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The Urban Sea:
Long Island Sound

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The Urban Sea:
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Foreword

One of the pioneering efforts in this country to bring about more rational management of valuable coastal areas has taken place in the Long Island Sound area.

Citizens in this region appreciate the importance of the health of the Sound and strongly support efforts to guide future growth on the land surrounding it.

This volume describing the essential characteristics of Long Island Sound constitutes an excellent introduction to the subject of coastal zone management. It makes a fundamental point about the coastal management effort—a viable program requires a base of essential scientific and technical information.

Coastal zone management attempts the difficult job of putting to work in the public decision-making arena, objective scientific information about conditions along the coastline. It is public policy makers, elected officials for the most part, who ultimately make the decisions about future development. Coastal zone management tries to bring to the decision makers the information they need to know about the likely consequences of their actions on valuable land and water resources.

The work in the Long Island Sound area described in this book can serve as a model for other areas in the country for bridging science and public policy making.

The authors of *The Urban Sea: Long Island Sound* provide us with a basic description of the characteristics of the water body. The Sound, essentially landlocked, is surrounded by a shoreline featuring varied and intensive uses. The water body performs numerous vital functions for the metropolitan area.

The book begins with the geologic formation of the Sound, continues through the history of the development of the region and ends with a discussion of the efforts by citizens in the area to perfect a more rational approach to the management of the resources of the area. The various functions that the Sound performs and their impacts on the quality of the water are carefully reviewed.

There is a chapter on the efforts to come to grips with the problems facing Long Island Sound. For instance, we learn of the Nassau-Suffolk Regional Planning Board established in 1965, an early effort in this country of local coastal zone management. The effort on Long Island attempted to deal with a governmental structure where 149 units have responsibilities for the coastal and marine environment.

The effort described represents a foremost example of regional planning. Clearly the problems of the Long Island Sound area can't be dealt with by one county and even one state alone. The need for regional approaches is increasingly clear around the country as we attempt to grapple with the problems presented by such requirements as providing adequate recreational outlets for our people or to locating major energy facilities in the coastal zone for regional use, for example.

Credit for much of the foresight exhibited in the Long Island Sound area goes to the principal author of this report, Dr. Lee Koppelman. A recognized leader in the field of planning and coastal zone management, Dr. Koppelman now serves on the National Coastal Zone Management Advisory Committee, a 15-member body providing policy guidance to the federal government in the operation of the national coastal zone program. His experience in leading efforts to bring together scientific information and public decision-making and his early recognition of the need to approach coastal area problems and solutions on a regional basis qualify him as a national leader in this important new field.

Robert W. Knecht
Assistant Administrator for
Coastal Zone Management

National Oceanographic and
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Part One

Physical Aspects

The "urban sea" at its most urbanized: Hell Gate area of the East River, looking south.

Introduction

Coastal zone management and planning have received increasing attention in recent years. More than 90 percent of the population of the United States now lives in urban centers concentrated in large measure near the shores of the Atlantic, Pacific, and Great Lakes. Thus, of major concern are the relationships between growing concentrations of people and the coastal fringes. This volume attempts to identify these interrelationships and their impacts as a first step in developing a methodology for coastal zone planning.

Long Island Sound was chosen for our study since in many ways it is a microcosm of national—even global—situations. The Sound lies at the center of the Boston-to-Washington megalopolis and has experienced massive urbanization since the end of World War II. Its diverse and often conflicting uses produce a concomitant array of environmental problems. Yet it is still a viable body of water with a definite potential if wisely used and managed.

The transition from the lonely lighthouses at the eastern end of the Sound to the bustle and traffic jams on the suspension bridges at the western end, where the Sound approaches the New York metropolitan area, is one of the major themes of our discussion. The Sound is constantly subjected to the influences of the largest city in the United States, with its growing suburbs, its sewage, its waste heat, its oil spills, and its millions of people seeking relief from the summer heat on a beach, looking for a place to catch fish, or trying to get just a glimpse of a distant horizon. All these leave their mark on the Sound. Most of the impact is felt in the western part of the Sound, the narrowest part, the part having the least capacity to recover from the accumulated problems of literally centuries of use and abuse.

Reflecting the complex nature of the Sound, the book attempts to relate the historical, social, political, economic, ecological, chemical, and physical aspects of the Long Island Sound region and the effects of man's presence. The material is presented in seven chapters and six appendixes.

