IV.5.30). The dredging and redredging of the Brownsville ship channel resulted in almost complete enclosure of the South Bay from Laguna Madre. Settlement of suspended sediment has caused a 60 percent reduction in depth in South Bay and has changed the bottom characteristics from desirable vegetative habitat to soft mud. The water circulation has been reduced and salinities have increased, and composition of the biological community has been altered in terms of number and density of species (IV–5–10).

### UNDERSEAS MINING OPERATIONS

Petroleum production in the estuarine areas of the Nation is now big business. The pollution potential of this extraction industry is staggering to the imagination. The damage that could occur to fish, wildlife recreational utilization, and shoreline structures from well blows and broken pipelines is immense. The oil industry is well aware of this hazard, and since 1955 there have been only eight such incidents. The primary pollutional effects of these occurrences to date have been high mortality of waterfowl in the area of the oil slick and nuisance contamination as a result of oil washing onto shoreline areas.

The 1956 blowout in Louisiana was accompanied by a rather severe fire. The crude oil spill was out of control for approximately 2 weeks. Ecological studies for 2 years after the spill did not demonstrate any significant damage to the biological community in the spill area as contrasted to control areas outside the sphere of influence (IV–5–10).

The well publicized blowout in Santa Barbara is another example of water quality impact from mining operations. As a result of this accident, in January 1969, large numbers of waterfowl were killed by contact with the oil and some prime recreational beaches were contaminated. The total extent of damages to the ecosystem have not been assessed and will await the findings of extensive studies.

### HEATED EFFLUENTS

As population centers develop in the estuarine zones of the country, demand for electric power increases. This growing power demand is usually met through the construction of either fossil-fueled or nuclear-powered thermo-electric plants. Since these plants are only between 20 and 40 percent efficient in the conversion of thermal energy to electric energy, tremendous quantities of heat must be wasted to the environment. There are many examples of water quality changes due to thermal discharges.

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The Chalk Point nuclear power plant on the Patuxent River estuary in Maryland has altered the temperature regime considerably. The Contra Costa and Pittsburg, Calif., plants have created a new temperature environment on the San Joaquin River in the delta area of San Francisco Bay. Cooling water from Turkey Point plant in Biscayne Bay, Fla., and the Morrow Bay plant in southern California has created thermal structures that may be as high as 10°F above ambient temperature.

These examples represent only a few of the many thermal discharges from power plants. Other industrial manufacturing processes utilize considerable quantities of cooling water and may cause the same type of environmental changes in addition to generating wastes.

### LAND USE AND RUNOFF

Indiscriminate use of land areas contiguous to estuaries has resulted in severe water quality problems (IV–5–10). There are many documented cases of pollution from land runoff. One of the most serious is the tremendous impact created by the widespread application of insecticides to control fire ants in the southeast. The spraying programs were apparently initiated without consideration of the potential unsought consequences, and the heavy toll of birds, fish, and other mammals was phenomenal.

Runoff from such uninhabited areas is not the only culprit. In 1968, Endrin released in storm sewers found its way into Northeast Cape Fear River in North Carolina. Thousands of fish, including many anadromous species, were killed (IV–5–10).

Studies of the pollutional effect of storm runoff in Boston Harbor have shown significant increases in deoxygenating substances, as well as bacterial indicator organisms. Control of storm runoff is extremely costly, but it is a very real part of pollution control.

Runoff from phosphate mining areas in North Carolina and Florida has added large quantities of nutrients to estuarine systems. The phosphate material combined with sewage and other nutrient sources forms a unique, enriched aquatic environment with a real nuisance potential.

### STREAM FLOW REGULATIONS

Stream flow regulation structures have been built on many of the rivers directly tributary to estuarine systems. For the most part these structures have had a beneficial influence on estuarine water quality. The regulated stream flow provides a more uniform source of fresh water with fairly constant quality which allows the estuarine system to reach a dynamic equilibrium. In addition, the reservoirs act as settling basins, reducing the sediment load in the estuaries. In a few cases the flow regulation has so restricted the fresh water inflow that the estuarine salinity structure has changed.

Water quality changes resulting from the construction of flow regulation structures are demonstrated in the following examples:

(1) In the San Francisco Delta, upstream salinity intrusion is controlled by releases from reservoirs on the Sacramento River. Conversely, regulation of flow in the San Joaquin River is partially responsible for recurring quality problems in the Stockton area of the Delta; and

(2) The construction of Santee-Cooper complex in South Carolina resulted in the diversion of the combined flows of the Santee and Cooper Rivers into Charleston Harbor. This flow regulation created a complex sedimentation problem and changed the vertical salinity in Charleston Harbor.

*Upstream water quality*

Among the more significant considerations in the quality of any estuarine environment is the quality of the inflowing stream. If the fresh water inflow is polluted, the impact may be felt throughout the entire system. A good example of this phenomenon is the St. Johns River in Florida. The St. Johns carries large quantities of municipal and industrial wastes into the tidal area (IV–5–10).

The poor quality is further degraded by additional waste discharges from the urbanized area near the estuary mouth. The total impact is a grossly polluted estuarine system which also affects the portions of the coastal beaches around the mouth.

*Wastes from watercraft*

Commercial and recreational boating on estuarine waters is the most visible and picturesque water use. These watercraft, however, constitute a continual threat to the quality of the estuarine environment. An ocean liner with 1,000 passengers is a small floating city and accordingly has wastes that must be discharged. A sailboat represents only one of the millions of pleasure craft in this country and when large numbers of the craft are congregated in a small area, a significant waste source is created.

The pollutants discharged include sewage, oils, chemicals, and other wastes, not infrequently involving accidental spills of valuable and/or dangerous cargoes. The uncertainty of discharges as to number, time, place, and frequency adds to the hazard and control problem. Recent activities by both Federal and State Government agencies to combat pollution from vessels should rectify this situation by requiring waste treatment devices (IV–5–11).

## Section 5. Conclusion

The complex nature of pollution in the estuarine zone prevents the separation of sources of pollution, kinds of pollution, and types of environmental damage into neat compartments of cause and effect. All human activities in the estuarine zone can damage the environment, and most of them do.

Wherever people live, work, and play in the estuarine zone their social and economic activities place stresses on the biophysical environment. These stresses frequently result in degradation of that environment, perhaps not immediately or even in a few years, but nonetheless certain in its devastating final impact.

Environmental degradation is not a necessary feature of man's association with the estuarine zone. The examples discussed in chapter 2 of the results of community effort as in San Diego Bay, and of industrial responsibility as in the management of Avery Island, show that pollution and socioeconomic activity need not be synonomous. The massive planning effort just completed in San Francisco Bay shows that even the most complex use and pollution problems can be resolved with careful, determined study.

Pollution in the estuarine zone has been largely a matter of a lack of concern and a lack of knowledge combined with nebulous management authority and responsibility. Continuing use of the estuarine zone for all human needs and desires is a fact of man's existence. Accommodating all uses while preserving the environment is a matter of knowledge, concern, and determination.

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# CHAPTER 6. USE CONFLICTS AND DAMAGES

The consequence of damage to the biophysical environment is loss of use either immediately or at some time in the future. Loss of use, however, may also be associated with the appropriation of part of the estuarine resource for one exclusive use even when no damage to the environment itself occurs.

Institutional management copes with the problems of responsibility and authority in achieving maximum multiple use of the estuarine resource. Within this comprehensive framework technical management must resolve the problems surrounding conflicts of use, competition for the resources of the estuarine zone, and environmental damage. The primary objective of technical management is to achieve the best possible combination of uses to serve the needs of society while protecting, preserving, and enhancing the biophysical environment for the continuing benefit of present and future generations.

This chapter deals with the problems of use conflicts and damages and relates these to probable trends in estuarine ecology as the basis for guidelines within which technical management can function effectively to achieve its primary objective.

## Section 1. The Nature of Use Conflicts

The uses of estuarine zone grew and changed in consonance with population growth and industrial development. Not until recent years was a concerted attempt made to understand and resolve the conflicts that arose in the competition to use and exploit these land and water resources. During the past 300 years of growth and industrial expansion with its emphasis on economic growth and direct monetary gain, large parts of the estuarine zone were preempted or usurped to serve the individual needs of commercial enterprises. The net result has been less a conflict in existing uses than an exclusion of some uses.

Nearly all estuarine uses involve both land and water, either directly or indirectly. For example, the construction of a manufacturing plant on the shore of an estuarine system may not involve any direct use of the water (even for waste disposal), yet it limits access by its occupation of the shoreline and so may interfere with other uses. Conversely, the disposal of liquid waste into the water may make the shoreline unusable for recreation as well as making the water itself unsafe.

The impact of one estuarine use on another may be either prohibitive or restrictive depending on the kind of use and sometimes on the manner in which it is carried out.

### PROHIBITIVE IMPACTS

These involve permanent changes in the environment and thereby prohibit all uses unable to cope with such changes. The geographical range of such impacts may be from the limited area in which they occur to an entire estuarine system, depending on the nature and size of the change. The impact may be temporary, if it is possible to return the environment to its original form, or it may be permanent.

Any use or activity requiring physical modification of the shoreline, marshes, or bottom of an estuarine system may have a prohibitive impact. Modification of water circulation also tends to be prohibitive when it has any conflicting impact.

*Navigation channel dredging*

This is probably the most widespread and constant permanent modifying activity in the estuarine system. It is carried out solely to maintain and improve navigation needed for commercial and recreational purposes and for national defense. Dredged navigation channels must be kept clear for navigational purposes, and the bottom is constantly being removed. Both of these conditions preclude the large-scale use of such areas for purposes other than navigation.

The disposal of dredging spoil may also be a prohibitive estuarine use when it is deposited in other parts of the system or on adjacent marshes or land. The destruction of habitat which can result from such disposal will, at a minimum, remove the areas used for productive participation in the estuarine ecosystem.

The prohibitive impact of navigation dredging may, however, affect an entire system, particularly where a major channel realinement or channel deepening occurs. The prohibitive impact of such modification may not be in direct destruction of habitat, but may result from a change in water circulation patterns.

For example, a change in current structure associated with channel deepening in the James River prevented the upstream transport of oyster spat to the beds where they normally settled and grew to edible size (IV–6–1).

Such prohibitive use impacts are not always associated with the dredging of navigation channels; in fact, such activities can enhance the environment by improving water circulation and creating new habitat. When there is an impact, however, it is prohibitive in that it permanently excludes other uses while the channel exists.

*Land fills*

The operations of dredging and filling associated with the creation of dry land from marshes and estuarine shallows may have severe prohibitive impact on other estuarine activities. The massive areas filled for large residential and industrial developments destroy much of the envronment directly; and, in many cases, the areas involved are large enough to make a significant impact on water circulation and even on the total volume of water in an estuarine system.

Large fills, such as those made for airports, also limit access to estuarine waters, thereby permanently limiting the recreational potential of such areas.

*Solid Waste Disposal*

The use of undeveloped estuarine shoreline areas for final disposal of garbage and other solid waste materials is not only prohibitive in the same sense as other filling operations, but also the drainage and runoff from such sites can have a severe and continuing impact on water quality.

Although reliable figures showing the impact of solid wastes on the estuarine environment are lacking, a situation from the San Francisco Bay area is instructive: "In some instances, bay water has leaked into old dumpsites; when the tide goes out, black sludge is carried into the water and hydrogen sulfide gas escapes into the air. In every dump, even including those where no garbage is buried, an increase in temperature plus an amount of decay produces hydrogen sulfide." (IV–6–2.) In combination with salt water this produces a vile odor that produces numerous complaints from residents near such dumps. In short, the cost of cheap dumping of solid refuse despoils not only the land surface to the west and the air for miles, but ultimately the water quality of the bay itself.

Such use has prohibitive impact because of the uncontrollable nature and permanent damage cause by such activities.

*Bridges, Jetties, Dikes, Breakwaters, Causeways*

The prohibitive impact of such structures, when it occurs, is usually far more gradual than the impact of large land fills. The group of structures discussed here are either deliberately placed in an estuary to control water movement or else cross the system to carry land transportation. In either case they are long, narrow structures which affect water movement patterns. Their effects may be beneficial to the environment or they may be the reverse.

The construction of a highway through the coastal area of Louisiana and Mississippi effectively separated the inland areas of the coastal marshes from the outer marsh areas, completely altering the circulation patterns of the entire marsh system. The result has been saltwater intrusion into the outer marsh system (in the absence of the freshwater inflow from inland sources now prevented by the highway), with the subsequent results of soil alteration and eventual alteration of the marsh vegetation (IV–6–3).

Such alterations may permanently change ecosystems and therefore exclude the estuarine uses which depend on them. Commercial fishing and sports fishing are particularly impacted by such changes.

*Shoreline Development*

Estuarine shorelines are extremely valuable for both commercial and residential development. The shorelines of large cities are extensively built up, primarily for navigation access and other commercial development, but with considerable areas of shoreline drives and residential developments. Nearly all of such kinds of development extend up to, and sometimes beyond, the natural shoreline and terminate in bulkheads, docks, or other permanent structures.

The individual impact of such development is probably minimal except in extremely confined areas, but the total effect of the shoreline development of a large city can be to drastically and irretrievably change the natural environment, even to the extent of damaging the uses for which the changes were made.

Reduced currents and changes in water circulation may result in increasing rates of sedimentation and added expense for channel maintenance.

Changes in circulation associated with both spoil disposal and manufactured residential islands in parts of Tampa Bay were followed by changes in sedimentation patterns and an apparent decrease in productivity in some areas (IV–6–4).

*Mining*

The taking of materials from the estuarine bottom immediately destroy the local habitat and the movement and settling of suspended material may extend the damage to other areas. Sand and gravel dredging are universal activities in the estuarine zone; oyster shell dredging exists in several areas along the Gulf and Atlantic coasts.

Posphate sand or rock mining in estuarine systems may raise the concentration of phosphorus in the water and change the ecological balance of the entire estuarine environment, as well as directly killing fish and other aquatic organisms.

Mining operations exploit a nonrenewable resource, and even after mining operations have ceased, the hole in the bottom of the estuary may affect water circulation throughout the estuarine system.

*Flow regulation*

The ecological balance of an estuarine system is the result of interaction of the dominating environmental factors discussed in part IV, chapter 1. Among these factors are the amount and annual distribution of fresh water inflow. Upstream flow regulation may have many beneficial effects, but radical changes in the annual riverflow pattern may cause drastic changes in both water circulation and in ecological balance.

The harbor of Charleston, S.C. was a deepwater port with freshwater inflow from only coastal drainage until the flow of the Santee River, averaging 15,000 cubic feet per second, was diverted into it. This caused salinity stratification to set in and sedimentation became a severe problem. Dredging requirements grew from 120,000 cubic yards per year to over 7,000,000 cubic yards per year and many of the docks had to be abandoned because adequate depths could not be maintained. The prohibitive dredging costs have resulted in a Corps of Engineers proposal to redivert the Santee River away from Charleston Harbor (see case study p. 302).

Some of the more productive oystering areas in the Potomac River are in a reach where high springtime river flows reduce salinities enough to kill the oyster drills (a predator) but not kill the oysters. Flow regulation to reduce the high spring flows would probably change this relationship.

### RESTRICTIVE IMPACTS

Some estuarine uses may restrict use for other purposes but do not automatically exclude other uses. These are those activities which do not require a permanent modification of the estuarine system; they generally include those uses directly involved with the estuarine waters and other renewable resources.

Restrictive impacts may involve damage to water quality, living organisms, or aesthetic quality; such impacts may also result from the exclusive appropriation of space. The key feature of uses which cause restrictive impacts is that they may, with proper management, be carried out simultaneously with other uses.

*Liquid waste disposal as a restrictive impact*

Although not generally regarded as a beneficial use, the discharge of liquid wastes to estuarine waters is and is likely to continue to be one of the major universal uses of the estuarine zone. The present discussion considers liquid waste disposal as one of many uses of the estuarine environment which has the potential of conflicting with other uses but which will probably have to be accommodated within the overall use patterns of nearly all estuarine environments.

The major restrictive impacts of liquid wastes arise from the disposal of untreated or inadequately treated wastes in massive quantity to estuarine waters. The discussion in part IV, chapter 5, pointed out the various pollutional effects different types of municipal and industrial wastes can have, and presented some typical examples of pollutional effects. Six types of impacts tend to restrict other uses:

1. Floating or settleable materials make the system unpleasant or destroy bottom-living organisms.
2. Decomposable organic materials deplete oxygen necessary for aquatic life and may cause nuisance conditions.
3. Toxic materials destroy living organisms by killing them directly, damaging their reproductive ability, or poisoning their food supply.
4. Nutrient materials cause over-production of some ecosystem components causing adverse effects on others.
5. Pathogens create public health hazards.
6. Heated waste discharges reduce available oxygen and cause other adverse effects on the ecosystem.

These kinds of impacts adversely affect the living resources or aesthetic quality or create a public health hazard. The damage to living resources can be catastrophic when waste discharges are large in volume, strong in concentration, or prolonged in time. Such discharges are restrictive rather than prohibitive, however, in that removal or significant reduction of the waste discharge will permit a healthful ecosystem to slowly reestablish itself with consequent full reestablishment of the formerly restricted uses. San Diego Bay, discussed earlier, is an excellent example of this. Commercial fishing, recreation, and water supply are the major uses restricted by pollution from liquid waste discharges.

*Commercial fishing as a restrictive impact*

Fisheries may be affected adversely either by damage to fishery resources or by imposing a public health hazard which makes the harvestable product unsafe. The fishery resource, whether finfish or shellfish, may be damaged by the direct killing of marketable species, by the killing or poisoning of a necessary food supply, or by damage to the reproductive capability of any part of the food chain. Any or all of these may occur, depending on the waste discharge characteristics.

Oysters, mussels, and clams are susceptible to these damages; in addition, their meats may be made unsafe for human consumption by the suspected present of wastes containing pathogenic organics or toxic materials which such animals tend to concentrate in their tissues. It is important to recognize that the conflict in use arises from the inability to market the shellfish product because of necessary public health considerations, and that there may be no damage at all to the shellfish habitat, particularly if the waste is treated domestic sewage, which contains excellent nutrients for shellfish.

*Recreation as a restrictive impact*

Liquid wastes may have restrictive impacts on both body contact and non-contact forms of recreation. The invisible dangers of water-borne pathogenic organisms are as important in restricting recreational use as the floating scum and oil which damage aesthetic quality and cause people to go elsewhere.

Recreational use is never entirely eliminated. Even around the most polluted estuarine areas can be found an occasional fisherman or boating enthusiast. The people who cannot go elsewhere will use their local estuarine zone in whatever fashion is possible, even if there is a public health danger or the environment is unpleasing. The dangers inherent in such use fall primarily on children, who tend to play in any available puddle, not caring whether it is the local swimming hole or New York harbor.

*Water supply as a restrictive impact*

The use of estuarine waters for municipal and industrial process water supplies is not extensive because its primarily brackish quality makes it difficult to treat adequately and economically. Estuarine waters are used extensively for industrial cooling water use, and waters with suspended solids, high acid of alkali concentrations, or high nutrient concentrations are difficult to use. Such waters clog screens, corrode pipes, or develop slimes which require added maintenance expense.

With increasing population and industrial growth in many coastal areas and increasing demands for potable and industrial process water, the use of fresh estuarine waters for water supplies may become an important estuarine water use. Fresh waters in the estuarine zone occur near where the rivers reach sea level, and it is here at the natural head of navigation that many of the large ports are located and discharge their wastes.

*Commercial fishing*

Some kinds of commercial fishing require the use of trawls or the setting of traps or nets that must be left for some time. The use of such devices restricts other uses while the devices are in place, but there is no permanent appropriation of estuarine waters or space. The major conflict is with recreation in that recreational boating must be excluded from areas where fishing gear is near the surface.

Shellfishing is restrictive in the sense that commercial oyster and clam beds require the waters above them to be of far better quality than is required for safe body contact. This has been a significant impact up to the present only in that waste treatment requirements of some municipal and industrial wastes have had to be set higher than would otherwise be necessary. With increasing numbers of watercraft in estuarine waters the potential additional human wastes from these boats may require restriction of some waters to recreational traffic in order to protect shellfish beds.

## Section 2. Examples of Use Damage

Where there is conflict, the scene is set for trade-off, that is, a willing substitution of one activity for another. The scene is equally set for uncompensated damage where one user group precludes the activities of a second unrelated user group but does not reimburse them for damage. Several examples will demonstrate the types of damages and the difficulties in quantifying them. Essentially, the damage is the value of the use which is precluded or foregone, and the same type of use valuation problems as discussed earlier are applicable.

Actual documented examples of use damages are difficult to find. One major reason is the basic fact that has permeated much of the discussion of economic and social values: Many estuarine values are not quantifiable. While damages to a commercial enterprise, such as commercial fishing, can be quantified in terms of the economic loss, the essentially intangible values of recreation and estuarine habitat are difficult to measure.

Recreational loss would have to be measured in terms of how many people don't swim or go boating in the Potomac River because it is polluted. It is far easier to find out how many people do go there even if it is polluted; even these values are hard to find.

The value of estuarine habitat is just as difficult to establish. There are now about 5.5 million acres of important estuarine marsh and wetland habitat remaining in the estuarine zone of the United States. Perhaps each acre is not valuable by itself, but the total habitat is irreplaceable. The problem of measuring the value can be illustrated by this example:

A poor worker had been given a loaf of bread for his supper. On his way home he met along the road several friends who each asked for a slice of bread. Being generous, and since a single slice of bread is a small thing, he gave each of them a slice. When he arrived home he had only the wrapping left. Since his family couldn't eat that, they went supperless to bed.

How valuable is a slice of bread?

How valuable is an acre of estuary?

### DAMAGE TO MARSH HABITAT

*Delaware Bay*

The following example shows how, in the Delaware Bay system, there has been steady attrition of estuarine marsh area for industrial development in recent years. The example is taken from testimony presented by Mr. Allston Jenkins, representing Philadelphia Conservationists, Inc., before a congressional subcommittee in March 1967.

**(1) In 1955 the Tidewater Oil Co. started acquiring some of the finest estuarine marshes in the State of Delaware for the purpose of constructing a large refinery in the vicinity of Delaware City about 30 miles north of the Bombay Hook National Wildlife Refuge. State conversation officials and citizen groups endeavored to persuade the company to locate its refinery on land other than the estuarine marshland. It was of no avail. Some 1,000 acres of productive estuarine marshes were purchased, filled-in, and lost as a natural resource.**

**(2) In 1961 the Shell Oil Co. started a similar acquisition of estuarine marshes in Delaware upon which to construct a large refinery in the vicinity of Smyrna**

about 5 miles north of the Bombay Hook National Wildlife Refuge. Efforts of State conservation officials and citizen groups to persuade the company to locate on the upland instead of on the marshes have proved futile. The company has acquired some 1,000 acres of natural estuarine marsh and is continuing a program of further acquisition. I am told that the vote of one member of a small township zoning board was the decisive factor in determining whether there should be 1,000 acres of prime estuarine resources or 1,000 acres of bottom silt landfill.

(3) Recently the B. F. Goodrich Co. applied to the Corps of Engineers, U.S. Army, for a permit to dredge in the Chesapeake-Delaware Canal (the connecting link between the Delaware River Estuary and the Chesapeake Bay Estuary) for the purpose of constructing a dock and berthing facilities for a plant to be constructed on the edge of the canal. Over 1,000 persons attended a public hearing on the application on February 9. Over 90 percent of those attending were opposed to the granting of a permit. Yet this may not be decisive with the Corps of Engineers. The corps is concerned primarily, almost solely, with the effect on navigation of the proposed dock and berthing facilities. If the company can show that the proposed facilities would not seriously hamper navigation it is not at all unlikely that the corps will grant a dredging and filling permit.

(4) Two or 3 years ago the Sinclair Oil Co. acquired 300 acres of estuarine marsh near Milford Neck, Del., 18 miles south of the Bombay Hook National Wildlife Refuge, for use as a tank farm and unloading port.

(5) A recent newspaper article, confirmed by the New Jersey Division of Fish and Game, states that the Atlantic City Electric Co. has acquired 4,500 to 5,000 acres of marsh between Stowe Creek and the Cohansey River along the Delaware River near Bridgeton, N.J. The company intends to construct a nuclear energy plant and industrial complex. The New Jersey green acres program and the division of fish and game had both marked this area for preservation. These are some of the finest estuarine marshes of the estuary.

*Connecticut coast*

Connecticut State Board of Fisheries and Game "Tidal Marsh Area—A Summary as of February 1965" says that the earliest record that seems to have been accurately obtained gives a figure of 36.5 square miles. This figure was published in 1914 in the First Annual Report of the New Jersey Mosquito Extermination Association. In the "1954 Wetlands of Connecticut," published by the U.S. Fish and Wildlife Service, about 21.7 square miles of this area remained, a reduction of 9,500 acres in 40 years. This reduction averages slightly less than 240 acres per year, slightly less than 1 percent per year.

A resurvey in 1959 led to the publication of a second "Wetlands of Connecticut, Revised June 1959". At that time these areas had been further reduced to about 20.2 square miles—12,937 acres. This reduction averaged about 190 acres per year, slightly less than 1.4 percent a year, 6.8 percent for the 5-year period. Hence, while the actual acreage lost during this period is less than in similar periods, earlier, the percentage lost each year is increasing. A second resurvey in 1964 shows a further reduction to about 18.6 square miles—11,900 acres for the areas of the 1914 survey. This reduction averaged about 200 acres per year, 1.6 percent per year of the 1959 acreage, 7.9 percent reduction in acreage over the 5-year period. Both percentagewise and in actual acreage lost the 1959–64 period is higher than was 1954–59.

The data in the wetlands publications are not directly comparable to those given above, since some upriver tidal marshes are grouped with the saline marshes. These are, in some cases, somewhat less vulnerable to destruction.

About 20,500 acres of tidal marsh in the State were rated for their value to wildlife in 1954. The high- and moderate-value acreage totaled about 13,000 acres, about 63 percent of the area. The resurvey in 1959 showed a reduction of more than 1,300 acres, leaving a total of 19,200 acres. Of the high- and moderate-value areas 12,600 acres remained, which represents a 3-percent loss in the more valuable tidal marsh during the 5-year period, a reduction in total area of about 6 percent. However, this is not the complete picture.

While more than 3 percent of the tidal marshes were completely or partially destroyed during this 5-year period, their value for waterfowl was not reviewed in 1959 or 1964, and much of the area that was of high or moderate value in 1954 may have been reduced in quality making the loss more severe than that recorded.

The total loss of tidal marsh tabulated in the 1954 and 1959 surveys is about 6 percent for the 5-year period. The loss for the 5 years 1959 to 1964 is about 7 percent.

The data on causes of marsh destruction do not fall into well-defined categories. Dredging for a marina and placing the fill on adjoining marsh represent two classes of destruction, but the figures do not separate them. Similarly, there are little data on the use to which filled areas are put—in housing, factories, boat storage, dumps. Major causes of this loss involved miscellaneous fill (48 percent); waste disposal (14 percent); roads and parking (9 percent); industry (7 percent); marinas (6 percent); housing (5 percent); recreational developments (3 percent); and schools (1 percent).

The loss of these marshlands can only be partly justified as needed for our economic growth and the demand of a growing population. Much of it has been the permanent destruction of an irreplaceable natural resource for a very temporary economic advantage. The accumulative effect has been changed in the ecology of the Connecticut shoreline with the decline of formerly abundant species of fish and shellfish as well as the total disappearance of certain species of shell and finfiish in specific areas.

## DAMAGE TO FISH AND WILDLIFE

### *Chesapeake Bay*

At the request of the Federal Water Pollution Control Administration the Bureau of Sport Fisheries and Wildlife conducted a study of "Fish and Wildlife Resources as related to Water Pollution" in the Chesapeake Bay area. The report was issued in 1968; its results are summarized here.

The study area covered by biological considerations in this report included Chesapeake Bay and its tributaries, except the Susquehanna River Basin. This area includes the major drainages of the James, Rappannock-York, and Potomac Rivers as well as Chesapeake Bay and its minor tributaries. These drainages encompass virtually all of Maryland, a sizable portion of Virginia, and small segments of Delaware, Pennsylvania, and West Virginia.

To evaluate the relative effect of pollution on fish and wildlife resources, the total resource potential under polluted conditions was compared with what would be available if pollution were eliminated. These resource potentials, both with and without pollution, were then compared to the expected user demand to determine their relative availability under both conditions. Specific data on present, future, or projected conditions are often minimal or lacking. Therefore, data analysis must be made on a general basis. This dictates that study results should be recognized as being relative in nature and utilized to gain an insight into problem areas. Figures quoted in the remaining portions of this narrative represent rounded data.

The 1960–64 average annual commercial fishery harvest from the study area included 288,740,000 pounds of finfish and 107,584,000 pounds of shellfish for a total of 396,324,000 pounds.

Wetlands wildlife habitat occupied approximately 614,000 acres of the study area in the mid-1950's. Since that time, losses resulting from drainage, land fill, highway construction, and similar developments have reduced wetland habitat to a current area of about 558,000 acres or less. Wetland loss is thus 56,000 acres.

Pollution affects approximately 432,000 acres of finfish habitat and 42,000 acres of shellfish grounds for a total of 463,000 surfaces acres (adjusted for overlap), or about 14 percent of the study area's fish habitat.

Average annual losses from significant pollution effects on 101,000 acres of finfish habitat and 42,000 acres of shellfish habitat amount to $1,861,000 and $1,090,000, respectively, or a total fishery loss of $2,951,-000. No losses were assigned to 331,000 acres of negligibly polluted finfish habitat. Projected demand for both sport and commercial fishery harvest presently, or in the near future, will exceed the average annual sustained harvest capability from most individual habitat classes under existing pollution levels.

Table 23 of the report (table IV. 6.1) shown on the next page, gives the loss broken down by drainage basins. Finfish resource plus shellfish resources equals fishery resource.

TABLE IV.6.1.—SUMMARY OF POLLUTED FISH HABITAT CHESAPEAKE BAY AREA AND TRIBUTARIES (EXCEPT SUSQUEHANNA RIVER BASINS)

FINFISH RESOURCES[1]

| | Pollution effects (acres) | | | | | Total | | Average annual loss | |
|---|---|---|---|---|---|---|---|---|---|
| | Negligible | Light | Moderate | Intense | Severe | Acres | Percent | Dollars | Percent |
| Chesapeake Bay Area | 51 | 4,578 | 427 | 17,905 | 4 | 22,965 | 5.3 | 687,971 | 37.0 |
| James River Basin | 87,047 | 24,976 | 19,385 | 1,541 | 73 | 133,022 | 30.8 | 768,927 | 41.3 |
| Rappahannock-York River Basins | | 593 | | 199 | | 792 | .2 | 13,549 | .7 |
| Potomac River Basin | 243,543 | 28,796 | 1,902 | 174 | 390 | 274,805 | 63.7 | 390,290 | 21.0 |
| Total study area | 330,641 | 58,943 | 21,714 | 19,819 | 467 | 431,584 | 100.0 | 1,860,737 | 100.0 |
| Percent | 76.6 | 13.7 | 5.0 | 4.6 | .1 | 100 | | | |

| | Shellfish resources | | | | Fishery resources | | | |
|---|---|---|---|---|---|---|---|---|
| | Closed areas | | Average annual loss | | Polluted habitat | | Average annual loss | |
| | Acres | Percent | Dollars | Percent | Acres[1] | Percent | Dollars | Percent |
| Chesapeake Bay area | 26,429 | 62.5 | 549,580 | 50.5 | 38,254 | 8.3 | 1,237,551 | 42.0 |
| James River Basin | 12,571 | 29.8 | 361,151 | 33.1 | 145,593 | 31.5 | 1,130,078 | 38.3 |
| Rappahannock-York River Basins | 3,077 | 7.3 | 173,483 | 15.9 | 3,869 | .8 | 187,032 | 6.3 |
| Potomac River Basin | 178 | .4 | 5,767 | .5 | 274,805 | 59.4 | 396,057 | 13.4 |
| Total study area | 42,255 | 100.0 | 1,089,981 | 100.0 | 462,521 | 100.0 | 2,950,718 | 100.0 |

[1] Area not cumulative owing to overlap.

*Hudson River (Wappinger Creek)*

The material for this case study was obtained from the New York State Conservation Department, Fish and Game Division, Albany, N.Y. They graciously provided a legal case from their records. The case study quoted here is one of less than a half dozen situations during the past 40 years in which legal evidence, sufficient to be assured of a successful court case, could be obtained. Faced with the evidence an out-of-court settlement was reached.

The fact that in 40 years less than six legal cases could be obtained along a river-estuary system as well developed as the Hudson River points out the extreme difficulty in obtaining positive confirmation of a use damage.

On June 27, 1962 a delivery of No. 6 fuel oil was made to a storage tank which was not emptied sufficiently to accommodate all the oil delivered. An unknown quantity was spilled in Wappinger Creek, a direct tributary of the lower Hudson River. The oil company received complaints from property owners along the stream and decided, after skimming and pumping failed, to use a chemical, Ozene, which would be sprayed on the oil. It is estimated that about 30 gallons of Ozene was actually used in the stream spraying operation. It can safety be assumed that at least 20 gallons went directly into the waters of Wappinger Creek.

An abundance of dead fish was observed from the site of the spraying operation to about 1 mile downstream. Occasional dead fish were observed as far as 4 miles downstream. The fish kill was estimated at 10,000 fish, with about 75 percent being rough fish and minnow, 15 percent pan fish, and 10 percent trout.

A bio-assay was conducted using a solution of Ozene at the Rome hatchery using spring water, and a solution concentration of 4.5 p.p.m. orthodichlorobenzene. One hundred percent of test fish were killed in 8 hours. On this basis, 20 gallons of Ozene would be capable of making toxic approximately 5,125,000 gallons of water. Since spraying would result in even higher local concentrations before complete mixing, the high concentration would kill in a time period of 10 minutes or less.

The fish kill was the direct result of the application of a material called Ozene to the surface of Wappinger Creek. A $500 settlement for violation of section 180 "Pollution of Streams Prohibited" of the New York State Conservation laws effected by out-of-court settlement. The oil spill itself was a violation of the classification standard established by the Water Pollution Control Board for Wappingers Creek.

## DAMAGE TO WILDLIFE FROM OIL SPILLS

*New Haven Harbor, Conn.*

The following quotation is from a release by Mr. O. E. Beckley, supervisor, Game Management, Board of Fisheries and Game, State of Connecticut, dated March 28, 1961, and describes the death and value of duck life destroyed by oil resulting from a tanker with a rupture in her hull:

"On December 17, 1960, the S. S. Sister Katingo, a supertanker owned by the Nautilus Petroleum Corp. of New York, carrying a cargo of bunker "C" oil, reportedly struck a submerged object somewhere off Brenton Reef, R.I., causing a rupture in her port side.

"According to the U.S. Army Corps of Engineers, a large quantity of oil was lost at the time of the impact, which resulted in the blackening of Nantucket Island. The ship proceeded to her destination, New Haven Harbor, and arrived during the evening of December 17. Pumping activities were started early the next morning and were completed by noon the following day.

"It has been estimated that upwards of 240,000 gallons of bunker "C" oil was lost, with a conservative estimate of over 42,000 gallons spilling into the confines of the New Haven Harbor. The oil quickly spread itself out upon the waters of the harbor, breaking up into pools and slicks, coating bulkheads, seawalls, and beaches with black. Incoming tides carried it to upper shores reaches and then receded, leaving pools which in some areas were 4-5 inches deep. Approximately 10 miles of shorelines were blackened in the Great New Haven Harbor area. Within a week, marks of the spillage could be observed extending along approximately 20 miles of shorelines from Guilford to Milford. Evidence of the spillage was present on many of the off-shore islands in the entire area.

"The Connecticut State Board of Fisheries and Game became aware of the problem on Tuesday evening, December 20. Investigations were initiated the following morning to determine the extent of the damage to wildlife.

"The first affected birds observed, while few in number, served for department game biologists as a grim warning of what might be expected in the days to come. Immediate efforts were made to initiate a clean-up operation and a series of contracts with the oil company and municipal officials and landowners was made in an attempt to expedite clean-up. But as negotiations proceeded the death toll grew. Dead, oil-encased birds appeared with greater frequency along the shore. Except for body form, these black, shrouded shapes with not a feather visible could hardy be recognized as ducks.

"A census of dead ducks was started on December 21. At the end of the first week of the investigation, 995 dead ducks had been counted in the Greater New Haven Harbor area. Of the dead ducks counted, approximately 400, or 40 percent were dabbling ducks, and 595, or 60 percent were diving species. Virtually all of the dabblers seen were black ducks with only a few, one mallard and two baldpates observed. The dead diving ducks counted included approximately 300, or 30 percent, scaup, 140, or 14 percent, goldeneyes, 60, or 6 percent, canvasbacks, and the remaining 10 percent included 35 scoters, 30 old squaw, 20 bufflehead, and 10 mergansers.

"In addition to ducks, other species affected included herring gulls, horned grebe, loon, purple sandpiper, cormorant, clapper rail, and kildeer.

"Biologists estimated through reports and observations that at the time when the count of dead birds in the Harbor area was completed, an additional 3,000 ducks had been affected. Of the total 4,000 birds affected, including 995 known dead at the end of the first week after censusing was started, it was estimated that 2,860, or 75 percent, consisted of scaup; 500, or 12 percent, or black ducks, including only a few mallard and baldpate; 340, or 9 percent, goldeneyes, and the remaining 7 percent were made up of 85 canvasbacks, 80 scoters, 90 old squaw, 30 bufflehead, and 15 mergansers.

"Spot checks of hunter bags were made from December 22, 1960, through the end of the gunning season on January 7, 1961. These bag checks, which were taken in an area extending approximately 20 miles both east and west from the New Haven Harbor, disclosed 185 oiled ducks of the 358 ducks killed, or approximately 52 percent oiled ducks for the entire area. During the period from December 22 to December 31, 1960, 55 percent of 293 ducks killed were oiled. During the period from January 2, through January 7, 1961, 35 percent of 65 birds killed were oiled.

"During the aerial inventory of waterfowl by Department personnel on January 9, 1961, 33,187 ducks were observed in the 20 mile oil-contaminated area from Guilford to Milford. Species represented in this count consisted of: 1,462 blacks, 200 mallards, 20,150 scaup, 220 canvasbacks, 112 scoters, 28 goldeneyes, 8 old squaw, 5 mergansers, 2 bufflehead.

It is a reasonable assumption that many of these ducks seen in the oil-contaminated area were affected by oil to varying degrees and could raise the total affected by many thousand.

From observations conducted when the oil spillage first occurred, through the end of the hunting season and during the abnormally cold period in January and February, it is conservatively estimated that at least 3,000 ducks perished as a result of being oiled.

Commercial game breeder's quotations on the following species show that blacks sell for $3 each, scaup $30 each, goldeneyes $100 each, and canvasbacks $50 each. No prices were available for scoters, old squaw, bufflehead, and mergansers since they are very difficult, if not impossible, to raise. It is estimated that replacement costs, if replacement were possible, would run well in excess of $100,000, based on current game breeder's prices.

During the early stages of the investigation, approximately 400 live ducks, oiled to varying degrees, were collected by Department personnel and shore residents. Various types of cleaning agents were experimented with; many of these cleansed birds were returned to the water. Some were kept penned at a game breeder's farm to observe survival rates. Of 22 penned that were cleansed, only six were surviving at the end of a 3-week period. Despite the efforts made to rehabilitate ducks, it is felt that their chance for survival is very poor.

*Thames River, Connecticut*

The information for this case study is quoted directly from the Connecticut Newsletter: of the Connecticut Audubon Council dated February 15, 1969, Vol. 2, No. 8.

An industrial oil barge ran aground, Thursday, January 16, 1969, on Bartlett's Reef near Waterford, Conn., causing an undetermined amount of heavy bunker "C" oil to be spilled in Long Island Sound. The Coast Guard apparently did not hear about this spillage until Saturday despite the fact that all oil ruptures are to be reported at once.

The beaches and rocky shore areas from Niantic to coastal Rhode Island were blackened with large globs of gooey tar-like oil.

The Thames Science Center, 622 William Street, New London, was notified and were first on the scene with their three-man professional staff to appraise the situation. Several oiled-horned grebes were picked up completely covered and unable to fly. Red-breasted merganser, black duck, greater scaup, common goldeneye, blufflehead, surf scoter, Canada Geese, mallard, mute swan, common loon, herring gull, and greater black-backed gulls were all found oiled in various stages in their struggle for survival. As of January 30 the following is a summary of accurate figures of birds observed by the Thames Science Center Staff.

| Species | Captivity | Known dead | Oil covered, in natural habitat recovery questioned | Totals |
|---|---|---|---|---|
| Common loon | 0 | 19 | 8 | 27 |
| Horned grebe | 4 | 140 | 2 | 146 |
| Mute swan | 2 | 3 | 18 | 23 |
| Mallard | 1 | 1 | 30 | 32 |
| Black duck | 0 | 3 | 6 | 9 |
| Greater scaup | 0 | 0 | 1 | 1 |
| Common goldeneye | 0 | 1 | 18 | 19 |
| Bufflehead | 1 | 8 | 19 | 28 |
| Red-breasted merganser | 13 | 13 | 36 | 62 |
| Herring gulls | 0 | 0 | 31 | 31 |
| Surf scooter | 0 | 1 | 0 | 1 |
| Black-back gull | 0 | 0 | 3 | 3 |
| Canada geese | 0 | 0 | 85 | 85 |
| White winged scoter | 1 | 0 | 0 | 1 |
| Total | 22 | 189 | 257 | 486 |

On January 22, all beaches from the Connecticut River at Griswold Point, Old Lyme to the Harkness Memorial State Park south of New London at the mouth of the Thames River were visually checked. The only beach still with noticeable oil was Harkness Memorial State which was fairly cleared of the heavy oil. A policeman in Niantic said the tides cleared most oil from their beach.

As of Friday, January 24, the Thames Science Center executive director, John Gardner, summarized the situation as follows:

"The oil pollution was not severe because of the limited volume of pollutant in the water, the tendency of the oil to remain in globular form, its rapid mixing with sand, and dissipation by wave action. Beaches appear in good condition on the surface. Marine life seems to have minimal problems. Because of wintering populations most waterfowl suffered moderate losses. However, we know that 80 percent of the loons, 90 percent of the horned grebes, and 23 percent of the red-breasted mergansers wintering in the survey area have been affected."

A revised appraisal on January 30 concludes that:

At this time beaches are relatively clean, although rocky beaches still contain varying amounts of oil. Marine life seems to have minimal problems. Algae on rocky shores are expected to die, but regrow by spring. Waterfowl deaths now stand at 189 (known and verified). Two hundred and fifty-seven birds have been sighted with some oil fouling, and we expect that the majority of these will not survive. Seventy-four birds reported last time are unaccounted for at this time. It is normal for injured or sick birds to move into grassy areas or dense marsh areas where they die or are preyed upon by predators. Consequently, we assume the 74 birds not accounted for are dead. (If these are added to confirmed deaths it brings the death toll to 263.) The 257 birds sighted with oil covering parts of their body are not expected to survive. Deaths are attributed to oil ingestion. All data based on actual field studies and confirmed reports. No estimates or projections included.

## DAMAGE TO COMMERCIAL SHELLFISHERIES

*Raritan Bay, N.Y. and N.J.*

Exhaustive studies in Raritan Bay were carried out by the Public Health Service as part of the investigations resulting from shellfish bed closures and public health hazards resulting from pollution of Narragansett Bay. Most of the information presented in this case study was taken from the enforcement conferences which resulted from these investigations.

An outbreak of hepatitis in 1961 was traced to consumption of raw shellfish from the Raritan Bay. In 1963 the Public Health Service found the same level of pollution as in 1961 and the project scientist concluded that in that year this health hazard "precluded a safe shellfish industry and interfered with legitimate use of the waters of Raritan Bay."

The bay was closed in 1961 to all shellfishing by order of the New Jersey State Commissioner of Health, Dr. Kandle.

Bathing has been restricted on most of the beaches on Staten Island along this bay (see case study on Staten Island beaches).

A total of 3,789 fishermen lost their livelihood in all of New Jersey due to closings, as of 1965. The Raritan Bay closing, therefore, would represent a maximum of 3,000 men out of work.

All 1961 and 1962 water samplings by the Public Health Service show a heavy fecal bacteria count, both on mean average as well as for spot samples (lowest mean 50/100 ml., highest 9,700/100 ml.). The origin was traced to many insufficiently treated sewerage plants particularly at Atlantic Highlands, and Keansburg and raw sewerage from the Earle Ammunition Depot (N.J.) and seven sewerages serving a total of 3,000 inhabitants in Tottenville, Staten Island. Besides these, three additional sources of pollution are (1) the Narrows where sewerage from New York City passes through a "funnel," (2) the Raritan River, and (3) Arthur Kill.

Great Kills Park was a man-made landfill, where garbage was dumped as a fill. It was impossible to ascertain how much pollution could be attributed to this fill operation. Only the statement by witnesses that the landfill operation caused pollution of the adjacent water is available.

Raritan Bay covers roughly 90 square miles of which an estimated 5 percent was once harvested for shellfish. Thus, about 2,850 acres (A. S. Merrill) are suitable for shellfish. At the rate of 2,000 bushels of oysters on one acre (A. S. Merrill, 1967 Conference—Pollution of the Navigable Waters of Eastern New Jersey (November 1967) prepared for FWPCA, p. 334) or 2,000 bushels of clams per acre (Jerome, Chesmore, and Anderson, Study of Marine Resources of Beverly-Salem Harbor (1967), p. 49) combined with a dockside price per bushel of $1.50, the loss per acre per year is $3,000. If 2,850 acres of the bay were so utilized, that total loss would amount tto $8.5 million annually. These figures will vary as follows:

(1) 2,000 bushels per acre represents the upper limit of current bottom harvest yields. Three dimensional farming is already yielding over twice this amount per acre. On the other hand, a more average bottom yield would be on the order of a few hundred to 1,000 bushels per acre.

(2) The $1.50 figure is very low since a bushel of oysters currently (1968) brings about $10 in the New England area. This would be the dockside landing value of the bushel. Then there is the expanded value of bushel or that represented by the flow of money and jobs generated by people employed in processing and marketing the product. The expanded value runs from five to ten times the dockside value.

The pollution of shellfish beds in Raritan Bay has resulted, therefore, in the following:

(1) loss of employment and loss of an industry;
(2) an epidemic of hepatitis;
(3) loss of recreational shellfish harvest; and
(4) loss of $8.5 million annually and five to ten times this amount if the expanded value is used.

From 1948 to 1960 Raritan Bay shellfish reaching the New York City market of 20,000 to 30,000 bushels a year brought $6 per bushel or $120,000 to $180,000 annual dockside value. A survey by the Northeast Shellfish Sanitation Research Center (circa 1965) indicated a standing crop of some 5 million bushels of clams which agrees with the estimate made above.

*Penobscot Bay, Maine*

The "Report on Pollution—Navigable Waters of the Penobscot River and Upper Penobscot Bay in Maine", Merrimack River Project-Northeast Region, Boston, Mass., February 1967, Federal Water Pollution Control Administration, provided the information for this case study.

Penobscot Bay and River are troubled with at least four major types of pollution which affect the shellfish beds. Untreated or insufficiently treated sewage, poultry processing wastes, sulfite waste liquor, and heavy metal contamination from mining operations have compounded the problem of trying to reopen the closed shellfish beds.

The long axis of the Penobscot River-Bay-Estuary system is approximately 35 miles in length. Shellfish growing areas of the upper bay were first closed in 1946. Since that time, more and more closures have been required along the entire upper perimeter of the bay and the lower estuary. Increases in poultry processing and other industrial and commercial expansion have required a drastic increase in the acreage of flats and waters closed because of pollution. Some of the problem is due to heavy metals mining.

Levels of toxic metals are at or above the maximum of the normal range for shellfish. In the case of lead, the concentration is double or triple the maximum guideline recommended by the U.S. Public Health Service.

In addition to the high coliform counts, there is a problem in the Penobscot Bay area due to poultry processing. The following information gives a picture of the problems caused by the poultry industry (report on "Pollution-Navigable Waters of the Penobscot River and Upper Penobscot Bay in Maine").

On June 28, 1966, the Maine Sea and Shore Fisheries reported finding floating chicken entrails in Stockton Harbor at the northeast side of Sears Island. They reported that these entrails had a total coliform value greater than 170,000 MPN/100 ml. Again on July 8, 1966, floating chicken entrails were found by fisheries personnel in Stockton Harbor at the same location. They also reported that on June 28, 1966, an animal fat film was found on the waters from the south tip of Sears Island to the north tip of Sears Island in Stockton Harbor. Large amounts of feathers have been reported found on Sears Island and Islesboro Island. A ferry running from Islesboro Island to Lincolnville, which is south of Northport, reported that their water intake screen had to be cleaned at least once a week in the past, due to chicken feathers clogging the screen. In the past, chicken entrails have been found all along the banks of Belfast Bay. During the period samples were being collected by the Merrimack River project, there were no significant discharges of either feathers or entrails, indicating that either the new screening devices were working properly or that closer attention was given to maintenance of these screens.

Sterile gauze swabs were placed at 21 stations for about 5 days. Salmonellae were found at five of the stations poultry plant effluent. The United States Public Health Services Communicable Disease Center determined the serotype. The results clearly pointed out that poultry plant wastes are pathogenic to man since all Salmonella bacteria are pathogenic. Salmonellae were isolated from both swabs placed in the Penobscot River.

The Maine Water Improvement Commission found that the dissolved oxygen placed the Penobscot River either in the nuisance condition or in class D (suitable for transportation of sewage and industrial waste without causing a public nuisance) from Bangor to Bucksport. Zero D.O. was found from Bangor to Winterport during the summer of 1963, with the oxygen sag curve moving downstream at low tide and upstream at high tide. This dissolved oxygen condition limits usage of the entire river below Bangor and prevents fish, including anadromous fish such as salmon, from passing through these waters.

Another problem is sulfite waste liquor resulting from the processing of pulp using the sulfite process. "Bioassays of Pulp Mill Wastes with Oysters, Biological Problems in Water Pollution," U.S. Department of Health, Education, and Welfare, Cincinnati, Ohio, 1965, showed that concentration of SWL above 10 p.p.m. prevented the embryonic development of the Olympic oyster from eggs to shelled larvae. Upper Penobscot Bay area had SWL concentration near 60 p.p.m. and at low tide near Fort Point the value was about 100 p.p.m.

In November 1954, about 5 miles of shoreline and a fivefold increase in the total area of flats and overlying waters were added to the original Belfast Bay closure. Prior to this time, 50 commercial diggers had been licensed in the Belfast area alone.

Additional closures have been made periodically since 1954. Finally, by July 1, 1966, the last remaining open areas were closed, making the closure complete from Great Spruce Head in Northport up the Penobscot River and down the east shore to Castine.

For the total area of Penobscot Bay affected by the recent shellfish area closures, the estimated population was placed at 96,000 bushels of marketable soft clams, valued from a community standpoint (note: this is the concept used in other case studies as the expanded value * * * it is generally 2.5 to 7 times the dockside or landing value) at $1,876,000 to $5,216,400. Potential harvest during a second season was estimated to be 46,200 bushels. These would have a value to the community of from $896,800 to $2,494,800.

DAMAGE TO SHELLFISH HABITAT

*Great Bay, N.H.*

Two documents provided the information for this case study: "Coastal Watershed" by the New Hampshire Water Pollution Commission, July 1965, staff report No. 51, and "A Biological Survey of Great Bay, New Hampshire by the Marine Fisheries Commission, No. 1, Physical and Biological Features of Great Bay and the Present Status of its Marine Resources," C. F. Jackson, director, Biological Institute, University of New Hampshire, Durham, N.H., March 1944.

Historical data indicate that the Great Bay area was at one time especially rich in natural resources, such as salmon, shad, cod, and various shellfish. Rapid decline or ultimate disappearance of many of these food fishes dates from the beginning of the industrial development of this region about 1800.

Great Bay and the tidal rivers afford some 2,815 acres of potential clam flats. Most of these are nonproductive due to pollution, silt, or the growth of Spartina. The situation in reference to oysters parallels closely that of clams. In early days the oyster fisheries probably exceeded in commercial importance those of the clam. In later years, however, this situation has been reversed, due first, to the growing scarcity of the oyster, and secondly, to restrictive legislation.

Clams and oysters were once harvested in Great Bay Estuary. In 1938 the estuary was closed to the commercial production of clams due to bacterial pollution. In his biological survey of Great Bay in 1944, C. F. Jackson estimated a loss of $2 million annually on clams in Great Bay. Thus, with no commercial utilization of clams in Great Bay over the last 30 years, a loss can be calculated at $60 million since it is based on a per bushel value of $1.50 and the 1944 price of clams. The current per bushel price of clams in the New England area is nearly $10. Thus the loss, dockside, may be nearly seven times greater or nearly $420 million since 1938. Oyster production in Great Bay Estuary has also been closed commercially since 1938. A recent survey estimated the total acreage of oyster beds at roughly 25 acres in Great Bay. At a production of 500 bushels per acre, this would result in a loss of 12,500 bushels annually. Oysters at $10 per bushel would then bring in $125,000 annually. Over the 30-year period since harvesting has been closed this loss due to pollution amounts to nearly $4 million.

All tributaries of Great Bay are dammed. Many of these dams have existed since 1800 and provide a block for fish such as salmon, alewives, and American shad, which need freshwater areas to complete their life cycles. The lost value of such fisheries over the years would run into many millions of dollars to both commercial and, more recently, sport fishermen. It should be pointed out that no definite estimate of this loss has been made but it is definitely measurable.

*Moriches Bay and Great South Bay, L.I.*

Information for this case study was supplied by contract investigations conducted as part of the National Estuarine Pollution Study, two Federal enforcement conference proceedings and a report of the Nassau-Suffolk Regional Planning Board (IV–6–5).

Up to 7 million ducks annually live in farms located on Moriches Bay and parts of Great South Bay. These ducks are a source of pollution to the bays. In one form, they cause the closing of valuable shellfish beds due to high coliform counts. Another form of pollution they create is BOD and eutrophication due to the duck sludge which covers the bottom of the bay in some sections.

Studies conducted by the Division of Laboratories and Research of the New York State Department of Health on duck wastes have shown them to be high in solids, BOD, nutrients, bacterial content, and constitute a public health hazard. It was found that the strength and volume of the wastes reaching the waste stream depended on the number, age, activity, position of ducks in the pens, amount of rainfall, runoff area, normal water use at the farms, and availability of water to the ducks.

Coliform densities were found to vary from a median MPN of $5.8 \times 10^6$ per 100 ml. to $60 \times 10^6$ per 100 ml. Typical water usages ranged from 0.290 mgd to 3.0 mgd per farm and from 14 gallon to 120 gallons per day per duck.

Since 1940, there has been a decline in the oyster and fish production of Great South Bay. These conditions have coincided with the buildup of the duck industry in the areas surrounding Moriches Bay. The wastes from the duck farms effectively fertilized these waters but with a low ratio of nitrogen to phosphorus.

As a result of the increased nutrients, especially phosphorus, the waters of Great South Bay have exhibited increased algal populations. Heavy growths of algae developed in the early spring and persisted through summer and fall. At its peak, the concentration of algal cells exceeded 10 million/ml. The dominant bloom algae was a small, unicellular species often termed "small form." This algae differed greatly from the flora typical of bays and estuaries in the same region and its persistance over long periods of time eliminated the typical seasonal succession of forms in the bay.

The decline of the oyster industry was directly correlated with the increase in the "small form." This was due to the fact that the optimum conditions for oytser growth included a mixed algal population. Although oysters do feed on the "small forms," these algae are an inadequate nutrient source. Serpulid worms which are capable of effectively utilizing the "small forms" for food have overrun the oyster beds periodically and thereby adversely affected oyster production by competitive exclusion.

The report of the Nassau-Suffolk Regional Planning Board, "The Status and Potential of the Marine Environment," states that "the oyster industry has declined 99 percent in the past 50 years from $50 million to $½ million" (p. 2–7).

In addition to the habitat damage caused by the duck farm wastes, there are productive areas of shellfish beds closed because of bacterial contamination.

The closed acreage, about 6,000 acres with 4,500 usable acres at 5 bushels per acre at $10 per bushel, is estimated to be capable of producing clams with a dockside value of $225,000 and an expanded value in excess of $2,250,000 annually. This loss has been in effect for 25 years. Adjacent open waters provide the proof of use and the dollar values used to estimate the loss.

### DAMAGE TO RECREATION

*Staten Island Beaches*

The information presented in this case study was obtained through interview of the manager of the Parks Department, Staten Island, F.D.R. Boardwalk, and the manager of Wolfe Pond Park, Staten Island, in April 1969. Additional information pertaining to average coliform density on the Staten Island Beaches was obtained from the New York City Department of Health. Former uses of the beaches are a matter of record and can be verified through old newspaper clippings of the Staten Island Advance as well as discussion with older residents of New Jersey and Staten Island. These statistics are not available in published form and have been verified and rechecked by interview and investigation as part of the contract studies of the National Estuarine Pollution Study.

The F.D.R. Boardwalk, Midland Beach, Great Kills Park, and South Beach are regularly posted in the summer season. The signs read "Not Recommended for Bathing," and are posted by the Board of Health of the city of New York. When this happened in 1968, it resulted in a drop of 50 percent in the use of these facilities.

Bathhouses and parking facilities were originated in the 1930's. The construction which is now evident dates from a reconstruction in 1950.

South Beach has two parking facilities for 800 cars each, Midland Beach for another 800 cars, amounting to a total of 2,400 cars parking facilities.

On a nonposted average day, 1,300 cars will use these lots. On a holiday, 2,000 cars will be using them. The admittance per car is 50 cents, therefore, $650 and $1,000 are paid for parking respectively. When the beach is posted "not recommended for bathing," an average day's parking fees amount to $325 and a peak day yields $500.

The beaches are open from May 24 to the weekend after Labor Day. With Memorial Day, July 4th, and Labor Day offering a total of 9 days peak activity at a loss of $500 per day in parking fees, a total loss of $4,500 per season for peak activity is attributed to pollution. In June, July, and August, weather and conditions permitting 25 days average usage per month is available. If the loss of use due to pollution runs at $325 a day, the loss computes to $8,125 per month and for the total season to about $24,000 in round figures. Conservatively speaking, the total annual loss amounts to $30,000 in parking fees alone.

It is most important, however, that these figures in dollars by no means reflect the true loss in recreational facilities due to pollution. Fifty cents is charged whether one car with one passenger or a whole family parks in the parking lots. Most of the time whole families are affected in this figure of 50 cents per car, usually most families from modest if not low socioeconomic background whose residences are within easy reach of these beaches, such as Newark, Elizabeth, Manhattan, and Staten Island.

The economic loss resulting from loss in corollary sales is not included: soft drinks, ice cream, and snack sales which constitute a business for many seasonally employed people are not included in this case study but have to be considered.

The present condition of loss in recreational facilities was reported by officials of the Park Department and verified through a direct interview on April 1969, with the Manager of the Parks Department, F.D.R. Boardwalk. The pollution was verified by N.Y.C. Department of Health. Coliform count at Midland and South Beach is in the order of 7,000 to 9,000 MPN/100 ml; the greatest pollution exists at the Narrows.

The sewage and human waste from New York City area decreases by dilution towards the middle of Staten Island shore and increases where contact with the Jersey shore is greater. The human waste materials emanating from these two points causes the lowest coliform density point at Wolfe Pond Park. The latter is never posted according to the guard interviewed on location. However, when the word spreads that the other beaches have been posted, the attendance at Wolfe Pond Park also drops up to 25 percent in spite of Wolfe Pond Park not being posted.

The fact that the parking lots, and hence the beaches themselves, are hardly ever used to full capacity indicated that even when the beaches are not posted, public opinion cannot react on a "day-to-day" posting basis and people consider the beaches as "polluted" at all times. The loss damage estimates could use the full parking lot capacity because the Staten Island area is in the midst of the largest metropolitan complex in the world with a corresponding need for any and all recreation facilities especially during the hot summer season when the requirement for providing activity for teenagers and unemployed is most critical.

*Santa Barbara, Calif.*

An emission of oil originating in the vicinity of an offshore drilling platform operated by Union Oil Co. began on January 28, 1969, and was not contained until 12 days later; subsequently, additional oil began leaking through the ocean floor.

The oil came ashore in the vicinity of Santa Barbara and covered beaches that are a major recreational resource of the area. The Union Oil Co. accepted responsibility for cleaning the beaches and other property damaged by the oil, and by June 1, 1969, had spent $4,600,000 for this purpose. (IV–6–6, IV–6–7.)

### DAMAGE TO NAVIGATION

*Charleston Harbor, S.C.*

The information for this case study was obtained from the U.S. Army Corps of Engineers report "Survey Report on Cooper River, S.C. (shoaling in Charleston Harbor)," 1966, and from "A retrospective economic analysis of the Santee-Cooper project," December 1967, by William Augustus Ward.

As part of the national plan to minimize unemployment during the great depression of the 1930's the South Carolina Public Service Authority was formed for the purpose of building a large dam, water supply, flood control, navigation lock, recreation and employment opportunity complex. Cost-benefit analysis was needed to show that the project merited the loan of Federal funds. The construction complex is referred to as the Santee-Cooper project.

In 1967 a study to check on the effectiveness of a cost-benefit analysis made 25 years previously was undertaken. Part of this analysis revealed that as a result of construction and hydraulic rerouting of rivers the silting in Charleston Harbor increased from what was estimated at $18,000 annually to an actual cost of over $2,029,756 annually. For every year in the future that the hydraulic regime of the harbor is not restored to a more suitable mode of circulation there will be a dredging cost of roughly the same magnitude incurred.

The diversion of the Santee River into the Cooper River constituted a remarkable engineering experiment. The designers of the diversion apparently foresaw no adverse effects. To the contrary, they felt that the effects of the added flow would be to flush out the harbor and prevent any serious pollution from ever occurring. As a result, the discovery that the shoaling rates were increasing in the harbor apparently came as a complete surprise to everyone. By 1947 the Corps of Engineers was undertaking model studies to try to determine a solution to the problem.

The finding of the Corps in their model studies at Vicksburg, Miss., indicated that the increased flow into the harbor area had created a partially mixed estuary. That is, the ratio of freshwater to salt water in the harbor area was such that a definite interface developed which moved longitudinally up and down with the tide. The dense saltwater was overlain by the freshwater inflow. As the freshwater flow increased to 15,000 c.f.s., the bottom flood currents became greater in duration over the bottom ebb currents. The effect was to create a net upstream movement of the bottom currents in the saline region of the harbor area, a condition which created a trap at the bottom of the estuary preventing the movement of settling materials out to sea.

At about the same time the Santee-Cooper project began operations, the project depth of the Charleston Harbor was changed from 30 feet to 35 feet. This further complicated the dredging problem for two reasons: first, the Corps had 5 additional feet of depth to maintain and second, the dredging itself loosened the accumulated silt outside of the shipping channels and allowed it to slip into the channels. The Corps maintained, however, that the natural depth of the Charleston Harbor had exceeded 35 feet, and that the greater project depth in itself would not have constituted much of a problem.

From its study of the shoaling problem in the Charleston Harbor, the Corps estimated that the Santee-Cooper project was responsible for approximately 85 percent of the shoaling in the harbor. The rest, they said, would have occurred without the project.

In 1965, dredging by the Corps was done at a cost of $2,237,949. It was estimated by the Corps that commercial shippers spent $100,000 on dredging operations while the Navy spent $50,000. Assigning 85 percent of this cost of the Santee-Cooper project, a negative benefit of $2,029,756 was attributed to operation of the project in 1965.

The most competent engineering firms in the Nation were employed in designing and constructing the project, and the design was checked and approved by the U.S. Army Corps of Engineers. Still, the analysis by the planners and engineers of the project yielded estimates of benefits and costs which were substantially different from those which actually occurred. Part of the discrepancy was due to simple optimism and even some bias on the part of the analysts. An equally large part seemed to be due to the inability of man to see even 25 years into the future. In the case of silting, the state-of-the-art was such in 1930 that no adverse effects were envisioned. As a result the dredging bill jumped from $18,000 to $2,029,756 annually.

## Section 3. Trends in Estuarine Ecology Associated With Man's Activities

The future character of estuarine ecological systems in the United States will be determined by present and future pressures affecting the estuarine zone, public decisions, and by the actions resulting from public policy. Thus, the future nature and operation of the total biophysical environment will be shaped primarily by the socioeconomic and institutional environments discussed in this report.

Existing estuarine ecological systems will continue to operate either in long-established dynamic patterns of chemical cycling, water circulation and species behavior, or these activities will be increasingly dominated by man's activities. Man's activities generally result in great stresses on established plant, animal, and chemical processes, if not total system modification. These activities may be controlled by decisions made in the socioeconomic and institutional environments to minimize impacts on the existing estuarine systems, thus retaining their structure and operation; or, the energy sources and stresses associated with man's activities may be allowed to dominate estuarine processes and, in effect, create wholly or partially different systems.

From a strictly empirical or descriptive viewpoint, the emerging new systems associated with man's activities are neither good nor bad per se; the determination of values relating to these modified systems must be made within the existing or potential socioeconomic and institutional frameworks. Values will be set in the marketplace, which include all the mechanisms whereby society normally measures the worth of goods, services and wages, which in turn largely determine the pressures placed on estuarine systems. The non-market system also determines values through the expression of choices expressing social costs and benefits not measured in standard economic terms. These two major components of value-setting must be balanced if modification and ultimate destruction of existing estuarine ecosystems is to be avoided.

### STRESS AND ESTUARINE ECOLOGY

Estuarine ecological systems consist of populations of organisms, flows of water, pathways of cycling chemical elements, and organizing mechanisms which are all tightly interrelated. These systems constantly adjust as the principal elements in their operation change in character, quantity, and composition. Thus, estuarine ecological systems, as with all ecological communities, are subject to change, and either successfully adapt, or are replaced by other systems.

Maintenance of estuarine ecological systems is dependent on an effective flow of energy and mineral cycles; it is these factors that most fundamentally determine the important features of system yield, system stability and water quality, rather than the presence of large, visible forms of life. In estuaries, the sun operating plant production processes and the mineral and organic fuels entering from fresh water inflows are the most important energy bases. Both the ecosystem components and overall energy flows primarily originating from these sources must be maintained without acute shortages or excesses. If the balance of cycling fails, estuarine ecological systems become less effective in processing food energies and are subject to replacement, either as a whole, or by substitution of their parts.

A stress on an estuary is a process which drains available energy. Stress can be either direct as in the case of harvesting finfish or shellfish from the system, or indirect as happens when increased turbidities shade out light or when some substance such as phenol is added to the aquatic system, either causing mortality or demanding special adaptive work on the part of surviving organisms to sustain life. Energy drains on existing organisms may also occur when excesses of nutrients added to the system deplete the available oxygen necessary for respiration.

In general, estuarine system diversity and organization is highest where energy inputs are high and stresses are low as in many relatively unmodified temperate and tropical estuarine areas. Conversely, those systems where stresses are high and sources of energy low are characterized by low species diversity and relatively simple organization as in the case of artic systems or those greatly modified by man. Thus, the relative diversity and organization of estuarine systems are due to both "natural" occurrences, such as sunlight, temperature fluxes and nutrient inflows, as well as those associated with man's activities such as modification of circulation regimes, addition of pollutants to the water, and thermal waste heating.

Estuarine systems in the United States are almost universally stressed by both natural and man-induced processes. The relative mixture of man-caused and naturally occurring stresses, and their respective roles in estuarine modification, are presently little known, and difficult to separate. It is certain, however, that the stresses resulting from man's present and potential activities in the estuarine zone play a decisive and increasing role in the foreseeable future operation of estuarine ecologies. Therefore, the following discussion focuses upon man's activities as they relate to modification of existing estuarine systems.

### MAN'S ACTIVITIES AND ESTUARINE SYSTEM STRESS

Part IV, chapter 4 showed the presently identifiable trends associated with population and economic development and with specific activities affecting the estuarine zone. At present, however, the rate of change effected by these trends on estuarine ecological systems is little known. The most recent work by ecologists is generally concerned with identification of system types, the development of general theory, and the measurement of system characteristics and operating phenomena. Much is known about certain elements of estuarine ecological systems, such as temperatures, salinities, abundance of certain biotic communities, but the specific processes and causal relationships of complex whole systems and interacting subsystems have only recently been partially understood.

Modification of estuarine ecological systems is nevertheless a trend which can be qualitatively, if not quantitatively, observed. Figure IV.6.1 indicates the general relationships between man's activities and estuarine ecological system modification.

The Nation's population and economy have expanded rapidly in the recent past and will continue to grow substantially in the foreseeable future. Moderate projections indicate a doubling of national population by the turn of the century. Much of this growth, probably more than one-third, will occur in the estuarine zone. Population growth will spur the expansion of urban and suburban developments. Major portions of urban development will develop along all major coastlines of the United States—particularly the Atlantic coastline north of North Carolina, Florida, the middle portions of the Gulf of Mexico and California. The economy will also expand both in scope and diversity to meet the demands of an increasing, wealthy population. Much of this economic activity will be centered on or closely adjacent to the Nation's estuaries and coastal shoreline. These economic activities will vary from place to place due to the location of natural resources and the demands for these resources, historic circumstance, availability of markets and changes in technology.

The general growth of both the population and economy is reflected in expanding trends noted for more specific activities related to the estuarine environment: marine fisheries, civilian and national defense transportation, marine mining and processing, outdoor recreation and waste discharge. All of these activities, as well as the associated secondary and marginal activities located in the estuarine zone, will intensify in future years. Marine fisheries and outdoor recreation are highly dependent upon naturally occurring properties of estuarine ecological systems. Transportation, mining and waste discharge are much less tied to these systems, although at some point in the continuum of degradation these too would be adversely affected.

The case has been made that although all of these activities vary in their impact and dependence on estuarine systems, they all tend increasingly to modify those systems in a multitude of ways.

There appear to be at least three forms of estuarine system modification common to the specific activities described above: waste discharge, dredging, and construction of physical structures. In other words, these activities, and many others, contribute significantly to not only one identified form of estuarine system modification, but are usually responsible for a number of alterations of the biophysical environment.

Although generalizations about the effects of man's activities on estuarine ecology are hazardous at best, the following results generally characterize the modifications associated with significant waste discharges, dredging and filling, and construction of physical structures either on fresh water inflows or in the estuaries themselves:

(1) Productivity of biotic communities is generally reduced. This is due to many factors including reduction or over provision of nutrients, abrupt changes in temperatures and salinities, changes in circulation patterns, and destruction of physical components of the system.

(2) Species diversity and organization is simplified.

(3) Trends toward severely modified ecosystems are established.

FIGURE IV.6.1

SELECTED ELEMENTS OF ESTUARINE ECOLOGICAL CHANGE DUE TO MAN'S INFLUENCE

| Economic and Population Growth | Some Major Resulting Agents of Modification | | Identified Stressed Systems Related to These Activities | The Multiple-Stressed System: Ecology of The Future? | Some Components in the Resulting Multiple-Stressed System |
|---|---|---|---|---|---|
| 1. Urban-Suburban Expansion in Response to Population Growth and Economic Opportunity | 1. Waste Discharge | Municipal<br>Industrial<br>Agricultural | Sewage Wastes<br>Seafood Wastes<br>Pesticides<br>Thermal Wastes<br>Radioactive Wastes<br>Papermill Wastes | Example of One Major Economic Component → | Development of Petrochemical Complexes |
| 2. General Economic Growth Diversification, and Sophistication | 2. Dredging | Navigation<br>Mining and Processing<br>Land Development | Dredging Spoil<br>Phosphate Waste<br>Destruction of Wetlands<br>Altered Currents<br>Salinities, etc. | Resulting Activities<br>Waste Discharge<br>--Municipal<br>--Industrial<br>--Ships<br>Transportation<br>Dredging and Filling<br>Population Growth and in-migration<br>Development of Secondary and Marginal Activities<br>Shoreline Development, etc. | Sewage Waste<br>Dredging Spoil<br>Impoundments<br>Petroleum Stores<br>Pilings<br>Brine Pollution<br>Petrochemicals<br>Etc. |
| 3. Expansion of Specific Activities Related to the Estuarine Zone<br>--Marine Fisheries<br>--Civilian and National Defense Transporation<br>--Marine Mining and Processing<br>--Outdoor Recreation<br>--Waste Discharge | 3. Physical Structures | Fresh Water Impoundment Diversion, etc.<br>Piers, jetties, Hurricane Barriers, etc.<br>Aids to Navigation | Impoundments<br>Acid Waters<br>Brine Pollution | | |

A review of recent literature indicates, however, that although these effects appear to be generalized, individual estuarine ecological systems must be studied in detail to establish precisely the parameters of change involved. Due to the complexity of the systems themselves, and of the causal interactions attributed to man's activities, no attempt can be made to establish national and regional trends in estuarine ecology. At this stage of knowledge such trending, based on scientifically tested information, is impossible. Yet one kind of estuarine ecological system does seem to be increasingly prevalent in the estuarine zone, and may become the predominant type if the impact of the socioeconomic environment on the biophysical environment continues unchecked.

### THE MULTIPLE-STRESSED SYSTEM: ESTUARINE ECOLOGY OF THE FUTURE?

It seems clear that most, if not all major estuarine areas in the continental United States are now or soon will be affected by disturbances of more than one identifiable type. These systems are characterized by heterogeneous patches of chemicals, fertilized waters, waters low in available oxygen, turbidities, acids and other conditions alien to normal life of estuarine ecosystems. The multiple stressed situation is possibly the Nation's most urgent estuarine problem because the condition is a mixture and the causes several. The stress of many different kinds of wastes may be more difficult for an ecosystem to adapt to than separate types of wastes acting alone. The continual fluctuations require more kinds of adaptation than there may be food energies to support. Some bays receiving mixed wastes which are primarily nutrient of non-toxic nature may develop extremely high metabolic rates and high rates of photosynthetic production. Such bays are almost microorganism cultures, but have active larger animal populations too. Potentially such fertile waters are a food-producing resource, although we know relatively little about the conditions for management of these mixtures which will channel energies into products of use to man, effectively mineralize the wastes, and stabilize the ecosystem.

Areas already noted as exhibiting these characteristics are, not surprisingly, those systems associated with concentrations of population and economic activity such as Boston Harbor, New York Harbor, Raritan Bay, portions of Chesapeake Bay, Tampa Bay, Galveston Bay and San Francisco Bay.

In a typical example, which is found in Galveston Bay, one major development alone, the petrochemical complex, is identified as contributing 12 major sources of modification to this naturally rich estuarine complex. At least seven identifiable stressed systems result: Sewage waste, dredging impoundments, petroleum shores, pilings, brine pollution, and petrochemical wastes (IV–6–8).

Situated at the upper end of Galveston Bay, Tex., is the Houston ship channel along which are located dozens of major industries that release wastes. Refineries, petrochemicals, sanitary wastes, and many others go into waters that pass out into Galveston Bay. The dredged channel is 40 feet deep, floored with waste sludge and generally black, and sometimes stratified with more saline waters on the bottom. Conditions are patchy, often low in oxygen, and often with high concentrations of oxidants and reducing compounds.

Similarly, one of the most fertile estuaries in America is Tampa Bay, that receives municipal wastes, food processing wastes, the outflows from phosphate district of Florida, and many other wastes. There are high concentrations of cells, nutrients, and other organisms.

High fertility persists from low salinities in small headwaters to the full salinities at the mouth under the Skyway Bridge. The Florida red tide is a recurring phytoplankton bloom of a dinoflagellate *Gymnodinium breve* that is poisonous to fish. This red water develops fish-killing blooms in high-salinity waters off the west coast of Florida and sometimes within the lower bay. The relationship of the fertile bay culture waters to the red tide outside is still uncertain and under study. However, the high fertility has not destroyed the general middle salinity characteristics of the ecosystem of the main bay where oysters, copepods, pinfish, and young shrimp are abundant. Much of the area has been disturbed in dredging and filling although there are still large areas of shallow ecosystems that serve as fertile nurseries (IV-6-9).

Examples of severe modification and the resulting multiple stressed systems could be multiplied many times. The point is that nearly every trend noted in the socioeconomic environment in the recent past, and in the future, indicates that much of the estuarine zone is likely to receive these multiple man-caused stresses. Thus, the estuarine ecological system of the future appears likely, if past use trends continue, to be characterized by a new emerging "stinko" environment. Clearly, reliance upon existing use, management, planning, economic restraints, and technology to provide solutions to this trend are inadequate. It is essential that the socioeconomic and institutional environments be mobilized to reverse this seemingly inexorable destruction of the irreplaceable estuarine ecologies of the Nation.

## Section 4. Resolution of Use Conflicts

Use damage and ecological disasters are not necessary features of civilization in the estuarine zone, but use conflicts will continue to exist as more and more demands are made on the natural environment. The ability of any management authority to prevent use damage and to resolve use conflicts depends not only upon its institutional composition and legal authority, but also upon the social, economic, and biophysical characteristics of the estuarine management unit within its authority is exercised.

The analyses of social and economic values of the estuarine zone examined concurrently with the similar analyses of use conflicts, pollutional effects, and use damages form the basis for this discussion of those means by which use conflicts can be resolved through the application of technical knowledge, i.e., technical management.

The primary objective of technical management is to accommodate the needed and desired uses of any estuarine management unit within that system without overall damage to the biophysical environment. The ability to achieve this objective depends on the boundaries of the management unit and upon the means available for resolving both prohibitive use conflicts and restrictive use conflicts.

### MANAGEMENT UNIT BOUNDARIES

The impact of the social and economic requirements of civilization on the natural estuarine environment is the technical problem with which management must deal, and effective control of this impact can be maintained only if both the major sources of damage and the geographic range of their influence are subject to unified control.

Estuarine use conflicts and damages involve activities and effects concerning both land and water.

Many of the wastes which damage the estuarine environment originate from cities, industries, and other activities on the land, and control of the wastes from such sources is essential to effective management. Shoreline development limits access to estuarine areas as well as modifying some parts of the estuarine environment.

An estuarine management unit, therefore, should consist not only of the estuarine waters, bottoms, and associated marshlands; but it should also include all of the shoreline surrounding the estuarine waters themselves and as much of the adjoining land as is necessary to regulate the discharge of wastes into estuarine waters.

Effective control of water quality is one key to effective technical management, and one essential requirement in accomplishing this is the ability to monitor water quality constantly and consistently. While the details of water quality monitoring are based on needs within individual estuarine systems, it is necessary that management unit boundaries be chosen so that the managing authority can measure both the quality and quantity of water entering and leaving the management unit. This is essential both to give warning of any incoming water quality degradation and to safeguard other estuarine environments by warning of any outgoing water quality degradation.

The size of the estuarine management unit is in itself a highly important factor in the technical managment of estuarine systems. In a very small management unit it may be impossible to accommodate more than one use, thus making futile efforts to resolve use conflicts and achieve multiple use. For example, the maintenance of a commercial oyster fishery in the midst of a dredged navigation channel might offer the same problems in achieving multiple use as would the maintenance of a commercial chicken ranch in the middle of Kennedy International Airport. Conversely, in very large, highly developed, management units it becomes difficult to deal with individual problems in sufficient detail to control use conflicts effectively.

The boundaries of viable estuarine management units are generally governed by social, economic, and political factors rather than the sizes of the estuarine systems they include. Thus, the capability of technical management to resolve use conflicts in some management units may be severely limited by external factors and it may therefore be necessary to forego some uses because of the small size of the estuarine resource available for use.

## RESOLUTION OF PROHIBITIVE USE CONFLICTS

Those uses which exclude other uses generally involve modification of the shoreline, marshes, or bottoms by dredging, filling, or the building of a permanent structure. Such activities may not only immediately affect the estuarine morphology and habitat, but they may also cause widespread, long-range changes in the ecosystem.

The evaluation of the effects of prohibitive uses on the estuarine environment is probably the most difficult problem currently facing technical management. The immediate and obvious effects of the habitat loss associated with such uses can be measured and described fairly easily, but the ultimate results of the modification of water movement patterns and flushing characteristics can only be estimated in general terms. The need for research on such problems is discussed in part VI, chapter 3; until a sufficient amount of knowledge is accumulated, however, the only useful guide is comparison with occurrences in similar systems.

In nearly every problem associated with prohibitive use conflicts, however, the area of primary concern is the effect on the estuarine ecosystem of any physical modifications proposed; the limitations of knowledge outlined above, therefore, present a critical problem in present efforts to resolve prohibitive use conflicts.

The great amount of modification that has already occurred in the estuarine zone has already resolved the problem of use conflicts in some estuarine sytems by preempting or usurping a part of the estuarine resource for a single purpose, in many cases making modifications too expensive or otherwise too difficult to change in spite of their effects on the local environment.

There is little that can be done directly to correct environmental damage associated with past changes, but future demands for prohibitive use in a management unit can be resolved through application of past experience.

Allocation of part of the estuarine resource for an exclusive single-purpose use is a necessary fact of estuarine management. The shoreline is a necessary location for shipping docks and for swimming beaches, but they cannot both occupy the same place on the shoreline.

Similarly, frequently dredged channels and oyster beds cannot occupy the same space at the same time. Resolution of such conflicts can be achieved by allocation of adequate space to each use through whatever institutional mechanism is established.

A more difficult problem arises where there is involved a massive dredge or fill operation with its concomitant immediate effect on the ecosystem. When such modifications are a necessary or desirable development of the environment it may be necessary to forego the habitat use; however, in many cases it may be possible to create new, equivalent habitat in a different part of the management unit, or it might be possible to restore part of the damaged environment.

For example, in recent negotiations concerning the dredging of phosphate rock along the Georgia coast, the company involved proposed to rebuild over 3,000 acres of the marsh that would be destroyed in the mining operation.

While the resolution of prohibitive use conflicts requires the abandoning of one use in favor of another, the potential for carrying out any modifications necessary so as to increase habitat value as well as economic value should be a key factor in the resolution of such problems.

### RESOLUTION OF RESTRICTIVE USE CONFLICTS

Disposal of liquid wastes to the estuarine enviroment is the major restrictive use impact of the socioeconomic environment. This use conflict can be resolved completely either by treating all wastes to such an extent that they do not interfere with any other uses or else removing them entirely from the environment.

Technology exists to provide thorough treatment for nearly every kind of municipal and industrial waste, and there is no reason not to provide treatment sufficient to protect the environment from the damage and to permit other uses. Treatment requirements for different wastes may vary from place to place according to local conditions, but damage to the environment and restriction of other uses can be prevented.

Water quality standards have been set and are now being implemented in all coastal States. These standards are the foundation upon which the effective control of estuarine pollution rests, and they provide the framework within which technical management can effectively operate.

As pointed out earlier in this chapter, however, estuarine waters even in busy harbors are used for recreational purposes by those who cannot afford to go elsewhere, regardless of whether the waters are safe for body contact or not. Also the role of the estuarine zone as a nursery for some fish, passage for others, and a residence for still more is readily apparent although its full implications in the energy conversion chain are not understood. For these reasons the water quality goal of estuarine management should be to keep all waters safe for direct contact by humans and also usable as a fish and wildlife habitat.

## Section 5. Summary

Loss of use and use damage in the estuarine environment are the direct results of unrestrained exploitation of estuarine resources. The examples presented, limited as they are by the difficulty of measuring use damages, show clearly the impact of one use on another and give a foretaste of the extensive damage that will occur if unrestrained exploitation continues.

Effective technical management of the estuarine zone requires the application of all pertinent existing knowledge to the resolution of use conflicts in estuarine management units.

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# CHAPTER 7. SUMMARY

The estuarine zone is an ecosystem. That is, it is an environment of land, water, and air inhabited by plants and animals that have specific relationships to each other. This particular ecosystem is the interface between land and ocean, and one of its key components is human society.

The social and economic environment that forms human society must be regulated by manmade laws intended to provide justice to each individual and part of the socioeconomic environment. The biological and physical environment of the estuarine zone, in contrast, obeys natural laws which are equally complex and less flexible than manmade laws. The welfare of American society now demands that manmade laws be extended to regulate the impact of man on the biophysical environment so that the national estuarine zone can be preserved, developed, and used for the continuing benefit of the citizens of the United States.

To apply manmade laws and regulations to the natural estuarine environment, it is necessary first to understand what natural conditions govern that environment, and then to understand how the socioeconomic and biophysical environments affect each other. Only then can there be developed an institutional environment which can effectively weld all three environments into one smoothly functioning self-sustaining ecosystem.

## Section 1. The Biophysical Environment

Laws regulating the socioeconomic environment exist at several levels of governmental authority. The Constitution presents general guiding principles, State constitutions operate within this framework while establishing a more detailed body of law designed to satisfy the needs of the statewide socioeconomic environment, and local ordinances regulate in detail the activities carried out in specific locations.

The biophysical environment is also subject to a hierarchy of laws, regulations, and conditions. The general guiding principles are those fundamental natural laws which govern all life on the earth; at the interfacial zone between land and sea the effects of these laws appear as universal dominating environmental factors. The structure of the coastline, formed and modified in obedience to these general conditions, imposes a second level of natural law which exerts its primary effects on water movement in the estuarine zone; and, within each structural form exists a host of organisms living according to specific natural ordinances which govern their relationships.

### DOMINATING ENVIRONMENTAL FACTORS

The natural estuarine environment is based on the conversion of radiant solar energy into other forms of energy with the assistance of the mechanical effects of gravitational energy. This conversion is accomplished by an intricate array of prey-predator relationships among living organisms, from the microscopic plants and animals which convert solar energy directly and are eaten by other organisms, to the fish and wildlife which are the ultimate life forms in the manless estuarine environment.

Solar radiation and gravitational forces control the natural environment through a complex series of mechanisms. In the estuarine zone this control exhibits itself through seven major environmental factors that exist throughout the estuarine zone.

(1) *Continental Shelf.*—The submerged land next to the continent slopes gently to a depth of about 600 feet, then it drops more rapidly to form the deep ocean basins. This fringe of slightly sloping submerged land, which along much of the Atlantic and gulf coasts would appear quite flat to the naked eye, is called the "Continental Shelf"; its width and general configuration along the U.S. coastline affects the force with which ocean waves strike the shore and consequently the manner and degree of shoreline erosion and accretion.

(2) *Ocean currents.*—The major ocean currents passing near or impinging on the continent exert strong, if subtle, effects on the estuarine zone through their temperatures, which affect continental land temperatures, and through their nutrients, which govern the nature and productivity of offshore and estuarine fisheries. The cold Labrador Current water from Maine to Virginia, warm Gulf Stream water along the South Atlantic and Gulf coasts, and the California Current along the Pacific coast all have noticeable effects on coastal land and water.

(3) *Coastline slope.*—The configuration of the coastline itself, even though subject to additional molding by the flow of rivers to the sea, is closely related to the shape and structure of the Continental Shelf. A wide Continental Shelf is generally associated with lowland next to the coast, while a narrow shelf is associated with mountainous terrain. These associations throughout the estuarine zone of the United States have produced estuarine systems characteristic of particular regions. Glaciation in New England, Washington, and Alaska; old mountain ranges and a sedimentary coastal plain from New Jersey to Texas, and the young, steep ranges of the Pacific coast are all continental features having different impacts on the estuarine zone.

(4) *River flow.*—The estuarine zone is also shaped through erosion and sediment transport by fresh water making its way to the sea. All along the coastlines are streams and rivers carrying water from land runoff to the sea. These waterways range from the Mississippi River, which drains 41 percent of the conterminous land mass of the United States, down to tiny trickles across a beach. The volumes of water and sediment moved reflect not only the total amount of precipitation and its annual cycle, but also the sizes and slopes of drainage basins and the types of soil over which the rivers flow.

(5) *Sedimentation.*—The general outlines of many estuaries, lagoons, and embayments in the estuarine zone were formed by erosion from land runoff during the last ice age when sea levels were much lower than they are now. As the sea level rose, the drowned river mouths became zones of mixing, sediment deposition, and erosion where the rivers and tidal currents met. These erosion and sedimentation processes molded the estuarine zone into its present shape and continue to change it.

(6) *Climate.*—Solar energy striking the earth sets up complex cycles of water and energy flow from the oceans to the sky and the land and back again. That part of the energy cycle occurring in the atmosphere gives rise to the various combinations of weather phenomena which make up local climates. Land, sea, and sky are mutually dependent in producing specific climates, and the great ocean currents play their indirect roles in modifying the climates of the estuarine zone.

(7) *Tide.*—The tide stands alone as a controlling force and symbol of the estuarine environment. The combination of tidal action and river flow gives rise to that unique phenomenon called an "estuarine circulation pattern," which means the fresh water flows in one direction in one layer and the salt water flows in the opposite direction in another layer with various degrees of mixing at the interface between them. This type of circulation pattern is of great importance in some of the estuaries along the Atlantic and Gulf coasts, and to a large extent governs the capacity of such estuaries to rid themselves of waste materials.

THE BIOPHYSICAL ESTUARINE REGIONS

Each estuarine system along the coastline is affected to some extent by all of these dominating environmental factors. In some cases the dominance of one particular factor is readily apparent. It is much more often the case that the competing environmental factors are so evenly balanced that none can be said to dominate and the estuarine zone appears to be composed of a bewildering variety of unique system.

Yet, the dominating environmental factors listed above form a set of natural guiding principles which govern the general characteristics of the estuarine zone of the United States, and the occurrence of various combinations of these environmental factors permits the grouping of the national estuarine system into 10 geographical zones, each governed by a different combination of environmental conditions.

*Characteristics of the biophysical regions*

*North Atlantic estuarine region.*—Canadian border to Cape Cod.

Cool, fertile waters with a large tidal range strike a steep, indented coast with deep water close inshore, but protected from the full force of the ocean waves by a wide continental shelf. Moderate precipitation with heavy snowfall leads to heavy spring river runoff which dominates local circulation. Natural erosion and sedimentation are not severe problems, and the evolution of drowned river valley estuaries is in an early stage in this region.

*Middle Atlantic estuarine region.*—Cape Cod to Cape Hatteras, exclusive of Chesapeake Bay.

A wide, gently sloping continental shelf with a smooth shoreline is cut by the entrances of several major river systems carrying moderate amounts of sediments. The same cool, fertile waters as in the North Atlantic estuarine region wash this coastline but with a smaller tidal range. The evolution of drowned river valleys into coastal marshes is in a secondary stage in the larger estuarine systems, with sand spits and barrier islands forming.

*Chesapeake Bay estuarine region.*—All the Chesapeake Bay system from Cape Charles and Cape Henry Island.

Isolation from direct oceanic effects in much of the greatly branched system, the many subsystems with major river flows, and the reduced concentration of the ocean salt throughout the Bay and its tributaries make this a unique estuarine system. This is a drowned river valley with numerous similar tributary systems in various stages of evolution.

*South Atlantic estuarine region.*—Cape Hatteras to Fort Lauderdale, Fla. (about 26° North Latitude).

The generally wide continental shelf is brushed by the warm waters of the well-defined Gulf Stream. The low-lying coastal plain terminates in barrier islands and marshes in which large amounts of sediments are being continually deposited by moderate-sized rivers fed by heavy summer rainfall. Many of the drowned river valley estuaries have evolved all the way to coastal marshes. Tidal ranges are small to moderate, depending on local conditions.

*Carribean estuarine region.*—Fort Lauderdale to Cape Romano (the Florida peninsula south of 26° North Latitude), plus Puerto Rico and the Virgin Islands.

High temperatures, heavy rainfall, and warm ocean currents along practically nonexistent continental shelves result in tropical estuarine environments throughout this region. Coral reefs and mangrove swamps are the typical coastal features of south Florida, while the islands are mountainous and are fringed with coral reefs and beaches. Tidal ranges are small.

*Gulf Coast estuarine region.*—Cape Romano to the Mexican border.

A wide continental shelf extends all the way around this large embayment, in which warm tropical waters are moved gently by weak currents and small tidal ranges. Heavy rainfall over most of the area brings sediments from the broad coastal plain to be deposited in the estuarine zone. Most of the drowned river valleys have evolved to a point intermediate between those of the Middle and South Atlantic regions—barrier islands are extensive and have large shallow bays behind them.

The Mississippi, carrying drainage from 41 percent of the conterminous land mass of the United States, forms one of the major deltas of the world and is unique among the estuarine systems of the United States, both in its size and in the extent to which it has built out over the continental shelf.

*Pacific Southwest estuarine region.*—Mexican border to Cape Mendocino.

Because of the narrow continental shelf, periodic upwelling of deep water close inshore as winds force the California current offshore brings cool, fertile water near the coast for several months of the year. The coastline has a typical beach and bluff configuration with only a few shallow embayments and the unique earthquake-born valley of San Francisco Bay, which, in the delta formed by the confluence of the San Joaquin and Sacramento Rivers, shows what erosion and sedimentation might have done along the southwest coast if rainfall were greater in that area of easily erodable mountains.

*Pacific Northwest estuarine region.*—Cape Mendocino to the Canadian border.

The Continental Shelf and coastal configurations are similar to those of the Pacific Southwest, but ocean water temperatures are lower here; the movement of the California current away from the coast is not as pronounced, and heavier rainfall has resulted in some major rivers cutting through the coastal mountains to form deeply embayed estuarine systems. Extensive erosion and sedimentation have caused wide tidal flats, bars, and shoals to be typical of these systems.

The straits of Juan de Fuca and Puget Sound, which were glacier-formed, do not have as severe sedimentation as exists along the ocean coast, and have retained much of their original configuration.

*Alaska Estuarine Region.*—All of Alaska including the Aleutian and Bering Sea Islands.

The dominant factors in this region are temperature and precipitation. Water temperatures are near freezing, and much of the precipitation falls as snow. The Continental Shelf is wide all through the region, and tide ranges are very large. The southeast and south coasts have active glaciation and consist primarily of glacier-cut embayments and fjords; the west and north coasts are much flatter and have been modified to some extent by sediments eroded from the interior, including glacial silt, and by the grinding action of pack ice during winter.

*Pacific Islands Region.*—The Hawaiian Islands, American Samoa, and Guam.

This region consists of tropical ocean islands of volcanic origin. Dominating factors are lack of a Continental Shelf, full exposure to oceanic conditions, and pleasantly warm temperatures. Coral reefs and beach and bluff configurations are typical.

## THE LAND AND THE WATER

Within the general domination of broad-scale environmental factors are smaller scale governing conditions that, through their effects on water movement and circulation, determine what kind of local environment can exist in a particular estuarine system.

### THE LAND

The shape of the land along the land-sea interface goes far toward determining what water movement and circulation patterns exist in particular local areas and, consequently, how fast a particular estuarine system will rid itself of pollutants. Within the general compass of the estuarine regions discussed in the preceding section there are different structural types which define patterns of water movement typical of particular structures, no matter what the external environment may be.

*Alaska* presents the greatest variety of estuarine form and structure of any of the estuarine regions. Nearly all kinds of systems typical of other regions are found there. In addition, Alaska has the only glaciated coast and most of the fjords found in the United States.

Characteristic of the North Atlantic region is a very irregular, hilly coastline with deep water close inshore and long, narrow embayments with open access to the sea. Estuarine systems within the Chesapeake Bay region consist of a group of branched rivers entering the Chesapeake Bay itself, which is in turn the former valley of the Susquehanna River.

In the Middle Atlantic region the estuarine zone consists primarily of a few large drowned river valley embayments (e.g., New York Harbor, Delaware Bay, Narragansett Bay) and some small marsh and barrier beach systems receiving only coastal fresh-water runoff. The estuarine zone of the Gulf region, on the other hand, consists mainly of moderate-sized embayments with barrier beaches and extensive marshes, but receiving river flow from upland drainage areas and representing an intermediate state in the evolution of drowned river valleys into coastal marshes.

The South Atlantic region has two dominant types of estuarine structure. From Cape Hatteras to about Jacksonville, Fla., there is a general input of upland river drainage to the estuarine zone and the estuarine systems are typical drowned river valleys in the later stages of evolution represented by barrier beaches or coastal marshes backed by extensive swamps. South of Jacksonville fresh-water runoff comes primarily from local coastal drainage, and there are uniform and extensive barrier island beaches with long narrow embayments behind them having continuous but generally narrow strips of marsh along the embayments. This structure fades into the extensive swamplands of the Everglades farther down the Florida Peninsula.

Both the Pacific Northwest and Pacific Southwest regions have few estuaries. The estuarine systems of the Northwest Pacific region tend to be the mouths of rivers which have cut their way through coastal mountain ranges, either of their own accord or aided by glaciers as in the case of Puget Sound. Shallow coastal embayments with little and sporadic river flow are characteristic of the few estuarine systems of the Southwest, except for San Francisco Bay, which receives fresh water runoff from much of central California.

Estuarine systems of the islands, both Atlantic and Pacific, are few and consist mostly of embayments without major river inflows,

The estuarine zone can be classified according to its local morphology into 10 major categories, several of which exist in each of the estuarine biophysical regions. Within each of these categories, the similarities in structure reflect similarities in water movement, water quality, and ecology which make it possible to apply lessons learned in managing an estuarine system in one region to similar estuarine systems in other regions. The morphological categories are:

1.1. Smooth shoreline without inlets.
1.2. Smooth shoreline with inlets.
1.3. Smooth shoreline with small embayments.
2.1. Indented shoreline without islands.
2.2. Indented shoreline with islands.
3. Marshy shoreline.
4. Unrestricted river entrance.
5.1. Embayment with only coastal drainage.
5.2. Embayment with continuous upland river inflow.
6. Fjord.

Unrestricted river entrances and embayments dominate the estuarine zone and are rather evenly distributed throughout all the regions, with the common type of estuarine system being a coastal embayment with drainage from only the local coastal area. Many of these latter embayments have large marsh areas, but the Middle Atlantic, South Atlantic, and Gulf are the regions in which marshes are the predominant feature in some parts of the estuarine zone.