The first part, composed of Chapters 1-4, discusses the physical aspects, i.e., the regional setting, basin, shoreline, and motion and chemistry of the water. (The biological aspects are dealt with only as they impinge on use or ecological considerations.)

Part two, containing the last three chapters, addresses the administrative and political issues that form the basis for an eventual management program—so vital for the protection and enhancement of this unique and precious inland sea.

There are definite institutional and political constraints on coastal zone management. Planning for the orderly development of Long Island Sound, or even a small part of it, must include consideration of these constraints, which come in part from the complex and often contradictory legal status of the waters and bottom of the Sound simultaneously imposed by two states, nine counties, twenty-seven towns, ten cities, thirty-nine villages, the City of New York, and the federal government. Chapters 5 and 6 review the uses and misuses that take place in and around the Sound, resulting from human needs and activities, and the governmental responses to them. Chapter 7 mentions the planning efforts undertaken thus far, with recommendations for the future.

The appendices contain detailed statistics, technical data, model guidelines, and bibliographies, which complement the more general discussion in the text.

I The Regional Setting

INTRODUCTION

Long Island Sound is that spindle-shaped part of the Atlantic coastal ocean bounded by Long Island on the south and Connecticut on the north. The Sound extends about 110 miles from west to east. At its widest section it is 21 miles across but narrows to about half a mile at the western end. The eastern extremity of the Sound is marked off from Block Island Sound and the Atlantic Ocean by a chain of islands that sit atop a submerged ridge. This ridge contains many deep passages through which the waters flow into Block Island Sound. Long Island Sound's eastern boundary is distinct to boaters by day or night because it is dotted with lighthouses—the majestic Great Gull light and the more modest ones on Plum Island and Race Point and Orient Point.

There is some difference of opinion over the western boundary. Some consider it the Triborough Bridge, but oceanographers prefer to go farther west to the Hell Gate Bridge, where a submerged ridge made navigation of the East River such a hell for sailing ships. This ridge, which also restricts the flow of water between the Upper and Lower East River, corresponds more closely to the boundary of the Sound in terms of water movements, as described in Chapter 4. The bottom waters of Long Island Sound can flow into the Upper East River but have difficulty getting beyond the Hell Gate region.

The Sound is a partially isolated ocean area with strong tidal currents at both ends—a fact which gained for it the early name of "Devil's Belt." It has many of the features of an estuary (an embayed area of the coastal ocean where salt water and fresh water mix). Because of fresh water discharged by its rivers, the Sound has this distinctive two-layered *estuarine circulation.* Estuarine circulation systems can be found in almost any bay or harbor on virtually any coast of the world. Long Island Sound also resembles much of the coastal ocean bordering the industrialized world. Thus, it can serve as a model for other areas not only in the United States but in the rest of the world.

GEOLOGICAL HISTORY

Long Island Sound is located at the northern end of the Atlantic coastal plain, a low-lying area that extends southward into Florida. The Sound lies on the "Fall Line," which marks the boundary between the Connecticut highlands and the softer (sedimentary) rocks that cover the older basement on the coastal plain (Long Island) and its extension, the submerged continental shelf. Long Island Sound's relationship to the ancient rock of New England and the more recently formed sediments of the coastal plain is shown in Figure 1.1.

Details of the formation of Long Island Sound are still obscure; many important clues are either covered by sediment deposits or submerged by the waters of the Sound. It is known that the basin now occupied by the Sound was formed by rivers eroding the land, probably over many millions of years, although investigators disagree as to the direction of the flow. A ridge (cuesta) left by those ancient rivers is the foundation of Long Island. Without its cover of later deposits, this ridge of Cretaceous sediments would form an island 10 to 12 miles long and about one-quarter the area of the present Long Island. The rocks that underlie Long Island Sound and form its shores fall into three different categories:

1. Hard, crystalline rocks (bedrock) underlying the entire region consist primarily of igneous and metamorphic rocks of Paleozoic age (over 200 million years old) or older.
2. Softer sands, silts, and shales (part of the coastal plain deposits, up to 100 million years old) cover the older, more resistant bedrock; these deposits, which are mostly buried, are the major producers—that is, reservoirs—of groundwater on Long Island.
3. Pleistocene deposits (perhaps 1 million years old) of sand and gravel from melting glacial ice cover the surface of Long Island and many areas in Connecticut.

The Connecticut shore is formed of the hard bedrock mostly overlaid by thin salt marsh or beach deposits, although in some areas the bedrock is exposed. A band of softer, more easily eroded Triassic sediments (about 200 million years old—just after the Paleozoic era) and Triassic basaltic rocks form much of the Connecticut River Valley; Triassic rocks probably extend under the Sound and possibly beneath Long Island as well, lying just above the bedrock. The bedrock slopes generally southward under Long Island and the adjacent continental shelf.

The coastal plain sediments form a sand-clay-gravel wedge (see Figure 1.2) that dips seaward and thickens to the south. This wedge of deposits starts out under Long Island Sound and Long Island. There is some evidence, however, that these sediments formerly extended northward, covering part of the coastal area of Connecticut. They are exposed in only a few places on Long Island's north shore but are well exposed on the coastal plain from New Jersey southward.

These sediments were originally formed in shallow marine waters on an earlier continental shelf (which included the coastal plain when it was submerged). The sea alternately advanced and retreated across the continental shelf/coastal plain while sediments accumulated.

Millions of years later, sand and gravel were deposited by continental ice sheets that twice came down to Long Island from the north. In passing over New England, glaciers perhaps a kilometer thick removed the soils and scoured the rocks beneath. The sands and gravels thus formed now cover the surface of Long Island and large parts of the Connecticut coast.

On Long Island, stiff, unsorted sediments (known as boulder clays) deposited by the glaciers form the two main ridges, the backbone of the Island; their extensions form the two "forks" at its eastern end. These ridges, called moraines, mark the southern limit of the Pleistocene ice sheets.

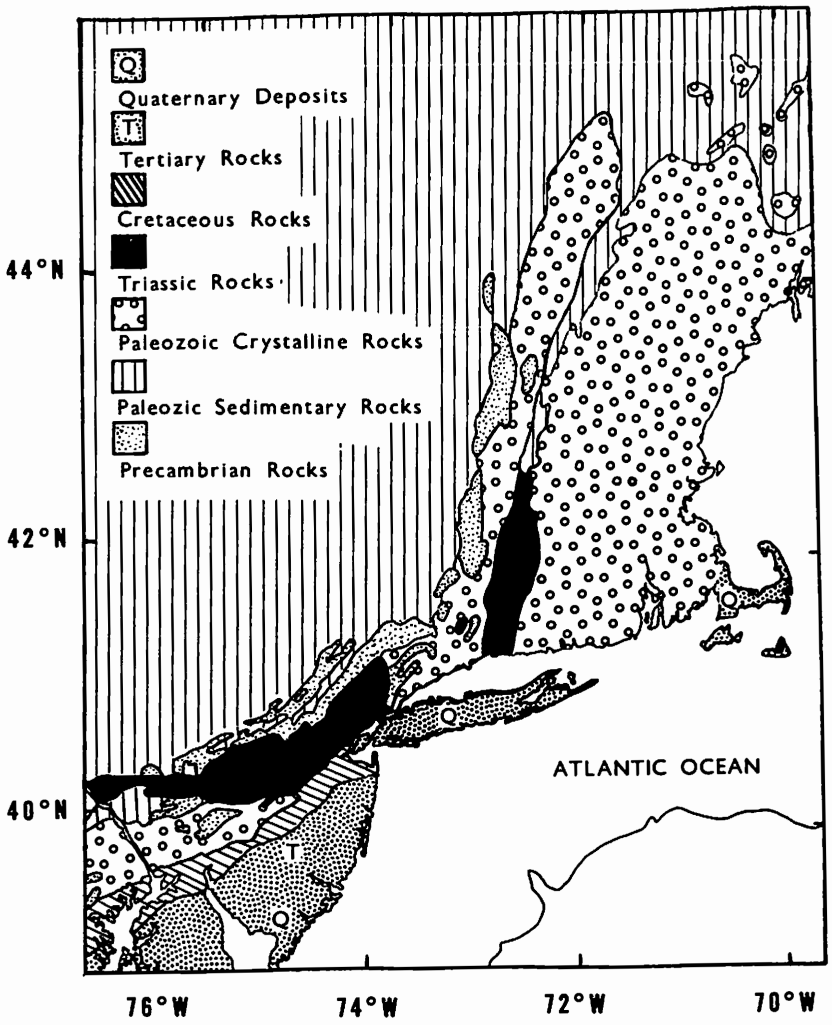

FIGURE 1.1 *Geologic map of the northeastern United States. Note that Long Island Sound lies along the boundary between the relatively old rocks exposed in New England and the younger rocks of Long Island and New Jersey.*