### THE WATER

The unique nature of water movement and circulation patterns in the estuarine zone are the result of the meeting and mixing of fresh river water and salty ocean water of slightly greater density under the oscillating influence of the tide. There may be additional complicating factors such as temperature and wind action, but the resulting circulation nearly always reflects the interaction of river flow and estuary shape with the tidal flow of the ocean water. General water movement patterns are predictable for each category of estuarine shape.

It is where moderately large rivers and streams meet the sea that the unique estuarine circulation patterns occur most frequently. Large fresh water flows in well-defined channels tend to slide over the top of the denser sea water without rapid mixing. Water movement in such cases exhibits various degrees of stratification.

With wider channels, smaller river flows, and greater tidal ranges, more mixing occurs and other forces come into play. Embayment shape, bottom configuration and material, and the effects of the earth's rotation all may play a role. In some estuarine systems of this type, the degree of stratification may change with changes in river flow, temperature, wind, or other transient conditions.

Estuarine water quality is the product of both land and water. From the land, erosion and solution in river water bring suspended and dissolved minerals, while decaying vegetation adds dissolved salts, but negligible quantities of organic matter.

In the estuarine zone these two different solutions meet and mix. Salt concentrations range from that of the oceans to the almost unmeasurable amounts present in some rivers. Where little stratification exists, sea salt dominates mineral concentrations in estuarine waters; in stratified systems, however, the small amounts of minerals entering in the fresh water may be as important in some parts of the estuarine zone as the much larger concentrations from the sea are in others.

### THE LIFE

The governance of the dominating environmental factors, as modified by estuarine shape and water quality, result in an input of energy into individual estuarine systems, and it is in the variety and diversity of estuarine life that the input of energy to the estuarine zone finds ultimate expression. Whether energy comes directly, as in solar radiation stimulating photosynthesis, or whether it comes indirectly, as with tidal flows or wind and rain pounding on the shoreline, its absorption and conversion to other forms of energy (such as food) are essential steps in the continuation of life in the water, in the marshes, and on the land.

Energy input from gravitational forces, as illustrated by tidal action and river flow, depends primarily on local or regional conditions, but direct energy input from solar radiation depends largely on latitude, the tropics receiving much more energy per acre than the arctic. The relative amounts of energy entering an estuarine system govern the kinds of life found there, and natural ecosystems show systematic variations related to the sources and amounts of energy received.

Estuarine zones with strong mechanical energy inputs from waves, currents, tides, or river flows develop similar ecosystems no matter whether in the tropics or the arctic. Where, however, such energy inputs do not dominate the input of radiant solar energy, natural communities develop compositions typical of tropical, temperate, or arctic latitudes.

Tropical systems are subject to unvarying warm temperatures; light energy input is both greater and more regular than in other altitudes. Within this general group there are the sparse populations along coasts with deep clear water close inshore; the teeming and colorful populations of coral reefs; and the mangroves and the submerged grasslands associated with shallow, nutrient-laden water. Only the southern part of Florida and the islands are of this type.

Arctic systems are subject to wide fluctuations of sunlight and temperature but ice is the key factor. Ecological systems develop in, on, and under the ice and in the fjords associated with glaciers. Only a small part of Alaska includes estuarine systems of this type.

Temperate systems are subject to moderate solar energy inputs, temperatures which change regularly with the seasons, and generally larger tide ranges and more wave action than either tropic or arctic systems. Most of the estuarine systems of the United States lie in the temperate zone, and the balancing of solar energy input against mechanical energy input in this zone leads to a great variety of ecosystem types, even within small geographic areas.

The grouping of ecosystems outlined here describes a limited range of recurring variation of chemical and physical properties to which certain forms of life have adapted and on which they are now dependent.

The basic environmental needs for all living plants and animals in such zones are zones of salinity consistently fluctuating over a limited range of concentration; solar energy; water temperature variation; water quality and nutrients favorable to their propagation, growth, and survivial; and, for some life forms, bottom conditions suitable to their unique needs.

The dependence of fish and shellfish on the estuarine zone is governed by particular environmental requirements for reproduction, protection, food supply, or a combination of these. Estuarine dependent species are of three types:

1. *Species restricted to estuaries*

Among the relatively few species of fish and shellfish that complete their entire life cycle in the estuarine zone is the Atlantic (American) oyster. It will die after long exposure to freshwater although it can stand limited periods of such exposure and can thrive in relatively high salinity water. The spotted sea trout occupies the estuary for all its life purposes and only occasionally leaves the estuary under unusual extremes of salinity and temperature.

2. *Anadromous and catadromous species*

Anadromous species pass through the estuarine zone on their journey from the sea to the freshwater environment where they spawn. Some species, such as the Pacific salmon, die after spawning and others, such as the striped bass, live to return to the estuarine zone and the sea. The young of all anadromous species spend varying periods of time in the freshwater areas where they were spawned, but all eventually migrate to the estuaries and then the sea.

There are few truly catadromous species that mature in the fresh or brackish water environments, and then migrate to higher salinity waters of the estuary of the adjacent sea to spawn. The American eel and the blue crab are examples of this type.

3. *Migratory estuarine species*

The great majority of estuarine dependent species fall under this classification. Some use the brackish and freshwater areas of the estuarine zone for reproduction; some as a source of food; some for shelter, either as adults or young; and some for all these reasons. They all have in common the basic need for both estuarine and ocean environments at some point in their life cycle. This group includes the great majority of fish and shellfish of direct importance to man, such as shrimp, menhaden, flounder, and red drum.

Estuarine wildlife can be classified into four categories: (1) furbearing animals, (2) game waterfowl, (3) ornamental shore birds, and (4) the common wildlife that can tolerate human presence.

The primary fur bearers are the fur seal in Alaska, nutria in the South Atlantic and Gulf States, the common eastern muskrat in New Jersey, the Virginia muskrat in the Central Atlantic States, and the Louisiana muskrat in Alabama, Mississippi, Louisiana, and Texas. Secondary in importance are the raccoon, mink, and otter.

The dependence of waterfowl on the estuarine zone is both complex and incompletely understood. The primary sport species, such as mallards and canvasbacks, have been successfully adapted to manmade changes in their environment, particularly those changes not affecting the nesting sites.

The ornamental shore and sea birds are a particular aesthetic attraction among the national fauna. These birds are generally more dependent upon estuarine conditions than the more mobile waterfowl and, in addition, have demonstrated a considerably greater sensitivity to the overall encroachment of man. These birds include whooping cranes, pelicans, bald eagles, egrets, ibis, and many others.

## GOVERNING SUBDIVISIONS OF THE BIOPHYSICAL ENVIRONMENT

Solar energy and gravitational energy are the basis for everything that happens naturally in the estuarine zone. This discussion of the biophysical environment has been concerned primarily with the environmental conditions surrounding the transformation of these energies into forms useful in living processes and exploitable by man. Three different sets of subdivisions of the biophysical environment were used in this discussion.

Differences in the external environment divided the estuarine zone of the United States naturally into ten geographic regions, each subject to a particular governing combination of the external influences of tide, ocean currents, wave action, sedimentation, and climate. This subdivision into estuarine biophysical regions gave broad ranges of conditions in each region, but the importance of local coastal conditions in governing energy flows via water movement paved the way for a subdivision of the estuarine zone according to 10 morphological groups having similarities in water movement, circulation, and the ability to rid themselves of wastes.

A subdivision according to ecological communities was also based primarily on geographical location, but again coastal conditions made it necessary to identify small ecosystems governed by specific local conditions within each of the major groupings.

## Section 2. The Socioeconomic Environment

The socioeconomic environment of the estuarine zone is the direct result of its value as a means of sustenance, a place to live, a source of enjoyment, and a route of transportation. The laws regulating man's activities in this zone are historically intended to protect and serve individual and group interest in dealing with each other. Only recently has it become apparent that the laws protecting man from himself must be extended to protect the natural environment from man.

This extension of the institutional environment must recognize not only the realities of how the biophysical environment operates, but it must also recognize the need of human society for the estuarine zone and its value to civilization both as an essential part of his ecosystem and as an exploitable resource.

### POPULATION AND INDUSTRIAL DEVELOPMENT IN THE ESTAURINE ZONE

The importance of the estuarine zone of the United States to the national community is shown most clearly by the numbers of people that use it. Population concentration in the coastal counties began when the first European colonist arrived. This concentration brought about the development of a corresponding amount of manufacturing industry in the estuarine zone, while the great harbors gave the estuarine zone its dominating position as the commercial center of the Nation.

Long before the settlement of Plymouth, British, French, and Spanish fishermen were exploring the North Atlantic fishery resources including those in the Gulf of Maine and along Georges Bank; after colonization of New England, the fisheries were the sustaining industry that provided the economic foundation for growth and development. The estuaries were also the entry portal for the immigrants that came to this Nation looking for the land of opportunity.

As the population grew, the relative importance of the fishery progressively declined as economic growth in other industries outstripped the demand for seafood as a staple diet item. The growth of industrial and population centers in the estuarine zone closely paralleled the growth of the rest of the Nation, with the estuarine zone becoming relatively more important in international commerce and less important in agricultural food production than the interior of the country.

The coastal counties contain only 15 percent of the land area of the United States, but within this area is concentrated 33 percent of the

Nation's population, with about four-fifths of it living in primarily urban areas which form about 10 percent of the total estuarine zone area. Another 13 percent of the estuarine land area is farmland, but this accounts for only 4 percent of the total agricultural land of the Nation. The estuarine zone, then, is nearly twice as densely populated as the rest of the country, and supports only one-fourth as much agriculture per unit area.

In those regions lying between Cape Hatteras, N.C., and Canada as well as in the Pacific Southwest, over 90 percent of the population lives in urban areas; over much of the Atlantic estuarine zone stretches the great northeastern megalopolis with population densities averaging over 1,000 persons per square mile. The remainder of the estuarine zone of the United States exhibits a pattern of major centers of population clustered around natural harbors and separated by stretches of coastline which are either empty and inaccessible or beginning to be sprinkled with private residences and resort communities in the vicinities of population centers.

The coastal counties have within their borders 40 percent of all manufacturing plants in the United States. The mixture of manufacturing types in the estuarine zone is the same as the national composition with only minor execptions, such as the concentration of the apparel manufacturing industry in the Middle Atlantic region, particularly in the New York area. Distribution of manufacturing types among the biophysical regions shows regional differences related to historical development as well as raw material and market availability.

Over half of all plants in the coastal counties and one-fifth of all manufacturing plants in the United States are located in the Middle Atlantic biophysical region, which was the historical center of the Nation's industrial growth and is still one of the major market areas. The Pacific Southwest is the major industrial center of the Pacific coast and is developed as intensively as the Middle Atlantic region. Some industrial development in other regions tends to follow historical or present raw material availability. Leather product plants are clustered in the North Atlantic region, and lumber manufacturing plants are most plentiful in the Pacific Northwest. Food processing plants, however, follow closely the distribution of population.

While much of the industrial development located in coastal counties affects the estuarine zone indirectly through use of adjacent land, some of the water-using industries have an impact on the estuarine zone far beyond their numbers. The paper, chemical, petroleum, and primary metals industries are the major water users among manufacturing establishments and are distributed universally throughout the estuarine zone.

### USE OF THE ESTUARINE ZONE

Many of the uses cataloged in this report occur only because the historical growth of the country makes the estuarine zone the place where the people and the industry are. Only commercial navigation and commercial fishing are uses which are primarily associated with the estuarine zone rather than other parts of man's environment. Uses such as water supply, waste disposal, and recreation are associated with civilization wherever it exists; in the estuarine zone they may have different values, different emphasis, or different impact on the biophysical environment.

The great unique use of the estuarine zone, which makes it of primary importance to man and his civilization, is its place in the life cycle of many animals which aid in converting solar energy into more usable forms. While no life form can be singled out as irreplaceable, the kinds of life which need the estuarine zone to survive represent essential links in the energy conversion chain upon which man depends for survival. Many of the human uses of the estuarine zone depend directly or indirectly on the existence of the estuarine zone as a healthy habitat.

### FISHING

The important fish species are those sought by either the sports fisherman or the commercial fisherman. Practically all of the sports fish species are dependent upon the estuarine zone for one or more phases of their life development, and approximately 65 percent of all commercial fish species are estuarine dependent.

In 1967 U.S. fishermen received $438 million for approximately 4.06 billion pounds of commercial fish and shellfish. It has been estimated that two-thirds of the total value, or approximately $300 million, can be considered for estuarine-dependent species. This is a conservative estimate of the direct value derived from the estuarine fishery for it does not include the value of fish harvested by foreign vessels off the United States coast. Five of the six leading species by weight, representing over one-half of the U.S. commercial fish tonnage in 1967, are estuarine dependent.

### RECREATION

The demand for outdoor recreation has increased significantly over the past decade. The trend toward higher personal income and more leisure time has made it possible for a greater percentage of the populace to seek new outlets. Companies manufacturing equipment for outdoor recreation have sprung up by the hundreds.

The advertising industry has campaigned vigorously to sell the public on the need for recreation, and service facilities to support the recreationalist are blossoming in all parts of the country.

There are a wide variety of land and water recreational activities available in the estuarine zone and many estuarine systems are intensively used for recreational pursuits. The unique combination of available resources in close proximity to large population centers offers an unparalleled recreational opportunity for many people who could not afford to travel far from their homes.

Each type of recreational activity has a certain sensitivity to the quality of the environment in which the activity takes place. Clusters of activities that require similar environmental conditions but differ in environmental quality needs can be grouped as follows: (1) Swimming and associated shore activities, including picnicing and camping; (2) sports fishing from shore or small boat; (3) boat-centered activities, such as cruising or water skiing; and (4) esthetic appreciation of the total environment.

The Nation's estuaries provide the physical, social, and economic conditions required for an effective system of water terminals serving international trade and coastal shipping. According to a 1966 inventory of ports and terminals by the Maritime Administration, there were 1,626 marine terminal facilities providing deep water berths in 132 ports on the Atlantic, Gulf, and Pacific coasts. The significance of these ports and terminal facilities is indicated by the 1965 statistics which show that these ports handled 346,315,000 tons of foreign-trade cargo which was 78 percent of the U.S. foreign trade total. In addition, the port facilities handled 332.1 million tons in coastal cargo and 288.2 million tons in local shipping.

The estuarine ports also serve as essential elements of the national defense system. The deep-water terminals exert a significant influence on the location of defense installations as well as of the industrial complexes necessary for logistical support of the defense effort. A direct indication of the use of estuaries by naval vessels is the total number of ships in commission. During the fiscal year 1967 this number was 931 with a planned increase to 960 in the fiscal year 1969.

The use of the harbors for waterborne transportation is competitive in that it may cause other uses to be forgone. Heavy ship traffic interferes with pleasure boating and related activities (fig. IV.55). Maintenance of the ship channels may alter the ecology and the surface area occupied by the large vessels may well interfere with safe pleasure boating.

Water transportation is not the only type of transportation consideration for estuaries. Since a major percentage of large cities are located on estuarine systems, there is considerable pressure to develop fill areas for airports which then utilize the long overwater approaches to keep the jet noise away from developed areas. The water areas offer a barrier to land travel that must be overcome with causeways or bridge-type structures which can interfere with navigation or cause habitat damage. On the other hand, peripheral roads offer some of the more scenic routes available and are frequently the only undeveloped area on which roads can be built.

### MUNICIPAL AND INDUSTRIAL WATER SUPPLY

The water in the estuary can serve as a source of both domestic and industrial water supply; but utilization of estuarine water for domestic supply is very limited at the present time. Normally the brackish water is unpotable and treatment costs to render it potable are extremely high. The brackish estuarine water is also a poor source for industrial process water. Here again a high degree of purity is normally required in the process water and the cost of removing the dissolved salts is prohibitive.

Estuarine waters are used extensively, however, as a source of industrial cooling water. For this use the most important considerations are the quantity and the ambient temperature. Water temperatures are generally well below the maximum for economical cooling, and since the ocean is connected to one side of the estuary, the quantity is no problem. Cooling water is required by both the manufacturing industry and electric power generation plants; the greatest use is in the thermal electric plants.

The distribution of cooling water use parallels population and industrial development in the coastal counties, even though electrical power can be transported economically over many miles. The greatest concentrations of cooling water use are in the Middle Atlantic and

Pacific Southwest regions; fortunately these regions both have moderate water temperatures which make possible efficient use of the available cooling water.

There are, however, 47 nuclear powerplants built or scheduled for completion by 1976. All of these are in the megawatt range, with a combined capacity of nearly 35,000 megawatts of electrical power. While the bulk of these will be in the cooler parts of the Nation, 12 will be in the South Atlantic, Gulf, and Caribbean regions where water temperatures are high, greater volumes must be used to achieve proper cooling, and the increase in water temperature through the powerplant may be sufficient to cause environmental damage.

### WASTE DISPOSAL

The concentration of population and industrial development in the estuarine zone has led naturally to the use of estuarine waters for removal of the waste materials of man's civilization from his immediate vicinity. It is unlikely that cities were built on the coastline with any conscious consideration of the use of the estuarine environment for waste disposal, yet it has happened that this use has become one of the major uses of estuarine waters and the associated land. Virtually all of the cities and industries in the costal counties dispose of wastes either directly or indirectly into the estuarine zone.

Liquid waste discharges to estuarine systems include domestic waste products, industrial waste materials of all degrees of chemical complexity and sophistication, used cooling water with its thermal load, and storm runoff. These wastes affect the estuarine environment in different ways and can eliminate other uses.

Liquid wastes are not the only concern. The use of the estuarine shoreline for refuse dumps and landfills results in considerable debris getting into the water; water leaching through these dumps has a pollutional impact on the estuarine water. Spoil disposal from dredging activities is another form of solid waste material that contributes to estuarine degradation, and solid materials entering the estuary in the form of debris from storm runoff can be significant in terms of damaging beneficial uses.

Waste disposal is a highly significant and universal use of the estuarine resource and it is likely to remain so. Along with the many other socioeconomic uses of the estuarine environment, it must be managed so that it does not damage the biophysical environment.

### EXPLOITATION OF MINERAL RESOURCES

Minerals within the water, on the bottom, and under the bottom are a valuable part of the estuarine resource and are being exploited widely.

Subbottom mining operations are limited to the recovery of sulfur, petroleum, and natural gas, with the major operations occurring in Louisiana, Texas, California, and Alaska. These operations exist both in the estuaries and out on the Continental Shelves with the governing criterion for location being the location of reserves.

Recovery of minerals from submerged estuarine zone bottoms by surface mining; i.e., dredging, is primarily directed toward sand, gravel, and oyster shell production. Sand and gravel operations are universal throughout coastal areas wherever suitable deposits and a market exist.

Oyster shell is an extremely useful construction material in the Gulf of Mexico biophysical region. Twenty of the 22 million tons of annual U.S. production are in the Gulf States, with Texas and Louisiana producing the vast majority of it.

Phosphate rock is an important estuarine mineral resource; about 75 percent of the total U.S. production is in the estuarine zone of Florida and North Carolina, particularly around Tampa Bay and Pamlico Sound.

### AQUACULTURE

The great fish and shellfish resources of U.S. coastal waters have adequately supplied the seafood demands of the increasing population for over 300 years. Now, however, the demands for some products is so great that the normal fishing grounds and fisheries are in great danger of being exhausted, both from overfishing and from the indirect effects of man's encroachment into the estuarine environment. To supply future needs of some fish products new approaches toward commercial fishing are needed, both in harvesting the natural growth and in controlling the entire fishery. Aquaculture is defined as the rearing of aquatic organisms, both plants and animals, under controlled conditions using the techniques of plant and animal husbandry. It involves a variety of operations, some that are highly sophisticated where man exercises control over the principal environmental factors affecting the cultured species, and others that are very simple with only minimal control of manipulation of the habitat and the cultured animal.

### SHORELINE DEVELOPMENT

The use or development of estuarine water either governs or depends on land or shoreline use.

Commercial development of the shoreline includes loading terminals, docks, and shipyards, airports, industrial plants, and the smaller municipal and local piers. Recreational facilities include marinas, beaches, parks, fishing piers, and vacation cottages, motels, and hotels. Although the motels and hotels are a commercial venture, their prime purpose is to support the recreationist. Residential development of water front property in many communities places on the shoreline intensive housing development accompanied by boat docks, fishing and swimming piers, and private beaches. Commercial and personal transportation requires airports, highways, and commercial port facilities.

Structures built to protect or conserve the shoreline include bulkheads to hold the shore in place, dikes to prevent flooding and to extend reclaimed land, jetties to provide a protective barrier between the sea and ship channels, and groins along beach areas to control sand movement.

### THE SOCIAL AND ECONOMIC VALUES OF ESTUARINE USE

All uses have value, both individually and as part of the development and use of the entire estuarine resource for the benefit of the present and future national community. The importance and total value of any

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estuarine system lie not in the measure of economic value for any particular use, but in multiplicity of use related to the needs of people who live there or otherwise depend on the estuarine resource.

## FISH AND WILDLIFE HABITAT

The value of the estuarine zone as fish and wildlife habitat both depends on and augments its value for other uses, particularly recreation and commercial fishing.

There is, in addition to these, the basic incalculable value of the estuarine habitat as a link in the essential energy-conversion chain which permits man to survive at all.

The trapping of fur bearers in the marshes of the gulf and Atlantic represents one of the few economic values directly attributable to estuarine habitat. Louisiana is the major producer; in the 1965–66 season total sales were $4.6 million out of the Nation's $6 million total.

### *Commercial fishing*

An entire complex of commerce and industry can rest upon one primary producing industry such as commercial fishing. Each time the basic product changes hands it generates economic activity and gains in value until by the time it reaches the ultimate consumer, its price may be many times what the fisherman was paid for it. The effect of such "value multiplier" factors will be such as to make the actual values of specific commercial fisheries several times the landed values.

Thus, the $438 million received by U.S. fishermen in 1967 probably represents a total input to estuarine zone economic activity of over $1 billion; exactly how much it is impossible to say. Case studies assign multiplier values of about three and four to commercial fishery landing values, but the magnitudes of such multipliers depend on the structure of the local economy as well as on other factors and generalities are likely to be misleading.

The relationship of the estuarine zone and commercial fishing cannot be expressed by any simple economic index. The importance of commercial fishing in the estuarine zone is related economically not only to estuarine habitat, but also to transportation, commerce, food processing, and aquaculture.

### *Recreation*

Each kind of recreational use has its own economic impact. Recreational boating supports a large boatbuilding, marina, and boat repair industry. Sport fishing supports not only a certain part of the boating industries, but also a very specialized industry manufacturing and selling fishing tackle. For example, the 1965 survey of fishing and hunting shows that salt water anglers spent $800 million in that year. Sightseeing and swimming support motel and restaurant services in the favored areas, as do other overnight recreational activities.

Attempts at the quantification of overall recreational economic values are not yet well developed. The user-day recreation benefits approach has been used in some Federal waterway and reservoir projects, but has been used in the estuarine system only in an analysis of fisheries and recreation in San Francisco Bay. Net benefits for general recreation activities, by this method, range from 50 cents to $1.50 per day. Specific forms of recreation may have higher values.

Applying such a figure to the population of the coastal counties suggests that the value of the recreational resource of the estuarine zone is about $300 million if each person has about 5 days of recreational use. Such an estimate would include only local use and no multiplier values and might therefore be regarded as minimum value of the entire value of the entire estuarine recreation resource.

The major problems in defining the economic values of recreation in the estuarine zone lie in the facts that recreation itself is not an easily defined commidity nor can it be isolated from other economic activities such as transportation, food and lodging services, and equipment manufacturing.

*Commercial navigation and national defense*

Estimates of the economic value of commercial navigation are based on the direct revenue to the port of handling a ton of cargo, generally $16 to $20. Such estimates lead to a total value of the estuarine resource of $4.7 billion annually for cargo revenues alone, without multiplier values. An additional economic value of $10 billion annually in salaries and wages has been estimated for 11 major ports.

These estimates do not show the impact of commercial navigation on land transportation, shoreline development, or the manufacturing industries. Without the deep, safe harbors commercial navigation could not exist on a large scale, and without commercial navigation the great cities around these harbors would not have developed.

Deepwater harbors are essential elements of the national defense system. Furthermore, the location of these deepwater ports has influenced the location of other defense installations as well as the industrial complexes necessary for the logistical support of the defense effort.

The cost of the national defense effort in the estuarine zone for 1967 is estimated at about $900 million, exclusive of pay and allowances for shore-based Navy and Marine Corps personnel. The economic impact of national defense activity overlaps into all other estuarine zone uses because of the massive payrolls associated with it. This impact is centered in the areas with major defense installations.

*Waste disposal*

The waters of the estuarine zone have received wastes from the people and industries on their shores ever since the first cities were founded. The economic benefit in the use of estuarine waters for waste disposal has been fully utilized by nearly all industries and communities in the estuarine zone, and only the tremendous capacity of estuarine waters to absorb and remove waste materials has kept the estuarine zone from suffering severe damage from such waste discharges.

No overall estimate of the value of this use of the estuarine resource is possible because the level of treatment necessary in any particular case depends on many local factors.

While the use of estuarine waters for waste disposal may not be aesthetically appealing it is an existing estuarine use with which other uses must compete, and it should be considered along with them in the overall economic evaluation of estuarine uses.

*Examples of socioeconomic environments in the estuarine zone*

Almost all estuarine systems have either a multiplicity of uses at the present time or such uses are available in the system. Estuaries presently support such varied uses as military berthing and associated activities, commercial port facilities, shipping channels, industrial uses, commercial fisheries, sport fishing, recreation, wildlife habitat, and purely aesthetic purposes. In most estuaries one or two of the uses predominate while the others take minor roles.

Narragansett Bay is an ideal example of an estuary that has developed in an unbalanced fashion. That is, the economic value of the estuary at the present time is largely associated with the industrial, military, and transportation uses of its waters. Other uses are, of course, made of the estuary but their economic significance is dwarfed by the tremendous magnitude of the military and commercial uses. However, it must be remembered that this economic measure is merely an indicator of the value of the waters and is not in any way related to the right or necessity of polluting such waters in the process of achieving this value. In fact, the only time that such an economic measure would be used would be for comparing one total use of the estuary to another total use. Of course, it is seldom that questions are so broad as to cover either/or propositions for the entire activity. Rather, the questions usually revolve around such things as the benefits to be derived from reducing pollution caused by users of the estuary compared with the costs of achieving the reduction in pollution.

Franklin County, Fla., is dependent upon pollution-free waters in Apalachicola Bay for its economic existence. The unpolluted waters of the bay provide the seafood caught by local commercial fishermen and processed at shore-based installations. Additional income for the area results from tourism engendered by the bay's waters.

Both tourism and commercial fishing are prime potential sources of income to any estuarine system. In the case of Apalachicola Bay, these happen to be the major sources of income because of the nature of the estuary and its location which prevent its development as a commercial shipping facility.

The San Diego economy, although heavily dependent upon the military and shipping activities in the bay, has diversified to the extent that it is no longer completely dependent upon such uses of the bay. At the same time there has been a growing demand for recreational uses of the bay. Evidence of the local resident's interest in the bay for recreation, tourism, and commercial uses can be found in their willingness to invest substantial sums of money in facilities to prevent pollution of the bay by municipal wastes.

Mission Bay, a separate estuary in the San Diego area, is an example of the recreational potential to be found in an estuarine system. However, this special study points up the fact that the best use of an estuary may not come about naturally. Rather, it shows that a planned development program with adequate investments are necessary to achieve optimal use of an estuary.

*Measures of overall value and importance*

The discussions of values of individual uses and the case studies of specific estuarine systems present a confusing picture of the relationship of estuarine uses to economic indicators.

Estimates of the direct gross economic benefit of the estuarine zone to the residents of the coastal counties can be made. The estimates of economic activity generated by the presence of Narragansett Bay in Rhode Island give a conservative annual economic benefit of $920 per capita, $420 of this is personal income. Average personal income for all of the coastal counties is, according to Bureau of the Census figures, $500 per capita greater than the average for the remainder of the country. The total economic activity generated by this additional personal income then amounts to about $1,100 per person, using the Narragansett Bay multiplier values.

The total direct economic benefit of the estuarine zone to the residents of the coastal counties is then about $60 billion in terms of additional economic activity stimulated by the presence of estuarine systems. This is not a measure of the total economic activity of the estuarine zone, but only of the "value added" to the total economic activity of the coastal counties by the presence of the estuarine zone.

Such gross means can give only an order-of-magnitude estimate of even the direct economic value of the estuarine zone and cannot possibly reflect either indirect benefits or the social importance of the estuarine zone, much less its ecological value.

Valid criteria for evaluating the importance of the estuarine environment or the value of individual estuarine uses, to a community must, however, go beyond the reach of economic approximation and recognize the fundamental relationship between man and his environment. Wherever there are people the environment will be exploited to satisfy the needs and desires of man and his civilization.

Increasing environmental pressures from demographic and commercial development are paralleled in the same community by the increasing desire for greater recreational use. That these can be compatible is clearly shown by the San Diego Bay example. Such community reactions as in San Diego and in San Francisco demonstrate that, while people need commercial development and use, they want a safe and enjoyable environment at the same time.

## SOCIAL AND ECONOMIC TRENDS IN THE ESTUARINE ZONE

At the present time, the major uses of estuaries, in terms of gross monetary return are: military use, shipping, and industrial activities. These uses are, of course, historical and do not necessarily reflect the uses that would be made of the estuary under today's conditions or future conditions, if each use were to compete for the water use at the same time. In other words, historical use has brought about the present use imbalance in many estuarine systems. However, given the opportunity to develop, other uses might attain equal importance economically while contributing important social benefits.

Estuaries at the present time represent underdeveloped natural resources that are important to the social as well as the economic wellbeing of the Nation. Based on present trends and demands, there is little doubt that there will be a tremendous need for estuarine uses other than for military, shipping, and industrial uses. That is, if the facilities are available for recreation, sports, or esthetic enjoyment, they will be used and used to great advantage from an economic standpoint as well as a social standpoint.

If normal circumstances prevail, the Nation's population and general high standard of living will continue to increase in the coming decades. A moderate estimate projects a doubling of the national population by the turn of the century, with a significant proportion of that growth occurring in urban areas.

The population will be made up of a large proportion of youth and young persons of working ages, with only a moderate increase in the elderly through the end of the century. Personal income will rise dramatically. Estimates of leisure time vary considerably, but all authorities agree that the work week will shorten, from a conservative estimate of 35 hours a week to as little as 20 hours per week. The National Planning Association has projected that in 1990, 10 percent, and in 2000, 20 percent of the men between the ages of 25 and 54 will be granted 1-year leave every 7 years.

Urban and particularly suburban growth will expand greatly both to accommodate the growing population and to provide amenities that it increasingly demands: single family dwellings, recreational areas, transportation facilities, industrial development, and so on. These demands will place rapidly increasing burdens on the Nation's resources and its environment. These burdens, in turn, will tax the ability of decisionmakers and the Nation's population to cope with the complexity and insistence of the problems generated by a post-industrial, urbanized society.

Information provided by this analysis of national population and economic trends gives only the grossest indication of the activities and expected pressures of population and economic activity on all of the Nation's environment. Analysis of these indicators can only provide a general indication of the magnitude of the demands which will be generated by these forces in the near future on the estuarine zone.

## Section 3: Pollution: The Impact of Human Society on the Estuarine Environment

Man has always used the biophysical environment as he needed it for survival and thrown back into it his waste products and anything else he did not need. As long as civilization was limited to small towns and villages the impact of such treatment on the estuarine environment was not noticeable and apparently insignificant with the development of a civilization based on a complex socioeconomic environment, however, his impact on the natural environment has increased until now the most accurate term to express the relationship of man to his biophysical environment is "pollution."

"Pollution" is the degradation of the biophysical environment by man's activities; it is no longer limited to the discharge of sewage and industrial wastes, but now includes direct or indirect damage to the environment by physical, chemical, or biological modification.

Environmental degradation is the result of often minute changes in water quality, water circulation, or other conditions which are part of the biophysical estuarine environment. There are brightly colored or otherwise visible waste materials which have obvious pollutional implications, but by far the deadliest pollutants are those which are invisible and often unsuspected until the damage is done. These pollutants can be found only by the most delicate and sensitive tests and, even then, the presence of some highly dangerous materials or conditions can only be inferred by indirect evidence.

## MATERIALS AND CONDITIONS WHICH DEGRADE THE ENVIRONMENT

One of the major constituents of municipal and many industrial wastes is *decomposable organic material.* Such materials consist primarily of carbohydrates from plants and paper, proteins from animal matter, and miscellaneous fats and oils. The decomposable organics are not necessarily deterimental by themselves but exert a secondary effect by reducing dissolved oxygen in the water. The level of dissolved oxygen is one direct index of the healthiness of the system. High levels are generally indicative of a healthy system which will support a diverse biota and multiple use. The lower the concentration of dissolved oxygen becomes, the sicker the system is, and the less desirable it is for habitat or use.

Another class of materials, primarily organic, that can have considerable impact on the estuarine ecosystem are the *flesh-tainting* substances. Generally these materials are contained in industrial waste effluents and they result in offensive tastes, odors and colors of fish and shellfish.

The salts of *heavy metals* are fairly soluble and stable in solution. Consequently, they will persist for extended length of time. Many of these are highly toxic to the aquatic biota, and since many marine organisms exhibit the ability to accumulate and concentrate substances within their cell structure, the presence of these metals in small concentrations can have deleterious effects.

Aquatic life forms require trace amounts of some minerals and vitamins for growth and reproduction. Elimination of such materials from the environment or their reduction below minimum levels can limit the growth and reproduction of some biota. Conversely, an oversupply of all necessary trace *mineral salts* and vitamins can stimulate growth; providing satisfactory conditions of temperature, salinity, and dissolved oxygen also exist. An oversupply of inorganic nutrient salts, such as those of nitrogen and phosphorus, may be associated with drastic shifts in the composition of the aquatic community.

One of the many unfavorable effects of municipal and some industrial wastes is the contamination of the receiving environment with bacteria, viruses and other organisms of public health significance. *Pathogenic organisms*, especially those from the intestines of warm blooded animals frequently persist for sufficient periods of time and distance to pose a threat to the health and well-being of unsuspecting water users. Secondary chances of exposure to these organisms exist through the contamination of shellfish which can be harvested for food.

Among the waste products that are frequently introduced into the estuarine environment are some directly toxic to marine organisms.

*Toxic materials* may exhibit a short catastrophic impact or a more subtle long-term interference with growth and reproduction processes. The end result is to create a biological desert in which no organism can survive. The pesticide group is of particular concern in the estuarine zone. Estuaries are the terminus for most of the major river systems, and as such they tend to concentrate the waterborne materials carried in by the large terrestrial drainage systems. The biological magnification capability of estuarine animals significantly increases the hazard and destructive potential of any contributed pesticides. The ultimate damage is to stress or eliminate parts of the energy conversion chain in the estuarine environment.

The addition of large quantities of heat from industrial cooling water constitutes a form of pollution which must be considered. The entire ecosystem may be stressed by *thermal pollution.* The amount of damage is dependent on the resulting temperature of the environment and the species composition of the biotic community. The total range of detriments should be carefully considered on an individual basis before heat is released to the environment. Heat affects the physical properties of water, the rates at which chemical and biological reactions progress, and can kill living organisms.

Man's activities may affect the rate at which the natural balance of inflow, deposition, and outflow is reached by purposely or inadvertently upsetting this balance. If upstream erosion is increased due to poor land management practices, the load carried in will increase. Conversely activities along the coast can result in increased shore erosion, removing more sediment than is contributed. The primary pollutional problem from sediment, however, is from increased influx and accelerated deposition. The detrimental effects of sedimentation are reflected in an impairment of uses such as navigation, recreation, and fish propagation.

One of the greatest threats to the estuarine ecosystem is the ever-present chance for a *catastrophic spill* of oil or other hazardous materials. The large volumes of petroleum and chemical products transported through the estuarine zone by ships, barges, pipelines, tracks, and railroads present a continuing opportunity for accidental bulk spills. The consequences of these spills depend on the amount and type of material released and the characteristics of the receiving water. They may range in magnitude from tragic loss of life to little more than economic loss for the transporter.

The effect any pollutant has on an estuarine environment depends on where it goes, how strong it is, and how rapidly it is assimilated or flushed out of the environment. All of these conditions depend on water movement and circulation patterns which are in turn governed by the relationship of tide and river flow to estuarine shape and size. *Physical modifications* such as the dredging of new or deeper navigation channels, building of causeways of jetties, and even construction of pier bridges can cause subtle changes in water movement that can change the balance of environmental conditions in an estuarine system and result in gradual undesirable changes in the ecosystem in addition to direct habitat damage.

## SOURCES OF POLLUTION

Nearly all of man's activities can result in environmental degradation. Pollutants and polluting conditions are very rarely unique to a particular use or specific activity, but may result from man's existence in the estuarine zone as well as his use of it. The major sources of pollution:

(1) Those sources associated with the extent of development of the estuarine zone, including waste discharges from municipalities and industries, and land runoff from these as well as agriculture;

(2) Those sources associated with particular activities of great pollutional significance, specifically dredging and filling, watercraft operation, underwater mining, and heated effluent discharges;

(3) External sources having impact derived through flow regulation and upstream water quality.

Over 8 billion gallons of *municipal wastes* are discharged daily into the waters of the estuarine zone. While most of this volume is domestic sewage, many municipal waste discharges also contain significant amounts of industrial wastes, which may add to the variability and complexity of the wastes discharged. Municipal waste discharges have four important effects on receiving water quality: depletion of dissolved oxygen, and introduction of pathogenic organisms, settleable material, and inorganic nutrients.

Sewage treatment reduces and alters the impact of municipal waste on the environment. Primary treatment with chlorination will remove part of the decomposable organic material, nearly all of the settleable and suspended solids, and almost eliminate the possibility of pathogens in the effluent. Secondary treatment can almost eliminate decomposable organic material, and some special processes can eliminate certain kinds of dissolved salts. About one half the municipal wastes discharges to estuarine waters receive secondary treatment, with the most extensive use of secondary treatment being in the Chesapeake Bay estuarine region.

Associated with the major metropolitan developments are large numbers of industrial complexes with their attendant waste products. Many of these *industrial wastes*, especially from the chemical industry, are of such a complicated nature that it is difficult both to identify them and to assess their effects on the receiving streams. Only 4,000 of the more than 200,000 manufacturing plants in the coastal States account for 97 percent of the total liquid wastes discharged. Of the nearly 22 billion gallons of industrial wastes discharge daily, only 29 percent receive any kind of waste treatment.

Intensification of use of the estuarine zone has resulted in many artificial changes being made in the physical structure. Shoreline areas have been filled to create more land area for residential and commercial use; channels have been dredged and maintained to permit safer and better navigation; and harbor facilities have been dredged and bridges and causeways have been built. All of this activity has had impact on the coastal zone ecosystem, but the activities having the most impact on water quality are dredging and filling. The potential for pollution of the system exists in both filling and dredging; both can introduce foreign materials into the water, destroy aquatic habitat, and physical circulation patterns.

The primary source of thermal pollution is from industrial cooling water effluents. Powerplants are the major users of cooling water in the estuarine zone, and power-generation capacity has approximately doubled each decade during this century. The impact of this growth on the estuarine areas is evidenced by the fact that in 1950 22 percent of the powerplants were in the coastal zone; it is anticipated that over 30 percent of the plants will be located there in the late 1970's.

Estuarine areas are also very important highways of commerce, and thousands of commercial vessels (foreign and domestic, from ocean liners to barges, traverse the coastal waterways each year. Added to this are many of the 1,500 Federal vessels and many, nearly 8 million, recreational vessels. All of these watercraft carry people and/or cargo, and are a real or potential pollution source.

Mining from the estuary floor causes alteration of the estuarine shape and water-circulation characteristics, with a secondary effect being the turbidity problems associated with material removal. Mining of sand and gravel from the estuarine floor are universal while oyster shell dredging in any great quantity is restricted to the Gulf coast. These operations remove part of the estuarine floor with a concomitant destruction of habitat and life. There are also great amounts of suspended and settleable solids frequently released into the water, from which they are redeposited in other places.

The water quality of estuarine areas is dependent not only on direct waste sources but also on the quality of the inflowing streams and runoff entering the system. Tributary influent quality is generally a good index of the type and intensity of land-use surroundings and upstream from estuarine system and can be a major cause of ecological stress within the system. The complex interactions between fresh and salt water may magnify the effects of pollutants carried into the tidal regime, resulting in quality anomalies completely alien to either fresh or oceanic environments.

## EXTENT OF POLLUTION EFFECTS

Environmental damage from human activities manifests itself in changes in water quality and in changes in the living communities. Either or both may be caused by any of the kinds of pollution or sources of pollution mentioned earlier. One key to the degree of environmental impact is measurement of alteration in water quality. Extensive data have been collected on a few of the estuaries with the most severe problems, and limited information is available on other estuarine systems to outline the emergence, or document the existence, of water-quality problems.

Examples of estuarine systems that show definite documented water-quality degradation as a result of human activities are these: Penobscot Bay, Boston Harbor, Moriches Bay, New York Harbor, Raritan Bay, Delaware estuary, Baltimore Harbor, Potomac River, James River, Charleston Harbor, Savannah River, Biscayne Bay, San Juan Harbor (P.R.), Tampa Bay, Pensacola Bay, Mississippi River, Galveston Bay, Laguna Madre, San Diego Bay, Santa Monica Bay, San Francisco Bay, Columbia River, Puget Sound, Silver Bay (Alaska), and Hilo Harbor (Hawaii).

Pollutional damage to estuarine ecosystems may be sudden and dramatic as fish or other equatic life forms suddenly dying, or it may be so gradual as not to be noticed for many years. Many studies of different aspects of estuarine biology have been made, but there are only a few cases in which comprehensive ecological studies have been made of pollutional effects.

All of the 25 estuarine systems listed above also show some ecological damage, but in 38 percent of the estuarine systems of the United States there is not sufficient information to decide whether there is no ecological damage, or whether there is just no easily identifiable pollution problem present.

The complex nature of pollution in the estuarine zone prevents the separation of sources of pollution, kinds of pollution, and types of environmental damage into neat compartments of cause and effect. All of human activities in the estuarine zone can damage the environment and most of them do.

Wherever people live, work, and play in the estuarine zone the demands of their social and economic activities place stresses on the biophysical environment. These stresses frequently result in degradation of that environment, perhaps not immediately or even in a few years, but nonetheless certain in their devastating final impact.

## Section 4. Use Conflicts and Damages: Man's Battle With Himself and Nature

The consequence of damage to the biophysical environment is loss of use either immediately or at some time in the future. Loss of use, however, may also be associated with the appropriation of part of the estuarine resource for one exclusive use even when no damage to the environment itself occurs.

Institutional management must cope with the problems of responsibility and authority in achieving maximum multiple use of the estuarine resource. Within this comprehensive framework technical management must resolve the problems surrounding conflicts of use, competition for the resources of the estuarine zone, and environmental damage. The primary objective of technical management is to achieve the best possible combination of uses to serve the needs of society while protecting, preserving, and enhancing the biophysical environment for the continuing benefit of present and future generations.

The uses of the estuarine zone grew and changed in consonance with population growth and industrial development. Not until recent years was a concerted attempt made to understand and resolve the conflicts that arose in the competition to use and exploit these land and water resources. During the past 300 years of growth and industrial expansion with its emphasis on economic growth and direct monetary gain, large parts of the estuarine zone were preempted or usurped to serve the individual needs of commercial enterprises. The net result has been less a conflict in existing uses than an exclusion of some uses.

Nearly all estuarine uses involve both land and water, either directly or indirectly. For example, the construction of a manufacturing plant on the shore of an estuarine system may not involve any direct use of the water (even for waste disposal), yet it limits access by its occupation of the shoreline and so may interfere with other uses. Conversely, the disposal of liquid wastes into the water may make the shoreline unusable for recreation as well as making the water itself unsafe.

The impact of one estuarine use on another may be either "prohibitive" or "restrictive" depending on the kind of use and sometimes on the manner in which it is carried out.

Prohibitive impacts involve permanent changes in the environment and thereby prohibit all uses unable to cope with such changes. The geographical range of such impacts may be from the limited area in which they occur to an entire estuarine system, depending on the nature and size of the change. The impact may be temporary, if it is possible to return the environment to its original form, or it may be permanent.

Any use or activity requiring physical modification of the shoreline, marshes, or bottom of an estuarine system may have a prohibitive impact. Modification of water circulation also tends to be prohibitive when it has any conflicting impact. Examples of estuarine uses and activities generally having prohibitive impacts are navigation dredging, other dredging and filling, solid waste disposal, construction of bridges, dikes, jetties, and other structures, shoreline development, mining from the estuarine bottom, and flow regulation.

Some estuarine uses may restrict estuarine use for other purposes but do not automatically exclude other uses. These are those activities which do not require a permanent modification of the estuarine system; they generally include those uses directly involved with the estuarine waters and other renewable resources.

Restrictive impacts may involve damage to water quality, living organisms, or esthetic quality; such impacts may also result from the exclusive appropriation of space. The key feature of uses which cause restrictive impacts is that they may, with proper management, be carried out simultaneously with other uses.

Any kind of municipal or industrial waste discharge may have a restricted impact and often does. Commercial fishing, recreation, and water supply are the major uses restricted by pollution from liquid waste discharges.

Some kinds of commercial fishing require the use of trawls or the setting of traps or nets that must be left for some time. The use of such devices restricts other uses while the devices are in place, but there is no permanent appropriation of estuarine waters or space. The major conflict is with recreation in that recreational boating must be excluded from areas where fishing gear is near the surface.

Where there is conflict, the scene is set for trade-off; i.e., a willing substitution of one activity for another. The scene is equally set for uncompensated damage where one user group precludes the activities of a second unrelated user group but does not reimburse them for damage. Actual documented examples of use damages are difficult to find. One major reason is the basic fact that has permeated much of the discussion of economic and social values: Many estuarine values are not quantifiable. While damages to a commercial enterpirse, such as commercial fishing, can be quantified in terms of the economic loss, the essentially intangible values of recreation and estuarine habitat are difficult to measure.

Recreational loss would have to be measured in terms of how many people don't swim or go boating in the Potomac River because it is polluted. It is far easier to find out how many people do go there even if it is polluted; even these values are hard to find.

The value of estuarine habitat is just as difficult to establish. There are now about 5.5 million acres of important estuarine marsh and wetland habitat remaining in the estuarine zone of the United States. Perhaps each acre is not valuable by itself, but the total habitat is irreplaceable.

Use damage is not a necessary feature of civilization in the estuarine zone, but use conflicts will continue to exist as more and more demands are made on the natural environment. The ability of any management authority to prevent use damage and to resolve use conflicts depends not only upon its institutional composition and legal authority, but also upon the social, economic, and biophysical characteristics of the estuarine management unit within which its authority is exercised.

The analyses of social and economic values of the estuarine zone examined concurrently with the similar analyses of use conflicts, pollutional effects, and use damages form the basis for resolving use conflicts through the application of technical knowledge; i.e., technical management.

The primary objective of technical management is to accommodate the needed and desired uses of any estuarine management unit within that system without overall damage to the biophysical environment. The ability to achieve this objective depends on the boundaries of the management unit and upon the means available for resolving both prohibitive-use conflicts and restrictive-use conflicts.

The impact of the social and economic requirements of civilization on the natural estuarine environment is the technical problem with which management must deal, and effective control of this impact can be maintained only if both the major sources of damage and the geographic range of their influence are subject to unified control.

An estuarine management unit, therefore, should consist not only of the estuarine waters, bottoms, and associated marshlands; but it should also include all of the shoreline surrounding the estuarine waters themselves and as much of the adjoining land as is necessary to regulate the discharge of wastes into estuarine waters.

Allocation of part of the estuarine resource for an exclusive single-purpose use is a necessary fact of estuarine management. The shoreline is a necessary location for shipping docks and for swimming beaches, but they cannot both occupy the same place on the shoreline. Similarly, frequently dredged channels and oyster beds cannot occupy the same space at the same time. Resolution of such conflicts can be achieved by allocation of adequate space to each use through whatever institutional mechanism is established.

The evaluation of the effects of prohibitive uses on the estuarine environment is probably the most difficult problem currently facing technical management. The immediate and obvious effects of the habitat loss associated with such uses can be measured and described fairly easily, but the ultimate results of the modification of water movement patterns and flushing characteristics can only be estimated in general terms.

In nearly every problem associated with prohibitive-use conflicts, however, the area of primary concern is the effect on the estuarine ecosystem of any physical modifications proposed; the limitations of knowledge mentioned above, therefore, present a critical problem in present efforts to resolve prohibitive-use conflicts.

A more difficult problem arises where there is involved a massive dredge or fill operation with its concomitant immediate effect on the ecosystem. When such modifications are a necessary or desirable development of the environment it may be necessary to forgo the habitat use; however, in many cases it may be possible to create a new, equivalent habitat in a different part of the management unit, or it might be possible to restore part of the damaged environment.

While the resolution of prohibitive-use conflicts requires the abandoning of one use in favor of another, the potential for carrying out any modifications necessary so as to increase habitat value as well as economic value should be a key factor in the resolution of such problems.

Disposal of liquid wastes to the estuarine environment is the major restrictive use impact of the socioeconomic environment. This use conflict can be resolved completely either by treating all wastes to such an extent that they do not interfere with any other uses or else removing them entirely from the environment.

Technology exists to provide thorough treatment for nearly every kind of municipal and industrial waste, and there is no reason not to provide treatment sufficient to protect the environment from damage and to permit other uses. Treatment requirements for different wastes may vary from place to place according to local conditions, but damage to the environment and restriction of other uses can be prevented.

Water quality standards have been set and are now being implemented in all the coastal States. These standards are the foundation upon which the effective control of estuarine pollution rests, and they provide the framework within which technical management can effectively operate.

As pointed out earlier in this chapter, however, estuarine waters even in busy harbors are used for recreational purposes by those who cannot afford to go elsewhere, regardless of whether the waters are safe for body contact or not. Also the role of the estuarine zone as a nursery for some fish, passage for others, and a residence for still more is readily apparent although its full implications in the energy conversion chain are not understood. For these reasons the long-range achievable water quality goal of estuarine management should be to keep all waters safe for direct contact by humans and also usable as a fish and wildlife habitat.

# THE NATIONAL ESTUARINE POLLUTION STUDY

Volume III

# PART V. DEVELOPMENT OF THE COMPREHENSIVE NATIONAL PROGRAM

## Introduction

As decreed by the Congress in section 5g of the act:

> The report shall include * * * recommendations for a comprehensive national program for the * * * development of estuaries * * * and the respective responsibilities which should be assumed by Federal, State, and local governments and by public and private interests.

The recommendations are included in part III of this report, and the following portion, part V, contains the background material for the recommendations plus descriptions of the various governmental responsibilities.

The rationale for this development is as follows. To provide a basis for the developing these recommendations and defining responsibilities, a volume of material was amassed on the views, suggestions, programs, and legislative authorities of all sectors of the national community—Federal, State, and local governments and public and private interests. This background information was obtained through very diligent solicitations of all these sectors. The resulting material consisted of reports, correspondence, and personal communications which were analyzed and summarized to produce relatively brief overviews. The source information used to produce the overviews is being retained separately from this report for future reference and updating.

These overviews, which are quite brief considering the original mass of information, are presented as the following chapters of this part of the report. The order in which they are presented is essentially the same as that used in the wording of the act, that is, chapter 1 is the Federal agencies; chapter 2, the "State" agencies; chapter 3, the local governments; chapter 4, the compact (or interstate) agencies; and chapter 5, the public and private interests. These overviews were related to those of other marine resource studies (chapter 6) and then related to specific geographic areas to present a concrete overall view (chapter 7) and finally summarized in the form of conclusions (chapter 8). In turn chapter 8 provides the skeletal outline for the development of the recommendations enumerated in part III of this report, and chapter 9 provides suggested guidelines for a management statute.



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# CHAPTER 1. ROLE AND PROGRAMS OF FEDERAL AGENCIES

This chapter describes the current Federal role and programs in the estuarine zone and identifies the needs to be met to provide for a stronger more effective Federal program.

The current Federal role as such, has grown over a period of many years and has as its basis the national interest which extends beyond State borders. The role is based on Federal legislation which itself has developed over a period of years to meet many specific needs seen and acted upon by Congress. It has also grown as one of concurrent jurisdiction with the States who exercise the primary authority in the estuarine zone. Even so the Federal role is a vital one and is essential to the preservation of national interests. Broadly speaking these are: (1) the protection and development of the Federal interest in the natural resources of the estuarine zone, (2) commerce and navigation and, (3) national security.

## Section 1. Current Federal Role in the Estuarine Zone

The description of the Federal program that follows is a more complete picture of how the Federal role is implemented. In very brief form the role itself has come to be:

(1) The provision of normal Federal projects such as navigation channels, flood control and protective works, aids to navigation, weather service including tides and currents, mapping and charting both for navigation and resources, and port security and shipping control.

(2) Grants and loans to States and other entities for planning, acquisition and development, for research and study, and for facilities construction.

(3) Technical advice and assistance through conference and consultation, mutual assistance projects, and joint projects and studies.

(4) The preparation of broad studies and investigations, including inventories and data collection necessary to meet the requirements of Federal programs.

(5) Acquisition and development of selected sites to preserve and protect them for the future.

(6) The exercising of regulatory authority in accordance with current Federal law and statute. These authorities include the issuance of permits, licenses, and other regulations governing certain permissible uses or modification of estuarine resources. They include also the enforcement of water quality standards and various other controls over pollution, and the enforcement of Federal law within the navigable waters of the United States.

(7) The exercise of coordinating activities, for the most part through close work with State counterpart organizations and at the

headquarters level through committee and council work, routine daily business and memorandum of agreement.

(8) Granting Federal consent to interstate and international compacts and commissions.

(9) Assuring appropriate Federal performances under regional and international obligations for the management of flyways, fisheries resources, etc.

## Section 2. The Federal Programs

To meet the requirements of the national interest and to carry out its role, the Federal Government has assumed fairly broad responsibilities in resource management, planning, regulation and control, and in many programs of technical and financial assistance to the States and the subdivisions. The description of the Federal programs that follows will show how this has developed and how these programs currently meet Federal responsibilities.

In describing the current Federal programs in the estuarine zone it is important to note that the greater part of these programs is of much broader scope than just that of the estuarine zone, and thus the activities reported herein are generally portions of larger programs which overlap and crossover the estuarine zone. Because these programs are of long-standing importance to the development and preservation of the Nation's resources and to the promotion of its commerce and industry they should not be fragmented or segmented by arbitrary geographic dividing lines; nevertheless, this description will confine itself as closely as possible to those parts of the programs relating to the estuarine zone, with the possible risk of appearing incomplete at times.

### FOUR GENERAL CATEGORIES OF PROGRAMS

Categorization of the multitudinous Federal activities in the estuarine zone cannot be clear cut as there is a continuous series of interlocking activities and concurrent jurisdictions. Nevertheless, four general categories become apparent when the overall activities are viewed. These are: (1) those activities and programs having a direct and significant operational effect; (2) programs or activities having indirect or related effects; (3) activities primarily of a research and study nature; and (4) activities of a planning and coordination nature.

### CATEGORY 1: PROGRAMS HAVING DIRECT AND SIGNIFICANT EFFECTS

Into category 1 have been placed the programs of the Department of the Interior, the Department of Commerce, the civil works program of the Corps of Engineers, and the Department of Transportation, as all these in themselves have a direct and major effect on the use of the estuarine zone.

*Department of the Interior*

By virtue of the numerous activities of the bureaus and offices in the Department of the Interior, the Department, in essence, is the resource manager of the estuarine zone. This applies to both the living and nonliving marine resources and to a slightly lesser extent the related land resources. This is well demonstrated in the description that follows.

Interior's estuarine programs are planned and managed to meet expanding national needs for material, esthetic, and environmental resources and qualities afforded by the estuarine areas. Programs in support of objectives provide for aggressive leadership in research and management. For the most part the programs also encourage and complement appropriately designed estuarine activities of other Federal agencies and State and local governments.

*Bureau of Commercial Fisheries*

Concerned largely with coastal waters and the open ocean, the Bureau of Commercial Fisheries works with nature as yet little affected by human management except for those anadromous species which use the estuaries and migrate into fresh water to spawn. It has the responsibility to insure an adequate, dependable, and diverse supply of fish and shellfish products of good quality; encourage optimum use of estuarine living resources; and contribute to man's understanding and control of estuarine living resources and their environment. To achieve these objectives, the agency conducts research on estuaries, estuarine problems, or estuarine-dependent species of fish at more than half of its 20 biological laboratories.

The Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife have, after more than a decade as a service, recently formed several interbureau committees on such matters of common interest as estuaries, anadromous fish, and conflicts between commercial and sport fishermen.

Task forces on ad hoc bases are constantly being formed for special interbureau purposes. These developments and other basic responsibilities of longer standing, place the Department of the Interior in an expanding role of leadership and responsibility in estuarine research, planning, and management.

*Bureau of Sport Fisheries and Wildlife*

In the conservation of estuarine fish and wildlife resources and the preservation of estuarine habitat, the Bureau of Sport Fisheries and Wildlife has a very substantial program. Under a variety of legislative authorities the Bureau activities include investigations and recommendations for the preservation and enhancement of fish and wildlife resources in connection with waterfowl population statistics and of regulations pertaining to waterfowl; Federal aid to the States for acquisition of wetlands, research on fish and wildlife, and access and development of facilities for fishing and hunting; training of biologists and dissemination of technical advice; conservation education; and pesticide monitoring.

The Bureau is also charged with the second estuary study underway in the Department, the National Estuary Protection Act (Public Law 90–454). This act expresses the intent of Congress "* * * to recognize, preserve, and protect the responsibilities of the States in protecting, conserving, and restoring the estuaries in the United States."

This legislation directs the Secretary, in cooperation with the States and with other Federal agencies, to conduct a detailed inventory of the estuaries of the Nation. Such inventory and analyses would be the base for determining appropriate means and measures of preserving or restoring particular areas, including legislation.

Coordination of the two estuary studies has been accomplished through the Office of Marine Resources, in accordance with Secretarial Order No. 2908, approved in October 1968. In order to avoid duplication of effort the estuarine protection act study will use the Estuarine Inventory being developed by the National Estuarine Pollution Study.

Of the 312 units in the National Wildlife Refuge System, 78 are coastal. These coastal refuges have a combined shoreline of more than 500 miles and an area of more than 18 million acres, of which 682,000 acres are identified as estuarine. As administrator of these areas, the Bureau is a potent factor in the conservation of these estuarine resources. An additional potent factor in the conservation of estuarine resources is the Bureau's responsibility to review and comment on Corps of Engineers permits as required by the Fish and Wildlife Coordination Act.

*Bureau of Land Management*

While the Bureau of Land Management is the designated management agency of public domain lands, a sizable portion of these lands is along the California and Oregon coasts. The Bureau plays strictly a management role, and, as such, has no authority to acquire any additional lands. It is the Nation's largest land manager.

*Bureau of Mines*

The Bureau of Mines is oriented to research and information services. In its estuarine related programs it seeks to develop the technology necessary to minimize the adverse effects associated with mineral recovery. They include a mineral resource evaluation study and the development of marine mineral mining technology. The Bureau has jurisdiction over that part of the solid waste program which involves materials resulting from mineral extraction.

*Bureau of Outdoor Recreation*

An examination of the Bureau of Outdoor Recreation program indicates a central role in promoting Federal-State cooperation and coordination in planning the acquisition and development of both existing and proposed new estuarine areas devoted to public recreational use. Although it administers no lands, it administers the Land and Water Conservation Fund Act of 1965 (Public Law 89–578), which other agencies—Federal, State, and local—make use of in their land programs. The act provides grants to the States for the planning, acquisition, and development of outdoor recreation areas and facilities, and to certain Federal agencies for the acquisition and development of outdoor recreation areas and facilities.

The Bureau also participates in comprehensive river basin planning, water resource project planning, and reviews reports related to such activities. The Bureau and the National Park Service also work together on area planning, often with the participation of the Bureau of Sport Fisheries and Wildlife. Emphasis is given to assure that adequate consideration is accorded to the estuarine environment.

*Federal Water Pollution Control Administration*

Created by the Water Quality Act of 1965 (Public Law 89–234) and significantly expanded in powers and funding through the Clean Water Restoration Act of 1966 (Public Law 89–753), the Federal

Water Pollution Control Administration has a singularly complex and essential program.

In carrying out its pollution control program, this Agency conducts a series of major programs in the estuarine zone. Briefly, these programs include comprehensive water quality management planning, technical services, construction grants program, enforcement, water quality standards and research.

The comprehensive water quality management planning program in the estuarine zone involves the coordination of the in-house water pollution control planning efforts with water resources planning conducted by other Federal, State, and interstate planning agencies to ensure adequate consideration of water quality factors. It also provides the means for systematic evaluation of multiple resource needs to meet future demands. This includes development of programs relating to the control of water pollution in the estuarine zone. Water quality management planning grants are made to State and local governments. Under Executive Order 11288, FWPCA carries out certain review and consultation responsibilities for the Department in connection with wastes from Federal activities. The Corps of Engineers dredge and fill permits on estuarine and coastal areas are reviewed in regard to effects on water quality.

The technical support program operates water quality surveillance networks and sampling programs (in cooperation with the Geological Survey) and conducts special studies on the character, effects and abatement of water pollution including that related to vessel wastes, dredging activities, thermal discharges, municipal and industrial waste discharges, land drainage and salt water intrusion. In addition, the program operationally administered the Oil Pollution Act of 1924, as amended, and develops and coordinates the implementation of the national multiagency oil and hazardous materials pollution contingency plan and the supporting regional plans.

Enforcement proceedings are conducted to abate pollution of coastal waters and also when there are violations of water quality standards. Some 14 enforcement proceedings have been carried out in the estuarine areas.

The research and development program provides for increasing the knowledge and techniques for monitoring water quality in the estuarine zone, for recovering those areas damaged by pollution through a variety of means, and for determining the effects of water pollution on estuarine life. The Federal Water Pollution Control Administration has an extensive research and development program involving the detection, control and clean-up of oils spilled into harbors, rivers, and estuaries.

Recently accomplished activities of the Federal Water Pollution Control Administration include:

(1) the partial or complete approval by the Secretary, of interstate

water quality standards for the 50 States, three territories, and the District of Columbia;

(2) completion of the oil pollution report and a completion and implementation of the national multiagency oil and hazardous materials contingency plan; and

(3) in conjunction with the Geological Survey, the agency is currently using STORET as a data storage and retrieval system. Its use will expand as funds permit.

*Geological Survey*

The Geological Survey has been describing and interpreting the environment for nearly a century, a prerequisite for intelligent efforts to shape, control, or preserve it. It maps the physical, hydrologic, and cultural features of the land and by aerial photographs provides a record of changes over time, thus, forming a basis for land-use planning and interpretation. This structural and historical geology of the Nation provides a guide to useful minerals and fuels, and is basic to an understanding of soils. Reliable knowledge about water is necessary for inland navigation, flood control, power development, irrigation, municipal and industrial water supplies, pollution abatement, fish and wildlife, and recreation. Geological research plays a supporting role for many Federal agencies, State programs, and private enterprises on land, at sea, and in space. It should be noted that much of the survey's activity is of a research nature and some of it is of a planning and coordinating nature.

Recent program accomplishments include the changes made in Outer Continental Shelf (O.C.S.) rules.

On February 17, 1969, an amendment was published in the Federal Register making the pollution prevention section of the Geological Survey (O.C.S.) regulations more restrictive. It also established that companies operating on the shelf shall be liable without proof of fault for pollution resulting from their operations. These particular changes apply to operations on the entire shelf all around the country. On March 21, the Secretary announced that certain California O.C.S. orders were changed. (O.C.S. orders are issued by Geological Survey Regional Oil and Gas Supervisors and they apply only to those parts of the shelf within the specific region under each supervisor's jurisdiction.) These changed orders provide for more strict control of oil drilling and production operations in all Federal waters off the entire State of California. Also, on March 21, the Secretary directed that a 2-mile wide permanent ecological preserve be established off Santa Barbara immediately seaward of the 3-mile limit of the State of California. He also directed that all unleased areas south of this permanent preserve will be held as an additional buffer zone where no oil drilling or production operations will be permitted.

*Bureau of Reclamation*

Although the Bureau programs in the 17 Western States have little direct involvement in the estuarine zones there is opportunity for its upstream water resource development activities to have long range impacts downstream on estuarine resources. The downstream influences of these projects are being considered and are of importance to the Department's interest and responsibility in the estuarine zones.

*National Park Service*

The preservation of marine life and environments and the provision for marine-related recreational activities are major considerations in the National Park Service's administration of 24 areas along the Nation's seacoast and along the shores of the Great Lakes. Fifteen of these areas are national parks and monuments where resource protection is a major management objective; seven are national seashores located along the Atlantic, Gulf, and Pacific coasts and two are national lakeshores located along the Great Lakes where outdoor recreation is a primary management consideration.

In addition, 28 units within the national park system are historical areas found along our coastlines. Total length of shoreline in these 52 areas exceeds 1,870 miles.

The service's combined role in marine-related areas is to preserve and manage natural, scenic, historical, and scientific features of these areas, to interpret these features for park visitors, to provide and maintain facilities and services necessary for park visitors to safely enjoy compatible recreational activities, and to provide access to waters and beaches. The service, also, participates in comprehensive river basin and water resources project planning and in review of project proposals and permit applications.

*Office of Saline Water*

The primary objective of the saline water conversion program is to develop practicable low-cost methods of producing fresh water from sea and other saline waters. The research and development program is conducted by means of research and development grants and contracts awarded to individuals, universities, private research organizations and industrial firms, and other government agencies. Estuarial waters are one source of saline waters for desalting. Disposal of waste brine from a large desalting plant may be a problem in relation to environmental conditions in certain estuarine situations from the viewpoint of increases in salinity and temperature. The Office of Saline Water brine disposal research program is directed to determining any detrimental effects and means of alleviating them so that the economic production of fresh water by desalination can be continued without imposing stresses on the environment.

*Office of Water Resources Research*

The Office of Water Resources Research, authorized under the Water Resources Research Act of 1964 (Public Law 89–404) provides a major benefit to the Nation. It seeks to stimulate, sponsor, and supplement present programs of research and training in the field of water and of resources that affect water. This is done through grants and contracts with academic and private institutions, private firms, individuals, and public agencies through operations in 50 States and Puerto Rico. Most of the studies are on water supply augmentation and conservation, while others are concerned with water quality management and protection, water quantity management and control, water resources planning, and the hydrological cycle.

In summary, Interior's programs cover most of the major resources and uses of the estuarine zone, including the rapidly increasing recreational use and the unquantified aesthetic values.

*The Department of Commerce*

The Department of Commerce is another organization whose programs have a direct and significant effect on the beneficial uses of the estuarine zones. Because estuarine zones are used for sea commerce, the Department of Commerce, and especially the Maritime Administration and the Environmental Science Services Administration (ESSA), are concerned with these areas. Action primarily is directed toward collection of navigational data and the development of harbor and port facilities. The Office of Business Economics, the Bureau of the Census, and the Economic Development Administration are indirectly involved in these efforts.

The Maritime Administration has statutory responsibilities for promoting and encouraging the development of an American-flag merchant marine and U.S. ports and related transportation facilities in connection with waterborne commerce. In recent years, the Maritime Administration has become increasingly aware of the detrimental effects of harbor pollution and is involved in activities to solve this problem. With the advent of nuclear powered vessels and the resulting radioactive discharges, the Administration has worked towards the establishment of stringent standards to prevent radioactive contamination of harbor waters. Contracts for the development of devices to detect and prevent oil pollution of harbors have been let; the results of this research have been published. This agency is also involved in comprehensive research studies with several other agencies to investigate the requirements of a national system of ports. The proposed study would consider long-range U.S. port and transportation needs, including detailed analysis of, recommended solutions for, and specific problems generated by rapidly changing shipping technology such as "the supercarrier." In the process important interrelationships between transportation, urban renewal and estuarine resource developments could be identified.

ESSA provides a direct and important service through its mission of mapping and charting the coast and harbors of the United States and its territories. In addition, it provides the adjunctive services of tide and current information, marine weather service, hurricane and tsunami warnings and various other supplemental services relating to marine safety and navigation. Its recently inaugurated flushing prediction service will grow in value to the beneficial use of the estuarine zones.

The Economic Development Administration although indirectly involved in estuary related programs does provide assistance in comprehensive planning affecting the estuarine zone and in support to actual projects in the zone. For example, the Coastal Plains Regional Commission established pursuant to the Public Works and Economic Development Act of 1965 has as an important segment of its activities a marine resources program designed to stimulate growth and use of marine resources in the region. The agency itself has contributed to numerous projects within the coastal area.

In brief summary, the Department of Commerce programs provide essential services in the estuarine zone contributing primarily, but not entirely to the commercial use of the zone.

*Corps of Engineers*

Perhaps the organization that has the greatest direct physical effect on the estuaries is the Corps of Engineers operating under the Department of Defense.

Through its civil works program it literally maintains and administers the navigable waters of the United States. Its programs in the estuarine zone include:

(1) provision of channels, basins and protective works;

(2) control of dredging, filling, excavation and construction in navigable waters through issuance of permits;

(3) development of areas for disposal of dredged material during construction and maintenance of navigation projects; and

(4) issuance of permits regulating the discharge of industrial and other wastes into navigable waters.

Other important Corps estuarine-related programs include:

(1) removal of wrecks, aquatic vegetation, debris, drifts, and other obstructions from navigable waters;

(2) restoration of beaches;

(3) construction and maintenance of small boat harbors;

(4) providing fishing sites on piers and breakwaters;

(5) fish and wildlife conservation;

(6) development of offshore sand sources for beach restoration;

(7) low flow augmentation;

(8) conduct of design and research studies of estuaries at Corps laboratories;

(9) administration of Federal laws protecting and preserving U.S. waters; and

(10) flood and hurricane protection.

In addition, it must be noted that the Corps of Engineers programs of dam building, flood control and river clearance upstream from the estuarine zone have very definite effects on the fresh water inflow to the estuary. Its study programs cover many facets of estuarine research, including physical, chemical, biological, and ecological factors. The comprehensive study of the Chesapeake Bay authorized in 1965 but not yet undertaken, is a typical example of Corps activity in this area.

*Department of Transportation*

The Department of Transportation is the fourth Federal agency whose programs have a direct and significant effect on the resources and the use of the estuarine zone.

Under this Department the Coast Guard performs a series of service activities of essential importance to the beneficial use of the estuaries. These include:

(1) the enforcement of Federal laws within the navigable waters of the United States;

(2) port security with emphasis on the control and movement of vessels and on the safe movement of hazardous cargoes;

(3) maintenance and operation of aids to navigation and regulation and administration of bridges over the navigable waters;

(4) search and rescue assistance to persons operating vehicles and aircraft in distress;

(5) administration of the Federal boating Act of 1958; and

(6) icebreaking.

In regard to the resources of the estuarine zone, those Coast Guard activities having the greatest effect are the enforcement activities concerned with oil pollution control, as provided under the Oil Pollution Act of 1924, as amended, and its attempts to find ways to ease or eliminate the unavoidable pollution. The Coast Guard now has an active research program in oil pollution abatement, containment, source control, and recovery of oil spills. Its role in the ocean data buoy system program could assist in inshore pollution monitoring at a later date.

Also under the Department of Transportation, the Federal Highway Administration's Bureau of Public Roads is concerned with estuarine resources because many of its highways cross and provide access to estuaries. The Federal Aviation Administration's activities in the construction and operation of airports encroach upon the estuaries and have impact on the surrounding environment.

CATEGORY 2: PROGRAMS HAVING INDIRECT OR RELATED EFFECTS

In this category are the programs and activities of the Department of Housing and Urban Development, Agriculture, and Health, Education, and Welfare. In general, certain of their programs do have direct and beneficial effect in the estuarine zone but they have it indirectly, a result of programs directed towards the land rather than the water areas of the estuarine zone.

*Department of Housing and Urban Development*

The Department of Housing and Urban Development provides direct financial and technical assistance to States, metropolitan, and local areas for comprehensive planning, housing, and other aspects of urban and metropolitan development. Much population growth and development is near estuarine zones, and assistance programs for the planning, development, and use of estuaries and adjacent properties have significant impact on these zones.

Comprehensive planning grants provide assistance to many levels of government for the preparation of comprehensive plans for land use, facilities, and the use of natural resources. Comprehensive planning on an areawide basis is required as a condition for funding many facility grant programs which directly affect estuarine zone management. Grants for water and sewer facilities, for acquisition of sites for public uses, and for the purchase of open space for parks, recreation, and conservation can all contribute to better use of waterfront areas and can aid in more effective estuarine management.

The national flood insurance program, authorized by the Housing and Urban Development Act of 1968, requires land use provisions to restrict future development of flood-prone lands. By June 30, 1970, permanent land use and control measures consistent with land management must be adopted by State or local areas before insurance coverage is provided. Title I of the Housing Act of 1949 provides loans and grants for urban renewal or redevelopment of waterfront areas. The open space program can help protect urban wetlands and develop or preserve undeveloped, waterfront areas for recreational use. Newer programs, such as model cities, can assist estuarine management by providing a coordinated program to improve the urban environment. The new communities provision of the 1968 act will encourage the private development of new communities by guaranteeing the financing by developers. These can contribute toward estuarine management through the location and design of land use patterns so as to reduce pollution loads and improve recreational facility development.

*Department of Agriculture*

The Department of Agriculture contributes to the overall management, use, and preservation of the estuarine system. The particular program concern of the Department is land use, soil and water conservation, erosion prevention practices, and certain measures involved in placing and maintaining these lands in a stable and productive condition. As erosion and the volume of sediment is diminished, the estuaries can more effectively perform their normal biological roles. Its areawide sewer and water planning grants and its sewer and water facilities loans and grant, contribute to the abatement of pollution to the extent that they are adjacent to the estuarine zone.

Under Public Law 566, watershed projects provide effective control and stabilization of sediment source areas that could otherwise contribute harmful deposits into estuarine areas.

The Forest Service has Federal leadership in the forestry phases of watershed protection. Twelve national forests, which involve lands that drain directly into estuarine areas, have land management activities that directly affect the estuarine resource.

Research directed toward pesticide residues in silt and the use of brackish water for irrigation will contribute to an increase in knowledge of the estuaries, their uses, and problems.

Here again is an example of programs directed toward land use and the preservation of that land contributing also to the preservation of the estuarine zone. In that they do so, the planning of such activities should be related to any comprehensive estuarine management plan.

*Department of Health, Education, and Welfare*

The relationship of this Department to estuarine zones and management includes its concern about the fitness or suitability of these areas for human use and the resulting impact on human health and well-being. The Public Health Service of the Department has jurisdiction over its estuarine-related activities through the Consumer Protection and Environmental Health Service; namely, the pesticides and shellfish sanitation programs of the Food and Drug Administration and the Bureaus of Solid Waste Management, Water Hygiene, and Radiological Health of the Environmental Control Administration.

Food and Drug Administration activities include the evaluation of food additives and pesticides in seafoods, conducting studies on flora and fauna of certain estuaries, the development of fish protein concentrate, ecological studies of clostridia (botulism), toxicity, and carcinogenicity of smoked fish, salmonella in fishery products, virus in marine foods, and toxicological screening. The Food and Drug Administration is also responsible for administering the national shellfish sanitation program, which is primarily concerned with the sanitary production of safe shellfish from high quality estuarine waters.

The Bureau of Water Hygiene conducts studies on health aspects of the water quality of the marine environment as it relates to shellfish production, recreation, and water resources planning.

The Bureau of Radiological Health conducts projects on reactor effluent radionuclides in marine ecosystems, radiological surveillance of marine environments, and the passage of radioelements through subtropical marine environment and biota.

The Bureau of Solid Waste Management is surveying through contract, the ocean disposal problem and expects to produce pollution potential data. A research project in Boston, Mass., is studying the effect upon the marine ecosystem of incinerator residue.

## CATEGORY 3: RESEARCH AND STUDY PROGRAMS

In category 3 are those agencies whose activities in the estuarine zone are primarily research in nature; namely, the National Science Foundation, the Smithsonian Institution, and the National Academy of Sciences-National Academy of Engineering. The programs and activities of all three of these organizations are extremely broad and it is only as their activities relate directly to the estuarine zone that we briefly describe them here.

*The National Science Foundation*

The National Science Foundation supports scientific research and education in the sciences, including estuarine-related disciplines. It has funded the development of marine and atmospheric research facilities. It has also sponsored a broad spectrum of research activities, and has supported the education of environmental scientists of all kinds. The agency was also given additional authority by the National Sea Grant College and Program Act of 1966 (Public Law 89-688). Under the provisions of the act, the National Science Foundation acts to support applied research by establishing an Office of Sea Grant program and by preparing policy guidelines for use by grant applicants. Several sea grant programs have been directed largely toward the estuaries.

*The Smithsonian Institution*

The Smithsonian Institution relates generally to the ecological, biological, and geological study, preservation, and educational aspects of fauna, flora, and sediments in estuarine area. It depends upon the accumulation and analysis of adequate biological and environmental data to predict the impact of environmental modifications on the estuarine biota. The modifications must represent improvement rather than degradation. It operates an Oceanographic Sorting Center for the processing of aquatic, biologic, and geologic samples. It develops interdisciplinary conferences, such as on pollution problems in New York Harbor. It conducts studies on subjects ranging from sedimentation and beach erosion to the distribution and abundance of marine plants and animals. The agency is involved with several research facilities with capabilities in the area of estuarine ecosystems and in various kinds of tropical research.

*National Academy of Sciences—National Academy of Engineering*

The National Academy of Sciences (NAS) and the National Academy of Engineering (NAE) are twin organizations composed of distinguished scientists and engineers dedicated to the furtherance of science and engineering and their uses for the general welfare. Although not Government agencies, the academies enjoy close relations with the Federal Government from which they hold congressional charters. Each charter specified, "the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose, but the Academy shall receive no compensation whatever for any service to the Government of the United States."

The NAS and the NAE contribute to the development of knowledge of the Nation's estuaries through their respective Committee on Oceanography (NASCO) and Committee on Ocean Engineering (NAECOE). The most recent contribution of the NASCO and NAECOE, acting in concert, has been the conduct, at the request and under the sponsorship of the Federal Water Pollution Control Administration, of a meeting: "Coastal Waste Management," held in June 1969. This session is described elsewhere in this report; the final resultant document will be published by the Academies early in 1970. The purpose of this meeting was to examine the following questions:

(1) What is known about the impact of wastes on the oceans?

(2) What is known about the magnitude of the impact the marine environment can tolerate?

(3) What is our present capability to predict future impact of wastes on the coastal ocean environment?

(4) What investigations should be undertaken in order to improve our ability to handle the above questions?

The National Academy of Sciences and the National Academy of Engineering have a history of significant contributions to knowledge necessary to develop a sound system of management for the estuaries and will continue to offer valuable guidance in the future by bringing together in appropriate groups the most competent scientists and engineers in the country to deal broadly with scientific and engineering problems in estuaries and to exchange information in the furtherance of research.

## CATEGORY 4: PLANNING, COORDINATING, AND LICENSING PROGRAMS

These are the Government agencies whose functions lie generally in the field of planning, coordinating, or licensing. Their activities as they relate to or affect the estuarine zone are briefly described.

*The Water Resources Council*

The Water Resources Council, established in the Water Resources Planning Act of 1965 (Public Law 89-90) awards planning grants to the States for their comprehensive planning in the development of water and related land resources, including estuarine resources. This planning considers that the Nation's estuaries and coastal areas are inseparably related to their watersheds and to the rivers which supply them with fresh water. These watershed relationships determine the characteristics of estuaries and coastal areas and influence their usefulness to man. Among the many objectives of such planning is a consideration of appropriate regional institutional arrangements necessary to implement the comprehensive plans. It also advises the President on national water policy, maintains a continuing assessment of national water supply needs, and coordinates the activities of Federal water resources agencies. The Council also oversees the execution of congressionally authorized comprehensive water and related land resources planning projects for specific river basins. Existing Federal-State river basin commissions under the aegis of the Council are organized and functioning in 15 of the 30 coastal States, and alternative Federal-State planning coordination mechanisms are organized in all the remaining coastal areas under the general leadership of the Water Resources Council.

*National Council on Marine Resources and Engineering Development*

The Marine Resources and Engineering Development Act of 1966 (Public Law 80–454) established two complementary bodies: The Commission on Marine Science, Engineering, and Resources and the National Council on Marine Resources and Engineering Development. The latter provides for the development, encouragement, and maintenance of a comprehensive long-range and coordinated national program in marine science. The national program applies to oceanographic and scientific endeavors and disciplines, engineering, and technology in and with relation to the total marine environment. The report of the Commission with respect to multiple use of the coastal zone will be discussed in some detail in a later chapter.

*The Atomic Energy Commission*

The interests and operations of the Atomic Energy Commission (AEC) regarding the estuarine zone lie almost completely in the effects of radiological and thermal wastes as pollutants in estuarine zones. Research programs and projects of the Commission most directly related to the estuarine system are conducted through contracts, with an emphasis on nuclear safety. Such board programs include—

(1) Disposal of radioactive wastes—their effects and movements through estuarine zones;

(2) Accumulation of radionuclides in wildlife and sediments of these zones and their relation to the ecology of the zone;

(3) Use of radionuclides in pollution study and the detection of pollution, and in some cases, the abatement of pollution; and

(4) Thermal effluents from atomic plants.

The AEC licenses nuclear plants from the standpoint of radiological safety only. This important licensing authority unfortunately does not now require consideration of other environmental effects, particularly those of thermal effluents.

*Federal Power Commission*

The Federal Power Commission is an independent agency operating under the Federal Power Act, the Natural Gas Act, and other statutes. It is concerned principally with the regulation of the interstate aspects of the electric power and natural gas industries. Some of the regulatory activities involve power and natural gas facilities located in estuarine zones.

Under the authority of the Federal Power Act, the Commission issues licenses for the construction and operation of non-Federal hydroelectric power projects on navigable waterways, on any stream over which Congress has jurisdiction where the project affects interstate commerce, or on public lands or reservations of the United States; it investigates and prepares reports on the water and power development of the rivers of the United States; it collects data on the electric power industry; and it studies plans for reservoir projects proposed to be constructed by Federal agencies and makes recommendations concerning the facilities to be installed for hydroelectric power development. That act directs the Commission to promote and encourage the voluntary interconnection and coordination of electric utility systems to assure an abundant supply of electric energy throughout the United States with the greatest possible economy and with regard to the proper utilization and conservation of natural resources.

## Section 3. A Synthesis of Federal Programs and Their Means of Coordination

The Federal programs in the estuarine zone are widespread and quite obviously have far-reaching effects. They must support the national interest and meet numerous Federal responsibilities. In addition, they have a considerable effect on State and local programs. To be effective the various Federal programs should complement each other, should avoid duplication, and should be well coordinated with one another and with the corresponding State-level programs.

In order to present a reasonably clear synthesis of the Federal programs, the accompanying table V.1.1 presents a summary of major Federal activities in six different estuaries. For each Department and for each of the selected estuaries there are listed the routine activities or programs of the Department and then the additional or special activities in that particular estuary. The routine activities generally stay the same for each estuary and are most often those imposed by statute or results of longstanding programs. The special activities are an attempt to note specific projects, studies, etc., of current or recent nature in individual estuaries. Means of coordination currently in use are listed in the final column. For purposes of simplicity the table presents only the programs having direct and important interest or related effects (categories 1 and 2). This is not to derogate the importance of other activities but only to provide for simpler presentation.

TABLE V.1.1.—SUMMARIZATION OF FEDERAL ACTIVITIES

| Federal department | Delaware Bay | Penobscot Bay | Chesapeake Bay | Coordination |
|---|---|---|---|---|
| Commerce | Routine activities: Mapping and charting environmental prediction Port Development. | Applies to all 6 estuaries | | Coordination is carried out in terms of the requirements imposed on the various programs. |
| | Special activities: None reported. | Special activities: Special Estaurine flushing studies and predictions. | Special activities: None reported. | Water Resources Council Associate Membership. |
| Transportation | Routine activities: All Coast Guard services, i.e., law enforcement, aids to navigation, rescue, boating safety, port security, control of shipping. | Applies to all 6 estuaries | | Coordination is carried out in terms of requirements imposed on the program in enforcement, boating safety, and the like. Enforcement is carried out in close coordination with State and local authorities. |
| | Special activities: None reported. | Special activities: None reported. | Special activities: None reported. | Water Resources Council Membership. |
| Corps of Engineers (Department of Defense). | Routine activities: Maintenance of navigable waters. Control of dredge and fill by permit. Harbor pollution. Harbor construction. | Applies to all 6 estuaries | | Coordination through working closely with State counterparts. Corps projects themselves are developed through extensive coordination of the various needs and expressed desires of State and local interests—and Federal interests. |
| | Special activities: Scale hydraulic model (Vicksburg). Study scheduled on deep draft channel. | Special activities: Deep draft channel study. | Special activities: Special study of the Chesapeake Bay authorized by Act of Congress 1965. | Mutual assistance projects, grants, joint projects and studies with States and other Federal agencies.<br>Coordination through regulatory activities (the permit system) granting of the permit coordinated with State authorities and with Federal agencies through Interior Corps memorandum of agreement.<br>Coordination through the Water Resources Council. |
| Interior | Routine activities: Permit review in conjunction with Corps of Engineers permit activities. Land and Water Conservation Fund Grants, Sewage and Construction Grants, various Planning and Manage- | Applies to all 6 estuaries | | Coordination through conference, consultation, and working in conjunction with State and local personnel. Field level conferences with State and other Federal agency personnel. Formal report coordination through State agencies. Participation in River Basin Commission |

| | | | | |
|---|---|---|---|---|
| | ment and Resource Preservation and Development Grants. Water flow data, participation in River Basin Commission Type I and II studies. | | | studies under the Water Resources Council. Coordination through the administration of grants and subsidies. Permit review in conjunction with Corps of Engineers permit system. Regulatory and Enforcement Activities. |
| | Special activities: Special shad study. Sedimentation study. Flushing pattern research. | Special activities: Participation in conservation, biological and heavy metal studies. | Special activities: Various Fisheries and Fisheries Economic Studies. Milfoil and Sea Nettle Studies. BCF Biological Laboratory. FWPCA Chesapeake Technical Support Laboratory. Water Quality Enforcement (Potomac) Administration of Historic Shrine. Participation in various ecological, biological, chemical and geologic studies. | |
| Agriculture | Routine activities: Soil and water conservation projects. Sewer and water planning and construction grants. Watershed protection. Flood control. | Applies to all 6 estuaries | | Coordination through working closely with State counterparts in Soil Conservation Districts. Administration of grants and subsidies. Interagency reviews of projects and work plans. Coordination and cooperation at State level by SCS and State Highway organizations. Participation in River Basin Commission Studies Type I and Type II under Water Resources Council. |
| | Special activities: Dune stabilization adjacent to Delaware Bay. | Special activities: Special assistance grants with measures to control pollution. | Special activities: Bank erosion control projects. | |
| Health, Education, and Welfare. | Routine activities: Marine Health, Pesticides, Public Water Supply Food and Drugs from Marine Sources. Solid Waste. Shellfish Sanitation Program. | Applies to all 6 estuaries | | Coordination through working directly and closely with State counterpart organizations. Technical assistance to State and Federal agencies on Marine Health. |
| | Special activities: Sewage sludge dump site study | Special activities: Special shellfish sanitation survey. | Special activities: Planned special study regarding effect of sewage plant. | |
| Housing and Urban Development. | Routine activities: Planning and assistance in use of water. Adjacent property. Areawide and local planning. Water and sewer facilities grants. Open space land grants. | Applies to all 6 estuaries | | Coordination through participation as associate member of Water Resources Council in River Basin Commission Studies. Operation of Planning Assistance Requirements Coordinating Committee (PARCC). DOB Circular A-95—Coordination of federally assisted planning activities. Inter-departmental reviews by executive order and name of agreement. |
| | Special activities: None reported. | Special activities: None reported. | Special activities: None reported. | |

TABLE V.1.1.—SUMMARIZATION OF FEDERAL ACTIVITIES—Continued

| Federal department | Tampa Bay | San Francisco Bay | Puget Sound | Coordination |
|---|---|---|---|---|
| Commerce | Special activities: None reported. | Special activities: None reported. | Special activities: None reported. | Coordination is carried out in terms of the requirements imposed on the various programs.<br>Water Resources Council Associate Membership. |
| Transportation | | | | Coordination is carried out in terms of requirements imposed on the program in enforcement, boating safety, and the like. Enforcement is carried out in close coordination with State and local authorities.<br>Water Resources Council Membership. |
| Corps of Engineers (Department of Defense). | Special activities: Special hurricane protection measures report. | Special activities: Coordinated comprehensive survey—navigation flood control, water supply land reclamation, recreation, national defense, etc., operates Hydraulic scale model. | Special activities: Comprehensive survey 1969. | Coordination through working closely with State counterparts. Corps projects themselves are developed through extensive coordination of the various needs and expressed desires of State and local interests—and Federal interests.<br>Mutual assistance projects, grants, joint projects and studies with States and other Federal agencies.<br>Coordination through regulatory activities (the permit system) granting of the permit coordinated with State authorities and with Federal agencies through Interior Corps memorandum of agreement.<br>Coordination through the Water Resources Council. |

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|---|---|---|---|---|
| Interior | Special activities: Commercial shellfish study, water quality study, Hillsboro Bay Administration of historic shrine. Oyster shell dredging study. BCF Biological Laboratory. | Special activities: Establishment of Interior Task Force to work with State. Special Navigation project studies, water quality management study. | Special activities: Various commercial fisheries studies, water quality enforcement (1962), Flushing and Sedimatation Studies. BCF Biological and Technical Laboratory. | Coordination through conference, consultation, and working in conjunction with State and local personnel. Field level conferences with State and other Federal agency personnel. Formal report coordination through State agencies. Participation in River Basin Commission studies under the Water Resources Council. Coordination thru the administration of grants and subsidies. Permit review in conjunction with Corps of Engineers permit system. Regulatory and Enforcement Activities. |
| Agriculture | Special activities: Sedimentation Study. | Special activities: Bay Council of Soil and Water Conservation Districts formed to improve Bay environment. | Special activites: Participation in comprehensive land and water resources study. Management of National Forest Lands (33% of drainage area) Special Watershed projects. | Coordination through working closely with State counterparts in Soil Conservation Districts. Administration of grants and subsidies. Interagency reviews of projects and work plans. Coordination and cooperation at State level by SCS and State Highway organizations. Participation in River Basin Commission Studies Type I and Type II under Water Resources Council. |
| Health, Education, and Welfare. | Special activities: Heavy Metals Study. | Special activities: None reported. | Special activities: Heavy Metals Study, Special Shellfish Studies, Marine Health Science Laboratory. | Coordination through working directly and closely with State counterpart organizations. Technical assistance to State and Federal agencies on Marine Health. |
| Housing and Urban Development. | Special activities: None reported. | | Special activities: None reported. | Coordination through participation as associate member of Water Resources Council in River Basin Commission Studies. Operation of Planning Assistance Requirements Coordinating Committee (PARCC). BOB Circular A-95—Coordination of Federally assisted planning activities. Inter-departmental reviews by executive order and memo of agreement. |

Working from the information presented in the table there follows a discussion as to the adequacy of the programs in meeting the requirements of national interest and Federal responsibility and a review of the current state of coordination.

ADEQUACY OF PROGRAMS

The national interests in the estuarine zone in relation to Federal programs are protection and development of natural resources, commerce, navigation, and national defense.

First, in regard to the protection and development of the natural resources of the estuarine zone, the Department of the Interior very likely has the strongest effect here since it has broad interests and management responsibilities in the use, preservation, development, and study of our living and nonliving marine and related land resources in the estuarine zone. At the same time, the Department is also interested in the equitable and reasonable exploitation of these areas for all manner of business and commercial activities. Through its permit review activities in connection with the Corps of Engineers, definite action goes on with particular emphasis on the protection of the vital fish and wildlife habitats and prevention of water pollution. In general, Interior's programs meet objectives. A serious weakness lies in financial limitations. What is being done is good but not enough can be done. This is particularly apparent in the need for estuarine zone or coastal zone research laboratories devoted to the problems and the resources of the estuaries and adjacent coastal areas.

The permit control activities of the Corps of Engineers under the Rivers and Harbors Act of 1899, the Fish and Wildlife Coordination Act, as amended, and the Interior-Army memorandum of understanding of 1967, act directly in the protection and development of the estuarine resources. Army policy requires permit applicants to seek State approval before its own consideration of the application. The Corps issues public notices and holds public hearings when there is appropriate demand. The permit control activities are effective and cover a large part of the preservation or protection problem, but there are two weaknesses. First, the authority of the Corps to deny a permit on any grounds except impediment to navigation has been successfully challenged in Federal court. Second, there is the matter of policing or enforcement. The Corps simply does not have sufficient facilities and personnel to police the Nation, thus change and alteration may take place without Corps authorization.

The licensing activities of the Atomic Energy Commission (not in the chart) now cover only radiological safety—this by statute. They do not take into account environmental effects, thus can supply only limited protection to estuarine natural resources.

The routine activities of the Departments of Agriculture, Health, Education, and Welfare, and Housing and Urban Development, as can be seen from the chart, contribute to the protection of natural resources for the overall public good. Their effect is not always a direct one but, nevertheless does make a strong and continuous contribution. Like those of Interior the programs are effective. With more funds and facilities they would naturally increase their effects.

For those national interests of commerce and navigation, the chart shows a series of activities both contributing and controlling, for this is essentially a direct Federal responsibility.

Commerce supplies the necessary mapping and charting for navigational purposes, the marine weather service and port development. The Coast Guard under Transportation regulates waterborne commerce and maintains navigational aids. The Corps of Engineers maintains the navigable waters and the Department of Health, Education, and Welfare maintains a marine health program. Since commercial shipping is one of the most valuable and efficient uses of the estuarine zone these Federal services can be considered adequate to meet the national interests, at least under current law and funding.

Nevertheless, as pointed out in the Report of the Commission on Marine Science, Engineering, and Resources, and in other studies, rapidly changing trends in shipping—containerization and larger ships among other things—make a review of the situation necessary. A thorough study and national survey covering future requirements is needed.

In regard to national security, as a national interest in the estuarine zone, the Federal programs appear to be adequate. The Navy as a user relies on the same support programs as does other commerce. Major naval bases, of course, are in the same area and all the logistic support of the many facets of defense beyond the continental limits pass through the area.

## THE COORDINATION OF FEDERAL PROGRAMS IN THE ESTUARINE ZONE

With many different Federal agencies managing active and important programs in the estuarine zone, the question is frequently asked, "How is coordination accomplished with this multitude of programs?", or, "Is there any coordination at all?" The assumption is usually made that it's all a very thorough mess and there is no proper control over the situation. In truth, there is coordination and there is progress in obtaining better coordination, yet there are some serious weaknesses, and corrective action is needed.

### *Specific means of coordination*

From the chart several distinct and important means of coordination can be seen. These are:

(1) Working closely with State and local counterparts in the development of programs and in mutual assistance—joint projects and studies—data gathering and exchange of information;

(2) The administration of grants and subsidies—joint review of plans and applications;

(3) Regulatory activities—permits, licensing and enforcement of Federal laws;

(4) Statutes, Executive orders, Bureau of the Budget circulars;

(5) Memoranda of agreement; and

(6) The work of the Water Resources Council and its river basin commission and interagency organizations.

The means of coordination are many—the point in question is "How do they work and what are the results?"—at State and Federal levels.

*Coordination at the State level*

As the table shows, perhaps the strongest means of coordination is that of working directly with State counterparts in the development and administration of various programs. Through the administration of grants and subsidies the Federal agencies also must work closely with appropriate State and local agencies. The granting of permits and licenses is normally done in conjunction with State agencies. The Corps of Engineers, for example, desires and usually obtains State approval of permits before granting the Federal permit. The Coast Guard in its law enforcement activities works in close conjunction with State authorities in inland and coastal waters. These are but a few of many examples. There is also coordination at the State level through the river basin commissions and interagency organizations under the aegis of the Water Resources Council since the States are members of these organizations and participate with various Federal agencies in the planning studies.

The fact that there is this coordination at the State and local level supplies an important component of coordination to the Federal programs since the States must attempt to integrate these Federal programs into their own activities. The great weakness is that all too frequently Federal agencies deal only with their particular State counterparts and thus work with the States does not tend to pull the Federal programs together. In those cases where there is a comprehensive State management plan for the estuarine zones and coastal area and there is a State agency implementing this plan, there could be much stronger and more effective coordination.

*Coordination at the Federal level*

Coordination of Federal programs in the estuarine zone takes place through several of the previously listed methods in addition to that which results from the extensive coordination at the State level. Memorandums of understanding are one of the most used methods and are particularly applicable to the joint reviews of applications in the administration of grants and subsidies. In regulatory activities there is a continuous series of joint reviews or permits and licenses. The 1967 Memorandum of Agreement between Interior and Army which calls for Interior review of permits from the standpoint of environment and natural resources results in coordination of Interior and Corps of Engineers activities. The enforcement of water quality standards brings about a form of coordination since Federal programs must be reviewed and considered to determine their effect. Passage of such legislation as S. 7 or H.R. 4148 would bring an even stronger control and coordination mechanism into play, in that State certification of the fact that an applicant's facility would not cause violation of water quality standards would be required prior to granting a permit or license.