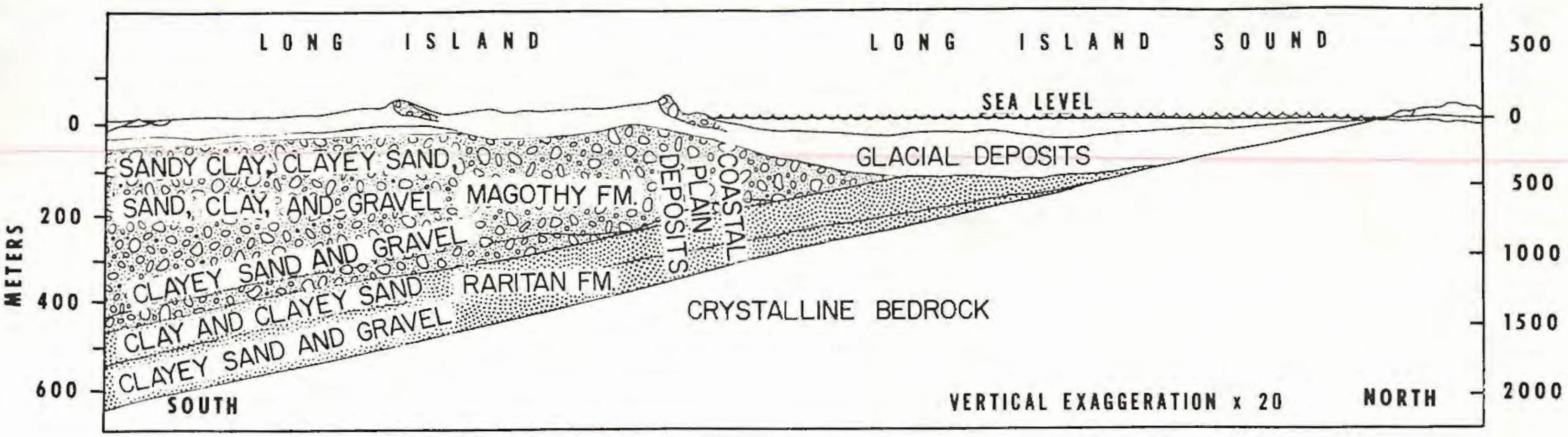

FIGURE 1.2 *Geological cross section showing the buried bedrock and coastal plain deposits beneath the surficial glacial deposits on Long Island. The section extends generally southward from the Connecticut River (after U.S. Geological Survey, 1967)*

As the glaciers melted, streams of meltwater carried iceborne sediment which they deposited south of the retreating glacier. These aprons of sand and gravel form the southward sloping plains of Long Island. Similar glacial deposits are found at the bottom of Long Island Sound; they are exposed where currents have scoured away more recent deposits on submerged ridges. Elsewhere they lie beneath deposits of more recent origin.

Although much of the Connecticut coastline was cut by streams, large areas are covered either with relatively thin, unstratified deposits (known as tills) laid down as the glaciers retreated or with the stratified sands and gravels formed by the stream deposits from the glacial meltwaters. Borings made for bridge construction show that the boulder clays laid down by the ice rest on river-cut rock surfaces.

The till deposits are usually overlaid by stratified sands and gravels deposited as outwash plains (areas of stream deposits), similar to those on southern Long Island. Present river beds or estuary bottoms commonly consist of mud or soft sands containing abundant plant remains, typical of estuarine or marsh deposits. Thus, these Connecticut valleys record the development of a streamcut valley, later slightly modified by glacial action, and partially filled by glacial deposits as the continental ice sheets melted. After sea level rose sufficiently to flood the area, sediment deposits began accumulating and presumably are still forming in estuaries and marshes.

SEA LEVEL CHANGES

Just as the advance and retreat of the continental glaciers sculpted the surface features of Long Island and the Connecticut coast, changes in sea level had a profound effect on Long Island Sound, although their precise effects have not yet been delineated.

When the continental ice sheets covered large sections of North America and Europe between 2 million and 15,000 years ago, sea level was as much as 330 to 390 feet lower than it is today, since the enormous ice sheets contained water withdrawn from the ocean. When the glaciers melted and released their water, sea level rose. At first it rose rapidly, perhaps as much as three feet per century, until about 9,000 years ago when it slowed to a rate of about 11 inches per century. Over most of the world ocean, the water attained its present level about 3,000 to 5,000 years ago.