Under statutes, Executive orders and Bureau of the Budget circulars, there is a continuous routine of coordination required. For example, Bureau of the Budget Circular A. 95 furnishes guidance to Federal agencies for added cooperation with States and local governments in the evaluation, review, and coordination of Federal assistance programs and projects.

Federal programs are also coordinated as necessary by the requirements imposed on them, or in other words, in general order of daily business.

A very good example of this is mapping and charting activities and aids to navigation. When the Corps of Engineers establishes a new navigation channel or changes one, the Coast Guard is informed and makes the necessary changes of navigation aids. The Environmental Sciences Services Administration under the Department of Commerce is aware and takes the necessary steps to have these changes placed on the proper navigational charts. Information regarding the changes is published in the form of Notices to Mariners and put out by the U.S. Naval Oceanographic Office under the Department of the Navy. This is all reasonably automatic coordination, there is much of it and it is very effective.

A most important form of coordination and one which encompasses all our charted organizations is that carried out under the guidance of the Water Resources Council. As noted in the table describing Federal activities in the six estuaries, membership or associate membership on the Water Resources Council and participation in the planning studies conducted by the river basin commissions or the interagency committees provide a significant means of coordination.

To highlight its interest in the estuaries and estuarine zones the Water Resources Council adopted on November 29, 1967, the following resolution:

> It is the policy of the Water Resources Council that the use, preservation or development, and management of coastal, lakes, and river shorelines and islands and estuaries are to be given full consideration in the planning of use of water and related land resources by river basin commissions established under the Water Resources Planning Act.
>
> The Council also considers the planning for the preservation, development and use of estuaries, islands and coastal, river, and lake shorelines and an appropriate use of Federal and State funds in accordance with title III of the Water Resources Planning Act (which provides authority to assist the States financially in planning for the use of water and related land resources).

The National Council on Marine Resources and Engineering Development charged with the coordination and development of marine sciences created the Committee on the Multiple Use of the Coastal Zone (CMUZ) in August 1967. This committee through its meetings, studies, and symposia was an excellent forum for bringing forth the problems of the estuaries and the adjacent coastal area.

In regard to the furtherance of coordination it should be noted that the Water Resources Council, by memorandum for the record dated June 18, 1969, has in agreement with the National Council for Marine Resources and Engineering Development established procedures whereby the National Council will review plans and studies relating to the coastal zone and that a member of the council staff would attend meetings of the Water Resources Council where such plans, studies and reports are to be discussed.

## SECTION 4. SUMMARY

It can be seen that the sum total of the current Federal programs in the estuarine zone are broad in scope and reach into every facet of the area. Within the limits of the authorities and resources available these remain well directed toward their objectives and are reasonably effective.

THE CURRENT ROLE

The role of the Federal Government in brief continues to be one of support and technical assistance, of regulatory activities within current law, and of the provision of normal Federal services, such as, navigation aids, channel and harbor maintenance, protective works, and weather service. The Federal Government continues to promote and encourage cooperation among the States in interstate estuaries. It participates in broad studies and inventories particularly as directed by Congress in specific acts. Land acquisition in the estuarine zone continues under the various current laws, and research goes forward.

*Augmentation*

Even though the Federal programs cooperate reasonably within their statutory authority the accomplishments when combined with State and local activity are not enough as yet to really slow down the loss of valuable estuarine zones. The conflicting demands on the resources of the estuarine zone increase at a rather rapid rate. Unplanned and unregulated alteration and modification of the area, mostly as the result of activities by the private sector continues with a consequent loss of wildlife habitat and a decreasing availability of open space for public use. The cause is in part rapid urban and suburban development, heavy industrial growth and increased population. Development in the estuaries is necessary and will continue, but it should be done in a planned and regulated way designed to provide the most beneficial use. To do so, integrated and coordinated management and planning is needed. This will require more technical assistance of all kinds, more knowledge to be gathered through research and data collection. Not in the least, it will require more effective use of current programs and authorities. This simply means more money and more people. As has been pointed out before in this chapter, the Corps of Engineers does not have the overall facilities and personnel to administer its permit program in the most effective manner. In cooperation with the States, land acquisition by the Federal Government directly and through grants-in-aid programs proceeds at too slow a pace. There is in particular no grant-in-aid program which concentrates its activities in the estuarine zone and which could assist the States in developing that type of State organization that could prepare and implement an integrated and comprehensive plan for its overall estuarine zone.

*Coordination*

In terms of coordination it is relatively easy to point out that the strongest coordination of the Federal programs takes place at the State level, that is, that it is accomplished to the greatest extent by working closely with the States. As noted, the weakness of this is generally the lack of a single strong State organization to deal with.

There have been noted many other means of coordination. All appear to work fairly well, but not well enough to provide an effective and comprehensive program of management in the estuarine zone. There is no single policy and no national policy which would provide for the protection of national interests and for development, preservation and use of the estuarine zones for the overall public good. Such a policy would be helpful in the coordination of Federal programs.

### A STRONGER FEDERAL ROLE

It is apparent from the above discussion that there are needed additions to the Federal role and programs and that augmentation would be helpful in certain areas.

There needs to be added:

(1) A national policy with specific objectives to provide coherence to the Federal programs and to lay the basis for better coordination of these programs. This national policy should also contain guidelines to the States based on the policy and objectives.

(2) A stronger means of coordination of the Federal programs. This could well lie in an interagency group charged with monitoring developments and conditions in the estuarine zones and with providing at specified times a review and report of the situation.

(3) A system of grants to the States to provide them the ability to prepare and implement comprehensive plans for their estuarine zones. These plans and the State organizations behind them could be a strong factor in the effective coordination of Federal programs within the State.

Augmentation is needed:

(1) In various technical assistance, research and information programs and the grant programs supporting these.

(2) In the programs of land acquisition in the estuarine zone.

(3) In strengthening the regulatory and enforcement activities of the Federal agencies. This in terms of personnel and facilities and in terms of strengthened Federal law. The terms of S. 7 and H.R. 4148, if passed, will contribute a great deal to this.

(4) In terms of increased broad studies at the Federal level and jointly with the States. Examples not now authorized are a national port study and studies on site locations for potential electric power generating plants. As noted in the chapter devoted to research needs, continuous broad studies in hydrology, living resources, and ecology are needed.

(5) Increased research effectiveness is needed in terms of better use of existing Federal research facilities through organization and reorientation to broader estuarine problems and their solutions. There are also needed additional facilities devoted to research in the estuarine zone, probably in the form of a network of estuarine and coastal zone laboratories, Federal in nature but with State participation.

### CONCLUSION

In very brief conclusion regarding the Federal programs in the estuarine zone, it would appear that both augmentation and better coordination are needed to assist in providing for a strengthened Federal role. There is also needed a national policy and a set of objectives to provide the basis for a comprehensive national program of management within which a newer and stronger Federal role will be carried out.

# CHAPTER 2. COASTAL STATES' RESPONSIBILITIES, PROGRAMS, AND ROLES

## SECTION 1. STATE PROFILE DEVELOPMENT

As specified in section 5g of the Clean Water Restoration Act of 1966 in amending the Federal Water Pollution Control Act, the National Estuarine Pollution Study and the resulting report to the Congress shall include the development of recommendations for the "* * * respective responsibilities which should be assumed by Federal, State, and local governments and by public and private interests." Also, the act specifies that the study shall be conducted in cooperation with appropriate State organizations, institutions, and individuals.

Because of the key or important role of the States in managing the estuarine zone, it is essential to define the scope of present management frameworks and from that to develop what should be the proper role of coastal State governments in regard to marine-coastal-estuarine resources. Coastal States are indicated in figure V.2.1. Likewise, it is essential to find out weaknesses as well as strengths, accomplishments versus needs, existing organizations versus proposed ones, negative as well as positive views, and deficiencies as well as resources. Thus, the overall State picture must be defined clearly as a basis for creating, building, and basing plans and programs for estuarine management. Toward this goal the National Estuarine Pollution Study obtained from the coastal States the information for the development of profiles which define and outline the State's overall picture, which define the States' views and which assure that States' opinions are included for consideration in the development of the management plan. The following section of this report summarizes these findings.

### METHODS OF PROFILE DEVELOPMENT

The source of material used in the profiles of the coastal States was developed through contracts, direct and indirect, with the State governments and supplemented by material and reports in the technical literature.

Beginning in 1967, the Governors of the 24 coastal States and the territories were notified that the advice and counsel of the States were essential to the success of the study, and they were asked to designate a person to serve as the State's primary contact point for this project. The primary concern underlying this procedure was that the study did

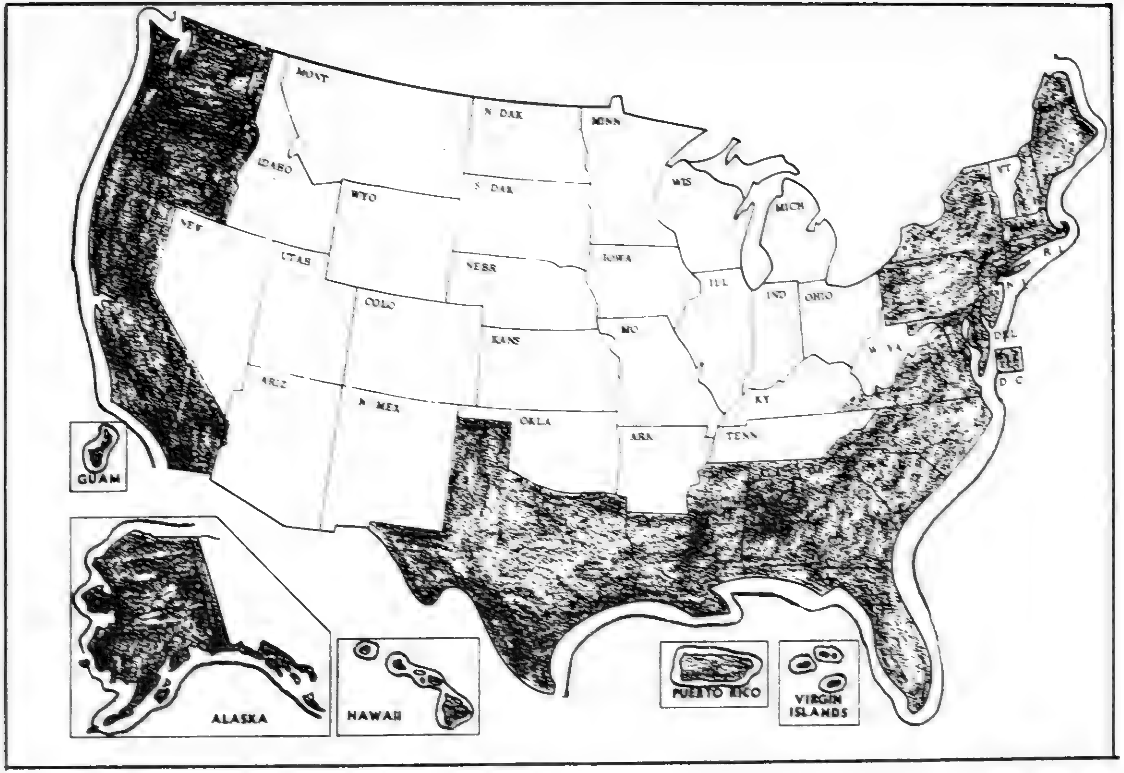


FIGURE V.2.1
The Coastal States (shaded areas)

not want to burden the States with the tasks of completing lengthy questionnaires or providing data summaries and that it wanted to avoid duplication of effort wherever possible.

Subsequently, the study's regional estuarine coordinators contacted the State estuarine representatives to collect information on the organization and activities of each coastal State in the use of its estuarine resources and to gain the individual State's views in respect to the responsibilities of Federal, State, and local governments in this program. Specifically, each State was asked to provide information on the following 10 topics.

(1) What State agencies are directly or indirectly involved in the use of the estuarine resources of the States? What are their specific programs and what fiscal and personnel resources are available for carrying out these programs?

(2) What mechanisms, if any, has the State provided for coordination of these programs? For example, highway construction, pollution control, and beneficial use.

(3) What are the current problems in estuarine resource utilization within the State, and what are the State views as to how these problems can be managed best?

(4) What information does the State now have on the use of its estuaries? We would like to have copies of relatively recent reports, and would like to have an idea of what additional data may be available in State files but which are not published or organized.

(5) What is the legal authority for the various programs?

(6) What is the legal status of estuary, tidelands, and wetland ownership?

(7) Do the State agencies now have projects underway which are directly related to estuarine resource utilization?

(8) What is the extent of the present direct control of estuaries by States? What is their size, location, and nature of use?

(9) What are examples of current problems in estuarine management or in conflict of uses? The emphasis should be on pollution or estuarine modification.

(10) What are the present State research facilities used in management of estuaries or study of estuarine resources?

The information obtained from the States on these 10 topics was used to develop the profiles. In many cases to supplement these responses, information available to Federal Water Pollution Control Administration Regional Offices in their files, material presented in transcripts of public meetings, reports published by or about the States, results of other studies such as the Commission's reports, other correspondence with the States' governors or agencies, plus direct consultation with appropriate State personnel were incorporated in the profiles. To assure accuracy and adequacy of the profiles, they were returned to State estuarine representatives for approval at the highest possible level, considering the time available. The following material represents a very brief condensation of this mass of information which is being retained and is available *separately* from this report. It is also referenced in part VII as a part of the supporting information used in the preparation of this report.

Since a most important part of this profile is to be an expression of the States' views on the composition and management of a comprehensive national program for estuarine resources, special attention was directed to this area. The individual State's views with respect to responsibilities of Federal, State, and local governments on this program were very diligently sought, not only through the mechanism mentioned above but also by direct correspondence to the States asking specifically for the official State's views. To assure in every way possible that the States had adequate opportunities to express their views, the preliminary recommendations for the comprehensive management plan, including a summary of the available States' views were sent to the States for review and then the States were asked to attend Regional/State review conferences held in various sections of the country. The responses varied widely. Because of the emphasis on this topic, in accordance with section 5g of the act, these views are presented separately, in section 6 of this chapter.

The following table V.2.1 presents a brief summary of information received from and about the coastal States in the area of estuarine management information.

TABLE V.2.1.—ESTUARINE MANAGEMENT INFORMATION RECEIVED FROM COASTAL STATES

| Coastal States and territories | Profile material | Letters [1] State reps. | Letters [1] Gov. letters | Letters [1] Other | Reports | Other [2] |
|---|---|---|---|---|---|---|
| Alabama | X | | | | X | |
| Alaska | X | | | | X | |
| California | X | | | | X | X |
| Connecticut | X | X | | | X | |
| Delaware | X | | | | X | |
| Florida | X | | X | X | X | X |
| Georgia | X | X | | | X | |
| Hawaii | X | | | | | X |
| Louisiana | X | X | | | X | |
| Maine | X | | | | X | |
| Maryland | X | | | | X | X |
| Massachusetts | X | X | | | X | |
| Mississippi | X | | | | X | |
| New Hampshire | X | X | | | | |
| New Jersey | X | X | | | X | |
| New York | X | X | | | X | |
| North Carolina | X | X | | | X | |
| Oregon | X | | X | | | |
| Pennsylvania | X | X | | | X | |
| Rhode Island | X | | | | X | X |
| South Carolina | X | X | | | X | |
| Texas | X | | X | X | X | X |
| Virginia | X | | | | X | |
| Washington | X | | X | | X | X |
| Virgin Islands | X | | | | | |
| District of Columbia | X | X | | | X | |
| Puerto Rico | X | | | | | |

[1] Views regarding Federal-State-local responsibilities in estuarine management.
[2] Including contracts.

## Section 2. Selected State Organizations—A Spectrum of Development

The 24 Coastal States have, in essence, 24 different estuarine management frameworks; viewed together they present a broad spectrum of development towards effective and efficient estuarine management.

To show or indicate this broad spectrum of development, the management frameworks of a few selected States are presented. They provide a basis for defining strengths, deficiencies, or weaknesses in the States' role and establish a path, leading to a more dynamic and effective role of the States in estuarine management.

The following section of the report previews the management systems of selected Coastal States, large to small, rich to less prosperous, populous to sparsely developed, urban to rural, and highly industrialized to mostly pastoral. The selected States are Massachusetts, Maryland, California, Florida, and Alaska. Following this will be a typical State's management framework, State laws, and States' views on estuarine management.

### MASSACHUSETTS

Massachusetts is a relatively small, densely populated, highly urban, highly industrialized, and affluent New England area. The population of Massachusetts is about 5,400,000; the tidal shoreline is about 1,500 linear miles including about 45,000 acres of coastal marshland; and about 85 percent of the people live in urban coastal areas. Ownership of the 1,519 miles of shoreline is as follows:

Federal Government, 110 miles or about 4,500 acres of coastal wetlands.
State government, 45 miles.
Local government, 50 miles.
Universities, and so forth, 25 miles.
Private, 1,289 miles.

Massachusetts' coastline is widely used by the surrounding New England and east coast community as a prime resort/vacation/historical area. The condition of Massachusetts' shoreline areas affects not only the populace of Massachusetts but also that of the surrounding area since so many people throng to Massachusetts for their livelihood, enjoyment, and relaxation.

Massachusetts has developed legislation and corresponding organizational structure for the management of its estuarine areas. The two principal enactments are an act providing for the protection of the coastal wetlands of the Commonwealth (General Laws, ch. 768, act of 1965) and an act relative to removal, filling, and dredging in coastal waters.

Other enactments include the new oil pollution and offshore mineral resource laws.

The estuarine management activities in Massachusetts are focused on the department of natural resources, headed by a commissioner. This department has both operational and regulatory responsibilities in estuarine areas. The coastal dredge and fill law, the coastal wetlands law and new oil pollution and offshore mineral resource laws are all administered by the divisions of this department. The organization of this department is described in figure V.2.2.

- GOVERNOR
  - Dept. of Public Works
    - Div. of Waterways
    - Div. of Sanitary Engr.
  - Dept. of Commerce and Development
  - Dept. of Administration and Finance
  - Dept. of Natural Resources
    - Commissioner
      - Div. of Forest and Parks
      - Div. of Marine Fisheries
      - Div. of Law Enforcement
      - Div. of Fisheries and Game
      - Div. of Conservation Services
      - Div. of Water Pollution Control

FIGURE V.2.2
Massachusetts' Agencies Involved in Management or Control of Estuarine Resources

The primary means by which the department manages the estuarine areas, other than federally controlled areas, such as the Park Service's Cape Cod National Seashore, and the Coast Guard's stations also on Cape Cod, is by restrictive orders—permits, licenses, leases, and so forth—as to the use of these areas, based on the results of public meetings. The department is placed organizationally high enough in the State governmental structure so that its activities and recommenda-

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tions are effective in controlling the development of and alteration of estuarine areas. Such an estuarine management organization must be capable of handling and acting on estuarine problems.

In May 1968, by a Commonwealth executive order (No. 59) the Massachusetts Commission on Ocean Management was created to develop a comprehensive long-range State plan for the management of Massachusetts estuarine areas and to recommend an appropriate State governmental organization to, in essence, carry out the plan. The commission's findings will be reported to the commissioner of natural resources.

Other Massachusetts departments which have organizational responsibilities are the department of public works which is also headed by a commissioner and reports directly to the Governor, and the department of commerce and development which provides planning and program development. A third department, the department of administration and finance acts to provide coordination and to guide joint planning. This department is the agency responsible for personnel, financing, and budget.

Details on the department of natural resources and the department of public works are included in the tabulations on the following pages.

The Massachusetts State government assists the local governments in estuarine management and acquisition through their self-help program which consists primarily of funds awarded to town or city conservation commissions.

The Wetlands Act restricts activities which may pollute the coastal wetlands, whether publicly or privately owned. The act states that "* * * to immediately provide for the protection of coastal wetlands against the imminent threat of the development of such lands for industrial and other uses detrimental to their preservation in their natural state, therefore, it is hereby declared to an emergency law, necessary for the immediate preservation of the public convenience."

Also, the act provides that a city or town may take (by eminent domain) coastal lands in the public interest in order to protect them and for the establishment by the U.S. Government of national wildlife refuges. Examples are the Parker River National Wildlife Refuge and Monomoy National Wildlife Refuge which place about 3,000 tidemarsh acres under permanent protection. Advantages of this act are that the State can restrict the use of large areas in general terms or can be very specific as to permissible uses in small areas.

The second act or Dredging Act restricts people from filling or dredging in any coastal waters without prior approval of the respective town or city and the State.

The Wet Lands Act of 1965 has resulted in State actions that have restricted the use of approximately 5,000 acres and in proposals to restrict 12,000 more coastal acres including immediate action on approximately 1,700 acres of salt marshes in the North River estuary. (See page 378 for coastline map, figure V.2.3, adapted from an outline map of Massachusetts coast, prepared by the Massachusetts Division of Marine Fisheries, Department of Natural Resources, 1969.)

The estuarine management activities and capabilities of the local-government level in Massachusetts are described in the following chapter 3 on local governments. However, in Massachusetts the towns or local level governments control both the leasing and regulation of shellfish. The above description of Massachusetts represents a condensation of material in the Massachusetts profile.

### DEPARTMENT OF NATURAL RESOURCES

*Division of Fisheries and Game.*—(DFG) Full functional responsibility for anadromous species and for waterfowl and animals. Enforces provisions of State inland fish and game laws and regulations.

*Division of Forests and Parks.*—(DFP) Responsible for providing technical assistance to communities and other agencies in the acquisition and development of marine environment recreation lands.

*Division of Law Enforcement.*—(DLE) Responsible for marine patrol and rescue assistance within the Commonwealth's waters. This agency is responsible for the enforcement of all laws, rules, and regulations relative to marine fish and fisheries.

*Division of Conservation Services.*—(DCS) Serves as a coordinating and interfacing agency between regional within-State groups and also with Federal agencies. Responsible for administering policy on preventing coastal pollution and for preserving biological and zoological systems as related to coastal wetlands.

*Division of Marine Fisheries.*—(DMF) Charged with management of all marine fishery resources within the territorial limits of the Commonwealth except such shellfish and alewife control as has been allocated to the cities and towns. The program concentrates on estuarine fisheries research and on both basic and applied research on shellfish and lobsters.

*Division of Water Pollution Control.*—A recently created agency to enforce water quality standards.

### DEPARTMENT OF PUBLIC WORKS

*Division of Waterways.*—(DW) Executive agency responsible for harbor pollution and for transportation and disposal of refuse at sea. Full functional responsibility for operation and maintenance of the four State beaches and for construction of public recreational boating facilities and for design and construction of shore protection structures and dredging projects in collaboration with local communities. Also licensing and permits for all tidewater structures including fish weirs. Specifically, the Division regulates an existing law concerning the removal of sand and gravel from tidal shores. An amendment to the basic law administered by this Division gives the local governments some authority since they may call hearings upon any application to remove, dredge, or fill.

*Division of Sanitary Engineering.*—Supervises and controls public water supplies and sewage disposal systems, and regulates public health aspects of shellfisheries.

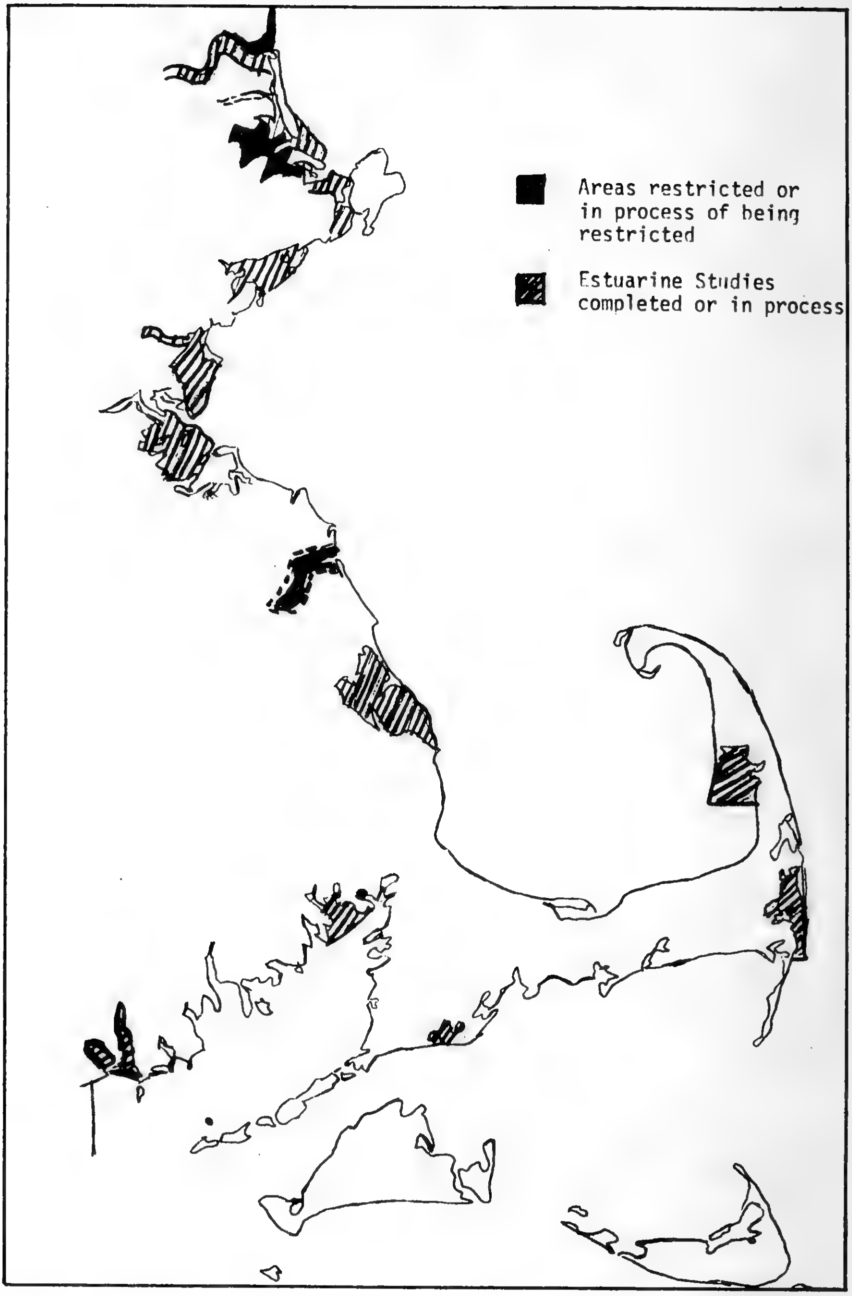


FIGURE V.2.3
Map of Massachusetts Coastline, Showing Restricted-Use Areas

Six activities, DMF, DW, DFG, DFP, DLE, DCS, have well-defined areas of cognizance and cooperate through cordinating committees—the Marine Coordinating Committee on Coastal Wetlands and the Recreation Advisory Council within the Department of Natural Resources. The latter council is composed of representatives of all State agencies and other recreation-oriented groups. On an overview basis, the Division of Conservation Services is the authority responsible for the act which governs keeping coastal areas free from pollution and an act relative to removal, filling, and dredging in coastal waters. The Division of Waterways, Division of Sanitary Engineering, and the Division of Water Pollution Control act in consort to complete the program. The Division of Marine Fisheries is responsible for identifying what measures must be taken to protect the fisheries but they do not regulate or enforce such measures—the Division of Conservation Services and its colleagues ostensibly do.

## MARYLAND

The State of Maryland is a political entity which encompasses a portion of a major estuarine area—the Chesapeake Bay. Maryland also can be considered as being representative of a State having an urban/rural population mixture with a moderate level of industry and development.

Until July 1969 the Board of Natural Resources acted as the coordinating agency for all public and private activities relating to the natural resources of the State of Maryland. At that time the Board was disbanded, and Maryland House bill 1311 (approved April 1969) created the Department of Natural Resources as a principal department of the State government to be responsible for carrying out policies in the area of natural resources research and development, management, and administration. This department is responsible for the coordination and direction of comprehensive planning in the area of natural resources. The Maryland Department of Natural Resources is composed of the previously existing Department of Chesapeake Bay Affairs, the Department of Game and Inland Fish, Department of Forests and Parks, Maryland Geological Survey, Department of Water Resources plus memberships in numerous commissions, committees, and groups of which the State is a member.

The Maryland Department of Natural Resources has not developed to its full potential in assuming its broad responsibilities of coordinating all duties related to natural resources which exist in other agencies in the State. Detailed description of the authorized scope of the department of natural resources is included in the Maryland House bill No. 1311. Therefore, this department's scope has been briefly described on the basis of the bill and the following discussion is concerned with the prior and continuously existing activities of its estuarine-related departments

The department of Chesapeake Bay affairs has the broad responsibility for planning for the development and management of the Chesapeake Bay and other tidal waters including protection and development of its resources.

The Department of Game and Inland Fish is indirectly involved in estuarine management issuing hunting, fishing, and other licenses and studying underwater problems affecting wildlife.

The Department of Forests and Parks is indirectly involved in the management or control of estuarine areas in that it promotes good forest management practices on both public and private woodlands, including those adjacent to tidal waters.

Maryland Geological Survey conducts surveys, prepares maps, conducts studies, and recommends plans to protect waterfront areas against erosion and deposition.

Department of Water Resources conducts water-resource studies; plans for multipurpose development of waters; cooperates with game and fish and Chesapeake Bay affairs in determining tidal and nontidal water boundaries; controls use of waters through issuance of permits for such things as waterworks and waterway obstructions; and cooperates with other State agencies in enforcing water pollution control laws and regulations. However, most of the zoning of lands for various uses is done by the local- or county-level governments.

Other previously existing and separate agencies that relate to estuarine management are the State Planning Department, which prepares plans for State resource development; Natural Resources Institute for the University of Maryland which conducts research and education programs on nonagricultural and forest resources; Water Resources Research Center of the University of Maryland which sponsors research on water resources development; and State Department of Health which has control over the sanitary condition of State waters. A selective organizational chart of the Maryland government is shown in figure V.2.4.

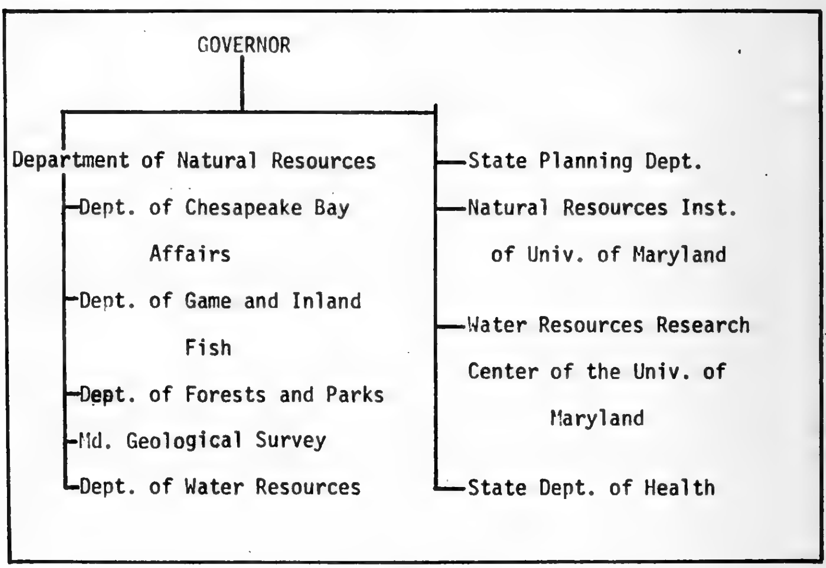


FIGURE V.2.4
Maryland's Agencies Involved in Management or Control of Estuarine Resources

The State believes that enforcement of water quality standards and effecting of pollution control is the essential responsibility of the State. To maintain the generally high water quality of the State and to provide for future quality control, the State considers that its responsibility is to expand its ability to perform water quality investigation and control. This is being done with some difficulty in acquiring needed professional personnel and operational funds. However, to meet its responsibilities, the State may need more funds—perhaps from another source. The State has stated the need for research on the effects from discharges at specific locations in Maryland on established or proposed water uses. On problems as this, specific research assistance is needed from the Federal agencies. The State has also stated the need or problem that the State's responsibility for controlling dredging and spoil disposal should be strengthened in order to prevent loss or damage to established or proposed water uses. More State-Federal coordination for planning and effecting the placing of dredge spoil is necessary. In the general area of coordination, however, this does not seem to have been a problem and with the newly established coordinating department of natural resources even previous capabilities will be increased and improved.

### CALIFORNIA

The State of California represents a western coastal State that is highly urban/highly industrial/low rural/highly developed (population, about 19 million). It has an extensive, tidal coastline (about 3,400 miles) that is used for a broad range of purposes and has encountered a wide range of coastal problems including actual coastal filling as in San Francisco Bay.

In general, California has title to all submerged lands, tidelands, and swamplands within its borders and can sell the tidelands and swamplands.

Estuarine management responsibilities in the State seem to be focused in the State of California's Resources Agency. This agency has the primary responsibility for managing the ocean resources of the State; it has advisory, planning, research, development, coordination, and policing functions. The agency and its component departments (fig. V.2.5, p. 382) have been assigned specific responsibilities by the legislature for various elements of the resource. A second State department involved in estuarine management is the department of public health. This department is responsible for protection of shellfish beds against contamination and for the health and safety of ocean water-contact-sport areas.

- GOVERNOR
  - Dept. of Public Health
  - Resources Agency
    - Dept. of Fish and Game
    - Dept. of Parks and Recreation
    - Dept. of Water Resources
    - Dept. of Conservation
    - Dept. of Harbors and Watercraft
    - Water Resources Control Board and Regional Water Quality Control Boards
    - State Lands Division

FIGURE V.2.5
California's Agencies Involved in Management or Control of Estuarine Resources

Special marine-oriented groups in the State government include the Interagency Council on Ocean Resources, California Advisory Commission on Marine and Coastal Resources, Marine Research Committee, Wildlife Conservation Board, and Pacific Marine Fisheries Compact Commission. In addition, there has been intense management activity in the San Francisco Bay area. The State realized the importance and impending dangers in exploration of estuarine resources, especially of San Francisco Bay, and established a program and commission to study and develop action plans for the most effective comprehensive management of the bay. The State is implementing these recommendations and the commission itself through the passage of recent legislation—The McAteer-Petris Act (as amended in 1969). Because the commission can be considered as an intrastate or local government function it is described and referenced as a case study in the following chapter on the role of local governments and it is included in the current overall program, chapter 7. Other bay area groups, in addition to the commission/program, are the San Francisco Bay-delta water quality control program and the joint committee on bay area regional organization.

Specifically the responsibilities of the departments in the resources agency are as follows.

Department of Fish and Game has the responsibility for protection, preservation, propagation, and enhancement of wildlife resources. It enforces the regulations regarding open and closed seasons, bag and possession limits, various aspects of both commercial fishing and sports fish and game, and supervises limited-use marine research zones.

Department of Parks and Recreation establishes rules and regulations for administration of beaches, parks, and historical monuments on State-owned lands. The Department acquires, preserves, develops, operates, and maintains for the public benefit, the units of the State park system and is directly interested in how the development and public use of the State parks, beaches, reserves, recreation areas, and historical units along the coast may be affected by unrelated development or use of the tidal and submerged lands.

Department of Water Resources has statewide jurisdiction and responsibilities relating to development of water resources. In regard to coastal resources the department has responsibility for beach erosion control and saline water conversion; studies erosion problems on the State's beaches; acts as advisors to all Government agencies; supervises Federal flood control projects; and makes loans and grants to local agencies for water development projects. It assists city and county governments in beach erosion problems by advancing funds for cooperative programs with the U.S. Army Corps of Engineers.

Department of Conservation is responsible for forest, range, and watershed protection; assists in formation of soil conservation districts and in watershed protection and flood prevention programs; and administers the Forest Practice Act regulating timber harvesting on private land.

Department of Harbors and Watercraft acquires, constructs, develops, and improves small craft harbors, facilities, and connecting waterways. The Department must, on request, transfer such a harbor and its operation to a qualified local governmental unit. It also has jurisdiction over the establishment of uniform boating regulations and makes loans and grants to assist in development of small craft harbors and marinas.

Water Resources Control Board. In 1967, the legislature enacted a bill forming the State water resources control board. This board, with the regional water quality control boards, is the primary State agency in the field of water rights, water pollution, and water quality control. The creation of this State board provides a coordinated administration of water quality and water quantity.

The board exercises advisory, planning, research, regulation, and coordination functions. Its principal responsibilities provide for the formulation and adoption of a statewide policy for water quality control, control of water quality and pollution, and administration of the budgets of the regional boards. Each regional board is responsible for the formulation and adoption of policies for water quality control within its respective region; it may order offenders to cease and desist and initiate legal action.

The State Lands Division, previously under the direction of the Department of Finance but transferred to the resources agency by the California State Legislature in 1969, handles all matters pertaining to the leasing or sale of State-owned (ungranted) tidelands and submerged lands. It also has an active marine inspection program and provides the focal point for oil pollution control activities in the estuaries and coastal waters of California.

In the realm of coordination, the California comprehensive ocean area plan, to be developed by the Interagency Council for Ocean Resources, will be the primary vehicle for coordinating the various programs concerned with the conservation and development of marine and coastal resources.

Problems in California center around the need to increase existing management/organization/legislation to keep pace with the extremely rapid development of the coastal areas. The preceding information on the State of California represents a very brief summary of information in the California profile, which also contains detailed descriptions of the various problems regarding estuarine management in the State in regard to both subject area and geographic area.

## FLORIDA

The following describes the recently augmented estuarine management framework in Florida which is due in some measure to the efforts of the National Estuarine Pollution Study through its 30 public meetings held across the country. The estuarine public meeting in Florida presented a forum whereby various factors of the community could express publicly their views on the Florida estuarine situation. These views subsequently reached the legislative bodies and it is felt that this meeting contributed views which prompted the Florida Legislature to consider the need for action to preserve/protect Floridian estuaries.

During 1969, the Florida Legislature created the Florida Department of Air and Water Pollution Control and reorganized the State board of health as a separate department—the Department of Health and Rehabilitative Services.

In Florida, there seems to be two coordinated and related foci for estuarine management.

First, the Florida Department of Air and Water Pollution Control is the primary State agency having the responsibility and authority for pollution control. Most of the powers, duties, and functions of other State agencies relating to pollution control, including those in estuarine areas, were transferred to the Department of Air and Water Pollution Control (Air and Water Pollution Control Commission) by the State legislature through the Florida Air and Water Pollution Control Act of 1967; this represents a consolidation of authority and improved coordination in air and water pollution control activities.

Second, the board (of trustees) of the Internal Improvement Fund owns the title to all State-owned submerged lands in estuaries, except those that are privately owned (as described in ch. 67–393, acts of 1967). By virtue of ownership, the board is responsible for the management, preservation, and administration of these submerged lands. The board can sell, based on approved applications, certain submerged lands after establishment of bulkhead lines by appropriate counties or municipalities. It can also reject applications for title to submerged lands (F.S. ch. 253.12) or for authority to fill such lands (F.S. ch. 253.124). The board approves permits, after initial approval by cities and counties, authorizing dredging and filling. However, some lands have been leased or set aside for specific purposes such as oyster culture, aquatic preserves, and State parks.

Other State departments whose responsibilities relate to estuaries include those duties which logically fall within their aegis, for example:

Department of Health and Rehabilitative Services: Surveillance of oyster- and clam-bearing waters.

Department of Natural Resources: Fisheries and shellfish management, beach erosion control, development of master plan for commercial and recreational waterways, waterfowl management, State park administration, seafood quality control, seafood marketing program, marine biological research, and ecological and environmental studies of projects pertaining to sale, modification, and development of submerged lands.

Department of Agriculture and Consumer Services: Surveillance of seafood quality and watershed management and land conservation and reclamation.

Department of Transportation: Bridge and causeway construction (mainly U.S. Army Corps of Engineers function).

An organization chart showing the Florida State agencies whose responsibilities relate to estuarine management is shown in figure

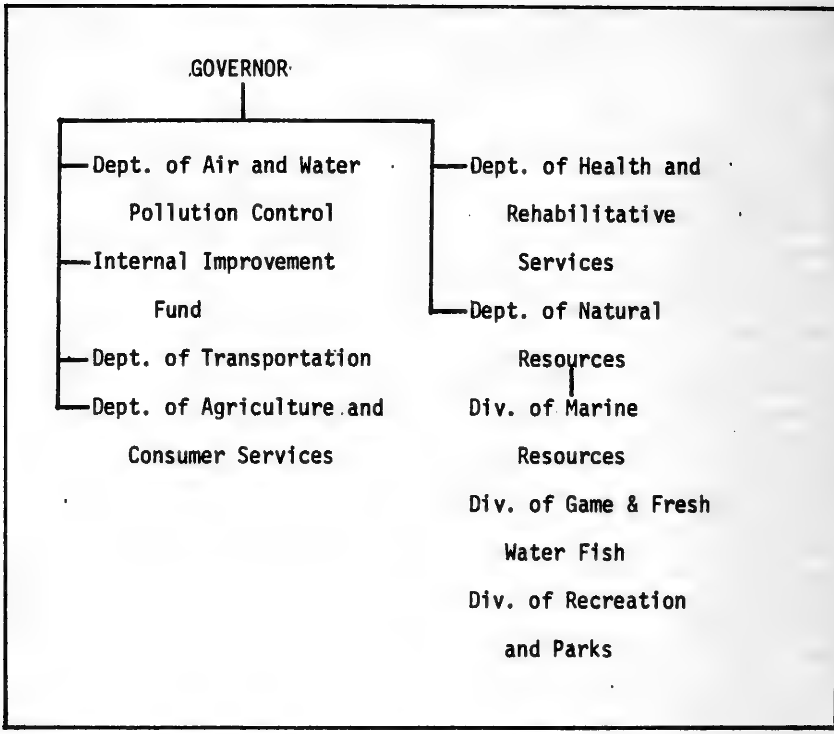


FIGURE V.2.6
Florida's Agencies Involved in Management or Control of Estuarine Resources

V.2.6. Further mechanisms for coordinating agency programs relating to estuarine management include: arrangements whereby plans of highway construction or modification are evaluated by the Department of Natural Resources for the Department of Transportation as to adverse effects on the marine environment. The department of Natural Resources and the Department of Health and Rehabilitative Services have a formal coordinating agreement regarding each agency's responsibilities in sanitary shellfish control. The Department of Natural resources cooperates with the Department of Air and Water Pollution Control on pollution control programs. The Department of Natural Resources' Marine Resources Division reports its findings on the results of ecological and environmental studies of proposed projects pertaining to the sale, modification, and development of submerged lands to the Internal Improvement Fund. Then, in the 1969 session, the State legislature passed a bill whereby the Department of Natural Resources and the Department of Air and Water Pollution Control are to be represented on the Department of Agriculture and Consumer Services' pesticide technical advisory committee.

In brief, Florida being a relatively highly urban, low rural, highly developed State seems to have the organizational and legislative basis for the relatively effective management of its estuaries. The current problems in estuarine resource utilization in the State seem not to lie in the area of adequate coordination but in the area of lack of funds and trained field and laboratory personnel to carry out effective pollution surveillance programs and to conduct necessary studies to determine effects of various water uses and assess damages when necessary. A potentially serious problem in estuarine management lies in the private ownership of thousands of acres of submerged land including most of the intertidal marshland in the less urbanized areas of northern Florida.

### ALASKA

The previously described case studies—Massachusetts, Florida, etc.—represent estuarine-management organizational frameworks of relatively well-established States. The following case study of Alaska represents a rural and generally light industrial (low development area) State that is relatively new. Alaska has a longer coastline than any other State—33,000 linear miles—a small population, and it is one of three or four political entities in the world that is bounded by two oceans, four seas, and two foreign nations. There is phenomenal public awareness and concern about the State's estuarine areas because more than 90 percent of the population depends on these areas for their livelihood and/or well-being.

In Alaska, because of the vast coastline, the short production or working season and small staff capabilities, the management framework is extremely flexible to allow activities in estuarine areas to be handled on a need basis, rather than based on a preplanned program. Since statehood, Alaska owns its tidal and submerged lands, with few exceptions. The State cannot sell its tidal or submerged lands but only leases them, maintaining State ownership and control. A large majority of the State's adjacent uplands are under Federal control (parks, preserves, refuges) with cooperative Federal-State management. Because of the general nonexistence of developed local-level governments and competencies, estuarine management is focused at the State level.

In Alaska's State government, three principal departments are responsible for management of the estuarine or coastal zones. These are the Departments of Natural Resources, Health and Welfare, and Fish and Game; ancillary groups are the Department of Public Works and Water Resources Board.

The Department of Natural Resources manages the use of the State's natural resources (water, land, and minerals). Specifically the Department's activities include the management, disposal, and protection of State lands (tidal and submerged within the 3-mile limit); water resources; forestry and mineral resources; issuance of leases and permits on tidal and submerged lands for development such as for log storage and rafting; construction of dock facilities; sale, leasing, and issuance of permits for use of adjacent State-owned uplands and wetlands; and last but not least, the classification of lands as to their highest and most beneficial use. The State has initiated this classification-zoning plan for its tidal and submerged lands as a part of its estuarine management system. At present, about 50 percent of the lands are classified for recreational purposes. In any consideration for leasing and issuance of permits, one of the prime factors is the potential effects of the proposed use on the ecosystem or fish and game in adjacent lands. If land is unclassified, then it must be classed for the highest and most beneficial use before leasing.

The Department of Fish and Game is responsible for managing, protecting, maintaining, improving, and extending the fish and game resources of Alaska. The department's environmental division coordinates the development of tidal and submerged lands or adjacent waters as they may affect the fish and game resources. This division is the main coordinating machanism among the department of natural resources, the department of fish and game, and department of health and welfare—that is, a coordinator for estuarine-related activities. The departments of fish and game and natural resources also coordinate their activities related to fish and wildlife through a memorandum of agreement intended to identify and classify fish and wildlife habitats for their maximum protection.

The Department of Health and Welfare includes responsibility for the prevention and abatement of water pollution and for the assurance of adequate supplies of water. This department has responsibility for pollution control.

Ancillary to the foregoing agencies are the Water Resources Board which consists of a group of private individuals who advise the Governor on any and all matters pertaining to the State's water resources (Alaska Statutes, sec. 46.15.210, art. 3) and the Department of Public Works which constructs and/or maintains small boat facilities, ferry sites, and locking facilities (see fig. V.2.7).

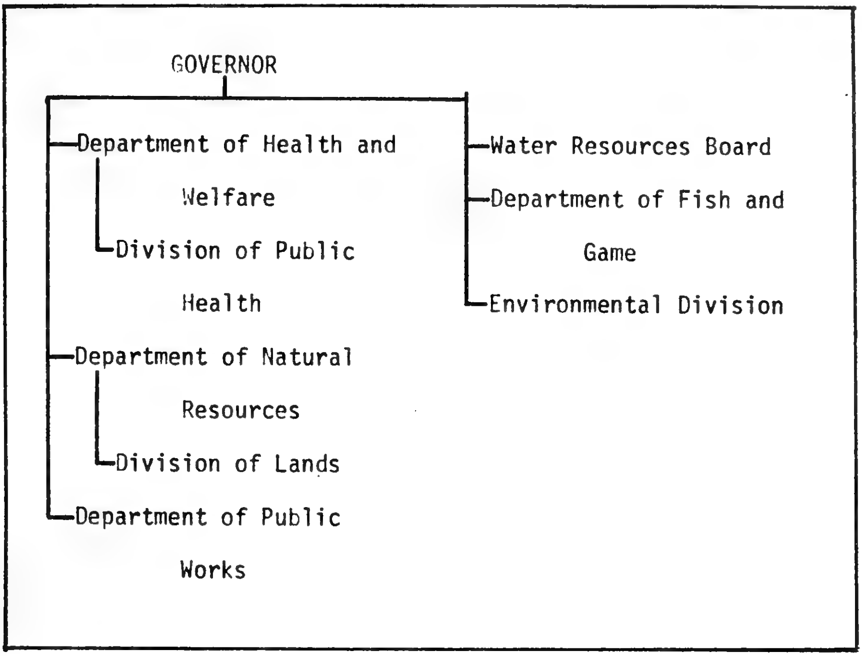


FIGURE V.2.7
Alaska's Agencies Involved In Management or Control of Estuarine Resources

In addition to the above coordinating machanisms, the State coordinates activities through the following two agreements. In southeastern Alaska about 2,000 miles of shoreline are in a national forest. This area is managed, and respective activities are coordinated through, an interagency agreement among the U.S. Forest Service, the Alaska Department of Natural Resources, and Alaska Department of Fish and Game. Timber sales are held by the U.S. Forest Service and they issue permits for all activities such as for log storage and rafting grounds, only after the plans have been reviewed and approved by the Alaska Department of Fish and Game.

Second, is the waterfowl protection agreement. Waterfowl areas in national forests bordered by tidal and submerged lands are managed through a Federal-State agreement among the U.S. Forest Service, Alaska Department of Natural Resources, and Alaska Department of Fish and Game; no activities are conducted on the lands unless agreed upon by all three parties.

Problems regarding estuarine management center on the need for more professional personnel, more funds to enlarge the scope of planning and classification of estuarine uses, and more comprehensive studies of estuarine uses. At present, supposedly the tax base is not sufficient to support an adequate staff; however, recent oil discoveries on the northern slope may drastically change this situation. Also needed are more precise definitions of territorial/sea boundaries and more waste disposal facilities.

## Section 3. A Coastal State's Organization for Managing Estuarine Resources

The preceding section presents a picture of several selected coastal State estuarine management frameworks which show the wide range in management capabilities. Because it is difficult to gain an overview of the 24 coastal State frameworks, the following description is presented as a single State-level estuarine management-organization-legislative framework. It is considered to be analogous to those of coastal States, and it is intended to show what the average State-level organization includes. It is neither extremely strong nor very weak.

The analogous State organization consists of an agency such as the division or department of State lands and resources which has significant responsibilities for management provided for by statute.

This issuing and approving agency has responsibility for developing natural resources for issuing/approving leases for the removal of material from natural waterways; for granting permits for structures and projects, such as laying cables on coastal lands; and for selling or leasing the lands under navigable waters and along State-owned estuarine areas. However, permits are not required for the disposal of "spoil" into estuarine areas.

Related to this agency are other agencies whose responsibilities involve the use of estuarine resources, generally in a particular area, as follows. The State fish commission or division has the responsibility for the protection, propagation, and preservation of food fish and for the protection and development of commercial fisheries. The commission studies, researches, and inventories the marine life and food fish resources; manages fish hatcheries; sets seasons and regulations on taking of food fish and marine life; and by intervention, protects against manmade structures or alterations which adversely affect all marine life.

The State game commission sets seasons, regulations, and licensing provisions for recreational harvest of sports fish and wildlife; propagates sports fish and wildlife; and studies, researches, and engages in management activities in estuarine waters. By intervention, the commission advises on all man-caused alterations to the estuaries of the State.

The State sanitary or water pollution control authority exercises control of estuarine areas with general powers and duties to set standards of water quality in all waters of the State; enjoins and abates water pollution; and conducts studies to promulgate specific water quality standards for each estuary and portions thereof.

The State parks division acquires, develops, expands, and manages all State parks. It protects, preserves, manages, acquires as necessary, and controls the public beaches of the State. The State has ownership and the department exercises jurisdiction for receratonal use of nearly all beaches between extremely low tide and ordinary high tide.

The State Marine Board has responsibility for making rules and regulations necessary for the control and use of boats and watercraft in the estuarine areas and applicable water uses. The board licenses and identifies boats; cooperates with State and Federal agencies to promote uniform boating laws and their enforcement; assists in local enforcement of boating law; studies, plans, and recommends the development of boating facilities throughout the State; publishes and distributes boating laws; and makes rules and regulations consistent with the State sanitary authority and State board of health.

The Economic Development Division directs a program of planning and development; serves as a coordinating agency for activities concerning the resources and economy of the State; assists local communities in industrial development; researches all aspects of the State's economy and resources for attracting industry; and publishes general and technical information.

The State Engineer administers laws regarding distribution and appropriation of water. The distribution includes the maintenance of minimum streamflows that have been provided for by policy statements of the water resources board.

The State Water Resources Board supervises and assists diking and drainage districts that may be established in the State and develops coordinated programs for use and control of all the State waters.

The State Forestry Department has direct responsibility for forest protection and conservation on private, county, municipal, and certain Federal forest lands, with the protection of the watersheds influencing both the quantity and quality of water in the estuarine areas.

The State Committee on Natural Resources coordinates resource management of the State and serves as a forum for establishing State policy on the protection, development, and use of the State's resources. Such State committees generally have very small budgets and/or staffs.

The State Soil and Water Conservation Committee supervises the soil and water conservation program. All of the estuarine areas of the State are in local soil and water conservation districts. Programs are underway with these districts in coastal erosion control.

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The Port Authorities Association makes technical, administrative, and industrial studies and reports to show the most appropriate and practical ways to formulate a statewide comprehensive plan for the orderly development of ports and waterways in the State.

All of the above-mentioned agencies are provided for by State statutes or State laws, or State constitution (see fig. V.2.8).

Coordination and consultation exist between State agencies and Federal or nongovernment entities not covered by permit systems, laws, or formal arrangements. However, no central coordinating agency exists to handle the management of the State's estuarine resources.

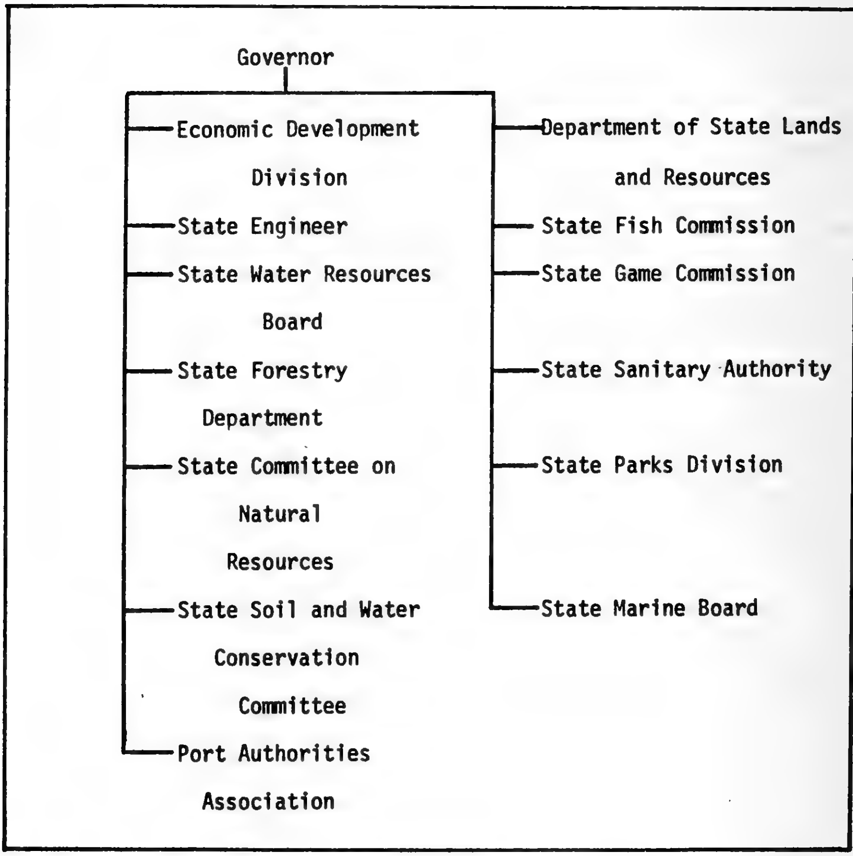


FIGURE V.2.8
Analogous State Agencies Involved in Management or Control of Estuarine Resources

Construction of any facility involving navigable waters requiring a permit from the Corps of Engineers is controlled by consultation between the corps and the State agencies involved. Water policy of the State is determined by the State water resources board through a public hearing and determination system involving the public and all State agencies concerned.

Principal problems existing in the analogous State are in the areas of the need for more coordination of existing activities; resolution of conflicts regarding ownership of estuarine and upland areas; clear statements of ownership which are basic to determination of rights, developments, and erasing of conflicts by wise long-range planning; comprehensive planning to preserve and provide for the orderly development of estuaries, with the States taking the initiative; funds (Federal) to assist the States in long-range planning and coordination; increased involvement of government, industry, and all citizens in estuarine planning, development, and protection; enforcement or strengthening of existing State laws; establishment of guidelines by the Federal Government for use by the State to assist in establishing uniform regulations especially for watercraft; and last but not least, the major need is for an orderly improvement program of water quality within the estuaries, providing broad guidelines allowing for multiuse.

In brief, the analogous or average State management framework includes capabilities for planning, regulating, and controlling, at least to some extent, certain uses of estuarine resources, through the use of restrictive provisions. For example, it can issue leases for the removal of material from waterways; issue permits for structures; lease lands under navigable waters; issue licenses for sport fishing and wildlife; control public beaches; set water quality standards; issue licenses for boats; and manage State park lands.

However, what is often lacking is a strong management organization able to coordinate all estuarine-related activities and able to produce and implement a statewide comprehensive management plan which includes enforceable provisions and regulatory authorities to control use or modification of the estuarine resources for the maximum benefit of the population.

## Section 4. State Estuarine Laws and Ownership Problems

No uniform State-level estuarine law framework exists; there are, instead, many laws, often conflicting, which affect the estuarine zone. The States' estuarine legal system is a confusing and complex blend of water rights, land ownership claims, use conflicts, and State, Federal, and local laws which vary from area to area and are often subject to varying interpretation and constant litigation. This section briefly discusses the legal aspects of estuarine management, in particular ownership problems and State laws; it does not include a comprehensive survey.

Some fundamental legal questions on estuarine use are (V–2–1):

(1) How much of the estuarine zone is owned by Federal, State, local governments, and by private parties?

(2) How was ownership acquired (e.g., colonial or legislative grants, adverse possession, condemnation, leases)?

(3) What limitations are there on ownership—what rights and privileges does the public have to use estuaries and their resources including privately owned lands?

(4) What kinds of legislation and regulatory tools are constitutional and offer the best framework for management of the estuarine zone?

### BASIC STATE-LEVEL LEGAL PRINCIPLES

The above questions indicate the variety of legal and policy problems. However, some basic legal principles and trends can be outlined, even though their application has varied historically from State to State. A fundamental doctrine dating from its English common law origin is that of the public trust and right—that these coastal and submerged lands are held by the State in trust to be used by all the people for certain purposes, such as navigation, commerce, hunting and fishing, and (more recently) for parks and recreation. Public ownership usually includes four types of lands:

(1) submerged lands (beds of navigable waters owned by the State up to the 3-mile territorial limit) and

(2) tidelands (generally defined as the coastal area between mean high and low tides).

The extent of the public's right to use and have access is less clear in the case of

(3) marshlands or swamplands (subject to extremely high tides) and

(4) abutting lands which are affected by water uses.

Subject to the paramount Federal interest in protecting navigation, the States generally control the uses of water within their territorial limits. Under their police power they may regulate pollution, sewage disposal, control harbor lines, grant fishing and hunting licenses, and issue boating permits. The land-use prerogatives of the State, such as zoning, have usually been delegated to the municipalities and local governments.

Although held by the State in trust for the public, some tidelands have been purchased by private owners. However when sold, the public has the right of commerce, navigation, and fishing in these areas. These use rights remain until the area is dredged or so changed physically that these rights can no longer be exercised.

### OWNERSHIP PROBLEMS

In practice, problems of estuarine zone ownership and use rights abound in every coastal State. Despite the commonly accepted public trust doctrine, States can and have transferred ownership to private individuals by outright grants. Short of purchasing the land, individuals have acquired rights and more limited interests through leases, easements, other licenses, and permits. Questionable surveys and dubious colonial and precolonial land grants further complicate the situation. The private interests who acquired ownership or use rights often proceeded to improve and develop the land through dredging and filling.

Thus, judicial clarification by each State is needed for such ownership questions as—are these titles still valid? Is the sold land still subject to the public trust? Can the State revoke licenses it granted and on what grounds?

### SUBMERGED LANDS: STATES VERSUS FEDERAL GOVERNMENT

Several court decisions and congressional acts have failed to settle definitely the question of Federal versus State jurisdictions over submerged lands, minerals, and ocean islands. In 1947, in *United States* vs. *California* (332 U.S. 1947), the Supreme Court ruled that the Federal Government and not the State had paramount rights in the submerged lands and oil found under it in offshore navigable waters. This displacement of State regulatory authority in the 3-mile belt off the coastline was subsequently applied to Louisiana and Texas by the Court. The Supreme Court's decision in issuing this opinion states that:

> California is not the owner of the 3-mile marginal belt along its coast, and . . . the Federal Government rather than the State has paramount rights in and power over that belt, in incident which has full dominion over the resources of the soil under that water area, including oil.

To offset these so-called tideland-oil rulings, Congress passed the Submerged Lands Act of 1953 which generally gave the States title to the lands, minerals, and other resources underlying the navigable waters within 3 miles off the coast; beyond that it was under Federal jurisdiction. Nevertheless, this law failed to clarify several questions of ownership, taxation, and regulation. For example, how the seaward boundary or island waters are defined is unclear.

Litigation has attempted to settle the question of measurement from artificial jetties and in relation to river deltas and islands. There is, however, still some jurisdictional uncertainty over the submerged lands surrounding some islands and over man-made lands and emerging islands.

A supplemental decree of the U.S. Supreme Court in 1966 established California's offshore ownership boundary line. The ownership boundary extends 3 geographical miles seaward from the coastline. Much difficulty is associated with the establishment of the exact location of this line. In addition to the problem of establishing the line, the base line for measuring the State's boundary is the "outermost permanent harbor works." Disputes have arisen over the interpretation of this phase. Another problem has to do with the State's seaward boundary in the Channel Islands area off the southern California coast. These jurisdictional problems are extremely important for planning and management of the coastal area and financially, because of royalties from oil leases and other developments of the submerged lands.

These difficulties point up the need for an organization to handle such boundary disputes on a national level or a higher-than-State level. This need has also been expressed by the panel (on management and development of the coastal zone of the Commission on Marine Science, Engineering and Resources) in their recommendation that a national seashore boundary commission be established by the Congress with authority to hear and determine coastal boundary questions and controversies involving proprietary interests of the States.

In addition, the Supreme Court was asked in June 1969 to rule on a dispute between the Federal Government and the 13 Atlantic States over title to offshore lands (docket No. 35 original, 37 Law Week 3483). These States claim that for the purposes of granting leases and collecting royalties for oil exploration and production, and on the basis of colonial charters granted by the British Government before the Constitution was adopted, their authority extends up to 100 miles to the outer Continental Shelf. Texas and Louisiana have also asserted jurisdiction beyond the 3-mile zone in another unresolved dispute.

### DIVERSITY OF STATUTES AMONG STATES

A survey of intergovernmental relations in the coastal zone disclosed that: (V–3–2)

> State statutes establishing distinctions between public resources and private property and the extent of State responsibility for management of public resources have little in the way of uniformity. Even if legislatively clear, the distinctions are difficult to fix on the ground. The resulting situation is a legal nightmare.

In effect there is a separate legal system for each coastal State and management programs for the States must take each of them into consideration. A broad range of estuarine zone policies are affected by some of these interstate variations:

(1) Basic Water Laws—Eastern States follow the riparian doctrine, in which water rights are tied to ownership of adjoining or underlying land. Western States generally accept the first-in-time, first-in-right appropriation doctrine in which rights are acquired or abandoned by use. Unlike riparian law, priority in time determines water rights, independent of land ownership. To complicate matters further, States on the Pacific recognize both these rights while Louisiana accepts elements of the Napoleonic code.

Water law does not closely control water use. For example, under riparian law, water should be free from "unreasonable" pollution so that "reasonable" use may be made of it. Yet the interpretation and application of these water rights affect the type of improvements and accertions that may be made by riparian owners, such as reclaiming land, constructing piers, or removing sand and gravel.

(2) Tideland Boundaries—a majority of States claim ownership under English common law from the high water mark seaward to the 3-mile limit, but, there are significant variations. Massachusetts, New Hampshire, Delaware, Pennsylvania, Virginia, and Georgia permit private land to the low water mark. Thus, in Chesapeake Bay, Maryland claims all the coastal land from the mean high tide mark while Virginia asserts its ownership only from the mean low tide.

Standards of measurements also frequently differ. Louisiana measures from the highest winter tide and Texas from the mean higher tide. Further complications arise from the fact that, even if precise and standardized measurements are used, tidal characteristics vary from coast to coast.

(3) Outer Limits Claims—While State territorial boundaries are generally considered to extend only out to 3 miles, some States exert claims to waters beyond this limit. Louisiana, for example, claims up to 27 miles and Texas up to the outer edges of Continental Shelf.

(4) Extent of Delegated Power—Most States delegate the responsibility for the use of land above the high water mark to their municipalities and counties. However, a few like Hawaii stress statewide zoning and reserve this prerogative to the State. In general, there is a wide variation in the extent of home rule granted by each State to its localities.

In conclusion, the boundaries of private property in tidelands vary from State to State. Almost each State differs from its neighbor in how it defines and interprets such basic units and concepts as submerged lands, navigability, tidelands, marshlands, and abutting lands.

## REGULATORY POWERS OF THE STATES

Under their police powers, the States can legislate for the protection of promotion of public health, safety, morals, or for the general good. This attribute of sovereignty enables the States to regulate the use of estuarine zone, land, and waters and to control the actions of individuals upon them. Despite the many variations among States, the basic constitutinal doctrines which allow them to create and enforce property rights for use and transfer can be outlined along with some important limitations on this power.

Among the legislative tools which can be utilized in estuarine management are the following:

(1) A declaration of public rights, such as access.

(2) Zoning or allocation and use controls, usually delegated to the local subdivision.

(3) Taxation, used preferentially for estuarine preservation.

(4) Development easements, or the purchasing of partial public rights.

(5) Eminent domain.

Yet there are limits to these broad State powers. First, the supremacy clause of the Constitution may prevent the State from acting in an area where the Federal Government, through its interstate commerce and treatymaking powers, has preempted the field. Secondly, the establishment of estuarine rulemaking bodies may occasionally be subject to attack as an improper or invalid delegation of legislative authority.

Third, procedural due-process may invalidate State actions that are taken without notice and/or the opportunity to have hearings before the affected parties.

Also, the equal protection doctrine requires the government to act fairly in treating all alike without arbitrary or discriminatory classifications.

Finally, and most controversial, substantive due-process, not allowing any property to be taken without just compensation, can be interpreted to disallow use restrictions that may deprive or damage property owners. Courts vary in their interpretation of the States' police power and the extent to which they will permit use restrictions without declaring them to amount to a taking of property without due compensation. It is particularly unclear if a State can repeal, modify, or deprive private owners of their future improvement rights. Especially in the case of fill control, there are few yardsticks as to what compensation or fair return must be allowed an owner. The variation in dredge-and-fill regulations among the coastal States is indicated in the following table V.2.2. It also points out the States which apparently do not have a state-level regulatory permit system for dredge-and-fill operations.

Most State laws are considered to be legitimate exercies of the police power under a presumption of validity, although there have been some significant exceptions to this rule. Thus, to avoid involved litigation and possible annulment, State laws must be carefully drafted to avoid being successfully contested on the above grounds.

### MODEL STATUTE GUIDELINES

Many of the coastal States expressed a need for quidelines for assistance, especially from the Federal Government, for the development of adequate or strengthened regulations for the use control of resources in estuarine areas, or portions thereof.

In response to this call for assistance, the national estuarine pollution study, through a contract awarded to the University of Maryland School of Law, developed a model statute for Chesapeake Bay Basin management. The Chesapeake Bay was selected for this project because it possesses many characteristics, benefits, potentials, and problems which are common to many of the estuarine areas of the United States. The model statute, developed under this contract, is included in the following chapter 9 of this part V of the report.

TABLE V.2.2.—STATE-LEVEL REGULATORY SYSTEMS FOR DREDGE AND FILL IN COASTAL AREAS

| State | Yes | No | Partial | State | Yes | No | Partial |
|---|---|---|---|---|---|---|---|
| Alabama | X | | | New Jersey | X | | |
| Alaska | | X | | New York | X | | |
| California | | X | | North Carolina | X | | |
| Connecticut | X | | | Oregon | | | X |
| Delaware | | X | | Pennsylvania | | X | |
| Florida | X | | | Rhode Island | | X | |
| Georgia | | X | | South Carolina | X | | |
| Hawaii | | X | | Texas | | X | |
| Louisiana | | X | | Virginia | | X | |
| Maine | X | | | Washington | | X | |
| Maryland | X | | | Virgin Islands | | X | |
| Massachusetts | X | | | District of Columbia | | X | |
| Mississippi | | X | | Puerto Rico | | | X |
| New Hampshire | X | | | | | | |

The statute is considered to be applicable in principle to other estuarine areas of the United States, and it is presented as suggested guidelines which could be tailored by the coastal States to meet their needs in important estuarine areas in order to improve or strengthen their management capabilities. Of course, it is recognized that some States have made significant progress in this direction. Such guidelines were developed on the basis of a selected geographic area (Chesapeake Bay) merely to insure an element of reality and practicality rather than a purely theoretical approach. Therefore, these guidelines do not imply the need for action by the governing States, but merely a response to an expressed need.

### SUMMARY OF STATE ESTUARINE-RELATED LAWS

State governments are both owners and regulators of the estuarine zone. They generally have sufficient legal and constitutional authorities to act. Yet in practice, most State laws are ineffective; they are sorely out of date and need updating, revision, and a basic reorientation toward comprehensive management and regulation of estuarine resources.

At their worst, State laws affecting estuaries are rudimentary, antiquated, and fragmented. There may be laws dealing with water quality or land zoning but they are uncoordinated and sometimes inconsistent with each other.

On the other hand, some States have adequate laws which touch upon estuaries but they fail to focus on the estuarine zone as a unit and deal with fragments and pieces of the total picture. Thus, a State may have a law to control dredging or filling or regulate leasing and sale of public lands or the construction of harbor and marina facilities and yet fail to develop a comprehensive estuarine management policy for optimum use. Further, they may fail to use effectively or enforce the laws that they have.

With the increasing concern over the future of the estuarine zone, there has been a gradual change from general permissiveness toward greater Government planning and control. A few States have begun to use the full array of tools already available in a total, coordinated manner for estuarine conservation and development—use control through planning, a less than full fee interest, permits and licenses, and favorable tax treatment. Here, too, the Federal Government can encourage State planning and coordination of the operations of several interrelated agencies dealing with water quality standards, economic development, recreation, and conservation. One of the best means toward this end are the grants for State planning under section 701 of the 1954 Housing Act (40 U.S.C. 461).

The Commonwealth of Massachusetts is probably farther along the way toward optimum estuarine management. First it enacted a stopgap law, the 1963 Coastal Dredge and Fill Act (Massachusetts General Laws ch. 130, sec. 27A, 1963), which gave the director of marine fisheries 14 days notice to impose protective conditions on the permit he issues. However, to allow for the long-range planning and optimal resource evaluation and allocation, the Massachusetts Coastal Wetlands Protection Act was enacted November 23, 1965 (Massachusetts General Laws ch. 130, sec. 105, 1965). This law authorized the commissioner of the department of natural resources to promulgate orders regulating, restricting, or prohibiting alteration or pollution of Massachusetts' coastal wetlands. Alarmed by a report (V–2–3) which stated that 43 percent of the remaining wetland acreage was subject to alteration and destruction in the near future, the legislature permitted these lands to remain privately owned, but allowed the commissioner to restrict their use. Such use retriction orders may be adopted only after holding a public hearing in the municipality in which the affected wetlands were located. It is still to early to assess fully the implementation of this act but its effectiveness as a legal tool for estuarine management has been widely praised (V–2–4).

Another approach towards land use has been taken by the State of Hawaii. Recognizing that land use is a policy power of the State, it has not delegated this authority to its local subdivisions. Rather it has adopted a zoning system to promote statewide and regional goals to protect its invaluable aesthetic and natural resources.

Finally, the State of Wisconsin has adopted a Shoreline Zoning Act which, although Wisconsin is not a coastal State, could be applied to the estuarine zone of coastal States. Under this act, the State sets standards for "county" zoning of unincorporated areas as well as broad objectives such as the prevention and control of water pollution plus the protection of fish and aquatic life and natural beauty. Further, the State is directed to adopt its own ordinance for counties that fail to enact or meet minimum objectives or standards. The State has also issued a model ordinance and planning guide which designates three zoning areas—conservancy districts, recreational areas, and general purpose zones (V–2–5).

Adoption and adaptation of the Wisconsin, Massachusetts, Hawaii, or model approaches to State zoning and/or use control would eliminate piecemeal estuarine zone planning and lead to optimum management and development in the public interest.

## Section 5. Evaluation of Coastal State Frameworks

An evaluation of the overall coastal State picture of estuarine management reveals a pattern or trend that is quite bleak. However, some coastal States have made significant progress toward effective estuarine management.

In the realm of organization, each coastal State has some type of mechanism, capabilities, or organizational framework directed towards estuarine management. But most of these frameworks are, unfortunately, inadequate, not effectively coordinated, not strong enough, or not adequately staffed nor financed. Those States, which seem to be making a definite attempt to handle their estuarine management capabilities, have a central organizational/coordinational focal point. A primary factor in the organizational format is that the effective ones are placed high enough in the State structure so that they can operate efficiently and not be overburdened by needless bureaucratic delays. But this focal point cannot exist alone. It is only a first step toward estuarine management. Second, the policy dictated and effected by this central agency must be in accordance with, and supported by, a statewide comprehensive estuarine management plan. The plan must be approved by the State and it must consider all aspects of the use, development, and protection of the estuarine resources for the maximum possible benefit of the populace, not only in the State but also in the region affected by the resource. Third, the comprehensive plan must include sufficiently strong regulatory authorities—licensing, permits, leasing, and restrictive use provisions—so that the implementation of the plan by the central agency will be truly effective. The effective tying together of these three points (organization-plan-authority) depends on coordination.

### THE ORGANIZATION

Details on the structure of the States' central organizational focal points can be gained from the preceding case studies. The specific structure would of course, vary with the size, scope, development, population, political atmosphere, and financial capabilities of the particular State. No one organizational format can be presented as being representative of all the coastal States; nor should one type of format be imposed on all of them.

Fanning out from an organizational entity are the various other State agencies which have responsibilities dealing with particular aspects of estuarine management; for example, the fish and wildlife agency issues hunting and fishing permits, the park service manages the State parks, and the port authorities handle the harbors. These individual agency responsibilities are generally not, and need not be, merged or included in the specific estuarine organization. This would often create additional difficulties and needless duplication, because estuarine activities cut across all facets of a coastal State government. However to be effective these individual responsibilities and activities must be effectively coordinated through a conscientious spirit of cooperation. More often than not, these activities are not sufficiently coordinated.

### THE PLAN

The State organizational entity, when effective, is backed up by and empowered to develop, approve, and/or implement a comprehensive statewide estuarine management plan or concept. In respect to these management plans, the States generally do not have approved comprehensive statewide management plans to guide or provide a basis for the activities of the organizational framework. When existent they are often very flexible, nebulous, incomplete, confusing, and rely more on the individual experts to solve problems, as they arise, than on preplanning.

### THE REGULATIONS

The comprehensive management plan and the corresponding organization entity, when existent, are empowered or strengthened, directly or indirectly through coordination mechanisms, by regulations, provisions, statutes, and procedures for use control either through zoning, acquisition, restrictive covenants, or State ownership of submerged lands. This lack of organizational frameworks, coordination, planning, and regulatory authorities is evidenced by the plight of our coastal areas and by the numerous responses from coastal States for the varied types of Federal assistance and coordination as described in the following section. Details on the range of State laws, which also vary based on the characteristics of the State can be gained from the preceding discussion of State estuarine laws. In general the coastal States either have confusing laws and statutes; have regulations that are inadequate, weak, or incomplete and need the passage of additional ones or the strengthening of existing ones; or they do not dynamically enforce, coordinate, or implement the regulations that are adequate and could be effective. As evidenced by table V.2.2. included in the preceding section on State laws, there is a surprising lack of dredge-and-fill regulations in the coastal States—a basic use/destruction control technique.

In many coastal States, zoning responsibilities have been delegated to the local-level governments but are often not adequately supervised/coordinated by the State level, possibly because of the general absence of comprehensive management planning.

### COORDINATION

In the realm of coordination, coastal States use the following mechanisms to coordinate their estuarine-related programs such as highway construction, pollution control, and various beneficial uses:

(1) comprehensive review and/or approval of licensing or leasing applications by multiple agencies;
(2) holding of public investigatory forums attended by various representatives;
(3) conduct of a coordination arbitration reconciliation agency such as a natural resources or public health agency;
(4) establishment of written agreements providing for coordination of activities—interstate, intrastate, and Federal;
(5) membership by various agencies on a coordinating board, commission, or the like; and
(6) development of a comprehensive management plan that provides the guidelines for activities and actions by all appropriate agencies and amounts to a coordination mechanism.

Table V.2.3 shows the distribution among selected coastal States of coordination mechanisms. More often than not, coordination is not adequate among intrastate agencies, nor is it adequate or truly effective between the Federal and State level components.

TABLE V.2.3.—STATE LEVEL COORDINATING MECHANISMS OF SELECTED COASTAL STATES

| States | Licensing review | Investigating forum | Coordinating agency | Agreements | Coordinating board | Management plan |
|---|---|---|---|---|---|---|
| Alaska | X | | | X | | |
| California | X | X | | | X | |
| Florida | | | X | | | |
| Georgia | | | | X | | |
| Maryland | | X | X | | | |
| Massachusetts | X | X | X | X | | X |
| North Carolina | | | X | | | X |
| Pennsylvania | X | | | | X | |
| Washington | | | | X | | |

The problems which abound in almost every coastal State pertain to shortcomings in ability to accomplish their programs. These shortcomings center around the need for a central, strong operational/

coordinating management organization, placed high enough in the State government to be effective; the need for the development and implementation of a comprehensive management plan, approved by the State; and the development, passage, and enforcement of restrictive use regulations and provisions plus the need for assistance in five areas: technical, scientific, legal, administrative, and last, but not least, additional funding of estuarine-related activities. For this assistance and coordination the States look to the Federal Government (as detailed later in this chapter) but first, they must fully utilize their own capabilities.

In an evaluation such as this it is very easy to let details and complexities overshadow and even obliterate the basic concept. A simple, though often and easily forgotten basic concept or common denominator in estuarine management, is that if estuarine uses are not controlled, regulated, planned, or guided, then the undaunted exploitation, by whoever happens to be there, continues and the estuaries are not managed for the maximum benefit of the population; this is against the public interest. As expected, the States consider it to be their responsibility to control their estuarine uses. However, if this responsibility is not adequately assumed by the States then the responsibility to prompt them into action must emanate from a source other than their own initiative—in this case, the Federal Government. The chance that the responsibilities for managing the estuaries would revert to the local level are highly remote because generally local governments have fewer capabilities than State-level governments. It follows then that if the responsibilities cannot be assumed by the State government they also cannot be assumed by the local level. Therefore, the States themselves must act, and act quickly, to develop adequate capabilities to assume their responsibilities of forestalling further degradation of our estuarine resources.

## Section 6. States Views on Comprehensive Management

### HOW OPINIONS WERE OBTAINED

To help develop a true picture of the opinions and expressions of the States on the comprehensive management of the estuarine zone, the coastal States were queried directly through several routes. The National Estuarine Pollution Study Staff directly and through its regional representatives asked the estuarine study representatives (appointed by the Governor) of each coastal State "What were the States views on the composition and management of the comprehensive national programs?" The responses were received via several routes: incorporated in the State profile, prepared and/or reviewed by the States; by correspondence received directly from the Governor, his assistant or the State's estuarine representative; and/or by statements included in the record of the 30 estuarine public meetings, held in the various sectors of the Nation and attended by several thousand people. Other sources included State-prepared reports, special study (contractor) reports, and miscellaneous study documents.

The result of all these responses was a mass of information containing an extremely wide range of ideas; however, there were some prevailing ideas. The following discussion constitutes a summary of the highlights of these responses, which are being recorded and preserved separately from this report for future reference, study, use and updating.

### SPECTRUM OF INTEREST

To organize and analyze the mass of information, it was necessary to develop a span of interest or a scheme for categorizing the various viewpoints of the States regarding the Federal-State-local management interplay. All of the viewpoints fell into one of three categories:

(1) Federl-State-local partnership for estuarine management.

(2) State ownership/management of estuarine resources with Federal assistance, and

(3) Autonomous State management.

Over 91 percent of the coastal States' responses fell in the second category. The coastal States want to own/manage their own estuarine resources but with a wide range of Federal assistance—technical, legal, scientific, administrative, and financial. Federal assistance does not necessarily mean only funds or financial support. Numerous States want advice, counsel, and guidance as to what they should do. Many States have the mechanics for managing the estuaries but often they are either not being used or not used effectively or coordinated. The States are asking for Federal assistance in interstate and intrastate matters, in order to assume effectively their expressed estuarine management responsibilities. This includes the concept that there are many administrative, technical, and research areas of a national nature that each State cannot, or probably should not cope with, or possibly should not be expected to cope with, such as the management of estuarine resources that have a regional or national impact that extends beyond the States' boundaries. From another viewpoint the States often have State-oriented vision—while the Federal Government can provide the national-scope overview. States can profit from others' experience through coordination at the Federal level.

Based on the general consensus of the State views, the following discussion presents the details, expressed by the States, regarding their ownership/management of estuarine resources with Federal assistance.

### ROLE OF FEDERAL AND LOCAL GOVERNMENTS AND PUBLIC AND PRIVATE INTEREST, VIEWED BY THE STATES

The coastal States believe that the Federal Government's primary role is to provide assistance to the States in conducting their activities related to the management of estuarine resources.

In general, the States expressed the viewpoint that the Federal Government should provide a wide range of assistance; this was grouped into five categories as follows: financial, scientific, technical, legal, and administrative assistance (table V.2.4).

TABLE V.2.4.—STATES' VIEWS AS TO DESIRED FEDERAL ASSISTANCE

| Coastal States | Suggested types of Federal assistance | | | | |
|---|---|---|---|---|---|
| | Financial | Scientific | Technical | Legal | Administrative |
| Alabama | X | X | X | | X |
| Alaska | X | | | X | |
| California | | | | X | |
| Connecticut | X | | | | |
| Delaware | | | | | |
| Florida | X | X | X | | X |
| Georgia | X | X | X | | X |
| Hawaii | | | | | |
| Louisiana | X | X | X | | X |
| Maine | X | | | | |
| Maryland | X | X | X | | |
| Massachusetts | X | X | X | | X |
| Mississippi | X | X | X | | X |
| New Hampshire | X | X | | | |
| New Jersey | | | | | |
| New York | X | X | | | X |
| North Carolina | | X | X | | |
| Oregon | | | X | | |
| Pennsylvania | | | | | |
| Rhode Island | | | | | |
| South Carolina | X | X | X | | X |
| Texas | X | | | | X |
| Virginia | | | | | X |
| Washington | X | | | | |
| Puerto Rico | X | | | | |
| Virgin Islands | X | | | | |
| District of Columbia | X | | | | |

The provision of financial assistance from the Federal Government to the States should, according to the States, include the funding of grants-in-aid for construction; funding of development and conduct of State, interstate, and regional activities; and funding for land acquisition. Perhaps the Federal Government should allow bonus points as an incentive to States in implementing adequate estuarine management.

The Federal Government should provide scientific assistance to the States in the form of:

(1) conducting demonstration projects to prove the reliability and dependability of pollution control devices or techniques, the testing of which would be too costly and would involve too much of a risk for an individual State to undertake;

(2) defining restraints on multipurpose uses;

(3) supporting or conducting wide-range programs including research/study that is beyond the scope of individual States (examples would be waste and water discharge rates and so forth); in addition the Federal Government should publish the resulting reports to adequately inform the States of the usable results;

(4) reviewing federally aided and licensed projects;

(5) regrouping of water classes to answer area needs; and

(6) scientific assistance in the form of managing interstate estuaries, especially in regard to research on physical and earth sciences, engineering, and biological problems.

Types of technical assistance that should be provided, or continue to be provided, to the States by the Federal Government include: recommendations as to estuarine systems and plans; provision of model statutes and suggested comprehensive management plans; recommendations for State standards and guidelines for tidal waters; coordination of interstate studies with State plans; coordination of estuarine programs; development of investigatory techniques, specifically in aerial mapping; development and provision of training programs to provide qualified individuals to manage the diverse aspects of estuarine resources; and assistance in defining, investigating, and solving water pollution problems. Several mentioned the need for more waste treatment equipment operators.

In the area of legal assistance some States are not able to maintain adequate counsel and witnesses for the multitude of legal problems involving jurisdiction and ownership of estuarine areas and especially the definition of tidal boundaries in interstate areas. In these cases, Federal coordination in the form of legal assistance to the States is needed. States may need expert legal advice from lawyers specializing in special water laws to assist them in dealing with specific problems; however, the States may not be able to justify the retention of such impartial expert counsel, while the Federal Government can and should provide such help on request.

Last, administrative assistance is needed by the States from the Federal level. This would include increased cooperation, coordination, and backing at the Federal level to facilitate aid to States; provision of trained specialists or consulting experts to assist States in handling specific problems that do not merit the retention of such specialists on the payroll; and provision of advice and support on administrative matters involving implementation of organizations and plans to handle estuarine management, such as adequate data processing systems; and assistance on mechanics of planning and setting up appropriate organizations.

The concept of Federal cooperation, coordination, advice, counsel, and backing to the States can be very critical and essential in those geographic areas where the estuarine resources have a regional or even national impact that extends far beyond the States' borders; examples would be: the Cape Cod-Provincetown-Plymouth Rock area of New England, the New Jersey-Maryland beaches, the Florida sands, San Francisco Bay, the Louisiana and Mississippi migratory routes (flyways) and the Hawaiian Isles. The effective rational management of such national impact areas must include a consideration of the national use and preservation which is above and beyond the State-wide concept. In some cases, responsible State plans that consider the national viewpoint may have difficulty in being passed and implemented by the State-level government and population because of their reluctance to shoulder the financial burdens and responsibilities for the pleasures of the Nation. In such situations, it does not seem altogether equitable to expect the States to shoulder the entire burden, and thus the Federal Government should have available the capabilities to provide coordination, assistance, advice, counsel, and general backing to insure a national management overview of State resources that have a national or regional impact.

Thus the Federal Government should provide, according to the States, increased coordination of its capabilities to assist the State in essentially any problem area that may arise in regard to management of their estuarine resources and to assist the States in finding the appropriate agency, program, mechanism, or procedure among the widely diversified estuarine-related programs of the numerous Federal agencies.

This viewpoint of the State (that the Federal Government should provide increased Federal-State coordination, especially in areas that are beyond the scope of the coastal States) relates to the recommendations in the panel reports, of the Commission on Marine Science, Engineering, and Resources (V-2-6). As recommended in the panel report, the Commission recommends that a

> . . . National seashore boundary commission, judicial in nature, be established by the Congress with authority to hear and determine seashore boundary questions and controversies involving proprietary interests of the States under Federal grants to them, using present principles of coastal boundary determination. Such a commission should have the following characteristics and authority:
>
> • The Congress should give its consent to State suit against the United States, permitting States to initiate boundary cases before the commission.
>
> • Jurisdiction of the Commission should be limited to boundary questions between the States and the United States, involving proprietary interests of the States under Federal grants to them.
>
> • Lines determined by the commission or by the Supreme Court of the United States after an appeal would be fixed permanently. Such stabilization should apply only to ownership of submerged lands or resources, not to general political jurisdiction and authority. Authority to regulate mineral lease operations should be stabilized at the property line so determined and fixed.

The general consensus of States' views regarding the role of local-level governments is that in most cases there are not, at present, sufficient local organizations to handle estuarine management responsibilities and that the people at the local level—that is, county—cannot support such an organization. However, whenever possible the local-level organization should be promoted and built up so that it can adequately handle the local government aspects of the State's overall comprehensive management plan for the estuaries. Local governments are often too susceptible to economic pressures and political influences in respect to estuarine development to enable them to manage the estuarine areas not only for the good of the county but also for the good of the State; thus they should rely on implementation of the statewide comprehensive management plans. Of course, there are notable exceptions to this, such as in New York, California, and Massachusetts. A complete discussion of the roles and capabilities of local-level governments is contained in the following chapter 3 on local governments.

The primary role of public and private interests, as viewed by the States, is to support in each and every way possible the comprehensive management plan of the State. Without the complete cooperation of the citizenry, a comprehensive management plan cannot be effective and thus cannot effectively protect the estuarine resources.

### THE STATES' ROLE AS VIEWED BY THE STATES

The overwhelming response from essentially all the coastal States was that they should manage their own estuarine zones; some of these responses were even, surprisingly, vehemently expressed. The remaining responses expressed by one or more States seemed to fall into five broad categories: State land ownership; cooperation/coordination of statewide activities; State development of new comprehensive management plans; strengthening/enforcing of existing State use regulations, controls, and standards; research/study; and State use control (table V.2.5).

TABLE V.2.5.—BRIEF TABLE OF VIEWPOINTS EXPRESSED BY COASTAL STATES AS TO THEIR ROLE AND RESPONSIBILITIES

| State | State estuarine management | Land ownership | Coordination of activities | Develop new management plan | Stronger controls and regulations on use | Research and study | State control over uses |
|---|---|---|---|---|---|---|---|
| Alabama | X | | | | | | X |
| Alaska | X | X | | | | | |
| California | X | X | X | X | | | |
| Connecticut | X | X | X | | | | |
| Delaware | X | | | | | | |
| Florida | X | | | | | | X |
| Georgia | X | | | | | | X |
| Hawaii | X | X | | | | | |
| Louisiana | X | | | X | | | |
| Maine | X | | | | | | |
| Maryland | X | | | X | X | X | |
| Massachusetts | X | | X | X | X | | |
| Mississippi | X | | | | | | |
| New Hampshire | X | | | | X | | |
| New Jersey | X | | | | | | |
| New York | X | | | | | | |
| North Carolina | X | | X | | X | | X |
| Oregon | X | | | X | | | |
| Pennsylvania | X | | | | | | |
| Rhode Island | X | | | | | | |
| South Carolina | X | X | X | | | | X |
| Texas | X | X | | | | X | X |
| Virginia | X | | X | | | | X |
| Washington | X | | X | X | | X | X |
| Puerto Rico | X | | | | | X | |
| Virgin Islands | X | | | | | | |

Because of their unique colonial legislative prerogatives, three States in particular own their estuarine (coastal zones) : Hawaii, Texas, and Alaska. Of course, they believe strongly in State ownership of estuarine lands. Certain other States that are relatively well developed—such as Massachusetts, California, and Connecticut—believe in and are engaged in, ownership through acquisition by use of State funds or Federal grants.

Many of the States viewed coordination of all estuarine activities as their prerogative and also stated that cooperation/coordination of Federal-State-local-private programs was an essential element of effective estuarine management that was often sorely lacking. Some States believed that they should coordinate the Federal and private activities in their area especially because they had a better on-site overall view of their area situation than the view from the Nation's Capitol or Federal level.

However, should a State be expected to view impartially its estuarine resources that are an areawide asset without national support? For example, the New Jersey beaches or Florida sands are enjoyed by the population far beyond each State. Their effective management involves consideration of regional significance instead of just statewide impact. Some States even alluded to the view that more effective intrastate coordination would nullify the need for additional regulations and legislation, or even organizations.

Akin to the States' view of estuarine management was the viewpoint that they should develop a statewide estuarine management plan, variously termed, and an effective mechanism for enforcing it.

Principally, such a plan should provide for State control of estuarine uses; that the States should control estuarine uses was definitely a prevailing view. A management organization to implement the plan should be placed high enough in the State-level governmental structure so that its recommendations and actions to control estuarine uses can be effectively heard and heeded. However, the mechanism or organization may consist principally of a coordination technique, because a separate estuarine organizational entity would cut across numerous existing organizational responsibilities and probably needlessly duplicate existing delegated tasks.

Numerous States recommended that effective State management and State use control could be achieved by strengthening and enforcing existing use regulations and controls, such as strengthening dredging and spoil controls, and enforcing water quality standards applicable to tidal waters. The essential point was that the States should control or regulate estuarine uses or multiple uses.

Other States took the opposite, though related, view that the State needed to develop new regulations, controls, and provisions, such as the development of zoning plans on a statewide basis, to govern estuarine areas. However, in general this view is essentially the same as the preceding one because States that do not have adequate estuarine management provisions should develop them and those States that already have them should enforce/strengthen them to control the uses of estuarine areas for the mutual maximum benefit for all aspects of the population.

Last, but not least, several States believed that they should conduct area studies/research but restrict them to solving problems that exist in the local area. Research and study needs as defined not only by the States but also from numerous other sources, are elaborated separately in part VI, chapter 3.

In summary, the States believe they should manage and control the use, mainly through ownership or restrictive covenants, of estuarine areas. This should be done through an efficiently coordinated State-level management organization, to implement a statewide comprehensive plan that is supportable or backed up by sufficiently strong regulations and needed research/studies designed to solve problems pertinent to the particular needs of the management organization and the corresponding estuarine resources.

## Section 7. Summary and Conclusions

An overview of the coastal States' management framework reveals the following conditions in many areas. Many management organizations and systems are individualistic, uncoordinated, piecemeal, and shortrange. Often they are burdened by noncomprehensive planning and development. In turn, the planning and development is often backed up by inadequate, confusing, not sufficiently enforced, or fragmented legislation and statutory regulations.

In contrast, the coastal States have the following general views with respect to their estuarine responsibilities:

(1) The States should manage their own intrastate estuarine (coastal) areas.

(2) They should control or determine the uses of the estuaries, for example by zoning plans, development of preserves or parks, or other restrictive use regulations.

(3) They should develop, where nonexistent, a comprehensive State estuarine management plan, often by the development or strengthening of State legislation.

(4) They should promote effective coordination and cooperation among State agencies, intrastate and interstate, for example; through commissions, councils, pacts, authorities, treaties, and agreements.

The coastal States' views on the role of the Federal Government in the management of estuaries was that the Federal-level responsibility is to "assist" the State-level estuarine (coastal) programs. In specific terms, this means that the Federal Government should:

(1) fund (assist) State estuarine programs and activities, when needed;

(2) conduct (assist) research and demonstration programs and projects on estuarine problems existent in the coastal States, and publish the results;

(3) develop guidelines, suggested plans, models, or standards that reflect the national estuarine policy so that State plans and programs can be developed in harmony with the national overview; and

(4) provide (or make available) trained scientific and technical specialists who can give advice, assistance, and counsel to, and cooperate with, the States in developing and managing their estuarine areas.

Such a general coastal States' consensus of opinion—State-level estuarine management with Federal assistance—in which the word "assistance" is used in a very wide context, would seem to offer a cooperative partnership arrangement which has been widely promulgated as the most effective mechanism for estuarine management.

Thus, the States believe they should manage and control the use, mainly through ownership or restrictive covenants, of estuarine areas. This should be done through a newer and stronger State role involving an efficiently coordinated State-level management organization, to implement a statewide comprehensive management plan that is supportable or backed up by sufficiently strong regulations and needed research studies designed to solve problems pertinent to the particular needs of the management organization and the corresponding estuarine resources.

Summing up these viewpoints reveals two essential points:

(1) Estuarine protective legislation cannot be effective without the corresponding organizational structure and function.

(2) An organizational structure must have the necessary legislative authorities, staffing, and budget to give it the proper and sufficient capabilities to do the job of effectively managing the estuaries. It is useless, of course, to have an inefficient and ineffective organizational unit that is buried so deeply in the State organizational hierarchy that it is unable to do, in essence, anything.

Thus, the essential aspects of the new and improved State's role are effective legislative policy enabling protection, with a corresponding efficient organization capable of actually managing the estuarine areas as an integral and essential part of the total water resources of the State and/or region.

Based on the above suggestions and views, and on the obvious need for a stronger and more effective State role in estuarine management, it is felt that the more effective and strengthened State role should approximate as closely as possible the following framework.

The new State role must include the exercise of primary responsibility by developing an overall statewide estuarine management program that provides for direct, effective State management and the delegation of the requisite authority to its political subdivisions for local direction and management in accordance with the statewide management plan.

Such a program should include:

(1) A mechanism for its implementation.

(2) Provision for:

(*a*) coordination of State and Federal programs;

(*b*) inventory of estuarine resources;

(*c*) acquisition of selected coastal areas;

(*d*) financial assistance and coordination of research and study of area problems;

(*e*) control regulation and enforcement;

(*f*) a program of public education and awareness; and

(*g*) manpower training programs.

The needed State actions to assume their new and strengthened role are:

(1) Establishment or designation of a specific State organization provided with the authority and means to develop and implement the comprehensive phase of management for the estuarine zone.

(2) Control and enforcement of water quality standards as an essential element in the long-range management plan.

(3) Consideration of legislation designed to preserve the public interest in the wetland and tidal areas. Such legislation should give authority to the State to delineate wet lands of significant natural resource value and to give them long-term protection. The State should initiate the action and should not have to wait until a particular wet land or estuary is in imminent danger of destruction.

(4) Establishment or authorization, as needed, of appropriate local/regional management organizations or special districts to provide effective implementation of the comprehensive management plan for the State's estuarine zone.

(5) Propose or work toward appropriate interstate compacts or relationships needed for management, regulation, and optimum multiple-use development in interstate waters including:

(*a*) Institution of State-level permit requirements for dredging, filling, or other modification of wet lands and other estuarine resources;

(*b*) Requirement for all State and local agencies engaged in activities that may physically or otherwise modify estuarine resources, either directly or through issuance of permits, licenses, leases, and so forth, to:

(1) minimize adverse effects on estuarine resources; and

(2) give notice of intended action and hold public hearings before acting, if there is indication that an adverse effect is a likely result;

(*c*) Resolution of problems in regulating use of tidal lands, wet lands, and so forth, under private ownership;

(*d*) Strengthening land acquisition and development programs for conservation purposes;

(*e*) Institution of State-level authority to review zoning and other action by local governments and to veto if inconsistent with an approved statewide management plan; and

(*f*) Augmented funding of all components of the State's comprehensive management program and plan.

The management plan must also be compatible with those of neighboring States. This approach seems altogether appropriate, especially because several States have voiced concern over the anticipated loss of substantial estuarine areas during the next 5 years. Relating the 5-year period to a protective action period indicates the following possible approach: that it would take 1 year to develop or strengthen the management plan and legislation; 1 year to get it enacted; 1 year to develop an organization; 1 year to get the organization moving; and 1 year to actually start improved estuarine management operations.

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# CHAPTER 3. ROLE AND ACTIVITIES OF LOCAL GOVERNMENTS

## SECTION 1. INTRODUCTION

The most crucial decisions on destruction and/or conservation of estuaries are made at the local government level. Yet the record of local government in estuarine management is disappointing. As Dr. Stanley A. Cain remarked:

> The authority for zoned use of the coastal zone—that is, its allocation to determined uses in specified places—lies with local government. And local government finds itself weak in the face of massive private economic power and the public resistance to increased taxes (V–3–1).

Local governments' present activities, problems, and effectiveness in the estuaries are discussed in this chapter and ways in which local direction and programs can share in the total national effort to preserve and develop our estuaries are recommended. Particular attention is given to imaginative land- and water-use management techniques by local agencies.

This discussion of local governments' role is made with full recognition that our American federal system is one of shared responsibilities between local, State, and Federal governments. Today there are no autonomous estuarine areas. Our functioning governmental system does not resemble a layer cake, as a common simile has it, but, more closely approximates a marble cake of joint powers and activities. Thus, rather than allocating specific functions exclusively to local agencies, their programs can be fitted into a cooperative, intergovernmental pattern of balanced estuarine uses.

An extensive survey and numeration of the activities of all local governments in estuaries is beyond the scope of this report. Rather, some functions of local governments relating to estuaries are briefly indicated, and their programs, problems, and regulatory tools discussed in general terms. For purposes of this report, "local government" includes not only cities and town but also, when applicable, counties and intrastate, multicounty, and regional agencies.

Estuaries are affected by a wide variety of local government activities and programs, including water resources (pollution control, waste disposal, and water supply); transportation (especially port and marina facilities); conservation and recreation (parks, fisheries, and wildlife); and commercial and economic development and public and private land use (planning, zoning, and housing). All of these must be considered in organizing a comprehensive estuarine management program.

## SECTION 2. MANAGEMENT TOOLS

In developing and conserving estuarine resources, the following management and regulatory tools have been used by local governments:

public ownership, legislation and permits, financial inducements, zoning, planning, and public education. A discussion of these categories follows.

## OWNERSHIP AND ACQUISITION

The most effective technique for conservation of estuaries is public acquisition and ownership. Although costly, Government purchase of private land by negotiation (or if necessary through the power of eminent domain) is the best guarantee against estuarine despoliation. The most common form of such an open-space program is outright purchase; other variations include advance acquisition and excess condemnation. Advance acquisition is a reserved land technique by which the Government purchases "land banks" before they are actually required for planned public projects in order to avoid price rises. Excess condemnation, for conservation purposes, involves the acquisition of land buffers, to maximize public access and enjoyment, near public facilities (such as small parks along highways) or schools, or between airports and residential areas.

In addition to ownership, public control may be acquired through leasing and purchasing development rights. The Government can arrange to purchase land and lease or sell it back, restricting its use (to farming or timber, for example) to preserve its open space. The Tennessee Valley Authority also uses a land covenant with restrictive provisions in it, such as prohibiting water pollution, in order to control land use (V–3–2). Additionally, the Government can purchase partial rights such as scenic, conservation, or natural resource easements. In this way, those who will not be able to sell their land for profit can be compensated. Such Government contracts with private owners, however, usually do not provide for public access.

Outside funding sources can be utilized by local governments for ownership and acquisition. Federal Government revenues can be used to purchase land for seashore, parks, and wildlife refuges. The land and water conservation fund (Department of the Interior) (V–3–3) and the open space land fund (Department of Housing and Urban Development) are especially suitable for estuarine preservation (V–3–4). State aid to localities, as exemplified by the New Jersey Green Acres bond issue, can be used for the purchase of marshlands. Finally, private sources often can be helpful, particularly such conservation organizations as the Audubon Society, Izaak Walton League, Nature Conservancy, and World Wildlife Fund, which have programs that use private funds and gifts. Further, tax-exempt private trusts have been established to maintain coastal parks and recreational areas, as well as golf and country clubs and private hunting preserves; such uses help protect estuaries. Despite these sources, however, local governments are still hard-pressed to find sufficient funds for acquisition.

## LEGISLATION AND PERMITS

Legislation, ordinances, and permits have had varying degrees of success in regulating estuarine development. Laws prohibiting certain uses, such as disposal of untreated wastes, refuse, dredged spoils, pesticides, and other hazardous materials are common. Uses are also regulated by ordinances, such as the Los Angeles ocean-submerged lands ordinance, which sets forth detailed criteria for structures, spacing, and operations affecting estuarine development (V-3-5).

To regulate dredging or fills, permits may specify that certain requirements be met; for example, the developer must dedicate a certain portion of his shoreland for parks, pay a fee for the increased value, or fill certain designated areas; he may also be required to provide for the right of public access. Detailed conditions are often contained in dredging permits, because this sensitive operation may cause irreversible physical and biological harm to estuaries.

#### FINANCIAL INDUCEMENTS

Local tax policies serve as financial inducements for private owners to conserve their estuarine land by giving them more favorable terms than the standard *ad valorem* assessment of real property. Preferential assessment of land—evaluation at actual or current use rather than the fair market or development value—is one such technique. A second is deferred taxation, by which taxes are held back until the land is converted to a higher use. Grants or subsidies by local governments to the landowner so that he may pay his property tax have also been proposed as a form of rental payment to induce him to keep his land open.

#### ZONING

Land use controls, especially zoning, are employed by most local governments, although their effectiveness is being increasingly questioned. Zoning, or districting by permissible use, varies widely from locality to locality. Some zoning tools are use lists, density standards, and, recently, performance standards (locating according to operational characteristics). Critics of this use-classification approach charge that it is unsatisfactory for land conservation purposes because it is either too rigid or allows for too many exceptions and variances. More imaginative and flexible approaches, however, such as cluster zoning, planned-unit development, and new-town zoning generally provide for open-space planning and allow greater land protection.

Another land-use measure is subdivision control, which requires the developer to allocate a specified portion of his land project for open space or parks. A recent example of creative use of this tool is the West Islip, Long Island, N.Y., residential builder who dedicated one-half of his land as a wildlife refuge. Finally, flood-plain lines can be established to protect against construction of houses, while specification of bulkhead lines for private tidelands can greatly limit dredging and filling.

#### PLANNING AND COORDINATION

Planning by local governments for orderly development and balanced usage of estuaries has generally been lacking. Presently, however, there are several possible means of increasing planning coordination at the local level. Section 204 of the Demonstration Cities and Metropolitan Development Act of 1966, as amended, provides that Federal grants for sewage treatment, hospitals, water supply, and transportation should be submitted for review to an areawide agency with metropolitan or regional planning authority, while section 701 provides for such planning grants (V–3–6). In addition, section 3c of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466), allocates funds for water quality management planning studies to local or State planning agencies designated by the Governor. Planning grants of this kind such as the one recently awarded to the Bay Conservation and Development Commission through the State of California to curb San Francisco Bay pollution are designed to seek solutions on a basinwide basis to reconcile the conflicting interests of polluters and other water users.

In local-State coordination, the codes of towns such as Westport and Brookhaven, N.Y., require that local officials approve permits for estuarine filling only after consulting with State officials. Planning studies by private organizations can be very helpful in establishing estuarine management programs. The Belle Baruch Foundation, for example, aided a survey study of Atlantic coast wetlands which extensively mapped and evaluated the legal aspects of their ownership (V–3–7). The conservation foundation has also shown how new and imaginative planning and design techniques can be applied to preserve and develop Rookery Bay in Florida (V–3–8). This study illustrates the feasibility of a multipurpose estuarine conservation and development plan using the efforts of both public and private sources. Implementation of this study, however, has been delayed by the reluctance of local officials to adopt a resolution endorsing the development objectives and general recommendations of the plan.

#### PUBLIC EDUCATION

Although programs to educate and inform the public are of great value, they are rarely found at the local level. One significant exception is the training of marine technicians by the city of San Diego, Calif. But on the whole there have been few local studies to guide developers in cost reduction by better planning of land and water use, or to acquaint developers with the benefits of open space.

### SECTION 3. PROBLEMS AND FAILURES

Having briefly enumerated the management tools that local governments could employ for rational estuarine development, this section will evaluate the reasons why local governments' failures in this area outweigh their successes, recognizing at the same time that the record of the State and the Federal Governments has also been disappointing.

#### LEGAL PROBLEMS

The confused legal situation is a direct cause of the failure of local government in preventing uncontrolled growth in the estuaries. Divided ownership, disputed titles, unresolved public-use rights, and varying State, Federal, and local laws considerably complicate the attempt to achieve planned land-water management.

There is an urgent need for court clarification of such essential questions as: The definition of tidelands and territorial waters; can they be sold? What is the extent of public-use rights in privately owned land?

When are such rights legally cut off or alienated? Which zoning regulations so restrict the use of land by its private owners to the point that these laws render the land essentially useless and amount to uncompensated taking of property without due process, which is unconstitutional?

These questions indicate complexities in the legal problems. Additional basic legal principles, problems and trends, existing at the State level, discussed in the preceding chapter 2 on coastal States responsibilities, programs, and roles.

Public trust doctrines, the idea that wetlands and tidelands are held by the State for the public trust, generally have been ineffective in preserving estuarial land from sale nor did they prevent public uses from being foreclosed. Historically, tidelands were considered to be worthless property whose "reclamation" was to be encouraged. In California, for example, the State delegated ownership of much of San Francisco Bay to its bordering counties who in turn sold the land to private developers for industrial and other types of developments. In this atmosphere of permissiveness, legislative "giveaways" were encouraged and private owners easily obtained permission to wharf out or construct piers and other structures in the tidelands.

Lately, however, there has been a shift in public policy and a recognition of the irreplaceable value of such areas. Stricter regulations have been devised to limit use of these areas formerly considered to be worthless.

While the States generally control the uses of navigable waters, local governments have been delegated the prime responsibility for managing the landward areas. There is, nevertheless, great uncertainty as to ownership, and each private title is unique and complicated. Extensive litigation over these lands, some of which have been fraudulently acquired, has been long delayed and is urgently needed. Despite the reassertion of public rights and interest in estuaries, no overall State or municipal policy on use and disposal has evolved. As a result, development is frequently unplanned and unregulated.

### PROGRAM DEFICIENCIES AND REVENUE PRESSURES

A second reason for the difficulty local agencies encounter in attempting to evolve rational and comprehensive estuarine management policies is programing deficiencies. Almost all coastal local agencies lack the Staff and funding capabilities to plan, decide, and implement regulations for compatible land and water uses. One survey reported that some local authorities were unaware of their jurisdiction and control powers over the coastal zone and its resources (V–3–9).

Decisionmaking is also hampered by fragmented jurisdictions. Almost all local governments are too small to encompass the entire estuarine area; they approach problems on a piecemeal basis rather than by an overall view of the suitability of uses and the total resource value of estuaries. In addition, local governments, including major metropolitan areas, have little impact on upstream water resource projects that can bring about major changes in the quality and amount of fresh water inflow to the estuary.

Another problem is that of coordination within local governments. As at other levels, local departments often work at cross purposes.

The port development agency may favor filling estuaries at the opposition of the parks department; or the building of public-access roads by the highway department may destroy the wildlife protected by the fish and game department.

Intergovernmental relations among agencies are also haphazard. For example, rational estuarial management must integrate related land and water uses. Yet land-water zoning plans are rarely coordinated, because the State sets water quality use standards and owns the submerged lands, while the counties and local governments control the use of land bordering these waterways.

Conflict may also occur, as illustrated by the following statement:

> State and local governments frequently find themselves in adversary positions concerning conservation and recreation facilities, with local governments both hesitating to move themselves (financial limitations being the chief factor) and objecting to State action that would remove real estate from local property tax or otherwise impinge on local government prerogative (V-3-10).

Strong economic pressures often work against preservation of estuaries. Heavily dependent on property taxes, local governments need the revenues brought in by "developed" land. Similarly, heavily taxed private landowners find selling their land to developers more profitabe than retaining it in natural state. Because of these immediate and tangible benefits and the insistence of industrial, commercial, and residential interests, it is very difficult for hard-pressed communities to conserve such things as the habitat and recreational values of the estuaries for long-range benefit. As a result of these compelling needs for revenues and profits, estuaries are dredged, filled, and developed.

The picture presented here is not encouraging: multiple fragmented units of government, inadequately staffed, desperately competing for use of the same tax base; permissive laws and regulations; few comprehensive programs; few formal mechanisms for State-local or interlocal cooperation; and little coordination of water and shoreline zoning and uses. Without local government direction, the decisionmaking initiative lies within the area of private interests as more and more estuares are destroyed.

## Section 4. Selected Interlocal Coastal Management Programs

### SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION

San Francisco Bay vividly illustrates the problems and promises of comprehensive estuarine management. Alarmed by this shrinking and polluted bay, the California Legislature in 1965 created the San Francisco Bay Conservation and Development Commission (BCDC). The act provided for a 27-member commission representing all elements of government including the cities and counties. It declared that:

> The present uncoordinated, haphazard manner in which San Francisco is being filled threatens the Bay itself and is, therefore, inimical to the welfare of both present and future residents of the area surrounding the Bay (V-3-11).

The BCDC was directed to make a detailed study of the bay and to prepare a comprehensive and enforceable plan for its conservation and the development of its shoreline (V-3-12). It was given the power to protect the bay during the study and planning period by issuing or denying, after public hearings, permits for all fill or excavation projects.

The BCDC study documented the deteriorating conditions and complex problems of the bay. In 1850, before extensive diking and filling had begun, the bay comprised about 680 square miles. Presently, it is 400 square miles in area. Further, if all relatively shallow parts of the bay were filled, as planned by some interests, the bay would consist of only 187 square miles. Similarly, marshlands and mudflats at the rim of the bay, once totaling 300 square miles, have been reduced to 75 square miles. The bay is especially vulnerable to land-fill projects because more than 70 percent of its area is less than 18 feet deep.

Existing political, administrative, and legal mechanisms were inadequate to protect this invaluable resource. Haphazard planning and zoning practices abounded, with each municipality operating independently of its neighbors. Ownership of the bay was divided between the State (50 percent), cities and counties (23 percent), the Federal Government (5 percent), and private owners (22 percent), whose titles were often disputed. Moreover, there were differences of opinion on the extent of the public trust, such as whether cities could fill in lands granted to them by the State

In January 1969, BCDC filed a final report which included the commission's detailed study of the bay (V–3–12). A comprehensive plan was adopted and to maintain and carry out this plan, an appropriate agency was recommended, at an estimated annual cost of $400,000 to $500,000. A bill, the McAteer-Petris Act as amended, implementing the BCDC recommendations and extending its life was enacted in August 1969 (V–3–13). The bill gives the commission in general terms the following powers: To analyze, plan, and regulate the entire bay and shoreline as a unit with jurisdiction up to 100 feet; to make an effective use of each prime site; and to grant or deny permits for all bay filling or dredging in accordance with the standards in the plan. The commission is also able to regulate shoreline development to insure that prime sites are reserved for priority uses, to provide for maximum public access and repurchase, and to encourage attractive design of shoreline development.

In conclusion, San Francisco Bay is not unique in its estuarial problems. The picture BCDC painted of a neglected, shrinking, polluted bay, yet an irreplaceable and immensely productive resource, is typical of most of our Nation's estuaries. What is significant about the San Francisco Bay experience, in addition to the comprehensive and detailed background reports, is that this study commission was oriented toward practical planning and implementation, and that it was also endowed with interim power to prevent further despoliation and uncoordinated development. Under the act that created BCDC, this commission could grant permits for fill or excavation only if a proposed project was "(1) necessary to the health, safety, or welfare of the public in the entire bay area, or (2) of such nature that it will not adversely affect the comprehensive plan being prepared." Thus BCDC showed how a regional agency endowed with permit powers and focusing its studies on program implementation did not merely study the problem but also served as a catalyzing agency to perserve this irreplaceable estuary.

### LONG ISLAND WETLANDS PROTECTIVE PLANS

The wetlands of Long Island have long been a cause for concern to those worried about the rapid loss of our estuaries. There is a lengthy history of political controversy over fillings and alleged dredging violations.

It has been estimated that 12.5 percent of these irreplaceable lands was lost between 1954 and 1959, and that at present 30 percent of Long Island's remaining wetlands is in immediate danger, while another 39 percent will be endangered in the foreseeable future. In addition, of 29 cases of dredging by the Corps of Engineers, undertaken between 1964 and 1966 over the objections of the U.S. Fish and Wildlife Service, 21 were in the Long Island area (V–3–14).

This has spurred legislative action on both State and Federal level to protect the rapidly disappearing estuarine resources of Long Island. In 1966 Congressman Herbert Tenzer, Democrat, of New York, of the fifth district, introduced legislation to create a National Wetlands Area in south Long Island. Broadened to include other estuarine areas, House bill H.R. 15770 barely failed to pass in the 89th Congress and was finally enacted as Public Law 90–454, the National Estuary Protection Act, in 1968 by the 90th Congress.

At about the same time, New York State passed the Long Island Wetlands Act, which provides that the States and localities share the costs on a 50–50 basis of maintaining, operating, and developing county or municipally owned wetlands that have been dedicated to conservation purposes. At present 15,500 acres, mostly in the town of Hempstead, are protected and authorities plan to extend the act's coverage to another 31,000 acres.

Also, a government instrumentality has recently been created in recognition of the importance to Long Island of its marine environment. In 1965 the Nassau-Suffolk Regional Planning Board created an oceanographic committee which prepared a report of the status and potential of Long Island's marine environment with recommendations on duck and vessel pollution and on regulating marine sand and gravel dredging (V–3–15). The report also recommended a comprehensive research and planning program to remedy present management and coordination deficiencies.

Following the committee's report, a regional marine resources council was created by the planning board in 1967 to act in an advisory capacity on all matters involving Long Island's marine resources on an ad hoc basis and to formulate a long-range management plan. The council serves as an informal coordinating agency and also brings together various nongovernmental and private interests through its bimonthly meetings. The council is now funding a research program and has been instrumental in bringing about improved methods for duck farm waste disposal, elimination of DDT used as a pesticide in several areas, and greater attention to improve wetland use and sewer outfall locations.

### MASSACHUSETTS LOCAL CONSERVATION COMMISSIONS

Recently, gains have been made in Massachusetts in recognizing conservation needs and effecting appropriate programs. During this time, 38 of 60 coastal towns established conservation commissions to administer to the conservation needs of the community. As stated by the 1964 Massachusetts Legislature:

The greater effort of many coastal commissions has been directed toward the protection of tidemarsh areas. Protection methods in various towns have included: establishment of dredging and filling bylaws; conservation district and/or subdivision zoning; and actual acquisition of tidemarsh acreages. Unfortunately that acquisition—the most highly desired form of protection—is being exercised in relatively few towns. The towns of Orleans and Chatham are leaders in acquisition, having procured 400 and 170 acres, respectively. Acquisition in both of these towns has been by gift, purchase, and eminent domain. In addition to the actual acquiring of tidemarsh acreages for conservation purposes, each of the above towns employs zoning, and dredging and filling bylaws to further regulate the use of coastal wetland areas.

The town of Barnstable . . . designated the great marshes of Barnstable as the great marshes conservation area. This area comprises about 3,300 acres of tidemarsh. It is expected that the entire area will be deeded over to the town within 2 or 3 years.

If all coastal conservation commissions could boast of similar accomplishments the problem of our vanishing wetlands would no longer exist. To date, less than 1,000 acres of coastal wetland have been acquired at the town level of government.

A primary goal of every coastal commission should be to acquire and place under permanent protection, at least one of its more important tidemarsh areas (V–3–16).

## Section 5. Recommendations and Conclusions

This chapter has briefly surveyed existing practices and evaluated the accomplishments and problems of local government activities relating to estuaries. On the following pages, some recommendations are made to promote effective local programs, bearing in mind that, under our federal system, operating success can best be achieved through cooperative local-State programs.

The purpose of these suggestions is not to freeze forever the estuaries in their present status, but rather to curb uncontrolled growth and haphazard but devastating urban incursions and to develop compatible land and water management systems that will provide for balanced use of estuaries.

First, local governments must be strengthened and reoriented to focus on estuarial problems. Carefully drafted model legislation, ordinances, and planning guides for local governments should be established to call attention to these vulnerable resources. They should include a statement of public purpose and interest along with a description of basic goals (such as open space and recreational development and the shoreline area, including wetlands and waterfront areas, to be covered). In addition to a legislative declaration of public rights and use claims, planning and regulatory authority should be given to a specific estuarine management agency. At least an interagency committee should be established to coordinate local policies.

Such legislation could establish an open space and estuarine preservation policy to control the alteration of estuaries and prohibit any pollution. Further grants of State-owned tidelands could be halted, and the State could definitely establish claim to all such lands unless it could be shown that colonial or territorial titles or special legislation had given this land to a private owner. The legislation could also designate essential areas to be preserved, or repurchased if necessary, and give the agency full planning and zoning power. Dredging or filling would not be permitted unless it was in accord with the estuarine use plan, with burden of proof on the filler or dredger that such alteration would not pollute or destroy the area.

With reference to geographic jurisdiction, it would be desirable to establish a regional agency to cover the entire estuarine problem area, because the individual municipalities or even counties may be too small. Whichever form such an areawide agency may take—independent special district, interagency cooperative committee, or multijurisdictional planning unit—this governmental mechanism should have management responsibility as well as study and research authority. This would include regulatory power over dredging and filling, zoning and land-water use authority, and perhaps even the ability to raise revenue from licenses and to study management techniques.

The regional estuarine agency should utilize the full array of management and planning tools described earlier, including especially the power of eminent domain with just compensation, repurchase and easement rights for public access, and development options to preserve the land. Its leases and permits should be flexible so they can be terminated or revoked should their conditions be violated. Regulations should not rigidly foreclose any further industrial, commercial or residential development. Sufficient safeguards for public representation, such as notices, hearings, and possibly an appeals board are also desirable. To survive legal attack, regulations should be reasonable and should be applied in a nonarbitrary, nondiscriminatory manner; they should not preclude some other public or private economic uses. Ideally these regulations and plans should be viewed as guides and standards, and, while restraining and controlling development, should serve as an inducement for better design and land use.

Such a multifunctional agency could also deal with hurricane, flood, and erosion control; waterfront access; architectural preservation and beautification; and upstream water projects influencing the estuarine zone. Its regulatory and policy powers could be subjected to the final decisionmaking of a review and appeals board composed of municipal officials and group representatives. In its decision on licenses and permits, the board would be empowered to consider such factors as recreational and economic, esthetic, and environmental effects. It is unlikely that many areas will immediately establish such a regional estuarine management agency, but in all probability will first choose to undertake an overall survey of their estuarine problems. Such a study, however, should not be an excuse for inaction. As in the case of BCDC a moratorium on further filling and sales could be declared until the study commission reports, and the commission could be given interim permit and zoning authority, such as the power to grant dredging licenses and establish bulkhead lines.

States have an important role to play in aiding local programs. Financial assistance in the form of matching grants for pollution control or open space bond issues can be crucial in local estuarine management. In addition to funding, cooperative programs can be utilized in such areas as zoning and planning. The State may choose to establish an official map or enact a broad zoning law with general requirements to be met by county and local government plans. Permits for dredging and filling issued by municipalities could be reviewed by State natural resources commissions or wetlands boards.

Utilization of the expertise and resources of private organizations is advantageous for local governments. For example, the Conservation Foundation study of Rookery Bay, Fla., could serve as the basis for a "model estuaries" Federal-State-local grant program. Also, the nature conservancy fund could be used by localities to establish parks and other refuges in estuaries for public purposes.

In addition to research on biological aspects and water quality, there is a great need for further study of the legal aspects of estuarine management. Clarification of conflicting ownership claims and titles is urgently needed in almost every estuary. A detailed survey and inventory of ownerships, to include legal basis, rights, title checks, and assessment of land value, should be undertaken by local governments. It is not unlikely that such a survey would disclose land still owned by the State and leases that need renegotiation because their terms have been breached. A continuous updating of this land register should also be part of local governments' management activities.

This chapter has stressed the crucial role that local governments can play in the direction and management of estuaries. In the past, localities have not been very effective in developing and maintaining comprehensive programs. Greatly handicapped by a lack of plans, administration, finances, and government personnel, they have been further hindered in decision making in the public interest by their limited geographic scope, taxable resources, and legal powers. In almost all cases they have failed to arouse the public or overcome popular indifference to the loss of estuaries to the encroachments of "civilization."

The record of estuarine management has been disappointing at all levels, Federal and State, as well as local. The only answer to the question "Can we rely on local government?" is that we must—for we have no choice—work through the municipalities, counties, and towns. Indeed, only a cooperative, intergovernmental approach can succeed because each level is ineffective by itself. Regional agencies covering the estuarine zone can promise the best results, but only by strengthening the existing decisionmaking machinery, as suggested here, can local government rise to this challenge. Local government has the capability to play a leading role in estuarine management, and it is essential that it do so. For, ultimately, any such program must rely on local initiative, organization, planning, and support.

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# CHAPTER 4. ROLE OF COMPACT AGENCIES IN ESTUARINE MANAGEMENT

This chapter describes and evaluates the present role of interstate and Federal-interstate compact agencies in estuarine management. It also develops recommendations concerning the role of such organizations in the comprehensive national estuarine management program.

## Section 1. Use of Compact Agencies to Date

Use of the compact instrument in managing the Nation's estuarine resources has been limited to management of water resources and management of fisheries. Included in the first category are the three pollution control compacts establishing, respectively, (1) the Interstate Sanitation Commission, (2) the Interstate Commission on the Potomac River Basin, and (3) the New England Interstate Water Pollution Control Commission. Also in this category is the multipurpose Delaware River Basin Commission.

Fisheries compacts include the regulatory Potomac River Fisheries Commission and the three advisory and research-oriented fisheries commissions for, respectively, the Atlantic, gulf, and Pacific fisheries.

Selected details on the purposes, powers, and roles of these compact agencies in estuarine management are presented in tables V.4.1 and V.4.2 on pages 426 and 427.

### GENERAL ACCOMPLISHMENTS OF WATER RESOURCE COMPACTS

Accomplishments of the compact instrument in managing water (and related land) resources generally fall into two broad categories.

The first is regulation of use and/or modification of water resources covered by the compact. This too takes two forms: (1) the enunciating or developing, by means of the compact, of a binding agreement among the signatories on basic policies which are to govern the use of the resources and (2) the implementation by a joint agency, which the compact establishes, of such basic policies through a variety of means, including action to induce or compel others to comply with these policies and direct operation of facilities and administration of resources by the compact agency itself.

The second category of accomplishments is the performance by the compact agency of services supporting resource use or regulatory programs.

Each of these accomplishments is illustrated and elaborated below.

### DEVELOPMENT OF BINDING POLICIES

Use of the compact can accomplish this in one or both of two ways. Under the first method, the compact itself expresses a negotiated agree-

TABLE V.4.1.—INTERSTATE POLLUTION CONTROL COMPACTS FOR ESTUARINE MANAGEMENT

| Agency and signatories | Major purpose | Major powers | Indication of special concern with estuaries |
|---|---|---|---|
| Interstate Sanitation Commission: Connecticut, New Jersey, and New York (1936). | To abate existing pollution and control future pollution. | To order entities discharging sewage to comply with treatment requirements specified in the compact; to bring court action to compel the enforcement of the compact's provisions and its own orders; and, for the purpose of coordinating the pollution control activities of the signatories, to prepare a general plan of the most practical and economical methods of securing conformity with the standards specified in the compact. | Other than its pollution control activity, has been limited to current investigations into wetlands problems and what its role should be in that area. |
| Interstate Commission on the Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia (1940). | To abate existing pollution and control future pollution. | To compile and report on stream quality data; to engage in fact-finding and research on the treatment of wastes; to promote uniform laws, rules, and regulations; to disseminate information to the public; and to recommend waste treatment and water quality standards. | Has attempted periodically to focus public attention on problems of the tidal portion of the basin through discussion at annual or special meetings and through publication of educational materials. |
| New England Interstate Water Pollution Control Commission: 6 New England States and State of New York (1947). | To abate existing pollution and control future pollution. | To establish water quality standards for various classifications of water use; and to review and approve the signatories' classifications of their interstate waters, tributaries thereto, and tidal waters ebbing and flowing past State boundaries in New England. | None other than the use of classifications and associated water quality standards recommended for tidal waters within its jurisdiction. |
| Delaware River Basin Commission: Delaware, New Jersey, New York, Pennsylvania, and the United States (1961). | Through intergovernmental cooperation, to develop and effectuate plans, policies, and projects relating to the water resources of the basin. | Are numerous and very broad. Include the power to prepare plans for all aspects of the development, use, and conservation of water and related natural resources and to implement these plans through regulation, its own operations, and other means. | Adopted water quality standards for estuarine portion of the river, developed 10 year fisheries research program which signatories are implementing—estuarine portion includes anadromous fish, shellfish, and finfish investigations, and study of relationship of wetlands to fishery resources. Appears to have included certain estuarine resources under its comprehensive development plan. Is preparing plans for a broad study leading to development of a plan for managing the water and related land resources of Delaware Bay specifically. |

TABLE V.4.2.—INTERSTATE FISHERY COMPACTS FOR ESTUARINE MANAGEMENT

| Agency and signatories | Major purpose | Major powers | Indication of special concern with estuaries |
|---|---|---|---|
| Atlantic States Marine Fisheries Commission: 15 Atlantic coastal States (1942). | To promote better use of fisheries by developing a joint Federal-State program for promotion and protection of fisheries and by preventing their physical waste. | To promote and undertake studies; through recommendations, to coordinate the States in their exercise of regulatory power; to draft and recommend fishery legislation; to consult with and advise State administrative agencies on fishery problems; and to act as a joint regulatory agency for 2 or more consenting States (no States have chosen to use the agency for this purpose.) | Has periodically attempted, through use of its recommendatory authority, to focus attention on damage occurring to estuaries, through pollution, dredging, and disposal of dredged materials and destruction of wetlands in particular. Their efforts include (1) bibliography on estuarine studies published in 1965; (2) 1964 compilation of State laws and regulations governing dredging, filling, and other disposition of wetlands; (3) issuance of guidelines for estuarine management in 1966; and (4) present preparation of educational pamphlet on estuarine management problems. |
| Pacific Marine Fisheries Commission: Alaska, California, Idaho, Oregon, and Washington (1947) (Hawaii also is eligible for membership). | do | To promote and undertake studies; through recommendations, to coordinate the States in their exercise of regulatory power; to draft and recommend fishery legislation; and to consult with and advise State administrative agencies on fishery problems. | Has periodically attempted, through use of its recommendatory authority, to secure action protecting fisheries from damage caused by pollution and alteration of natural flows. |
| Gulf States Marine Fisheries Commission: Alabama, Florida, Louisiana, Mississippi, and Texas (1949). | do | To promote and undertake studies; through recommendations, to coordinate the States in their exercise of regulatory power; to draft and recommend fishery legislation; to consult with and advise State administrative agencies on fishery problems; and to act as a joint regulatory agency for 2 or more consenting States (no States have chosen to use the agency for this purpose). | Has attempted, through its recommendatory authority and the leadership of its estuarine technical coordinating committee, to give particular attention to protecting the estuarine environment for the gulf fisheries. Their efforts include service as a coordinator in gulfwide Federal-State inventory of estuaries and current preparation of an educational film demonstrating the importance of estuaries to the gulf fisheries. |
| Potomac River Fisheries Commission: Maryland and Virginia (1958). | To conserve and improve the fishery resources of the tidewater portion of the Potomac River. | To regulate, license, and tax, fishing | Has voiced concern over proposed industrial development it regards as potentially adverse in its consequences to fisheries. Otherwise, has confined its actions to matters pertaining to management of fisheries. |

ment among the signatories on basic policies which, by virtue of that enunciation, become binding upon all of them. The typical water allocation compact is probably the best example of this type of accomplishment. Among compacts more directly involved in estuarine management, the best example is the Tri-State compact, which creates the Interstate Sanitation Commission. Here the compact itself specifies the type of waste treatment each signatory will require for each of certain classifications of water use.

Under the second form, the compact itself does not express the basic policy agreement among the signatories. Instead, each State in the compact agrees to be bound by the policy decisions which the States collectively will reach within the framework of the compact agency. Examples are the Delaware River Basin Commission in its decision on water quality standards for the Delaware River and in the policies it applied to the recent drought emergency in that basin. Also illustrative are the policies adopted by the Potomac River Fisheries Commission to regulate fishing in the waters under its jurisdiction.

In either form, this accomplishment effectively achieves program coordination between the signatories to the compact, perhaps in the only sure way possible short of transferring the responsibility for coordination to a higher level of government.

### IMPLEMENTATION OF BASIC POLICIES

Use of the compact can achieve implementation of basic policy agreements among the signatories in two ways. Under the first form, the compact agency is authorized to require those proposing use of the basin's waters to obtain its prior permission. Depending on its exact authority, the agency thus is able to implement policies, either enunciated by the compact itself or which the agency itself has developed, through such means as: (1) the attaching of performance requirements as a condition to its permission to others to utilize or modify the resource, (2) the issuing of directives ordering other entities to take steps, or halt activities, specified by the agency, and (3) the initiating of court to compel compliance by others with the agency's permits and orders. Exemplifying this accomplishment among the agencies here surveyed are the Interstate Sanitation Commission and the Delaware River Basin Commission. The former's accomplishments in this regard are limited to the prevention or abatement of pollution. In contrast, the latter's actual or potential accomplishments extend also to such matters as the withdrawal and diversion of water from the basin and to the use of water for purposes other than waste disposal.

A compact agency can implement policies, secondly through its own direct operation of various facilities affecting water resources or through directly administering certain resources. Although not strictly water resource agencies, examples are: the Breaks Interstate Park Commission and the Palisades Interstate Park Commission, both of which administer interstate recreational facilities; and the Port of New York Authority and the Delaware River Port Authority, both of which administer transportation facilities in interstate metropolitan areas. Although none of the agencies included in this survey has accomplishments in this area, the Delaware River Basin Commission is authorized directly to administer and operate a broad variety of estuarine-related sites and facilities.

PERFORMANCE OF SERVICE FUNCTIONS

A major objective of the States in utilizing the compact instrument has been the creation of a joint agency to support the private development and use of such resources and/or their management by the signatories or others. Although these services may not seem as prestigious or significant as the development and implementation of basic policies governing the use of water resources, such compacts too can make an important contribution to improved use and management of resources.

The nature of these supporting services varies. They include: (1) serving as a clearinghouse and regional forum through which the signatories gain improved understanding of one another's objectives and needs and through which they voluntarily coordinate their respective programs; (2) planning in the sense of development by the compact agency of policies and plans of an advisory or recommendatory nature; (3) the conducting or promoting by the agency of research and studies aimed at expanding the knowledge base and thus improving management policies; (4) increasing public awareness and understanding of program needs by information dissemination and education programs; and (5) representation by the agency of State views and interests at the Federal level.

Although most compact agencies perform one or more of the services mentioned above, the programs of several of the agencies included in this review are limited to these services. Specifically, this is true of three of the fisheries compacts (Atlantic, Gulf, and Pacific); the present Potomac pollution control compact, whose agency has stressed studies, public education programs, and service as a regional clearinghouse and forum; and the New England Interstate Water Pollution Control Commission, whose activities have been characterized by advisory program planning, program coordination, research and studies, and service as a regional clearinghouse and forum.

EVALUATION OF THEIR PAST ROLE IN ESTUARINE MANAGEMENT

As shown in table V.4.2 each of the three interstate fisheries commissions has stressed the improved use of fishery resources as its major purpose. As part of this effort, each also has attempted to reduce the damage of estuaries through pollution and other causes. Limited in each case to a research-coordination and recommendatory role, none of the agencies has itself been able to do much about such damage. Moreover, even in the restricted role of these agencies, their limited resources—in money and size of the staff—have seriously handicapped their effectiveness.

Like their counterparts in the fisheries, the three interstate pollution control agencies have not become significantly involved in estuarine management. In the case of two—the New England Interstate Water Pollution Control Commission and the Interstate Commission on Potomac River Basin—authority is limited to support of State pollution control agencies. It also extends, in the case of the first agency, over a geographic area much larger than this region's estuaries. This latter point appears less important in the case of the Potomac commission, because it has shown special concern with the estuarine portion of the river. That concern, however, has almost solely stressed the pollution threat. In both of these agencies, limited financial resources also have curtailed the overall contribution which they can make.

Although concerned with what clearly are estuarine waters, the authority of the Interstate Sanitation Commission extends only to the control of pollution. Also, while it technically has regulatory authority, this may be more apparent than real; for it can compel a polluter to take corrective action only if its order to that effect receives assent from a majority of the commissioners from each member State. Thus, a decision by the commission to order abatement of pollution, or to enforce compliance with such an order, is really a decision by the State in which the polluter is located, and the role of the interstate commission can more properly be described as ministerial in nature.

Unlike the agencies already discussed, the Delaware River Basin Commission is multipurpose in nature. Moreover, in developing a more comprehensive approach to water resource management, it can employ a broad range of authority, including regulation and operation of its own facilities. It also can exercise regulatory authority on the basis of a simple majority decision by its commissioners. Federal membership in the commission also enables it to coordinate Federal and State activities in the basin. To date, however, its concern with the estuarine resources of the basin appear to have been quite limited. It includes adoption of water quality standards for the estuarine portion of the river, the development of a 10-year fisheries research program, the inclusion of certain estuarine resources under its comprehensive development plan for the basin, and the preparation of plans for a broad study of Delaware Bay, leading to the development of a plan for managing its water and related land resources. This limited role presumably reflects a decision to give priority to the river itself.

Although the Delaware River Basin Commission clearly has the potential to develop into a more significant force for a comprehensive approach to the management of the estuarine resources of that basin, its role in this regard can be expected to emphasize the management of estuarine water resources. This is because its authority to control land use appears to be primarily advisory and recommendatory in nature.

Compact agencies thus to date have not played an extensive or significant role in managing the Nation's estuaries. With the exception of the Delaware River Basin Commission, each agency has been predominantly concerned with a single phase of estuarine management problems. In most cases, the agency's concern with estuaries also has been only an incidental part of a broader mission. Finally, the role of most agencies—in law or in fact—has been restricted primarily to service to the signatory States. In other words, the States usually have stopped short of giving the compact agency real decisionmaking and enforcement authority on estuarine management questions and issues.

### POTENTIAL ROLE IN ESTUARINE MANAGEMENT

What about the role of the interstate compact in the comprehensive national program to manage estuaries more effectively? Can, and should, the compact instrument play a significant part in this emerging program? The answer to this second question is "Yes," if two conditions are met.

First, if a compact is proposed for more than the performance of service functions, the States must in fact give their joint agency authority and resources sufficient to enable it to override each State's independent prerogative to make and carry out its own policies in its own portion of the estuary. Put differently, this condition requires that the authority and resources given to a compact agency be commensurate with its basic mission. If that mission is regulatory in the sense that the agency is to develop the basic policies that are to govern the management of a particular estuary, then the decisions of the compact agency must be binding and preclude any signatory from administering less restrictive management policies. There also must be a means of avoiding deadlocks between the signatories which stall needed decisions, and of compelling the agency to make those decisions. The latter is especially essential in situations where differences in State views concerning policy in the estuary reflect very fundamental conflicts among different uses of estuarine resources.

Similarly, if the basic mission of the compact agency also includes the implementation and enforcement of these basic policies, then its authority (1) must not be subject to the veto of a single State, (2) should include all of the usual legal powers employed to abate pollution and other public nuisances, (3) should include the power to disallow action that is inconsistent with established policies, (4) should include authority to perform functions of a State or local agency if made necessary by the inaction of one of its signatories, and (5) should be supported by adequate financial and staff resources.

Likewise, if the agency's mission does not include either the setting or implementation of policy and is limited to that of regional service, then too its authority must be designed and supported so that the staff of the agency in fact can perform that service effectively and usefully.

The second condition is that the compact cannot be allowed to supersede or diminish Federal responsibility and authority for sound management of the Nation's estuaries. With or without Federal membership in the compact agency, a compact cannot abrograte the Federal Government's obligation to view the problems and needs of each estuary from a national perspective and to act accordingly within the limits of its authority.

Given adherence to these conditions, the compact instrument should prove to be a constructive way of achieving improved management in interstate estuaries. It also could achieve the decentralization of policy-making and administration that is essential if a major enlargement of Federal management responsibility is to be avoided.

## Section 2. Proposed Uses of the Compact Instrument in the Chesapeake Basin

### THE SUSQUEHANNA AND POTOMAC COMPACTS

Both of these new compacts are concerned with the management of resources indirectly affecting the estuarine resources of Chesapeake Bay. The first, the proposed Susquehanna River Basin compact, has been approved by Maryland, New York, and Pennsylvania, and legislation granting congressional consent is awaiting action in the 91st Congress. The second, the proposed Potomac River Basin compact, was drafted by a special committee established by the Governors of Maryland, Pennsylvania, Virginia, and West Virginia. It presently awaits action by the State legislatures and by the District of Columbia, which the compact includes as a member.

In brief, each compact would establish a joint agency of the signatory States and the Federal Government patterned after the Delaware River Basin Commission. Each would be empowered to perform essentially three broad functions.

The first would be to serve as a special organizational mechanism through which the basin States and the Federal Government would consult on mutual problems and interests regarding the water and related land resources of the basin.

The second function would be to coordinate the activities of these governments and of nongovernmental entities directed toward the use and management of the basin's water and related land resources. This coordination would be achieved principally through a comprehensive water resources plan—which would be an expression of basinwide goals, standards, objectives, programs, and projects—to be adopted, and revised as appropriate, by the compact agency; and through the water resources program, which the compact agency would be required to adopt annually as a statement of how the comprehensive water resources plan would be implemented by the signatories, the commission, and others.

The third broad function proposed for the agency is to construct and operate necessary projects and facilities, or to undertake other desirable activities, when no other governmental agency or nongovernmental entity does so, or when the signatory parties decide that the compact agency is the most appropriate entity to do so.

Although substantially similar, the Potomac compact differs in that it would also extend the agency's authority to the preservation and promotion of, in the words of the compact, "* * * the esthetic and other values inherent in the historic, scenic, and environmental amenities * * *" of the Potomac River Basin. The Susquehanna compact, in other words, is more strictly confined to the management of water resources.

If the new Potomac compact is enacted, the new basin agency would absorb the present interstate commission on the Potomac River Basin.

## OBJECTIONS TO PROPOSED COMPACTS

A number of Federal agencies have voiced objections to certain features in the Susquehanna compact. As stated in WRC agenda memorandum No. 2, prepared for the Water Resources Council, these agencies are objecting to:

(1) Voting and other provisions that could be used to adversely affect the duties and responsibilities of Federal agencies under the Federal statutes defining their respective missions.

(2) The provision that the Federal member on the compact agency is to be "* * * the direct representative of the President * * *." The Federal agencies object to this because the States reportedly have indicated this wording would mean that no Federal agency would be authorized to guide the decisions of the Federal member and, further,

that this member could disregard the wishes of the Cabinet officers directing the Federal departments dealing with water resources.

(3) The absence of safeguards giving assurance that the action of Federal licensing and regulatory agencies would prevail, in the event of conflict or confusion resulting from the exercise by the compact agency of comparable powers vested in it by the compact.

(4) The absence of provisions requiring the compact agency to give preference to public bodies and cooperatives in the sale of hydroelectric power generated at projects constructed and operated by the agency.

Because the proposed Potomac compact follows substantially the same approach on each of the above issues, one must conclude that it will encounter similar objections from Federal agencies.

In addition, however, objections already are being raised to this compact as it is being considered for possible ratification by the State legislatures. This early opposition appears to stem from various local governments and private interests in the basin, and particularly from the West Virginia portion of the basin. Although phrased in a variety of ways, the objections seem basically to reflect the following: (1) that the interests of upstream water users are inadequately protected; (2) that local governments in the basin are subordinated to a too-powerful compact agency; (3) that there is a lack of popular or citizen control over the compact agency; (4) that the agency's regulatory authority over the use of land resources of the basin is too extensive; and (5) that the District of Columbia should not be included as a signatory equal to the basin States.

## A SUGGESTED USE OF THE INTERSTATE COMPACT IN MANAGING CHESAPEAKE BAY

Proposals to utilize a compact to improve State-level management of the estuarine resources of Chesapeake Bay have been advanced from time to time. In recent years, this proposal usually has called for the enactment of a compact modeled after the Delaware River Basin compact and the two compacts now being urged for the Susquehanna and Potomac River Basins. Adherence to this approach would place the estuarine resources of Chesapeake Bay under a Federal-interstate commission empowered to perform the three broad management functions which were noted earlier in describing the latter two compacts.

As here conceived, however, the interstate compact to manage the estuarine resources of Chesapeake Bay would be an agreement between Maryland and Virginia under which each State would commit itself to take four actions:

(1) To prepare and, after consulting with the other State, to adopt and implement a management plan for the portion of Chesapeake Bay under its jurisdiction; to prepare this plan in cooperation with local governments, the other States, appropriate Federal agencies, and others; and to include in such plan at least the following components: (*a*) wetlands protection and management component; (*b*) water quality management component; (*c*) recreational use component; and (*d*) waterway utilities, and industrial use component.

(2) To establish policies and procedures whereby each State assures

that its local political subdivisions will implement and comply with the plan after its adoption.

(3) To require its agencies and local subdivisions, when developing legislative or other significant action proposals affecting the bay resources, to (*a*) study and consider all impacts, including the long-range effects, of the proposed action on the estuarine resources of the bay; and (*b*) explicitly state considerations of national, State, or local policy which justify any adverse effects that cannot be avoided by following reasonable alternatives.

(4) To establish and maintain a joint agency in cooperation with the Federal Government that shall: (*a*) coordinate State and Federal research and studies in the bay and conduct its own work along these lines; (*b*) conduct an education program concerning issues in the use and management of the bay's resources; (*c*) evaluate proposed plans and projects, both public and private, for the use and management of the bay and its estuarine resources by identifying the proposal's advantages and disadvantages, weighing tradeoffs between disparate benefits involved in the proposal, pointing out effects on the various interdependent uses of the bay's estuarine resources, and suggesting alternatives that should be considered; and (*d*) periodically evaluate existing management programs and the condition of the bay's estuarine resources, economic, and other trends affecting those resources, and report its conclusions and recommendations to the two States and the Federal Government.

Three major objectives underline the proposed use of the compact instrument along the preceding lines.

The first is to create a governmental institution whose predominant concern and mission would be to define and clarify issues and the consequences of alternative policies for the use and management of the estuarine resources of Chesapeake Bay. Decisions on those issues and execution of those decisions would remain with the politically responsible legislative and administrative institutions of the two States and the Federal Government.

The aim would be to dramatize more effectively, to the political process which must choose among alternative ways of utilizing and managing the resources of the bay, the two central needs that are the core of sound resource management. These are, first, to eliminate or reduce the adverse spillovers from certain uses that decrease or destroy the possibility of other use of the same resources. The need, in other words, is maximum preservation or conservation of the resource in order to maintain multiple use, and therefore maximum use, both now and in the future. The other need is to resolve the competition among different uses which results from the ever-increasing intensity of utilization, and from the inherent ultimate scarcity of some estuarine resources, through the conferring of priority on that mix of uses which society deems most beneficial, based on both short- and long-range considerations.

To facilitate the compact agency's performance of this unique function, which today is largely not performed, each signatory's membership in the agency should represent broad citizen interest and values in estuarine resources rather than those of the individual Federal or State agencies administering resource development or protection programs. It is the nature of the governmental process in this country that these line agencies as a rule must be especially responsive to special client groups. Sound management, therefore, requires that the special evaluative function here proposed for the compact agency be directed by persons not associated with the more narrow interest or viewpoint usually characteristic of these agencies.

The second objective is to obtain an agreement between Maryland and Virginia that each will develop and implement a comprehensive plan for the use and management of its portion of the estuarine resources of Chesapeake Bay. In essence, the goal here is to apply to the resources of the interstate bay the planning and management approach that the San Francisco Bay Conservation and Development Commission has applied to, and proposed for, the resources of that intrastate estuary. (See part V, chapter 3, for a discussion of BCDC.) Also implicit in each State's agreement on this point would be a commitment on its part to establish a greater degree of State-level supervision and control over zoning and other local regulations over land uses within the basin that affect estuarine values. At present, of course, each State's original authority to exercise these controls itself has largely been delegated to its local units of government. These units, not surprisingly, have wanted to promote the economic growth of the local area and improve its tax base. However, in the absence of effective review and supervision by a State agency charged with protecting estuarine resources, the result too often has been that local governments succumb to strong local pressures to proceed with poorly planned or limited-purpose development of these resources.

The third objective is to enact in each State, by means of the compact, statutory provisions requiring that all State or local legislative or other significant action proposals affecting the estuarine resources of the bay include an assessment and justification by the proposing entity of the proposal's effect on those resources and their use.

## Section 3. Summary and Conclusions

The effectiveness of existing compact agencies in managing the Nation's estuarine resources has been limited. The reasons are basically three.

First, the predominant concern of most compact agencies in existence has been with a single phase, or at most a few of the multiple phases, of estuarine management. Single purposes that have received special emphasis are the protection of fishery resources and the prevention or control of water pollution.

Second, concern with estuarine resources in most instances has been only an incidental part of a broader assigned mission to the agency. In other words, estuarine resources and problems ordinarily have not been the agency's special point of focus.

Third, the actual role of most compact agencies—in law or in fact—has been predominantly one of rendering supporting services to the signatory States. The States, in other words, have continued to make and execute most of the important estuarine management decisions outside of the compact agency's framework and procedures.

The potential contributions that the compact instrument can make to improved management of estuarine resources are important, nevertheless. They fall broadly into two categories.

1. Regulation of use and modification of interstate estuarine resources through, first, the enunciating or developing of a binding agreement among the signatories on basic policies which are to govern the use of those resources; and, second, the implementation of such policies by the compact agency through a variety of means, including action to induce or compel compliance by others with these policies and the direct management and operation of estuarine sites and facilities by the agency itself.

2. Performance of services supporting the use of estuarine resources or their management by the signatories.

The use of the compact instrument which this chapter has suggested in the case of the Chesapeake Bay is an example of each contribution.

For a compact device to contribute to improved management of interstate estuaries, it must meet two requirements:

1. The authority and resources of a compact agency must be commensurate with its basic mission. It is especially essential, if a compact authorizes the signatories' joint agency to develop and implement the basic policies which are to govern the use of the estuary, that each member State in fact should subordinate its authority to that of the compact agency.

2. The compact cannot be allowed to supersede or diminish the Federal Government's responsibility and authority to view the problems and needs of each estuary from a national perspective and to act accordingly within the limits of its authority.

# CHAPTER 5. VIEWS AND RECOMMENDATIONS OF THE PUBLIC AND PRIVATE SECTORS ON ROLES IN THE ESTUARINE ZONE

## SECTION 1. INTRODUCTION

The Clean Water Restoration Act of 1966, in establishing the National Estuarine Pollution Study, directed that the study be conducted in cooperation with various Federal, State, and interstate bodies, and, in addition, with "* * * local public bodies and private organizations institutions, and individuals * * *," and that "recommendations [shall be made] for a comprehensive national program for the preservation, study, use, and development of estuaries of the Nation, and the respective responsibilities which should be assumed by Federal, State, and local governments and by public and private interests."

Much was done through appointed representatives and many briefings, consultations, and exchanges of correspondence. But, to meet the requirement of bringing the study to the local level and to private individuals, and generally to reach all those who were not being reached by other means, it was decided to hold a series of public meetings—at least one in each coastal State—to obtain the views of all those concerned about the condition of the estuaries.

The decision was a fortunate one, in that the meetings proved to be an excellent vehicle for obtaining a comprehensive cross section of public opinion regarding the needs of and dangers to the estuarine zone. Attendance at the 30 meetings was good—not only in terms of number, but also in variety of organizations and individuals represented. Many statements, both oral and written, were made. Complete transcripts of each meeting were prepared, and, a a result, it is possible to extract from them a reasonably accurate report of the major concerns of those in attendance.

An additional important result of these meetings has been increased public awareness of the values and problems of the estuaries, because of the publicity given them. This has already resulted in favorable action at both State and local level to further the protection of the estuarine zone.

The public meeting proved to be an invaluable mechanism for obtaining statements of concern and recommendation from those groups and individuals who are usually left without a voice in studies of this kind. It was hoped that a variety of presentations would be made, and the success of the public meetings in this regard was far beyond anyone's expectations.

Because the public meetings were most important in bringing the study to the attention of individuals and to private organizations, the remainder of this chapter is devoted to an alalysis of these meetings and the conclusions to be reached from such analysis.

In addition, there were other successful means of contact which resulted in a continuous flow of information. The wide diversity of sources and methods used has been briefly described in the introduction to the study, and is more fully delineated in the outline in appendix A. The outline also further indicates the importance of the public meetings in reaching various group.

There were, of course, many other sources of information used that made particular efforts to gain the views and ideas of both the public and private sectors. The report by the panel on management and development of the coastal zone is an excellent example. This panel of the Commission on Marine Science, Engineering, and Resources held eight informal hearings in various parts of the Nation at which a total of 126 persons testified. The panel, in addition, interviewed or corresponded with over 600 persons.

The results of the above panel studies are discussed in greater detail in another chapter; they are noted here because of their importance as sources of public contract.

## Section 2. Planning and Conduct of the Public Meetings

In order to bring the planning of the public meetings as close as possible to potential witnesses, this responsibility was delegated to the six regional offices of the Federal Water Pollution Control Administration involved with the coastal States.

To reach as many people as possible, and to allow for the broadest possible representation, invitations were sent to organizations, business and industrial concerns and groups, and State and local government bodies; and announcements were made in the local press and on local radio stations, in an effort to encourage individual citizens to attend and speak.

Each meeting was presided over jointly by the regional director and by the Governor's representative to the national estuarine pollution study.

Because of the high degree of interest shown by the people in attendance, transcripts of the meetings, including written submissions, were prepared and sent to the participants and other interested persons.

Between January of 1968 and February of 1969, 30 meetings were held. A map showing the meeting locations appears in appendix B, and the schedule of these meetings appears in appendix C.

The meetings reached a total of 2,868 persons and groups in attendance, with 1,069 statements presented for the record. Attendance and participation involved many different types of organizations, government and nongovernmenl institutions, business, and individuals.

Transcripts frequently ran to 350 pages, and included a number of technical reports on the effects of pollution and on the general condition of specific estuaries, among other things.

Because the transcripts are a permanent part of the study, it is possible to analyze them for a number of features, and report the results.

## Section 3. Method of Analysis

Perhaps the hallmark of the public meetings was the tremendous volume of information and recommendations presented by the various representatives of national organizations and their local affiliates, of

State and local government bodies, of academic and research institutions; and by the individuals who spoke only for themselves.

Attendance was good and varied. Testimony was most frequent from the national organizations and government bodies. Academic institutions and industry were somewhat less involved in testifying, but did present good information and recommendations. In addition, the involvement of individual citizens was most heartening.

All of these people presented input vital to the study, and the public meeting provided the only real forum for them.

In order that the material presented at the public meetings could be reported with some accuracy, it was important that there be some means for identifying the affiliation of each speaker, and the nature of his statement.

Accordingly, the first step was to determine the kinds of representation, and the numbers of speakers within each group. After determining categories of speakers, a count was made of the speakers and total attendance within the groupings for all meetings. The four groupings selected are as follow:

Group I. National organizations and their local affiliates, local organizations, and individuals;

Group II. Academic institutions, private research firms, and scientific foundations;

Group III. Industry, users, and industrial groups; and

Group IV. Federal, State, and local government bodies.

Table V.5.1 presents the tabulation of witnesses and attendees in each of the groups, and the total number of statements and attendance.

TABLE V.5.1.—TYPES OF GROUPS AND PARTICIPATION IN PUBLIC MEETINGS FOR THE NATIONAL ESTUARINE POLLUTION STUDY

| Group | Number of statements | Total attendance |
|---|---|---|
| I. National organizations and local affiliates, local organizations, and individuals | 407 | 746 |
| II. Academic institutions, private research organizations, and scientific foundations | 133 | 264 |
| III. Industry and users, and industrial groups | 168 | 705 |
| IV. Federal, State, and local government bodies | 361 | 1,153 |
| Total of all groups | 1,069 | 2,868 |

As will be noted, organizations (group I, above) and governments (group IV) were most strongly represented in statements, with users (group III) and academic people (group II) speaking in lesser numbers. However, governments, organizations, and industry were well represented in terms of total attendance.

After organizing the statements by type of speaker, it was then necessary to determine subject areas for the information and recommendations presented in the various statements. These subject categories were established as a series of eight questions, as follow:

(1) What are the major uses and values of the estuaries and estuarine zones?

(2) What are the dangers and problems in the estuaries and estuarine zones?

(3) What have been the results of pollution, modification, and use in the estuaries and estuarine zones?

(4) What needs to be done to restore, preserve, and protect the estuaries?

(5) What types of research and study are needed, and how should this research be done?

(6) What type of organization is needed to best protect, control, and manage the estuaries?

(7) What should be the role of the State and local governments in management of the estuaries?

(8) What should be the role of the Federal Government in management of the estuaries?

Table V.5.2 shows the number of statements responding to each question by group, and in gross total.

As will be noted, the questions on dangers to, uses and values of, and needs to restore the estuaries received the largest numbers of replies. Slightly behind were the questions on effects of pollution and research and study needs. The questions concerning management organizations and the recommended roles of the various levels of government received considerably fewer responses.

The next step, and without doubt a most important one, was to analyze the replies to the questions in order to bring out the concerns and specific answers most frequently expressed. To do so, each of the eight questions was analyzed separately on one of the accompanying series V.5.3 formats. The views, concerns, and answers expressed were synthesized into a few brief statements listed in the left-hand column of the table, and then the number of statements expressing each of the views was entered by group and in total in the columns to the right side. From this process, a more-or-less priority listing of the major concerns expressed by the greatest number of participants was prepared for each question. Because most of the people attending the public meetings made several points in each statement that responded to any question or questions, the total derived by adding the responses shown on the appropriate series V.5.3 format will be greater than the total shown for the corresponding question on table V.5.2.

TABLE V.5.2.—RESPONSES TO EACH QUESTION RECIEVED AT THE PUBLIC MEETINGS

| Questions | Major uses and values | Dangers and problems | Effects of pollution | Needs to be done | Research and study | Management organization | Roles of State and local governments | Role of Federal Governments |
|---|---|---|---|---|---|---|---|---|
| Group I. National orgainzations and local affiliates, local organizations, and individuals | 179 | 196 | 147 | 194 | 102 | 85 | 95 | 95 |
| Group II. Academic institutions, private research organizations, and scientific foundations | 46 | 57 | 49 | 58 | 47 | 28 | 18 | 18 |
| Group III. Industry and users, and industrial groups | 86 | 80 | 47 | 75 | 57 | 43 | 43 | 40 |
| Group IV. Federal, State, and local government bodies | 159 | 193 | 118 | 184 | 119 | 91 | 110 | 104 |
| Total | 470 | 526 | 361 | 511 | 325 | 247 | 266 | 257 |

Tables V.5.3a through V.5.3H demonstrate this analysis for each of the eight questions for 66 percent of the public meetings.

SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3a

As can be seen from table V.5.3a, the highest use expressed is recreation, and its outgrowths of sport fishing and tourism (385). The next greatest concern was that of the natural resources, particularly the conservation of fish and wildlife (222). Following that, statements of the importance of marine food resources (213) recognized the sea to be an increasingly important source of food, and that sound conservation practices must be put into effect to prevent loss of productivity.

Also discussed by a number of participants in the public meetings were the economic values of residential and industrial development (113), and of maritime commerce and ports (84).

The term "multiple beneficial use" came up several times (46), and the concept was implied much more frequently. This is the idea that many uses can coexist and work to each others' benefit, if certain precautions are taken.

Also presented was the value of the estuary as a natural laboratory and locus for ecological research (19).

NOTE.—The numbers appearing in parentheses in this and the following summaries represent the number of statements raising the point, as indicated in the accompanying tables.

TABLE V.5.3a.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
|---|---|---|---|---|---|
| Question No. 1: What are the major uses and values of the estuaries and estuarine zones? | | | | | |
| Marine food resources, including nursery and aquaculture | 73 | 21 | 31 | 88 | 213 |
| Recreation, including sport fishing and tourism | 134 | 31 | 44 | 126 | 335 |
| Natural resources, especially fish and wildlife, and the conservation thereof | 102 | 23 | 27 | 70 | 222 |
| Multiple beneficial use | 11 | 5 | 17 | 13 | 46 |
| Flood control and protective barrier | 8 | 4 | 3 | 7 | 22 |
| Mineral resources | 0 | 1 | 3 | 5 | 9 |
| Transportation—maritime commerce and ports | 22 | 11 | 17 | 34 | 84 |
| Water supply, including industrial | 6 | 0 | 12 | 10 | 28 |
| Waste assimilation, including thermal | 5 | 2 | 6 | 11 | 24 |
| Natural laboratory | 8 | 4 | 4 | 3 | 19 |
| Climate modification | 0 | 0 | 0 | 2 | 2 |
| Residential and industrial siting, and resulting economic benefits | 41 | 10 | 23 | 39 | 113 |

SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3b

From table V.5.3b, it can be seen that the most frequently mentioned danger was simply pollution (396). Most frequently stated types were municipal wastes, especially sewage (121), industrial wastes, including thermal effluents (111), vessel discharges, especially oil and grease resulting from careless shipping and unloading methods and bilge emptying (84), oil and grease from petroleum processes, including undersea wells (42), and agricultural wastes (35).

Modification, whether manmade or natural, was the second concern (285). While it was recognized that some limited dredging and filling may be desirable, it was stated that the current methods are not adequately supervised to protect the areas in which they are carried out. Also commented upon was the problem of material carried from upriver (sedimentation). In this context, the problems of indiscriminate development and improper land management could be mentioned, as they allow land to lie unprotected for rain to wash off the topsoil and add to sediment loads (107).

Conflicting use demands and lack of planning criteria were also frequently mentioned problems (90).

TABLE V.5.3b.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
|---|---|---|---|---|---|
| Pollution of all kinds | 157 | 46 | 47 | 144 | 396 |
| Oil and grease | 20 | 5 | 4 | 13 | |
| Vessel—boat and ship | 38 | 8 | 7 | 31 | |
| Industrial, including thermal | 42 | 15 | 10 | 34 | |
| Agricultural | 9 | 7 | 3 | 16 | |
| Municipal, especially sewage | 43 | 19 | 13 | 46 | |
| Inadequate waste treatment | 10 | 7 | 1 | 9 | 27 |
| Modification—sedimentation, dredging and fill, and lack of supervision over them | 115 | 27 | 35 | 108 | 285 |
| Indiscriminate development and improper land management | 42 | 9 | 8 | 48 | 107 |
| Changing water quality standards; loss of water resource | 5 | 0 | 3 | 8 | 16 |
| Multitude of agencies, laws, jurisdictions, ownerships | 9 | 1 | 2 | 5 | 17 |
| Lack of scientific data | 4 | 4 | 4 | 6 | 18 |
| Conflicting use demands and lack of planning criteria | 42 | 11 | 9 | 28 | 90 |
| Nonenforcement of laws and weak laws | 5 | 0 | 4 | 4 | 13 |
| Resource demands, especially for electricity | 6 | 4 | 5 | 5 | 20 |
| Cost of pollution control and defeat of financing bonds | 3 | 0 | 2 | 5 | 10 |
| Public attitudes towards estuaries and marshes | 4 | 2 | 1 | 4 | 11 |

## SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3C

Table V.5.3c indicates that the most frequently mentioned result of pollution, modification, and use in the estuaries was the destruction of natural resources, especially fish and wildlife (231). Related to this effect was the depression of the seafood industry, through either killing or contamination of the species (106), coupled with the concurrent loss of marine food potential (117).

Mentioned somewhat less frequently, but perhaps having more importance, was the destruction of the estuaries themselves and their adjacent wetlands and marshes (122), for this is damage that cannot be undone.

In addition, dirty water, littered beaches, raw sewage, and other pollutants cause the area to become unhealthy (47), or at least ugly. Needless to say, these factors destroy the recreational (108), residential (41), and navigational (38) values people seek in the estuarine area.

Several witnesses, when asked to describe the results of pollution in the estuary nearest them, said, succinctly, "It stinks" (33).

TABLE V.5.3c.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
|---|---|---|---|---|---|
| Question No. 3: What have been the results of pollution, modification, and use in the estuaries and estuarine zones? | | | | | |
| Loss of marine food potential | 44 | 15 | 14 | 44 | 117 |
| Destruction of natural resources, including fish and wildlife, and detriment to conservation efforts | 101 | 28 | 31 | 71 | 231 |
| Loss of recreation, potential, including tourism | 50 | 16 | 13 | 29 | 108 |
| Loss of land value and productivity, increased erosion, and damage to buildings | 18 | 7 | 3 | 13 | 41 |
| Public health endangered | 15 | 5 | 2 | 25 | 47 |
| Destruction of seafood industry and jobs | 33 | 15 | 19 | 39 | 106 |
| Obstruction of navigation, reduction of water supply and usability, and alteration of tides, salinity, currents | 14 | 5 | 7 | 12 | 38 |
| Damage to laboratory function | 0 | 2 | 0 | 0 | 2 |
| Waste heat used elsewhere to enhance growth of fish, shellfish, and beneficial plants—may work here | 0 | 3 | 3 | 3 | 9 |
| Permanent destruction of estuaries and wetlands | 49 | 14 | 19 | 40 | 122 |
| Stagnant water, mosquitoes, eutrophication, and malodor | 16 | 5 | 1 | 11 | 33 |

SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3d

Table V.5.3d demonstrates that the chief recommendation for dealing with the problems of estuarine pollution was comprehensive management, based on long-range planning and careful land and water use (212). Because one of the problems mentioned earlier was a lack of planning criteria, these would have to be developed, and a set of priorities established.

The next recommendation involved strengthening the pollution laws we now have, and enacting new ones as needed. But, more importantly, the laws, including water quality standards (63), must be enforced to be effective (165).

Other recommendations included adequate waste treatment (95), regulation of activities such as dredging (86), legal protection of the estuaries, including acquisition and conservation practices (82), pollution control and abatement (78), and public education to the values of estuaries and the consequent need to clean them up (50). Also stressed was the need to prevent pollution, especially from shipping and petroleum activity, before it has a chance to occur (51).

TABLE V.5.3d.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
|---|---|---|---|---|---|
| Question number 4: What needs to be done to restore preserve, and protect the estuaries? | | | | | |
| Adequate waste treatment | 38 | 12 | 16 | 29 | 95 |
| Comprehensive long-range planning for management and use control—zoning | 94 | 24 | 31 | 73 | 212 |
| Strict water quality standards enforcement | 28 | 7 | 10 | 18 | 63 |
| Legal protection, including acquisition and conservation | 24 | 10 | 9 | 39 | 82 |
| Clarification of laws, ownerships, jurisdictions, etc. | 5 | 1 | 1 | 8 | 15 |
| Public education to estuary values and need to clean up, and citizen action | 28 | 7 | 2 | 13 | 50 |
| Strong antipollution laws and enforcement | 80 | 21 | 14 | 50 | 165 |
| Erosion control | 5 | 2 | 2 | 17 | 26 |
| Regulation of activities, including moratorium on fill and dredging | 36 | 8 | 9 | 33 | 86 |
| Prevention of pollution, especially vessel and oil | 20 | 4 | 5 | 22 | 51 |
| Low-flow augmentation | 5 | 0 | 1 | 7 | 14 |
| Improved seafood habitats and growth conditions | 6 | 1 | 2 | 5 | 14 |
| Pollution control and abatement, including air | 29 | 7 | 8 | 34 | 78 |

SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3e

One thing brought out at the public meetings, and indicated in table V.5.3e, was that relatively little is known about estuaries—that specific knowledge is very limited. Accordingly, it was recommended that a comprehensive, estuary-by-estuary inventory be made. This would include ecologic, geologic, and hydrologic features (127).

Also felt to be a real study need was the question of the effects of pollution, and possible beneficial uses for some items now considered pollutant (105), as well as research to develop some better methods of treating and disposing of wastes (56).

In earlier questions, the problem of a lack of planning criteria and the need to develop them were discussed. A significant number of replies to this question indicated that research/study is needed for this development, and in the general area of providing assistance to developing and administering a management plan.

Generally, it was recommended that these studies be carried out as comprehensive, multidiscipline efforts (6) by as many different types of organizations as possible (20), and, frequently, with Federal funding (8). However, the majority of responses did not include recommendations as to the source of personnel or funds to accomplish the suggested studies.

TABLE V.5.3E.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
|---|---|---|---|---|---|
| Question No. 5: What types of research and studya are needed, and how should this research be done? | | | | | |
| Effects of pollution, especially thermal and pesticide | 33 | 18 | 16 | 38 | 105 |
| Comprehensive studies to assist in plan development and administration of the management program | 42 | 16 | 18 | 38 | 114 |
| Legal and economic aspects—effects of estuaries | 6 | 2 | 4 | 5 | 17 |
| Aquaculture and increased marine food production | 3 | 0 | 3 | 4 | 10 |
| Inventory—all features, by estuary | 42 | 19 | 17 | 49 | 127 |
| To develop better waste treatment methods | 20 | 6 | 7 | 23 | 56 |
| To determine adequacy of water quality standards | 5 | 2 | 3 | 2 | 12 |
| This study is a good start | 0 | 1 | 2 | 8 | 11 |
| Comprehensive, multidiscipline effort | 0 | 1 | 0 | 5 | 6 |
| By government, academic institutions, and others | 9 | 3 | 1 | 7 | 20 |
| By industry, at least in part | 0 | 0 | 1 | 0 | 1 |
| By all levels of government | 5 | 1 | 1 | 1 | 8 |
| By all available persons and groups, Federal coordination | 2 | 0 | 1 | 1 | 4 |
| With Federal funds, including FWPCA | 5 | 0 | 1 | 2 | 8 |

SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3f

No one organizational recommendation dominated table V.5.3f, but the general opinion was that the organization had to include representation from beyond the immediate estuarine jurisdiction (56), and should include nongovernment representation (55).

Most frequently recommended were joint, intergovernmental organizations—Federal-State-local (111), State-local (22), Federal-State (3), etc.

Also recommended, especially in the case of interestate estuaries, was a regional body, which would include appropriate Federal, State, and local government representation (38).

Several participants felt that the present system works well, but that it needs more power, especially of enforcement (12). However, these people were in the minority.

Most felt that, regardless of the nature of the management organization, it should be so established as to avoid duplication of function and effort (implied in virtually all answers).

TABLE V.5.3f.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Tota |
|---|---|---|---|---|---|
| Question No. 6: What type of organization is needed to best protect, control, and manage the estuaries? | | | | | |
| Cooperative Federal, State, and local government organization, possibly under a superagency | 17 | 7 | 8 | 24 | 56 |
| State control only | 5 | 3 | 6 | 8 | 22 |
| A type that will promote industry cooperation | 0 | 0 | 3 | 2 | 5 |
| Present organization works well, but could use more power, especially for enforcement | 5 | 1 | 2 | 4 | 12 |
| Joint State-local organization, with nongovernment representation as appropriate | 5 | 2 | 6 | 9 | 22 |
| State and/or Federal organization | 7 | 0 | 0 | 9 | 16 |
| Cooperative Federal, State, and local, with nongovernment representation, including those not involved or affected | 22 | 3 | 13 | 17 | 55 |
| Local management organization | 2 | 3 | 0 | 5 | 10 |
| A single coordinating agency | 5 | 0 | 2 | 5 | 11 |
| Joint Federal-State organization | 2 | 0 | 0 | 1 | 3 |
| Regional organization, with Federal representation | 13 | 6 | 4 | 15 | 38 |
| New State research and development agency | 2 | 1 | 0 | 2 | 5 |

## SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3g

Table V.5.3g demonstrates the concensus to have been that the States should play a more active role in estuarine management and pollution control than they now do (14 specifically, but implied in most of the answers).

Generally, the local responsibility was seen to be in sharing the management functions with the States (102), or in planning and effecting waste treatment and monitoring systems (11). Several said that the localities should have the primary managment responsibility (51).

State management through a number of instrumentalities was recommended (107). It was also proposed that the State management program be carried out within a national plan, and that the States and localities provide input to assist in developing and, as needed, revising the national plan (65).

TABLE V.5.3g.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— | | | | |
|---|---|---|---|---|---|
| | I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
| Question No. 7: What should be the role of the State and local governments in management? | | | | | |
| State management, utilizing a number of control tools | 40 | 12 | 21 | 34 | 107 |
| Cooperative State-local management, including zoning and coordination; more investment | 48 | 6 | 13 | 35 | 102 |
| Local management, utilizing State and Federal assistance; State financial and technical aid to localities | 16 | 4 | 6 | 25 | 51 |
| Public education to needs and progress | 3 | 1 | 2 | 0 | 6 |
| Local installation of monitoring and waste treatment facilities; State when localities cannot | 4 | 2 | 0 | 5 | 11 |
| Cooperation with the Federal Government in management | 8 | 3 | 1 | 12 | 24 |
| State management within a national plan, and provision of input to help develop the plan | 19 | 5 | 12 | 29 | 65 |
| More State activity than present | 3 | 1 | 4 | 6 | 14 |

SUMMARIZATION OF VIEWS AND ANSWERS IN TABLE V.5.3h

Table V.5.3h indicates that the witnesses generally saw the Federal role as being a backup for the States.

The backup would be provided in the form of financial and technical assistance for a number of different purposes (145), including construction (25) and research (41). It would also be in a preparedness to move in and manage the estuaries, in the event the States failed to do so (18).

As a corollary, it was recommended that the Federal Government work with the States to achieve a coordinated national effort (118). This would include the setting of operating guidelines and minimum water quality standards for use by the States (37).

It was also suggested that the Federal Government lead in taking protective and conservative action, including acquisition (37).

In a few instances, it was stated that the estuarine pollution problem was too great for the States to handle, and that the Federal Government should assume the management function (6).

TABLE V.5.3h.—SUMMARY OF PREVAILING TONE OF RESPONSES PER TYPE OF PUBLIC/PRIVATE GROUP AND PER CATEGORY

| Subject category | Distribution of responses among groups— | | | | |
|---|---|---|---|---|---|
| | I. National organizations and citizens | II. Academic institutions and research organizations | III. Industry and users | IV. Government organizations | Total |
| General assistance, financial and technical | 32 | 4 | 12 | 31 | 79 |
| Construction assistance | 9 | 2 | 5 | 9 | 25 |
| Research and training grants | 11 | 5 | 12 | 13 | 41 |
| Operate only in interstate estuarine areas | 1 | 0 | 0 | 2 | 3 |
| Cooperate with States and localities for a coordinated national program | 24 | 8 | 13 | 35 | 81 |
| Management, when States fail to act | 12 | 0 | 3 | 3 | 18 |
| Minimum water quality standards and program guidelines for States to use | 12 | 6 | 6 | 13 | 37 |
| Strong protective action, including acquisition and activity control | 26 | 1 | 4 | 26 | 57 |
| Federal management, States cannot handle | 2 | 1 | 2 | 1 | 6 |
| Publication of research results and public education to needs and progress | 5 | 1 | 1 | 4 | 12 |
| Continue in present role | 1 | 1 | 4 | 3 | 9 |

## Section 4. Summary Analysis of Major Concerns

Summarizing the major interests and concerns of the witnesses, as expressed in the replies to the first five questions, a number of factors were demonstrated, as described in the ensuing paragraphs.

The primary interests of the speakers were: the estuary as a source of food, the estuary as an ecosystem, and the estuary as a locus for leisure activity. The estuary also serves as a protective barrier against storms and flooding, and it helps to modify the climate. It is a source of commercial resources—harbors for shipping, fish and shellfish for food, minerals for industry, and water for human and industrial use.

For these reasons, the estuarine environment is considered a good place to live and work.

An additional use of the estuary is as a natural laboratory to increase understanding and knowledge of its biota and other features.

Accordingly, concern was expressed over any activity or phenomenon that acts to destroy the values of the estuary, and over the resultant damages.

The major worry was pollution of all kinds, and especially inadequately treated municipal, industrial, and vessel wastes.

Modification, whether natural or artificial, was the second concern. This would include drainage ditches used for pest control, impoundments for water supply, and fill for residential development. Related to this, and to some degree involving it, would be the problems created by indiscriminate and too rapid development and by improper land management. These concerns were expressed in terms of upriver as well as estuarine activities.

Jurisdictional and legal questions were also mentioned as being of concern, especially as they lead various authorities to a reluctance to take action and a tendency to complain that nobody is doing anything. The need to resolve these questions, and those related to the lack of planning criteria for coping with conflicting use demands, is critical.

The destruction of natural resources despite conservation efforts was a source of uneasiness for a number of witnesses, as was the related loss of marine food potential and consequent depression of the seafood industry.

Related to the shipping and water supply values was concern about phenomena reducing these uses—obstruction, salinity intrusion, and tidal and current alterations.

Because recreation was cited as a prime estuarine use, the thought of the destruction of its potential through health hazards, stagnant water, foul odors, increased pest populations, and sheer ugliness was particularly bothersome to many of the speakers.

Among needs that concerned the participants were: long-range planning, stronger laws, enforcement of laws and water quality standards, pollution control and abatement including air, and clarification of jurisdictions. Related to several of these were recommendations for activity control, including in many cases a moratorium on dredging and filling.

Another problem brought out at the meetings was that relatively little is known about the estuaries, per se, or about the effects of many pollutants on the estuarine ecosystem and environment, nor is there sufficient background knowledge for effective use planning and administration. Research in these areas is needed.

To summarize, the chief concerns are shown in chart form below. Numbers of the items correspond to the questions which they answer, and the numbers to the right are obtained from the appropriate table V.5.3 format.

| | |
|---|---|
| 1. A place for leisure activity | 335 |
| 1b. A habitat for fish and wildlife | 222 |
| 1c. A source of food | 213 |
| 2a. A pollution collector | 396 |
| 2b. A place subject to modification | 285 |
| 3a. Destruction of resources | 231 |
| 3b. Destruction of estuary itself | 122 |
| 3c. Loss of recreational value | 108 |
| 4a. Mismanagement | 212 |
| 4b. Weak and unenforced laws | 165 |
| 5a. Lack of knowledge | 127 |
| 5b. Lack of planning criteria and data | 114 |

In discussing the areas of concern, the four groups expressed substantial agreement.

## Section 5. Summary Analysis of Recommended Management Organization and Roles of the Various Levels of Government

Before presenting a synthesis of recommendations on management organizations and roles, a brief summary of recommendations by the public sector (group IV witnesses), the nonindustrial private sector (groups I and II), and the industrial private sector (group III) will be given, based on their replies to the last three questions.

### THE PUBLIC (GOVERNMENT) SECTOR

The representatives of the various levels of government (group IV speakers), especially State and local, provided the greatest number of answers to these questions. Some Federal personnel testified, but these were generally regional representatives of various agencies and Congressmen. Since the various governments will of necessity be directly active in any management plan, their views are particularly important.

These witnesses felt that the Federal role in management should be:

(1) Provision of financial and technical assistance, including that specifically allocated for construction and research and training, to the States and localities;

(2) Leadership in protective action, including acquisition and activity control;

(3) Cooperation with the State and local governments to maximize coordination throughout the country; and

(4) Establishment of minimum water quality standards and operating program guidelines for the States to use as a basis for their efforts.

They saw the States' role to be:

(1) Operation of the management plan through a number of instrumentalities;

(2) Management within a national plan;

(3) Cooperation with the local governments in management, including program coordination;

(4) Provision of financial and technical assistance to local governments; and

(5) Cooperation with the Federal Government in management.

The local role was seen to be:

(1) Management, utilizing all State and Federal assistance available;

(2) Cooperation with the States in management; and

(3) Development of plans and installation of equipment for monitoring and waste treatment.

The optimal management organization was seen to be a cooperative Federal, State, and local venture, including, in many instances, nongovernment representation. Alternatives offered were:

(1) A cooperative State-local organization with nongovernment representation as appropriate; and

(2) A regional organization, including Federal representatives in the membership.

### THE NONINDUSTRIAL PRIVATE SECTOR

The witnesses in this category, which was devised by combining groups I and II (national organizations, etc.; and academic people), also gave frequent answers to these questions.

These speakers stated that the Federal role should be:

(1) Provision of technical and financial assistance, including that allocated for research and training and for construction;

(2) Taking of strong protective action, including acquisition and activity control;

(3) Cooperation with State and local governments to coordinate the national effort; and

(4) Management of those estuaries which the States fail to manage.

The State role was seen by the nonindustrial private sector to be:

(1) Cooperation with the localities in management, including coordination of programs;

(2) Operations of the management plan through a number of instrumentalities;

(3) Management within a national plan; and

(4) Provision of financial and technical aid to the local governments.

The witnesses saw the local role to be management, utilizing all available financial and technical assistance programs of the Federal and State governments.

The best management system was seen to be by a cooperative Federal, State, and local organization, preferably with nongovernment representatives included. As an alternative, the nonindustrial private sector would like to see a regional organization, including Federal representation.

### THE INDUSTRIAL PRIVATE SECTOR

The industry and user representatives (group III witnesses) were of two distinct types—fishermen (including shellfish harvesters) and others. This fact is mentioned, as the fishermen had a quite different view from that of the other group III speakers.

The industrial witnesses felt that the Federal role should be:

(1) Financial and technical assistance, especially for research and training and for construction;

(2) Cooperation with the State and local governments for a coordinated national effort; and

(3) Establishment of operating program guidelines and minimum water quality standards for the States.

The fishermen were more concerned that the Federal Government:

(1) Take strong protective action, especially in acquisition and activity control; and

(2) Manage, as the problems were felt to be too great for the State and local governments to handle.

Industry generally wanted the State to:

(1) Operate the management plan through a number of instrumentalities, especially water quality control;

(2) Manage in cooperation with the local governments; and

(3) Manage within the framework of a national plan.

The fishermen wanted only a very minor role for the States, as they felt that the States have done very little of what they could or should have been doing.

The industrial representatives saw the local role to be:

(1) Management, in cooperation with the States; or

(2) Conduct of the management plan, utilizing Federal and State financial and technical assistance.

The fishermen felt that the local governments should not be directly involved in management, as they are too subject to the pressure of special interest groups.

The industrial participants felt that the management organization should be cooperative Federal, State, and local, with nongovernment representation.

The fishermen did not express recommendations for a management organization.

### SUMMARY OVERVIEW

Generally, it was felt that intergovernmental cooperation is needed, and that all levels of government should be represented in any organization. Several people commented on the duplication of programs and effort, not only among the various levels of government, but also within each level of government. For this reason, recommendations for a new organizational method appeared with relative frequency, although the present components could be included in the resulting new organization.

By and large, opinion was that the problem of estuarine management and pollution control is too great to be handled at one level. Therefore, it was recommended, in several different ways, that a national program, incorporating operating guidelines and minimum water quality standards, is needed at the Federal level. In addition, because of shortages of funds and technical capabilities at the State and local levels, the States and localities look to the Federal Government for assistance in these areas.

The States would, in most instances, conduct the management program and coordinate local activities. The major exception would be interstate or regional organizations' management of interstate estuaries, such as Long Island Sound or Chesapeake Bay. While some saw the local role as the actual management, it was more frequently seen as being cooperation with the State and the planning and development of sewer systems and waste treatment facilities, as well as monitoring for water quality maintenance. County or State government would carry out zoning and activity-regulating programs, in the view of most witnesses.

It was the contention of some of the speakers that no one type of organization would be best in all estuaries, nor would any set assignation of roles have any more validity. These people wanted to see a primary coordination of effort among the various governmental levels, and action and method dictated by conditions in the particular estuary.

Regardless of recommended management organization or roles, the primary concern was for coordination to avoid duplication of programs and functions. It was generally felt that the State and local effort and investment should be increased, and that the Federal effort should be primarily as a backup—providing technical and financial assistance, minimum standards, and operating guidelines, and being prepared to step in and manage those estuaries which the States and localities fail to manage.

## Section 6. Summary Analysis of Recommended Role of the Private Sector

While the analysis of the public meetings was not designed to bring forth recommendations specifically as to action that should be taken by individuals and nongovernment organizations, institutions, and business, a number of opinions on the subject can be extrapolated from the replies to several of the questions.

Without the concerned interest of the private sector, and the citizens comprising it, no management program can succeed.

Public attitudes toward estuaries and marshlands, and the general lack of knowledge about these vitally productive areas, are two of the major problems faced in the development of a management program. Therefore, there is a need for people to learn of the resources and potential of the estuaries, and the importance of the estuaries to themselves.

Accordingly, the private sector's first action should be to become informed about the values of the estuaries—to learn that an acre of estuarine marsh, without human intervention, is 2 to 7 times as productive as an acre of cultivated farmland, and that virtually all seafood is dependent on the estuarine invironment during at least part of the life cycle.

The informed private sector can be of great assistance in bringing about the kind of comprehensive long-range management plans needed by spreading information, by putting pressure on those having responsibility for the laws and ordinances required to effect such plans, by making enforcement officials aware of violations, and by supporting strong protective measures at all levels of government, among other things.

One segment of the private sector, industry, is beginning to recognize the importance of treating its wastes and acting to improve the environment of its location. Many industries have employed environmental specialists to develop programs along these lines. A number of industrial plants have spent a large amount of money to install waste treatment equipment, sometimes with tax credits or other incentives from the States. This is all to the good, but more needs to be done. Industry must fully recognize that investment in pollution control is investment in its own future.

## Section 7. Conclusions

The public meetings, the mechanism selected to receive input from the public and private sectors that could not have been received by other means, brought forth much helpful information and many useful recommendations.

Primarily, concern was expressed about destruction and damages in the estuaries from pollution, modification, and improper and fragmented management methods, and the need to rectify these situations. Secondarily, but closely related to the foregoing, was the feeling that all segments of the public and private sectors should take a more active role in estuarine management and pollution control.

Management recommendations were diverse, but the predominant view was that the organization should include all levels of government, and nongovernment representatives, as well. The system should be essentially:

(1) The formulation at the Federal level of minimum water quality standards and operating program guidelines for State use;

(2) The provision of financial and technical assistance to State and local governments by the Federal Government;

(3) The conduct of the management plan, utilizing water quality standards and operating program guidelines, by the States;

(4) The assignment of financial and technical aid to the localities by the States;

(5) The planning and installation of monitoring and waste treatment equipment, and the conduct of the monitoring and waste treatment activities by the local governments; and

(6) The cooperation with the States in management by the localities.

The recommendations for the national program, discussed in length in part III, incorporate the recommendations from this chapter, as well as those from other sources discussed elsewhere in this report.

## Appendix A. Report of Sources and Methods Used for Coordination and Data Gathering for the National Estuarine Pollution Study

I. Means of gathering information, views, opinions, and recommendations:
   - A. Correspondence, consultation, and briefing—at headquarters and regional levels.
   - B. Public meetings.
   - C. Contracts for specific data gathering.
   - D. Preparation of the National Estuarine Inventory.

II. Sources of information:
   - A. Federal agencies having activities and interests in the estuaries, and their reports.
   - B. State, interstate, regional, territorial, and local government bodies and their reports.
   - C. National organizations, including institutions and foundations.
   - D. Academic community.
   - E. Industrial representatives and groups.
   - F. Other individuals.

III. Means of coordination with sources:

A. Government agencies, including Department of the Interior and subdivisions:

1. Letter/memorandum request for information on programs, views, and means of coordination.
2. Direct consultation with high-level personnel.
3. Assigned Study coordinator from each non-Interior agency concerned.
4. Advisory committee composed of assigned representatives from each Interior agency concerned.
5. Conferences with assigned coordinators and representatives from the agencies.
6. Input from specific requests for data to meet inventory needs from the Corps of Engineers and Bureau of Commercial Fisheries.
7. Input from service contracts for data to meet inventory needs with the Office of Business Economics, the Bureau of Mines, and the Geological Survey.

B. States, territories, and their local subdivisions:

1. State coordinator named by Governor in reply to a request from the Secretary of the Interior.
2. Direct consultation with and data requests to the States and localities by the Directors of the coastal Federal Water Pollution Control Administration Regional Offices for the Inventory and other purposes.
3. Preparation by the regions of State profiles including information on organizations and activities involved with the estuaries, and especially on views and recommendations regarding a comprehensive management program and responsibilities of the various government levels—Federal, State, and local.
4. State coordinator served as co-chairman of the public meetings, and State officials testified at the public meetings.
5. Local government representatives testified at the public meetings.

C. National organizations:

1. Appointment of representative to the study in reply to a letter from the Secreary of Interior.
2. Letter requests for information and data on programs, views, and opinions.
3. Attendance at conferences, meetings, and symposia sponsored by these organizations.
4. Briefings and conferences with Washington personnel of national organizations.
5. Statements at public meetings by national organizations and local affiliates.
6. Letters requesting views on research and study needs.

D. Academic community:

1. Letters, consultations, and briefings with academic members of certain national organizations.
2. Attendance at conferences and symposia sponsored by academic institutions and organizations.
3. Testimony of academic personnel, both as individuals and as representatives of universities and laboratories, at public meetings.
4. Letters to selected organizations requesting views on research and study needs.
5. Letters and consultations at regional level on research and study needs.
6. Input from study contracts to meet general information needs with the University of Maryland, Florida State University, University of North Carolina, University of Washington, University of Rhode Island, Gulf Universities Research Corporation, University of Hawaii, and University of Alaska.

E. Industrial representatives:

1. Testimony at the public meetings.
2. Input through meetings of the National Security Industrial Association and Marine Technology Society.

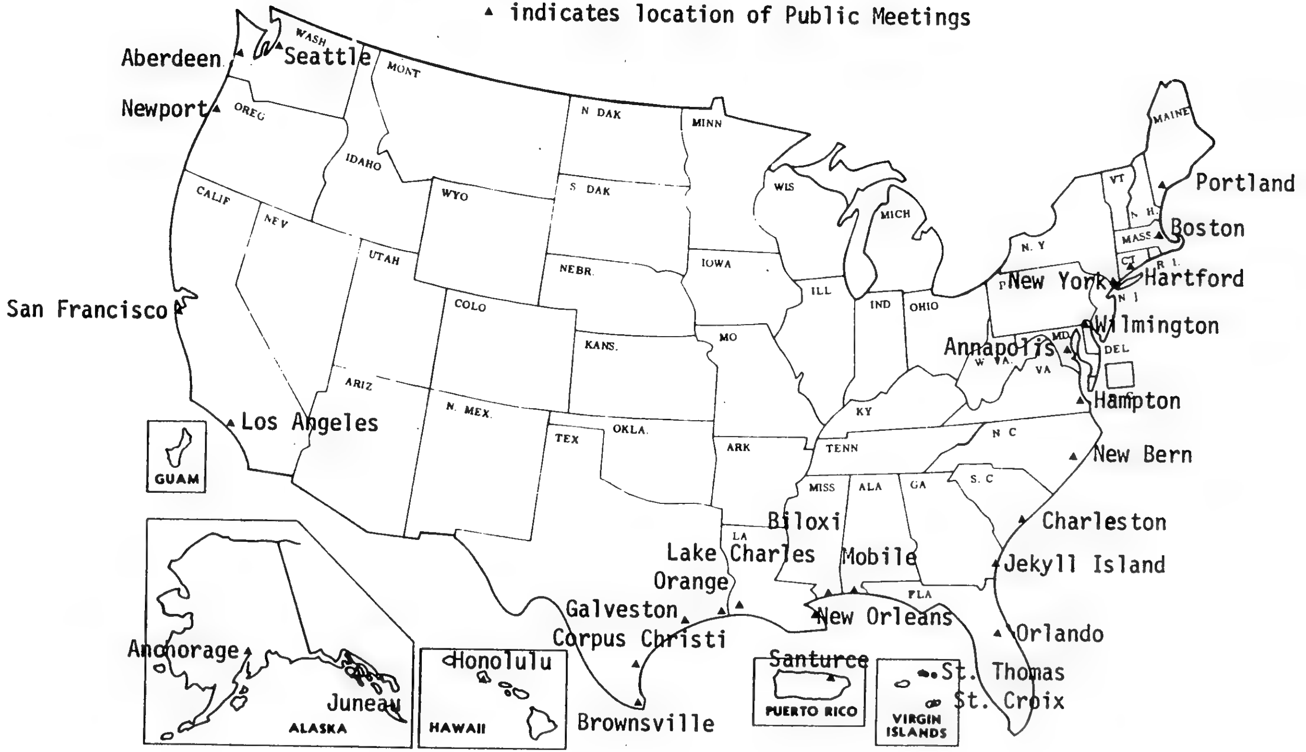
F. Other individuals:

1. Testimony at the public meetings.
2. Personal correspondence.

# APPENDIX B

## MAP SHOWING LOCATION OF PUBLIC MEETINGS

▲ indicates location of Public Meetings



## APPENDIX C

## SCHEDULE OF NATIONAL ESTUARINE POLLUTION STUDY PUBLIC MEETINGS

| Location of Meeting | Date of Meeting |
|---|---|
| Alabama, Mobile | November 21, 1968 |
| Alaska, Anchorage | June 13, 1968 |
| Alaska, Juneau | June 11, 1968 |
| California, Los Angeles | February 25-26, 1969 |
| California, San Francisco | February 18-19, 1969 |
| Connecticut, Hartford | August 19-20, 1968 |
| Delaware, Wilmington | June 27, 1968 |
| Florida, Orlando | March 12-13, 1968 |
| Georgia, Jekyll Island | February 29, 1968 |
| Hawaii, Honolulu | January 28-29, 1969 |
| Louisiana, Lake Charles | October 22, 1968 |
| Louisiana, New Orleans | October 24, 1968 |
| Maine, Portland | September 10-11, 1968 |
| Maryland, Annapolis | October 30, 1968 |
| Massachusetts, Boston | October 8, 1968 |
| Mississippi, Biloxi | January 17, 1968 |
| New York, New York | July 23-24, 1968 |
| North Carolina, New Bern | July 26, 1968 |
| Oregon, Newport | May 9, 1968 |
| South Carolina, Charleston | June 5, 1968 |
| Texas, Brownsville | October 1, 1968 |
| Texas, Corpus Christi | October 3, 1968 |
| Texas, Galveston | October 8, 1968 |
| Texas, Orange | October 10, 1968 |
| Virginia, Hampton | November 19, 1968 |
| Washington, Aberdeen | July 25, 1968 |
| Washington, Seattle | July 23, 1968 |
| Puerto Rico, Santurce | April 22, 1968 |
| Virgin Islands, St. Croix | April 17, 1968 |
| Virgin Islands, St. Thomas | April 19, 1968 |

# CHAPTER 6. THE ESTUARY STUDY RECOMMENDATIONS COMPARED WITH OTHER PROPOSALS FOR MANAGING THE ESTUARINE AND COASTAL ZONE

In addition to the present Study, management of the coastal zone also has been the subject of one other report at the Federal level during the past year. This is chapter 3 in the report by the Commission on Marine Science, Engineering, and Resources entitled "Our Nation and the Sea" (hereafter referred to as Commission report).

This chapter reviews the Commission report in summary fashion and compares its policy recommendations with those advanced by the National Estuarine Pollution Study.

## Recommendations of the Commission Report

A major conclusion reached by the Commission is that, although, Federal, State, and local governments share the responsibility for managing estuarine and coastal zone resources, the States must be the "focus for responsibility and action." It considers, however, that effective management of these resources thus far has been thwarted by the variety of government jurisdictions involved, the low priority afforded marine matters by State governments, the diffusion of responsibilities among State agencies, and the failure of State agencies to develop and implement long-range plans. It adds that, until recently, navigation—over which Federal authority is preeminent—has tended to dominate the uses of the coastal zone, and the Commission suggests that this perhaps is the reason why the States have been slow to assume their management responsibilities. Based on these conclusions, the Commission's major recommendations are as follows:

### ESTABLISHMENT BY THE STATES OF COASTAL ZONE AUTHORITIES

Each coastal State should establish one or more coastal zone authorities capable of developing and implementing management plans which would "resolve problems of competing uses" in the coastal zone. The number, form, and exact powers of these authorities would be left to each State. In general, however, the Commission expects that these authorities would be organized so as to "prevent domination by State agencies charged with narrower responsibilities." Powers to be made available to the typical coastal zone authority should include planning, regulation, acquisition and eminent domain, and development.

Planning is defined by the Commission as the making of comprehensive plans for coastal waters and adjacent lands and the conduct of necessary studies and investigations. Regulation includes zoning, the granting of easements, licenses, or permits, and the exercising of other necessary controls to insure that use of waters and adjacent lands conforms to the plan for that area. Acquisition and eminent domain are self-explanatory. Development, as defined by the Commission, is the provision, either directly or by arrangement with other governmental agencies, of such public facilities as beaches, marinas, and other waterfront works. It includes also the leasing of estuarine and coastal zone lands.