But in southern New England and Long Island Sound, there was a second complication. The weight of the glacial ice also depressed the earth's crust beneath it. The relatively soft rocks in the earth's interior gave under the weight of such loads, allowing New England and the Sound to sink. The weight of glacial ice on New England depressed the area as much as 150 feet below its present level. Lying near the edge of the glacier, Long Island Sound was undoubtedly not as depressed; the actual amount of depression has not been determined. When the glaciers melted, removing the load, the land rose slowly.

As the ice melted, sea level rose more rapidly than the land was uplifted. Thus, the shoreline advanced across the now-submerged continental shelf. Dating of radioactive carbon-14 in shells from shallow-water organisms, carbon from the campsites of early inhabitants, and teeth of mastodons and mammoths indicates that about 12,000 years ago, the shoreline was located where the water is now 90 to 100 feet deep. At this level the sea apparently entered Long Island Sound and the Hudson River Valley.

Later uplift of the land complicated the picture by interfering with river drainage, thereby forming lakes and swamps. At least one such lake apparently formed in the Long Island Sound area. A ridge now submerged about 80 feet in the eastern end of the Sound may have dammed rivers flowing into the Sound, forming a freshwater lake. The size of such a lake can only be conjectured. Freshwater lakes also formed in northern New Jersey and in the Hudson River Valley.

The best available records of sea level changes are contained in marsh deposits bordering Long Island Sound. From studies of the Connecticut coast and its marshes, Arthur Bloom of Cornell University showed that sea level has risen (relative to the land) about 10 feet in the last 3,500 years and about 27 feet in the last 8,000 years (see Figure 1.3). The present shoreline and its adjacent marshes and harbors were formed in the past 3,000 years, after the rate of sea level rise slowed down. When sea level was still rising rapidly, intertidal grasses, characteristic of marshes, could not gain a hold, and the shallow embayments remained open water. But within 1,000 years after the slowdown in the sea level rise, marsh grasses took hold and the marshes formed. Most marshes quickly built up to the high-tide level because of the efficient sediment trapping of the marsh grasses.

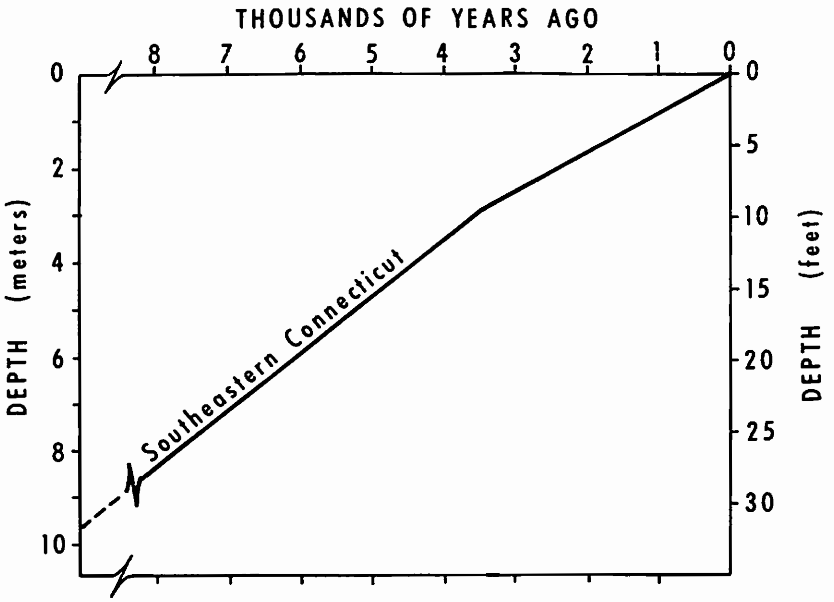

FIGURE 1.3 *Rise of sea level on the Connecticut coast of Long Island (after Bloom, 1967).*

Small barrier islands, sand spits, and gravel bars that line the shore of Long Island Sound also formed during the past 3,000 years. On both sides of the Sound, development of beaches is inhibited by the absence of large waves and swells. Formation of beaches on the Connecticut shore is further inhibited by the scarcity of easily eroded glacial deposits there. On the north shore of Long Island, however, sand and gravel are more abundant and beaches tend to be better developed.