The Commission also suggests that the States may be forced to regain zoning powers over land use which most States have yielded to local jurisdictions. Presumably, this regained authority would be exercised by the coastal zone authority (or authorities). Its report adds, "Additionally, it may be desirable to delegate to the State coastal zone authorities certain regulatory functions of Federal agencies, such as reviewing proposals for construction in navigable waterways and advising Federal construction agencies."

### FEDERAL GRANT ASSISTANCE

To assist the States in developing coastal zone management plans, the Commission proposes that the Federal government fund one-half of each authority's operating costs during the first 2 years of its existence. Matching grants also should be provided for planning studies, either through existing Federal grant programs or under new legislation. Other grant programs now available at the Federal level and applicable to other phases of the management of the coastal zone should be used to the full.

### FEDERAL REVIEW OF STATE PLANS

In the Commission's view, the multiplicity of Federal interests in the coastal zone calls for Federal review of "proposed State plans and their implementation." This Federal review should occur at three stages: (a) when the State first proposes a particular type of coastal zone authority; (b) when the comprehensive coastal plan is submitted by the authority; and (c) if the plan is approved, when further grants, contracts for acquisition and development, or other financing are proposed. Failure by a coastal zone authority to safeguard national interests could lead to Federal intercession, and inadequate performance by an authority could lead to withdrawal of funding support and of specific Federal functions delegated to the State.

### CENTRALIZATION OF FEDERAL RESPONSIBILITIES

The Commission recommends that Federal responsibilities for dealing with the State authorities be centralized to assure that the Federal Government speaks with a single voice on coastal zone matters. To achieve this centralization, the Commission recommends that these responsibilities be assigned to the new National Oceanic and Atmospheric Agency (NOAA), which its report elsewhere proposes be established to secure "more effective use of the seas." Specific responsibilities which the Commission would assign to NOAA include (a) administration of Federal grants in support of the planning and enforcement activities of the State coastal zone authorities—this would include the power to revoke or withhold grants if the authorities failed to comply with plans approved by NOAA; (b) assistance to the States in the resolution of problems resulting from the divergent objectives of other Federal agencies; (c) leadership in identifying and funding the diverse research programs needed to solve the problems of the coastal zone; (d) in cooperation with other Federal agencies, development of necessary monitoring programs in the coastal zone; (e) encouragement of university research and training programs relating to coastal zone management and the support of a system of coastal zone laboratories; (f) in collaboration with other Federal agencies, support of feasibility studies and fundamental engineering relevant to the development of offshore terminals, storage facilities, and nuclear power plants; and (g) in surveys in the coastal zone by other Federal agencies, identification of areas of common interest and coordination of plans to avoid overlap and incompatibilities.

### FEDERAL COMPLIANCE WITH STATE PLANS

Other Federal agencies providing grants-in-aid to the States, or engaging in coastal activities, are to review their projects for consistency with plans adopted by the State coastal zone authorities.

### FIXING OF TERRITORIAL BOUNDARIES

Congress should establish a National Seashore Boundary Commission to fix, subject to appropriate judicial review, the baselines from which to measure the territorial sea and areas covered by the Submerged Lands Act of 1953 and to determine, again subject to judicial review, the seaward lateral boundaries between the States.

## Comparison of Commission Report With Recommendations in this Study

Like the Commission report, the estuary study concludes that primary responsibility for achieving sound management of the Nation's estuarine and coastal zone resources should continue to reside in the States. Consistent with that finding, it too seeks to create a Federal-State relationship in the management of these resources through which Federal programs and activities will encourage and assist the States more effectively to discharge their primary responsibility. And like the earlier report, it proposes reliance on the grant-in-aid mechanism to achieve needed State action.

The estuary study also agrees with the Commission in calling for a Federal role which will influence and guide the key State-level management decisions which from here on will control the use of a State's estuarine and coastal resources. Thus it would make the grant of Federal funds to a State for administrative purposes conditional upon the State meeting three criteria imposed by the Federal Government: (1) the existence of a State organization for the management of estuarine and coastal resources not dominated either by preservation or economic development interests; (2) the capability of that organization to review Federal and federally-assisted State and local projects for consistency with the plan that organization is expected to develop; and (3) the authority within that organization to (a) require a State permit for dredging, filling, and other alteration of the lands and waters in the estuarine and coastal zone, (b) override local zoning that is inconsistent with the State plan, and (c) acquire estuarine and coastal sites which the plan earmarks for acquisition by the State.

Other recommendations in the estuary study similarly have the intent of achieving a role for the Federal Government which will influence State-level management decisions without usurping State management responsibility and authority. These include (1) the recommendation that failure by a State to prepare and adhere to a comprehensive management plan should be the basis for a withdrawal by the Secretary of the Interior of additional grant support; (2) the recommended bonus attaching to the administrative grant if the State institutes an effective moratorium on further dredging and filling during the preparation of its comprehensive management plan; and (3) the comparable bonus that it recommends if that plan is acceptable to the Secretary.

The estuary study also concurs with the Commission report in proposing the establishment by the Congress of a special commission to fix boundaries in the estuarine and coastal zone.

However, the estuary study is in fundamental disagreement with the Commission report on the question of centralizing Federal activities in a single Federal agency. It proposes instead that coordination and integration of Federal programs and activities be the responsibility and a capability of the State organization administering or coordinating the States' estuarine and coastal zone management activities. The administration of the new Federal grants for estuarine and coastal zone management specifically would be assigned, under the estuary study recommendations, to the Secretary of the Interior. Existing authority of other Federal agencies basically would remain unaltered.

Other important differences between the estuary study and the Commission report concern the new Federal grant programs. This study recommends an initial, one-time grant of 100 percent to each State for use in appraising its present management program in the estuarine and coastal zone and in preparing recommendations for improving the program. No such grant is proposed by the Commission. Also unique to this study are the bonus recommendations already noted in describing the grant for administrative purposes.

Other recommendations in the estuary study not included in the Commission report (a) would require consideration of other resource use and management plans bearing on estuarine and coastal resources in preparing the comprehensive plan for using and managing the States' estuarine and coastal zone; (b) would direct the Secretary of the Interior to make a biennial review of problems and program needs, followed by a report to the President and the Congress; (c) would require the Secretary to establish both an interagency advisory council and a non-Federal advisory board; and (d) suggests that the President issue appropriate Executive orders and proclamations to be effective in the interim before the Congress can enact legislation establishing the national estuarine management program.

# CHAPTER 7. OVERALL ESTUARINE MANAGEMENT, A SUMMARIZATION BY CASE STUDY

## SECTION 1. INTRODUCTION

Having presented in the previous chapters of this part of the study the roles and programs of various levels of government, it is desired at this point to present a picture of how and how well these programs are working. To do so the case study approach has been adopted and two major estuarine zones selected for review and evaluation.

The method of operation here will be to present a reasonably complete description of the estuarine zone, its uses and resources, the major problems and dangers facing it, and conditions resulting from these. Then there will be described the programs and activities of the various levels of government being carried out in each case and an attempt to evaluate the effectiveness of these programs.

Any comprehensive program of management should contain to some extent the following elements:

(1) Mutually agreed-upon policy objectives and functions.

(2) Legislative authorization to carry out the programs functional activities.

(3) Development of the basic kowledge necessary for effective management.

(4) Provisions for planning and implementation.

(5) Active administration in terms of regulation, control, and coordination.

(6) Financial resources.

(7) Public awareness and acceptance.

As it is possible the evaluation of the progress and success of management will be made in terms of the above elements.

The Chesapeake Bay on the east coast was selected as representing an interstate estuary. On the west coast, San Francisco Bay was selected as representing an intrastate estuary. The two are very different physically but the same in that they run the gamut from highly industrialized and populated areas to very rural areas. Each has a major series of problems including industrial growth, pollution, modification, and many others.

Sections 2 through 5 that follow will describe the Chesapeake Bay and its major problems, outline the activities and programs therein and make an evaluation as to effectiveness. Sections 6 through 9 will do the same for San Francisco Bay.

## SECTION 2. DESCRIPTION AND USES OF THE CHESAPEAKE BAY

In describing the Chesapeake Bay and its uses we have turned to a brief but excellent work by Dr. L. Eugene Cronin, director of the Chesapeake Biological Laboratory, Natural Resources Institute, University of Maryland (V–7–1) and quote as follows:

Chesapeake Bay [Figure V.7.1] is about 165 nautical miles long, averages less than 20 feet deep with a maximum depth of 175 feet, and contains about 18,520 billion gallons of water. The surface area is 4,300 square miles and the shoreline is 4,500 miles long. The total drainage basin is 74,000 square miles. This includes the Susqehanna River, the largest on the east coast of the United States, which drains 42 percent of the basin and dominates the upper bay. * * * The Potomac drains 22 percent of the basin and the Rappahanock-York-James complex drains about 24 percent. There are over 50 tributary rivers, with widely varying geochemical and hydrological characteristics, so that the physical circulation of the bay is complex.

The bay is the drowned valley of the Susquehanna; its natural deep channels are the only remnants of the original flow-carved riverhead. It is characterized by the presence of great deposits of fine sediments in the deeper portions.

Large cities, especially Baltimore, Washington, and Norfolk, arose because of the bay and increasingly impinge upon it. This is the southern end of the eastern megalopolis, with an enormous growth of population in sight.

Salinity is near zero at the head of each tributary and at the north end of the bay and about 30-31 parts per thousand at the Capes. Circulation is controlled primarily by river flow and the resulting density gradients. A strongly two-layered stratified system develops in summer, with a somewhat weaker winter system, and general vertical mixing occurs in spring and fall. This produces a net downstream flow of surface water and net upstream flow of deeper waters. This pattern of circulation affects many of the organisms of the bay.

## USES

### *Transportation*

Ships have used the bay since its discovery in the 16th century, and Baltimore and Norfolk are among the Nation's great ports. In 1964, 107,253,730 tons of material were handled by these ports, and Baltimore alone receives about 5,000 oceangoing ships per year. This commercially activity affects other uses of the bay, principally through pollution by bilgepumping and accidental spillage and through insatiable demands for the deepening and maintenance of channels. In the main channel of the bay, control depth is now 35 feet, but further cuts to 45 feet are now proposed.

### *Biotic Yield*

Extraction of organic material from the bay has increased from the inconsequential harvests by Indians and colonists to present efficient removal of fish and shellfish. Oyster production has been decimated by excessive exploitation, and other species have been reduced by tributary dams and pollution; but changes in gear have vastly increased the catch of menhaden, soft shell clams, and crabs. Landings for 1965 included 501,600,000 pounds of fish and shellfish for commercial use, with a value of at least $65 million (twice the dockside value). Menhaden dominated the fish catch, with 319 million pounds landed, but 108,200,000 pounds of shellfish provided 74 percent of the value. . . .

The yield to sport fishing is much more difficult to measure and evaluate. [Researchers] . . . have made valuable surveys of parts of the burgeoning recreational fishery, but no satisfactory estimates of baywide effort, catch or value are available.

In addition to these aquatic crops, the bay area supports large populations of many species of birds and mammals. They cannot be fully reviewed here, but are of high use to the human population and affected by the changes which are occurring.

### *Recreation and esthetics*

Recreational uses of the waters of the Chesapeake Bay are very poorly documented. Boating, swimming, skiing, beaching, fishing, and hunting are all increasing rapidly, but reliable data are scarce.

Boat registration provides one helpful index. Maryland salt water boat listings increased 33 percent from 1960 to 1966. Sixty-one thousand craft are registered, about 20,000 are not required to register and about 20,000 visiting boats enter the Maryland portion of the bay, for an annual total of 100,000. Over 300 marinas serve these boats. Virginia has a fleet of about the same size.

The Chesapeake is the focal point of the Atlantic flyway for migratory waterfowl, and about 30 species of ducks, geese, and swans concentrate there in winter. These support heavy hunting during the winter months.

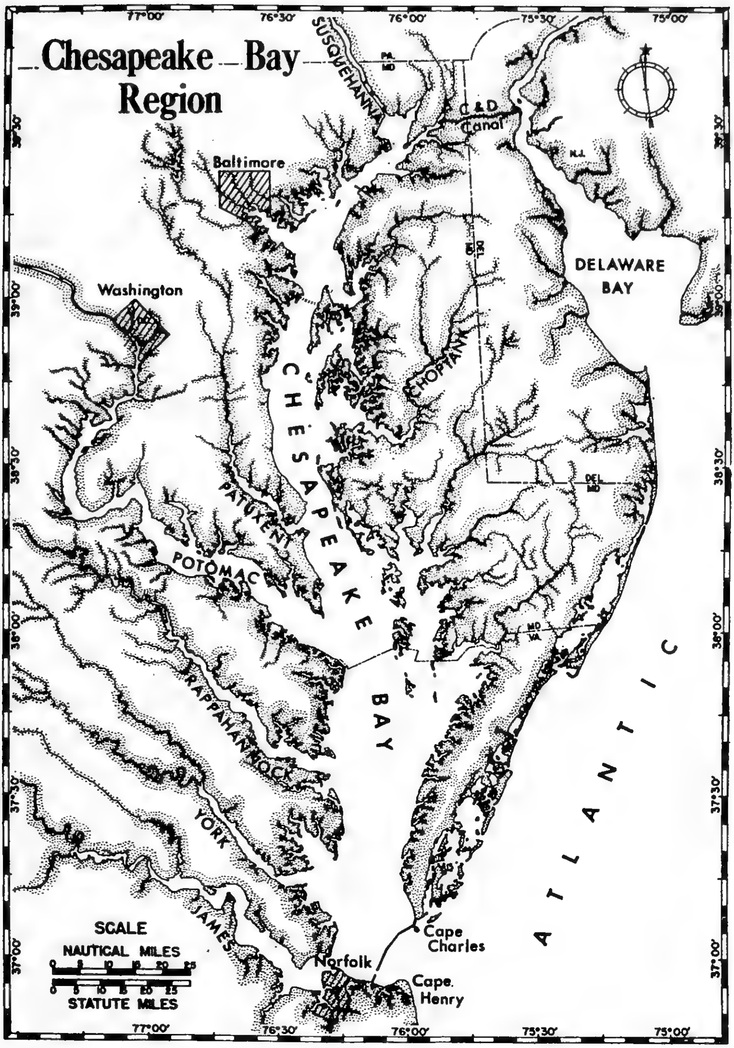



FIGURE V.7.1
Chesapeake Bay and its Principal Tributaries.
(Adapted from the report by L. E. Cronin, V-7-1.)

*Waste disposal*

The Baltimore-Washington metropolitan complex contained 3,771,000 people in 1960, with an expected doubling time of 25 years. While vast and expensive systems are under constuction for collection of the wastes fom this population and treatment to remove pathogenic bacteria and solids, almost no attention is given to the effects of pouring increasing quantities of nitrogen and phosphous into the bay and its tributaries. Brehmer . . . points out that the use of the Potomac River as the final treatment stage in the Washington disposal system releases 8 million pounds of phosphorus and 25 million pounds of nitrogen annually into the estuary. Doubling of this quantity is predicted within 30 years, and the estuary is already badly damaged. . . .

Thermal pollution is very rapidly increasing as power companies move to the large volumes of low-corrosion water of the estuaries. There is a complex of some 16 relatively small plants in existence now with rapid baywide proliferation proposed for the near future. The new seven stations planned are designed to produce about 1 million kilowatts each and to use about 1 million gallons of water per minute for condenser cooling, with a rise of 10–12° F. Some will be twice that large.

## Section 3. Major Problems and Dangers to the Bay

We have already noted in some detail two of the increasing problem areas of the Chesapeake; namely, waste loading and thermal pollution. Others that must be considered in current and future planning are as follows:

(1) The use of the Chesapeake Bay for maritime shipping results in local nuisance conditions from oil spills and overboard waste disposal. The major impact of the shipping industry is the dredging and spoil-disposal problems. The Chesapeake & Delaware Canal, a favored route for the Port of Baltimore, required an extensive dredging program in the upper bay with attendant spoil disposal problems. Demand already exists for further deeping of the shipping channels.

The disposal of spoil in the bay becomes of increasing concern. With the filling of deeper trenches, less salt water is able to move up the estuary in the two-layer system, changing the environment. The estuary is a natural sediment trap with most of the runoff materials deposited within it, with very little reaching the Continental Shelf. Spoil disposal practices of large magnitude will greatly accelerate the filling of deeper trenches of the bay, not of immediate concern for shipping, but possibly significant in its effects on hydrography and ecology. The deep trenches are known to be wintering areas for certain commercial finfishes. More recently the problem of the toxic nature of spoil from industrialized Baltimore Harbor has raised the question of immediate toxic effects in disposal areas.

(2) Altered salinity patterns in the bay are due to diversion of fresh water to the Delaware Basin through the deepened Chesapeake and Delaware Canal and because of increased potable water needs in the Delaware Basin. The use of the Susequehanna River at the Conowingo Dam for hydroelectric purposes causes problems of low flow with the resultant intrusion of salinity further up the bay.

(3) Aquatic plants such as wild celery, coontail, sea lettuce, Eurasian milfoil, and water chestnut have been found in the Chesapeake Bay Area. At times some of these aquatic plants have increased in

such abundance they created navigation problems, choked out desirable waterflow plants, interfered with shellfishing and finfishing, discouraged swimming, and created suitable breeding grounds for mosquitoes.

(4) Shoreline erosion control is, most certainly, another significant problem. Shoreline erosion can be a major source of sediment where headlands of easily eroded material are subject to wave attack.

Today, pressures for the varied use of Cheaspeake Bay are more intense than ever before. An increasing population looks toward the bay for new habitable areas and recreational facilities, and as a conduit for the disposal of wastes. Nevertheless, the very factors which make the bay more valuable for some human uses threaten to dissipate other resources. The filling of wetlands, the disposal of municipal and industrial wastes, the deposition of spoil from channel dredging, and thermal discharges all tend to diminish the bay's usefulness as a commercial source of fish, shellfish, and crabs; and as a site for waterfront housing, swimming, boating, and hunting.

Returning to a quote from Cronin (V–7–1), he states that:

> Prospects are that * * * Nutrient pollution from domestic waste poses the greatest of all recognized threats to the Chesapeake. It will seriously change and partially destroy local areas, and there is no assurance that it will not ultimately damage major portions of the bay and its tributaries.

## Section 4. Progress in Current Management Activities

In chapter 1, the "Federal Role and Activities in the Estuarine Zone," were described and a general outline of such activities was presented in table form. In addition, the weaknesses and the needs of the Federal program were noted. In chapter 2, the "Management Activities of the States and the Problems Facing Them," were discussed in considerable detail. With this in mind, it is intended to present here for later evaluation what appears to be progress in management; namely, organization, planning, implementation, and the knowledge-gathering activities necessary for effective support.

### MARYLAND

(1) Maryland has this year created a department of natural resources responsible for policies, management, administration and research, and study in the area of natural resources. Among other things, this department is responsible for the coordination and direction of comprehensive planning.

This in itself should be a most effective step in meeting recommendations in FWPCA's legal study of the bay (V–7–2).

The recommendations noted were "the need for a single agency within the State to control and regulate water and related land resources, and the need for a comprehensive plan."

(2) Water quality standards have been adopted and approved by the Secretary of the Interior.

(3) There is in preparation a comprehensive plan for the bay and its related resources—coordinated under the State planning department—possibly to include the inventory of Maryland's wetlands as directed by House Resolution No. 2 of 1967.

(4) Planning is going forward for a statewide waste control and acceptance plan.

(5) Zoning or the control of land use adjacent to the estuarine waters is not yet well established except in and near large metropolitan areas; nor does it appear to be planned—which, of course, is on the negative side of progress.

(6) Maryland has a form of dredge, fill, and alteration control in its navigable waters, but the controls are considered weak.

(7) Regional planning appears effective, but like zoning is confined to the metropolitan areas, that is, "Baltimore Regional Planning Council" and "Metropolitan Washington Council of Governments"—both of which plan and coordinate waste disposal problems in their areas of concern.

(8) The research and study to support improved management activities is proceeding as shown by a quote from L. Eugene Cronin (V–7–1):

> Research has expanded rapidly on the problems and potentials of the Chesapeake area. The Chesapeake Biological Laboratory of the University of Maryland, the Virginia Institute of Marine Science, and the Chesapeake Bay Institute of the Johns Hopkins University not only maintain substantial institutional research and training programs but have also formed the Chesapeake Research Council. . . . This brings together a total staff of about 110 scientists, 40 of whom hold doctorates, to share information and to undertake cooperative research projects. The council is probably the largest aggregation of estuarine scientists in the world. The first joint venture utilizes six vessels for simultaneous sampling of the bay and its tributaries. These laboratories have, since the 1930's and 1940's provided a considerable flow of information on estuarine hydrography, ecology, geology ,sprt and cmmercial fisheries, and pollution. . . .

VIRGINIA

(1) The department of water resources is to prepare a comprehensive plan for the water resources and development of the State.

(2) A basin planning program for the James River estuary is being completed.

(3) Water quality standards have been adopted and approved by the Secretary of the Interior.

(4) As in Maryland, zoning or the control of land use adjacent to the estuarine zone is confined to the metropolitan areas.

(5) Virginia *does not have* State permit control of dredge, fill, and alteration in its navigable waters.

(6) Virginia regards the Virginia Institute of Marine Sciences (VIMS) at Gloucester Point as its key agency in the marine environment. As noted above, VIMS is a member of the Chesapeake Research Council.

(7) Regional planning and organization are, as in Maryland, generally only active in or near metropolitan areas. Examples are:

(a) *Hampton Roads Sanitation District Commission* to serve Hampton, Norfolk, Virginia Beach, and Chesapeake.

(b) *Alexandria Sanitation Authority* to serve Fairfax County and the city of Alexandria.

(c) *Virginia Beach Erosion Commission* to serve the city of Virginia Beach.

(d) *Southeastern Virginia Regional Planning Commission* which includes Suffolk City, Virginia Beach City, and Nansemond County.

(e) *Richmond Regional Planning Commission* which includes Richmond City, Chesterfield County, and Henrico County.

(f) *Peninsula Regional Planning Commission* which includes Hampton City, Newport News, James City, Williamsburg County, and York County.

INTERSTATE ACTIVITIES

There are a number of interstate activities and agencies in the Chesapeake Bay area each of which serves to some extent to coordinate both Federal and State programs and operations.

These include the:

(1) *Interstate Commission on the Potomac River Basin* was created by the Potomac River Basin compact in 1939. Members include Maryland, Virginia, West Virginia, Pennsylvania, the District of Columbia, and the United States.

(2) *Potomac River Fisheries Commission*, established by the Potomac River compact, 1958, includes both the States of Maryland and Virginia. The work of the Commission provides for research, regulation, and licensing with respect to fish and shellfish, and the taking or catching of such fish in the tidewater portion of the Potomac River.

(3) *Atlantic States Marine Fisheries Commission* created in 1941, includes the States of Virginia and Maryland among the 15 signatory States to this compact. The U.S. Fish and Wildlife Service of the Department of the Interior is the primary research arm of the Commission. The purpose of the Commission is to recommend and coordinate legislation and general exercise of police powers with respect to marine, shell, and anadromous fisheries.

(4) *Chesapeake Research Council* includes members such as the Virginia Institute of Marine Science, Chesapeake Bay Institute of Johns Hopkins University and the Chesapeake Biological Laboratory of Natural Resources Institute of the University of Maryland. Its purpose is to promote and coordinate research on Chesapeake Bay.

(5) *DELMARVA Advisory Council* is primarily concerned with economic development. In particular, it coordinates and promotes travel and industrial development in Delaware, Maryland, and Virginia.

(6) *Atlantic Waterfowl Council* includes all the Atlantic seaboard States as well as Pennsylvania, West Virginia, and Vermont. Its main activity is the protection of marine waterfowl habitat and the regulation of migratory waterfowl routes.

(7) *Four-State Study Group* includes the States of New Jersey, Delaware, Maryland, and Virginia. Its main function is the coordination of research on MSX oyster disease and the related marine environment.

Two of the most significant management schemes that are now being considered for the Chesapeake Bay region are the proposed Federal-interstate compacts for the Susquehanna River Basin and the Potomac River Basin.

Both are modeled after the well-known Delaware River Basin compact of 1961, and concern the use of water and related land resources, and encompass all management functions including comprehensive planning, regulation, construction, financing, maintenance, and operation of public facilities. Both stop short of entering Chesapeake Bay.

## Section 5. Evaluation of the Chesapeake Bay

In the introduction, the various elements that should be considered in any comprehensive plan of management were listed and the evaluation of management in the Chesapeake Bay that follows is made in reference to those elements.

### POLICY AND OBJECTIVES

First, in regard to mutually agreed-upon policy and objectives, some exist at the State level; but it would appear that an overall national policy coupled with objectives should be established at the national level. There is need for such guidance not only for State management, but to provide better objectives for interstate programs of management.

### LEGISLATIVE AUTHORIZATION

At the State level Maryland's recent creation of its Department of Natural Resources has very likely produced an excellent start in this direction. Nevertheless, because of the many unsolved problems, stronger State legislation may still be needed. As was pointed out in chapter 1, a study of the Federal programs, a stronger, more effective Federal role is needed to provide not only much greater technical assistance to the States, but also to provide the impetus and the objectives for better and more effective management. A review of the Chesapeake only verifies this. Progress is apparent, but legislative action is needed to provide a stronger and more far-reaching program.

### DEVELOPMENT OF BASIC KNOWLEDGE

There exists a reasonably good understanding of the knowledge gaps that need to be filled to provide a better grade of technical knowledge. Research goes forward on many fronts and appears to be well directed toward the principal problems of the bay. Augmentation of research and study is no doubt needed if we are to stay ahead of the developing problems. A better coordination of the Federal research and study programs, possibly through the establishment of a multibureau/department estuarine laboratory devoted both to overall study of the bay and to its individual problems is needed. The Chesapeake Bay Research Council at the State level is an excellent vehicle for coordination and cooperative exchange of information.

### PLANNING AND IMPLEMENTATION

As for planning, there has been much of it at many levels, but as yet there are no overall comprehensive plans for the administration of the bay. The State of Maryland is moving in this direction. Virginia's long-range study will help. The Corps of Engineers' study authorized in 1965 is not yet properly funded. It could, if carried to completion, include the authorized hydraulic model and give much assistance to State comprehensive plans and their implementation.

### ACTIVE ADMINISTRATION—REGULATION, CONTROL, AND COORDINATION

It can only be said, that, although progress is being made, regulation and control are fragmented and less than fully effective. What is available cannot be applied in terms of the needs of comprehensive plans, because these do not yet exist. Again, there is needed the single State organization with the authority and the resources to effectively administer the many good but uncoordinated programs. In addition to the lack of a comprehensive plan, neither Virginia nor Maryland has effective State control over dredge, fills, and alteration in the wetlands and navigable waters at the present time. Neither is there zoning nor other control over the use of the adjacent lands except at the local level. Even at this level the amount of control is quite limited.

#### FINANCIAL RESOURCES

There has been steady growth in the personnel and financial resources devoted to estuarine management; nevertheless, considerable augmentation will be needed if comprehensive plans are to be made and implemented.

#### PUBLIC AWARENESS AND ACCEPTANCE

There is a considerable amount of public awareness and interest in the management of the Chesapeake Bay, as was evidenced by attendance at the public meetings sponsored by this study, and by other meetings and symposia. There is still much to do in obtaining public participation in the decisions to be made. This is particularly necessary at the level of local government where the important decisions on land use are made. Public participation in St. Mary's County, Md., decisions on locating a new oil refinery on the shore of the Potomac is an excellent example. Increasing public interest and action and understanding of the estuarine zone and its long-term value are necessities.

### Section 6. Description and Uses of the San Francisco Bay [1]

San Francisco Bay and delta comprises an extensive system of shallow interconnecting channels and bays. Its water quality ranges from sea water at the Golden Gate to fresh water at the upstream areas of the delta suitable for a variety of uses.

By its location and natural features the bay system from Spanish times to the present has been a hub of commerce and a defense center, regional first, and national later. With growth there were added the recreational values of the immediate area and the national parks to which the area gave access, and the beginning of an industrial sector. With postWorld War II development, the industrial sector became a major component of the economy.

The bay is a single body of water, with a total area of 480 square miles and a shoreline exceeding 276 miles, which receives drainage from a 50,000-square-mile area. Although the bay is a single body of water, its appearance varies greatly from one part to another. To present an adequate or even a reasonably complete description of the bay with its massive variety in terrain, appearance, condition, and general development is almost an impossibility in this brief discussion of management.

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[1] The information describing San Francisco Bay was taken from the San Francisco Bay Conservation and Development Commission study. Extensive use was made of the report entitled "San Francisco Bay Plan Supplement."

FIGURE V.7.2 AERIAL PHOTO OF SAN FRANCISCO BAY

Therefore, we present one aerial view (fig. V.7.2—courtesy of the Pacific Resources Inc., Oakland, Calif.,) and further attempt to describe the bay in terms of its uses and the problems facing it.

## USES

San Francisco Bay is the most important harbor system on the Pacific coast of the United States. Waterborne commerce through the Golden Gate amounted to nearly 32 million tons in 1965. A deep-water ship channel extends up the Sacramento River for 43 miles to Sacramento. Total traffic amounts to 2.2 million tons per year with 340,000 tons being in deep-draft vessels and the remainder in barges. Another deep-water channel extends to Stockton.

Supervessels, particularly for transporting petroleum, have increased the need for greater project depths.

The physical bay is a natural resource in itself—of minerals (sand, salt, cement), of marine life (commercial and sports fishing), a waterfowl habitat frequented by lovers of the most expensive form of hunting, and a recreational boater's Mediterranean in miniature.

The mineral resources of the bay include the salt, cement, and sand industries. The bay area supplies almost all of the salt consumed in northern California, Oregon, Washington, northern Idaho, and western Nevada. Almost a third of the total supply is used by large chlorine-caustic plants. Even the brine drawn from the salt ponds in the last stages of the solar evaporation process is considered important. It is called bittern and from it are extracted magnesium chloride and bromine as well as chemicals used in the manufacture of gypsum. The salt ponds are located in San Mateo, Santa Clara, Alameda, and Napa Counties.

Deposits of oyster shells and blue clay found in the bay are less important economically than the salt and other chemicals. The shells are sold to chemical companies and firms manufacturing soil conditioners and poultry feed.

Sand deposits in the bay have served as a basic source of fill for tideland areas, but have been of too poor quality for general industrial use. Sand for industrial purposes is largely extracted from pits in ancient riverbeds in Alameda County. Approximately 5 million tons come from these sources each year for building and paving in the bay area.

The bay provides a matchless natural harbor and habitat for probably the greatest variety of fish and wildlife of any comparable body of water in California. The area's marshlands, mudflats, and permanent water areas (an important resting spot for migatory birds in the Pacific flyway) support large populations of waterfowl. At least six species of anadromous fish run into or through the bay going to or from spawning grounds, while 150 species permanently inhabit these waters.

Activities that are principally concerned with the use of water as a medium for movement include power boating, sailing, water skiing, fishing from boats, scuba diving, and riding sightseeing boats and ferryboats.

Boating registration in the bay area counties increased from 53,000 in 1960 to 83,000 in 1965, an increase of some 57 percent. It has been reported that an inventory taken in 1965 of wet-storage facilities indicated a total 12,700 spaces available and 270 lanes of launching also existed.

San Francisco Bay is a receptacle for waste from municipal (domestic), industrial, and agricultural sources throughout its tributary area.

Three hundred ninety-eight million gallons of treated sewage and industrial wastes are discharged daily during dry weather to the tidal waters of the bay system from 77 municipal sewerage systems. Approximately 35 percent of these waste flows receive secondary treatment at 23 sewage treatment plants with the remaining flow receiving primary treatment at 54 sewage treatment plants. No community is discharging waste without treatment in the San Francisco Bay region. Forty-seven municipal waste discharges are now disinfecting or have facilities capable of disinfecting their waste flow which amounts to 245 million gallons per day, while 32 dischargers with a total waste flow of 153 million gallons per day do not have disinfection facilities.

A total of 269 million gallons per day of industrial wastes is discharged into the bay system by 47 industries. It is estimated that approximately 94 percent of this waste flow is cooling water drawn from the bay system and circulated in closed cooling systems. Most of the industrial waste discharges are located along the shorelines of Contra Costa County and discharge their wastes to San Pablo or Suisun Bay. These discharges contribute more than 70 percent of the biochemical oxygen demand loading in these areas; however, the depletion of dissolved oxygen below 5 mg/1 has not been measured immediately beyond industrial waste effluent dilution areas delineated by the regional board.

The number, location, and degree of treatment of both municipal and industrial waste discharges changes with the continuing implementation of recommendations in studies of sewerage needs and of master plans.

Storm water runoff not containing sewage, discharged from storm sewers, from flood control channels and from tributary streams is a factor affecting water use. Also governing water usability are the sediments from such activities as: agricultural practices, residential development, highway construction, and mining of natural resourcees.

The tributary streams and rivers also carry unknown quantities of nutrients, pesticides, and organic and inorganic material drained from residential, agricultural, and forested lands. The magnitude of the present water quality problem created by these factors is unknown.

## Section 7. Major Problems and Dangers to the Bay

Enjoyment of the bay is adversely affected by:

(1) Land fill problems. Wildlife and shellfish resources are damaged and sometimes lost when tidelands and marshes are filled. Eighty percent of the marshland has been "reclaimed." About 20 percent of the reclaimed areas are salt ponds and are currently used by wildlife. Fifty percent of the remaining water area of the bay is vulnerable to reclamation and fill. Current uncontrolled urban growth threatens both tidelands and marshes.

| Habitat | Original amounts (before reclamation) (square miles) | Amounts in 1967 (square miles) | Reclamation losses | |
|---|---|---|---|---|
| | | | Amounts (square miles) | Percent |
| Marshlands | 300 | 50 | 250 | 83 |
| Tideflats | 82 | 65 | 17 | 21 |

The effects have been noticeable. Wintering waterfowl population originally numbered about 2 million to 3 million. Today, wintering waterfowl populations number about 600,000 to 800,000, a loss of approximately 1.8 million waterfowl.

Prior to 1900 the annual commercial harvesting of the oyster fishery amounted to 10 to 15 million pounds. With the advent of water pollution, today there is no oyster fishery.

Before 1935 the annual commercial harvest of soft-shell clam fishery varied from 100,000 to 300,000 pounds. Because of the water pollution problem there is no commercial soft-shell clam industry. Recreational clam-digging is virtually nonexistent due to contamination.

The annual commercial landings of the shrimp fishery prior to 1936 were as high as 6.5 million pounds. Landings in 1965 were 10,000 pounds.

In 1830, 5,000 sea otter skins were annually taken from the bay. Today there are no sea otters. Kelp beds were abundant in the bay at that time. Today we know of no kelp beds.

The harbor seal were abundant until about 1890. Today there are about 90 to 150.

(2) Water quality damage. Historically, upstream hydraulic mining has severely altered the ecology of the bay, through siltation.

More recently the volume of poorly treated industrial, agricultural, and domestic wastes have increased to the point where fishlife has been damaged in some areas.

Annual die-offs of hundreds of striped bass continue to occur throughout the bay during the late spring and summer. The cause of these mysterious phenomena and their relationships to other factors in the bay remains unknown. Reports of tainted striped bass flesh have been received. The problem is being investigated by a joint committee of State and private agencies.

The ever-increasing tonnage in shipping in the bay area has caused an increase in the number of accidental oil spills from ships.

(3) Loss of esthetic enjoyment.—Floating debris, trash and litter from pleasure and commercial vessels, oil slicks and other waterborne wastes all contribute to the unsightliness of bay waters.

At the same time a few of the shoreline developments are of poor quality, and are inappropriate to a waterfront location.

There has also been a failure to take advantage of the dramatic view potential from hills surrounding the bay because of poor road layout and poorly placed buildings or plantings. (There are many notches, passes, and tunnels through the rim of hills around the bay on which the traveler is suddenly introduced or reintroduced to views of the bay.)

(4) Inadequate public access.—Loss of public access to the bay is a serious problem. Public access is now extremely inadequate and will become even more serious in the future. Of the 276 miles of San Francisco shoreline, scarcely 4 miles form the boundaries of waterside parks.

(5) Population and pollution problems.—The heart of the San Francisco Bay planning problem is people and more people. The population of this area will grow but the bay cannot.

Historically, California and the bay area have experienced a much faster rate of population growth than the rest of the Nation, because so many people have migrated to California from elsewhere in the United States. The Association of Bay Area Governments' projections assume these migrations will gradually decline over the coming decade. The estimates assume that in about 50 years almost as many people will be leaving California every year as will be moving into the State; the U.S. Census Bureau studies have found that the rate of intrastate migration is slowing down and the Bureau expects an eventual "state of equilibrium."

The population of the bay area, the delta, and the Central Valley, whose rivers and streams feed into the delta and bay, is about 6 million now and will increase more than 3½ times by the year 2020. The 16 million new residents will require tremendous supplies of water—and they will produce even larger quantities of wastes.

There is as yet no detailed prediction of the expected increase in liquid wastes. The U.S. Public Health Service indicated in 1963 that the volume of effluent discharged into the bay would increase to perhaps 1,100 million gallons per day by 1990 and to more than 1,700 million gallons daily by 2015.

(6) Agricultural wastes.—The Federal Water Pollution Control Administration has completed a study of the effects of the proposed San Joaquin master drain on the bay. The study concluded that the proposed drain, which would carry agricultural wastes from the Central Valley to an outfall near Antioch, would have a significantly harmful effect on the waters of the bay and delta, adversely affecting fishing, recreation, and esthetic values.

This harm would come primarily from nutrients the drain would deposit in the bay; the nutrients would stimulate the growth of large quantities of algae and other aquatic plants. The FWPCA study also concluded, however, that these detrimental effects would be minimized by treatment of waste waters; therefore, the FWPCA recommended that no discharge from the drain be permitted for at least 5 years, that is until 1972, so that pilot treatment facilities can be built and tested.

Interestingly, the FWPCA study also concluded that the drain, as presently planned, would not increase the present pesticide content of the bay and delta, principally because most pesticides are absorbed or decomposed as they pass through the soil of farmlands, while the drain would collect subsurface waters.

The pressures on San Francisco Bay area are very similar to those of Chesapeake Bay. Population pressures are present and these people look to the bay as a source for water supply, transportation, recreation, and waste disposal. Dredging and filling are present to the extent that more than 80 percent of marshland, and 20 percent of the tidelands have filled with resulting losses to fish, shellfish, and wildlife. There is a need for deepening shipping channels to accommodate larger ships.

## Section 8. Progress in Current Management

In San Francisco, after the completion of the excellent, in-depth study report by the San Francisco Bay Conservation and Development Commission and its recommendations, followed by extensive legislative debate and passage, progress in providing the necessary management capability could be classed as excellent.

On August 7, 1969, the Governor of the State of California signed into law the McAteer-Petris Act which provided for stringent control of shoreline development in the San Francisco Bay area.

The BCDC became the permanently established agency with powers and jurisdiction enabling it to protect the bay.

The amended McAteer-Petris Act provides for the following:

(1) Future development of the shoreline will include a number of prime water-oriented uses such as "ports, water-related industries, airports, wildlife refuges, water-oriented recreation and public assembly, desalinization plants and powerplants. . . ."

2. Saltponds and wetlands and a 100-foot strip of shoreline surrounding the bay are to be protected.

(3) BCDC has the power to issue or deny permits for any dredge and fill projects or any substantial change in the use of water, land, or structures within the commission's jurisdiction.

(4) Filling will be authorized only when its benefits are greater than the detriment resulting from the loss of water areas. Fill should be limited to water-oriented uses.

(5) Fill should be authorized only when an alternative upland location cannot be found. Any water area authorized to be filled should be the minimum area necessary.

(6) The nature, extent, and location of fill should be such that it will minimize harmful effects to the bay. Fill should be authorized when it will establish a permanent shoreline. Applicant must have valid title to property which is to be filled.

(7) In order to make the bay more accessible to the people, the shoreline area should be improved, developed, and preserved. Private and public development of the shoreline should be encouraged.

(8) The commission will review and prepare reports on estimated costs and method of financing proposed acquisition of private property for public use.

These definitive and incisive powers are to be exercised by a 27-member commission, nearly half of whom are to be elected officials. In addition, there are also two members appointed from the State legislature who are to participate in the activities of the commission.

The legislative enactment of BCDC goes a long way toward providing the necessary ingredients in the comprehensive management of San Francisco Bay.

The concept of a comprehensive ocean area plan is now also being formulated by the State of California.

Water quality standards for San Francisco Bay have been adopted and approved by the Secretary of the Interior.

The Governor also recently signed the most comprehensive water quality control law in the Nation. The California Water Quality Improvement Act of 1969, authorizes, among other things, a fine of up to $6,000 a day for failure to comply with the State's water discharge standards.

Prior to the creation of the San Francisco Bay Conservation and Development Commission and its subsequent legislative enactment, there was no coordinated regional control of dredge and fill except for the permit-granting authority of the U.S. Army Corps of Engineers concerning navigation. No State permit was required except for very specialized reasons, such as, removal of minerals from State lands.

Regional planning has been present, but not very effective since there has been no regional agency given jurisdiction over the entire bay prior to the San Francisco Bay Conservation and Development Commission. Other regional developments include: the Bay Area Transportation Study Commission, which completed a regional transportation plan with recommendations for implementation; the Association of Bay Area Government, which began in 1961 performing advisory regional planning; and the Joint Committee on Bay Area Regional Organization, a committee of the State legislature, after a 16-month study, proposed a limited-function nine-county regional government to encompass the State-designated water basin boundaries.

Research and study to support improved management activities is proceeding as is shown from the following activities:

(1) The State legislature, in 1965, authorized a comprehensive study and development of a water quality management program for the bay area. The report has been recently published.

(2) The Bureau of Sport Fisheries and Wildlife is examining the effects of dredging on bottom life in the bay.

(3) The Geological Survey has authorized programs to collect geologic and hydrologic data and to investigate the bad sediments.

(4) The Federal Water Pollution Control Administration completed a study on the effects of the proposed San Joaquin master drain on the bay in December 1966.

(5) The San Francisco Bay-Delta water quality control program financed partially with an FWPCA grant is involved in a comprehensive water quality management study concerning the development of a master plan for construction of a collection, treatment, reclamation, and disposal system to be staged over the 50-year period, 1970 to 2020.

(6) The Secretary of the Interior has established both field and headquarters task forces to cooperate with the State of California and to improve coordination of Interior's interests in the bay.

(7) The Corps of Engineers has undertaken a coordinated comprehensive survey of the entire bay complex with other Federal agencies concerning navigation, flood control, transportation, water supply, land reclamation, recreation, national defense, and allied subjects. The survey is scheduled for completion in 1972; it is operating a scale hydraulic model of the bay at Sausalito and is extending the model to include the Sacramento-San Joaquin Delta; and the Corps of Engineers has proposed a multimillion dollar, multiagency study of the development of San Francisco Bay as a port to handle supersized vessels.

## Section 9. Evaluation of the San Francisco Bay

At the beginning of chapter 7, section 1, mention was made of the several necessary elements for a comprehensive program of management. The evaluation of management in San Francisco Bay which follows is made in reference to those seven elements.

### POLICY AND OBJECTIVES

Regarding mutually agreed upon policy and objectives, very little, if any, existed on the State level, prior to the enactment of BCDC. In fact, the State of California, inessence, had surrendered control; there was no areawide political authority guiding the destiny of the San Francisco Bay. Such policy and objectives now exist for the bay. There is additional need for a national policy and objectives.

### LEGISLATIVE AUTHORIZATION

On the State level the recent legislative passage of the BCDC bill and its signing by the Governor has produced the necessary first step in this direction by establishing a permanent agency with powers and jurisdiction to care for, protect, and properly manage the nine-county area of the bay. At the same time, on the Federal level there is also a need for a much stronger program of technical information and assistance to the States, as well as objectives for more effective management.

### DEVELOPMENT OF BASIC KNOWLEDGE

The BCDC Study and the report published as a result of that study indicate quite satisfactorily the existence of the best available information. Nevertheless, new information and knowledge are constantly being produced and BCDC, the responsible agency for coordinating activities of the bay, is authorized under the enacting legislation to continually review subject areas under its jurisdiction.

### PLANNING AND IMPLEMENTATION

In the past, planning has not been one of the hallmarks in the administration of the bay. Consider the size of the bay in 1850 and what it is today. Where 300 square miles of marshland once remained in the bay, 250 square miles had been "reclaimed" by 1967. The fiilling in of the tidal and submerged lands have dried up 17 square miles that once were bay. Passage of the BCDC, hopefully, will put a stop to these activities.

Responsible Federal officials have indicated a satisfaction with what BCDC has accomplished, and are now watching to see if it will have the power to protect the national as well as local interest, and thereby serve as a prototype for State and regional action elsewhere in the Nation.

### ACTIVE ADMINISTRATION—REGULATION, CONTROL, AND COORDINATION

In the past there were mangament problems which contributed to interference and damage to the beneficial uses of the bay area. There was, for example, a lack of coordinated control of land and water uses.

Administration of bay lands and waters was accomplished by Federal and State agencies, nine counties and 91 city governments. Local entities appeared unwilling to sacrifice local autonomy to some overall coordinated controlling power. There was only limited control over dredging, filling, and alternation, and there was no coordinated regional zoning or other control over the use of water and adjacent land. There was a lack of coordinated planning. No true comprehensive development plan coupled with the authority for implementation existed. The Association of Bay Area Governments presented such a plan but, due to conflicting local interests, its implementation has become bogged down indefinitely while uncontrolled development reduced the remaining natural values of the bay. Finally, there was also a lack of legal definitions of landownership. Boundary lines between State and private lands are confused and complex. Clearer definition of existing State lands will be needed along with the acquisition of additional shallow water area.

#### FINANCIAL RESOURCES

There has been a steady growth in the number of personnel and the amount of moneys devoted to estuarine management. Nevertheless, considerable augmentation will be needed if comprehensive plans are to be made and implemented as provided by the BCDC legislation. For example, funds will be necessary (1) to finance development of the bay and shoreline to their highest potential, and (2) to pay the operating costs of the agency designated to carry out the bay plan. If it were desired to compensate private owners of the bay lands that cannot be filled, then additional funds would be required for this purpose.

#### PUBLIC AWARENESS AND ACCEPTANCE

The timely rescue of San Francisco Bay represents a demonstration of what concerned Americans can still do to protect their environment, and even to save what is left of grace in their urban areas. This untiring citizen effort, aided by a steadily swelling number of organizations, and local governments led first in 1965 to the establishment of a temporary BCDS with limited power and, secondly, to its permanent establishment with strong powers and effective authority.

Almost as refreshing as the outcome itself is the fact that the movement to rescue San Francisco Bay resulted in a plan which devoted a large part of its future effects to the social values of the estuaries—those which unfortunately have all too long in the past been neglected.

The public continues to participate in the membership of the 27-man San Francisco Bay Conservation and Development Commission. Seven representatives of these 27 members are appointed from the general public, another 13 of the 27 are elected officials and the remaining 7 are representatives of State and Federal agencies.

### Section 10. Summary and Conclusions

Summarizing from the evaluations of management in the Chesapeake and San Francisco Bays, it is apparent that the immense value and the need for action both to conserve and to develop them has been recognized both by Government and by the people. But even more so has been the recognition by the people and private organizations who brought their governments to the point of action.

The need for a comprehensive plan of management remains evident in the Chesapeake. In San Francisco Bay such a plan is in force. However, in terms of administration and regulation, neither California, Maryland, nor Virginia have instituted effective State control of dredge, fill, and alteration. Zoning or the control of land use adjacent to the estuarine waters is exercised at the level of local government and certainly has not yet been generally effective in the preservation of estuarine areas. The Bay Conservation and Development Commission plan for San Francisco Bay has been an exception to this for the past 3 years and hopefully will continue to exercise appropriate controls.

At the Federal level there is considerable evidence to indicate that a national policy with accompanying objectives and guidelines would provide helpful impetus to State programs even though many are proceeding without it. The augmentation and coordination of Federal programs in the estuarine zone is a very current need. Although the development of the necessary basic knowledge by research and study has made much progress, there remains much more to be done if comprehensive management plans are to receive the support they need.

San Francisco Bay suffered rather severe degradation before the "Save the Bay" organizations by their efforts brought the Bay Conservation and Development Commission into being. As a result, there is now a comprehensive plan for the preservation, use, and development of the bay. The Chesapeake Bay, on the other hand, is at present little damaged except in local areas generally near the population centers. Nevertheless, it faces growing problems of population pressures and industrial development with the problems involved in being an interstate estuary. This means, of course, that preparing and carrying out a comprehensive plan of management must sooner or later be a coordinated effort on the parts of both the States of Maryland and Virginia.

As can be seen, these two case studies, as brief as they are, again bring out the need for and the importance of a comprehensive plan at the State level, national policy and objectives, augmentation of programs directed to the estuarine and coastal zone, and the establishment and implementation of better and stronger regulatory controls.

These conclusions reinforce the discussion and findings in the study of the roles of local, State, interstate, and Federal programs in developing a comprehensive national estuarine program.

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# CHAPTER 8. SUMMARY AND CONCLUSIONS

## General Summary

The Nation's estuarine and coastal resources today are seriously impaired and, in some cases, have suffered impairment which is irreversible. Fundamentally, this loss is the result of unwillingness or inability of the governments sharing responsibility and authority for their management to do the things necessary to protect these resources for all beneficial uses today and to conserve or preserve their maximum future usefulness.

The reasons for this unwillingness or inability are various and highly complex. Most basic, perhaps, are four reasons:

(1) Shortsighted, imbalanced, or otherwise inadequate public policies governing the use of these resources up to now necessarily have reflected the dominant values of the American people. These traditionally have given a high priority to economic growth and technological development without adequately considering the adverse effects upon the estuarine and coastal environment.

(2) Another reason, undoubtedly, is ignorance concerning the sometimes fragile and always interdependent nature of the complex of resources found in the estuarine and coastal zone.

(3) Fragmentation and conflicts among governmental programs charged with the management of these resources have handicapped sound management. Closely related are, on the one hand, the limited use of plans which in fact coordinate the fragmented activities of the numerous agencies and governments involved in the management of these resources; and, on the other hand, the limited effectiveness of institutional arrangements now in being which were intended to overcome this fragmentation through interagency and/or intergovernmental review and consultation or through joint or cooperative action. Also a contributing factor is the absence in these programs of policies and organization focusing specifically on the resources of the estuarine and coastal zone.

(4) Although governments in the more recent period have moved to establish essential programs to conserve or preserve these resources, inadequate funding has prevented these programs from adequately accomplishing their mission.

## General Conclusions

The national estuarine management program must achieve, first, the determination, in and out of government, to manage the use of these resources so as to protect them for as many beneficial uses as possible both now and in the future; and, second, the capability at all levels of government to do so.

More specifically, this means that the national estuarine management program should be directed toward five broad objectives:

(1) The first is development and adoption of plans which will result in balanced development, conservation, and preservation of estuarine and coastal zone resources. Developed for specific estuarine and coastal areas, these plans should control the use of the resources of these areas for as many beneficial purposes as possible. Where some uses are precluded, the plan should allow that mix of uses which, based on both short- and long-range considerations, is judged to be the most beneficial. Once adopted, it should control the activities of all involved in managing the estuary or coastal area included in the plan.

(2) The second objective is the strengthening of governmental regulatory programs and other activities directed toward implementing and obtaining compliance with the use and management plan adopted for a specific estuary or coastal area. Basically, this requires improved management authority and organization.

(3) A third objective is the initiation of studies, research, and inventories in the estuarine and coastal zone to greatly increase knowledge about these resources and understanding of their interrelationships and behavior.

(4) The fourth objective is the adequate funding of all of the essential governmental programs.

(5) The fifth objective is the development of the public support on which achievement of the other objectives ultimately is dependent.

A second conclusion is that the sharing of responsibility and authority which marks the present approach to the management of the estuarine and coastal zone also must become an essential feature of the national estuarine management program. In turn, this means that the national program should create a Federal-State-local relationship which makes maximum use of the particular and sometimes unique capabilities which each level of government can bring to bear in a coordinated and comprehensive effort to wisely manage the resources of the estuarine and coastal zone. The outlines of such a relationship are defined in the sections which follow.

## Role of State Governments

### SUMMARY

The States today exercise the primary responsibility for the management of the resources of the estuarine and coastal zone. It is the States which are primarily responsible for the prevention and control of pollution in the estuaries and coastal waters. They hold title to the submerged and tidal lands and are thus in a position to control their use and modification. Although most States have delegated authority to control land use to their local governmental units, they legally retain the ultimate authority to control the use of shorelines and related uplands in the estuarine and coastal zone and thus to decide whether these lands are to be used for industry and commerce, parks and recreation, fish and wildlife habitat, residential housing, or other purposes. They determine the forms and functions of local government generally in managing water and related land resources, and the same holds true for the interstate instrumentalities which, at their option, they may create for management purposes. Fisheries and other living estuarine resources are under their direct control. Each State presides over the legal system which governs private relations and resolves the conflicting rights, interests, and privileges of its citizens in the development and use of estuarine and coastal resources. And, finally, even in those areas in which the Federal Government exercises exclusive or primary authority, the nature of this country's political process gives State groups and officials substantial power to influence the objectives and the exercise of Federal policies.

### CONCLUSIONS

The powers which the States possess clearly are strategic ones in achieving balanced development, conservation, and preservation of the resources of the estuarine and coastal zone. The national estuarine management program accordingly should continue to vest the primary responsibility for the management of these resources in the States. As this analysis has shown, the States have ample constitutional authority and, in all instances, they already are administering ongoing programs in the estuarine and coastal zone on which the national program can be built. Through their authority over local governments, the States also are able to delegate to the local level that authority which can best be performed locally. As a corollary, they also can oversee the exercise of local authority so as to insure that the larger State and national interests in the development and use of locally situated resources prevail over more limited or erroneous local perceptions of the public's interest in these resources. They also are close to the scene and thus better able than the Federal Government to respond to the unique needs and opportunities of each estuary and coastal area. At the same time, however, they are in a better position than local governments to resist pressures for unwise development.

In order that the States will effectively discharge this primary responsibility, the tactics of the national estuarine management program should seek to have each State develop, either directly or through its local subdivisions, the plan (or plans) which will control future use of the State's estuarine and coastal zone; and, further, take the steps necessary to insure compliance with these plans by its own agencies and its local governmental units. Two steps are especially essential in this regard. One is the better establishment of State-level organization, not dominated by any particular interest, with the capability of administering or coordinating State-level management activities in the estuarine and coastal zone. The other is the establishment by the State of more effective supervision and control over the actions of local governments in that zone. In addition, the State organization created or designated for this purpose should have the capacity to integrate Federal service programs into the State's management activities in its estaurine and coastal areas and, even more important, to play a strong advisory role with respect to Federal programs and projects more directly managing the resources of these areas.

## Role of Local Governments

### SUMMARY

The States typically have delegated or assigned authority to their local subdivisions to carry out a broad range of functions which directly or indirectly may have important effects on estuarine and coastal resources. Among these significant activities are: (1) planning and zoning of land use; (2) provision, either directly or otherwise, of water supply, waste collection and treatment, and other utilities; (3) construction of port facilities, roads, and bridges; (4) provision of beaches, parks, marinas, fishing piers, and other recreational facilities; (5) regulation of the use of septic tanks in the zone and the administration of pest control and other public health protection programs; (6) regulation of fills and the administration of drainage projects; (7) promotion of industrial or other economic development; (8) maintenance of property and other essential records; and (9) administration of local courts to establish justice and equity in interpersonal relations.

Although the primary responsibility for the management of the resources of the estuarine and coastal zone now rests with the States, the above listing clearly demonstrates that local governments today in fact are making many of the most crucially important decisions which actually govern the management and use of these resources. Located "on scene" they are themselves major users of the zone's resources. Moreover, they are highly responsive to public and private interests in the nongovernmental sector which also are directly engaged in developing and using these resources to satisfy human wants and needs. In both respects, therefore, local governments today occupy the most crucial spot in the management of estuarine and coastal resources, because of the consequences, for the good or ill of the estuarine or coastal resources concerned, of the States' local assignment of control over local activities.

Local governments naturally desire to promote the economic growth of the local area and to improve the community's property-tax base which traditionally has financed most of their activities. However, each local unit usually is too small to envision or respond effectively to the needs of an entire estuary or coastal area. Frequently, they also have lacked funds, and therefore the staff, to maintain the expertise which is capable of fully understanding all of the ramifications of local actions upon the larger estuarine and coastal zone. The result is that all too often local governments have succumbed to strong economic and political pressure to proceed with poorly planned or unwise development of estuarine and coastal resources, or to permit such development by those in the nongovernmental sector. In succumbing to these pressures, local governments unfortunately have contributed much to the impairment of the Nation's estuarine and coastal resources.

### CONCLUSIONS

Although the record of local governments in managing estuarine and coastal zone resources on the whole is subject to criticism, the Nation's effort to improve management of these resources should retain a significant role for local governments in the new national program.

The reasons include the already-mentioned "on scene" relationship and its effect on the ability of local government to sense and respond to unique conditions, and also its ability to mobilize the support and cooperation of local civic and private interests. But they also include the value which the American people attach to self-government, to decentralization of governmental authority and responsibility, and to local experimentation and innovation in developing new national programs.

In brief, therefore, the role of local government in the National Estuarine Management Program should be to carry out, with State and Federal support and assistance, and under the State's supervision, the estuarine and coastal management functions delegated or assigned to it by each State. This conclusion recognizes that the resulting local role may vary from State to State. Thus, in some States, a review of the present combined State-local management capability and effectiveness may conclude that local governments should continue to exercise substantially the same functions as they now do, but also recommend improved supervision by the State. In others, a review may recommend that the State government assume and itself directly exercise important components of estuarine and coastal management authority and responsibility now delegated to its local governments.

What is essential in most States, if not all, is a better State-local division of authority and relationship which will enable these two levels of government together more effectively to discharge the State's primary responsibility for achieving balanced development, conservation, and preservation of estuarine and coastal resources.

## Role of the Federal Government

### SUMMARY

Under the Constitution, the Federal Government possesses the primary authority to conduct foreign affairs and to maintain the national security, a consideration obviously of major importance in managing the estuarine and coastal zone. Moreover, as interrelated parts of a single governmental system, the Federal, State, and local governments in this country share in the exercise of most domestic functions. It is not surprising, therefore, that the Nation's approach to the management of its estuarine and coastal resources also has been characterized by important involvement by the Federal Government. This involvement has reflected not only the primary authority of the Federal Government in the areas mentioned and its paramount authority over the use of estuarine and coastal waters for navigation and commerce. It also reflects numerous decisions by the Congress, supported by the Supreme Court, that the Federal Government too has a major responsibility to promote and protect a broad variety of other beneficial uses of the resources of this zone.

The resulting activities of the Federal Government today in participating in the management of these resources are extensive and fall into five broad categories.

First, the Federal Government regulates, either directly or in support of regulatory activities by the States: (1) the use of estuarine and coastal waters for the disposal of various wastes; (2) the placing of structures over and in navigable waters; (3) the designation of navigable waters as danger zones and for certain uses such as fishing grounds; (4) the establishment of harbor lines; and (5) the use of estuarine and coastal waters for the generation of electric power.

Second, Federal agencies directly acquire and administer estuarine and coastal sites for a variety of uses, including habitat to protect fish and wildlife resources; seashores areas, parks, or other recreational facilities; military installations; saline water conversion; and other purposes.

Third, the Federal Government makes grants to the States, local governments, and others for activities which span the entire range of estuarine and coastal zone management functions and purposes.

Fourth, most Federal agencies perform functions to assist and support the use and management of estuarine and coastal resources generally, and State and local programs in particular. Services include: (1) preparation of comprehensive or functional plans for the use and management of water and related natural resources; (2) special studies, inventories, research, and data collection activities; (3) information dissemination and other education programs; (4) technical aid and assistance in a broad range of areas; and (5) provision of navigation, flood control, beach protection, and other public works, facilities or services in the estuarine and coastal zone.

Fifth, by enacting statutes such as the Fish and Wildlife Coordination Act, the Water Resources Planning Act, and other statutes, and by consenting to interstate compacts, the Congress has provided, or agreed to, procedures and organization designed to improve the coordination of the programs of different agencies and governments in the estuarine and coastal zone.

## CONCLUSIONS

The National Estuarine Management Program cannot abrogate the Federal interests in the estuarine and coastal zone nor the missions which the Congress, pursuant to those interests, has assigned to various Federal agencies. Instead, it is imperative that the program include the Federal Government as a strong and active participant. This means Federal action on three fronts:

(1) The first is the full and effective mobilization and use by all Federal agencies of estuarine and coastal zone management authority and responsibility which they now possess by assignment from the Congress. This will, in many instances, also require increased funding of these programs by the Congress. It also may require action by the executive, both at the Presidential and departmental levels, to improve utilization of authority now available.

Although all present Federal activities applicable to estuarine and coastal zone management purposes—ranging from service to regulatory functions—clearly can and must participate on this front, a number of actions are especially critical and essential. These include:

(a) Increased funding of Federal construction grants for waste treatment facilities to facilitate prompt implementation of established water quality standards in estuaries and coastal waters. Funding of all of the waste treatment facilities needed at Federal installations to eliminate their contribution to pollution in these waters also is urgent.

(b) Maximum utilization of other existing Federal grant programs which can be applied to estuarine and coastal zone management purposes. Examples are programs under (1) section 701 of the Housing Act of 1954, title III of the Water Resources Planning Act, and section 3(c) of the Water Pollution Control Act, all providing grants for comprehensive planning; (2) the Land and Water Conservation Fund Act, which provides grants for Federal, State, and local acquisition and development of estuarine and coastal sites for conservation and recreation purposes; (3) section 6 of the Water Pollution Control Act, the Water Resources Research Act, and the National Sea-Grant College and Program Act of 1966, all authorizing grants which can be utilized for research and study in estuarine and coastal areas; and (4) section 7 of the Water Pollution Control Act, providing grants for the administration of State and interstate water pollution control programs.

(c) Full use of direct Federal authority for functional or comprehensive planning to prepare, in cooperation with the States and others, use and management plans for specific estuaries and coastal areas. Completion by the Corps of Engineers of the comprehensive study of Chesapeake Bay, including the construction of the authorized hydraulic model of this estuary, is particularly important. Also urgent is greater attention in the present framework studies being conducted under the aegis of the Water Resources Council and other Federal water resource planning programs in rivers tributary to estuaries and coastal waters to the impact of upstream developments upon downstream estuarine and coastal resources.

(d) Completion and maintenance by the Department of the Interior of the broad national inventory of estuaries and their resources initiated by the national estuarine pollution study and also the inventory directed by the National Estuary Protection Act (P.L. 90–454).

(e) Completion of presently authorized studies bearing on the use and management of estuarine resources, including the study by the Department of the Interior under the National Estuarine Protection Act of the feasibility and desirability of establishing a nationwide system of estuarine areas; and the Corps of Engineers national shoreline erosion survey authorized by Congress in Public Law 90–483.

(2) On the second front of required Federal action, the Congress should enact legislation establishing the national estuarine management program. Purposes of this legislation should be three:

(a) To establish the basic policies and objectives which are to guide that program at all levels of government.

(b) To provide the Federal incentives which will act as an impetus for needed action by the States under that program.

(c) To authorize the new actions which that program should require from Federal administrative agencies.

The legislation's statement of policies and objectives should stress the national interest in the balanced multipurpose development, conservation, and preservation of estuarine and coastal resources over both the short and long range. In setting this as the objective, it also should emphasize the importance of giving priority consideration to nonrenewable resources and to maintaining those resources and uses which are estuarine dependent. While affirming the States' primary management responsibility, it also should make clear the Federal Government's right and obligation in two respects. These are, first, to directly manage the use of estuarine and coastal zone resources where vital Federal interests are involved. The second is to provide continuing guidance to the States in their important management decisions. Such guidance includes not only advice and recommendations but also the delineation of improvements which the States are expected to make as a condition of Federal financial aid and support.

To create the incentives which will provide the impetus for needed State action, the new legislation should authorize a new program of grants-in-aid to be used for estuarine and coastal zone management specifically. Particular purposes of such assistance should include the establishment of organization at the State level for estuarine and coastal zone management, the administration of that organization during its first years of operation, the development of comprehensive plans to govern the use of specific estuarine and coastal resources, and research and training programs in estuarine and coastal zone management.

(3) On the third front of Federal action, the President should issue an appropriate Executive order or proclamation calling upon Federal agencies, the States, and others to make the maximum possible effort under existing law to implement the objectives of the proposed national policy in the interim before the national estuarine management program can be activated.

### Role of Public and Private Interests

Achievement of balanced development, conservation, and preservation of the resources of the estuarine and coastal zone for multiple purposes will become a reality only if the public and private interests in the nongovernmental sector want and demand it. This means that these interests now must actively seek the establishment of the national estuarine management program and, thereafter, give continuing attention and support to its administration at all levels of government. It means too that these interests must themselves actively participate in the administration of that program by taking part in the preparation of use and management plans for specific estuaries and coastal areas and through research and education, experimentation with new management concepts, their own programs to acquire and administer important sites within the zone to protect them from undesirable development, and continuing evaluation and criticism of governmental programs. Compliance with adopted plans in the activities which these interests conduct on their own in the estuarine and coastal zone also is absolutely essential.

Conclusions presented in this chapter are developed in greater detail in Part III. "Recommendations—The Proposed Program," of the Report of the National Estuarine Pollution Study.

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# CHAPTER 9. SUGGESTED GUIDELINES FOR A STATE MANAGEMENT STATUTE

Numerous representatives of the coastal States have expressed, through the public meetings, through State profile presentations, and through direct correspondence with the National Estuarine Pollution Study staff a need for suggestions from the Federal Government as to how the States can develop improved or strengthened provisions for the use control of their estuarine resources. Details on these suggestions are included in the preceding chapters 2 and 5.

Consequently, the National Estuarine Pollution Study made an initial attempt to develop such guidelines through a contract awarded to the University of Maryland School of Law. The result of this contract was the development of a model statute for Chesapeake Bay Basin management based upon the existing condition in the adjacent Chesapeake Bay. This specific geographic area was selected as the basis for the development of the guidelines because of its wide range of governmental relationships, characteristics, benefits, potentials, and use conflicts which exist not only in the basin area but also in other major estuarine areas. Therefore, this suggested statute, presented in the following pages of this chapter, is considered to meet many of these problems and to include many of the basic principles which would be applicable to other estuarine areas of the United States; also it is included because it is an excellent piece of work. It is of course not presented as this study's recommendation for any action by the State of Maryland, or any other coastal State.

# A MODEL STATUTE FOR BAY BASIN MANAGEMENT: ADAPTED FOR ADOPTION IN MARYLAND

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## General Comments

The starting point in drafting "model" legislation is a question—what is wrong with existing laws and legal institutions? The most frequent response when this question is asked with reference to Chesapeake Bay is—"fragmentation of authority." It is true that there is no shortage of Bay government. The Federal Government, the governments of Maryland and Virginia, the governments of their respective counties and cities, and an interstate compact commission, all have spheres of governmental authority.

But this is not the crux of the problem. The Federal Government has demonstrated its willingness to cooperate with, and to defer to, effective State action. The Federal water quality program affords a good illustration. The legislatures of Maryland and Virginia have zealously avoided the delegation of significant powers over the Bay to counties or cities. Although the Bay is divided between Maryland and Virginia, both have a significantly broad territorial expanse to effectively manage their respective portions. The only extant compact commission is limited in power to the Potomac fishery.

Hence the problems which exist are to be found primarily within Maryland and Virginia State government. Existing State legal institutions suffer from two major inadequacies. First, the State legislatures, clinging vestigially to the nineteenth century, have attempted to administer the Bay themselves. Rather than delegating broad managerial power to the executive branch, they have responded to narrow problems with narrow legislation. These responses rapidly become out-of-date but linger on as law. In short, the legislatures have refused to give administrators the "range of choice" necessary for effective management.

Second, these powers which have been delegated by the legislatures have been scattered throughout the States' administrative apparatus. Various State agencies have duplicating, overlapping and sometimes inconsistent powers, but in neither Maryland nor Virginia is there a single agency with the requisite authority to plan and coordinate the administration of the Bay and its resources.

In recent years the most popular model for meeting the problems of river basin management has been the Federal-interstate compact. The success of the Delaware River Basin Commission has led to the negotiation and proposal of similar compacts for the Potomac and Susquehanna Rivers. Such a management model has certain advantages for the Chesapeake Bay. A compact between Maryland, Virginia, the United States (and perhaps Delaware) could be given territorial jurisdiction over the whole Bay. Theoretically, at least, the State legislatures could delegate broad powers to the compact commission which could exercise them in coordinated, autonomous fashion (free from State legislative interference) for the compact's duration.

But the compact model also has disadvantages. It adds yet another tier to the existing surfeit of Bay governments. It would be difficult to integrate such a compact with the already negotiated and proposed Potomac River Basin Compact which has powers over the estuarine portions of the Potomac. Finally, it would be difficult to negotiate a compact which gives adequate powers to the governing commission and still would be acceptable to both Virginia and Maryland. Although Maryland and Virginia have a common interest in various aspects of Bay management they also have disparate and competitive interests in preserving the Bay resources within their respective boundaries exclusively for themselves and their citizens. At best, such a compact would take years to negotiate; at worst, it would be emasculated through the retention of powers by the States.

Because of the disadvantages of the compact format, it was decided to reform State government rather than supplant it. The legislation which follows provides such a reform, adapted for adoption in Maryland. Basically it is a legislative delegation of broad planning, regulatory, administrative and operational powers to a single state agency—The Chesapeake Bay Basin Department. The Department is given territorial jurisdiction over all waters of the State. This jurisdiction was decided upon by starting with Bay waters and moving upstream into the fresh water tributaries of the basin with the realization that fresh water input so intimately affects estuarine waters that the two cannot be rationally separated. Also involved was the perception that—since almost all Maryland waters are in the basin except for some waters on the eastern shore which drain into the bays behind the Atlantic barrier beaches and which present similar management problems—the Department might as well have authority over all State waters. Hence the title of the Department is a misnomer, chosen on the theory that the dog should wag the tail.

The territorial jurisdiction of the Department would, of course, be curtailed upon the adoption of the Susquehanna and Potomac River Basin Compacts. Assuming the adoption of these compacts, their respective commissions would have primary power within their jurisdictional bounds but to the extent they permit State regulation and activity the Department would be the Maryland operative.

The Chesapeake Bay Basin Department is designed to replace two existing State agencies—the Department of Water Resources and the Department of Chesapeake Bay Affairs. It is also designed to take from the State Health Department the power to regulate discharges of human and municipal wastes. Its primary role is as a coordinator, planner and regulator. It is charged with the duty of developing a plan for the utilization and conservation of the waters of the State and a complementary plan for utilization and conservation of Chesapeake Bay resources. It is given regulatory powers necessary to assure implementation of these plans. In addition when a need appears for Statewide development and management (for example, a State run waste acceptance system) it may own and administer facilities.

## Specific Comments

### ARTICLE 1

### CHESAPEAKE BAY BASIN DEPARTMENT CREATED

This article defines the terms used throughout the act and lays the organizational groundwork for the new Chesapeake Bay Basin Department. This Department replaces the Department of Water Resources and the Department of Chesapeake Bay Affairs under the umbrella of the Department of Natural Resources. The Secretary of Natural Resources has powers under other sections of the Maryland Code to coordinate the activities of the Department with the activities of other related resource agencies such as the Department of Forests and Parks and Department of Game and Inland Fish.

The Director of the Department is appointed by and serves at the pleasure of the Governor. Accordingly the Director will be responsive to the Governor (or his intermediary, the Secretary of Natural Resources) and the Governor is responsible for decisions of the Department. No commissions are established which interfere with this well defined line of responsibility and authority.

Section 1.204 which provides that all moneys received by the Department shall be paid into the general fund, in essence abolishes several special funds which now exist (e.g., Fisheries Research and Development Fund, Waterways Improvement Fund). It is felt that since this act represents a broad delegation of authority to the Department, the Department should be required to clear all expenditures through the ordinary budget process.

Section 1.302 articulates the relationship between the Department and the Federal Government or interstate compact commissions. Powers of these paramount bodies take procedence.

## ARTICLE 2

## WATERS OF THE STATE

This article charges the Department with the obligation to adopt a plan for utilization of State waters and gives the Department the powers necessary to implement the plan.

Section 2.201 gives the Department authority to promulgate and enforce quality standards for waters of the State. Section 2.202 supplements this basic power by authorizing the Department to impose other controls such as permits establishing assimilative capacity quotas or effluent charges.

Section 2.204 is designed to foreclose the possibility of collateral attack on the decisions of the Department such as happened in Stanton v. Trustees, 233 A.2d 718 (Me. 1967) where a downstream riparian secured an injunction against an upstream discharger, even though the discharger had secured a permit from the State water quality commission.

Section 2.302 carries over the appropriations permit system for the use of water which has existed in Maryland since 1934. The cross reference to Section 3.203 adds a new wrinkle, by making clear that the State, through the Director, can require payment for the use of tidal waters. This affords a useful managerial tool in limiting the placement of thermal loads on the Bay. Certainly the use of Bay waters as a coolant becomes less attractive to a commercial user if he may be charged the fair market value of such use (one measure of which would be the cost of an alternative cooling system).

Section 2.302(c) functions as a "grandfather's clause." Under Maryland law there is some possibility that pre-1934 users of fresh water and pre-1966 users of tidal waters have some vested rights in such waters. See Md. Ann. Code, Art. 96A, Secs. 2, 11 as amended 1968. These rights have never been legally tested. This subsection recognizes that such rights may exist but places the burden of going forward on the person asserting them.

Sections 2.401 through 2.403 give the Department broad discretion to regulate the operation of boats. The Department of Chesapeake Bay Affairs presently has similar (although more circumscribed) powers under Section 1-11 of Article 14B of the Maryland Code. Section 2.404, however, transfers powers relating to the licensing of boats, presently exercised by Chesapeake Bay Affairs, to the Department of Motor Vehicles.

## ARTICLE 3

## THE TIDAL REGION

This Article lays the foundation for a series of special regulations over Chesapeake Bay and the bays behind Maryland's barrier beach on the Atlantic Coast.

Section 3.101 directs the Department to prepare a comprehensive plan for Bay development. The sort of plan envisioned is the San Francisco Bay Plan already developed in California.

Section 3.201 restates the State's common law ownership of tidal waters and submerged tidal lands and Section 3.202 specifies the rights of riparian land owners therein. Section 3.202 is designed to replace Sections 45 through 48 of Article 54 of the Maryland Code. It gives to the riparian essentially the same rights that the Maryland Attorney General says he has under existing law. See 50 Op. Att'y. General 452 (1965). Whether in fact, Section 3.202 is a constriction of riparian rights depends on whether the Attorney General's narrow reading of existing law is correct.

Section 3.203 provides a procedure through which the Director can transfer the State's interest in tidal waters and submerged tidal lands. Since the Director is the Governor's man the decision is the Governor's. It may be used to sell water (for use as a coolant), sand, gravel, minerals, oil, gas, etc., or land itself as a site for filling. It represents a consolidation of a variety of procedures under existing law. It should be noted that the procedure is hedged with significant safeguards. Before a person can acquire any interest, he must first acquire a permit under the regulatory procedures in either Section 2.302 or 4.302. These permit procedures give optimum protection to both public and private interests. The special notice procedure within 3.203 holds open to public scrutiny the Director's (or Governor's) decision of the price to be charged.

Sections 3.301 through 3.303 provide a new and flexible procedure through which the Department can control development of Bay shoreline. For example, it might use the power in Section 3.301 to protect non-tidal wetlands or to reserve certain shorelines for priority uses such as water-related industry or water-related recreation. Section 3.302 provides a technique through which local governments can preserve their primary land use control jurisdiction by meeting Department standards. Under Section 3.303 the Department is delegated broad powers to promulgate land use control regulations which may take the form of zoning, subdivision controls or permit procedures.

Sections 3.401 through 3.404 make a significant change in existing law. They transfer management of the Bay's fishery from statute to regulation. This will give the Department the range of choice necessary for efficient and rational management. Section 3.403 makes possible a dramatic change in oyster management. It permits the Department to shift from a public to private oyster fishery, in whole or part. The Department is given broad enough discretion so that it can negotiate mutually advantageous trade-offs with its counterpart in Virginia.

## ARTICLE 4

## PROJECTS AND FACILITIES

This Article provides for the regulation, management and operation of projects and facilities affecting the waters of the State and the resources of the tidal region.

Section 4.201 delegates to the Department police power authority to regulate existing projects and facilities and Section 4.202 adds special enforcement powers.

Sections 4.301 through 4.303 establish prior approval procedures for all projects affecting State waters and the tidal region. Section 4.301 regulates private projects on privately owned land. Accordingly the Department's approval authority is limited to its police powers. Section 4.302 regulates private projects on what is presumptively publicly owned land or water. Accordingly the Department is given greater discretion in the determination of whether to approve such projects. Persons receiving a permit are required to comply with the procedure outlined in Section 3.203. This provides a mechanism for assuring that the State will receive a fair return for property rights it relinquishes. Section 4.302(c) provides a procedure whereby a person who can rebut the presumption of State ownership (e.g., the owner of a valid and extant patent to submerged tidal land) can vindicate his rights if the Department refuses to recognize them.

Section 4.303 authorizes the Department to regulate projects of other governmental agencies. When dealing with other State or local agencies the powers are plenary—the Department is the supervisor of State waters and the tidal region. When dealing with the U.S. Government or compact commissions, in the exercise of their valid powers, the Department has only the power of persuasion.

Sections 4.401 through 4.403 define the Department's role as an operative and financier. It is empowered to buy, build, manage and operate necessary projects and facilities (e.g., waste collection systems, waterways improvements, shore erosion control structures, recreation areas, etc.). It may also contribute towards the financing of such projects and facilities by other governmental agencies or persons but may only contribute amounts to persons that it can justify on a cost-benefit basis.

## ARTICLE 5

## GENERAL PROVISIONS

Sections 5.101 through 5.106 outline the internal working procedures of the Department. Sections 5.102 through 5.104 mandate that notice be given and a public hearing be held before important Department decisions are made. Interested persons and governmental agencies are guaranteed an opportunity to present their views.

Sections 5.201 and 5.202 provide for judicial review of Department decisions. The procedures outlined therein are supplemented by various other possibilities of review available at common law.

Sections 5.301 and 5.302 give to the Department civil and criminal sanction which they may use in the enforcement of the statute and the regulations promulgated thereunder.

## Repeal, Transfer and Amendment of Existing Statutes

All references are to the Annotated Code of Maryland, as amended.

### Repeal

Article 14B, Secs. 1-4, 7-13.

Article 27, Sec. 485.

Article 43, Secs. 387A, 387B, 389, 393, 394A, 396A, 397.

Article 54, Secs. 45-48.

Article 66C, Secs. 6-13L, 22-30, 33, 234-255, 262-342, 696-717, 756-758.

Article 96A, Secs. 1-58, 76-88.

### Transfer

Article 14B, Secs. 4A-4-0 to Article 66-1/2.

### Amendments

Article 43

The following sections should be amended to eliminate references to sewage, sanitary facilities and sanitary districts: 387, 388, 390-392, 394, 398, 402, 404-406A.

The following sections should be amended to substitute "Chesapeake Bay Basin Department" for "State Board of Health": 387C, 395.

Article 62B

Section 5(q) should be amended to divest the Maryland Port Authority of power to regulate wharves, bulkheads, piers and piling.

## CHESAPEAKE BAY BASIN DEPARTMENT

Table of Contents

# ARTICLE 1

## CHESAPEAKE BAY BASIN DEPARTMENT

## CREATED

### Part One

### Purposes and Definitions

1.101 – Purposes

It is the intention of the General Assembly in the enactment of this act that the planning, development, management and conservation of the waters of the State, the Chesapeake Bay, and all other tidal waters and tidal resources are the proper responsibility of the State.

1.102 – Definitions

For the purpose of this act, except as may be otherwise required by the context:

(a) "Department" means the Chesapeake Bay Basin Department created by this act.

(b) "Director" means the Director of the Chesapeake Bay Basin Department.

(c) "Person" means an individual, partnership, corporation, joint stock company, firm, society, association or other unincorporated organization, receiver, trustee, and any officer, agent or employee of any of the foregoing acting in his capacity as such, but shall not include governmental agencies or their officers and employees.

(d) "Governmental Agencies" means the Government of the United States, Maryland, and all other States, their political subdivisions, and every department, agency, commission and other unit or instrumentality thereof and interstate compact commissions.

(e) "Waters of the State" means all waters, surface and underground, tidal and non-tidal within the boundaries of the State, the Atlantic Ocean bordering on the coast of the State for a distance of three (3) miles from the mean low watermark on the coast, and the flood plain of free-flowing waters determined by the Department as being subject to a fifty (50) year flood frequency.

(f) "Tidal Waters" means all waters within the boundaries of the State where the tide ebbs and flows, and the Atlantic Ocean bordering on the coast of the State for a distance of three (3) miles from the mean low watermark on such coast.

(g) "Non-Tidal Surface Waters" means all surface waters of the State which are not affected by the ebb and flow of the tides.

(h) "Tidal Region" means the entire geographical area embraced by tidal waters and submerged tidal land, and all lands located within one (1) mile of the mean high watermark on tidal waters, and all lands which are one hundred (100) feet above sea level, or less, in Somerset, Worchester, Wicomico, Dorchester, Talbot, Caroline, Kent, Queen Annes, Cecil, Harford, Baltimore, Anne Arundel, Prince Georges, Calvert, Charles, St. Mary's Counties and Baltimore City.

(i) "Resources of the Tidal Region" means all natural resources within the tidal region including but not limited to, fresh water, tidal water, open space, scenic, historic, wilderness, wetland and other natural areas, harbors, aquatic life, wildlife, sand, gravel, earth, clay, shell deposits, minerals, ore, metals, oil and gas.

(j) "Aquatic Animal Life" means all species of finfish, crabs, oysters, clams, terrapins, lobsters, zooplankton and all other animal species that live or habitually reside in water.

(k) "Aquatic Plant Life" means all species of plants that live in water.

(l) "Tidal Shore Land" means all land within the tidal region except submerged tidal land.

(m) "Submerged Tidal Land" means all land lying under the tidal waters up to the means high watermark.

(n) "Project" means any work, service or activity which is determined by the Department to be a separate entity for purposes of evaluation, except that it shall not include the taking of aquatic animal life.

(o) "Facility" means any real or personal property, structures thereon and improvements thereof, except that it shall not include vessels.

(p) "Structure" means any assembly of materials above or below the surface of land or water, including but not limited to houses, buildings, plants, bulkheads, jetties, wharves, piers, docks, landings, dams, and waterway obstructions.

(q) "Development" means the division of land into two or more parcels, the construction, reconstruction, conversion, structural alterations, relocation or enlargement of any structure, or of any excavation or landfill, the filling of submerged land, and any change in the use of any structure, or land, or extension of use of land.

(r) "Development Regulation" means all regulations which restrict the use and development of land, including but not limited to zoning restrictions, subdivisions controls, master plans and permits procedures placing restrictions on building, construction and filling.

(s) "Filling" means either the displacement of the waters of the State either by the deposition of sand, gravel, earth or other materials or the artificial alteration of the levels of such waters by structures, drainage ditches or otherwise.

(t) "Vessel" means every description of watercraft capable of being used as a means of transportation on water or on ice except that it shall not include watercraft moored in the waters of the State at a stationary location on a semi-permanent or permanent basis or sea planes.

(u) "Court" means the Circuit Court of a county or the Baltimore City Court.

## Part Two

## Organization

### 1.201 – Creation

There is hereby created a Chesapeake Bay Basin Department, which shall be part of the Department of Natural Resources.

### 1.202 – Director

(a) The Governor shall appoint, upon the recommendation of the Secretary of Natural Resources, a competent person with the qualifications prescribed herein as Director of the Chesapeake Bay Basin Department. The Director shall be the head of the Department and shall personally direct its operations and activities. The Director shall be a person with executive ability and experience, and shall have an academic degree and knowledge of the general principles involved in the administration, improvement, planning, management and conservation of the waters of the State and the resources of the tidal region. The Director shall devote his full time to the work of the Department and shall receive such salary as may be provided in the annual State Budget. The Director shall hold office under and subject to the provisions of Section 234(c) of Article 41 of the Annotated Code of Maryland, as amended.

(b) As the head of the Chesapeake Bay Basin Department, the Director shall, subject to the authority of the Secretary of Natural Resources as provided by law, be responsible for the exercise of all the powers and duties conferred upon the Department by the provisions of this act.

1.203 – Staff

The Director shall appoint the staff of the Department, subject to the authority of the Secretary of Natural Resources under Section 234(c) of Article 41 of the Annotated Code of Maryland, as amended, and subject to the provisions of the merit system. The staff of the Department shall consist of such employees as may be necessary to carry out the duties of the Department, in such numbers and at the salaries provided in the annual State Budget. Insofar as the provisions of the merit system provide for disciplinary or dismissal proceedings against employees to be brought by the appointing authority, the Director shall be the appointing authority unless the Secretary of Natural Resources by written directive provides that the Secretary shall be the appointing authority. All employees shall be under the supervision and control of the Director and shall perform such duties as he may prescribe. The Director may require any employee who receives moneys to furnish bond in such amount as the Director may determine.

1.204 – Disposition of Moneys

All moneys received under the provisions of this act from license fees, taxes, fines, penalties, forfeitures, rent, royalties and other sources shall be paid to the Comptroller of the Treasury and credited to general funds.

Part Three

General Powers, Relationship of Department to Federal

Government and Interstate Compact Commissions, Severability

1.301 – General Powers

In addition to the powers specifically delegated to the Department by this act, it shall also have the power to:

(a) supervise, regulate and control the water of the State and the resources of the tidal region;
(b) exercise the powers conferred and perform the duties imposed by all laws hereafter enacted relating to the water of the State and the resources of the tidal region;
(c) enter into contracts, and in its own name sue and be sued;
(d) collect, compile, analyze, interpret, coordinate, tabulate, summarize, and distribute technical and other data, and conduct studies, sponsor research and prepare reports on resource problems of the State;

(e) prepare, publish and disseminate information and reports in relation to the waters of the State and the resources of the tidal region and on the views, policies and recommendations of the Department in relation thereto;

(f) establish standards to guide the construction, operation and management of projects and facilities;

(g) plan, design, acquire, construct, reconstruct, complete, own, improve, extend, develop, operate, maintain, and regulate any and all projects, facilities, properties, activities and services, determined by the Department to be necessary, convenient or useful for the purposes of this act;

(h) negotiate for such loans, grants, services, or other aids as may be available from public or private sources to finance or assist in effectuating any of the purposes of this act;

(i) adopt, amend and repeal such rules and regulations as it may deem appropriate for the effectuation and enforcement of this act;

(j) institute an action or actions in its own name to compel compliance with any and all of the provisions of this act or any of the rules and regulations of the Department adopted pursuant thereto;

(k) acquire real or personal property and any interest therein as it may deem appropriate for carrying out its functions under this act, by eminent domain;

(l) hold, administer, maintain and dispose of real and personal property and any interest therein as it may deem appropriate for carrying out its functions under this act;

(m) sell or dispose of any of its products or services and make charges in connection with the use of any of its facilities;

(n) conduct such investigations and inspections as it may deem appropriate to carry out its functions under this act;

(o) undertake or contract for with any private or governmental organization, laboratory or research group, studies, surveys and experiments concerning the water resources of the State.

1.302 – Relationship of Department to Federal Government and Interstate Compact Commissions

(a) Nothing in this act shall in any way impair the powers of the United States or of any agency or department thereof, over public waters. Should any conflict arise between the powers of the United States and those of the Department under this act, the conflicting provisions of this act shall be abrogated to the extent of the conflict.

(b) For all purposes the Department shall be considered the successor to the duties and powers of the Tidewater Fisheries Commission as such duties and powers are specified in the Potomac River Compact of 1958. To the extent that the terms of this Compact limit, restrict or otherwise conflict with the powers of the Department under this act, the Compact provisions shall take precedence. After the effective date of this act, the Maryland members of the Potomac River Fisheries Commission shall be appointed by the Director.

(c) To the extent that any interstate compacts other than the Potomac River Compact of 1958 to which the State is now or may become a party concern all or part of the waters of the State, or the resources of the tidal region, the Department shall be the coordinating and enforcing agency of the State and shall perform all activities and functions which devolve upon the State under the compact. To the extent that any such compact may limit, restrict or conflict with the powers of the Department under this act, the compact provisions shall take precedence.

1.303 – Severability

If any provision of this act or the application thereof to any person or governmental agency is held invalid, such invalidity shall not affect the other provisions or any other application of the act which can be given effect without the invalid provision or application, and to this end the provisions of this act are declared to be severable.

## ARTICLE 2

## WATERS OF THE STATE

### Part One

### Water Plan

2.101 – Development, Adoption and Contents

The Department shall develop and adopt and, from time to time, review, revise and amend a plan for development, conservation, utilization and management of the waters of the State, and may adopt such plan or any revision thereof in such part or parts as it may deem appropriate. The water plan shall include, but need not be limited to, determinations of immediate and long-range needs and objectives, classifications of water uses which are to be protected and preserved, and projects and facilities, governmental or private, which the Department determines are necessary or useful for the optimum development, conservation, utilization and management of the waters of the State.

2.102 – Relationship to Other Plans

The water plan shall be complementary to the plan for the tidal region provided for by Section 3.101 of this act, and the Department, in developing, reviewing, revising and amending the water plan shall give consideration to relevant portions of Federal, State, regional and local plans.

### Part Two

### Water Quality Control

2.201 – Water Quality Standards

(a) In implementing the water plan the Department, by regulation, shall adopt, and may from time to time change, the following: water quality standards for the waters of the State; standards of water quality for particular waters of the State; criteria of water quality for each classification of water use established by the comprehensive water plan; standards and methods of preserving, regulating, controlling and improving water quality; definitions of pollution and identification of pollutants.

(b) Standards of water quality and criteria of water quality may relate, but need not be limited to bacterial, viral, chemical, radioactive, organic, thermal, gaseous, liquid, solid or soil additions to the waters of the State from any source, or to enrichment of the waters of the State from any source.

(c) No person or governmental agency shall discharge any effluents into the waters of the State which interfere with maintenance of the standards and criteria of water quality adopted by the Department. The Department may, by regulation, require that any person or governmental agency discharging effluent into the waters of the State shall monitor the quality of such effluent and make reports to the Department, or that the Department shall monitor the quality of such effluent itself and charge such person or governmental agency the expense thereof.

2.202 – Other Water Quality Controls

(a) The Department may require that any person or governmental agency secure a permit, as the Department may prescribe by regulation, before discharging effluent into the waters of the State. In the issuance of such permits the Department may impose such limitations on the duration, location, nature and quality of the effluent as it may find necessary for the effective maintenance of the water quality standards it has promulgated.

(b) The Department may, by regulation, require that persons or governmental agencies discharging effluent into the waters of the State pay a charge to the Department. If the Department imposes such charges, it shall prescribe, by regulation, reasonable standards for the determination of the amount.

(c) The Department may, by regulation, require vessels registered in the State to carry waste collection and disposal equipment of a type suited to reduce the deposition in the waters of the State of human and other sewage and waste.

(d) The Department may adopt any other regulations necessary for the implementation and enforcement of the water plan and the water quality standards for the waters of the State.

2.203 – Existing Discharges

The fact that any person or governmental agency has, prior to the effective date of this act, been discharging effluent at a given location, in a given quantity or of a given quality shall in no way be considered to exempt such person or governmental agency from any procedures the Department may adopt pursuant to this act to regulate and control effluent discharges and water quality.

2.204 – Defense in Private Suit

In any suit brought by any person or governmental agency against any other person or governmental agency for reducing the quality of water or for rendering it harmful or noxious or for in any way affecting the usefulness of the water, proof that the defendant is acting within all the applicable regulations and procedures of the Department shall be a complete defense to the action.

2.205 – Transition

All water quality standards, regulations, controls and effluent permits in effect on the effective date of this act shall continue in full force and effect until changed, amended or modified by the Department pursuant to the provisions of this act.

## Part Three

## Use of Waters

### 2.301 – General Powers

In implementing the water plan the Department may adopt regulations it deems necessary for the optimum development, conservation and utilization of the waters of the State.

### 2.302 – Uses by Persons

(a) No person may use, divert, or appropriate, consumptively or non-consumptively, any of the waters of the State without first securing a permit from the Department pursuant to such regulations as the Department shall prescribe, except that the Department may, by regulation, exempt from the requirements of this Section such uses, diversions or appropriations as it may reasonably find to have a minimal effect on the waters of the State. The Department shall only issue a permit if it determines that the contemplated use, diversion or appropriation is in the public interest as a practicable and efficient utilization of the waters of the State and will not adversely affect either the water plan or such part or parts thereof which have been adopted. Any person issued a permit which entails the use, diversion or appropriation of tidal waters shall comply with the procedure in Section 3.203 of this act before starting such use, diversion or appropriation.

(b) Permits issued under this Section shall specify the character, location and duration of the use, diversion or appropriation, the methods to be applied in its execution and such other conditions, restrictions or qualifications as the Department deems necessary to insure conformity with the water plan.

(c) Permits issued pursuant to this Section shall not create any vested rights and may not be sold, assigned or transferred, and do not become appurtenant to land. The Department shall periodically review such permits at least once every five (5) years and may revise, amend or revoke them in effectuating the comprehensive water plan and the comprehensive plan for the tidal region.

(d) Any person having a vested right to use, divert or appropriate any water of the State by virtue of prior statute or of common law who is refused a permit to exercise such right or granted a permit with conditions, restrictions or qualifications which derogate such right, may petition a court as provided in Section 5.201 of this act to determine whether the action of the Department is an unreasonable exercise of the police power and therefore constitutes a taking of property without compensation. If the court finds the action of the Department to be a taking of property without compensation the court shall order the Department to issue an appropriate permit but the order shall not affect the rights of any other person.

### 2.303 – Uses of Governmental Agencies

No governmental agency may use, divert or appropriate, consumptively or non-consumptively, any of the waters of the State without first securing the approval of the Department. The Department shall, by regulation, prescribe the procedure to be followed in securing such approval.

2.304 – Transition

All rules, regulations and permits relating to the use, diversion or appropriation of waters of the State in effect on the effective date of this act shall remain in effect until changed, amended or modified by the Department pursuant to the provisions of this act.

## Part Four

## Boating

2.401 – General Powers

In implementation of the water plan and the plan for the tidal region, and to protect public safety and welfare the Department may, by regulation, prescribe the type, size and description of all vessels which may be operated on the waters of the State, the place where they may be operated and the manner of operation.

2.402 – Safety

The Department may, by regulation, impose restrictions on the operation of vessels that it deems appropriate to protect public safety, including but not limited to, requirements that vessels carry safety equipment, speed limits and restrictions on water skiing and aquaplaning.

2.403 – Enforcement

The Department is charged with the primary duty of enforcing the provisions of this act relating to the use of vessels and the regulations promulgated thereunder, and officers, agents or employees of the Department are authorized to stop and inspect vessels in the exercise of this duty.

2.404 – Transfer of Powers

All powers and duties relating to the numbering, identification, certificates of title, sale, assignment or transfer, fees and excise taxes, liens, licensing of manufacturers or dealers of, for, or on vessels and the reporting of boating accidents, found in Article 14B, Sections 1-10 of the Annotated Code of Maryland, as amended, on the effective date of this act are herewith transferred to the Department of Motor Vehicles.

2.405 – Transition

All rules and regulations governing the operation and use of vessels in the waters of the State in effect on the effective date of this act and all laws relating to the operation and use of vessels in the waters of the State which are repealed by this act, shall remain in effect as regulations of the Department until changed, amended or modified by the Department pursuant to the provisions of this act.

# ARTICLE 3

# THE TIDAL REGION

## Part One

## Plan for the Tidal Region

### 3.101 – Development and Adoption

The Department shall develop and adopt and, from time to time, review, revise and amend a plan for the development, conservation, utilization and management of the resources of the tidal region, and may adopt such plan or any revision thereof in such part or parts as it may deem appropriate. The plan for the tidal region shall generally comprise a report or statement of development and conservation proposals with maps, diagrams and text, and shall include, but need not be limited to:

(a) a determination of immediate and long-range needs and objectives;

(b) a land use plan element, showing the existing location, extent and intensity of uses of tidal shore land and submerged tidal land, and providing standards for the development of such lands for residential, commercial, industrial, agricultural, recreational, maritime and fishing purposes, so as to encourage multiple compatible uses of such land, to effect a reconciliation of alternative and conflicting uses of such lands and to enhance public access to tidal waters;

(c) a circulation plan element showing the location and types of facilities for all modes of transportation by land, water and air required for the efficient movement of people and goods into, about and through the tidal region, including terminals, facilities and rights of way;

(d) a utility service plan element analyzing the need for and showing the future location of facilities for water supply and distribution, drainage, sewage and waste treatment and solid waste disposal and provision for other related utilities;

(e) a recreation plan element showing a comprehensive system of areas and public sites for recreation, including the following, with their locations and proposed development: natural reservations, parks, parkways, bicycle paths, trails, beaches, vista points and other recreational facilities;

(f) a conservation plan element for the conservation, development and utilization of natural resources, including open space, fresh water, tidal waters, forests, soils, marshes, wetlands, harbors, shore land, submerged land, aquatic life, wildlife, sand, gravel, earth, clay, shell deposits, minerals, ore, metals, oil, gas and other resources of the tidal region;

(g) an economic development plan element providing for the development and maintenance of full employment opportunity.

### 3.102 – Relationship to Other Plans

The plan for the tidal region shall be complementary to the water plan provided for by Section 2.101 of this act, and the Department, in developing, reviewing, revising and amending the plan for the tidal region shall give consideration to relevant portions of Federal, State, regional and local plans.

## Part Two

## Rights in Tidal Waters and Submerged Tidal Lands

### 3.201 – Ownership of Tidal Waters and Submerged Tidal Lands

The State of Maryland owns all tidal waters and all submerged tidal land except to the extent that such submerged tidal lands have been transferred by the State by a valid and extant grant, lease or patent, or by a valid and extant grant confirmed by Article 5 of the Declaration of Rights of the Constitution of Maryland.

### 3.202 – Riparian Rights in Tidal Waters and Submerged Tidal Lands

Except to the extent given other rights by statute, persons owning land bounding on tidal waters shall, by virtue of such ownership, only have the following rights in tidal waters and submerged tidal lands:

(a) the right of access to tidal waters;
(b) the right to land formed by natural accretion in front of such land;
(c) the right to build in front of such land for non-commercial use, landings, wharves, docks or shore erosion control structures, any of which upon completion becomes their property. The exercise of these rights is subject to the regulatory procedure in Sections 4.201 and 4.302 of this act and to all other regulatory powers given by law to any governmental agency.

### 3.203 – Transfer of the State's Interest

Any person issued a permit to use, divert or appropriate tidal waters under Section 2.302, or to engage in a project under Section 4.302 shall, before starting on such use, diversion, appropriation or project, present the permit to the Director, who shall be the trustee of tidal waters and submerged tidal lands owned by the State. The Director shall review the use, diversion, appropriation or project authorized by the permit and shall determine the extent to which it requires the use or taking of tidal waters, submerged tidal land or other resources owned by the State. The Director shall determine the consideration, if any, which the person shall be required to transfer to the State in return for such use or taking, the nature and terms of payment and the statements which the person shall be required to furnish the Department, provided that the Director shall not require any person owning land bounding on tidal waters to transfer any consideration in payment for the exercise of rights given such person under Section 3.202. The Director shall set forth his determinations in an order which shall be published once a week for two successive weeks in a newspaper having general circulation in the area of the use, appropriation, diversion or project and the order shall not become final unless it remains unrevoked ten (10) days after final publication. After the order becomes final the Director shall be empowered to transfer in the name of the State any interest in real or personal property necessary for the use, appropriation, diversion or project to be pursued. Any person who fails to comply with the terms of the order shall forfeit the permit and all interests in real or personal property transferred to him by the Director.

## Part Three

## Tidal Shore Lands Controls

### 3.301 – Designation of Areas of Restricted Development

The Department may, pursuant to such procedures as it shall prescribe, by regulation, designate all or any portion of the shore lands of the tidal region as areas of restricted development upon a finding that additional controls on land development are necessary within such area or areas to implement the plan for the tidal region. The Department may, from time to time, revise or abolish such designations. Any shore lands designated as an area of restricted development may not be used for any purpose other than that for which they were actually and lawfully being used when they were so designated, except as authorized by the provision of Section 3.302 or Section 3.303.

### 3.302 – Jurisdiction of Other Governmental Agencies

Any other governmental agency having land use control jurisdiction over a portion of shore lands designated as an area of restricted development may submit to the Department development regulations governing such portion of shore lands. If the Department finds that such development regulations meet or exceed the minimum requirements of the plan for the tidal region it shall approve them, but the Department shall not approve any such development regulations unless they provide that, insofar as the Department may prescribe, any changes in, or special exceptions or variances thereafter made or authorized relating to the use to which any land may be put, shall not become effective until accepted by the Department. If the Department has approved the development regulations of another governmental agency, such governmental agency shall enforce them and the development of land in such area of restricted development may be authorized as provided therein. Approval may be revoked if the Department finds that development regulations are not being adequately enforced or no longer meet the minimum requirements of the plan for the tidal region due to a revision of such plan.

### 3.303 – Jurisdiction of the Department

The Department shall, by regulation, prescribe development regulations for any area designated as an area of limited development if the Department has not approved the development regulations of any other governmental agency or if such approval has been revoked. Such development regulations shall implement the plan for the tidal region, and the development of land in such areas of restricted development may be authorized as provided therein. The Department shall have discretion, by regulation, to, from time to time, revise or abolish such development restriction in whole or part.

## Part Four

## Aquatic Life

### 3.401 – General Powers

(a) The Department may, by regulation, prescribe the type, size and description of all aquatic animal life which may be taken from tidal waters or submerged land, the places where they may be taken and the manner of taking.

(b) The Department is empowered to inspect all aquatic animal life taken from tidal waters or submerged tidal land and all aquatic animal life sold within the State, pursuant to such regulations as it may prescribe. The Department may, by regulation, prescribe the type, size and description of aquatic animal life which may be sold within the State or exported without the State.

(c) The Department may, by regulation, prohibit the importation of any aquatic animal life from sources outside of the State when there is a reasonable suspicion that such aquatic animal life might be harmful to the aquatic animal life of the tidal waters.

### 3.402 – Licenses

(a) The Department shall issue such licenses as it may prescribe, by regulation, which shall thereupon be required for the taking, buying, selling, marketing, packing, or canning of aquatic animal life from tidal waters or submerged land, and for boats, vessels and equipment used for such taking, buying, selling, marketing, packing or canning.

(b) The Department shall, by regulation, prescribe the qualifications necessary for obtaining such licenses, the privileges granted by such licenses, the fees for such licenses and the manner and extent to which such licenses may be transferred.

### 3.403 – Oyster and Shellfish Leases

(a) The Department is empowered, in the name of State, to lease to any person parcels of submerged tidal land to be used for protecting, sowing, bedding or cultivating oyster or other shellfish. The Department shall, by regulation, prescribe the procedures and qualifications necessary for obtaining such leases, the portions of submerged land available for such leases and the extent to which such leases can be transferred or assigned.

(b) The Department shall only grant the lease if it deems the lease to be in the best interests of the State, provided that no lease shall be granted which is incompatible with the water plan or the plan for the tidal region, and that no lease shall be granted which infringes upon the the rights of any other person under Sections 3.202 or 4.302 of this act, or under this Section, unless such person gives his written consent.

(c) The Department shall set forth in all leases granted under this Section the duration, location, size of parcel, consideration, terms of payment and the statements the lessee is required to make. Any person who fails to comply with these terms of the lease shall forfeit his rights under the lease.

### 3.404 – Transition

All laws relating to the taking, buying, selling, packing or canning of aquatic animal life from tidal waters or submerged tidal land and all laws relating to the importation or exportation of aquatic animal life to and from the State which are repealed by this act shall remain in effect as regulations of the Department until changed, amended or modified by the Department pursuant to this act; except that all taxes on the taking, buying, selling, marketing, packing or canning of aquatic animal life from tidal waters or submerged land, and all taxes on the importation or exportation of aquatic animal life to or from the State, in effect when this act is enacted shall continue in force and effect until changed, amended, modified or repealed by the General Assembly. The Department, within two years after the effective date of this act, shall present to the General Assembly a proposed revision of such taxes for its consideration.

# ARTICLE 4

## PROJECT AND FACILITIES

### Part One

### General Powers

4.101 – Programs

The Department shall, from time to time, formulate and adopt programs based upon the water plan and the plan for the tidal region, determining the quality and quantity of water needs of the State and the needs for conservation, enhancement and development of the resources of the tidal region, and proposing projects and facilities to be undertaken by persons, other governmental agencies and the Department in satisfaction of such needs.

4.102 – Assistance

The Department shall provide administrative and technical assistance to persons and governmental agencies in the development of coordinated programs for the implementation of the water plan and the plan for the tidal region and for the planning and design of projects and facilities in conformity with the water plan and the plan for the tidal region.

4.103 – Recommendations

The Department may recommend to persons or governmental agencies that they acquire, construct, operate or maintain projects and facilities as the Department may deem appropriate for the implementation of the water plan or the plan for the tidal region.

### Part Two

### Regulation of Projects and Facilities

4.201 – Regulations

(a) The Department shall, by regulation, establish standards for the construction, operation and maintenance of projects and facilities which the Department deems necessary to implement the water plan and the plan for the tidal region, in or upon non-tidal surface waters, the flood plain of freeflowing waters determined by the Department as being subject to a fifty (50) year flood frequency, tidal waters or submerged tidal lands, or which are used to appropriate underground water, to assure the optimum development, conservation and utilization of the waters of the State and the resources of the tidal region and to protect the public health, safety and welfare.

(b) No person or governmental agency shall construct, operate or maintain any such project or facility in violation of these standards.

4.202 – Enforcement

The Department may, at reasonable times, inspect any projects and facilities within the purview of Section 4.201 to determine whether such projects and facilities are being constructed, operated and maintained in compliance with the regulations promulgated thereunder. If the Department finds that such regulations are not being complied with it may issue an order requiring the person or governmental agency to cease construction or operation, to change his mode of construction, operation or maintenance or to make necessary repairs or alterations, so as to comply with such regulations. If such person or governmental agency fails to comply with an order to make repairs or alterations, the Department may make such repairs and alterations and charge such person or governmental agency the expense thereof.

## Part Three

## Approval of Projects

4.301 – Projects on Non-Tidal Waters by Persons

No person shall undertake any project in or upon non-tidal surface waters or the flood plain of free-flowing waters determined by the Department as being subject to a fifty (50) year flood frequency or which will be used to appropriate underground water without first having secured the approval of the Department pursuant to such regulations as the Department may prescribe except that the Department may, by regulation, exempt from the requirements of this Section such projects as it may reasonably find to have a minimal effect upon the waters of the State. Projects within the purview of this Section shall include, but not be limited to, the following:

(a) building, maintaining or modifying of any structure in or upon non-tidal surface waters or the fifty (50) year flood plain;
(b) constructing, maintaining or modifying any reservoir or pond;
(c) changing or diminishing the course or current of any non-tidal surface waters;
(d) changing the configuration of the fifty (50) year flood plain;
(e) drilling or digging of wells, test holes or other borings.

The Department shall only approve such project if it determines that it will not adversely affect the water plan or such part or parts thereof which have been adopted and will not interfere with maintenance of the standards and criteria of water quality established by the Department.

4.302 – Projects on Tidal Waters by Persons

(a) No person shall undertake any project in or upon tidal waters or submerged tidal lands without first securing a permit from the Department pursuant to such regulations as the Department shall prescribe, except that the Department may, by regulation, exempt from the requirements of this Section such projects as it may reasonably find to have a minimal effect on the tidal region. Projects within the purview of this Section shall include, but not be limited to, the following:

(1) the building, maintaining or modifying of any structure on tidal waters or submerged tidal lands;

(2) the mooring of floating structures in tidal waters at a stationary location on a semi-permanent or permanent basis;

(3) the filling of submerged tidal lands or the disposal of dredged materials in tidal waters;

(4) the dredging, taking or extracting of any sand, gravel, earth, clay, shell deposits, minerals, ore, metals, oil or gas or other materials from tidal waters or submerged tidal lands, except that it shall not include the taking of aquatic animal life.

Before issuing a permit the Department shall consider the potential effects of the project on the waters of the State and the resources of the tidal region and, giving due regard to the need for encouraging multiple compatible use of the waters of the State and the resources of the tidal region and for effecting a reconciliation between alternative and conflicting use, shall only issue a permit if it deems the project in the public interest, provided that no permit shall be issued for any project which adversely affects either the water plan or the plan for the tidal region, or such part or parts thereof as have been adopted, and that no permit shall be issued for any project which will derogate the rights of any person under Sections 3.202 or 3.403 of this act or under this Section, unless such persons give their written consent. Any person issued a permit under this Section which entails the use or taking of tidal waters, submerged lands or other resources owned by the State shall comply with the procedure in Section 3.203 of this act before starting such project.

(b) Permits issued under this Section shall specify the character, location and duration of the project, the method to be employed in its execution and such other conditions, restrictions or qualifications as the Department deems in the best interest of the State.

(c) Any person having a vested right in tidal waters or submerged tidal land by virtue of a valid and extant grant, lease or patent or by prior statute or common law, who is refused a permit to exercise such rights, or is granted a permit with conditions, restrictions or qualifications which derogate such right, may petition a court as provided in Section 5.201 of this act to determine whether the action of the Department is an unreasonable exercise of the police power and therefore constitutes a taking of property without compensation. If the court finds the action of the Department to be a taking of property without compensation the court shall order the Department to issue an appropriate permit but the order shall not affect the right of any other person or governmental agency.

4.303 – <u>Projects by Governmental Agencies</u>

No governmental agency shall engage in any projects which affect the waters of the State or the resources of the tidal region without first securing the approval of the Department. The Department shall, by regulation, prescribe the procedure to be followed in securing such approval.

Part Four

Acquisition, Operation, Management and Financing of Projects

and Facilities by the Department

4.401 – <u>General Powers</u>

(a) The Department, alone or in cooperation with one or more persons or governmental agencies, may acquire, construct, operate, maintain and administer such projects and facilities as it deems appropriate for the implementation of the water plan and the plan for the tidal region.

(b) Facilities within the purview of this Section include, but are not limited to the following:

(1) sewage or waste collection systems, treatment plants and related facilities;

(2) systems for the collection, storage, appropriation, transmission, sale or exchange of waters;

(3) marine terminals and other improvements to waterways for navigational purposes;

(4) parks, recreation, scenic and historic areas including open space, development rights and easements;

(5) natural areas including wetlands, marsh and other areas suitable for the propogation of fish and wildlife;

(6) shore erosion control devices.

(c) Projects within the purview of this Section include, but are not limited to, all activities incident to the construction, operation and maintenance of such facilities and the clearing of debris,aquatic plant life and obstructions from waters of the State, the dredging and marking of channels, and the repletion of fishery resources.

(d) In operation, maintenance and administration of such projects and facilities the Department may act through public or private lessees or concessionaires.

4.402 – Acquisition

(a) The Department may acquire such facilities by purchase, gift, grant, devise, bequest, lease, condemnation, exchange or otherwise.

(b) The Department may, in the acquisition of such facilities by condemnation, take property already devoted to a public use.

(c) The acquisition of interests or rights in real property for the preservation of open spaces and areas constitutes a public purpose for which public funds may be expended.

4.403 – Financing

(a) The Department may contribute all or a portion of the costs of acquisition, construction, operation, maintenance or administration of any project or facility by the Department or by some other governmental agency.

(b) The Department may contribute all or a portion of the costs of acquisition, construction, operation, maintenance and administration of any project or facility by the Department in cooperation with one or more persons, or by one or more persons, provided that the Department finds that the benefits to the State from such contribution equal or are greater than the amount of the contribution.

(c) Department contributions may be used to match Federal funds that may be or become available.

# ARTICLE 5

## GENERAL PROVISIONS

### Part One

### Administrative Procedures

5.101 – Rules and Regulations

(a) The Department shall adopt, amend and repeal, and prescribe the effective dates for rules of procedures for all activities it is authorized to undertake, and for regulations it may deem necessary or desirable for the implementation and enforcement of this act, or to carry out its responsibility under this act.

(b) The Department shall prepare and provide for the editing, publishing, compiling and indexing of all such rules and regulations.

(c) Any person or governmental agency may petition the Department requesting the promulgation, amendment or repeal of any rule or regulation. The Department shall prescribe by rule the form for such petitions and the procedure for their submission, consideration and disposition.

5.102 – Notice and Hearing Required

In addition to when required by other provisions of this act, notice shall be given and a hearing held whenever the Department makes or takes the following decisions or actions: (a) the adoption, amendment or repeal of rules and regulations except those relating solely to the internal management of the Department; (b) the adoption, revision, amendment or repeal of the water plan or the plan for the tidal region, or part or parts thereof; (c) the issuance, revision or revocation of permits; (d) the approval or refusal to approve of projects; (e) the designation of all or any portions of the shore lands of the tidal region as areas of restricted development and revisions or abolition of such designations; (f) the approval or disapproval of development regulations submitted by other governmental agencies and any revocation of such approval; and (g) the leasing of parcels of submerged tidal lands to be used for protecting, sowing, bedding or cultivating of oyster or other shellfish.

5.103 – Notice

(a) Unless otherwise specified in this act whenever notice is required it shall be given by publication once a week for two successive weeks in a newspaper having general circulation in the area, or portion or portions of the State to be affected by the proposed action of the Department. If the purpose of such notice is to give notice of a proposed public hearing, the notice shall identify the subject or subjects to be considered and specify the time, not less than ten (10) days after final publication, and place of hearing at which interested persons or governmental agencies may appear and present their views. In addition to newspaper publication, notice of the proposed action of the Department, or of the public hearing, shall be posted in a conspicuous place at the offices of the Department.

(b) The Department may mail a copy of the notice to each person and governmental agency which the Department believes may be affected by the proposed action of the Department or by the action it may take after such public hearing, and may also mail a copy of the notice to any other person or governmental agency who shall request such notice. The Department may provide for other means of giving notice to the end that all persons and governmental agencies having an interest in the subject may reasonably be apprised thereof. Any failure of the Department to give notice as provided in this paragraph (b) shall not affect the validity of any action taken by the Department.

(c) The notice need not contain the entire text, plan, or detail of the proposed action of the Department or of the subject matter of the hearing, but shall reasonably identify the same and state the place at which the same may be examined. Whenever copies of such text, plans, or details may be provided by the Department, the notice shall so state and shall give the post office address to which requests for such data may be sent and the price, if any, charged by the Department therefor.

5.104 – Hearings

(a) The Department shall, after notice and at such place or places as it may determine, conduct at least one public hearing, whenever a hearing is required by this act. Any person or governmental agency claiming to have an interest in the subject matter of the proposed action by the Department shall be entitled to submit data or views at such public hearing.

(b) The Department in the conduct of hearings may admit and give probative force to evidence which possesses probative value commonly accepted by reasonably prudent men in the conduct of their affairs and may take notice of judicially cognizable facts and other general, technical, or scientific facts within its specialized knowledge.

(c) The Department shall adopt rules and regulations governing hearings, including rules of practice and procedure and may prescribe the form and content of pleadings and other documents that may be filed with the Department.

(d) Department hearings may be conducted by the Director or such person or persons as the Director may direct. The Director or any person authorized by the Director may administer oaths and affirmations, examine witnesses and receive evidence at a hearing. Any willful false swearing or affirming at a hearing as to any material fact shall be deemed perjury under the law of the State.

(e) Any final order, decision or action taken after hearing shall be in writing or stated in the record and shall be accompanied by findings of fact and conclusions of law.

5.105 – Subpoenas

The Director or any persons authorized by the Director may issue subpoenas in the name of the Department to compel witnesses to appear and testify or to produce books, records, papers, documents or other tangible forms of evidence relating to any matter within the authority of the Department.

5.106 – No Review by Board of Review

The Board of Review of the Department of Natural Resources shall have no power to review any order, decision or action taken by the Department.

## Part Two

## Judicial Review

5.201 – Review

(a) Upon the petition of any person or governmental agency aggrieved, any final order, decision or action of the Department made or taken after hearing or with respect to which a hearing is required, and any other order, decision or action which this act provides shall be subject to judicial review, may be reviewed by any court of competent jurisdiction. The petition for review shall be filed within thirty (30) days after the date of such order, decision or action of the Department. Upon the filing of the petition the Clerk of Court shall forthwith, by mail, serve a copy thereof upon the Department which shall thereupon file in the court a certified list of the materials comprising the record of the proceedings and hold for the court all such materials and transmit the original or certified copies of the same or any part thereof to the court, when and as required by it, at any time prior to the final determination of the review.

(b) The filing of a petition for review shall not operate as a stay of the operation of such order or decision unless so ordered by the Department or by the court for good cause shown. For good cause shown, and upon such conditions as may be required and to the extent necessary to prevent irreparable injury, the court may take appropriate and necessary action to preserve the status quo or rights of any of the parties, or others, pending conclusion of the review proceedings.

(c) The court without a jury shall hear and decide the review on the record of proceedings before the Department, and may affirm the decision of the Department or remand the case for further proceedings; or it may reverse or modify the decision if the findings, conclusions or decision, are (1) in violation of constitutional or statutory provisions, or (2) in excess of the authority of the Commission, or (3) made upon unlawful procedure, or (4) affected by other error of law, or (5) unsupported by substantial evidence on the record considered as a whole, or (6) arbitrary, capricious, or an abuse of discretion. The court may appoint a special master to take evidence and make recommendations to the court with respect to any question raised in a petition for review if the court is of the opinion that the question can not be adequately determined from the record of the proceedings before the Department and that the interest of justice so requires.

5.202 – Appeal

Any petitioner may secure a review of any final judgment of the court by appeal to the Court of Appeals. Such appeal shall be taken in the manner provided by law for appeals from law courts in other civil cases.

## Part Three

## Enforcement by the Department

5.301 – Injunction

The Department may enforce or require compliance with any provision of this act or any rule, regulation, decision or order of the Department made pursuant thereto, or restrain any violation of any such provisions, rule, regulation, decision or order, by injunction or any other appropriate action brought in the name of the Department in a court.

5.302 – Penal Sanctions

(a) Any person violating any provision of this act or regulation of the Department, other than one of a procedural nature or relating solely to the internal management of the Department, shall be guilty of a misdemeanor and, upon conviction, shall be punished by a fine not exceeding five hundred dollars ($500.00) for each offense. Each day during which a violation occurs shall be deemed a separate and additional violation. The employees of the Department assigned to law enforcement duties and all other law enforcement officers are authorized and directed to enforce the provisions of this act and the regulations of the Department, and to make arrests for violation thereof.

(b) Notwithstanding any criminal liability, any person violating any provision of this act or any regulation of the Department shall be civilly liable to the Department for any actual damage sustained by the Department by reason of such violation.

(c) The penal sanctions herein provided shall not be applicable to any failure or refusal to pay any charge imposed by the Department.

* * *

# PART VI. DEVELOPMENT OF DATA ON THE ESTUARINE ZONE

## INTRODUCTION

As required by sec. 5(g) of the Clean Water Restoration Act of 1966, the National Estuarine Pollution Study, acting on behalf of the Secretary of the Interior—

> * * * shall assemble, coordinate, and organize all existing pertinent information on the Nation's estuaries and estuarine zones; carry out a program of investigations and surveys to supplement existing information in representative estuaries and estuarine zones; and identify the problems and areas where further reserach and study are required * * *

To fulfill both the spirit and the letter of the act, the National Estuarine Pollution Study acquired and consolidated all available existing information in the form of the National Estuarine Inventory, an automated framework for organizing the tremendously large mass of data assembled. The study conducted investigations and inquiries both to acquire and to develop this available information. As a corollary, the data assembly was also useful in defining areas where data and information are not available and are needed. The data gaps, in turn, were used in conjunction with state-of-the-art studies designed to identify necessary research and study.

Consequently, these two phases of the study—assembly of data and definition of research and study needs—being so closely related, are presented together in this part of the report. The first chapter discusses the National Estuarine Inventory, its development, and its past and future applications. Chapter 2 points out the major data gaps as shown by the inventory and sets out a program for a needed data acquisition, analysis, and interpretation.

In chapter 3 the results of the research and study needs investigations are outlined in some detail.

Two basic programs are outlined in chapters 2 and 3. The first is to satisfy the need for basic data; that is, numbers and information which can be analyzed and interpreted to give information. The second program is designed to search for basic knowledge; that is, the understanding necessary to clearly and unmistakably use the basic data.

The tying together of what-is-known to show what-is-not-known, is a common denominator in these two programs. Of necessity, some overlap appears, pointing up the fact that the search for knowledge results in data, and the search for data results in knowledge.



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# CHAPTER 1. THE NATIONAL ESTUARINE INVENTORY

**"In conducting the * * * study, the Secretary shall assemble, cooridnate, and organize all existing pertinent information on the Nation's estuaries and estuarine zones . . ."**

**Clean Water Restoration Act of 1966**
**Section 5 (g) (2)**

The National Estuarine Inventory is the primary repository of the quantitative documentation used in the National Estuarine Pollution Study to describe the Nation's estuarine system, its uses and problems. While the directive calling for this study did not explicitly require an inventory, the breath of information required implicitly demanded inventory techniques, including automation.

The inventory differs from a basic data storage-and-retrieval system in three respects: First, the intent is to supply information for institutional and technical management rather than for scientific analyses, thus introducing a very wide variety of information and also preventing duplication of existing federally financed data systems. Second, to increase its value to the estuarine manager, much material has been entered as statistical summaries rather than in raw data form; and, third, information which does not readily lend itself to automation techniques has been "assembled, coordinated, and organized" by other methods.

This discussion describes in some detail the selection of the descriptors used; the sources of information; how the information was collected, organized, and automated (fig. VI–1–1); the present status of the data bank; and the need for, and value of, a management information system based on this system.

## Section 1. The Handbook of Descriptors

The framework around which the inventory is built is the "Handbook of Descriptors" (VI–1–1), an outline showing the information necessary to describe the Nation's coastal areas.

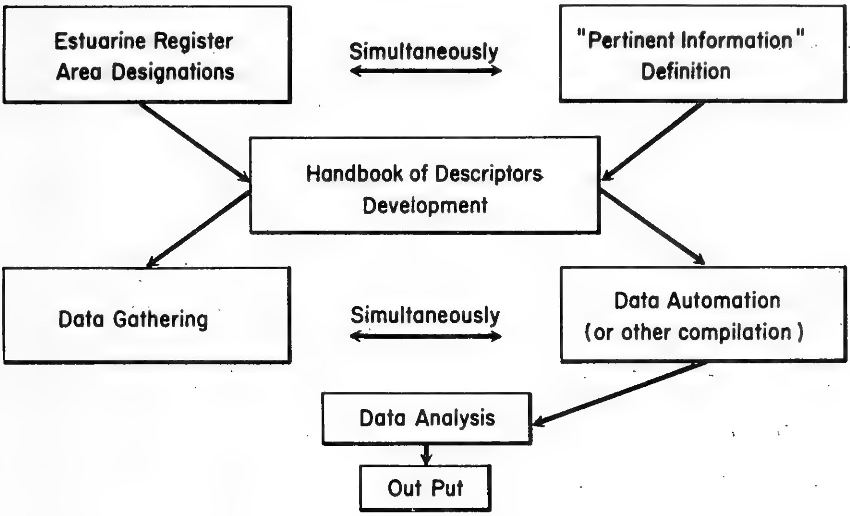
The original list of descriptors, developed within the Federal Water Pollution Control Administration (FWPCA), was reviewed in detail by other agencies of the Department of the Interior and a number of State water pollution control and natural resource agencies. Critical review by this diverse group helped to build a more comprehensive data base than otherwise would have resulted.

### COMPOSITION OF THE HANDBOOK

The "Handbook" is comprised of the outlines for the two basic types of management information needed to work with any estuarine system. It contains sets of blank forms and instructions for their completion with specific data. First, there must be institutional management information consisting of those kinds of information which would be required by a responsible management entity to determine:

Figure VI.I.I

DEVELOPMENT OF THE NATIONAL ESTUARINE INVENTORY




the most nearly optimum use balance; the kind of organization which could achieve and maintain the balance most effectively; whether such an organization exists; and the existing institutional framework within which it must work. Such information would include the political makeup, that is, the States, counties, municipalities, and special districts involved; groups with management responsibilities in the system; existing zoning restrictions; water quality standards; economic makeup of the area; present and historical uses; sources of pollution; and damages to use from pollution and other causes.

Second, there must be technical management information which includes those aspects of management which determine best use of an estuarine system from a scientific and technical standpoint. For example, it would be useless to manage an estuary for oyster production if the habitat in its natural state were not suitable for oysters. To resolve questions of best estuarine use, necessary information would include the following: size and shape; existing water quality; amount of water quality degradation; sources and types of wastes; climate, hydrology, circulation, ecology, present and potential habitat value; physical modification, bathymetry, and bottom conditions. The list of required management information, both institutional and technical, is organized into 14 "Handbook of Descriptors" sections. A brief description of each of these sections and the types of information they are designed to contain follows:

Section 1 identifies each estuarine subdivision according to its type, location in the United States, including States, counties, congressional districts, and the systems to which it is tributary.

Section 2 describes the physical structure of each estuarine subdivision; including its size, shape, total water area, area of marshland, climate, and any artificial circulation-modifying structures in the system.

Section 3 gives those areas which are owned by various political subdivisions, or which are zoned and under the control of special districts or management compacts; areas of parks and other recreation areas; and a list of the management compacts with particular interest in the estuarine zone.

Section 4 describes the hydrology of the estuarine system, including data on river flow and identification of major flow regulation structures.

Section 5 includes economic statistics on population, extent of urbanization, industrialization, commercial buildup, employment, etc.

Section 6 describes the oceanography of the area, including tidal regime, current patterns, and tidal prism.

Section 7 includes water quality information, listing extremes and variations and pertinent typical values in many water quality parameters.

Section 8 includes information on sedimentation and bottom characteristics of the area.

Section 9 describes the uses to which the area is put.

Section 10 describes sources of wastes, both municipal and industrial. It also includes a summary of the total amounts of waste and an individual listing of major waste discharges.

Section 11 includes statistics on use damages, both in terms of quantity of use lost and amount of monetary damage.

Section 12 included a list of immediate pollution abatement needs. FWPCA is now in process of developing a system of records maintenance on these needs and progress in meeting them so this section has been deleted from the inventory until a later date.

Section 13 includes the water quality standards as presently approved for each State, and the acreages reserved for various beneficial uses as required by the standards.

Section 14 presents a list of past and current studies in the system identified by date, type of study, and the person or organization responsible.

Each of these major sections contain many individual parameters which were selected to att mpt a full description of pertinent characteristics.

### SELECTION OF DESCRIPTORS

Four criteria governed the selection of descriptors:

*Availability*

Although selected primarily on the basis of importance to management, where possible parameters reported on a national basis by a Federal agency were selected. Elsewhere, data in standard professional usage in the respective fields were used. Provision has been made to include additional types of data as the state-of-the-art advances.

*Meaning*

Each descriptor is a valid measure of some system characteristic needed for either technical or institutional estuarine management purposes.

*Compatibility*

Each descriptor is either directly informative or can be compared or combined with other descriptors to be meaningful. For example, except in extreme cases, tide range along is not a useful management statistic; but in combination with the area of the estuary, it can help in determining flushing characteristics and overall ability of the system to rid itself of pollutants.

*Uniqueness*

Each descriptor is a fundamental datum; that is, it cannot be derived from other information included in the inventory.

For two reasons, 1950 has been set as an arbitrary cutoff date for most historical data. First, water quality and waste discharge information, and many kinds of economic data extremely pertinent to the needs of this study, were rarely collected before that date. Second, ecological and biological changes caused by estuarine alteration before that date would scarcely be discernible now, nor could their causes be traced.

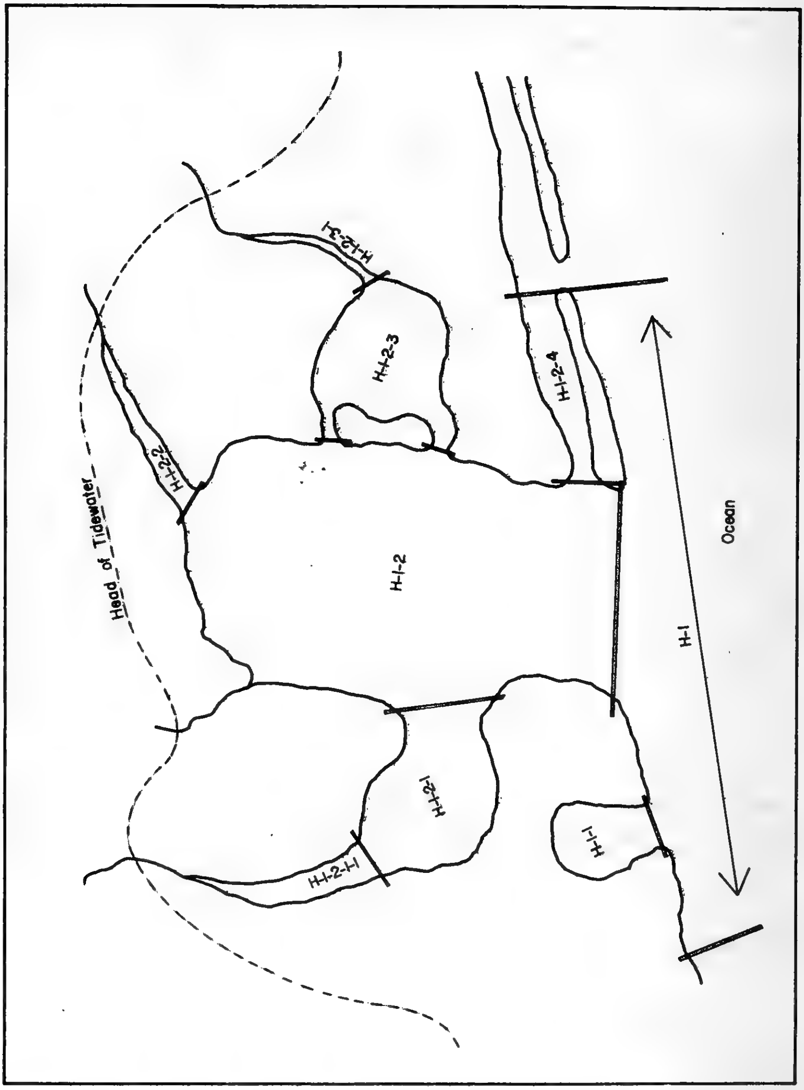
### SECTION 2. ESTUARINE REGISTER AREAS

As another means of organizing the pertinent information, a classification scheme for the estuarine areas of the United States was developed.

The entire coastline was divided into subdivisions called estuarine register areas (ERA). (See fig. VI.1.2)

Figure VI.1.2

SCHEMATIC OF ESTUARINE SYSTEM SHOWING SUBSYSTEMS




The object of this division and classification is to separate the coastal area into units within which information may be organized independently. The choice of boundaries for each system was based on consideration of its water pollution control and resource management aspects and does not necessarily reflect a scientific or engineering classification of estuarine systems.

Each coastal system tributary to, or composed partially of, an ocean or sea is designated a primary system. Estuaries tributary to a primary system are secondary systems; those tributary to secondary systems are tertiary systems; etc. This identification scheme includes all coastal waters of the United States, from the oceans to the limit of tidal effect. Although somewhat arbitrary, it offers a means of identifying areas without a cumbersome latitude and longitude arrangements and permits the addition of ERA's as needed.

As a further classification and identification of estuarine register areas, a description classification scheme in terms of dominating physical shape and configuration was developed (see table VI.1.1. and fig. IV.4.23). Basically, the classifications range from a smooth shoreline to the deep indentation of a fjord. While not quantitative, this system is workable for the estuaries and estuarine zones of the United States.

TABLE VI.1.1—MORPHOLOGICAL CLASSIFICATIONS

*Type number and description:*

1.1—Smooth shoreline without inlets.
1.2—Smooth shoreline with inlets.
1.3—Smooth shoreline with small embayments.
2.1—Indented shoreline without islands.
2.2—Indented shoreline with islands.
3.0—Marshy shoreline.
4.0—Unrestricted river entrance.
5.1—Embayment with coastal drainage.
5.2—Embayment with upland river flow.
6.0—Fjord.

## SECTION 3. COLLECTION OF INFORMATION

The sources of information for the list of descriptors were many and varied. They include nearly all agencies of the Department of the Interior, many agencies of other Federal Departments, individual States, and private entities. Table VI.1.2. lists the primary sources of information for each major section of the inventory. Note that the types of information obtained from each source are related directly to its operational missions.

In most cases, the information was obtained by direct request to the prime source agency. Where a compilation on a regional basis already existed this created no problems, however, in some cases, as with the U.S. Army Corps of Engineers and the Bureau of Sports Fisheries and Wildlife, it was necessary to compile some of the basic statistics. In most cases, the agencies were extremely cooperative in supplying the available information. In two cases, for the States of Alaska and Texas, contracts were negotiated to obtain inventory data from widely scattered State files. Thousands of additional items, however, were obtained from a wide variety of other sources.

The operational missions of the Federal Water Pollution Control Administration make it the primary Federal data source for information on water quality related to water pollution waste discharges and water quality standards in interstate waters. The major repository of interstate water pollution data, then, is the FWPCA regional offices. However, in all intrastate waters the States have primary responsibility for water pollution problems. Thus, they are actually the primary source for the bulk of water quality and waste discharge information and in many cases it was necessary for the regional offices to work through the States for that information.

To provide information for indepth case studies, a group of estuarine register areas for which data were known to be available were chosen and designated selected estuarine register areas (SERA) (table VI.1.3). With this designation went first priority for data collection. Information on these areas represents the most complete sections of the inventory.

TABLE VI.1.2—PRIME DATA SOURCES—NATIONAL ESTUARINE INVENTORY

*Inventory section and prime source*

Identification—Federal Water Pollution Control Administration.

2. Area description—Bureau of Sport Fisheries and Wildlife, U.S. Army Corps of Engineers, Federal Water Pollution Control Administration.
3. Managing entities—Bureau of the Budget, Department of Housing and Urban Development, Bureau of Outdoor Recreation.
4. Hydrology—U.S. Geological Survey.
5. Stage of development—Office of Business Economics.
6. Physical oceanography—U.S. Coast and Geodetic Survey.
7. Water quality—Federal Water Pollution Control Administration, the States.
8. Sediments and sedimentation—U.S. Geological Survey.
9. Uses—U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, National Park Service, Department of Defense, U.S. Geological Survey, Bureau of Mines.
10. Sources of pollution—Federal Water Pollution Control Administration, the States.
11. Use damages—Bureau of Sport Fisheries and Wildlife, Bureau of Commercial Fisheries, U.S. Army Corps of Engineers, U.S. Public Health Service.
12. Immediate pollution control needs—Federal Water Pollution Control Administration.
13. Water quality standards—Federal Water Pollution Control Administration.
14. Past and current studies—Federal Water Pollution Control Administration, Bureau of Sport Fisheries and Wildlife, the States.

TABLE VI.1.3—SELECTED ESTUARINE REGISTER AREAS (SERA) BY BIOPHYSICAL REGION

North Atlantic:
- Penobscot Bay
- Merrimack River-Ipswich Bay
- Broad Sound (Boston Harbor)
- Narragansett Bay

Middle Atlantic:
- Connecticut River
- Hudson River
- Raritan River
- Delaware Bay
- Pamlico Sound

Chesapeake Bay:
- James River
- Potomac River
- Patapsco River (Baltimore Harbor)
- Patuxent River
- Choptank River
- Nanticoke River
- Wicomico River

South Atlantic:
- Charleston, S.C. Coastal
- Savannah Estuary
- St. John's River

Caribbean: Biscayne Bay Coastal

Pacific Islands: Kaneohe Bay

Gulf of Mexico:
- Tampa Bay
- Apalachicola Bay
- Mobile Bay
- Biloxi Bay
- Mississippi Delta
- Barataria Bay
- Atchafalaya Bay
- Calcasieu Pass—Lake
- Galveston Bay
- Corpus Christi Bay

Pacific Southwest:
- San Francisco Coastal
- Morro Bay
- Newport Bay
- San Diego Bay

Pacific Northwest:
- Humboldt Bay
- Coos Bay
- Yaquina Bay
- Tillamook Bay
- Columbia River
- Willapa Bay
- Grays Harbor
- Bellingham-Anacortes
- Hood Canal
- Elliott Bay (Seattle Harbor)

Alaska:
- Gastineau Channel (Juneau)
- Cook Inlet

## Section 4. Present Status of the Inventory

Presently, the inventory consists of some 150 magnetic tapes of data containing more than 200 million individual pieces of information; several voluminous compilations of information not amenable to automation; hundreds of charts, maps, papers, books, and files; the complete coastline of the conterminous United States on microfilm; several thousand index cards containing a detailed bibliography; and considerable documentation ranging from step-by-step instructions for coding each column of each data card to multivolume reports on sedimentation and ecology. It is unfortunate that the above represents complete and detailed information on no single estuary or estuarine zone in the United States. In a few cases only one or two crucial sections may be missing, but for the remainder there are large knowledge gaps which will be discussed in chapter 2 of this part. Overall, probably only about one-third to one-half of the existing pertinent information is stored in the inventory data bank.

In compiling the mass of data mentioned above, pure research was found to be rare. The availability of data depends on there having been a sound economic reason for its collection. Among Federal or State agencies, for example, data are gathered as a matter of agency mission and are usually readily available; that is, the Bureau of Census and the Office of Business Economics function as data gatherers and can provide nationwide information as a matter of course.

Elsewhere, data may be collected for a single special purpose, such as a Corps of Engineers project study or an FWPCA technical assistance study. These usually result in a single report which may or may not include all the data gathered during the study, and which almost certainly would not be included in a nationwide compilation. In the last instance, each datum must be pulled from widely separated regional or district office files and arranged in a uniform manner to be useful on a broad scale.

A third large category of available data is that which is routinely gathered but is not routinely published. Included here are water pollution surveillance data, daily river flows, dredging statistics, and many, many others.

The routinely published information was, of course, the easiest to obtain. The decentralized report files were somewhat more difficult to acquire. Less significant because of the relatively small volumes of information involved, but most difficult to acquire, were the data from special surveys. In all cases, if required data are not in published reports, it is extremely difficult to locate and acquire them.

Of the published pertinent information, virtually all has either been included directly in the inventory or has been summarized to be included in some form.

Several hundred thousand items from sources other than those mentioned above have also been entered.

As the process of collecting information developed, revisions in the descriptor list became necessary. In certain cases descriptors listed were not available on a basis broad enough to be useful, and an alternate descriptor which would provide the same type of information was substituted. In other cases no alternate descriptor could be selected. Table VI.1.4 lists these and contains comments on impact of their loss on management planning.

In summary, some data are available but have never been compiled; some data are available but will never be released; some data are available in massive quantities but have never been extracted; and other data have never been taken at all. Numerous examples of each kind were encountered. Where sufficient data were not available to describe an estuarine attribute adequately, alternative data were gathered and analyzed.

TABLE IV.1.4.—MISSING DESCRIPTORS AND THEIR IMPACT

| Inventory section | Descriptor and status | Impact on NEPS |
|---|---|---|
| Sec. 2—Area description | Fills (in most cases, only estimates by Bureau of Sport Fisheries and Wildlife and others, plus measurements of spoil areas from Coast & Geodetic Survey charts, are available). | Alteration is not necessarily synonymous with destruction. Exact fill data on a variety of types of estuarine systems would allow evaluation of the destructive or constructive values of various schemes for filling. |
| Sec. 3—Managing entities | Legally owned facilities and reserved zones (not generally available below Federal level). | A comprehensive management plan for a single estuary or for the complete national coastline must consider all the existing management entities. Without this data the minute specifics of a management plan are impossible to delineate. |
| Sec. 3—Zoning or regional development. | Zoning or regional development (the names of responsible groups are available; however, little information relating to actual estuarine planning has been located). | A national plan should not conflict with a workable regional, State, or local plan. Fuller knowledge of existing planning organizations could allow fuller Federal/State/local cooperation through existing groups (whether currently engaged in estuarine planning or not) without the necessity of establishing another level in the hierarchy. |
| Sec. 6—Physical oceanography | Currents and current speeds | These are the major indicators of rates of flushing of pollutants. |
| Sec. 8—Sediments and sedimentation. | Sediment quantities and characteristics (with the exception of a few case studies almost no information is available). | Through fuller knowledge of sediment amounts and their effects, specific and positive actions could be suggested to alleviate many problems by existing interested entities; i.e., the Soil Conservation Service, the U.S. Army Corps of Engineers, etc. |

## SECTION 5. PROBLEMS AND SOLUTIONS

Because no section in the inventory contains all of the data deemed necessary, there follows a brief discussion of each inventory section in which major problems were encountered and the measures taken to overcome them. The results of these actions are reflected primarily in this report and not in the data entries of the inventory.

### *Handbook Section 2. Area description*

Problem: Many of the necessary data are implicit on available maps and charts, but very few measurements of estuaries and their associated marshes and tidelands have never been extracted or organized. Not even the U.S. Army Corps of Engineers which performs, or issues permits for, most of the dredging in the Nation, was able to provide information on spoil areas and fills therein. No consistent data were available on landfills of any kind, whether industrial, residential, or sanitary.

Solution: Using U.S. Coast and Geodetic Survey navigation charts and a 1940 U.S. Coast and Geodetic Survey of tidal shoreline measurements, the areas of many estuaries, marshes, and spoil areas have been hand measured and compiled. Many fills and spoil areas have also been estimated by the Bureau of Sport Fisheries and Wildlife who stress that most of these data are only estimates, not measurements. Their consistency, however, constitutes best-source information and as such they are included in the inventory.

*Handbook Section 3. Managing entities*

Problem: Legal ownership at the Federal level is available information; but State and local ownership, as well as zoning information, is practically unobtainable at other than the level of the responsible organizations, generally municipality or county. Some special study information on specific areas constitutes most of the available data.

Solution: Based on material gathered through the Department of Housing and Urban Development and the Bureau of the Budget, as well as several public and private reports and documents, it was possible to identify almost 200 Federal, interstate, State-Federal, county, and sub- or multi-county planning groups who receive Federal moneys and may have concern in the estuarine zone. This must be regarded only as a step in the right direction.

*Handbook Section 5. Stage of development*

Problem: Some pertinent statistics on economic development were found to be available at no lower level than by State. A number of statistics, shown as available in the Departments of Agriculture and Commerce census catalogs, were added to the descriptors in hopes of alleviating the problem. However, examinations of the computer printouts of both groups showed significantly incomplete or erratic inclusions of information.

Solution: Attack from all available angles. Some data are included from the U.S. Department of Agriculture, the Office of Business Economics, reports contained in the "Statistical Abstract of the United States," and still other information came from special reports on specific areas. This section is still not satisfactorily complete particularly for Alaska and Hawaii since data on these States is not included on current data tapes procured from the Departments of Agriculture and Commerce.

*Handbook Section 6. Physical oceanography*

Problem: Tidal information for the entire coastline is fairly complete, but actual measurements of currents and current speeds are sparse. Some information is available on major ports and areas where special studies have been made.

Solution: Since the data have never been taken, this problem has no present solution.

*Handbook Section 7. Water quality*

Problem: Because there apparently have been no consistent monitoring programs carried out on the Federal or State level, most of the available data is only for those areas which have serious habitat or pollution problems.

Solutions: Those areas which lack water quality data were compared with available "Stage of Development" data. There is a strong correlation between lack of data and lack of population pressures. While demographic information is no substitute for water quality data, it does at least serve as an indicator of potential problem areas.

*Handbook Section 8. Sediments and sedimentation*

Problem: Sampling of estuarine sediments has apparently been done principally as a part of a specific U.S. Army Corps of Engineers project investigation or as part of a research project. The majority of this sampling has been limited to surface samples of the bottom, with only occasional core samples. U.S. Army Corps of Engineers navigation channel data is, of course, the best source, but is still extremely limited.

Solution: Although little concrete data exists, much has been written on the subject. Two contracts were let with U.S. Geological Survey to investigate the literature and additional contracts were let to perform sediment case studies in estuaries of various types.

*Handbook Section 9. Uses*

Problem: While commercial use data are generally available, recreational use is not so easily documented. Only in areas where intensive studies have been made are there concrete data on participation days, boat use, swimming, sports fishing, etc. The same is true of use by fish and wildlife.

Solution: Examination of related data—fishing and hunting license sales, the results of creel surveys, the number of marinas and boat slips—permitted extrapolation wherever feasible. Many of the data included in this area are estimates by the field staff of the Bureau of Sport Fisheries and Wildlife and State commercial and sports fishing agencies.

*Handbook Section 10. Sources of pollution*

Problem: While the locations of most of the major waste discharges are known, information on the characteristics of individual waste effluents is extremely limited. They are known accurately only for the largest municipal waste discharges and for waste discharges in areas which have been the subject of an enforcement or technical assistance study. In particular, knowledge of the characteristics of individual industrial waste discharges is very poor, and data on them are extremely scattered. This is also true of other waste discharges, such as agricultural land drainage, waste from recreational facilities, and the specific effects of watercraft wastes in estuaries.

Solution: The principal waste characteristics of each major type of industry with locations in the coastal zone were defined, then combined with known water use by various of these existing industries, where the processes and types of treatment are known. The results of such combinations are very general at best and have been automated in the inventory only where actual measurements were encountered.

*Handbook Section 11. Use damages*

Problem: Concrete use damages information is very rare. Although the citizen can easily see and smell the results of pollution in many areas, documentary proof is another matter. Only in cases which have been the subject of an enforcement action of one kind or another, has there been any real effort to prove a damage to use. Even then, it has been much easier to get information on commercial damages than on those recreational or esthetic use.

Damage to a species not of commercial or sports value is almost impossible to document, although it may be critical to the food chain. Most of the remaining information is subjective estimation, by local residents or political entities, which provide coverage limited by the intensity of local interest in estuary or estuarine zone. Unfortunately, it appears that many of these estimates were chosen for dramatic effect, rather than as an actual indication of damage caused.

Solution: An effort has been made to eliminate the wild estimate and to enter only actual measurements. Data considered when making such an estimate would include such items as declining water quality, decrease of pollution-sensitive species and increase of pollution-tolerant species, closed shellfish beds, etc.

*Handbook Section 13. Water quality standards*

Problem: The water quality standards information for the entire coastline is complete, but the various States use different bases for classifying their waters and reserving them for particular uses. The categories of use sometimes do not fit overtly with those shown in the act which set up the water quality standards procedures. Also, the standards frequently refer to an entire water area or to a part of an area with such vagueness that obtaining an idea of actual acreage included is impossible.

Solution: The uses which are allowed were often available and have been entered in the inventory. The rest of the problem does not appear amenable to solution at this time.

It is apparent that while there is a wide variety of information on the estuaries of the United States, there are some very large gaps from a management standpoint. Much water quality, waste discharge, ecological, and habitat information is simply not available becuse there has been no consistent program of monitoring or collecting basic data in the estuarine zone. Economic data are available down to the county level for most commercial enterprises, but quantitative information in terms of recreation and aesthetic values is sadly lacking. While the resources available to this study have not permitted a thoroughly exhaustive compilation of data (with the exception of a few areas), the very large amount of material compiled does show where the significant gaps in information are. These gaps are such as to severely limit adequate analysis of quantifiable values in estuaries as a national entity except for commercially and economically reported uses. Some solutions to this problem will be discussed in chapter 2 of this part.

## Section 6. Automation of the Inventory

The products of an inventory are neat, well-organized tables, and lists containing the information required in the subject area. The National Estuarine Inventory, then, required a technique which could be used to store, retrieve, and manipulate a wide variety of information types to describe the dynamic conditions of the Nation's 884 ERA's. The two prerequisites were huge capacity and great flexibility. To satisfy these needs, all inventory data amenable to the technique are automated.

All of the automated information has been placed on magnetic tape, including both numeric and narrative information. Retrieval is possible either by estuarine register area number (table VI.1.5) or by the individual descriptor itself (table VI.1.6), making it possible to call for any combination of descriptors for any combination of estuarine register areas.

Programing was also developed to secure printouts in a finished format so that if necessary, printout from the inventory could be photographed directly for inclusion in a report as a table (table VI.1.7) or as computerized plots (figs. VI.1.3 and VI.1.4). Most of the tables in this report were prepared in this fashion (table VI.1.8). The capability for storing narrative information also increases the system's usefulness as a respository for management information.

Although much qualitative information is automated in the inventory, some such information is not amenable to automation, or is less expensive to compile by other methods into an equally useful form. Specifics on current institutional arrangements and broad-scale descriptive materials are examples.

Access to the available information will be open to all Federal, State, and local agencies through FWPCA.

### Table VI.1.5

### Example of a Partial ERA Retrieval

NOTES

(1) The following five pages are from the Inventory's master file summary tapes. The shortened titles and coded entries shown are used in the master only. Full titles and code translations will be used in regional, State, or local level retrievals.

(2) The ERA presented, Eel River, Calif., is neither the most, nor the least complete. It is fairly typical of the smaller ERA's.

(3) In addition to the ERA level data shown, other files contain information on the land areas adjacent to the Eel River. These include populations, employment statistics, industrial locations, and so forth, as well as offshore oceanographic and fisheries data.

(4) The pages shown were chosen to illustrate the manner of organiztion rather than to provide data.

(5) The information contained in the Inventory files is that gathered to provide quantitative information for the national estuarine pollution study.

| ERA NUMBER | NAME | LAT---LONG | LAT---LONG | LAT---LONG | LAT---LONG | DESC |
|---|---|---|---|---|---|---|
| 1SW-03-03-00-00-00 | EEL RIVER | 040378 124193 | 040379 124199 | 000000 000000 | 000000 000000 | UNRESTRICTED RIV ENTRANCE |

EEL RIVER EMPTIES 8 MILES NORTHWARD OF FALSE CAPE.
THIS IS A STREAM OF CONSIDERABLE SIZE AND IS OCCASIONALLY ENTERED BY LIGHT-DRAFT VESSELS, BUT THE CHANNEL OVER THE BAR IS CONTINUALLY SHIFTING. THE DEPTH ON THE BAR VARIES LARGELY WITH THE AMOUNT OF WATER IN THE RIVER, DEPENDING UPON THE CHARACTER OF THE WINTER, AND HAS BEEN AT TIMES AS MUCH AS 14 FEET, BUT GENERALLY THE DEPTH IS ABOUT 8 OR 9 FEET. THE RIVER IS SELDOM ENTERED EXCEPT BY FISHING BOATS AND OTHER VERY SMALL CRAFT, AND THEN ONLY BY THOSE WITH LOCAL KNOWLEDGE OF THE BAR.
EEL CANYON IS A SUBMARINE VALLEY EXTENDING IN A NORTH-WESTERLY DIRECTION. IT COMES TO A HEAD 10 MILES NORTH-WESTWARD OF CAPE MENDOCINO. VESSELS ARE CAUTIONED AGAINST MISTAKING THIS VALLEY FOR ONE OF THOSE SOUTHWARD OF THE CAPE.

| RECEIVING SYSTEM #1 | #2 | #3 | #4 | #5 | #6 |
|---|---|---|---|---|---|
| HUMBOLDT COASTAL | PACIFIC OCEAN | | | | |

| NATION | STATE | COUNTY AND CONGRESSIONAL CODES |
|---|---|---|
| 01 | 04 | 23 |
| | | 1 |

| ENT-LENGTH | NR-ENT | TOT-LENGTH | NAV-DEPTH | REG-AREAS | SUB-SYS | ISLANDS | IS-AREA | MAX-LENGTH | MAX-WIDTH | SHORELINE-LENGTH |
|---|---|---|---|---|---|---|---|---|---|---|
| .29 | 1 | .29 | 2- | | 5 | | | 25.9 | .6 | |

TOTAL WATER AND WETLAND AREA

| MHW/MHHW | MLW/MLLW | MARSH | 1/10 | 2/20 | 3/40 | 4/60 | 5/80 | 6/100 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2- | 1850 | 2- | | | | | | | | | |

FLOW OF RIVERS

| RIVER NAME | GAGE NR | TOTAL AREA | GAGED AREA | WATER YEAR | MEAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|---|---|---|
| EEL | 11,4770,00 | 3113 | | 11 | 5709 | 75 | 116000 |
| | | | | 12 | 4835 | 75 | 137000 |
| | | | | 13 | 7227 | 104 | 111000 |
| | | | | 14 | 11862 | 102 | 231000 |
| | | | | 17 | 5937 | 90 | 218000 |
| | | | | 18 | 3099 | 50 | 53600 |
| | | | | 19 | 7322 | 63 | 108000 |
| | | | | 20 | 1873 | 40 | 52000 |
| | | | | 21 | 10707 | 63 | 138000 |
| | | | | 22 | 4999 | 88 | 100000 |
| | | | | 23 | 3550 | 60 | 69200 |
| | | | | 24 | 1145 | 12 | 62000 |
| | | | | 25 | 9908 | 20 | 121000 |
| | | | | 26 | 4494 | 35 | 141000 |
| | | | | 27 | 10869 | 48 | 179000 |
| | | | | 28 | 6130 | 52 | 166000 |
| | | | | 29 | 2493 | 42 | 37100 |
| | | | | 30 | 4658 | 42 | 81800 |

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| ERA NUMBER | NAME | LAT---LONG | LAT---LONG | LAT---LONG | LAT---LONG | DESC |
|---|---|---|---|---|---|---|
| 1SW-03-03-00-00-00 | EFL RIVER | 040378 124193 | 040379 124190 | 000000 000000 | 000000 000000 | UNRESTRICTED RIV ENTRANCE |

FLOW OF RIVERS

| RIVER NAME | GAGE NR | TOTAL AREA | GAGED AREA | WATER YEAR | MEAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|---|---|---|
| | | | | 31 | 2082 | 32 | 64600 |
| | | | | 32 | 4729 | 34 | 123000 |
| | | | | 33 | 4811 | 43 | 53600 |
| | | | | 34 | 3330 | 52 | 44500 |
| | | | | 35 | 6841 | 53 | 77300 |
| | | | | 36 | 7816 | 67 | 182000 |
| | | | | 37 | 4862 | 60 | 95300 |
| | | | | 38 | 14891 | 85 | 316000 |
| | | | | 39 | 3582 | 42 | 96500 |
| | | | | 40 | 9949 | 42 | 261000 |
| | | | | 41 | 11238 | 97 | 124000 |
| | | | | 42 | 10177 | 105 | 184000 |
| | | | | 43 | 7672 | 100 | 208000 |
| | | | | 44 | 2958 | 55 | 43400 |
| | | | | 45 | 6502 | 67 | 86400 |
| | | | | 46 | 8093 | 50 | 186000 |
| | | | | 47 | 3477 | 47 | 62500 |
| | | | | 48 | 6352 | 47 | 91600 |
| | | | | 49 | 5588 | 42 | 115000 |
| | | | | 50 | 5578 | 38 | 105000 |
| | | | | 51 | 9691 | 80 | 199000 |
| | | | | 52 | 10808 | 85 | 188000 |
| | | | | 53 | 9533 | 76 | 158000 |
| | | | | 54 | 9394 | 144 | 213000 |
| | | | | 55 | 4163 | 102 | 40000 |
| | | | | 56 | 13772 | 82 | 433000 |
| | | | | 57 | 5843 | 82 | 130000 |
| | | | | 58 | 84030 | | 2290000 |
| | | | | 59 | 27835 | | 1970000 |
| | | | | 60 | 42870 | | 5380000 |
| | | | | 61 | 7275 | 95 | 94800 |
| | | | | 62 | 5335 | 96 | 81900 |
| | | | | 63 | 9643 | 128 | 212000 |
| | | | | 64 | 4587 | 67 | 122000 |
| | | | | 65 | 12628 | 67 | 648000 |
| VAN DUZEN | 11,4785,00 | 216 | | 51 | 1011 | 6 | 14500 |
| | | | | 52 | 1033 | 8 | 16100 |
| | | | | 53 | 991 | 8 | 16100 |
| | | | | 54 | 1020 | 11 | 21400 |
| | | | | 55 | 497 | 8 | 11600 |
| | | | | 56 | 1360 | 9 | 30300 |
| | | | | 57 | 685 | 8 | 15900 |
| | | | | 58 | 1422 | 13 | 15600 |
| | | | | 59 | 688 | 6 | 18300 |
| | | | | 60 | 653 | 8 | 20500 |
| | | | | 61 | 819 | 8 | 11900 |
| | | | | 62 | 589 | 8 | 7550 |
| | | | | 63 | 1073 | 11 | 12400 |

| ERA NUMBER | NAME | LAT---LONG | LAT---LONG | LAT---LONG | LAT---LONG | DESC |
|---|---|---|---|---|---|---|
| 1SW-03-03-00-00-00 | EEL RIVER | 040378 124193 | 040379 124190 | 000000 000000 | 000000 000000 | UNRESTRICTED RIV ENTRANCE |

FLOW OF RIVERS

| RIVER NAME | GAGE NR | TOTAL AREA | GAGED AREA | WATER YEAR | MEAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|---|---|---|
| | | | | 64 | 628 | 8 | 21700 |
| | | | | 65 | 1085 | 7 | 33900 |
| YAGER CK. | 11,4790,00 | 127 | | 54 | 418 | 6 | 6330 |
| | | | | 55 | 288 | 6 | 7730 |
| | | | | 57 | 370 | 4 | 6310 |
| | | | | 58 | 622 | 5 | 8720 |
| | | | | 59 | 324 | 5 | 7750 |
| | | | | 60 | 263 | 5 | 7810 |

PHYSICAL OCEANOGRAPHY

| TIDE TYPE | RANGE AT ENTRANCE MEAN | RANGE AT ENTRANCE SPRING | RANGE AT ENTRANCE NEAP | MAXIMUM RANGE LOC | MAXIMUM RANGE MEAN | MAXIMUM RANGE SPRING | MAXIMUM RANGE NEAP | ENTRANCE CURRENT | CURRENTS AT ENTRANCE FLOOD MAX | FLOOD MEAN | FLOOD MAX | FLOOD MEAN | EBB MAX | EBB MEAN | EBB MAX | EBB MEAN | TIDAL PRISM AT ENTRANCE MEAN | SPRING | NEAP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4.4 | 6.4 | | | | | | | 1- | 1- | 1- | 1- | 1- | | | 1- | | | |

ANNUAL VARIATION OF WATER QUALITY

| PARAMETER | UNIT | YEAR | LATITUDE | LONGITUDE | DEPTH | MINIMUM | MEAN | MAXIMUM | |
|---|---|---|---|---|---|---|---|---|---|
| 000010 | 33 | 66 | 039430 | 123210 | 0000 | 4000 | 5800 | 8300 | (TEMPERATURE) |
| 000075 | 15 | 66 | 039430 | 123210 | 0000 | | 9100 | 37500 | (TURBIDITY) |
| 000300 | 18 | 66 | 039430 | 123210 | 0000 | 96 | 1070 | 1330 | (DISSOLVED OXYGEN) |
| 000400 | 34 | 66 | 039430 | 123210 | 0000 | 81 | 830 | 850 | (PH) |
| 000620 | 18 | 66 | 039430 | 123210 | 0000 | 20 | 60 | 150 | (NITRATE) |
| 000650 | 18 | 66 | 039430 | 123210 | 0000 | 1 | 6 | 14 | (PHOSTPHATE) |
| 000940 | 18 | 66 | 040310 | 124070 | 0000 | 140 | 440 | 300 | (CHLORIDE) |
| 031505 | 29 | 66 | 040310 | 124070 | 0000 | 23 | 7013 | 620 | (COLIFORM) |

TYPICAL WATER QUALITY VALUES

| PARAMETER | UNIT | RIVER DISCHARGE | DATE | TIDE RANGE | LATITUDE | LONGITUDE | DEPTH | LEFT SIDE | CENTER | RIGHT SIDE |
|---|---|---|---|---|---|---|---|---|---|---|
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 44 | (BIOCHEMICAL OXYGEN DEMAND) |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 172 | | 76 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 44 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 74 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | | | 132 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 74 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 211 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 132 | | 9 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 1155 | | 24 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | | | 212 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 495 | | 16 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 165 | | 109 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 330 | | 25 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 60 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 33 | | 68 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 1155 | | 7005 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 66 | | 44 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 330 | | 35 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 330 | | 25 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 132 | | 59 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 66 | | 83 | |

NATIONAL ESTUARINE INVENTORY REPORT AS OF 10-31-69



| ERA NUMBER | NAME | LAT---LONG | LAT---LONG | LAT---LONG | LAT---LONG | DESC |
|---|---|---|---|---|---|---|
| ISW-03-03-00-00-00 | EEL RIVER | 040378 124193 | 040379 124190 | 000000 000000 | 000000 000000 | UNRESTRICTED RIV ENTRANCE |

TYPICAL WATER QUALITY VALUES

| PARAMETER | UNIT | RIVER DISCHARGE | DATE | TIDE RANGE | LATITUDE | LONGITUDE | DEPTH | LEFT SIDE | CENTER | RIGHT SIDE |
|---|---|---|---|---|---|---|---|---|---|---|
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 198 | | 23 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 33 | | 5 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 132 | | 14 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 495 | | 90 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 231 | | 13 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 66 | | 54 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 1155 | | 114 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 76 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 330 | | 39 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 211 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 132 | | 9 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 1155 | | 24 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | | | 212 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 495 | | 16 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 165 | | 109 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 330 | | 25 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 60 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 33 | | 68 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 1155 | | 7005 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 66 | | 44 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 330 | | 35 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 330 | | 25 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 132 | | 58 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 66 | | 83 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 198 | | 23 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 33 | | 5 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 132 | | 14 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 495 | | 90 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 231 | | 13 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 66 | | 54 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | 1155 | | 114 | |
| 000310 | 18 | 2 | 01-17-69 | | 040389 | 124333 | | | 76 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 330 | | 39 | |
| 000310 | 18 | 2 | 01-17-69 | | 040365 | 124275 | 264 | | 53 | |
| 000620 | 15 | 1350 | 01-17-69 | | 040310 | 124070 | | | 190 | |
| 000620 | 15 | 1350 | 01-17-69 | | 040310 | 124070 | | | 190 | |
| 000620 | 15 | 6320 | 01-17-69 | | 040310 | 124070 | | | 130 | |
| 000620 | 15 | 6320 | 01-17-69 | | 040310 | 124070 | | | 130 | |
| 000620 | 18 | 2524 | 01-17-69 | | 040310 | 124070 | | | 70 | |
| 000620 | 18 | 2524 | 01-17-69 | | 040310 | 124070 | | | 70 | |
| 000650 | 15 | 1350 | 01-17-69 | | 040310 | 124070 | | | 5 | |
| 000650 | 15 | 1350 | 01-17-69 | | 040310 | 124070 | | | 5 | |
| 000650 | 15 | 6320 | 01-17-69 | | 040310 | 124070 | | | 10 | |
| 000650 | 15 | 6320 | 01-17-69 | | 040310 | 124070 | | | 10 | |
| 000650 | 15 | 2524 | 01-17-69 | | 040310 | 124070 | | | 16 | |
| 000650 | 15 | 2524 | 01-17-69 | | 040310 | 124070 | | | 16 | |
| 910000 | 95 | 707 | 01-17-69 | 3 | 040380 | 124190 | 703 | 440 | | 630 (TIDAL CHARACTERISTIC 1) |
| 920000 | 95 | 360032 | 01-17-69 | 3 | 040380 | 124193 | 703 | 10 | 1000000 | 340 (TIDAL CHARACTERISTIC 2) |

| ERA NUMBER | NAME | LAT---LONG | LAT---LONG | LAT---LONG | LAT---LONG | DESC |
|---|---|---|---|---|---|---|
| 1SW-03-03-00-00-00 | FEL RIVER | 040378 124193 | 040379 124190 | 000000 000000 | 000000 000000 | UNRESTRICTED RIV ENTRANCE |

| YEAR | COMMERCIAL SHIPPING IMPORTS EXPORTS | DOMESTIC TRAFFIC | NR. SHIPS | CARGO EARNINGS | FISHING NR. VESSELS | NR. BOATS | BEACHES LENGTH TOTAL | PUB | USAGE DAYS | PUBLIC ACCESS SHORE | RAMPS | BOATING MOORING | MARINAS | FISHING FISHERMAN REG | EST DAYS | ANNUAL COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | | | | | | | | | | | | |

| YEAR | LICENCES | HUNTING DUCK STAMPS | COST | NUMBERS TAKEN BIRDS | FUR | OTH | DAYS | PIPELINE CROSSING NR | NAVY | NR | FEDERAL PORT FACILITIES COAST GUARD | NR | GEODETIC SURVEY | NR | CORP OF ENGINEERS | NR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | | | 32200 | 20 | 2- | 2- | 5000 | | | | | | | | | | |

NUMBER AND AREA OF AIRPORT

| YEAR | NR-SEAPLANES | NR-APPROACHES | NR-AIRPORTS | NR-EXPANSION |
|---|---|---|---|---|
| 65 | | | | |

SPORT AND COMMERCIAL FISHING

| TYPE | YEAR | FISHING CATCH POUNDS | VALUE | PRESENT AQUACULTURE AREA | VALUE | POTENTIAL AREA PRESENT | WQS | RELATIVE ABUNDANCE EGGS | JUVENILES | ADULTS |
|---|---|---|---|---|---|---|---|---|---|---|
| | 03 | 30000002304 | | | | | | 0 | 0 | 0 |

SPORT AND COMMERCIAL FISHING LOST

| TYPE | YEAR | STATUS | QUANTITY | UNIT | VALUE | HABITAT-LOST | UNIT | | CAUSE |
|---|---|---|---|---|---|---|---|---|---|
| 999 | 65 | | | 00 | | 2- | 02 | SFE SW0301 | |

| TYPE | YEAR | FEDERAL | MANAGED AREAS STATE | LOCAL | PRIVATE | NUMBER CAUGHT | VALUE | CURRENT POPULATION | HABITAT LOST QUANTITY | UNIT | VALUE | CAUSE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 701 | 68 | | | | | | | 1600 | | | | |
| 702 | 68 | | | | | | | 3- | | | | |
| 703 | 69 | | | | | | | 3- | | | | |
| 801 | 68 | | | | | | | 3- | | | | |
| 802 | 69 | | | | | | | 3- | | | | |
| 803 | 69 | | | | | | | 3- | | | | |

WASTE OR TREATED EFFLUENT DISCHARGE CHARACTERISTICS

| NAME | TREATMENT 1 2 3 | LOCATION LAT. | LONG | SIC CODE | SPEC-PROB 1 2 3 | PARA | UNIT | INFLUENT | EFFLUENT |
|---|---|---|---|---|---|---|---|---|---|
| FORTUNA | 04 | 000002 | 000002 | | | 032001 | 25 | 2- | 3 |
| | | | | | | 000310 | 19 | 2- | 6090 |
| | | | | | | 032001 | 25 | 2- | 3 |
| | | | | | | 000310 | 18 | 2- | 2040 |

# TABLE VI.1.6 RETRIEVAL OF AN INDIVIDUAL DESCRIPTOR, NATIONAL ESTUARINE INVENTORY

COASTAL ZONE FARM ACTIVITY *
BY BIO-REGION
BY ESTUARINE PORTION OF STATES

| BIO-REGION | STATE | NUMBER OF FARMS | ACREAGE OF FARMS 1000 AC. | PERCENT OF ALL LAND | VALUE-FARM PRODUCTS SOLD-$1000 |
|---|---|---|---|---|---|
| NORTH ATLANTIC | MAINE | 5,087 | 842 | 21.6 | 60,706 |
| | NEW HAMPSHIRE | 1,115 | 153 | 22.7 | 12,191 |
| | MASSACHUSETTS | 3,149 | 263 | 10.7 | 54,877 |
| | TOTAL | 9,351 | 1,258 | 18.3 | 127,774 |
| MIDDLE ATLANTIC | MASSACHUSETTS | 778 | 58 | 16.2 | 13,897 |
| | RHODE ISLAND | 1,100 | 105 | 17.9 | 18,537 |
| | CONNECTICUT | 2,546 | 254 | 17.0 | 46,513 |
| | NEW YORK | 1,768 | 104 | 4.5 | 64,763 |
| | NEW JERSEY | 7,019 | 675 | 17.1 | 150,774 |
| | PENNSYLVANIA | 3,914 | 393 | 26.4 | 65,240 |
| | DELAWARE | 4,401 | 717 | 54.8 | 107,631 |
| | VIRGINIA | ** | ** | ** | 6,339 |
| | MARYLAND | 824 | 140 | 45.2 | 25,742 |
| | NORTH CAROLINA | 7,768 | 1,014 | 38.6 | 77,647 |
| | TOTAL | 30,118 | 3,460 | 23.8 | 577,143 |
| CHESAPEAKE BAY | VIRGINIA | 7,765 | 1,388 | 32.6 | 59,812 |
| | MARYLAND | 12,532 | 1,986 | 51.5 | 169,185 |
| | TOTAL | 20,297 | 3,374 | 42.1 | 228,997 |
| SOUTH ATLANTIC | NORTH CAROLINA | 11,441 | 1,255 | 27.5 | 113,292 |
| | SOUTH CAROLINA | 10,003 | 1,367 | 30.6 | 54,666 |
| | GEORGIA | 721 | 295 | 15.9 | 3,867 |
| | FLORIDA | 4,106 | 2,102 | 42.6 | 222,066 |
| | TOTAL | 26,271 | 5,019 | 29.2 | 393,891 |
| CARRIBEAN | FLORIDA | 1,511 | 498 | 11.7 | 76,326 |
| | PUERTO RICO | *** | *** | *** | *** |
| | VIRGIN ISLANDS | *** | *** | *** | *** |
| | TOTAL | *** | *** | *** | *** |
| GULF OF MEXICO | FLORIDA | 10,620 | 3,472 | 34.8 | 122,743 |
| | ALABAMA | 3,336 | 544 | 29.6 | 27,833 |
| | MISSISSIPPI | 1,527 | 167 | 15.0 | 2,959 |
| | LOUISANA | 9,217 | 2,267 | 26.2 | 90,633 |
| | TEXAS | 13,367 | 8,675 | 82.1 | 229,068 |
| | TOTAL | 38,067 | 15,125 | 37.5 | 473,236 |
| PACIFIC SOUTHWEST | CALIFORNIA | 26,772 | 9,753 | 48.1 | 1,002,313 |
| | TOTAL | 26,772 | 9,753 | 48.1 | 1,002,313 |
| PACIFIC NORTHWEST | CALIFORNIA | 1,270 | 823 | 20.0 | 17,281 |
| | OREGON | 12,377 | 1,839 | 18.5 | 78,476 |
| | WASHINGTON | 19,458 | 1,461 | 15.5 | 144,850 |
| | TOTAL | 33,105 | 4,123 | 18.0 | 240,607 |
| PACIFIC ISLANDS | HAWAII | 6,242 | 2,354 | 64.7 | 187,557 |
| | GUAM | *** | *** | *** | *** |
| | AMERICAN SAMOA | *** | *** | *** | *** |
| | TOTAL | *** | *** | *** | *** |
| ALASKA | ALASKA [ALL] | 382 | 1,959 | 0.6 | 3,771 |
| | | 382 | 1,959 | 0.6 | 3,771 |

* USDA RECORDS-1967 ** NEGLIGIBLE *** INFORMATION NOT AVAILABLE

## TABLE VI.1.6 RETRIEVAL OF AN INDIVIDUAL DESCRIPTOR, NATIONAL ESTUARINE INVENTORY (continued)

BOAT REGISTRATION BY STATE [1967] **
[COASTAL ONLY]

| STATE | LICENSING CRITERIA | INBOARD AND OUTBOARD TOTAL - 65: AND LESS |
|---|---|---|
| ALABAMA | ALL MOTORBOATS,SAILBOATS | 95,620 |
| ALASKA * | MORE THAN 10 HP. | 14,284 |
| CALIFORNIA | ALL MOTORBOATS,SAILBOATS OVER 8: | 345,441 |
| CONNECTICUT | MORE THAN 5 HP. | 64,646 |
| DELAWARE | ALL MOTORBOATS | 12,003 |
| D.COLUMBIA * | MORE THAN 10 HP. | 2,989 |
| FLORIDA | 10 HP. OR MORE | 175,757 |
| GEORGIA | MORE THAN 10 HP. | 82,085 |
| HAWAII | ALL MOTORBOATS,SAILBOATS OVER 8: | 6,024 |
| LOUISIANA | MORE THAN 10 HP. | 73,711 |
| MAINE | MORE THAN 10 HP. | 34,249 |
| MARYLAND | MORE THAN 7.5 HP. | 65,692 |
| MASSACHUSETTS | 5 HP. OR MORE | 90,481 |
| MISSISSIPPI | MORE THAN 10 HP. | 17,585 |
| NEW HAMPSHIRE * | MORE THAN 10 HP. | 5,259 |
| NEW JERSEY | ALL MOTORBOATS | 127,734 |
| NEW YORK | ALL MOTORBOATS | 391,207 |
| NORTH CAROLINA | MORE THAN 10 HP. | 81,348 |
| OREGON | MORE THAN 3.5 HP.,SAILBOATS 12: UP | 71,560 |
| PENNSYLVANIA | ALL MOTORBOATS | 108,042 |
| RHODE ISLAND | ALL MOTORBOATS | 10,412 |
| SOUTH CAROLINA | 10 HP. OR MORE | 59,858 |
| TEXAS | MORE THAN 10 HP.& ALL MOTORBOATS OVER 14: | 207,125 |
| VIRGINIA | 10 HP. OR MORE | 58,174 |
| WASHINGTON | MORE THAN 10 HP. | 86,775 |
| GUAM * | MORE THAN 10 HP. | 215 |
| PUERTO RICO | ALL MOTORBOATS | 1,834 |
| VIRGIN ISLANDS | ALL MOTORBOATS | 1,901 |

* NO COAST GUARD BOAT NUMBERING AS OF 12/31/67

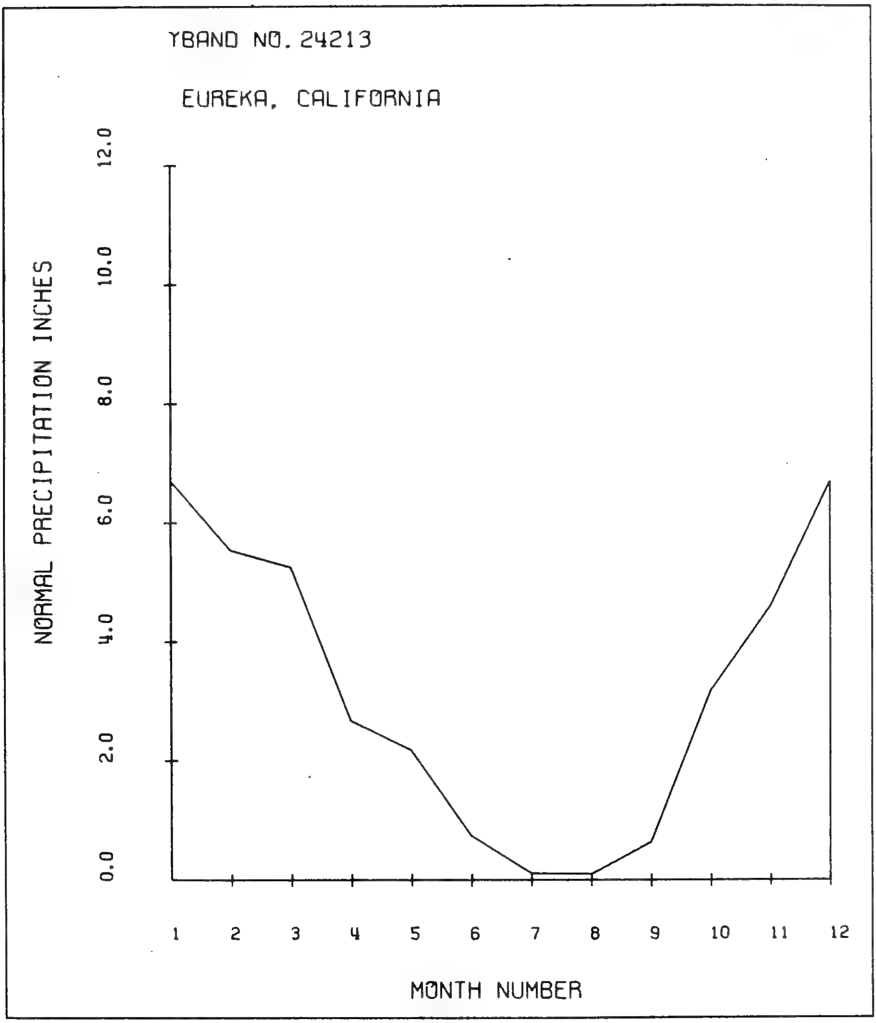
** COURTESY BOATING IND.ASSOC.,OUTDOOR BOATING CLUB,& USCG

# TABLE VI.1.7 SAMPLE TABLE OF NATIONAL ESTUARINE INVENTORY PRINTOUT

MID-MONTH LENGTH OF DAY AT SELECT COASTAL STATIONS

| STATION | HOURS OF DAYLIGHT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
| PORTLAND, MAINE | 9.30 | 10.52 | 11.88 | 13.42 | 14.72 | 15.42 | 15.13 | 14.00 | 12.53 | 11.05 | 9.68 | 8.95 |
| ROSTON,MASS | 9.43 | 10.58 | 11.88 | 13.37 | 14.60 | 15.27 | 14.98 | 13.92 | 12.50 | 11.10 | 9.80 | 9.10 |
| NANTUCKET, MASS | 9.53 | 10.65 | 11.90 | 13.32 | 14.50 | 15.13 | 14.87 | 13.85 | 12.50 | 11.13 | 9.88 | 9.22 |
| BRIDGEPORT, CONN | 9.53 | 10.63 | 11.90 | 13.30 | 14.48 | 15.13 | 14.87 | 13.83 | 12.48 | 11.13 | 9.90 | 9.23 |
| BLOCK ISLAND, R.I. | 9.53 | 10.63 | 11.90 | 13.30 | 14.48 | 15.13 | 14.87 | 13.85 | 12.50 | 11.13 | 9.90 | 9.22 |
| LA GUARDIA, NEW YORK | 9.58 | 10.68 | 11.92 | 13.28 | 14.45 | 15.08 | 14.82 | 13.80 | 12.50 | 11.15 | 9.92 | 9.28 |
| ATLANTIC CITY, N.J. | 9.70 | 10.73 | 11.90 | 13.23 | 14.33 | 14.93 | 14.68 | 13.73 | 12.47 | 11.20 | 10.03 | 9.42 |
| BALTIMORE, MARYLAND | 9.72 | 10.75 | 11.90 | 13.23 | 14.32 | 14.90 | 14.67 | 13.72 | 12.47 | 11.20 | 10.03 | 9.43 |
| CAPE HATTERAS, N.C. | 10.03 | 10.92 | 11.95 | 13.08 | 14.02 | 14.52 | 14.30 | 13.50 | 12.42 | 11.32 | 10.32 | 9.80 |
| WILMINGTON, N.C. | 10.12 | 10.97 | 11.93 | 13.03 | 13.93 | 14.43 | 14.22 | 13.45 | 12.40 | 11.35 | 10.40 | 9.88 |
| CHARLESTON, S.C. | 10.22 | 11.02 | 11.95 | 12.98 | 13.85 | 14.32 | 14.12 | 13.38 | 12.40 | 11.38 | 10.48 | 10.00 |
| SAVANNAH, GEORGIA | 10.28 | 11.05 | 11.97 | 12.97 | 13.80 | 14.25 | 14.05 | 13.33 | 12.38 | 11.42 | 10.52 | 10.07 |
| JACKSONVILLE, FLA. | 10.40 | 11.13 | 11.97 | 12.90 | 13.68 | 14.10 | 13.93 | 13.27 | 12.35 | 11.45 | 10.63 | 10.20 |
| DAYTONA, FLA. | 10.48 | 11.18 | 11.97 | 12.87 | 13.62 | 14.00 | 13.83 | 13.20 | 12.35 | 11.48 | 10.70 | 10.28 |
| WEST PALM BEACH, FLA. | 10.63 | 11.27 | 11.98 | 12.78 | 13.45 | 13.82 | 13.67 | 13.08 | 12.32 | 11.53 | 10.83 | 10.48 |
| MIAMI, FLORIDA | 10.70 | 11.30 | 12.00 | 12.77 | 13.40 | 13.73 | 13.60 | 13.05 | 12.32 | 11.57 | 10.90 | 10.53 |
| FORT MYERS, FLA. | 10.67 | 11.27 | 11.98 | 12.78 | 13.45 | 13.80 | 13.65 | 13.08 | 12.32 | 11.55 | 10.83 | 10.48 |
| TAMPA, FLORIDA | 10.57 | 11.22 | 11.98 | 12.82 | 13.53 | 13.92 | 13.75 | 13.15 | 12.33 | 11.52 | 10.77 | 10.38 |
| APALACHICOLA, FLA. | 10.45 | 11.15 | 11.97 | 12.88 | 13.65 | 14.05 | 13.88 | 13.23 | 12.37 | 11.48 | 10.67 | 10.25 |
| PENSACOLA, FLA. | 10.38 | 11.12 | 11.97 | 12.90 | 13.68 | 14.10 | 13.92 | 13.27 | 12.37 | 11.45 | 10.63 | 10.20 |
| MOBILE, ALABAMA | 10.38 | 11.12 | 11.97 | 12.92 | 13.70 | 14.12 | 13.95 | 13.27 | 12.37 | 11.45 | 10.62 | 10.17 |
| PUERTO RICO & VIRGIN IS | 11.15 | 11.55 | 12.02 | 12.55 | 13.00 | 13.23 | 13.13 | 12.75 | 12.25 | 11.73 | 11.28 | 11.03 |
| NEW ORLEANS, LA. | 10.43 | 11.15 | 11.95 | 12.88 | 13.65 | 14.07 | 13.90 | 13.25 | 12.35 | 11.47 | 10.65 | 10.23 |
| LAKE CHARLES, LA. | 10.42 | 11.13 | 11.97 | 12.90 | 13.67 | 14.10 | 13.92 | 13.25 | 12.35 | 11.47 | 10.63 | 10.22 |
| GALVESTON, TEXAS | 10.47 | 11.17 | 11.97 | 12.87 | 13.62 | 14.02 | 13.83 | 13.22 | 12.35 | 11.48 | 10.70 | 10.28 |
| CORPUS CHRISTI, TEXAS | 10.58 | 11.23 | 11.97 | 12.83 | 13.52 | 13.90 | 13.72 | 13.13 | 12.33 | 11.52 | 10.78 | 10.40 |
| BROWNSVILLE, TEXAS | 10.70 | 11.30 | 11.98 | 12.77 | 13.40 | 13.75 | 13.62 | 13.07 | 12.32 | 11.57 | 10.88 | 10.53 |
| SAN DIEGO, CALIFORNIA | 10.23 | 11.03 | 11.95 | 13.00 | 13.83 | 14.30 | 14.12 | 13.37 | 12.38 | 11.38 | 10.48 | 10.02 |
| SANTA MARIA, CALIFORNIA | 10.08 | 10.95 | 11.93 | 13.07 | 13.98 | 14.50 | 14.28 | 13.47 | 12.42 | 11.33 | 10.35 | 9.83 |
| SAN FRANCISCO, CALIF. | 9.85 | 10.82 | 11.93 | 13.17 | 14.20 | 14.77 | 14.53 | 13.63 | 12.45 | 11.25 | 10.15 | 9.57 |
| EUREKA, CALIFORNIA | 9.58 | 10.67 | 11.90 | 13.30 | 14.45 | 15.10 | 14.82 | 13.82 | 12.48 | 11.15 | 9.93 | 9.27 |
| HONOLULU, HAWAII | 10.98 | 11.47 | 12.02 | 12.63 | 13.15 | 13.43 | 13.32 | 12.87 | 12.27 | 11.67 | 11.12 | 10.83 |
| HILO, HAWAII | 11.07 | 11.52 | 12.02 | 12.58 | 13.07 | 13.32 | 13.20 | 12.82 | 12.25 | 11.70 | 11.20 | 10.95 |
| ASTORIA, OREGON | 9.03 | 10.37 | 11.87 | 13.53 | 14.97 | 15.77 | 15.42 | 14.18 | 12.57 | 10.97 | 9.47 | 8.65 |
| SEATTLE- TACOMA,WASH | 8.88 | 10.30 | 11.85 | 13.62 | 15.10 | 15.95 | 15.58 | 14.27 | 12.60 | 10.92 | 9.33 | 8.48 |
| ANETTE, ALASKA | 7.80 | 9.73 | 11.80 | 14.12 | 16.15 | 17.35 | 16.82 | 15.00 | 12.77 | 10.55 | 8.42 | 7.22 |
| JUNEAU, ALASKA | 7.13 | 9.40 | 11.77 | 14.40 | 16.78 | 18.25 | 17.60 | 15.43 | 12.85 | 10.32 | 7.87 | 6.42 |
| YAKUTAT, ALASKA | 6.85 | 9.27 | 11.75 | 14.52 | 17.03 | 18.63 | 17.93 | 15.58 | 12.88 | 10.23 | 7.63 | 6.08 |
| ANCHORAGE, ALASKA | 6.42 | 9.07 | 11.73 | 14.70 | 17.45 | 19.28 | 18.47 | 15.85 | 12.95 | 10.12 | 7.30 | 5.53 |
| COLD BAY, ALASKA | 7.75 | 9.72 | 11.82 | 14.15 | 16.18 | 17.38 | 16.85 | 15.02 | 12.75 | 10.52 | 8.38 | 7.17 |
| ST. PAUL, ALASKA | 7.38 | 9.52 | 11.78 | 14.30 | 16.53 | 17.88 | 17.28 | 15.25 | 12.82 | 10.40 | 8.07 | 6.73 |
| KING SALMON, ALASKA | 7.05 | 9.37 | 11.77 | 14.45 | 16.85 | 18.37 | 17.68 | 15.47 | 12.87 | 10.30 | 7.80 | 6.32 |
| BARROW, ALASKA | 0.0 | 6.97 | 11.55 | 16.53 | 24.00 | 24.00 | 24.00 | 19.70 | 13.50 | 8.83 | 2.58 | 0.0 |
| DARTER ISLAND, ALASKA | 0.0 | 7.32 | 11.58 | 14.20 | 24.00 | 24.00 | 24.00 | 18.28 | 13.42 | 9.05 | 3.73 | 0.0 |

FIGURE VI.1.3 A DETAIL PLOT FROM THE NATIONAL ESTUARINE INVENTORY



# FIGURE VI.1.4
## EXAMPLE OF SUMMARY DATA AND PLOTS (HILO, HAWAII)

Temperature; Normal degree days; Precipitation

| Month | Temperature – Normal – Daily maximum | Temperature – Normal – Daily minimum | Temperature – Normal – Monthly | Temperature – Extremes – Record highest | Year | Temperature – Extremes – Record lowest | Year | Normal degree days | Precipitation – Normal total | Maximum monthly | Year | Minimum monthly | Year | Maximum in 24 hrs. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (a) | (b) | (b) | (b) | 21 | | 21 | | (b) | (b) | 25 | | 25 | | 25 | |
| J | 78.7 | 62.8 | 70.8 | 89 | 1967+ | 55 | 1961 | | 11.82 | 29.11 | 1949 | 0.36 | 1953 | 9.94 | 1949 |
| F | 78.6 | 62.6 | 70.6 | 88 | 1947 | 53 | 1962 | | 12.94 | 39.32 | 1956 | 1.70 | 1963 | 13.41 | 1944 |
| M | 78.2 | 63.0 | 70.6 | 88 | 1967+ | 55 | 1949 | | 14.70 | 31.91 | 1948 | 2.97 | 1944 | 9.18 | 1953 |
| A | 78.9 | 64.3 | 71.6 | 89 | 1963 | 56 | 1949 | | 11.92 | 31.94 | 1963 | 2.93 | 1962 | 9.39 | 1954 |
| M | 80.4 | 65.6 | 73.0 | 94 | 1966 | 58 | 1947 | | 9.33 | 25.01 | 1964 | 1.18 | 1945 | 10.26 | 1965 |
| J | 82.0 | 66.6 | 74.3 | 89 | 1962 | 60 | 1946 | | 6.79 | 15.50 | 1943 | 2.68 | 1949 | 2.83 | 1963 |
| J | 82.4 | 67.4 | 74.9 | 88 | 1965+ | 62 | 1947+ | | 9.82 | 14.89 | 1958 | 4.25 | 1953 | 5.42 | 1951 |
| A | 83.1 | 68.4 | 75.8 | 93 | 1950 | 63 | 1955+ | | 11.45 | 26.42 | 1957 | 4.15 | 1962 | 9.38 | 1967 |
| S | 82.9 | 68.1 | 75.5 | 92 | 1951 | 62 | 1959+ | | 8.50 | 13.63 | 1947 | 2.45 | 1951 | 6.02 | 1960 |
| O | 82.5 | 67.6 | 75.1 | 91 | 1965+ | 62 | 1962+ | | 10.80 | 26.10 | 1951 | 2.40 | 1962 | 8.88 | 1951 |
| N | 80.4 | 65.9 | 73.2 | 88 | 1965+ | 58 | 1948 | | 13.37 | 27.03 | 1959 | 3.74 | 1943 | 15.59 | 1959 |
| D | 78.8 | 64.1 | 71.5 | 90 | 1964 | 56 | 1947 | | 15.18 | 50.82 | 1954 | 0.77 | 1963 | 10.50 | 1946 |
| YR | 80.6 | 65.5 | 73.1 | 94 | MAY 1966 | 53 | FEB. 1962 | | 136.62 | 50.82 | DEC. 1954 | 0.36 | JAN. 1953 | 15.59 | NOV. 1959 |

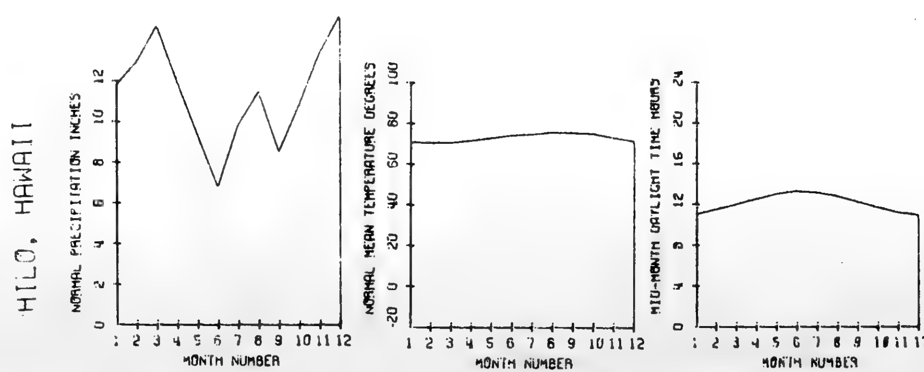
Snow, Sleet; Relative humidity; Wind

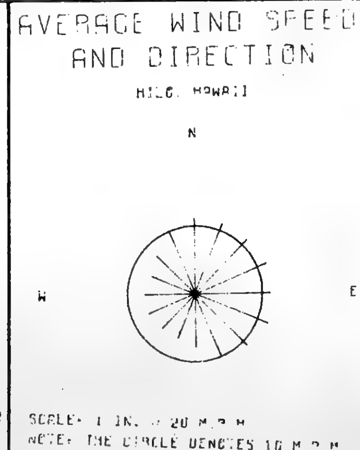
| Month | Snow, Sleet – Mean total | Maximum monthly | Year | Maximum in 24 hrs. | Year | Relative humidity 2 AM | 8 AM | 2 PM | 8 PM | Wind – Mean hourly speed | Prevailing direction | Fastest mile – Speed | Direction | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (a) | 25 | 25 | | 25 | | 18 | 18 | 18 | 18 | 18 | 14 | 13 | 13 | |
| J | 0.0 | 0.0 | | 0.0 | | 84 | 80 | 66 | 84 | 7.9 | SW | 41 | 36 | 1965 |
| F | 0.0 | 0.0 | | 0.0 | | 85 | 81 | 68 | 83 | 8.3 | SW | 46 | 07 | 1963 |
| M | 0.0 | 0.0 | | 0.0 | | 87 | 81 | 67 | 83 | 8.1 | SW | 38 | 36 | 1954 |
| A | 0.0 | 0.0 | | 0.0 | | 87 | 81 | 68 | 83 | 7.8 | WSW | 43 | 14 | 1963 |
| M | 0.0 | 0.0 | | 0.0 | | 88 | 81 | 68 | 83 | 7.6 | WSW | 28 | 11 | 1963+ |
| J | 0.0 | 0.0 | | 0.0 | | 86 | 79 | 66 | 81 | 7.5 | WSW | 30 | 11 | 1961+ |
| J | 0.0 | 0.0 | | 0.0 | | 88 | 82 | 67 | 81 | 7.3 | WSW | 26 | 36 | 1957 |
| A | 0.0 | 0.0 | | 0.0 | | 88 | 82 | 68 | 83 | 7.3 | WSW | 37 | 34 | 1958 |
| S | 0.0 | 0.0 | | 0.0 | | 87 | 80 | 66 | 83 | 7.1 | WSW | 38 | 14 | 1960 |
| O | 0.0 | 0.0 | | 0.0 | | 87 | 80 | 68 | 85 | 7.0 | SW | 30 | 14 | 1960 |
| N | 0.0 | 0.0 | | 0.0 | | 87 | 82 | 70 | 86 | 6.9 | WSW | 36 | 16 | 1955 |
| D | 0.0 | 0.0 | | 0.0 | | 86 | 82 | 70 | 85 | 7.6 | SW | 35 | 36 | 1958 |
| YR | 0.0 | 0.0 | | 0.0 | | 87 | 81 | 68 | 83 | 7.5 | WSW | 46 | 07 | FEB. 1963 |

Standard time used: ALASKAN

Sunshine, sky cover; Mean number of days

| Month | Pct. of possible sunshine | Mean sky cover sunrise to sunset | Sunrise to sunset – Clear | Partly cloudy | Cloudy | Precipitation .01 inch or more | Snow, Sleet 1.0 inch or more | Thunderstorms | Heavy fog | Temperatures Max. 90° and above | Max. 32° and below | Min. 32° and below | Min. 0 and below |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (a) | 17 | 21 | 21 | 21 | 21 | 25 | 25 | 22 | 22 | 22 | 22 | 22 | 22 |
| J | 46 | 6.7 | 5 | 11 | 15 | 19 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| F | 43 | 6.9 | 4 | 10 | 14 | 18 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| M | 38 | 7.8 | 2 | 9 | 20 | 24 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| A | 34 | 8.2 | 1 | 8 | 21 | 24 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| M | 29 | 8.2 | 1 | 9 | 21 | 25 | 0 | 1 | 0 | * | 0 | 0 | 0 |
| J | 40 | 7.5 | 2 | 11 | 17 | 24 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| J | 41 | 7.7 | 1 | 12 | 18 | 28 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| A | 38 | 7.7 | 1 | 11 | 19 | 27 | 0 | * | 0 | * | 0 | 0 | 0 |
| S | 39 | 7.1 | 3 | 11 | 16 | 24 | 0 | * | 0 | * | 0 | 0 | 0 |
| O | 39 | 7.3 | 3 | 11 | 17 | 24 | 0 | 1 | 0 | * | 0 | 0 | 0 |
| N | 32 | 7.5 | 2 | 10 | 18 | 24 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| D | 35 | 7.2 | 4 | 10 | 17 | 23 | 0 | 1 | 0 | * | 0 | 0 | 0 |
| YR | 38 | 7.5 | 29 | 123 | 213 | 283 | 0 | 8 | 0 | * | 0 | 0 | 0 |




Source: ESSA, U.S. Weather Bureau, 30-Year Normals

TABLE VI.1.8—INVENTORY INFORMATION IN OTHER PARTS OF THIS REPORT

*Table number and table subject:*

IV.1.1—River Flow.
IV.1.2—Sediments.
IV.1.3—Climate.
IV.1.4—Tidal Characteristics.
IV.1.5—Dominating Environmental Characteristics.
IV.1.6—Size and Shape Comparisons.
IV.1.7—Morphological Classifications.
IV.1.8—Natural Ocean and River Water Quality.
IV.3.1—Population and Agriculture.
IV.3.2—Industrialization.
IV.3.3—Land Ownership.
IV.3.5—Commercial Fisheries.
IV.2.4—Recreation Shoreline.
IV.2.5—Commercial Shipping.
IV.2.7—Cooling Water Withdrawals.
IV.2.8—Coastal Mining.
IV.2.9—Navigation Dredging.
IV.2.10—Marsh Habitat Lost by Filling.
IV.2.11—Flow Regulation Structures.
IV.5.4—Artificial Modifying Structures.
IV.5.7—Total Industrial Wastes.
IV.5.8—Major Industrial Wastes.
IV.5.11—Sstuarine Systems with Degraded Water Quality.

## SECTION 7. THE FUTURE OF THE INVENTORY

The National Estuarine Inventory was initially intended only to satisfy the needs of the National Estuarine Pollution Study. However, as the project developed, it became apparent that the inventory, or its lineal descendant, can be of far-reaching value in the estuarine management, research, and study.

There are many agencies and groups involved both institutional and technical management planning, plan implementation, and research in the coastal zone. They are concerned at all levels—national, regional, State, county, and local. The inventory automation system is capable of supplying all of these groups with data pertinent to their own different needs with these two advantages: First, available information can be acquired from a single source, providing a baseline of usable information with which the planner can begin work immediately. Secondly, knowledge gaps are identifiable, making it possible for the manager, the scientist, or the technician to concentrate study capability in areas of true ignorance, directing their efforts to new or complementary rather than duplicative, activities.

There is nothing new or unusual about data storage and retrieval systems. They differ only in the contents that they are written to contain. There are many in the Federal Government, such as the detailed file of oceanographic water quality data maintained by the National Oceanographic Data Center (NODC); the hydrologic information managed by the U.S. Geological Survey (USGS Hydrologic); the files of water quality data which FWPCA (STORET) maintains and many others. The majority of these systems are designed primarily for the scientist and the technician involved in solving technical problems in the environment. The inventory, on the other hand, is written to contain information of a more general nature and is intended to serve a different purpose, that of estuarine management. What this means in the practical sense, is that the generalized inventory system draws on the detailed data systems for part of its supply of raw environmental data input. The intermeshing of these four systems will be discussed in chapter 2 of this part.

A management information system is of negligible value unless it is used by the management and planning groups it is intended to serve. It is anticipated that these will be primarily on the State level, so a major first step is to develop a working relationship in order to determine how State agencies can most effectively use the system in contributing and withdrawing data from it. A pilot study for this purpose is being carried out with the State of South Carolina. Present indications are that a successful and mutually satisfactory arrangement can be developed for continuing application.

Universities and private organizations can also make use of the information contained in such a management information system by working either through their respective State agencies or directly with the Department of the Interior.

The development of the inventory into a continuing management information system must be accompanied by an aggressive program of assistance to user groups, both in learning about the information available and in making use of it. This can be accomplished through personal contact, aggressive public service, and demonstrations of how the information can be used to help solve actual problems.

A management information system such as described here would need to acquire data on some regular basis from many Federal and State agencies. Much of the information to be collected on the Federal level will come from agencies of the Department of the Interior; so it would be logical that this system should be a departmental one.

A management information system is necessary to the timely and efficient implementation of a comprehensive national program of estuarine management and the first steps toward establishment of such a system have been taken as part of the national estuarine pollution study.

## Section 8. Summary

The inventory is designed to serve management by providing information over the wide range of subject areas required for satisfactory management perspective, whereas indepth data on individual subjects is the focus of most other information systems.

It began as a means to organize and coordinate the great variety and volume of available information pertinent to estuarine management. As the program of data gathering and analysis progressed, large data gaps began to appear, and it became apparent that the inventory would be valuable not only as a source of data but also as a delineator of data needs.

These needs fall into two categories: that for data which exist and are available though widely scattered, and that for information which has never been developed. Sources to fill the first need have been located and must be tapped and a consistent program of data gathering must be developed to fill the second need.

The highly compressed tabular data presented throughout this report consists of national ad regional summaries of information stored in the inventory on a local geographic basis. A continuing estuarine management information system can provide a local, State, regional, and national management similar current information upon which to base a program for the preservation, use, study, and development of the estuarine zone of the United States.

REFERENCES

IV–1–1—Wastler, T. A., and L. C. de Guerrero, National Estuarine Inventory Handbook of Descriptors. Washington, D.C., U.S. Department of the Interior, Federal Water Pollution Control Administration, Revised, September 1968. p. 77.

# CHAPTER 2. INFORMATION AND DATA NEEDS AS SHOWN BY THE NATIONAL ESTUARINE INVENTORY

No management program can be effective without adequate knowledge of the environment to be managed. This is especially true in the estuarine zone where the biophysical, the socioeconomic, and the institutional environments are so intimately connected and interdependent.

The inventory contains much information on these three separate but interlocked environments. However, as has been pointed out, it also contains large areas where the required data have not been available. While the data and information required to fill these gaps are important in themselves, it is in their interrelationsips that their real importance lies. There is nothing straight-forward in combined consideration of the biophysical, the socioeconomic and the institutional environments, yet this consideration produces the fundamental rules which guide the course of technical management.

The information gathering and study program shown necessary by the inventory is intended to serve one purpose. That is to increase knowledge of the estuarine zone enough to use, develop and preserve the estuarine resource for maximum use without undue damage now or in the future. This program makes no attempt to obtain all knowledge on the study area; it is directed toward management needs, and therefore basic data collection and studies to supply basic data are the key features. A study program such as that presented here can be effective in management only if carried out as an integrated part of the overall management program.

## Section 1. Nonexistent Data

Compilation of the inventory revealed that a great many kinds of essential information have never been collected in sufficient detail or with a geographical coverage large enough to be useful in overall management planning, even in resource utilization planning for small estuarine management units.

Many studies of estuarine environments have been carried out, but these have almost always been done or supported by mission-oriented agencies whose activities are directed toward the achievement of specific objectives. The extremely dynamic conditions usually prevailing within estuarine systems, combined with personnel and budget limitations, often prevents the collection of all but the most essential information.

For example, in an enforcement field study intended to determine the damages resulting from shellfish bed closures, the essential investigations would require the study of sources of pollution, their effects on water quality, shellfish habitat damage, and economic damage to the shellfish industry. A general environmental study (including investigations of sediment type and distribution, fish habitat value, oceanographic features, and recreational use, among others) would probably have to be foregone because of the lack of people and equipment to carry them out.

This limited approach toward estuarine study has severely limited the value of the information collected in each study and has made a duplication of effort inevitable. If, for instance, a fish habitat study were carried out at a time different from the enforcement study mentioned above, it would be necessary for the investigators to obtain water quality information of the same type required by the previous study, because there would be no other way of knowing if water quality conditions had remained the same.

The estuarine environments most often studied have been those with specific problems in need of solution. Those estuarine systems undisturbed by man have generally been studied only by single investigators interested in and able to work on only a few aspects of the environment. Yet, information on these kinds of systems is needed in order to understand the changes that have occurred in other estuarine environments.

The net result of historical estuarine studies has been a large quantity of partial information collected at different times and different places by different people. Only on a very few systems has a broad spectrum of synoptic information been collected. While much of the data collected is indeed still valuable, it is not now possible to use it to establish key interrelationships among the ecosystem components. The development of the information necessary to establish ecosystem relationships is a research problem to be discussed in chapter 3, but much of this information is required for other purposes directly related to management needs.

Information to support management efforts is lacking in most of those information categories which require extensive field survey or study to secure it.

### PHYSICAL OCEANOGRAPHY

The information needed includes actual measurements of tidal, current, and stratification phenomena on many different estuarine systems.

While many estimates of these types of data are available, actual measurements are necessary to establish the true characteristics of each estuary. These measurements, together with area, shape, and size information, will provide the detailed morphological description which forms the foundation for studies in which the physical characteristics of individual estuarine management units are described in order that its capacity for use can be understood, and, of more far-reaching consequences, the studies in which one estuarine system is compared with another. A recurrent theme throughout this study—and this report—is the concept of learning enough about the nature of the estuarine zone to permit development of study methods applicable to a wide range of estuarine types.

The great amount of effort now being expended in the development of estuarine mathematical models and the attempts to apply systems analysis techniques in the estuarine zone are seriously hampered by the lack of fundamental information on the physical oceanography of estuaries. The data needs pertinent to this section are for actual measurements of tidal, current, and stratification phenomena.

The obtaining of physical oceanographic information requires both a program of consistent routine data collection over a large geographic range and intensive case studies in individual systems.

### SEDIMENTS AND SEDIMENTATION

All water, even the tiniest trickle, picks up and bears along minute particles from its bed. These particles may be invisible to the eye, but they are there and they are carried along suspended until, at some place where the current slows and gravity gets the upper hand, they fall to the bottom of the watercourse. These particles are "sediments" and the way in which they settle out is "sedimentation."

In some areas of the estuarine zone, natural sediment transport and sedimentation cause drastic changes. However, natural sedimentation is generally a long term process to which the ecosystem can adapt—that is, if a given species cannot tolerate a natural characteristic of a given environment, the species would not exist in that environment in any case. A species sensitive to sediments, therefore, would not normally be present in turbid waters. Generally, then, natural sedimentation cannot be considered highly damaging to estuarine biota.

Man-induced sedimentation is unfortunately another story. Denuding an area of earth releases to the hydrologic system an exponentially large amount of sediments. Rainfall washing over these bare areas carries sediment loads in slugs into the surface water drainage system, disturbing the ecosystem with unaccustomed turbidity. It is frequently when these streams reach sea level—the estuaries—that the water's momentum is slowed sufficiently to permit the sedimentation process to take place. The ecosystem is disturbed not only by excess turbidity, but also by an excess sedimentary covering which coats the bottom, smothering many life forms and changing the basic configuration of the estuary.

Sediment loads in rivers are transient phenomena related to sudden increases in flow and other climatological conditions. Understanding and mastering the problems of sedimentation pollution in estuaries requires a much broader data base than is now available. Much of the necessary data can be obtained through consistent sediment load and bottom condition monitoring throughout the estuarine zone.

### USES AND USE DAMAGES

A body of water may be littered with floating debris, it may be turbid and foul-smelling, and to all intents and purposes, dead, yet proving a damage to use is very difficult. One reason for the difficulty is that damage must be measured by the yardstick of the values that were present when the body of water was clean. If no data from that time are available, precise quantification may be impossible.

Enforcement of the water quality standards will negate much of the necessity for proving damage to use, but use damage data is, and for some time to come will continue to be, the basis for evaluation and enforcement of water quality standards. The standards criteria—actual measurements of water quality parameters—in many cases yet have to be tested for adequacy in the estuaries where so much knowledge is lacking. This is probably the most important area of neglected study indicated by the inventory.

Use damage identification requires information on many aspects of the estuarine environment; this is one reason there is so little available at the present time. It not only requires a detailed study of water quality and sources of pollution, but it also demands an economic analysis of the damage involved.

The identification of use damages requires the measurement of various uses at different times. This kind of information is collected most efficiently through a routine program of data collection such as that administered by the Bureau of the Census. Such a program of data collection cannot only show when use damages have occurred, but, when the information is studied as it is collected, such a routine basic data collection program can provide the information to illuminate damaging trends so as to counteract them before a catastrophe occurs.

WATER QUALITY AND SOURCES OF POLLUTION

In the final analysis, the greatest deficiency in basic information on estuaries is the lack of water quality data, and water quality is one of the basic environmental conditions a management program should protect. The collection of water quality information is particularly susceptible to the kind of partial effort required by the missions of many Federal and State agencies. It is easy to reduce a water sampling program by a station or two or a point or two, until the maximum is reached that the available personnel can do. While this is a necessary approach, for other users it damages the value of the data collected.

In any system receiving wastes, water quality data are of severely limited value unless coupled with data on the sources of pollution which may affect water quality.

To evaluate effects of waste discharges on any receiving body of water there are certain basic items of information which must be obtained. This information may be grouped into three general categories. First, there is the nature of the waste material itself; second, there is the manner of its movement within the estuarine system; and third, there is the way in which it interacts chemically and biologically with the estuarine environment.

None of the characteristics of waste discharges are unique to wastes discharged to the coastal environment. What is unique is that small variations in volume, concentration, or composition of wastes can have much more impact on an estuarine environment, where wastes may remain in one area for extended periods of time, than in a freely flowing river, where wastes are being constantly carried away from an outfall. This means that waste discharges into estuarine and coastal environments must be more constantly and carefully monitored than those discharged into rivers.

The obvious means to acquire information would be (1) a stringent and wide-spread monitoring program, or (2) development of a mandatory reporting system for use by individual industrial and municipal facilities themselves. Actual implementation of either method presents equally obvious problems, however. The vast expenditure of time and money for routine monitoring of every waste outfall in the estuarine zone is prohibitive. The enforcement of a mandatory reporting system also represents more man-hours and money than are feasible to consider. Yet monitoring is a necessity, so a simple reporting method for all possible studies and existing monitoring systems must be devised and the data gathered funneled into a central location for broad-scale analysis.

The adequacy, or lack thereof, of existing monitoring systems can then be determined and broadened only as absolutely necessary.

The information needed for routine water quality monitoring associated with pollution surveillance is also needed as basic data input for management and for basic research. An effective routine monitoring program should therefore integrate all of these needs to avoid overlapping data collection programs and insure acquiring the broad data base needed to advance scientific knowledge of the estuarine zone.

A further need related to the advancement of knowledge is basic data on unpolluted and unmodified estuarine systems; it is the lack of these kinds of data that hampers many present efforts at evaluating the effects of past changes on the environment.

Present efforts at water quality monitoring in estuarine systems are scattered; they are primarily a matter of State concern, and have been carried out directly by State agencies or through cooperation with local governments and industries. These efforts should be integrated into a nationwide water quality monitoring program designed to satisfy national as well as local needs.

## Section 2. "Gray" Data

There is a vast quantity of information which would be extremely useful at all levels of management if it were readily available. This so-called gray data exists, but it requires a special level of effort to secure it and put it in a form useful for management purposes.

These are the kinds of information that are collected by Federal, State, or local agencies as a matter of routine operation and merely filed away when they have served their purpose. For example, routine water quality measurements over shellfish beds, or a beach access toll bridge receipts, or numbers and kinds of Corps of Engineers dredging permits issued, would all provide pertinent information to estuarine management if readily available.

These kinds of information exist also in unpublished reports on contracts designed to satisfy a need. For example, a contractor's report to a State planning board on the need for more parks might never be published but would still contain valuable information to estuarine management if it were readily available. Many unpublished reports and informal technical memorandums will be released for public use if they can be found—but they do not appear in indexes or bibliographies; special efforts are required to find them.

A third kind of "gray" data is information that is available from published material but requires particular skill or effort to extract it. For example, the areas and volumes of all estuarine systems in the United States can be extracted from available navigation or topographic charts if someone will painstakingly measure the areas at different depth contours.

All of these data sources have one thing in common—the available information is difficult to find or extract, prohibitively so for the limited studies characteristic of the historical approach toward studying the estuarine environment. A much broader approach toward collecting such information, implemented as part of a national program, would achieve economy of scale and efficiency in operation by developing and applying the overall expertise as a centralized function.

Not all information existing in the "gray" data is pertinent and valuable for estuarine management. Examples of the kinds of pertinent information which exist primarily as "gray" data may be summarized according to their categories in the "Handbook of Descriptions" of the National Estuarine Inventory.

### MANAGEMENT AUTHORITY IDENTIFICATION

Part V of this report deals with Government entities and their interests and programs in the estuarine zone. Although the States have prime responsibility in most waters relating to the estuarine zone, it is at, or through the county and municipal governments that much of the implementation of a national plan must take place. This area of specific responsibility needs more complete definition.

The information needs by county are:

(1) Governmental structure;
(2) Its relationship to municipalities within the county; and
(3) Range of authority concerning the estuarine zone.

The studies required are a thorough literature search on a county-by-county basis to be supplemented by direct contact where it is not possible to acquire the necessary information from the literature.

The identification of other entities who have managerial authority over an estuarine zone can help to form the basis for a continuing institutional management plan. Each segment of the institutional mosiac must be placed into its proper position, so that each entity involved can be recognized and can participate at its own level.

Other needed data is information on the types and sizes of estuarine areas already under active management by any level of government as well as those areas which are included in zoning and regional planning districts.

All of these data exist. They are filed away in county court houses, chamber of commerce files, and government record books. An intensive literature study and files search will be necessary to search out the required information.

### HYDROLOGY AND MORPHOLOGY

In order to use a resource effectively, management first must quantify how much of the resource there is to use. In the case of estuaries—which, like all water resources, are primarily self-renewing when used

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properly—the quantity of water, the areas of marsh and associated lands, and the types of modifications which have been made constitute the total resource which is presently available. Most of this information exists, either in available literature or in widely scattered files.

The data required include "Fills," a tiny word, yet it represents only final and irretrievable damage that can be inflicted on a body of water. Information on circulation-modifying structures of other types—dredged channels, bridges, causeways, small upstream impoundments, et cetera—are also needed.

It is imperative that records be kept of such construction and that their effects on a system be carefully monitored. These records and monitoring data must be studied minutely in order to learn the most effective and least damging methods to use when estuarine modification is necessary.

Considered separately these small structures—dikes, weirs, locks, et cetera—appear innocuous, yet even one on a stream tributary to an estuary can have profound effects on salinity levels and current patterns. Changes in these, in turn, can upset the ecological balance of an area far out of proportion to the size of the regulation structure itself.

Though these small flow-regulation structures, along with their larger counterparts, the high dams and large impoundments, may be above tide water, their influence is as important as that of structures within the estuarine zone itself.

### SOCIOECONOMIC DATA

These data describe the basic economic makeup of an estuarine-associated land area which is usually a county, since the county is the smallest unit for which data are available. The majority of data which have been assembled, including those for standard metropolitan statistical areas (SMSA's) are relatively gross. They provide an adequate picture at the State or regional level, but are generally lacking in the fine grain detail which would be necessary to do an indepth analysis of a small area.

Some detail records have been acquired recently and the first step toward a nationwide economic breakdown of small specific areas on the coastline should commence with careful study of the material which is available inhouse. A study of this type would serve two purposes: (1) Full usefulness would be made of the data records already acquired, and (2) additional information needs would be clearly pinpointed.

The continuing need in this segment of information is not so much one of locating and acquiring additional data. Emphasis should be placed, instead, on constant updating and retention of historical records for trend establishment, and careful, detailed analyses to present clear and accurate pictures of any area, large or small.

## Section 3. Program Definition

Table VI.2.1 summarizes the important information lacks found during the initial compilation of the National Estuarine Inventory, and outlines briefly the means by which to acquire each kind of information.

TABLE VI.2.1.—BASIC DATA NEEDS AS SHOWN BY THE NATIONAL ESTUARINE INVENTORY (BY "HANDBOOK OF DESCRIPTORS" SECTIONS)

| Subject | Items required | Type of study | Category | Update period | Sources |
|---|---|---|---|---|---|
| 1. Identification of estuarine register area. | Institutional data | Literature, studies, supplemented by questionnaires where, necessary, will be required. | 1, 3 | 5 years | The States, the counties, Library of Congress' National Association of Counties. |
| 2. Area description | Areas, contours, fills, modifications | Available publications, i.e., navigation charts, maps, books, published statistical summaries, etc., must be searched manually. Both historical and current data should be included. | 1 | 1 year | U.S. Coast and Geodetic Survey, U.S. Army Corps of Engineers, U.S. Geological Survey. |
| 3. Managing entities | Public ownership and management compacts and commissions; zoning and regional planning. | Literature studies and numerous file searches will be needed to gather data at other than Federal level. | 1 | do | The States, the counties, FWPCA regional offices, the Department of Housing and Urban Development, Fish and Wildlife and Parks, USDI. |
| 4. Hydrology | Flow regulation structures—locks, dikes, small impoundments, etc. | Literature study | 1 | 5 years | U.S. Geological Survey. |
| 5. Stage of development | Specific values added; industrial, farming, and recreation activities and trends, population shifts and trends, etc. | Selected census data as well as commerical files must be compared and analyzed. | 1 | 1 year | U.S. Bureau of the Census, Commercial Sources. |
| 6. Physical oceanography | Current speeds and patterns, volume, circulation characteristics. | Literature studies will provide scattered data. Basic field measurements or monitoring will be required for all areas other than major ports. | 2 | 5 years | National Oceanographic Data Center, U.S. Coast and Geodetic Survey, U.S. Coast Guard, U.S. Geological Survey. |
| 7. Water quality | Measurements in areas not currently described. | Literature studies, file searches, basic field measurements, and routine monitoring will be required. | 2 | Constant | The States, FWPCA, U.S. Geological Survey, National Oceanographic Data Center. |
| 8. Sediments and sedimentation | Detailed data | Literature studies, file searches, field measurements, and routine monitoring will be required. | 2 | do | U.S. Geological Survey, FWPCA, U.S. Army Corps of Engineers, Fish and Wildlife and Parks, U.S. Coast and Geodetic Survey. |
| 9. Uses | Recreation, fish and wildlife use | Further literature studies and file searches supplemented by field studies. | 1 | 1 year | FWPCA, Bureau of Outdoor Recreation. |
| 10. Sources of pollution | Effluent characteristics | Routine monitoring, mandatory reporting, and other methods will be required. | 2, 3 | Constant | FWPCA, the States, U.S. Public Health Service. |
| 11. Use damages | Loss of past, current, and potential uses of all types, particularly ecological. | All available methods of study and research should be concentrated in this area. | 1, 2, 3 | do | FWPCA, the States, the counties, Fish and Wildlife, and Parks, USDI. |
| 12. Immediate pollution control needs. | Identification of specific damaging waste sources. | Routine monitoring will be required | 2 | do | FWPCA, the States, U.S. Geological Survey. |
| 13. Water quality standards | Information on compliance on an estuary-by-estuary basis. | Routine monitoring and close investigation to determine whether the standards as accepted may serve purposes of estuarine zoning. | 2 | do | Do. |
| 14. Past and current studies | | Literature searches should continue and a standard reporting method must be devised. | 3 | 1 year | All Federal agencies, all federally financed study groups. |

Note: Category No. 1 includes existing information for which a literature study and files search will be adequate. Category No. 2 includes that information for which basic field studies will also be rebuired. Category No. 3 requires other methods.

The foregoing discussions showed that the major kinds of available management information can be grouped into two broad categories: that information which has never been collected, and that information which has been collected but not published or released in a usable form.

There is a need, therefore, for an overall basic data collection program including a nationwide system of routine field data collection and estuarine water quality, pollution source, and ecological monitoring as well as a system for the collection of "gray" data. As corollarys to these, however, there must be a means for handling, using, and disseminating the information being collected, and there must be a means for advancing the state of knowledge to increase management capability.

The need in the estuarine zone is not for three separate programs, but for one integrated program with the three facets outlined above. Such a program must also recognize and cope with the realities of operating a large data collection and dissemination system which depends on contributions from diverse sources.

The 2-year effort in collecting information on the estuarine zone has led to these conclusions about the problems of locating and acquiring data:

(1) Most agencies, groups, and individuals will permit ready access to their files and data records, but lack manpower and/or incentive to "assemble, coordinate, and organize" them for the use of other groups.

(2) Large central data systems often have difficulty acquiring data, because users—who are also the potential contributors—frequently encounter problems caused by system inflexibility and the slowness of ponderous size, often becoming skeptical of its value and loathe to contribute information.

(3) All data sources mentioned in table VI.2.1, with the exception of the county governments, have been queried for this information and have already responded to the greatest extent possible; therefore, the data gaps existing in the inventory represent the limits of present capability in providing data.

(4) Experience has shown that frequently there may appear to be a lack of data when actually the data exist but in an obscure form or place, or else held under proprietary restriction.

(5) Data are taken primarily where there is a direct economic return or a problem associated with an agency mission.

None of the problems associated with collecting management information and efficiently disseminating it to serve management purposes is unsolvable, but these problems set the framework within which a program must operate to provide needed management information to users.

## Section 4. The Recommended Program

A general program to acquire and organize information on the estuarine zone to satisfy management needs should consist of three equally important and interrelated activities:

1. An integrated and comprehensive program of routine estuarine zone data collection, including monitoring of estuarine water quality and habitat.

2. A centralized system for the collection, organization, and dissemination of estuarine management information in a form directly useful to managers.

3. A program of applied research investigations designed to increase knowledge needed for management.

### BASIC DATA COLLECTION AND ROUTINE MONITORING

The object of this activity is to establish and maintain a nationwide program of basic data collection and environmental monitoring in the estuarine zone of the United States.

Many different agencies operate routine monitoring programs covering limited aspects of the estuarine environment. Each of these operates for a different purpose and is often uncoordinated with other efforts. Frequently, this is simple because there is no mechanism for interchanging information rapidly and efficiently at the working level so that programs of mutual benefit can be readily established.

The program recommended here should not compete with existing monitoring programs, but through providing a valuable service, should stimulate the interest of other Federal, State, local, and private entities in working cooperatively toward a nationwide program that will make use of the full capabilities of existing monitoring activities.

A nationwide environmental monitoring system can exist only if there is centralized knowledge of the program associated with responsibility and authority for implementation. The routine data collection efforts of Federal agencies, particularly within the Department of the Interior, can be organized into a unified nationwide estuarine monitoring system and coordinated with similar State efforts through amalgamating into one organization the necessary responsibility and authority for carrying out such a program without interference with the assigned missions of any agency, either Federal or State.

Within the framework of a unified sampling network, an effective nationwide estaurine monitoring program can be developed from existing monitoring programs by combining with this activity the centralized authority to supplement ongoing programs by:

1. providing to Federal agencies funds specifically allocated for broadening their existing pertinent programs;
2. supporting State programs with funds or contract support for environmental monitoring;
3. carrying out additional monitoring activities through inhouse capability or by contract;
4. supporting research and development activities designed to improve monitoring capability.

This program should concern itself with the broadest possible scale of environmental information, including all categories of information incorporated into the national estuarine inventory. While water quality, pollution source, and ecological data are badly needed and require major effort, there should also be regularly scheduled monitoring of other aspects of the estuarine environment such as recreational demand and use.

The basic data collection and routine monitoring program should be an integral part of the overall management information system required to support management efforts.

MANAGEMENT INFORMATION SYSTEM

The object of this activity is to provide a continuing institutional and technical information service on estuarine problems. As such there should be the in-house capability of operating a large automated data and information library; but there should also be the capability of recognizing data needs, finding and acquiring data, organizing information for management use, and developing new techniques and applications involving management information. Given these capabilities the elements of an information acquisition and service program for completing and maintaining a current estuarine management information program follow naturally from the information problem areas outlined previously.

1. Additional existing unclassified data from the Federal agencies and other sources listed in table VI.2.1 should be compiled by contract or other arrangement. The compilation of historical data from these sources would be rather massive and it is not reasonable to expect such agencies to either assign the task to personnel who are busy with other tasks nor to acquire the temporary work force required.

2. Reimbursible agreements on contracts should be let with data contributors and others to provide for updating their input to the inventory at specific intervals.

In those cases where nationwide data blocks have been included in the inventory, for example, mining use, volumes and costs of dredging, commercial shipping, etc., only updating would be necessary.

3. A simple and direct reporting system should be implemented.

All studies wholly or partially funded by the Federal Government which deal with the estuarine zone, including associated land areas (coastal counties, coastal SMSA's or parts thereof) should be required to forward copies of raw data gathered and reports completed to a central facility for processing and cataloging.

The reporting system should require no special form or method of submission, but simply copies of material gathered. (At the field level where the actual work takes place, special requirements of data and information submission would require too many man-hours to be feasible.)

This reporting system will serve two purposes. First, it will serve as an update mechanism for knowledge being gained in the estuarine zone. Second, it will provide an accurate mechanism to help prevent duplication of effort among federally financed programs.

4. All entities wholly or partially financed by the Federal Government, which monitor estuarine water quality parameters, including sediments and sedimentation, should be identified, their sampling station locations pinpointed, and copies of the data taken submitted to a central location for processing.

Unified identification of existing stations and analysis of the data collected would point out current coverage and permit any expansion necessary to proceed logically and without duplication.

Much of the work of identification of the sampling points used by Federal agencies has already been accomplished by the U.S. Geological Survey and by the Federal Water Pollution Control Administration. It is among States, university groups, and Federal grant program receivers that most of the identification work should be concentrated.

5. Existing similar data systems should be used reciprocally and cooperatively to store and retrieve various data types. These systems include the Inventory, STORET, USGS Hydrologic, and NODC. The compatibility of system concept and structure of these four systems is such that they can function as complementary segments of a single large storage and retrieval system.

In data gathering, for example, each organization searches primarily for the type of data which its "software" (that is, programs—the machines themselves are "hardware") will accept. It is inevitable that the searches will encounter information which can be stored in a sister system more efficiently; thus, a considerable amount of duplication can be saved.

6. Concurrently with data gathering, processing, and servicing, there must be a constant background of analytical data information investigation to identify special needs and conditions, and to explore new possibilities and applications, both directly and by contract.

### APPLIED RESEARCH

A program of research and study to advance the state of knowledge in estuarine management is presented in chapter 3. It is important to recognize, however, that the research program, the routine monitoring program, and the information service program are all integral parts of the overall effort intended to provide management with the ability to preserve, use, and develop the national estuarine system of the United States.

### SUMMARY

The object of building and maintaining the National Estuarine Inventory is to aid in the application of existing knowledge to maintain environmental stability in the coastal lands and waters of the United States. The program of data and information collection and handling set out in this chapter is devised to be able to supply current and accurate information to the institutional and technical manager, to the scientist and student, and to the institutions and agencies who help in the fight to preserve and maintain our environment. The prerequisites are a central facility, the men and machines to perform the labor, and constant application of a vigorous and aggressive public service policy.

# CHAPTER 3. MAJOR RESEARCH AND STUDY NEEDS

## SECTION 1. INTRODUCTION

The National Estuarine Pollution Study was specifically instructed by the Congress to identify problems and areas in which further research and study are required for the preservation, study, use, and development of the estuaries of the Nation.

This chapter will discuss these research and study needs in fairly broad terms. The intent here is to present an overview, providing a guide toward the purpose for doing research, the kind of basic information needed to designate desired estuarine uses and goals, and to support a comprehensive plan of management. Next the knowledge gaps are identified and the research and study programs needed to supply this knowledge are developed. Examples of study programs to satisfy specific goals are outlined and the principles and a system of managing estuarine research and studies are proposed. Finally, the recommendations of the combined National Academy of Sciences Committee on Oceanography and National Academy of Engineering Committee on Ocean Engineering together with a scheme of priorities are presented.

By no means does this chapter attempt to present every possible need. This would be an impossible and pointless effort, for it is our task and our intent to indicate here the broad areas in which research and study are needed and to encourage those people who have the most knowledge concerning specific problems to design and implement the special studies that will increase our knowledge.

The information needed to prepare this chapter was obtained by several approaches with the overriding goals being to represent as broad a diversity of interests and as many knowledgeable people as possible. Many people, numbering in the hundreds, have contributed generously of their time, effort, and thinking to make up this chapter. It would be impossible to mention them all and indeed, unfair, because of the variation in quality and quantity of the various individual contributions and the applicability of the various recommendations.

Some needs were identified by many people from various parts of the country indicating great importance, yet each recognized need appears as only a single item. Other needs suggested by perhaps only one person, are vitally important in a specific locality but would not have the same national impact as others.

### HOW THIS CHAPTER WAS DEVELOPED AND SOURCES OF INFORMATION

The best source of information concerning needed research and studies in the estuaries is the people who work directly on estuarine problems on a firsthand basis: The scientists, engineers, planners, and economists in the various universities, institutions, and State and local governments who will actually do the research suggested here. In order to take direct advantage of this vast reservoir of knowledge and experience throughout the country, each region of the Federal Water Pollution Control Administration was instructed to contact individuals and institutions in its vicinity who are knowledgeable and were interested in supplying information to the National Estuarine Pollution Study. The response to this call for information was generous and provided an extremely valuable and diversified array of research needs. This group also supplied many valuable concepts towards establishing a system of management of research.

In order to sample the thinking of the many organizations of learned men, letters were written to 15 selected professional societies and organizations requesting their official opinions on research needs. This group was selected as being representative of those societies whose memberships are closely concerned with the problems of estuarine water pollution and its abatement. A more comprehensive list would have introduced considerable redundancy because of the many other sources of information used. The organizations contacted were:

(1) Atlantic Estuarine Research Society.
(2) The American Fisheries Society.
(3) American Society of Ichthyologists and Herpetologists.
(4) American Society of Limnology and Oceanography.
(5) American Institute of Biological Sciences.
(6) Ecological Society of America.
(7) American Water Resources Association.
(8) Water Pollution Control Federation.
(9) American Society of Civil Engineers.
(10) American Chemical Society.
(11) American Geological Institute.
(12) Atlantic States Marine Fisheries Commission.
(13) Gulf States Marine Fisheries Commission.
(14) Pacific Marine Fisheries Commission.
(15) Gulf and Caribbean Fisheries Commission.

As discussed in detail elsewhere in the report, 30 public meetings were held throughout the country to learn what the public desired for their estuaries. Each of these meetings contained many statements of importance to the development of a research and study program. The transcripts of these meetings were analyzed in detail. The research and study needs so identified have been incorporated into this chapter of the report.

In the course of the National Estuarian Pollution Study, many special study contracts were let. Many of these requested a discussion of the research and study needs in the specific area under consideration. Information so derived has been incorporated into the preparation of this chapter.

The Office of Research and Development of the Federal Water Pollution Control Administration supplied to the study a statement of research needs. This statement was broad in scope yet detailed where needed. This information also has been incorporated into this chapter.

Many of the Federal Government agency profiles presented elsewhere in this study had a component concerning research activities and study needs. This information has been incorporated into this chapter.

Each State profile has a comparable research activities and needs component.

The National Academy of Sciences and the National Academy of Engineering has prepared, through their respective Committee on Oceanography and Committee on Ocean Engineering, a statement on the research needed for coastal waste management. Because of the importance of these groups and the excellence of their suggestions, this contribution has been included as its own section within this chapter. This section represents the thinking of a consortium of established and recognized authorities and tends to supply a cohesive and interpretive overview of the research and study needed in the estuarine zones. To a lesser extent, they also supply a scheme of priorities that will serve all beneficial uses of the estuarine zones most effectively and serve as a guide in the implementation of the recommendations of the National Estuarine Pollution Study.

The purpose of this broadly diversified program of data acquisition was to insure that each of the user groups and conservation interests would have an opportunity to be heard and to have their recommendations for a program of research and study needs presented. The sections that follow will propose as many of these study needs as possible and will relate them to the comprehensive program of estuarine management presented earlier in this report.

## Section 2. The Data Base Necessary for Effective Technical Management

It is becoming generally recognized that the basic need in estuarine zones is a comprehensive management system designed to maximize the net benefits possible. A great deal of technical and socioeconomic information is necessary for developing and implementing such a management system. Unfortunately, present knowledge is inadequate for most estuarine areas.

The knowledge required for wise and effective estuarine management must be supplied through cooperative efforts of engineers, biologists, economists, and others and incorporated into a conventionalized system of data processing and storage. The availability of data from engineering and ecological studies for socioeconomic analysis should not be merely coincidental, but should be a carefully planned objective incorporated into research designs through multidisciplinary interaction and planning.

The range of estuarine information needed transcends the scope of biological, physical, and chemical data; it must also include specific information of demographic, social, and economic significance. Knowledge of the uses and values of estuarine resources is also a requirement of this data base. We must also be fully cognizant of the institutional arrangements operating in the estuarine zone, for any management program must operate within the legal and political framework applicable to the specific estuary under consideration.

A full and adequate knowledge of these three broad categories of information—technical, socioeconomic, and political—is inextricably related to establishing goals and assigning uses for individual estuaries or estuarine regions. The assignation of desired uses of a natural resource is a basic management decision which requires the kinds of information discussed above.

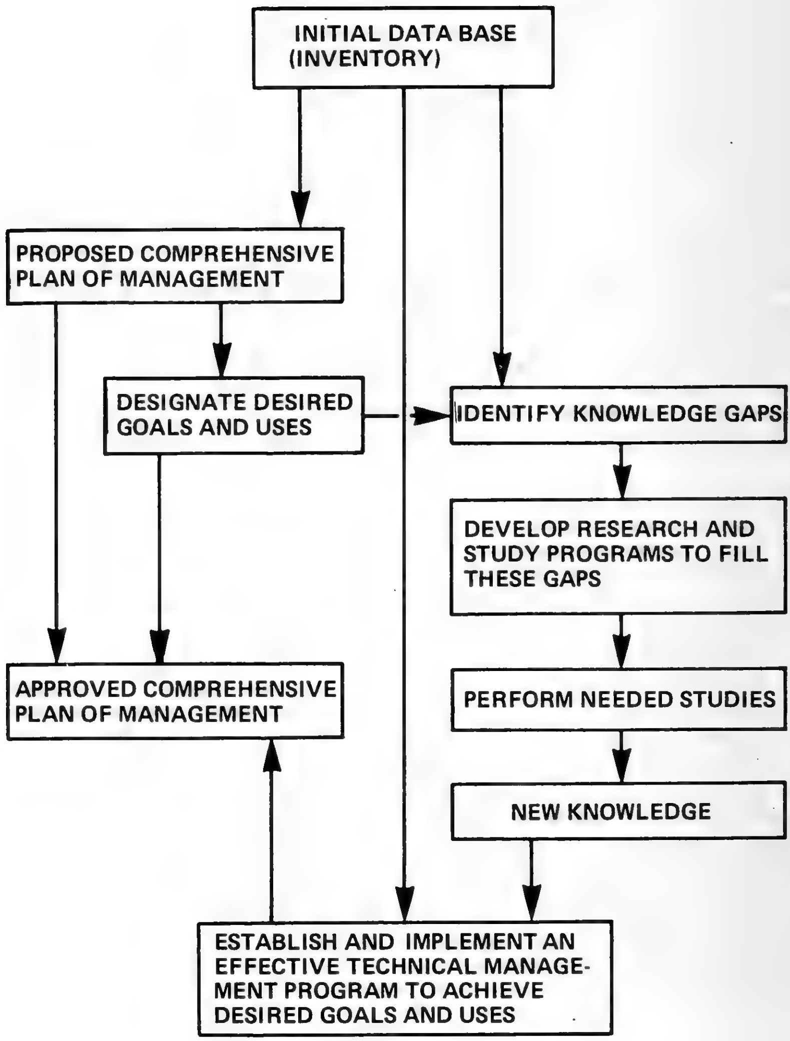
The overall purpose of applied research and study is to provide the knowledge required to establish and implement and effective comprehensive management program which will achieve optimum beneficial uses of the Nation's estuaries. This, of course, calls for a sequence of intermediate steps. The very first thing that must be done is to collate the currently known biological, chemical, and physical conditions of each portion of the estuarine zone. This assemblage of information should also indicate the current uses of the estuarine zone, its resources, the management situation currently in effect, and the problems and dangers that exist. This body of knowledge, the initial data base, is essentially the content of the National Estuarine Inventory (NEI) discussed at length in chapters 1 and 2 of part VI.

The National Estuarine Inventory is based on a series of handbooks which will fully describe each segment of the estuarine zone. Information is recorded under the following classifications:

(1) Identification of estuarine register area.
(2) Area description.
(3) Managing entities.
(4) Hydrology.
(5) Stage of development.
(6) Physical oceanography.
(7) Water quality.
(8) Sediments and sedimentation.
(9) Uses.
(10) Sources of pollution.
(11) Use damages.
(12) Immediate pollution control needs.
(13) Water quality standards.
(14) Past and current studies.

Based on this assemblage of present knowledge, we develop a proposed comprehensive plan of management and designate desired goals and uses. This, of course, frames the questions of feasibility of such goals and uses. Reference again to our known data base identifies the knowledge gaps—the knowledge we must have to make proper decisions on uses and the knowledge which is needed for effective technical management to provide for the desired uses. Identification of these knowledge gaps then leads rather directly to the development of the most essential research and study programs. The results of such programs augment the initial data base and provide the required information for both political and scientific management. This sequence is shown diagramatically in figure VI.3.1.

FIGURE VI.3.1 RELATIONSHIP BETWEEN KNOWLEDGE AND COMPREHENSIVE MANAGEMENT



In order to serve its purpose as a management tool, this data base must satisfy five broad requirements. These requirements are: (1) baseline knowledge of biological, physical, and chemical data describing the estuarine zone, (2) knowledge of the institutional framework governing each portion of the estuarine zone, (3) knowledge of the demographic, social, and economic factors and their trends affecting the estuarine zone, (4) an establishment of goals and uses so that future studies can be relevantly oriented, and (5) an augmentation and synthesis of the previous four adequate to permit estuarine management. The next portion of this section will discuss each of these requirements in greater detail.

### THE NEED FOR BASELINE STUDIES OF BIOLOGICAL, PHYSICAL, AND CHEMICAL FACTORS DESCRIBING THE ESTUARINE ZONE

The need for baseline studies is so basic and so obvious that it frequently is overlooked. Simply stated, a physical, chemical, and biological inventory must be conducted of all important estuaries and as many as possible of those of lesser importance. The purpose of such inventories would be to establish conditions as they are now; a baseline against which to determine the nature, extent, and rate of any future change. Research programs ensuing from this information would be addressed toward two basic questions: (1) what forces and combination of factors made each estuary the way it is, and (2) what must be done to make (or keep) each estuary the way we want it to be.

These are the compelling reasons for establishing baseline conditions and for developing background information now. An inventory of all estuarine areas to determine their condition precedes prediction of their potential for supporting valuable living resources along with other desired uses. We also need to know what is happening to such areas; how and to what extent they are being altered or threatened. Biological, chemical, and physical baselines must be established as a foundation for further studies and evaluations. Some work of this kind has been done or is underway, but much more remains to be done.

### THE NEED FOR SOCIAL, ECONOMIC, AND DEMOGRAPHIC INFORMATION

In the final analysis, the success of a management program is measured in terms of satisfaction of human needs and desires. Thus, the purpose of a management program is to provide the most benefits to the most people with the least amount of conflicting use—in brief: accurate resource evaluation and optimum beneficial resource allocation. The information needed for this is not as clearly definable as it is for technical purposes because the uses, values, and goals are not as quantifiable. This portion of an inventory would detail historical, present, and proposed specific uses and values within the estuarine zone; damages to use from pollution and other causes; demographic distributions and trends; transportation and navigational facilities; industrial installations, impact, and values; recreational benefits and potential, esthetic demands; economic values associated directly with the estuarine zone; sport and commercial fishing use and value; home development, and the alternatives and potential of as yet undiscovered parts of the estuarine zone.

## THE NEED TO KNOW THE INSTITUTIONAL AND POLITICAL ARRANGEMENTS OF EACH PORTION OF THE ESTUARINE ZONE

The institutional and political organization of each part of the estuarine zone is the framework within which any management program must operate. It is thus axiomatic that detailed knowledge of all aspects of these arrangements are an intrinsic part of the data base needed for management. Such information includes: the political makeup of the estuarine zone; i.e., the States, counties, municipalities, and special districts and/or interstate groups involved; the legal responsibilities and authorities of each of these; groups with management responsibilities in the system; existing zoning information and other applicable governing regulation; water quality standards and status of implementation; and Federal activities in the estuarine zone.

## THE NEED TO ESTABLISH GOALS AND USES

The data base described earlier is prerequisite to the establishment of goals and uses in the estuarine zone. Once these are established, they form a vital portion of the data base because the acquisition of further information is governed by the desired uses. Hence, we must know what we want to achieve. We must know where we are going. Goals and uses for each estuary and the various portions within each estuary must be established. Goals must be identified in terms of long-, medium-, and short-term achievements. Uses must be established from an objective point of view. It must be accepted that not all waters are suitable for all purposes. Potential uses, conflicts, and alternatives for development must be identified, described, and evaluated. This knowledge is essential to the setting of priorities for research, planning, and other actions.

This bring us to the hardest decision of all, for after uses are designated and alternatives are identified and evaluated, specific goals must be established. Then trade-offs must be made and sacrifices must be endured if, indeed, optimum benefits are to be achieved. With respect to all that needs to be done, we must not lose sight of our objectives. Where will we be able to swim that we cannot now swim; are there places for boating where we do not dare boat now; are our waterfront environments unhealthy or devalued, and if so, should these values be restored; can and should we safely and successfully grow shellfish where they cannot now be grown; what are the health, recreational, and commercial effects of pollution from large vessels or small boats or from casual uses of our waters; where might we catch fish that none can now be caught; are there waterborne diseases and what measures will correct them; what values should we place on the physical properties of width, depth, and appearance of water which must be restored or preserved; what will be the long-term effects of excess plant nutrients? Then, with respect to all of these and similar questions, we must necessarily balance against lost values, the burdens which their correction will create and be sure that the burdens we create are commensurate with the values regained.

### THE NEED TO AUGMENT AND SYNTHESIZE BASIC KNOWLEDGE TO PERMIT OPTIMUM ESTUARINE MANAGEMENT

The quintessence of any management system is the development of predictive capability. Having established the goals and uses; having established the knowledge of the potential, the capability, and intrinsic values of our estuaries; we must then know what will occur in response to a given stress or stimulus or activity of man or nature. It is this ability of prediction, of knowing what would be the *sequelae* of our actions, that will enable us to truly manage our estuaries in an intelligent fashion. The way we technically manage a specific estuary depends upon the goals established for that estuary and on what uses we wish to make of it. The research program to support this technical management is then dependent upon the goals and uses we have selected. All information gathered and studies performed must be oriented toward developing predictive capability if the benefits of wise management are to be attained.

## SECTION 3. MAJOR KNOWLEDGE GAPS AND A PROGRAM OF NEEDED STUDY AND RESEARCH

This section introduces the discussion of what must be done to provide the data base outlined in section 2, coupled with the analysis, research, and study required to provide the knowledge and understanding necessary to support a program of technical management. We intend to identify the major problem areas in which there are large knowledge gaps and concurrently present research and study programs that will provide the needed information. We will also discuss the kinds of research that will supply a basis for decisions that will optimize beneficial uses of the estuarine resources. The research programs proposed below are designed to recognize and interpret the causal relationships that are an integral part of any research program of value for management decisions. This understanding of causal relationships is the key to developing the capability to predict the effects of natural and man-induced activities on the estuarine zone, and, hence, to manage them.

Any discussion of knowledge gaps in major problem areas leads naturally to a description of the broad programs necessary to satisfy this need for information. Thus, as such gaps are identified, the remedial research and study activities are developed and incorporated into the appropriate discussion.

There is no attempt to exhaustively list research projects but rather to delineate the broad areas which need further study. Many of these research and study needs do not conveniently fall into categories or disciplines. In fact, most of them do not, reflecting the complex interacting nature of the estuary itself: a complex of air, sediment, ocean, freshwater influx, marsh, beach, or rock, and the estuary itself. Because of this, problem areas have been identified largely on the basis of kinds of approaches that will yield meaningful results.

A study of all our sources of information, recommendations received, replies to specific requests, and symposia on research needs leads to the imperative research and study needs lie in the following major areas:

1. Ecology, taken to include baseline studies, broad ecological studies, biology, water quality, natural variablity, and interface factors;
2. Toxicity, taken to include bioassay and methodology, sublethal effects, and mortality phenomena;
3. Microbiology, taken to include the regeneration of plant nutrients, biodegradation of organic wastes, the phenomenon of eutrophication or overfertilization to cause nuisance conditions, and pathogenic organisms to either humans or aquatic organisms;
4. Physics and mathematics, taken to include hydraulics, sedimentation, effects of structures and physical modifications, physical and mathematical modeling;
5. Socioeconomic factors, taken to include planning, economics, law, social and demographic factors and trends, resource evaluation and allocation, and the role of technical research and study in supporting a comprehensive management plan; and
6. Ancillary research and study needs, taken to include environmental monitoring, methodology (both laboratory and field techniques), data processing, training needs, and estuarine zone laboratories.

Bearing in mind that each of these categories overlaps the others to a greater or lesser extent and that no one of them is truly meaningful in the absence of consideration of all the others, knowledge developed in any one of them must be integrated with the others to develop the broad understanding of the estuarine zone necessary to implement a useful management program. The sections that follow, 4 through 9, will discuss each of these categories in greater detail and present a relevant program of study and investigation.

## Section 4. Ecology

Ecology is the science of the interrelationships between living organisms and their environment. As such, it encompasses all of the natural biological, physical, and chemical aspects of the estuarine and coastal zones. The overall complex formed by the community of organisms and its environment is called an ecosystem. The discussion below deals with certain aspects of the ecosystem, why these are especially important in a program of technical and comprehensive program of estuarine management, and the most urgent knowledge gaps concerning these ecosystems. The various kinds of ecological research needed lie in the categories of baseline studies to provide basic data, broad ecological studies to determine mechanisms and ecosystem interrelationships, biological studies to elucidate purely biological phenomena, water quality studies to understand the physicochemical environment, natural variations to differentiate against man-made changes, and interface factors to account for exchanges between the estuarine ecosystem and its bordering influences.

BASELINE STUDIES

*Purpose*

The most important gaps to be filled by a baseline study are a knowledge of the physical and chemical characteristics, identification, disopinion that our most important knowledge gaps and thus the most tribution, diversity, and abundance of resident and nonresident organisms, exhaustive studies of their interactions, and the underlying causes for these characteristics. This would permit classification of each estuary into a characteristic habitat type and prediction of the productivity of fish, shellfish, wildlife, and other renewable resources for each habitat. Properly conducted baseline studies would increase understanding of the causes and mechanisms of natural and man-made fluctuations in species abundance. Baseline studies would be necessary before considering the merit of preserving certain estuaries in their present condition for future comparative reference. Perhaps the most valuable benefit to be derived from baseline studies is information bearing on the key management question of how much natural habitat—estuary, marsh, lagoon—is required for the maintenance and production of adequate numbers of desired species of plants and animals.

*Studies of unpolluted estuaries*

Knowledge of baseline conditions is particularly important in estuaries relatively unaffected by man's activities. These pristine areas serve as controls for purposes of comparison with bays that have been modified to various degrees by human activities. It is extremely difficult to assess changes in the productivity or the decline or disappearance of economically important species without sufficient background information. In some cases, such changes can be attributed fairly accurately to specific causes such as pollution, overexploitation, or natural variation. On the other hand, the general decline of a species over a wide geographic area, such as the Olympia oyster over much of the Pacific Northwest, suggests subtle ecological changes which are much more difficult to assess. It would be invaluable to be able to compare existing water quality conditions in given estuaries with conditions as they were 50 years ago. One wonders, for example, how seasonal and annual stream flow regimes have changed due to human activities in watershed areas and how such changes have affected the estuarine environment and hence the indigenuous biota.

*Necessary kinds of information*

The information needed as a base for technical management should be in the form of an outline describing the Nation's coastal areas. To resolve questions of best estuarine use, necessary information includes the following: size and shape, existing water quality, degradation, sources and types of wastes, climate, hydrology, circulation, ecology, present and potential habitat value, identification, distribution and abundance of organisms, physical modifications, bathymetry, and bottom conditions.

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## BROAD ECOLOGICAL STUDIES

*Scope of ecological studies*

Broad ecological studies are needed to integrate all of the factors acting to shape the nature of the estuarine zone. We need to expand the baseline research on estuarine systems to include studies on nutrient and thermal additions, circulation and transfer of substances and energy, productivity, species interaction, effects of pollution, biological indicators of environmental change, and ecosystem analysis. The broad impact of economic poisons,[1] must be identified and quantified. What are the sources, effects, and fate of the various pesticides and herbicides, and how may these effects be mitigated? What are the details of the life histories and environmental requirements of estuarine-associated and estuarine-dependent species? Studies should be conducted to determine the dependence of marine species on estuarine nursery areas, to measure the impact of inland development on the estuarine ecosystem, and to determine the quality and quantity of fish and wildlife habitat areas necessary to maintain present population levels and to satisfy predicted future use. Studies should be implemented on rare and endangered species of fish and shellfish. One of the most important gaps remaining is our lack of knowledge of the dynamics of food chains, the relationships between phytoplankton on one end of the food chain and fish at the other, especially quantitative data on biomass and replacement rates of both benthic and pelagic invertebrates which are not of economic value themselves but are important parts of the food chain or, in some cases, are antagonistic to economically important species.

*Energy flow in food webs*

Much study is required to determine the absolute and relative contributions of phytoplankton, spermatophytes such as turtle grass and *Spartina*, and organic detritus to the energy used in these food chains. This concept of energy transfer is one of the most important aspects to understand in order to efficiently manage complex estuarine environments, for it is a fundamental property of the system and provides an extremely valuable approach to evaluation of the effects of pollution and change. It is essential to be able to quantitatively describe the energy transfer for individual species, for trophic levels, and for communities. Constructive manipulations of the sequential nature of energy transfer and utilization can be achieved by the application of system models for studies on movements and rates of transfer of selected pollutants within the system, such as insecticides and heavy metals. Such programs are dependent upon the availability of raw data on input to the ecosystem, bioconcentration, sedimentation, and output from the ecosystem. One of the early requirements in any management program should include an energy budget analysis.

*Ecosystem rehabilitation*

Research is needed on the recovery of an area during the course of cleaning it up. How long does it take, what indications do we have along the way, and how will cleaner water affect the area; for exam-

[1] Pesticides, herbicides, defoliants, rodenticides, etc.

ple, will there be more fouling and wood borer problems? Is just the removal of pollution enough to reclaim an area or do we need to develop techniques for rehabilitating despoiled estuarine areas and for increasing fish and wildlife production in low value habitats? How do we reconstruct a marsh after dredging, filling, and channelization projects, if, in fact, we can reconstruct a marsh ecosystem? Another need is to establish the time required for an estuary despoiled by over-fertilization and decreased flushing to reestablish a normally diverse flora and fauna upon stoppage of nutrient input and increase in flushing rate. This could be accomplished by constructing experimental embayments using survey data available for known polluted areas; and by developing model analogs based upon existing survey data and experimental results. Progress on reconstruction and rehabilitation of a despoiled estuarine area is based again on the information which would result from exhaustive detailed baseline studies described earlier.

*Ecosystem management*

The use of systems analysis techniques to determine the effects of various changes in the environment and harvesting techniques on population levels is extremely productive. It seems that some of the very critical problems of estuarine and Continental Shelf resources, such as trash fishing, may be amenable to such analysis. In no other way can we ever hope to determine what the effect of removal of a certain portion of a population at a given age would have on the ability of the population to survive and multiply. Based on this kind of data, we could satisfy the need to develop better estuarine husbandry programs, and aquaculture might be more profitably and productively pursued. Fish production might be increased by altering currents and by other means. Mitigating effects of environmental alterations, controlling disposal of waste products, controlling fish diseases and predators, and developing genetic strains of desired species more suited to moderately disturbed habitats might possibly ensue from a sophisticated analysis of the above factors. Certainly we should know more about the effects of any changes in the estuarine environment on the increase or buildup that might be expected of aquatic weeds, pest species of insects and other arthropods, and diseases and predator species that may reduce populations of desirable organisms or inhibit recreational uses of estuarine areas.

## BIOLOGICAL STUDIES

Estuarine biological systems are extremely complex when compared to fresh water or truly marine environments. The areas between the fresh water and the sea remain the biological link between the systems which, if broken, will result in the elimination of many valuable resources. The planktonic stages which are characteristic of life histories of species having commercial or recreational importance are especially vulnerable to environmental changes.

*Sources of food*

The complicated food chains, associated with the polymorphic life histories of estuarine organisms, are poorly understood. For example, the American oyster, which is often called the most thoroughly studied of all estuarine organisms, can starve in waters containing large populations of certain unicellular green algae which appear to be as suitable for food as other green algae on which they thrive. There needs to be more definitive work done on the actual sources of food used by various estuarine organisms, particularly those of commercial importance, as well as the specific kinds of food. We need to know how much of the diet of the given species comes from a given source. This is particularly true for the detritus feeders. We need to know how much detritus eaten comes from salt marshes; how much from fresh water sources upriver; how much from submerged aquatic vegetation; and how much from other sources. Better knowledge in this area is necessary in order to make intelligent decisions about how much of a given sort of habitat is necessary to "carry" a given level of resource. A better understanding and more knowledge of carbon fixation by plants in estuaries is necessary, for this is the basic source of all food for all levels of animals in the estuary.

*The estuary as a nursery*

We need to identify what is in the estuarine environment that makes it so suitable a nursery for larval and juvenile animals. This in turn means identifying, among other things, individual steps in food webs. Enough aspects should be investigated to allow us to make estimates of energy turnover. We already know that ocean basins are nutrient traps—places where energy is trapped and not returned to the cycle. What is the role of estuaries in this "running down" process? Do fine sediments act as traps for organic and inorganic particles which are then used by bacteria, and what organisms might "graze" on the bacteria?

An important link in the food webs of the estuaries is the plankton serving as a food supply for higher, more predacious organisms. These higher predators are in the estuary as permanent residents, as migrants coming in to feed, or as organisms that may use the estuary as a migratory path going upstream or downstream, during which time they might be feeding. One often hears of the conservation efforts directed toward such major sport fish as the salmon, but little emphasis is placed on the conservation of lower members of the food web which are quite important, not only to forms such as salmon, but also to all of the other forms utilizing this basic food stuff of the ocean as a food supply. In brief, we must determine the degree to which estuarine and offshore commercially and recreationally important fishes, and their respective food chains, depend upon the estuary.

*Habitat requirements*

We must determine the fish and wildlife habitat areas necessary to maintain adequate population levels for future uses in the estuaries of food organisms, as well as the desirable species themselves. This question of adequate habitat has proved to be a very difficult determination to make, in view of the lack of positive knowledge of the quantitative requirements for marsh, as well as other estuarine environments as nursery and habitat areas for fish and wildlife and for other purposes. Substantial research must be devoted to this question, meanwhile attempting to preserve marsh and other coastal regions to the greatest extent possible through influence on permits for dredging, filling, draining, or other modifications of estuarine zones.

An extension of the study of necessary habitats would be to determine in quantitative terms, the importance of the estuary as a spawning area, and then its importance as a nursery area. These data on life cycle events, population dynamics, food chains, nursery, habitat, spawning area values, may exist already in one form or another, but they are certainly not generally available. They need to be drawn together in a way so that they can be used by the resource manager.

## WATER QUALITY CONSIDERATIONS

As indicated in the discussion on baseline studies, it is essential to have a full knowledge of the characteristics of the receiving waters in the development of a realistic program for pollution control and water quality management. In most cases, the pollutional control characteristics are unknown for the various estuarine areas. These characteristics need to be established for each estuary. While some basic data concerning expected norms can be interchanged among estuaries, much work with each individual system is needed to establish the validity of such interchanges.

### *Effects of combined wastes*

Residential, recreational, agricultural, and industrial development of the estuarine zones is proceeding at a rapid rate. These activities frequently result in highly complex waste waters from many sources that eventually become mixed in the bays and oceans. While the toxic and other characteristics of some of the individual types of waste water have been studied, effects of combined waste waters, including synergistic and antagonistic effects, are largely unknown.

### *Water quality requirements for fish, other aquatic life, and wildlife*

Having learned something of the water quality of the estuaries, the next step is to ascertain the water quality requirements for the estuarine and near-shore environment. At the present time, knowledge in this area is incomplete, with the resulting tendency to use criteria that have been developed for fresh water systems. Because of the complexity of the marine system, many of the measures used in the fresh water environments are of questionable value or at least difficult to interpret. Although there has been a considerable amount of work done, there still exist gaps in our knowledge of water quality requirements for the various finfish, shellfish, organisms that comprise their food chains, and other marine species. Further, much of the work that has been done on the subject has addressed itself to toxicity limits which determine the level of various materials that are fatal to marine species. This approach is undesirable because the objective for management of the marine environment is not to determine the minimum level or quality that can be tolerated, but is to maintain the quality that is necessary to sustain and enhance the fishery production and other beneficial uses of marine areas. This requirement is of particular importance because the estuaries and near-shore zones comprise the nursery grounds and habitat for 75 percent of the important marine species.

*Water quality requirements for plants*

We must be careful to concern ourselves with the plants as well as the animals present in the marine environment. Environmental, chemical, and physical requirements of important species of inshore and estuarine phytoplankton should be determined with reference to the major cations (sodium, potassium, calcium, magnesium), minor cations (manganese, molybdenum, zinc, vanadium, cobalt, copper, iron, strontium), anions (chlorine, boron, fluorine, iodine nitrogen phosphorous, silicon, carbonate, ammonium, sulphate, sulphite, sulphide, bicarbonate nitrite, and nitrate), vitamins ($B_{12}$, biotin, thiamin), light (photo-period, intensity, spectral distribution), temperature (ranges, optimum, rate of change), pH (range, optimum, rate of pH change adaptation), and eH (ranges, optimum, and rate of eH change adaptation).

Determination of the amount and chemical identification of naturally occurring antimetabolites present in sea water and determination of their effects upon the abundance and distribution of important phytoplankton species should be made. Information so derived could be very useful for managing water quality that would inhibit undesirable organisms.

*Water quality requirements for recreation*

Water quality research should not be dominated by concern for fish and shellfish alone but should also give a major consideraiton of water quality requirements for the preservation of esthetic and recreational uses of the estuarine and near-shore areas. The need for intensive research on water quality requirements for recreation is directly related to the optimum recreational carrying capacity of the estuarine area. This is particularly true for the effect of multiple pollutants acting at the same time in the same location. Consideration should also be given to public health implications; for example, the present coliform criteria for oyster production areas is highly questionable in the light of present knowledge on bacterial regrowth and the relationship of this indicator organism to the probable presence of disease-producing organisms.

*The need for nonharmful discharges*

Waste water quality criteria should be developed to assure that the discharge of waste to natural receiving waters results in a neutral or beneficial effect upon the biota of the receiving waters. Many estuarine animals are capable of ingesting and eliminating heavy metals without harm when these elements occur in natural ratios.

Artificially induced imbalances, however, can result in ingestion rates exceeding elimination causing accumulation of heavy metals in the tissues. For example, in long-term bioassay tests, severe oyster mortalities occurred due to minute amounts of chromium, nickel, and molybdenum originating from a stainless steel water intake line. The gradual increase of heavy metals and other trace elements over background values are an outstanding example of a subtle kind of ecological change in our estuaries. There are many sources of metallic contamination, some of which are known, others not even suspected. One wonders, for example, about the quantity of heavy metals originating from the use of water in households. There are many miles of copper tubing and galvanized water piping in our modern urban dwellings subject to corrosion and leaching, releasing unknown quantities of copper and zinc.

*Oil*

Because of the increase in oil pollution and the associated use of oil dispersants, it is urgent that a better understanding of degradation processes involving both treated and untreated oil spills be reached without delay. The extent and kinds of effects exerted by oil dispersants must be known so that appropriate reactions can be made when an oil-spill-induced emergency occurs. For example, oil or petroleum concentration, per se, at high levels is considered deleterious to the ecosystem and maximum levels of oil or grease are established for estuaries. However, evidence from both the *Torrey Canyon* and Santa Barbara oil spills indicate that some crudes and petroleum byproducts are excellent substrates for many organisms, becoming part of an enriched food chain, while others may be either poisonous or have virtually no food value. Thus, one must know not only how much oil and grease is present, but also their compositions and their effects on important plants and animals. Much of the mortality in these accidents was caused by the dispersant and not by the crude oil.

## NATURAL VARIABILITY

A major gap in our knowledge of estuaries is an understanding of natural variability. While there is a growing backlog of information on natural variability within populations of certain estuarine animals, the fluctuation of those parameters of the environment (such as temperature, dissolved oxygen, salinity, $CO_2$, pH, turbidity, etc.), which are recognized as controlling mechanisms for population distributions, are poorly understood. Maximum and minimum values, duration of excursions (period of increase, plateau, and decrease), and time trends (ranging in intervals from hours to decades) in these environmental parameters must be intensively studied so that pollution effects due to man's activity may be separated from natural environmental fluctuations. We must also develop knowledge of the natural variations in water quality that are encountered in estuarine and near-shore areas in order to provide a basis for interpreting changes that are brought about by human activity. Tidal flats and other estuarine areas rich in various biological forms are highly productive. There is a continual cycle of life, production, death, and decay in these areas which apparently operates at a much higher level of activity than might be encountered in fresh water systems. The magnitude of water quality variations, caused by these natural effects is for the most part unknown. Without knowledge of natural variations in water quality, it is nearly impossible to set water quality standards.

*Range of natural variation*

An outstanding illustration of the need for understanding natural variability is found in the Patuxent River, Md., estuary studies. A long-term drought has resulted in an intrusion of a saline wedge into the upper reaches of the river. A powerplant has been introducing thermal effluents into the river. It has been impossible to distinguish between thermal effects and effects of the saline wedge (resulting from a long term natural fluctuation) on the river animals in many instances. In this case, a history of intensive physical observations, correlated with occasional biological surveys accumulated over an extended period of time (such as has been extensively discussed earlier in connection with baseline studies), may well have resulted in a basis for separating the natural from the manmade alterations in animal populations. These observations need not have been carried out on the Patuxent River itself, but rather need only to have been concerned with the detailed documentation of saline encroachment into a brackish system.

Another example of the importance of knowing natural variations occurs in the bays along Texas, Louisiana, and other areas of the Gulf coast. In general, these bays are shallow bodies of water with large surface areas. They are thus subject to natural buildup of temperature and salinity. While the fauna of these areas has adapted to the natural buildups, the discharge of heated waters and reduction of freshwater inflows may result in buildups to a level above that of any natural condition. In order to provide a firm basis for the evaluation of the effects of proposed thermal and high dissolved residue content waste discharges, investigations into the temperature and salinity characteristics of each estuarine area are needed. Correlated with this is the need to understand the biological principles of estuarine management.

*Timing of natural variation*

For the most part, we know that brackish water is necessary for the maintenance of a large fraction of our coastal fisheries. We do not, however, know exactly what are the limits of salt concentration that will encourage optimal development of desirable species. In addition to this, we have little idea of the optimal seasonality of salinity changes. Although it is apparent that a seasonal fluctation of salinity may be desirable, we scarcely have an idea as to when it would be best to reduce or raise the salinity. We do know when certain important food animals reproduce, so we might assume that reduced salinity would be most optimal at this time, but we do not know what would be the effects of raised salinities in other seasons. All work of this kind on natural variations ties back to the baseline studies proposed earlier in this report.

## INTERFACE FACTORS

An important portion of understanding the ecology of the estuarine system is a knowledge of interface factors. By this we mean the exchanges which occur between the estuarine waters and offshore waters, the influx of fresh water and other drainage from the land; between the water mass and the bottom sediments; and between the water mass and the atmosphere. Another area of interface concern, the movement of materials between the biological compartment and the aquatic compartments of the estuary, is the major theme of much of this chapter and hence will not be discussed here.

*Land drainage—estuary—sea interface*

Because the estuary itself is the interface between the sea and the land, the ocean-estuary interface and the estuary-land drainage interface are complementary in many ways. The alteration of either one is reflected in the change in effect of the other. In some cases the estuary is a gradual continuum from fresh to sea water; in others the lines of demarcation are abrupt and well defined. The most obvious physical demarcations of land drainage-estuary-sea are based on salinity, thus, the discussion of these two interfaces is combined.

It is established that various biological life is dependent on salinity gradients throughout the estuarine zone. For example, the high value of the Gulf coast shrimp industry is dependent on the bays as nursery grounds; however, the amounts and quality of fresh water required to support the ecological system of each individual bay has not yet been established. This is a pressing research need.

Fresh water inflows of many of our bays have already been reduced or altered through construction of upstream water supply dams. In addition to the obvious effect of increasing salt water intrusion into fresh water systems of the riverine flows, we must also know how the estuarine habitat is being limited by this increased salinity due to increased ocean influence and the reduced mass of water in a more brackish condition. The same question might well be framed with any of the many other forms of parameter alteration that have occurred. Temperature increase in critical areas might be extremely important, perhaps far in excess of the actual amount of water being affected, for if a critical area is affected, we might find ourselves with a situation of a "gate" that has been closed and whole areas of a formerly beneficial ecosystem removed from use by desirable organisms.

*Residual pollutants*

Residual pollutional material such as trace organic compounds and minerals, pesticides, herbicides, heavy metals, etc., are reaching estuarine areas from either surface runoff or riverine inputs. The specific kinds, amounts, and effects of these compounds are generally unknown. Investigations are needed to identify and quantify the residual pollutants and to evaluate their pollutional effect. These investigations should include, but not be restricted to, shellfish, tissue buildup of residuals, tainted fish flesh, destruction of food chains, and intrusion into other standing compartments of the estuarine ecosystem such as the sediments, the marsh, or the major rooted aquatic plants therein.

*Contiguous wetlands*

There also needs to be a thorough study of the relationship of contiguous wetland to estuarine ecological systems, including the effects of drainage on estuarine water quality. The salt marshes which are irregularly flooded are especially important. These are areas which are flooded by tide only at sporadic intervals, and consequently, there is no regular interchange of water with the estuary. It has generally been assumed, and what scanty data are available support the assumption, that such marshes contribute very little to the estuary in the way of organic matter and nutrients. The case for the importance of regularly flooded marshes has been made convincingly and consequently there is general agreement on the importance of their preservation.

People tend to regard the irregularly flooded marsh as expendable, and the pressures for modification of this habitat rapidly are becoming greater. More data is needed in this area in order to make informed decisions as to whether or not we can sacrifice large acreage of the irregularly flooded marsh. One of the most active programs in these areas has been ditching and draining for mosquito control. There is considerable disagreement as to the impact and value of this kind of activity; it can be argued that it is beneficial—while others feel that it is detrimental. Probably a case can be made for both points.

*Bottom sediment—water interface*

The bottom sediments represent an important element in the balancing of the marine community and must be included in any consideration of estuarine management. Disturbing these sediments by dredging or by the working of bottom animals such as worm and fish, can reintroduce materials which have become associated with the bottom sediments into the water mass. Heavy metals, pesticides, herbicides, nutrients, oil residues, and many industrial chemical mixtures are examples of the kinds of materials which become incorporated into the bottom. For example, lead is found present in almost all types of deposits in amounts varying from 70 to 580 parts per million on a dry mud basis. Most of this lead comes from atmospheric pollution which has passed through the waters, precipitated, and adsorbed to bottom sediments. The presence of high concentrations of copper varying from 209 to 600 parts per million on a dry mud basis are also found. These are due to sewage effluents containing human excreta. Nickel is present in amounts ranging from 290 to 1,300 parts per million in muds which are polluted with industrial waste. Investigations of conditions effecting the biological and chemical release of adsorbed or precipitated nutrients and toxicants from marine benthic environments are essential. The bottom sediments also serve as a reservoir into which these materials may be extracted from the water mass. They can also serve as the reservoir of carbonate materials which help to maintain the innate buffering system of marine waters. Thus, any consideration of the estuarine ecosystem must include full understanding of the relationship between the bottom sediments and the overlying water mass.

*Air-water interface*

The fourth major interface, that of the water and the atmosphere, frequently is ignored in investigations. These interfaces are characterized by surface films which are areas of concentration not only of surface active materials, but of bacteria and other micro-organisms as well as inorganic particles of various kinds. These natural films should be distinguished from layers of oil which are much thicker and possess different properties. They occur on the sea surface around all islands and along all continental shores and, hence, are characteristic of estuarine zones. They travel with the wind at speeds approaching the wind speed and can rapidly concentrate materials along shore lines, especially on a windward coast. These effects are very important in case of associated radioactive pollution, as well as bacterial pollution. Some of the surface active materials are of natural origin and are greatly increased by agents that kill marine organisms. Other film-forming materials result from oil spillage. The film, from whatever source, changes the transfer rate of gas through the water surface, the sinking rates of inorganic particles, and the distribution of small organisms. Research is required to better understand the origin, distribution, and importance of surface films.

SUMMARY

A. Baseline studies

1. Inventory biological, physical, and chemical characteristics.

2. Answer key management questions of habitat requirements (how much and what kind) for adequate numbers of plants and animals.

3. Studies of unpolluted estuaries are essential for comparative bases against which to measure changes.

B. Broad ecological studies

1. Expand baseline knowledge to provide understanding of estuarine ecosystems, the effects of pollution and environmental changes.

2. Study the mechanisms and course of recovery of an area after halting pollution as well as methods of reestablishing a physically damaged estuarine ecosystem.

3. Develop techniques to determine and predict the effects of changes in the environment on the resources we want to utilize.

4. Develop better estuarine husbandry programs, augment aquaculture, and generally improve estuarine management.

C. Biological Studies

1. Determine food webs and trophic relationships.

2. Determine life cycles and the relationships between estuarine residency and offshore fisheries.

3. Determine what it is about the estuary that makes it so suitable as a nursery area and quantify habitat requirements for spawning and nursery functions.

D. Water quality considerations:

1. Determine water quality characteristics of receiving waters and develop a realistic program of water quality management.

2. Study the effects of combined wastes, i.e., multiple pollutants.

3. Ascertain water quality requirements for desired uses.

4. Develop water quality criteria for optimal beneficial use rather than minimum tolerable quality.

E. Natural variability:

1. Determine the natural variability of the biotic populations as well as of the physical-chemical environment and water quality.

2. Learn to distinguish between the effects of natural variability and of man-induced alterations.

F. Interface factors:

1. Determine the amounts and quality of fresh water required to support the desired estuarine ecosystem.

2. Identify and understand the characteristics, the phenomena associated with, and the influence of the estuary-ocean and estuary-fresh water interfaces.

3. Identify and quantify the residual pollutants introduced by land drainage and their effects.

4. Determine the relationships of contiguous wetlands to estuarine ecosystems.

5. Determine exchanges between the bottom sediments and the overlying water mass.

6. Increase understanding of the origin, distribution and importance of surface films.

7. Determine exchanges between the atmosphere and the estuarine water mass.

It is evident that a fresh new approach to ecological research is necessary if we are to gain needed knowledge and understand estuarine ecosystems in time for it to be of value for management decisions. If the old patterns of investigations are followed, wherein detailed studies by many investigators are made on individual species, it is quite probable that answers will be unavailable in time to be of any real value in shaping decisions for the management of estuarine zones. A highly coordinated approach to this problem is needed. One approach would be to concentrate research in a number of centers where a high degree of proficiency exists, developing a system of coastal laboratories to satisfy both national and regional needs. Extramural reaserch for the most part would probably be done under contract to assure appropriate direction in terms of national goals, bearing in mind, however, that this direction should take full advantage of consultation and advice from knowledgeable scientists and engineers from all segments of the industrial, academic, and government communities.

## Section 5. Toxicity

All too often data required to interpret toxic conditions are obtained solely through field observations after the environment has been irreversibly changed and an ecological catastrophe has occurred. Predictions and management decisions based on this kind of information are poor at best. The only way that the knowledge needed by managers to cope with potentially toxic situations can be available in time to be useful is by having previously established tolerable levels of pollutants, developed through bioassay techniques, and appropriately extrapolated to natural conditions. Toxicity studies would be concerned not simply with levels at which a species could survive, but also at what levels it will reproduce to complete its life cycle without significant change. From such studies, criteria could be established much as they are for public health measures, but relevant to the organisms as well as to man. Only through such long-range programs can the desirable biologically productive aspects of estuaries be preserved and the other beneficial uses augmented.

### SUBLETHAL EFFECTS

There is a growing awareness that, in the long term, the major concern should be for an understanding of sublethal chronic effects in order that realistic water quality criteria may be developed based upon the interrelationships within ecological systems. Much of the presently available data have been derived from acute toxicity tests on adults without adequate consideration of the chronic effects upon the development of organisms and communities. There is an urgent need, therefore, for diversified programs to develop new indexes of toxicity at the individual, the population, and the community levels, with emphasis on long-term exposure at sublethal concentrations.

*Food chain effects*

The outright poisoning of various organisms is easily recognized. Perhaps an even more important problem is the effect of various toxicants present in concentrations which reduce the populations of food organisms to such a low level that they are inadequate for the forms depending on them as a food supply. For example, fish such as salmon, migrating downstream, will be feeding on their way to sea. If these young fish are feeding on a subadequate food supply, then they must be in a weakened condition for their subsequent journey in the ocean and, thus, be more susceptible to attack by predators and disease than they would be otherwise. Various kinds of pollution such as toxic materials or heated effluents could cause such results.

Another food chain effect is the phenomenon of biological magnification. Biological magnification is an additional chronic effect of toxic pollutants (such as heavy metals, pesticides, radionuclides, bacteria, and viruses) which must be recognized and studied. Many animals, and especially shellfish such as the oyster, have the ability to remove from the environment and store in their tissues substances present at nontoxic levels in the surrounding water. This process may continue until the body burden of the toxicant reaches such levels that the animal's death would result if the pollutant were released into the bloodstream by physiological activity. This may occur, as in the case of chlorinated hydrocarbon pesticides (such as DDT and endrin) stored in fat depots, when the animals's food supply is restricted and the body fat is mobilized. The appearance of the toxicant in the bloodstream causes the death of the animal. Equally disastrous is the mobilization of body fat to form sex products which may contain sufficiently high levels of the pollutant so that the normal development of the young is impossible.

The biological magnification and storage of toxic residues of polluting substances and micro-organisms may have another after effect. Herbivorous and carnivorous fish at lower trophic stages may gradually build up DDT residues without apparent ill effect. Carnivorous fish, mammals, and birds preying on these contaminated fish may be killed immediately or suffer irreparable damage because of the pesticide residue or infectious agent.

A great deal of work must be done to determine the significance of the phenomenon of biological magnification. We must develop techniques for predicting potential hazards before toxic material is introduced into the environment; and poisons must be used so as to minimize the possibility of biological magnification.

## BIOASSAY CRITERIA

Bioassay criteria are sorely needed to determine the effects of thermal, domestic, and industrial wastes. Synergistic effects of pollutants must also be known and understood. Once the tolerance limits of individual species for individual pollutants is known, the effects of combinations of various toxicants and physicochemical water characteristics should be determined, since combined effects are often worse than the sum of individual effects.

*The need for bioassay procedures and field testing*

The ultimate goal should be the development of rapid, practical, and definitive bioassay procedures. These procedures should be designed for multiparameter analysis in order to correlate the response to a variety of common pollutants and environmental variations. In this way, effective water quality criteria can be developed coupled with a capability for predicting biological effects. A major problem in the development of these practical bioassay procedures to determine the water quality requirements of estuarine and marine organisms is the lack of suitable testing methods. There is always the question about the realism of work done in a laboratory; that is to say, how truly results so derived reflect what takes place in nature. Test organisms in the laboratory are certainly not confronted with the complex interacting factors which occur in the natural environment. Under natural conditions, there may be a rapid reduction in the concentration of a toxicant by precipitation, absorption on soils and bottom materials, chemical decomposition, reactions with other substances in the water, absorption by microscopic organisms, removal by organisms, or biochemical degradation. Accumulation of toxicants in the food chain and ingestion of food organisms bearing relatively high concentration of these materials may increase the exposure to higher animals.

Laboratory findings on the safe levels of potential toxicants must be field tested under conditions wherein the organisms in question are exposed to all stresses occurring in the natural environment. When developed, tested, and evaluated, field studies can be used for simultaneously testing the entire community under natural conditions. Such studies integrate the effects of biological magnification; storage, passage through the food chain, accumulation in bottom materials, competition for food, cover, and living space; disease, parasites, and predators; synergism, antagonism, and the interaction of materials; and all other complicating factors present in the natural environment.

To be a truly useful management tool, a catalog should be developed indicating the tolerance levels of plant, animal, and bacterial estuarine species for the pollutants so commonly found in the estuaries: sewage, heavy metals, industrial wastes, runoff from urban and agricultural areas, oils, and a host of other materials foreign to the estuarine environment.

### SUMMARY

Wise management decisions require knowledge of the effects of potentially toxic substances as determined by long-range bioassay procedures extrapolated to natural conditions. Environmental levels of toxicants which do not inhibit any portion of the life cycle, food chain, behavior, or exert any detrimental sublethal effects must be determined.

## Section 6. Microbiology

Microbiological aspects must be considered in a special category because of their widespread and diversified influence. Bacteria serve to break down dead organic material and wastes into inorganic nutrients necessary for plant growth. These nutrients in moderation and in proper balance make possible the normal algal productivity which, in turn, supports all animal life. In excess or imbalance, these nutrients permit or encourage eutrophication, the accelerated superabundance of algae to nuisance conditions. Bacteria are responsible for causing foul odors, unacceptable bottom conditions, digusting slimes that foul fishermen's nets, and depletion of dissolved oxygen in the water which drives out fish and other desirable organisms. Bacteria, protozoans, and viruses are extremely important as disease organisms, both to humans and to desirable estuarine plants and animals.

## ALGAL GROWTH PROCESSES

As more and more studies determine that eutrophication is a major current or potential concern in our estuaries, it is imperative that we seek to understand the cause-effect relationships governing algal growth processes. Both field and laboratory studies are required. The actual impact of nutrients on estuarine eutrophication problems must be understood. We must establish the major nutrient concentrations allowable in various estuaries based on watershed characteristics, influent stream concentrations, and the overall watershed management policies. An approach often overlooked on this topic is the complementary use of experimental studies and modeling techniques in which each is employed to direct the development of the other in the same way as computer analyses and test flights have interacted in the space program. Certainly, more knowledge will have to be developed about the rates and conditions under which organic material is mineralized by bacteria to the active chemical stage where it can be reincorporated into new plant material.

## ECOLOGY AND ENVIRONMENTAL REQUIREMENTS OF MARINE BACTERIA

Detailed knowledge of the environmental requirements and ecological relationships of marine benthic bacteria and of attached algal forms as well as the free-living and more economically important marine species is necessary to insure that environmental changes allowed do not effect water use at a point many biological steps removed from the initial effect. Studies of factors involved in natural population succession and natural fluctuations in populations of a single species and/or a community of species are required when it becomes desirable to control these natural changes. It is certainly necessary to recognize them as factors affecting management of natural resources. It must be borne in mind that bacteria themselves are an exceedingly valuable prey species as well as is the phytoplankton whose development is made possible by the mineralization activity of bacteria.

### *The use of indicator bacteria*

In order to assess biological contamination and potential health hazards in estuaries, adequate bacterial assay techniques are necessary. The use of indicator bacteria, mainly fecal coliforms, is the major and most widely used detection system. Current water quality criteria for contact recreational waters place emphasis on fecal coliform data and consider this group to be a more realistic indicator than total coliforms of the presence of pathogenic micro-organisms. It has been the practice to utilize techniques that are workable for fresh water systems. As a result, the widely accepted rapid MF (membrane filter) fecal coliform procedure is being used for salt water bacterial analyses. Only recently have attempts been made to assess and verify the reliability of such MF techniques for bacterial assay in salt water. Apparently, interferences and factors associated with the saline environment cause coliforms and pathogenic microorganisms to behave differently than when in fresh water. These studies have revealed specific problems and indicate the need to develop information concerning behavior of these indicator bacteria in salt water. Examples of needed work include improved procedures for specificity and recovery of MF fecal coliforms, determination of growth characteristics of fecal coliforms, and establishment of whether the "after growth" phenomenon exists in estuaries; establishment of *in situ* survival patterns of fecal coliforms in various conditions of temperatures, salinity, and nutrient levels; establishment of the relationship between fecal coliforms and pathogens; and development of rapid detection systems and continuous bacteria assay devices to monitor shellfish waters and bathing beaches.

*Pathogenic bacteria*

Recent studies have shown that *Salmonella* are more prevalent than once believed to be. *Salmonella* have been isolated from polluted estuarine waters on numerous occasions and have been isolated when low numbers of fecal coliforms were present. The *Salmonella* data, however, are qualitative and give no true indication of densities initially present in the water.

Because of the repeated demonstration of *Salmonella* in polluted estuaries and shellfish harvested from such waters, such organisms pose a serious potential human health hazard. Methodology for detection, identification, and quantitation of *Salmonella* are essential for establishing the presence or absence of these pathogens. Associated needs are to develop a rapid detection system for quantifying and identifying *Salmonella* serotypes; determine the growth characteristics of *Salmonella* and establish whether multiplication occurs in the saline environment at various temperatures, salinities, and nutrient levels; develop *in situ* survival patterns to determine relative persistence in salt water and establish the relationship between *Salmonella* and the fecal coliform group of bacteria.

The fecal streptococci have provided supplementary data when the fecal origin of coliforms has been in question and when the recency of contamination had to be ascertained. Because of specific animal strains, such as *Streptococcus bovis*, and *Streptococcus equinus*, animal contamination can be detected and separated from human waste sources. However, as with fecal coliforms, data on the efficiency of detection and on the behavior of fecal streptococci in salt water are limited and need to be developed. Desirable investigations should involve increase in the specificity of recovery media; establishment of the various conditions of temperatures, salinity, and nutrient levels; *in situ* survival patterns of fecal streptococci, establishment of the relationship between fecal streptococci and *Salmonella*, and development of rapid detection and identification systems amenable to continuous water quality monitoring.

Parallel studies should be done for other disease-causing organisms such as the viruses and microscopic organisms such as the viruses and microscopic organisms that produce toxicants such as *Clostridium* and *Gonyaulax.*

Another group of pathogens sorely in need of research and understanding are those which affect desirable estuarine organisms. Crabs in Chesapeake Bay have been known to suffer epidemics of viral diseases. Oysters in the Northeast have been subjected to, and nearly eliminated from large areas, by the disease MSX. A great deal of work must be done to determine the extent and variety of these disease-causing organisms and to develop control measures so that desirable crops might be maintained. The ability to protect economically important organisms is essential before aquaculture can be pursued on a profitable basis.

#### SUMMARY

1. The cause and effect relationships of nutrient supply, bacterial action, and algal growth processes must be better understood. Environmental conditions inducing and supporting nuisance eutrophication must be controlled.
2. Detailed knowledge of the environmental requirements and the ecology of estuarine bacteria should be developed.
3. More must be learned about coliform bacteria as indicators of pollution. Methodology appropriate for estuarine waters must be made more definitive.
4. Methodology for detection, identification, and quantitation of *Salmonella* and other disease organisms must be developed. The persistence and transmission of disease organisms must be better understood and methods of control developed.
5. A great deal of work must be done to determine the extent and variety of organisms which cause disease in desirable organisms, and control measures developed.

## Section 7. Physics and Mathematics

The specific kinds of research that must be done within the physical and mathematical aspects of estuarine management fall generally into the broad categories of hydraulics, sedimentation, physical modification and structures, and physical and mathematical modeling.

#### HYDRAULICS

*Scope*

The briefest statement of what is needed in hydraulics is an understanding of the water dynamics of the estuary, including details of tidal and current regimes, an evaluation of the effects of river flow, rates of water exchange, characteristics of flushing, and all of the other phenomena related to the nature and behavior of the fluid portion of the estuarine zone.

*Flow characteristics*

A starting point in understanding the hydraulics of an estuarine system would be an analysis of macroscopic flow and circulatory patterns including seasonal discharges from rivers, seasonal temperature inputs from rivers, density aspects (completely mixed versus stratified

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estuaries), tidal cycles, effects of wind stress, effects of upstream reservoir management, of flow quantity and quality, measurements of direction and magnitude of water masses, and of velocity relationships.

*Flushing characteristics*

Closely related to a knowledge of the flow characteristics of an estuary is a more detailed knowledge of its flushing characteristics. It appears that we know very little about the true flushing time of many of the contaminating conservative materials which are in solution. We, of course, can make use of the freshwater-saltwater relationship to arrive at some estimate of flushing time, but, it is extremely doubtful whether information so derived applies to nutrients or such materials as pesticides or other nonconservative materials. Many of the nutrient chemicals become trapped in the biomass distributed throughout the estuarine zone and, thus, nutrients may not be flushed as would be predicted from a knowledge of the behavior of the water mass. The same thing can happen with pesticides. For example, studies on the Mississippi River tend to indicate that pesticides are complexed onto sediment particles which then settle to the bottom, resulting in a very high level of pesticides near where sediments build up and a fairly low level in other areas. In other words, in a bay or estuary, pesticides and other compounds may tend to be trapped on sludge or sediment particles and not be passed out into the ocean. This provides a reservoir of undesirable materials which, as discussed earlier, may become reintroduced into the water mass or the biotic compartments. These caveats notwithstanding, an accurate and quick way of determining flushing characteristics of an estuary would still be extremely valuable. Adequate methods of quickly determining flushing are imperative before any other studies can be meaningfully undertaken, because all estuarine characteristics are regulated to some extent by flushing.

This approach leads naturally to a classification of estuaries by type describing flushing rates as a definition of salinity patterns, mixing rates, and extent of salt water intrusion. The true value of all this would be to develop predictive capability of estuary flushing which, in turn, will yield understanding of what will happen to introduced wastes and of the assimilative capacity of the receiving waters. Such predictions, if reliable, are important in an estuarial water quality management program. Further investigation of the feasibility of this should be encouraged.

*Mixing and transport processes*

Mixing and transport processes are important aspects of estuarine hydraulics. A considerable amount of research on diffusion and dispersion of wastes has been done and a body of knowledge appears in the literature. Many feel that research in these areas has generally fallen into two classes. It has either been too descriptive to permit the transfer of specific knowledge to other estuarine areas or it has consisted of a highly complex and idealized mathematical solution that cannot be applied reliably to another estuarine area. Although the technology for predicting probable water quality effects in freshwater streams has advanced to the point where predictions can be made with some degree of reliability, the same circumstance does not exist for estuarine areas. Applied research to develop practical predictive methods is necessary in order that management agencies can approach water quality problems in a given estuary without first mounting a large-scale, expensive, and time consuming field investigation to define the assimilative capacity of the estuary through classical methods. Inputs into such a technique, of course, demand knowledge of the sources, characters, amounts, and time distribution of polluting discharges, including urban and agricultural land runoff as well as discrete sources.

At the other end of the estuary is the exchange with the ocean. The hydromechanical exchange which occurs between the estuary and the ocean is an extremely complex phenomenon about which little is known. This is a significant factor in the loss or retention of water quality constituents in the estuary and is related to all of the other discussion on hydraulics, sedimentation, and other physical aspects. All kinds of modeling activity require qualitative and quantitative data on ocean exchange, particularly in areas like Monterey Bay which have an ill-defined interface with the ocean.

*Ground water*

Not to be overlooked in any investigation of the hydraulics of an estuary is an understanding of the ground water to surface water relationships, including subsurface water discharges and salt intrusion. This calls for knowledge and quantification of the chemical and physical characteristics of ground water and ground water flow in the estuaries.

*Engineering controls on water movement*

A natural sequence of an understanding of the hydraulics of an estuary would be the utilization of this knowledge in engineering controls on water movement. Apparently, little work has been done to take advantage of the energy contained in the moving water for the purpose of flushing and bottom-cleansing action. The research question would be: "Is it possible to design engineering works that utilize water movements, including, tidal action of estuarial flushing and bottom-cleansing?" This question warrants investigation.

## SEDIMENTATION

Substantial pollution problems in estuaries result from the effects of benthic deposits. These in most estuaries represent a heritage of pollutional materials brought in over the years by streams, outfalls, and sewer overflows discharging into the estuaries. Research is called for to provide an adequate knowledge of how to prevent and control the effects of this material. Such research should be directed to methods for determining the origin of bottom deposits, their physical characterization, acceptable measurement techniques, transport phenomena, effect on the ecology of the system, and the die-away and fate of these materials. The ultimate question is, of course, how to prevent undesirable sedimentation from increasing and how to get rid of existing deposits economically and efficiently. It may well be that practical solutions to this problem will not be forthcoming. In this case, dependable information on the natural die-away characteristics of bottom deposits would be very desirable. Studies should be made toward developing biological systems or marine sludges capable of degrading industrial and domestic wastes discharged into marine waters.

*Dredging and spoil*

The pollution effects resulting from dredging operations are part of the problem of control of undesirable bottom deposits. Conceivably, dredging may be offered as the method of choice for removing objectionable bottom deposits; thus, the disposal of such dredgings is a matter of importance and additional research on its handling and disposition should be pursued. Much of the spoil from commercial and navigational dredging operations is deposited in the low-lying marsh areas. As the value of wetlands increases, other areas for spoil disposal must be developed.

One possibility is the use of spoil for reclaiming certain areas. If this is possible, the structural properties of the spoil must be improved so that it will stabilize when placed in these areas. Methods, procedures, and additives which would help to stabilize these materials should be investigated.

*Offshore and near-shore dumping*

Much material is dumped offshore. Offshore dumping is a method of disposal for both solid and liquid materials in the open sea. It includes discharge to coastal waters, both within and outside the territorial waters of the United States. In shallow areas, much of this material is subject to complicated energy forces which vary from day to day. Wind forces appear to exert stronger influences in shallow areas than are generally encountered in deeper waters, perhaps further inshore. Because of this, much more information is needed on wind, tide current, and other offshore or onshore hydraulic effects before the fate of dumped materials can be accurately predicted and a program of disposal wisely managed.

*Sources and rates of sedimentation*

We need to develop new and improved ways of measuring sedimentatation rates, including model studies to evaluate methods of curtailing sediment deposition and more effective and beneficial means of sediment removal and disposal. We need to know what levels of sedimentation rates are tolerated by organisms, and what levels are damaging to desirable organisms. Since organisms are affected differentially by sedimentation processes, rates of change would have to be studied specifically for key individual species. Another source of sedimentation is the flocculation of colloidal suspensions of materials entering sea water with resulting deposition at the salt water interface. In order to avoid the problems of silting and deposition of sediments within lagoons or in channels, we must know more about rates of filling, mechanisms of clay and silt deposition, and concentration of organic debris and pollutants in sediments and in marsh vegetation.

## STRUCTURES AND PHYSICAL MODIFICATIONS

It is well known that structures and physical modifications within the estuary may change the hydraulic, biological, sedimentological, and many of the other characteristics of the area. While it is desirable to reduce our activities of this nature, it is probable that pressures of population and economics will force continuing estuarine construction. As construction takes place within coastal areas, many changes will occur in the estuaries. The effects of these changes should be known before constructing industrial plants, homes, highways, or airports; dredging canals or draining marshes. This sort of information is especially essential if a meaningful permit review system is to be instituted and maintained. Physical alterations of estuarine and coastal zones by dredging, filling, bulkhead construction, ditching for mosquito control, and construction of new marsh requires investigative work that would determine the effects on water quality, the effects on biological life, and the effects on hydraulics. Special attention should be paid in the development of new harbors to retain or enhance the structural components necessary for those organisms requiring protected waters for their reproductive activities.

## PHYSICAL AND MATHEMATICAL MODELING

Estuarine systems will continue to receive heavy utilization for all types of man's activities. Population trends indicate that coastal areas are attracting a disproportionate percentage of our expanding populations. With this trend we also have the industrial activities necessary to support the economy. At the present time, we cannot predict accurately the assimilative capacity of estuarine systems, nor can we predict the degree of degradation that will result from the engineering projects proposed as necessary to provide the supporting services for the social and industrial structure.

The solution to these problems might well be approached by simulation techniques. It is urged that efforts be intensified to provide physical and mathematical models of estuarine systems which are being subjected to population and industrial pressures. Experience indicates that when such models are available they are used extensively by Federal, State, and industrial interests to provide guidance for the proper management of estuarine resources.

Two systems of simulation or modeling are normally considered: the physical model and the mathematical model. Probably the true utility of the physical model has not yet been established. The development of such a model for an important estuary has a great deal of appeal for teaching, demonstration, and to some extent for control purposes in addition to the predictive capability rendered. There is no question that advantages of such a model are clear for teaching and demonstration. What is not as clear is the extent to which such physical models may be employed to predict and solve problems of pollution, sedimentation, physical modification, and structures in the estuary.

The use of mathematical models to simulate the dynamic phenomenon of the estuary has only recently been subjected to rigorous examination. Research in this area should be encouraged. A complete appraisal of the relative merits of physical and mathematical models should be made. The advantages and disadvantages of each type of model for different purpose studies should be fully delineated.

Finally, to complete the objective of optimally maintaining or enhancing estuarine water quality, management models need to be developed and demonstrated which will determine the optimum control strategy drawing upon all of the aforementioned quality control techniques.

*Physical models*

Physical models can be considered essentially as three types. One type, and perhaps most dramatic and most expensive, is one in which the complete water mass and its basin under consideration are constructed in a scale keeping with that of the natural configuration and in which the natural forces working on that basin can be applied and varied at will. This sort of model is used effectively by the Corps of Engineers and a great deal of excellent information has been derived from them. Of all of the possible modeling alternatives, this is probably the most useful and, hence, should be the most widely applied for each of the major estuaries and minor estuaries of special interest in the country. Research is needed to obtain similarly reliable information without going through the expense and time required to construct these.

Another kind of model is one in which a specific machine is developed and constructed which will reproduce certain of the natural phenomena in the laboratory. These normally are flumes, wave basins, or some other single-phenomenon simulating device.

Utilizing these laboratory simulation devices, the following studies should be conducted.

(a) Large movable flume tests using the typical range of littoral drift material (sand and shell) found along the coast are essential to verify or modify the various sediment transport formulas; determine lower and upper limits for application of such formulas; improve definition of roughness coefficient with changing geometry, sand riffles, and dunes; and determine definite usable values of entrainment functions and tractive force (bottom shear stress).

(b) Utilizing three dimensional wave basins, studies should be done to help yield first approximation designs of inlet and inlet model studies to help locate and determine the size and shape of jetties; determine effects of winds and waves on tidal flow, erosion, siltation, sediment transport, and sand bypassing; and check the effects of density currents on flow and sediment transport. Information of this kind allows a revision and refinement of inlet designs. Studies should be done to determine the effects of changes in tidal differentials, changes in circulation and efficiency of mixing, and structural modifications for controlled water releases, for restoring and improving internal circulation, for enhanced fishery environments, and for augmented assimilation of treated return flows.

A third method of physical modeling is to use a portion of an actual estuary. Such model estuaries have the dual advantages of providing both a natural environment and a means of control over many variable factors. Model facilities are built outdoors in a relatively unpolluted bay near its mouth. Proximity to the open ocean assures waters with salinity values sufficiently high to support a wide variety of organisms the year around. Adjustment of salinities is accomplished by adding fresh water from some nearby source such as a stream. Renewal of the water in the facility is by natural tidal action through properly designed tide gates. Currents of varing velocities are maintained by the use of recirculating pumps or paddle wheels. Various types of bottom substrates are provided to meet the requirements of a wide variety of benthic organisms.

Studies using the above-described model estuary facilities provide a controlled natural environment for determining realistically the water quality requirements of estuarine organisms. A corollary objective is to determine how various pollutants affect the water quality requirements of estuarine organisms and ultimately their productivity. It is apparent that properly conducted, comprehensive studies of this type would take a great deal of time, effort, and money. Significant economies can be achieved in all of the latter if the model facilities would be successfully miniaturized. Other advantages to the use of miniaturized model estuaries greater flexibility in the study of variable factors and a substantial reduction in the quantity of pollutants required for testing. A basic requirement for such model facilities is the ability to maintain on a self-sustaining basis the biota representative of the parent bay. Accordingly, the initial phase of study would be concerned with developing the various size model estuaries to determine the degree of miniaturization possible without sacrificing the basic requirements.

Development and use of model estuaries would be especially suited for supplying much of the water quality information identified by the National Technical Advisory Committee on water quality requirements. It also would serve as a bridge between laboratory and field studies and, as such, assume a priority role as a research need.

*Special values of physical modeling*

The value of physical models of the tidal and estuarine environment lies in their adaptability of use to study a wide spectrum of problems. Some of the most significant are: flooding due to hurricane surges; efficiency of tidal mixing and the resulting salinity distributions; diffusion, dispersion, and flushing of waste discharges (sewage, chemical, thermal, etc.) in bays and estuaries along the coast; shoaling and erosion in bays, navigation channels, coastal inlets, etc., due to deposition of dredging spoil, and river and coastal sediment movements; improvement and verification of designs for navigation channels, estuarine coastal structures, tidal inlets, jetties, etc. They provide a means of determining in advance the effects of channel deepening, jetty extension and construction of new jetties, the effects of land fills and destruction of parts of tidal flats, and the effects such projects would have on the total physical picture of an estuary.

*Mathematical models*

Mathematical models have the advantage of requiring little expensive construction and maintenance. They are basically expansions of equations of state of various physicochemical phenomena in a water course. They theoretically should allow for proper consideration of all of the variables, when known. Simulation is done through computer techniques and, hence, has the advantage of speed and flexibility. The drawback in the application of these models is the need to know.

understand, and quantify every one of the factors of the system being modeled. In the absence of any portion of this kind of information, assumptions must be made. The more complicated a system, the greater the area of ignorance, the more assumptions must be made, and the less confidence can be placed in the results. To date, effective mathematical modeling activities have been applied for some of the more important water quality parameters, such as dissolved oxygen, in some of the simpler estuarine systems. The research need here is to overcome all of the difficulties and satisfy the drawbacks just stated. Obviously, this approach should be most valuable if and when perfected.

SUMMARY

A. Hydraulics:

1. Develop complete understanding of the water dynamics of the estuary, including details of tidal and current regimes, evaluations of the effects of river flows, rates of water exchange, and characteristics of flushing.

2. Determine the source, activity, and fate of both conservative (e.g., salt) and nonconservative (e.g., pesticides, nutrients) materials in the estuary.

3. Classify estuaries according to flushing characteristics in order to enhance our predictive capability for waste disposal purposes.

4. Increase our knowledge of mixing and transport processes at the various interfaces and within the estuarine water mass itself.

5. Determine the significance of ground water inputs to the estuary.

6. Develop engineering ability to use water movements, including tidal action for estuarial flushing and bottom cleansing.

B. Sedimentation:

1. A wide range of research is required to provide an adequate knowledge of how to prevent and control the effects of pollutional benthic deposits.

2. Develop methods for mitigating the estuarine damage due to dredging activity and improve spoil disposal practices.

3. Increase knowledge of the effects of offshore and nearshore dumping.

4. Increase knowledge of the sources and rates of sedimentation and of the effects of sedimentation on the ecosystem.

C. Structures and physical modifications:

1. Determine the effects of structures and physical modifications on the hydraulic, biological, and sedimentological characteristics of the estuarine zone.

D. Physical and mathematical modeling:

1. Develop physical and mathematical modeling techniques to the level of yielding reliable predictive capability and to determine optimum control strategies for estuarine management.

2. Develop more effective and less expensive simulation capability.

## SECTION 8. SOCIOECONOMIC FACTORS

Perhaps the most important area in need of research and study is that of socioeconomic factors broadly grouped under planning, economics, and law. Unlike the previous discussions on study needs concerning technical subjects, the research and study needs to supply information necessary for wise planning is more difficult to define in terms of separable projects. Certainly, the guidelines are more diffuse and the areas of overlap are greater, for here we are dealing with human factors, with intangible values, with esthetics, and with recreational satisfactions. Further, it is in this area where we must come to grips with the conflicts existing in estuarine use and abuse. It is in this area where the hard questions subject to litigation arise, for having developed all of the information required to support technical management of the estuaries, we must now amalgamate this knowledge with a comprehensive plan of management which will provide for a program of optimum beneficial action.

## PLANNING

By definition, the need here is to establish comprehensive long-range use plans for each estuary, including industrial and recreational areas as well as wildlife and fishery preserves. A necessary balance between preservation, study, multiple use, and development of estuarine areas must be achieved in this planning, and hence, we must also determine methods for developing desirable uses in areas where none exist now. Because one of the greatest unrealized values of the Nation's estuaries will be for recreational purposes, there is a need to identify the optimum recreational carrying capacities for the various estuarine areas.

It is necessary to increase capabilities for estuarine resources appraisal, coordination, and planning to assure that research findings are used to maximum advantage and to assure that all the possible uses and all the possible available resources will receive optimum consideration in the multiple use concept of planning, development, and management of the estuarine zone. Methods must be developed which will enable the planning agency to answer questions that relate the cost of treatment applied to waste to the value of benefits attainable or resulting from such treatment. While the costs of waste treatments are reasonably well known, the value of the benefits that would result frequently are less tangible and their quantification requires first the development of an acceptable methodology for making such a study.

There is no doubt that increasing pressure will be brought on estuary planning agencies to beautify shore front land. Landscape architects and others trained in land development should do research toward developing planning criteria.

And, as is required in all management schemes, research must be done which leads up to the development of alternative master plans for the long-term uses of estuarine and land-related zones.

## ECONOMICS

The economics of conservation and development, and the planned utilization of estuarine resources must consider all aspects of the ecosystem as well as human factors. Past and present techniques have seldom defined the beneficial uses of the resource adequately. Research is needed to develop techniques which permit the consideration of social, economic, and esthetic factors as well as technological factors.

Further development of decision models which can "quantify" these factors on a design or operational basis is a high priority item in a list of needed research. A central problem of estuarine resource management is unquestionably the matter of economic evaluation and resource allocation. It is ironic that even though management activity is specifically designed to add to the sum total of human satisfactions and benefits, it is probably the most mishandled aspect of long-term resource planning.

*Estuaries resources evaluation*

To define the economic value of the estuaries of the country would require detailed studies which, while underway, are not complete. It is possible, however, to project what the loss of the estuarine areas would mean and it may be possible to apportion the increased value of restored or preserved estuaries on the basis of current patterns of usage and importance to our society. It is certain that whatever value may be placed upon the estuaries today, the value of estuaries can only be predicted to increase in the future.

We need to develop a sound basis for determining the economic and social benefits from estuarine areas and their living resources, both in terms of tangible values and their intangible returns to society. Land-water use studies to determine the real value of the estuaries for commercial and sport fisheries, recreation, navigation, and other commercial and industrial uses probably can be quantified even though there are no thorough statistics developed to document the exact value of the millions of acres of bays, estuaries, and coastlines near these estuaries.

For example, in southern California the loss of the estuaries would destroy the major resource currently available to the bait fishing industry. It would result in the extirpation of those fishes which require the estuaries during their life cycle, such as the striped bass and the croaker. It would result in the loss of a habitat for migratory waterfowl and it would result in the loss of an important area for public recreation and esthetic enjoyment. Recreation includes fishing, swimming, boating, and just being by the water. Esthetic enjoyment includes the pleasure of watching persons and animals living in their environment of the moment as well as the natural beauty of the estuary itself. We would lose the type habitat required as an example of the estuarine ecosystem for the education of our students as well as the opportunity to delve into the mysteries of life in this area through research. We would lose the example of the zone where it is most likely that animals left the sea to roam the land.

The estuaries are valuable, not only for their biological resources, for recreation, commercial harvesting of fish and shellfish, education, and research, but also as open spaces and opportunities for further development such as placing still another road, a marina, housing, plantsites, highways, or anything for which raw land is required, or for siting powerplants or any other facility for which large amounts of cooling waters are required. The current trend is to convert the natural resource of the estuary to some other use with the elimination of all other options or alternative uses.

Research and study then is needed in techniques of measuring estuarine utility which could result in added productivity of the national economy by providing standards to optimize economic consequences of estuarine resource activities. Additionally, or alternatively, since it is likely that the development of realistic evaluation procedures in this difficult area will require generations of research, recognition of marginal concepts and extra market utility in the context of risk and uncertainty would be of immense value to management policy and program formulation.

*Pollution control*

In the specific area of water pollution control, studies should be made on the development of a better information system on the capitalization of in-place pollution abatement facilities. Adequate reporting of investment data exists only for the period from 1952 to the present, and there is little in the way of reliable depreciation information relating to sewers and wastes treatment facilities. Development of historical investment and depreciation levels would be useful in the development of national investment policies informed by an adequate awareness of capital requirements.

There is a requirement for research into the effectiveness of the various pollution abatement strategies. Comparative evaluation of results of the several program emphases, that is, various controlling jurisdictions, consequences in terms of financial outlays, water quality preservation or degradation, water utilization constraints, would be useful in forming least cost national and State-controlled programs in the future.

Related to this is research into the influence of water availability and public policy regarding water use and pollution control on industrial location decisions. There is evidence that separate industrial categories are affected by and react to a single set of water conditions in different fashions, but no comprehensive survey of response to conditions has been conducted at this time. There are a large number of conditions where controls must be developed to deal with diffuse pollutional influences of natural runoff (siltation, water-borne pesticides, concentrated urban runoff, etc.) and where costs have been inadequately examined or are unknown. Such cost data are essential to formulation of meaningful abatement programs and their development should provide a number of research projects. In general, however, these kinds of information requirements cannot be satisfied by economists alone, since they require technical determinations demanding the skill of hydrologists, biologists, engineers, and others.

*Economic planning units*

One of the most immediate needs is for the delineation of suitable economic planning units for comprehensive estuarine management. What is the minimum area of the estuarine resource that must be incorporated into a system before it can be managed effectively? If suitable economic planning units can be delineated and the economic research can begin, then these management units can be modified as knowledge of other factors—hydrology, ecology, geology—becomes available.

## LAW

As in the area of economics and planning, it is difficult to conceptualize the research and study needs involved with legal aspects of estuarine management in the same framework as that of the technical questions. Notwithstanding, a great deal of work must be done if we are to answer the questions having legal overtones in the Nation's estuaries.

There is a lack of clearly defined jurisdiction for the management of the Nation's estuaries. In terms of conventional legal categories, the rights of competing parties to resources which the estuary supports must be determined. Who owns the shoreline and the bed of the various estuaries? What special rights does the law give to private owners of land abutting the estuary? What rights does the law give all private individuals in estuarine resources? What is the difference between the rights to flowing waters, to tidal waters, and to marsh areas? What are the constitutional and territorial limitations on the regulatory powers of the State, the municipalities, and the Federal Government? This brings us to the need to examine and study institutional barriers that prevent sound and equitable management and utilization of estuarine resources, to determine whether they can be removed. We need to promote new institutional arrangements to provide a nationwide protective mantle for estuaries. Studies of State and local government, law, and policies as they pertain to ownership, planning, zoning, and land and water use must be made. Model legislation for the desired results must be developed.

There is the whole new question of the legal aspects of offshore waters that has been introduced by increased offshore dumping and long outfalls having effects beyond territorial limits, as well as the commercial aspects of fishing, oil development, mining, and other resources exploitation. Concentrated research into the means for local control of dumps outside the continental United States needs to be initiated and completed. While certain controls can be exercised at the loading points and during transport of the materials within continental waters, there is a serious question as to whether any legal controls can be exercised by State or Federal authorities over dumps outside the continental United States. Legal control methods must be developed quickly and international ramifications must be fully explored.

SUMMARY

A. Planning:

1. Planners need information concerning human factors to amalgamate with technical knowledge in order to develop a comprehensive plan of estuarine management which will provide for a program of optimal beneficial action.

2. Develop capabilities for estuarine resource identification, evaluation, and allocation.

3. Develop planning criteria for estuarine use.

4. Develop alternative master plans for long-term estuarine uses.

B. Economics:

1. Develop techniques for quantification of social, economic, and aesthetic factors along with technological factors which permit the use of decision models.

2. Evaluate all aspects of the estuarine resource and determine economic and social benefits and costs.

3. Determine the costs of in-place pollution abatement facilities.
4. Evaluate the effectiveness of the various pollution abatement strategies and formulate optimum beneficial national and State controlled programs.
5. Determine the importance of water quality and quantity and pollution control requirements on categories of users.
6. Delineate suitable economic planing units.

C. Law:
1. Define legal jurisdictions for management purposes.
2. Define the rights and responsibilities of parties competing for estuarine resources.
3. Study State, Federal, and local government law and policies as they pertain to estuarine ownership, planning, zoning; and land and water use.
4. Develop model legislation for estuarine development, study, use, and preservation.
5. Determine the legal aspects of offshore dumping and outfalls as well as of offshore fishing, oil development, mining, and other resource exploitation.

## SECTION 9. ANCILLARY RESEARCH AND STUDY NEEDS

There is a considerable need for knowledge which, while not in direct support of a system of technical estuarine management, is a significant part of the overall research and study program needed. These might be considered as needs of researchers and include environmental monitoring and surveillance, methodology (both laboratory and field), data processing, training, and estuarine zone laboratories.

### MONITORING

There is a well recognized need for routinely monitoring the estuarine environment to complete and maintain the data base discussed earlier. A continuing program of environmental surveillance supplies the information needed to determine water quality conditions and the effectiveness of water pollution control activities. Surveillance also indicates the location, nature, and severity of pollution problems and is necessary to support legal and administrative actions to abate pollution and other destruction of the estuarine resource. All of the values of an adequate data base for planning and managing the estuarine resource also accrue to an effective system of monitoring. Effective monitoring of marine and estuarine waters requires a continuing series of synoptic measurements at strategic locations. It will require an approach based upon adequate knowledge of the ecology involved and an understanding of the related physical, chemical, and geological processes.

*Instrumentation*

Field investigation and research in estuarine and near shore areas is extremely expensive in terms of manpower, time, and equipment commitments, thus, research to advance the state-of-the-art of surveillance and monitoring is necessary in order that information essential for management decisions can be obtained at less cost and in an expeditious manner. Instrumentation must be developed which will simplify data collection, will be reliable, and will require little maintenance. With the technological advancement in data acquisition capabilities such as remote telemetering systems, it is now possible to continuously record pertinent environmental parameters for extended time periods. In the recent past, man-hour requirements made sure intensive data acquisition impossible, thereby excusing our present inability to distinguish man-made alterations of estuarine biota from natural fluctuations. However, we can no longer use the excuse. We must initiate intensive long-term estuarine monitoring programs that reflect existing capability in remote telemetering systems. Although the equipment price tag is high, it is cheaper in the long run than any other method and we can no longer afford not to develop this approach. A valuable system would be one which would warn directly of variations in monitored parameters which exceed previously determined limits. This would allow a biological survey to assess immediate and/or delayed effects on the biota from natural environmental fluctuations.

*Positioning data collection stations*

Another need is in positioning data collection stations. In order to assure information relative to our research needs, the selection of monitoring sites for data collection must be as carefully selected as sampling sites for current methods of environmental analysis. While it is recognized that intensive monitoring systems cannot be deployed in every estuary or coastal area of the United States, all major geographic and ecological zones should be covered. The development of buoy, barge, or other types of field stations offer a basis for the placing of monitoring systems.

*Long-term synoptic monitoring*

Many short-term (2 to 4 years) baseline ecological studies have been completed. Their results most frequently resemble a disjointed mosaic when synthesis for practical application is attempted. One of the major causes for a lack of unity among such studies is the "atypical year" or the "atypical area" syndrome which in essence is an admission that not enough detailed environmental data were taken before, during, or after such surveys to pinpoint the effort in "ecological time" or "ecological space." Long-term synoptic monitoring will identify and satisfy many of the knowledge gaps that must be filled if there is to be any hope for coordinating and synthesizing results of estuarine research in the future.

*Water quality criteria*

Detailed, open ended, continuous monitoring of whatever environmental parameters are recognized as requirements for, or potential toxicants to, aquatic life and for which appropriate technological capability exists, is necessary so that natural variation may be intelligently incorporated into the establishment of water quality criteria and the most productive use can be made of our coastal resources. Existing computer capability allows for selective data storage and reduction so that long-term trends, such as the saline encroachment of the Patuxent River, could be documented and a biological relationship established.

The major geographic and ecological areas of the United States should be monitored in a manner that is coordinated with research interests. Monitoring capability for future enforcement should be standardized and developed as a function of the research upon which enforcement needs will be based.

We have just begun to scratch the surface in the area of enforcing water quality standards by monitoring the aquatic system itself. Substantial research needs to be carried out in both the instrumentation and in the methodology of using instrumentation so that we can achieve a capability of enforcing water quality standards.

## ANALYTICAL METHODS

Measurement and interpretation of water quality in the marine environment is a complex problem and is quite different from that encountered in the fresh water environment. Background values of organic and inorganic constituents are for the most part much higher than those encountered in fresh water. In addition, they are constantly changing with respect to depth, location, and time. Estuarine analytical methods frequently are more difficult technically because of the interferences encountered in analyzing specific constituents. Even after values are determined, the interpretation of these values frequently is difficult. Some wastes that remain dispersed or dissolved in fresh water are encountered in ocean waters because of precipitation or by wave foaming. Marine waters at times have a high concentration of plankton and other forms which contribute to high natural organic carbon content; measures of BOD, COD, or total organic carbon as indicators of pollution are extmerely difficult to interpret under these conditions. Research on analytical methods to resolve these and other problems should receive a high priority. The emphasis of such research should not be limited merely to chemical considerations but should incorporate the elements of significance and interpretation. Encouragement and opportunity should be provided for the development of new sampling and measurement methods for marine pollutants ranging from oil, pesticides, herbicides, and radioactive materials to ordinary sewage. Increase as well as decrease in concentration of these materials can be rapid. The emphasis, therefore, should be on the development of rapid simple methods inexpensive enough for practical use.

Methodology is required for describing the estuarine ecosystem. It hase been pointed out that there is a need for conducting studies on an ecosystem basis. Even today, comprehensive ecological studies of estuaries are uncommon, and most of those are of limited scope. In order to enhance our progress it is necessary to greatly improve biological data collection systems. Techniques must be developed which will develop more significant knowledge with simpler, faster, and more reliable sampling and analytical techniques. Aerial reconnnaissance of vegetation, distribution and abundance and *in situ* measurements of chlorophyll (a measure of standing crop) using a continuous recording fluormeter are examples of promising possibilities.

## DATA PROCESSING

Scientific data describing the various estuarine systems has been collected for many years. Regrettably, this information rarely is put into a form in which it is generally available and useful for geographic areas beyond that in which the study was done. A specific need of research workers is for conventionalized methods of observation and data recording to be made and a central exchange where such information might be inserted and extracted by workers of all disciplines from all areas of the country. Such a system would rapidly become an encyclopedic form of inventory. A great deal of thought and work must be devoted to the formulation of this system and for the development of a program to manage this system. Studies which have been conducted for specific purposes in specific areas should be integrated into a larger mass of information and made generally available. This system would serve not only researchers, but would also be an integral part of the information needed for planning, funding, and managing estuarine areas.

A second area of need in data processing is increased emphasis on correlating the collection of physical, chemical, and biological data in estuaries. For purposes of water quality management, descriptive data in one of these categories is essentially useless without comparable information in the other two. A critical core of data (including temperature, dissolved oxygen, salinity and pH profiles, chlorophylls, current velocities, bottom sediment, characterization, transparency, total sestion, dissolved carbon, etc.) should be identified as commonly needed in all ecological studies of estauries. Federal and federally sponsored researchers should be required to collect this data at reasonable time intervals during the course of all estuarine studies. Standard data processing techniques should be established and copies of information received should be collected in a central data storage bank.

If these two suggested approaches to data collection and data management are followed, the benefit to be derived by all estuarine workers will repay many times over the extra effort and nuisance required to supply a central source with duplicate copies of data.

## TRAINING

The success of a national estuarine research program will to a very great extent depend on the availability of well-trained and imaginative manpower that can implement national goals. Modern approaches to estuarine research will require more people on laboratory staffs with interdisciplinary training in quantitative ecology and resource management. A program should be initiated to encourage scientists in a given discipline to undertake studies related to estuarine management. Economists should be encouraged to acquire a basic understanding of hydrology, ecology, and law. Engineers should be encouraged to study economics and ecology. Laboratories must now pursue comprehensive programs combining many disciplines if we are to expect to manage our coastal resources and their environments effectively. This approach requires a staff which most laboratories cannot acquire without additional support. Small laboratories should consider combining with larger laboratories, at least by using computer links which could coordinate programs. Training grants or contracts to academic institutions for studies by individuals in different fields related to estuarine management will materially fill the present gap. Research must be fully coordinated with management needs and river basin activities to assure optimum application for all resources.

### ESTUARINE ZONE LABORATORIES

The best way to provide the analysis, research, and development needed for a rational approach to the proper management and utilization of the estuarine and coastal zone would be to establish and designate multidisciplinary laboratories with area and regional interests. While most research and development analyses must be directed to regional and local coastal zones components, there are clear national requirements which have been imposed on agencies of the Federal Government. Consequently, laboratories must be maintained both by Federal Government and by institutions capable of meeting regional and local needs. This would call for estuarine laboratories and regional estuarine laboratories.

Federal estuarine laboratories would conduct research necessary to the implementation of Federal missions and, in addition, could provide certain facilities for common use in the areas they serve. Regional estuarine laboratories conduct research, analysis, and development specifically related to the coastal zones of their region and would serve as scientific and technical advisors to coastal zone authorities and appropriate State agencies.

The establishment of these laboratories would (a) demonstrate the Federal Government's recognition of the clear interest of the State Government in many matters relating to estuarine management and its recognition that it is in the interest of the national well-being that appropriate State authorities have as much technically competent judgment as possible to base their decisions, (b) create technical organizations to give adequate research and technological support to the Federal decisionmaking process as it relates to estuarine matters, (c) recognize through Federal action the need to support regional estuarine laboratories which can conduct a vigorous research program, develop the technology for the effective utilization of the coastal zone, and assume responsibility for training the necessary scientists, engineers, and others needed for estuarine management.

### SUMMARY

A. Monitoring:

(1) Routine monitoring and surveillance of the estuarine environment should be pursued.

(2) Instrumentation and techniques should be developed to simplify data collection, increase reliability, and reduce costs and time required.

(3) Automatic remote telemetering should be increased and improved.

(4) Monitoring is necessary to satisfy many of the baseline data gaps discussed earlier.

(5) Monitoring systems should be coordinated with each other.

(6) Monitoring plays a key role in enforcing water quality standards.

B. Analytical methods:

(1) Sampling techniques must be simplified and improved.

(2) Methodology must be developed to simplify the interpretation and correlation of collected data.

C. Data processing: (1) Data processing must be conventionalized and central data exchanges established.

D. Training:

(1) Interdisciplinary training of estuarine workers is required.

(2) Training institutions should increase coordination to optimize their activities.

(3) Training should reflect the needs of estuarine management.

E. Estuarine laboratories:

(1) Federal estuarine laboratories should be established to conduct research necessary to the implementation of Federal missions.

(2) Regional estuarine laboratories should be established to conduct research specifically related to the estuarine zones of their regions, and to serve as technical and scientific advisers to appropriate State agencies.

## Section 10. Specific Research Programs

Research is conducted in an estuary, bay, or coastal zone usually for the solution of a specific problem or for understanding natural phenomena. Elsewhere in this report, the importance of baseline studies has been stressed, but in addition to this, there must be approaches to understanding and solving specific problems in specific estuaries. The purpose of this section is to present three research and study programs that have been performed or are in progress. This illustration by example demonstrates the way in which knowledge is developed to meet specific needs of technical management and, in turn, comprehensive management of the estuarine zone. In this section, a baseline study originally designed for Biscayne Bay, Fla., but applicable to virtually any estuarine zone will be presented. The second example is a discussion of a study of the Kaneohe Bay estuary in Hawaii designed as a preliminary study prior to its increased use for sewage disposal, that is, a "before" study with a specific stress in mind. The third specific research program is a proposal for reestablishing a desirable ecosystem in an estuary after damage has occurred and the source of damage has been removed. There will be many similarities in each of these studies, indicating that there is a basic fund of knowledge necessary regardless of the purpose of a research activity in an estuarine zone. Each of these proposals demonstrates the necessity of considering any estuarine zone in the context of a complete system.

### BISCAYNE BAY, FLA.: A BASELINE STUDY FOR ESTUARINE POLLUTION

The purpose of this Study, designed as a long-term program for Biscayne Bay, Fla., is to develop the factual knowledge necessary for the optimum management of that estuarine resource. As in most of this Nation's important estuaries, man's activities already have had an effect. There is no pretension that we are dealing with a pristine ecosystem. Note also that this plan recognizes the importance of the legal and economic aspects that exist in real-world resource allocation and management. It does not attempt to satisfy the basic need for long range planning, nor does it specifically identify goals. It does, however, pose the questions that will supply quantified alternatives from which goals may be selected and plans formulated.

This model baseline study is thus applicable to virtually every estuarine zone in the country and is, in fact, practically a prerequisite to the elucidation of specific plans for management and development.

I. Surveys to identify existing pollution in the estuary and in tributary streams:

- (A) Literature survey of existing knowledge.
- (B) Field studies to identify and measure the amount and seasonal occurrence of pollutants:
  - 1. Chemical pollutants:
    - (*a*) Organic:
      - (i) Economic poisons, e.g., herbicides, pesticides.
      - (ii) Detergents.
      - (iii) Oils and solvents from industry.
    - (*b*) Inorganic:
      - (i) Metal ions.
      - (ii) Substances that alter the acid-base balance of the estuary.
  - 2. Sewage and waste discharge pollutants:
    - (*a*) Excess plant nutrients.
    - (*b*) Pathogens, e.g., bacteria, viruses, parasites.
    - (*c*) Solid wastes that increase turbidity, form sludge beds, or settle out to cover over the bottom.
  - 3. Fresh water.
  - 4. Heated discharges.
  - 5. Air-borne pollutants.

II. Continuous monitoring of significant pollution, as identified by studies above.

III. Identification of sources of pollution. This requires industrial and domestic waste inventories, evaluation of nonpoint source pollution such as urban street run-off, erosion, agricultural run-off, and irrigation return flows, as well as domestic sewage and industrial discharges. Pollution from vessels, oil discharges, and accidents involving hazardous substances must be recognized along with effluents from saline water conversion plants and heated water discharges.

IV. Disposition and fate of pollutants in the estuary: dispersion, concentration, degradation, precipitation, disposal to the air.

V. Field studies of the estuarine environment:

- (A) Physical-Chemical factors:
  - 1. Salinity.
  - 2. Temperature.
  - 3. Dissolved Oxygen.
  - 4. Turbidity.
  - 5. Water currents, flushing, tidal action, and other hydraulic features.

6. Wave and wind action.
7. Fresh water inflow.
8. Phosphates, nitrates, nitrites, silicates, sugar.
9. Sediment deposition, removal, character, and variation.

(B) Biological factors:

1. Phytoplankton identification, distribution, abundance, and contribution to the food web.
2. Zooplankton; identification, distribution, abundance, role in the food web, and significance as economically important species.
3. Fixed vegetation; identification, distribution, abundance, contribution to the food web and habitat value.
4. Sessile animals—identification, distribution, abundance, importance in the ecosystem, and economic values.
5. Mobile animals—identification, distribution, abundance, importance in the ecosystem, and economic value.

VI. Laboratory studies of the physiology and behavior of plants and animals under natural conditions and under pollutional stress:

(A) Responses and tolerance of plants and animals to variations in:

(*a*) Salinity.
(*b*) Temperature.
(*c*) Currents.
(*d*) Factors of pollutional impacts.
(*e*) Other pertinent physical, chemical, and biological factors.
(*f*) Combinations of these.
(*g*) Habitat.

(B) Requirements for optimum production and reproduction of desirable organisims

VII. Legal, economic, and planning aspects:

(A) Survey of existing laws and regulations on pollution and environmental conservation;

1. Adequacy and scope of legislation;
2. Enforcement of these laws;
3. Identifying needed legislation.

(B) Economic studies to determine the values and benefits of the estuary:

1. Dollar values;
2. Recreational and esthetic values;
3. Potential values;
4. Benefit/cost relationship of exploitation, both existing and potential;

(C) Review and development of long- and short-range plans.

## KANEOHE BAY, HAWAII: A STUDY PRIOR TO INCREASING ITS USE FOR SEWAGE DISPOSAL

This study was proposed and coordinated by the Water Resources Research Center, University of Hawaii. Cooperating departments of the university include: Agricultural Economics, Public Health, Microbiology, Geography, Oceanography, Geosciences, and the Hawaii Institute of Marine Biology.

The objectives of the study were:

1. To postulate the ecology of Kaneohe Bay prior to its use for sewage disposal;
2. To determine the present patterns of water quality and sedimentation in the bay and the effects of present effluents from land on the important elements of the biota, separating, to the extent possible, the effects of sewage effluent discharge and stream discharge;
3. To project ecological effects of increased sewage effluent discharges and altered stream discharges as the population of the area increases, assuming present methods of treatment;
4. To outline alternative methods of treatment of both stream and sewage effluent and stream discharges, and estimate the effects of their adoption on the ecology of the bay;
5. To determine costs of present and alternative methods of control and treatment of both sewage effluent discharge and stream discharge;
6. To identify and measure the value of other major uses of the estuary including recreation, industry, bait fishing, and esthetic aspects versus use of the bay as a sink and transporting medium for wastes associated with urban development.

The nature of the problems associated with attaining these objectives requires a closely coordinated interdisciplinary approach. For simplicity in presentation, the procedures followed in this study are described in relation to the several semi-independent programs that are the respective special responsibilities of more or less separately identifiable groups of investigators. It should be recognized, however, that constant interchange of information exists among these groups. The separate studies include:

1. Studies of the plankton of Kaneohe Bay; analyses of the diversity and structure of tropical zooplankton communities. Included in this work is an attempt to understand the relationships with the open ocean forms and the interdependency that exists. There would also be detailed analyses of tropic relationships and energy flow, as associated with enrichment, transport, and mixing.
2. Studies of the fish and benthos of Kaneohe Bay. Determine the identity, distribution, and abundance of the fish and benthos of the bay, and relate these to environmental factors.
3. Sedimentation of the estuary via the watershed:
   (*a*) Types of sediment entering the bay;
   (*b*) Rate of sedimentation, including normal and runoff;
   (*c*) Sediment pattern in the bay;
   (*d*) Composition and rate of sediment discharge from the bay to the ocean;
   (*e*) Effects of urbanization and agriculture on erosion and runoff, and on the resulting sediment pattern in the bay;
   (*f*) Inter-relationships with other studies;
4. Bacterial pollution, mineralization processes, and photosynthetic activity:
   (*a*) Extent and magnitude of bacterial pollution from existing sources;

(*b*) Mineralization processes:
1. Site of activity: water or sediment;
2. Micro-organisms involved in oxidizing and reducing processes, including ammonification, sulfate reduction, nitrification, and sulfur oxidation.
3. Chemical and physical parameters: dissolved oxygen, pH, redox potential, particulate and dissolved organic carbon; $NH_3$, $NO_2$, $NO_3$, total nitgrogen; and total and soluble phosphate.

(*c*) Photosynthetic activity:
1. Site of activity and light profile of the water column;
2. Productivity rates;
3. Identity, distribution, and abundance of photosynthetic organisms (phytoplankton, attached plants, and bacteria).

5. Water quality factors:
(*a*) Tidal ranges;
(*b*) Circulation;
(*c*) Salinity;
(*d*) Temperature;
(*e*) Surface runoff and precipitation versus evaporation;
(*f*) Chemical constituents of the water and sediment at selected sites;
(*g*) Sewage discharges into the Bay, their strength, volume, and distribution;
(*h*) Effects of sewage discharges on algae, coral, and other biota.

6. Engineering analysis:
(*a*) Determine alternative methods for dealing with expected levels of sewage discharge over time to meet a range of specified water quality criteria;
(*b*) Estimate the investment and operational costs of the various alternatives for primary, secondary, and tertiary treatment of the effluent to meet these criteria;
(*c*) Determine methods for controlling stream discharge at various levels of the watershed and project costs for each alternative.

7. Identify and quantify the various uses, present and potential, of Kaneohe Bay and relate the value of these uses to the cost of fostering them.

### NEWPORT BAY, CALIF.: REESTABLISHING A DESIRABLE ECOSYSTEM AFTER PHYSICAL MODIFICATION OF THE ESTUARY

Physical modification of an estauary by construction, dredging, filling, and other human activities usually triggers ecological changes followed by a period of readjustment. The natural fauna and flora initially are impoverished but the area is slowly recolonized. Recovery may take years and the final result may not be as desirable or productive as the original community.

Bays and harbors have a specialized biota adapted to estuarine environments. If a species is eliminated by human activities, recolonizing individuals must originate from undisturbed populations in nearby bays. Ths process usually requires that larval or juvenile forms from the undisturbed population find their way into the ocean, survive there, and thence migrate into the modified bay. It also requires that the modified bay be once again a suitable habitat for the original inhabitants. Probability of such a sequence of events may be low, explaining the long periods generally required for recolonization of a despoiled area.

This particular study would seek to develop methods for facilitating this process. The ultimate climax communities in the modified bay would thus be enhanced both in terms of species diversity and the production of organisms useful to man.

The case study selected here is Newport Bay, Calif., because of the plans being made to develop this area within the next few years.

Bay development typically involves replacing shallow marshland with navigable open water (usually 10 to 30 feet deep). Entirely terrestrial islands and peninsulas may be left in the bay or built up by filling. Organic productivity by marsh vegetation is eliminated, and the food base remaining for animal communities are either phytoplankton or dimly illuminated (and hence sparse) bottom vegetation. Populations dwelling in shallow zones find their habitat greatly reduced. Deep-water animals have an expanded habitat, but cannot multiply faster than their basic organic food resources.

If deep-water attached plants existed in the bay, and if they survive the construction activities, they can colonize the newly created deeper bottoms. As plant cover develops, habitats and food resources become available for animal communities. If the proper plants are absent or lost, or if bottom illumination is low, attached vegetation may never gain a foothold. Bay life then depends totally on phytoplankton productivity. Many species, including animals sought by man, cannot utilize planktonic food resources. These forms dwindle or vanish.

Whatever the course of events, results add up to biological impoverishment for years or even indefinitely. Man could intervene in several ways. Most importantly, stands of suitable attached vegetation must be created to provide food bases for animal communities. If desirable fauna and flora totally perish during bay modification, seed stock populations could be introduced to strategic areas. Last, but by no means least, ecological counsel could be provided to planning engineers to insure that the best possible decisions are made before bay modification commences.

The proposed plan of study consists of several interrelated studies. Objectives can best be achieved by developing information in all these lines of work, more or less concurrently.

1. The important plant and animal species of southern California bays would be identified and their ecological requirements determined.

2. Various types of construction used in bays (i.e., riprap bulkheads, pilings, artificial islands, etc.) would be evaluated for suitability as substrata for colonizing organisms. Criteria of suitability are diversity and abundance of species associated with the substrates. Evaluations take account of hydrographic conditions, age of the particular construction, and other modifying factors.

3. To assess feasibility of establishing seed stock populations, transplantation experiments would be conducted with important species and with species possessing excellent potential for enhancing bay environments. Particular attention would be given to seaweeds such as eelgrass (*Zostera marina*) that frequently dominate significant stretches of bay floor and provide important food bases for animal communities. Animal species there are apt to suffer seriously from construction and dredging during bay modification should also be studied. The transplantations would be particularly valuable if they can follow actual dredging and construction operations.

4. Laboratory cultures of potentially useful seaweeds would be developed. Feasibility of transplanting large numbers of juveniles or reproductive bodies (seeds, spores, etc.) from laboratory cultures to bay environments would be tested. The purpose of this study is to develop techniques for establishing dense stands of attached vegetation over large areas of bay bottom in a relatively short time. If this can be done, the food bases for animal communities in freshly created habitats could be brought into existence rather quickly and should greatly shorten the period for recovery from operations of bay modification. Intensive work would be done on two or three species known to be ecologically desirable such as palm kelp (*Eisenia arborea*) and eel grass (*Zostera marina*).

5. Feasibility of conserving portions of populations presently existing in upper Newport Bay would be studied. As ecological requirements for the various species become catalogued, a basis will be available for predicting survival in various habitats. Many new environments will be created in upper Newport Bay (for example, shallow underwater slopes of artificial islands). Some of these probably could accommodate organisms presently inhabiting areas that will become unsuitable. The practicality of relocating entire populations will be influenced by several variables (ability of the species to survive transplantation, costs of collecting and then dispersing the population, etc.). Other study phases of this project will provide the information required for making decisions.

## Section 11. A Management Program for Research and Study in the Estuarine Zone

The conflicts over estuarine use are described and documented earlier in this report. It has been shown that development is proceeding so rapidly that there will be little left to preserve and conserve unless an effective program of comprehensive management is developed and implemented immediately to protect the desirable natural qualities of estuaries. A comprehensive management program can succeed only if it is based on knowledge and understanding of the environment. This knowledge, in turn, can be developed only through a program of research and study in the estuarine zone. The purpose of this section is to identify the principles on which a technical management program of research and study must be based and to propose the Federal and State roles in implementing such a program.

## PRINCIPLES OF TECHNICAL MANAGEMENT

The following 10 principles underly a program of technical management. The implementation of these principles constitutes the framework of the proposed program of research and study.

*Ecosystems as management units*

Estuarine resources occur in interacting complexes. What man does to one resource can and does have significant effects on the others. Estuarine and coastal areas exist as ecological systems, frequently as integral parts of large river basin complexes. The systems concept is thus the most logical approach to sound management of coastal areas. Any plans for the successful development, management, and regulation of estuaries in the United States must be consistent with the ecological and economic principles by which such systems operate, with and without modern man. Because estuarine systems differ from the land systems in having moving fluid, the land laws and practices often do not provide for sensible management and new laws and practices must be developed to recognize the limitations and requirements of estuarine systems. Hence, a management program must involve a total effort toward providing a total solution. More often than not, piecemeal solutions create additional problems, and we find ourselves forced to commit all of our resources to current crises and not able to prepare for the more difficult problems of tomorrow.

Programs for estuarine research and study capable of providing total solutions require not only a multidisciplinary approach but also a sizable concerted effort, because the areas are both large and complex. Estuarine studies are not wholly the problems of one discipline nor of only a select number of State institutions, but must be carried out by a number of agencies, both private and governmental. A great deal of coordination is needed. The magnitude of the problem is such that use can be made of all interested groups to attain the objectives of optimal estuarine utilization. The single-purpose concept of water resources which has been generally abandoned in the development of our upland water resources is still being used in the estuarine area. Such public works as powerplants, new ship channels, diked areas, etc., are still being planned and constructed as individual entities without regard to the entire circulation scheme of the estuary. A great deal of effort must be applied to seek new ideas and even bold ideas for the management of estuaries as total ecosystems.

*The multiple-use philosophy*

As a general guide, the multiple-use philosophy must prevail for future planning of estuarine use. Maximum consideration must be given to both public and private enterprise and values in these coastal areas with particular efforts to accommodate all compatible uses practicable. In general, the exploitation of a single resource or a use that is contrary to, or irreversibly precludes other desirable uses, cannot be permitted. The achievement of a desirable balance among uses was a principal purpose of the Congress in commissioning the national estuarine pollution study. However, it needs to be stressed that public recreation areas, wildlife sanctuaries, national defense areas, and other situations of this type are usually single-purpose but frequently desirable.

*Evaluating all potential uses*

Better techniques must be developed for evaluating all potential uses and combinations of uses for a given estuarine area in terms of optimum longrun social as well as economic benefits and including esthetic and recreational values. Certainly natural science will continue to be an important area of investigation, but the social and humanitarian aspects of the natural environment also will have to be evaluated. This will require definitive economic base studies to define values and uses at all levels in common terms which will permit option of various use alternatives.

While various uses amenable to benefit/cost analysis should be evaluated in a comparable manner to determine the economic impact of various combinations of such uses, uses not subject to the usual benefit/cost analysis such as fish and wildlife habitat, open space, esthetics, and natural beauty should, nevertheless, be fully considered as an important aspect of any plan for estuarine development. Criteria with which to judge these sorts of values must be developed and applied equitably along with criteria for the more readily evaluated characteristics. Commercial developments considered essential and which are locationally dependent on estuaries should be planned so as to prevent or mitigate damages to all other public values. The responsible unit of government should require adequate protective measures as a condition of approval of any development plans. As in the establishment of water quality standards, the determination should be justified in terms of overall public or social value rather than solely through conventional benefit/cost analysis. The various techniques and criteria on which these sorts of values will be based will require research of a novel and specialized kind, perhaps abandoning traditional attitudes.

*Conserving and enhancing estuarine ecosystems*

Estuarine areas must be managed conservatively, leaving adequate margins of safety for protection for miscalculation, political error, or extreme natural variations. At the present time, there is widespread awareness that we can no longer afford to neglect and destroy estuarine systems which cannot be replaced. The question now is how to accomplish and provide for a sufficient measure of protection for these areas.

Future development of estuarine areas should provide the environmental niches needed by the inhabitants of the estuary and for the use of the estuary as a nursery ground for marine life. Special precautions must be taken not to impair the desirable hydrology of the estuary. Efficient flushing characteristics and innocuous sedimentation patterns must be retained or achieved. This need is consonant with all the other beneficial uses of natural waters except the receipt of waste. Estuarine areas in a state of neglect and poor use should be restored to functional status within the concept of an integrated ecosystem of the whole in-shore region. Methods should be developed for reestablishing the areas of the estuarine zone where desired values have been lost. Special attention must be given to the effect of man upon the water quality of the estuary, for this is the most easily controlled of all the factors in the estuarine economy and yet is one which will most seriously effect the esthetic, recreational, economic, and habitat value of the estuary during periods of extreme environmental stress.

The concept of natural preserves or wilderness areas is well accepted in terrestrial environments. It should be expanded and implemented in the estuarine environment as well, for, if we are ever to achieve the understanding of estuarine ecosystems essential for their wise management and fullest beneficial use, it is important that we set aside and fully protect a series of representative estuaries along our shores for scientific study and technical management. Such estuarine reserves should be established in several different States, on the east coast, the gulf coast, and the west coast of the United States, as well as in Alaska, Hawaii, and the various island possessions. If this action is not taken soon, we will find that few, if any estuaries will be left which will be suitable for such studies. It is particularly urgent that use for scientific study be included among the beneficial uses of estuaries.

*Coordination of estuarine activities*

Close coordination and unanimity of purpose among all agencies, institutions, organizations, and individuals having an interest in estuarine areas must be encouraged. This would require cooperation of Federal, State, and local governments, private enterprise, and the public. Communication among the various sciences is often poor, as is communication between the various levels of government and the private sector. Results of work done by State agencies frequently are narrowly distributed. State agencies oftentimes completely overlook or ignore work done by the universities. Federal agencies working on the national level are frequently unaware of the excellent work done at the State and local levels.

It is difficult to over-emphasize the need for the coordination of data gathering, storage, reduction, and retrieval.

An especially important area of cooperation is between all levels of government and the universities, for it is the universities that can concentrate on highly productive research in specific areas on a long-term continuing program. This has the advantage not only of the application of some of the best minds in the country, but also of training the cadre of scientists which will be needed as was discussed earlier. The government agencies should keep the universities aware of their needs and help support appropriate research.

It is also important to recognize that several of the United States' estuarine zones overlap with Mexico and Canada. The Federal and State governments should coordinate their estuarine research and management programs related to these areas with Canada on both the Federal and provincial level and with Mexico on the Federal and State level. The Great Lakes soon will fall into the definition of an estuarine protection area and hence all research and management programs relating to the Great Lakes should be coordinated between Canadian and the United States agencies. Federal funding of State estuarine research projects has and will continue to help coordinate State and Federal efforts. This funding should be expanded to include local, university, and private endeavors in the estuarine zone as well, to increase the scope of coordination.

*The importance of regional emphasis*

A national program for estuarine study and management should be developed with strong regional emphasis. The United States should be divided into regions corresponding to certain conditions. The biological-physical-chemical properties of estuaries should determine the definition of the regions. Positive estuaries along the Pacific coast from central California northward would comprise one region, the negative estuaries of southern California another region, the highly variable estuaries of the Gulf of Mexico another region, the estuaries of the Southeast States another region, and the estuaries of the Northeast a fifth region. Chesapeake Bay, south Florida and the islands of the Caribbean, Alaska, and Hawaii, are each unique enough to be separate regions also. These are roughly the biophysical regions which are described and utilized as a basis of information presented earlier in this report. Each region should have a complete inventory of what has been done in the past. Each region should develop a program whereby it would be determined what the estuarine resources of that area are now, what changes may occur to increase these resources, and what changes may be allowed in future development without damaging the current and potential resources of the region.

*The need for public planning and regulation*

The public sector must take the initiative by developing plans and enforceable regulations to deal with increasing demands for alteration of land, water, and estuaries, a demand now largely in the hands of the private sector. Strong and competent organizations, such as State or interstate compact authorities, are required to administer these areas, with Federal financial assistance where appropriate, and always on the basis of sound scientific, legal, economic, and social criteria. In most cases, such machinery is not available, nor is the data base on which such machinery must function. Such organizations must be staffed with people competent to analyze and develop quantitative environmental models for evaluation alternatives capable of developing comprehensive plans for carrying out complete regional programs, or must have ready access to such skills through a core of consultants, either Federal, multi-State, or private.

*The need for estuarine criteria*

A system of criteria must be developed to encourage adequate standards throughout the country covering the allowable extent and conditions of further physical or other alterations of estuarine natural values. Such Federal criteria might well employ the concept used in the development of our water quality standards. In other words, the Federal Government could judge the adequacy of criteria for the technical management of estuarine areas to qualify for any Federal aid program. Additional Federal funds might be made available to encourage even higher standards or to assure nondegradation policies.

*Key management roles*

The problem of estuarine pollution are essentially of an ecological nature. The resources which we are most anxious to exploit and the nuisances which we wish to prevent are primarily biologically based. The technical management of estuarine systems must be consistent with natural processes; biological, physical, and chemical. Man's activities must be fitted into the natural system—not forced upon it. All too frequently, the natural environment is mechanically manipulated for narrowly defined economic purposes, and the value of natural areas such as estuaries is threatened or destroyed forever, due to ignoring sound ecological practices. This approach does not depreciate the essentiality of any discipline, for many of the solutions to biological problems can be achieved only through engineering expertise. The very framework within which all estuarine uses occur is the institutional arrangements of the law. It is only the economist who can recognize market and nonmarket values and supply administrators this information so necessary for resource evaluation and allocation.

A part of the implementation of key management roles is training people in estuarine management. The need for answers to the complex problems of the present is great, and will become even more critical in the near future. Research projects such as estuarine pollution studies must provide for supporting new, high-caliber personnel specifically trained for the difficult tasks ahead. Manpower deficiencies exist at all levels of estuarine scientists, engineers, economists, and planners. The lack of funding for training of personnel will be a prime deterrent to getting the more difficult research underway expeditiously. Unless such provisions are included in any management program, complex research programs will move at a frustratingly slow pace, if at all.

*The need for an informed public*

There must be an informed public willing to support policies and costs leading to the sound technical management of our estuarine and coastal zones. The techniques of informing the public on problems of natural resource management are not as well known as may be assumed by the glib presentations with which we are faced so frequently. Research programs designed toward understanding the public's need and desire to preserve its natural heritage of a beneficial environment are essential. The values, the problems, the achievements of the estuaries must be presented to the public in terms which are meaningful to the electorate. A repetition of cries of panic and destruction and impending doom serves only to attract the attention of those people who are already interested and concerned. We must achieve better methods of educating the public and preparing them to accept the policies and costs required to maintain a high quality environment for them and their future generations.

Study of these 10 principles reveals the most important objectives of a coordinated program of research and study. The fact that the appropriate management unit is the total ecosystem demands that we fully understand the ecology of estuarines and appreciate the need for multidisciplinary studies. Maximum effort must be directed toward implementing the multiple-use concept in the estuarine zone. It follows from this, that all potential uses must be evaluated. Special effort must be made to assess nonmarket values in terms compatible with benefit/cost analysis. Estuarine areas must be conserved and enhanced; damaged areas should be reconstituted; water quality must not be degraded; and habitats should not be destroyed. Natural preserves should be established for study and research.

The various agencies and institutions working in estuaries should coordinate their activities; results of research should be widely disseminated. The national program for estuarine study should be developed with strong regional emphasis based on ecology, geography, and a commonality of problems and objectives. Planning for estuarine use and development must be based on broad public benefits rather than narrow private interests. A system of criteria by which to gauge estuarine quality is necessary. Key management roles require adequately trained people in ecology, engineering, economics, planning, and law. Finally, the public must be informed of its stake in the estuary.

THE FEDERAL AND STATE PROGRAMS IN ESTUARINE RESEARCH

The primary objective of a program of research and study is to supply the knowledge, understanding, and predictive capability to support a comprehensive national program for the preservation, study, use, and development of the Nation's estuarine zone. To promote the coordination of research activities with management needs, a program of responsibilities and the role of the Federal and State Government is proposed. These programs are parallel to those suggested in part III of this report because of the essential sameness of the goals to be achieved. The difference lies in that the comprehensive program is primarily concerned with the institutional environment, i.e., the framework of law, political institutions, and organizational mechanisms that man must use to provide himself the capability to control, develop, and use the estuarine zone; the research and study program is concerned primarily with the natural environment, i.e., the framework of knowledge that provides the technical support to achieve the objectives of the comprehensive program.

*The Federal role in estuarine research*

The Federal Government is responsible for defining the policy and objectives of a national research and study program to support wise comprehensive management of the estuarine zones of the United States. It is also the responsibility of the Federal Government to (*a*) implement its portion of the announced national program, (*b*) coordinate the research activities of its appropriate departments and agencies, and (*c*) augment and encourage the development of new knowledge by State and local agencies as well as by educational institutions. Many of these responsibilities are already receiving attention and the Federal role is one of continuation and augmentation; those responsibilities not yet satisfied require new Federal activities.

The overall Federal role in research should be:

(1) To provide the impetus for the enhancement, augmentation, and initiation of a national program of research needed to support a comprehensive management system and by offering guidelines for State, intrastate, local, and academic actions consistent with developing needed estuarine knowledge.

(2) To provide continuing support and guidance through grants to State, interstate, and local agencies, and to academic institutions, foundations, and individuals meeting the research and study needs of the comprehensive management plan. Purposes of such grants should include:

(*a*) Research and study of estuarine problems
(*b*) Establishment of estuarine zone laboratories
(*c*) Inventory activities in the States' estuarine zones

(*d*) Training of estuarine scientists

(*e*) Management of programs coordinating research and study activities of separate institutions

(*f*) Enhancement of increased nondestructive estuarine use, such as aquaculture

(3) Continue broad estuarine studies not of a local nature.

(4) Participate in local and regional studies where appropriate to augment local and regional research resources.

(5) Acquire or otherwise develop in cooperation with the States and their political subdivisions selected estuarine areas for preservation and study purposes, as specifically authorized by Public Law 90–454 and other statutes.

(6) Supply appropriate support required for the optimum management of flyways, fisheries resources, etc., and perform studies aimed at improving the utility and values of these areas and stocks.

(7) Coordinate Federal estuarine research activities and provide means for coordinating these activities with those of the States, their subdivisions, interstate agencies, educational institutions, and appropriate foundations and organizations.

(8) In cooperation with the States, continuously monitor developments and conditions and evaluate the effectiveness of the national research and study program.

(9) Maintain a network of Federal laboratories in the estuarine zone for basic and applied research supporting estuarine management. The organization of these laboratories should be based on natural estuarine areas established on the basis of geography, biophysical factors, and commonality of problems. These laboratories would be operated by the Federal Government. Their primary purpose would be to support Federal responsibilities and specific agency missions. There should be a laboratory in each designated estuarine area. They would be staffed along multidisciplinary lines and would attack estuarine problems along the lines of total system analysis and management. The initial nucleus for these laboratories would be established functioning laboratories. Siting future government laboratories in conjunction with this nucleus would serve the broader needs anticipated in the estuaries.

(10) Support and encourage a network of laboratories specifically performing research, analysis, and development related to the estuarine areas of their region. These regional laboratories would be under the auspices of institutions of higher education or affiliated organizations competent to study the estuarine zone. They would also serve as scientific and technical advisers to estuarine zone authorities and appropriate State agencies. The research activities should be augmented, as appropriate by participating in consortia and sharing facilities with other public and private institutions. Provision should be made for visiting scholars and for training personnel. The total competence of the regional laboratories should be broad, including scientists, engineers, economists, planners, lawyers, and the others necessary for total system analysis and research into estuarine problems and opportunities.

The National Science Foundation should exercise the Federal responsibility for designation and core support of the regional laboratories, and review and recommend any changes in legislation required to carry out this responsibility.

(11) The Sea Grant College and Program Act of 1966 should be amended to permit grants for construction and maintenance of vessels and other facilities necessary for research and study in the estuarine zone.

*The State role in estuarine research*

The State role in estuarine research parallels the Federal role in that both governmental entities have the same objectives of estuarine development, use, preservation, and study. Because so much of the needed estuarine research is a cooperative function, much of the previously discussed Federal program also defines the State role. The essential differences lie in the fact that the States are the primary management authority in the estuarine zone and hence possess primary responsibility. As such, they are much closer to the urgency of specific estuarine problems as well as being able to plan more accurately for impending ones. The States' role in estuarine research is thus to implement its portions of the overall national program, to coordinate the research activities of its appropriate agencies, educational institutions, and organizations, and to augment and encourage the development of new knowledge most applicable to its estuaries and their management.

The overall State role in estuarine research should be:

(1) To provide encouragement for the enhancement, augmentation, and initiation of a State program of research needed to support their portion of a comprehensive management program.

(2) To provide continuing support and guidance through:

(*a*) Administering grants to interstate and local agencies and to institutions, organizations, and individuals meeting the research and study needs of the States' comprehensive management plan. Purposes to be served by these grants are:

(1) Research and study of estuarine problems.

(2) Establishment of estuarine zone laboratories.

(3) Inventory activities in the States' estuarine zones.

(4) Training of estuarine scientists.

(5) Coordinating research and study activities of the various agencies and institutions within the State.

(*b*) Cooperative activities between State and other agencies and institutions.

(*c*) Technical advice to local agencies and others.

(*d*) Promotion of, and guidance and support to, cooperation among the various State agencies doing research in the estuarine zone.

(3) Perform broad estuarine studies of a statewide and local nature.

(4) Participate in studies of interstate estuaries. An example of this is the activities of the Chesapeake Research Council composed of the Chesapeake Biological Laboratory of the University of Maryland, the Virginia Institute of Marine Sciences, and the

Chesapeake Bay Institute of the Johns Hopkins University. This brings together a total staff of over 110 scientists to share information and to undertake cooperative research projects.

(5) Acquire or otherwise preserve selected estuarine areas for research and study purposes.

(6) In cooperation with the Federal Government, monitor developments and conditions, and evaluate the effectiveness of the State research and study program.

(7) Participate fully in the activities of the regional laboratories described under the role of the Federal Government.

## Section 12. Study on Coastal Wastes Management: National Academy of Sciences-National Academy of Engineering

### INTRODUCTION

In response to a request from the Federal Water Pollution Control Administration, the National Academy of Sciences, and the National Academy of Engineering jointly agreed to provide advice to the Administration on the management of wastes in the coastal marine environment. A study was carried out by a group of experts assembled by the Committee on Oceanography of the National Academy of Sciences (NASCO) and the Committee on Ocean Engineering of the National Academy of Engineering (NAECOE). This group of experts, after a series of planning sessions, met from July 7 through 12, 1969, to examine the following questions:

(1) What is known about the impact of wastes on the oceans?

(2) What is known about the magnitude of the impact the marine environment can tolerate?

(3) What is our present capability to predict future impact of wastes on the coastal ocean environment?

(4) What investigations should be undertaken in order to improve our ability to respond to the above questions?

Approximately 60 scientists and engineers deliberated on these problems at this session. The results of their deliberations will be in the NAS–NAE report "Wastes Management Concepts for the Coastal Zone—Requirements for Research and Investigation" (in press).

A sumary of the recommendations is presented here. It is the purpose of this section of the national estuarine pollution study report to present the most salient features of the recommendations growing out of that working session.

Early in their deliberations, it became apparent that the four basic questions listed above could best be approached in terms of the following subject areas: (a) waste discharge and monitoring, (b) physical processes and interactions, (c) chemical effects, and (d) biological effects. The final NAS–NAE report will be released early in 1970.

### GENERAL RECOMMENDATION

One of the greatest contributions that scientists, especially biologists, can make to conserving marine values is through furnishing quantitative guidelines to assist the engineers having responsibility for designing waste treatment and disposal systems. Also, the design of waste treatment and disposal systems must become much more scientifically oriented than in the past. Historically such design has been concerned primarily with maintaining aerobic conditions in the receiving waters and in keeping these waters safe for human health. Now that scientific methods are becoming available for assessing a broad range of marine receiving water values, the engineer's design should become less based on use of "standard" systems and instead be tailored to preserve the specific receiving water values of concern.

### RECOMMENDATIONS FOR MONITORING WASTE DISCHARGES AND RECEIVING WATERS

*Monitoring program*

Monitoring of the coastal marine environment for waste components and their effects on this environment must be considered on the basis of a total system concept. In this regard, a monitoring system should serve the following functions:

(1) Provide intermittent or continuous characterization of waste inputs together with the receiving body of water and its terrestrial and atmospheric interfaces. This may be accomplished by means of pertinent physical, chemical, or biological measurements sufficient to define the significant nature of the water body throughout a time period specified on the basis of statistical validity.

(2) Provide a knowledge of all sources of mass movement into and residence time within the receiving water body, establish the significant character [1] of such sources, and evaluate the relative contribution of each to the nature of the water body.

(3) Provide for rapid data evaluation and indicate the response procedures appropriate for the given water condition.

Efforts to characterize wastes and receiving waters should take cognizance of the need for rapid, accurate, and economical methods for measurement of the selected parameters. In addition, instrumentation should be adapted or developed to perform the analyses and to transmit or record the observed data. Finally, data analysis techniques should be developed so that corrective action can be initiated promptly.

In any monitoring program the value of observed data depends upon:

(1) Sampling procedures which provide samples representative of the condition of the air, land, and water interfaces at any point in time.

(2) Sufficient vertical and horizontal control points, the samples from which will adequately describe the system.

(3) Sufficient frequency of sample collection to validate the analyses within any preselected statistical confidence limits.

(4) Analytical procedures which are of defined precision in terms of the parameter being measured.

In recognition of the fact that the character of one restricted water body or coastal regime is quite likely different from another, no rec-

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[1] The phrase "significant character" for these purposes is in need of further definition and this subject is dealt with in the main part of this report. Criteria for such classification would necessarily have to be applied on a case-by-case basis.

ommendation can be made concerning the items 2, 3, and 4 above without enumerating the definitive characteristics of each water body. This hopefully will be accomplished by a monitoring program with sufficient sampling locations and with sufficient frequency to describe the system within reasonable confidence limits.

It is realized that any monitoring program designed to meet what are present, and as well as can be predicted, future needs may require modification from time to time. It is, therefore, obvious that periodic examination must be given to monitoring specifications to insure their continuing adequacy and to remove redundancy.

*Monitoring waste discharges*

It was concluded that specifications should be developed for a minimum or core-type monitoring program that should be applied to all "significant" waste discharges. "Significant" waste discharges are not defined herein; but they are to be defined as part of the recommended research and development program. However, they are considered here to include but not necessarily be limited to the following candidate waste materials:

(1) Municipal and industrial waste streams;
(2) Storm runoff and combined sewer overflows;
(3) Water courses containing significant waste materials; and
(4) Batch waste dumping and barging operations.

It should be recognized at the outset that it is both logical and likely that all waste discharges, especially minor ones such as the treated strictly domestic wastes from 100 persons discharging into open coastal waters, would not be classified as "significant." On the other hand, it should be recognized that many major waste discharges will require many more analyses than the core minimum program to characterize properly the waste discharge characteristics.

(1) *Objectives.*—The general objective of the core waste discharge monitoring program is to provide the minimum information needed to assess adequately the pollutional contribution of waste materials to the Nation's coastal environment. Specific objectives would include but not necessarily be limited to the following:

(*a*) To provide quantitative information on the unit and total mass emission rates for the common significant groups of pollutants from significant waste-generating activity such as municipal, industrial, agricultural, natural, and other sources so that:

[1] Adequate data are available for forecasting future waste contributions based upon the level of future estimated waste-generating activity (population, industrial production, etc.);

[2] Accurate input data are available for use in various modeling systems to provide estimates of waste concentrations and their variation in space and time; and

[3] It is possible to attempt to correlate or develop functional relationships between waste emission rates and waste effects which are principally biological in character.

(*b*) To assess performance on a gross basis of waste treatment installations.

(*c*) To insure that adequate information is available to permit improvements in waste treatment and disposal system design and operation.

(*d*) Other specific needs are met on a particular problem basis.

The general characteristics of the minimum monitoring program are described below:

(2) *Sampling.*—All samples (except for grab samples collected for special analyses for high decay rate constituents) collected for routine analysis should be near-continuous, proportional composite samples which accurately represent the characteristics of the waste stream (i.e., floatable, suspended, and dissolved constituents) with respect to their true mass emission rates (i.e., lbs/day).

Sufficient samples should be collected to provide an adequate statistical description for both the constituent concentration and the mass emission rate of the contaminant. After the waste has been statistically defined, analyses not pertinent to the local problem or to the wastes characterization should be deleted.

(3) *Analyses.*—The following analyses should be conducted on essentially all samples collected:

(*a*) Floatable matter—method needs development;
(*b*) Total and organic suspended solid—methods adequate;
(*c*) Acute toxicity—method needs review;
(*d*) Persistent pesticides—method needs review;
(*e*) Persistent organic compounds—method needs development;
(*f*) Biostimulants—method needs development;
(*g*) Gross heavy metals—method needs development;
(*h*) Coliforms (or equivalent)—method under continuous review;
(*i*) Radioactivity—methods adequate.

(4) *Supplemental information:*

(*a*) Information on the accuracy and precision of both the sampling and analytical methods is to be obtained and reported.

(*b*) Data should be obtained on the level of waste-generating activity (i.e., for municipal waste—population tributary; for industrial wastes, level of production and type—tons of product/day, and so forth) so that waste discharges can be reported on a unit mass emission rate basis (i.e., lbs/capita-day or lbs/$10^3$ lbs) product.

(5) *Significant discharge.*—It should be noted that the recommended minimum monitoring program is, as stated, the minimum to be applied to all "significant" waste discharges. Many significant waste discharges may require numerous additional characteristics or parameters to be added to the minimum listing to describe properly the waste characteristics. For example, cooling water discharges may require numerous additional characteristics or parameters such as temperature, heat flux, density, etc., to be added to the minimum listing to describe properly the waste characteristics.

Considerable investigation and study will be needed to define properly waste discharges that should be specifically included in the "significant discharge" category. It should be obvious that a number of considerations are involved in the decision as to whether or not a particular waste discharge is "significant." Some of the considerations are:

(a) The magnitude (flow and pollutant mass emission rates) of the discharge as compared to:

(1) The available dilution and quality requirements of the receiving waters;

(2) The relative magnitude of the discharge as compared to other discharges in the general area; and

(3) The defined or undefined character of the effect of the waste on the receiving water and beneficial uses.

(b) The relative cost of conducting the minimum "core" characterization program as compared to:

(1) The cost of at least secondary treatment for the waste discharge;

(2) The cost of alternative and possible inferior methods of disposal; and

(3) The potential damage of the discharge.

Specifications for the "significant discharge" category must be sufficiently general so as not to exclude some specific and significant discharges of potential ecological damage.

*Monitoring receiving water*

To make a basic assessment of the condition of receiving waters and and the effect thereon of the discharge of treated effluents, the following tests are recommended for a minimum core monitoring program for the water column and sediments (table VI.3.1). It should be noted that the core monitoring program is not intended to be applied in its entirety to all marine waters but only to those bodies of water that receive "significant waste discharges."

Table VI.3.2 presents a summary listing of the recommended core program analyses of the waters and sediments and indicates their recommended application to either restricted waters or the open ocean, or both.

TABLE VI.3.1.—RECOMMENDED TESTS

Water column:
1. Physical:
   (a) Quantification of floatable material and films with analysis for determination of probable origin of material (require method development).
   (b) Water clarity by photometric or other methods (methods adequate).
   (c) Temperature—continuous recording with depth or at least three points in vertical column (method adequate).
2. Biological:
   (a) Coliform determination (method needs evaluation).
   (b) Biostimulatory characteristics (method to be developed).
   (c) Assessment of biomass including standing stock and community structure to determine long-term effect of waste discharges (techniques to be developed).
3. Chemical:
   (a) Dissolved oxygen (method adequate).
   (b) Chlorosity (method adequate).
   (c) pH (method adequate).
   (d) Nitrates (method needs periodic evaluation).
   (e) Phosphates (method needs periodic evaluation).

Sediments:
1. Physical:
   (a) Particle size distribution (methods adequate).
   (b) Temperature (methods adequate).
   (c) Other observations may also be needed for particle density, in-place density, and thickness of waste deposits to permit an estimate of the volume and mass of wastes accumulated (techniques need evaluation).
2. Biological:
   (a) Quantitative description of the standing crop of benthic organisms (quantitative technique needs development).
   (b) Other tests including an index of bottom respiration may be useful to indicate the amount of readily biodegradable organic matter in the deposit (technique needs development).
3. Chemical:
   (a) Concentration of organic matter by concentration of organic carbon or organic nitrogen (technique needs evaluation).
   (b) Presence or absence of $H_2S$ (quantitative technique needs evaluation).
   (c) pH (technique adequate).
   (d) Other measurements should be made for suspected toxicants when appropriate including specific trace metals (technique needs evaluation).

TABLE VI.3.2.—SUMMARY OF RECOMMENDED CORE PROGRAM ANALYSES WATER COLUMN AND SEDIMENTS

| Analyses | Restricted water | Ocean water |
|---|---|---|
| Water column: | | |
| Physical: | | |
| (a) Flotables and films | X | X |
| (b) Clarity | X | X |
| (c) Temperature | X | X |
| Biological: | | |
| (a) Coliforms | X | X |
| (b) Biostimulants | X | X |
| (c) Biomass characterization [1] | X | X |
| Chemical: | | |
| (a) Dissolved oxygen | X | |
| (b) Chlorosity | X | X |
| (c) pH | X | X |
| (d) Nitrates | X | |
| (e) Phosphates | X | |
| Sediments: | | |
| Physical: | | |
| (a) Particle size distribution | X | X |
| (b) Temperature | X | X |
| Biological: Benthos characterization [1] | X | X |
| Chemical: | | |
| (a) Organic matter | X | X |
| (b) $H_2S$ (presence or absence) | X | X |
| (c) pH | X | X |

[1] Quantitative.

## RECOMMENDATIONS CONCERNING PHYSICAL PROCESSES AND INTERACTIONS

### *Initial dilution and diffuser design*

(1) Present knowledge of buoyant jet diffusion is nearly adequate for design of an outfall (including a multiple-port diffuser) to achieve a prescribed initial jet dilution and submergence below any given thermocline. However, further research is needed in a number of areas. Primarily, there is need for understanding of line sources, and how well multiple-jet diffusers may be represented by line sources. Although current effects on initial plume behavior are not well understood, they are not as critical as density stratification as a factor in predicting initial dilutions due to jet mixing.

(2) Methods do not exist for predicting the size and shape of waste fields (of either conventional or heated effluents) which are developed at the end of the initial jet-mixing stage. Closely coupled with this is the problem of lateral spreading due to density differences between the field and its environment. Research should be conducted on both of these problems.

(3) For barge dumping of sludges in the ocean, research is needed on flows generated by suddenly released sinking sludge in a stratified environment.

(4) Control of thermal pollution in coastal waters involves the same kind of stratified flow problems as sewage disposal. Inasmuch as large submerged diffusion structures are not in use yet, some problems of large single jets need special study, such as the behavior of a buoyant surface jet injected in a stream perpendicular to the current.

(5) Field studies of flow patterns and dilutions over waste outfalls are needed urgently to confirm design predictions and methods. Most of the hydrodynamics of buoyant jet mixing has been confirmed only in laboratory experiments.

*Physical processes in estuaries*

It is necessary to develop a sound physical basis for quantitative predictive models of time and space variations of constituent distributions in estuaries. This will require further work on theoretical, numerical, and physical models, determining the correlation between the models and field studies. Priorities need to be set based on the urgency of the practical problem and the relative degree of understanding of the particular class of estuary. The most urgent problems are likely to occur in those estuaries which we know the most about, primarily coastal plain estuaries.

(1) Further knowledge is required of the relationship of the mean circulation, tidal currents, and turbulent exchanges to the river inputs, external tides, external density distribution, wind, and the shape and size of the estuary.

(2) There is little knowledge of conditions responsible for the change in an estuary from a salt-wedge to a partially mixed estuary, or from a fjord to either a salt-wedge or partially mixed estuary. These conditions need study, particularly those in fjords.

(3) In the development of models, both theoretical and numerical models should be stressed as they include the possibility of the incorporation of biological, chemical, and physical processes at prototype scales.

(4) The turbulent processes need investigation as their dependence on density stratification and mean velocity shear plays a dominant role in the behavior of these estuaries.

*Turbulent flux and diffusion*

(1) Detailed observational approaches to the problem of turbulent diffusion are needed. Simultaneous measurements of turbulent fluctuations in velocity, salinity, and other properties together with environmental factors such as shears in mean velocity and stability of the water column are necessary. Likewise, tracer studies on a scale of 10–100 meters should be carried out under various environmental conditions.

(2) There is need to develop predictive models for gross spreading of patches and plumes in the ocean from the combined effects of eddy diffusion (both horizontal and vertical) and shear in the mean velocity field. The research in item 1 above will provide a basis for this development and will allow a better interpretation of previously reported values of gross dispersion coefficients.

(3) It is recommended that systematic tracer experiments be carried out in subsurface waters in order to have more reliable information on the dispersion or rate of speed of a patch or plume. These experiments should include the use of artificial tracers, such as fluorescent dye, and studies of existing waste fields which occur at subsurface depths.

*Physical processes in coastal areas*

(1) To achieve a proper understanding of coastal circulation on all scales, a program of collection of oceanographic and meteorological data is recommended. The observations should be made over a long enough period of time to reveal all periodicities up to and including

annual. Although such a program could be carried out by multiship operations, moored arrays of instruments capable of sampling the entire water column would probably be better. Such a program should permit evaluation of wind, river inflow, tide, and internal waves as transport mechanisms.

(2) To improve our ability to predict the fate of pollutants introduced into estuaries and coastal waters under specific environmental conditions, a study is recommended of the effects of intermediate-scale variations in the current pattern on the time-varying concentrations of waste components at various distances from the source, using tracers such as fluorescent dyes as well as waste components from existing outfalls.

(3) It is recommended that the large-scale processes which lead to exchange of coastal water with oceanic water be studied. One possibility is the development of a fluorometer capable of sampling at all depths which is an order of magnitude more sensitive than at present so that large-scale dye tracer experiments could be carried out economically. Another possibility is a search for a more economical tracer.

*Decay of nonconservative constituents as related to physical factors*

A series of controlled field experiments should be conducted to study the nonconservative properites of such constituents of wastewater as enteric bacteria and other toxic substances discharged into coastal and estuarine waters. As soon as reliable detection and enumeration techniques have been developed these studies should be expanded to include pathogenic viruses.

*Interactions between floatable and settlable components of wastes and physical factors*

Floatables are defined here as those materials which appear at the air-water interface. These materials may appear in the form of floating particulate matter (detritus), surface films (monolayers, duplex, or lenses), scum, and foam.

(1) Studies should be conducted to ascertain the prevalence, properties, and character of floatables of wastewater and sludge origin (including barged materials) in coastal waters and in estuaries. The substances comprising the various forms of the floatables (particulate matter, films, scum, and foam) should be identified as to primary source.

(2) Investigations should be made to determine the means by which the floatables are collected and compressed into slicks or streaks on the water surface as well as the natural mechanisms available for transporting the materials in the water surface.

(3) Studies should be made to ascertain methods of treating or handling the wastewaters and sludges to reduce or eliminate problems of surface pollution.

(4) Studies should be conducted to evaluate the movement and dispersion of releases of sludge at sites currently in use, such as in the New York Bight and off southern California. These studies should include, but not necessarily be limited to, investigation of the methods of introducing the sludge; i.e., by barge or outfall, and the transport mechanisms, including settling and resuspension, which influence the distribution and spread of the materials.

RECOMMENDATIONS CONCERNING CHEMICAL FACTORS

*Research preserves*

Because of the enormous complexity of the physical, chemical, and biological interactions in marine ecosystems, there should be a system of ecological classification of natural coastal systems that can be used to make first approximations of the impact of specific types of wastes on them. Such classifications may require new geochemical surveys of coastal systems, but in large part could be erected from extant knowledge.

The classification of coastal systems should be used to select and set aside type preserves for experimental use, for such purposes as stressing the environment to determine the effects of the stress and the rate of recovery of the system when the stress is removed. Such study areas would allow the carrying out of experiments that might not be permissible in areas not so set aside, and would prevent the intrusion of other human influences. The stresses applied might include the addition of growth-suppressing substances, nutrient substances, heat, etc. The study areas would be provided with adequate laboratory facilities for intensive investigation and manipulation.

Type systems to be set aside should include tropical, temperate, and boreal systems, and would include open coastal areas, salt marsh estuaries, tidal estuaries, salt-wedge estuaries, mangrove swamps, and fjords. They should encompass systems of varying depths, sizes, and geomorphology to permit the collection of data to construct models useful for coastal waste management. We consider this to be a matter requiring immediate attention.

*Chemical processes involving dissolved inorganic constituents*

(1) The concentrations and the forms of trace elements believed to be biologically significant in the waters and sediments and their concentrations in organisms in different areas should be determined. The forms in which these elements occur affect their availability to organisms. Areas that should be examined are near the mouths of large rivers and coastal areas where fresh water inputs come primarily from waste water discharges. The elements of concern would probably include but not be limited to copper, zinc, cobalt, chromium, arsenic, molybdenum, selenium, mercury, cadmium, and lead.

(2) The degree of complexing of trace metals by the organic and inorganic constituents of wastewater effluents, sea water, and estuarine waters should be evaluated in both laboratory and field studies. Temperature ranges in the natural environment as well as in the vicinity of thermal outfalls should be represented in the experimental program. Not only may the degree of complexing prove significant in controlling the behavior of the metal ions, it may be pertinent in understanding the action of organic residues. The forms in which the metals exist are important factors in their biological activity.

*Chemistry of particles and processes in sediments*

(1) Experiments should be carried out to establish the effects on soluble components, particularly waste solutes, of flocculation, aggregation, coprecipitation, and sorption. A study should be made of the physical-chemical factors and the role of organisms in affecting

the flocculation rates of sediments in estuaries and coastal waters. Pertinent variables appear to be in the degree of dilution of fresh water suspensions entering sea water, the levels of organic matter, the pH of the mixture, the oxidation potential, the relative percentages of different clay minerals and other solid phases, the mixing characteristics of the flow, and the temperature.

(2) The rates of aggregation and sedimentation of organic particles in the marine environment should be studied. Such factors as pH, temperature, organic-metal ion complexing at organic particle surfaces, and the concentration of inorganic particles should be evaluated. Organic debris appears to play a role in transporting trace metals to the sediments. The organic debris may associate with inorganic particles, thus affecting the sedimentation of inorganic phases (oxides, clays, silica).

(3) The biological and chemical transformations occurring in polluted and unpolluted sediments should be determined with particular reference to nutrients and trace elements. These studies should include considerations of concentration gradients, movement of water at the sediment interface, eddy diffusion, and the release of gas on the rates of transport from sediments to the water column. Also included should be the effects of changes from oxidizing to reducing conditions and vice versa.

(4) Adequate procedures must be developed for distinguishing among inorganic particles, living organisms, and dead organic matter, both in the water column and in the sediments.

*Nutrient chemistry and biochemical changes*

(1) The fluxes of nitrogen and phosphorus in all phases of the cycles affecting the marine environment should be explored. The study should not overlook the fluxes due to rooted benthic plants, birds, and humans.

(2) An understanding should be developed of the amount and character of dissolved and particulate organic matter in the ocean, its origin, including the contributions from rivers and waste discharges, its spatial distribution, and the biological significance.

(3) A study of the factors that control the qualitative and quantitative aspects of phytoplankton blooms in estuarial and coastal waters should be carried out.

(4) The effects of additions of nutrients (phosphate, nitrate, silicate) and oxidizable carbon on the primary productivity and on the resulting organic load in restricted coastal environments should be determined. The relative effects of the individual nutrients are important considerations. The rates of oxygen exchange between the atmosphere and other sources (e.g., ferric oxide in sediments) and the coastal waters should also be studied. These studies will help predict to what extent re-aeration can compensate for the oxygen demand caused by the introduction of oxidizable carbon and nutrients from waste outfalls. Factors such as wind stress, depth, pressure head, density gradient and stability, and surface films such as petroleum should be considered.

(5) The biochemical mechanisms for concentration of trace components by the biota, the subsequent effect of this concentration on the organisms involved, and the transport and further concentration of these trace components as they move up the food chain should be determined.

(6) Subtle, nonlethal effects of waste products on physiological and biochemical processes, such as enzyme induction or inhibition, ion transfer across membranes, and chemosensitive reception should be studied. Such effects may significantly influence the growth, reproduction, development, or survival of marine animals in ways not detected by conventional assay or toxicity tests or population studies. It is in this area of sublethal effects that ocean disposal of wastes may encounter its most serious problems.

*The chemistry of specific pollutants*

(1) In view of increasing pollution by oil leakage and bilge washings from ships, by catastrophic events such as shipwrecks, and by oil seepage and operating wells on the continental shelf, research is needed on:

(*a*) natural biochemical processes responsible for degradation of oil films or oil droplets;

(*b*) techniques of analysis for detecting and characterizing low concentrations of oil in water and for identifying sources;

(*c*) the effects of different oil dispersants in degradation of the oil, the toxicity of dispersant and dispersant-oil mixtures to marine organisms, and the uptake of the oil, dispersant and/or dispersant-oil mixtures in the food chain;

(*d*) the effects of added settling agents on bottom characteristics and on benthos, and the fate of oil so deposited;

(*e*) fractionation of oil films on exposure to environmental influences, and the fate of residual materials in the sea; and

(*f*) the effect of oil films on the air-sea oxygen exchange; and interference in processes of biological productivity, such as changes in light penetration and mixing.

(2) The fluxes of synthetic organic chemicals into the ocean through sewage outfalls, rivers, atmosphere and biota should be determined. Priorities should be given to potentially hazardous or deleterious materials such as pesticides, detergents, fuel residues, certain solvents, etc.

*Chemical consequences of man's physical activities*

(1) The effects of human activities (such as forestry, agriculture, terrestrial and marine mining, dredging, impoundments, etc.) on the flow of inorganic suspended matter to the oceans and on the distribution and character of the sediments should be determined. Among the potentially significant effects are those on transparency of overlying waters, oxygen demand from reducing sediments, transport or release of nutrients including trace elements, alterations of the benthos, silting of harbors, and erosion of beaches.

RECOMMENDATIONS CONCERNING BIOLOGICAL EFFECTS

Current waste disposal practices have often resulted in obvious deterioration of certain estuarine and coastal marine environments. Adequate techniques are not at hand for definitive assessment of all of the important impacts of wastes (including domestic and industrial effluents) imposed on coastal waters. Nevertheless, there is a strong sense of urgency to adduce now whatever useful information can be obtained with existing methods. Four areas urgently need increased attention.

(1) Studies should be made immedately of existing outfalls and disposal areas of a variety of magnitudes in several distinct marine bio-

geographic provinces. These studies and relationships derived from them must serve as an interim basis for improved evaluation of the acceptability of new disposal facilities and sites. They must include at least the following:

(*a*) Quantitative floral and faunal surveys in the immediate vicinity of discharge, within the measurable zones of influence and at reference sites.

(*b*) Sludge fields (when present):

(1) Measurement of the temporal and spatial dimensions of sludge fields,

(2) Chemical analyses of sample sludges from various outfalls with emphasis on substances likely to have biological importance, and

(3) Measurement of the rates of biodegradation and utilization of sludge components by marine organisms.

(*c*) Determination of the dissolved inorganic and organic substances resulting from coastal discharges and their effects by means of:

(1) A chemical inventory of components,

(2) Bioassays of both effluents and affected waters for toxicity and stimulation, and

(3) A study of primary productivity and other community responses in affected waters.

(2) A detailed examination of the public health significance of coastal discharges should be made, including:

(a) Reevaluation of the adequacy of traditional fresh water biological indices in marine waters and in organisms consumed by man, and

(b) Development and application of improved indices.

(3) Research on the biological concentration of waste components by marine organisms should be expanded and intensified. Special attention must be given to organisms involved either directly or indirectly in the food chain of man, without sacrificing adequate attention to the complete environment.

(4) The input of DDT into the marine environment by the United States should be eliminated. In order to avoid a repetition of the DDT type of problem, we further recommend that any material that combines the properties of mobility, chemical stability, low solubility in water and high solubility in lipids be kept out of the marine environment unless it has been proven not to have the broad biological activity that is characteristic of DDT.

(5) The U.S. Government should provide encouragement and funding for increased graduate education in the combined fields of oceanography, ecology, and engineering in order to provide the manpower and competence necessary for insuring rational use of the nearshore ocean and estuaries. In order to make this effective, certain other fields, especially taxonomy and marine chemistry, must also be encouraged and funded.

(6) The U.S. Government should take the initiative, in cooperation with the States, in development on a broad regional basis of a long-range plan for the uses of the coastal waters and estuaries that would be affected by wastes. The plan should project uses for at least 10 years

from the current year and be subject to periodic review and adjustment. The area considered should extend as far from the coast as wastes are likely to have significant effects. The plan should include designation of uses and the setting of standards of tolerable pollution consistent with the uses. This planning must take into account the total water resources of each region.

(7) Long-range, properly designed, detailed, quantitative studies of the structure and dynamics of animal and plant communities and their relationship to waste disposal in carefully selected areas, should be established and supported. These areas should include those that are relatively little affected, those being affected at an increasing rate, and those that are already seriously affected. Some of the studies should be done in designated and protected marine preserves. All should be related to the uses defined in the long-range plan.

(8) Programs of physiological studies to define the tolerable limits of pollution for each of the specific uses envisioned for the zones designated in the long-range plan should be established and supported.

(9) Programs of systems analysis and model development that will improve prediction of the biological effects of various possible combinations of waste treatments, disposal systems, and uses of the receiving water should be instituted and supported. As more data become available from the studies suggested above, models can be continually refined.

(10) All proposals for new installations, modifications or activities that may result in major changes in the amounts or nature of the pollutants should be reviewed to determine whether quantitative ecological studies of the biota are required, both before and after the change. If such studies would lead to greater protection of the biota or provide better bases for regulation, adequate funds for them must be included in the budget. Enough time must be allowed for careful studies, especially those to be done before the change is made. The data from such studies would increase the accuracy of models and would strengthen the objective bases for setting standards.

(11) The U.S. Government should encourage the coordination of wastes management over large regions in order to obtain more economical and efficient treatment. This will allow better use of the limited supply of high quality manpower, improve management of waste disposal and allow better control. It will lead to better regulated, and probably reduced, effects on the biota of the receiving waters.

(12) All of the proceding programs must be subjected to frequent, independent assessment by outside experts in the fields concerned.

(13) Because the biological impact of many pollutants is international, the U.S. Government should accelerate negotiations looking toward international control of pollution of international waters by both airborne and waterborne toxicants.

(14) The U.S. Government should consider and act effectively upon the ultimate disposal problems and the biological effects of new products of any kind which, after release in the commercial market, could result in the impairment of the biological values of the marine environment. The burden of proof of biological effects must rest with the manufacturer.

## Section 13. Summary and Conclusions

The purpose of this chapter is to identify the estuarine problems and areas requiring further research and study. The discussion represents a synthesized consensus of the leading estuarine scientists, engineers, planners, and economists in various universities, organizations and Federal, State, and local government agencies; 15 professional organizations in the forefront of estuarine research; the public, as determined in 30 public meetings; several special studies; the Office of Research and Development of the Federal Water Pollution Control Administration; and the combined Committee on Oceanography of the National Academy of Sciences and the Committee on Ocean Engineering of the National Academy of Engineering.

A great deal of technical and socioeconomic knowledge is necessary to support a comprehensive program of estuarine management. This knowledge must be supplied through multidisciplinary efforts. The knowledge thus developed must include: (1) knowledge and understanding of the biological, physical, and chemical factors of the estuarine zone, (2) knowledge of the institutional framework governing each portion of the estuarine zone, (3) knowledge of the demographic, social, and economic factors and their trends, (4) establishment of goals and uses so that future studies can be relevantly oriented, and (5) an augmentation and synthesis of the previous four adequate to enhance estuarine management.

The most important knowledge to be gained is an understanding of the estuarine environment adequate to permit the recognition and interpretation of causal relationships which, in turn, provides the capability to predict the effects of natural and human activities in the estuarine zone and hence supports a program of technical management. The research programs which will yield this information are in the categories of:

(1) Ecology, taken to include baseline information, broad ecological studies, biology, water quality, natural variability, and interface factors.

(2) Toxicity, taken to include bioassay needs and methodology, sublethal effects, and mortality phenomena.

(3) Microbiology, taken to include the regeneration of plant nutrients, biodegraduation of organic wastes, eutrophication, and pathogens.

(4) Physics and mathematics, taken to include hydraulics, sedimentation, effects of structures and physical modifications, and physical and mathematical modeling.

(5) Socioeconomic factors, taken to include planning, economics, law, social and demographic factors and trends, resource evaluation and allocation, and the role of technical research and study in supporting a comprehensive management program.

(6) Ancillary research and study needs, taken to include environmental monitoring, methodology (both laboratory and field techniques), data processing, training needs, and estuarine zone laboratories.

# CHAPTER 4—SUMMARY

Two major efforts in the national estuarine pollution study have been directed toward two interlocking goals. One has been the development of the national estuarine inventory, which stores the masses of information gathered to satisfy the directive, ". . . The Secretary shall . . . assemble, coordinate, and organize all existing pertinent information. . . ." This data assembly has also led to definition of large data gaps.

The second effort has been to investigate by various methods the state of the art in estuarine sciences in order to ". . . identify the problems and areas where further research and study are required. . . ."

The programs submitted in chapters 2 and 3 of this part appear in several instances to overlap. In those cases the intention is not to develop two different programs, but to develop a single program to serve two different needs. The difference lies in the rather subtle implications of the two terms "basic data" and "basic knowledge." These are symbiotic terms, for without the one, the other does not exist.

The national estuarine inventory itself has proven to be a valuable tool in several respects. Although its prime function is to provide information for estuarine management, it can also serve several other purposes including the following:

(1) A central storehouse of basic estuarine information;

(2) A delineator of data information needs;

(3) A link between existing Federal data systems;

(4) A mechanism for evaluation of estuarine-related programs (such as sampling networks); and

(5) A device to provide data for estuarine systems analysis studies.

In the final analysis, the inventory and the programs outlined in this part are designed and submitted as integral parts of a national program of rational management, preservation and use of the Nation's estuaries and estuarine zones.

# PART VII. COLLECTION OF SUPPORTING INFORMATION

## Introduction

The preceding parts of this report represent in relatively brief form the efforts of the National Estuarine Pollution Study, acting on behalf of the Secretary of the Interior, to "assemble, coordinate, and organize all existing [available] pertinent information on the Nation's estauries and estuarine zones . . ." as dictated by Sec. 5g of the Clean Water Restoration Act of 1966.

The source information was obtained from many different sources, constitutes a tremendously large mass of materials, and includes published and unpublished material in the technical and scientific literature. The quantitative data in the sources was abstracted and consolidated in the form of the National Estuarine Inventory, described in part VI.

In general the sources can be grouped into four categories—transcripts of estuarine study public meetings, Federal and State profiles, estuarine study contractors' report, and the reference collection. The sources are described, herein, only in general terms because of the already voluminous nature of this report. The preceding parts contain references only to those documents which constitute an integral part of the text. A list of all the documents would unduly burden the report and the reader.

## Transcripts of Public Meetings

During 1968 and 1969, the National Estuarine Pollution Study conducted 30 public meetings across the Nation to provide a forum of contacting and receiving the views from the public and private sectors and also from individuals not already contacted and wishing to present their views on the current situation in the estuarine zone. The actual proceedings of these meetings were recorded and most of the transcripts have already been assembled into individual volumes for use in preparing this report and also for future reference. The assembly has been handled by the Study's regional representatives. Since the transcripts represent the actual statements by the attendees, selective distribution has been made to those people involved or interested in the conduct of the study. A limited number of additional copies are being retained for future reference. Volumewise the transcripts amount to several thousand pages of copy. These transcripts are referred to as Transcripts of the Estuarine Study Public Meetings in the place where they were held. A list of the meeting sites, dates of occurrence, and analysis of them are included in chapter 5 of part V. A few of the transcripts has been summarized in the form of brief brochures covering the highlights of the particular meetings. A limited number of these brochures are retained for reference.

## Agency Profiles

Information on the estuarine-related programs and responsibilities received from the Federal agencies participating in the study, and from the coastal State governments have been summarized in the form of profiles which were used in the preparation of the chapters in part V dealing with the roles of the Federal and States agencies. These profiles have been retained in manuscript copy for reference but not for distribution.

## Contract Reports

During the course of the study, some 22 contracts, including reimbursable agreements, were awarded to other Federal agencies, academic institutions, investigatory organizations, and individuals to develop documents surveying a particular phase of the total scope of the study. All of the contracts were designed to result in reports, retained in manuscript copy, for analysis and use in preparing the chapters, primarily in part IV, of the report. These documents, because they are in manuscript copy and represent selected, isolated phases of the total scope of the study, have not been released or prepared for distribution by the study. However, press releases and information sheets on these contracts have been prepared and distributed. The project titles and name of contractor are as follows:

(1) *University of North Carolina.*—State-of-Knowledge on Estuarine Ecology and the Effects of Pollution on Estuarine Ecosystems.

(2) *University of Washington.*—Socio-Economic, Institutional and Legal Considerartions in the Management of Puget Sound Estuarine Resources.

(3) *University of Maryland.*—Analysis of Legal Problems Related to the Development and Management of Chesapeake Bay Resources.

(4) *Florida State University.*—An Analysis of the Socio-Economic Values of Apalachicola Bay, Fla.

(5) *University of Rhode Island.*—Socio-Economic Study of the Narragansett Bay, R.I.

(6) *Florida State University.*—Identification and Analysis of Biological Values of Apalachicola Bay, Florida.

(7) *Gulf Universities Research Corp.*—Case Studies of Estuarine Sedimentation and its Relation to Pollution of the Estuarine Environment (Mississippi Delta; Galveston, Tex.; Mobile Bay, Ala.; and Tampa Bay, Fla.).

(8) *Water Resources Research Center of the University of Hawaii.*—Study of Estuarine Pollution in the State of Hawaii.

(9) *Institute of Water Resources of the University of Alaska.*—Alaska Estuarine Inventory and Cook Inlet Case Study.

(10) *Office of Business Economics, Department of Commerce.*—Demographic and Economic Trends Analysis.

(11) *U.S. Geological Survey, Department of the Interior.*—Studies of Estuarine Sedimentation.

(12) *U.S. Bureau of Mines, Department of the Interior.*—Mining Statistics for Coastal Areas.

(13) *Office of Saline Water.*—Relationship of Saline Water Conversion to the Estuarine Environment.

(14) *Texas Water Quality Board.*—Socio-economic, Land/Estuarine Study of Galveston Bay, Texas.

(15) *Bendix Marine Advisors, Inc.*—A Case Study of Estuarine Sedimentation and its Relation to Pollution of the Estuarine Environment (San Diego Bay, Calif.).

(16) *Alpine Geophysical Associates.*—A Case Study of Estuarine Sedimentation and its Relation to Pollution of the Estuarine Environment (Raritan Bay, N.J.).

(17) *Ralph Stone and Co., Inc.*—Community Planning in an Estuarine-Oriented Community (San Diego Bay).

(18) *The Franklin Institute.*—Selected Abstracts of Storm Water Discharges and Combined Sewer Overflows.

(19) *Infinity, Ltd.*—Case Studies of Pollutional Damage to Estuaries.

(20) *Harold F. Wise & Associates.*—A Study of the Effects of Population Trends and Industrial Trends in the Estuarine Zones on Pollution in the Estuaries.

(21) *Battelle Memorial Institute.*—Socio-economic Values of the Nation's Estuarine System.

(22) *James B. Ayres.*—A Case-History Study of the Massachusetts Estuarine Management System.

## Reference Collection

Finally, the published and unpublished documents perused by the study, directly and indirectly, probably amount to at least 5,000 reports, conservatively. Of this number approximately 3,000 have been cataloged and indexed as to the general type of material included. For possible future use, the Battelle Memorial Institute developed a computerized information retrieval program for estuarine documents which would allow the automatic retrieval of documents, related to the method used for the quantitative data in the national estuarine inventory.

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(14) *Texas Water Quality Board.*—Socio-economic Land/Estuarine Study of Galveston Bay, Texas.

(15) *Bendix Marine Advisers, Inc.*—A Case Study of Estuarine Sedimentation and its Relation to Pollution of the Estuarine Environment (San Diego Bay, Calif.).

(16) *Alpine Geophysical Associates.*—A Case Study of Estuarine Sedimentation and its Relation to Pollution of the Estuarine Environment (Raritan Bay, N.J.).

(17) *Ralph Stone and Co., Inc.*—Community Planning [illegible] Estuarine-Oriented Community [illegible]

(18) *The Franklin Institute.*—[illegible] Storm Water Discharges and Combined Sewer Overflows.

(19) *Pepper, E.H.*—Case Studies of Institutional [illegible] Estuaries [illegible]

(20) *Travis P. Walsh & Associates.*—[illegible] Study of [illegible] ulation Trends and Industrial [illegible] tion in the Estuaries.

(21) *Battelle Memorial Institute.*—[illegible] Nation's Estuarine System.

(22) *Arthur D. Little.*—A Case [illegible] Study of the [illegible] Estuarine Management System.

Finally, the published and [illegible] study, directly and indirectly, [illegible] ports conservatively. Of this [illegible] cataloged and indexed as to [illegible] possible future use, the National [illegible] puterized information [illegible] which would allow the amount [illegible] the method used for the [illegible] inventory.