HUMAN HISTORY IN THE LONG ISLAND SOUND REGION

The dramatic changes that have taken place in Long Island Sound as the result of man's presence have been instantaneous compared with the natural processes that created the geological formations of the Sound and its surrounding land areas.

From the time of the first Indians to the present, the human history of Long Island indicates a continued but varying dependency on the marine environment. Long Island waters offered the Indian an ample protein diet to be had literally for the taking. For this reason, many tribes encamped near the Sound.

Food from the sea was an important staple in the Indian diet. In fact, one early Dutch account noted that "if oysters had legs, the Indians would starve." It has been postulated that the ease of food gathering for coastal Indians led to their rather passive nature, in contrast with the more aggressive tribes on the Plains that were dependent on hunting big game.

Agriculture was also essential to Indians living on both sides of the Sound. Corn was the staple; pumpkins, squash, and beans were grown with the corn. Unfortunately, the soils around Long Island Sound were poorly suited to the primitive agriculture practiced by the Indians. Today the industrious suburbanite applies chemical fertilizers to supply nitrogen and other nutrients for his grass and shrubs. Some Indians used the abundant fish (menhaden and alewives, and the heads and entrails of cod) for the same purpose. These fish were planted along with the seed to supply the needed nutrients. But even with this, the soils were quickly depleted. Thus, the tribes had to move frequently to nearby virgin land to grow adequate crops. This casual approach to property rights later caused trouble with European settlers.

European contact with Long Island Sound probably started in 1524 when Giovanni Verrazano explored New York Harbor and may have entered western Long Island Sound. But we know for a fact that the Sound was explored in the spring of 1614 by Captain Adrian Block, a Dutchman. After his ship *Tiger* burned in New York Harbor in late 1613, Block and his crew built *Onrust* ("the Restless"), a ship 38 feet long, with a beam of 11.5 feet and about 16 tons burden—a modest vessel indeed. He sailed through and explored Long Island Sound and the Connecticut River, and he crossed Block Island Sound and landed at Block Island, both named in his honor. Not only was he the first European to explore the Sound, but he was the first to build a ship in the region.

In 1619, five years after Block's voyages, Captain Thomas Dermer, an Englishman, entered Long Island Sound from the east. Sailing westward, he passed through "Hell Gate," as Block had named that turbulent, dangerous portion of the East River, to enter what is now New York Harbor. Thus, two European ships had navigated Long Island Sound before the *Mayflower* brought the Pilgrims to Plymouth Harbor in 1620.

A few Dutch settled here and there on the shores of western Long Island Sound as far east as Oyster Bay on Long Island and the Connecticut River on the north. But it was predominantly the English who settled the shores of Long Island Sound. Coming by way of Massachusetts, they reached Connecticut and Long Island in the 1630s, founding towns as they went—New Haven (in Connecticut) in 1638, Southold and Southampton (on Long Island) in 1640, New London (Conn.) and Flushing (L.I.) in 1643, East Hampton (L.I.) in 1648, and Setauket (L.I.) in 1655.

The first European settlers relied heavily on seafood until the ground was cleared and crops sown and harvested. These hardy people, no strangers to the sea, brought a heritage of shipbuilding, fishing, and sailing. It was thus natural that maritime activities flourished along with agriculture. Fishing fleets set sail for the Grand Banks from Greenport and other eastern Long Island ports, and whalers embarked from Greenport and Sag Harbor, from Mystic and New London. Then as now, 300 years later, baymen and lobstermen collected a rich harvest of clams, oysters, scallops, crabs, and lobsters from Long Island Sound waters.

The nomadic agricultural practices of the Indians did not blend well with the more fixed patterns of the Dutch and English settlers. This cultural clash resulted in hostilities which, combined with disease (smallpox and alcoholism), decimated the Indian population. The Long Island Indian population, about 5,000 before the European colonization, dropped precipitously. In 1670, there were only two small Indian villages remaining. By 1732, tribal life there was virtually ended.

Long Island Sound has a long history as the maritime highway for southern New England and the north shore of Long Island. During the early colonial period, roads were poor or non-existent. Long Island Sound and the navigable rivers flowing into it were the major transportation routes. Most of the early communities were established on the shores of the Sound and these rivers.

The West Indies trade gave the first commercial impetus to the region. Rum, sugar, and molasses were brought by ship to the Sound area—especially to New London. Fish, flour, ham, and wood products were exported to the Caribbean Islands. Just before the American Revolution, this flourishing trade was ended by war in the Caribbean and the threat of war in the American colonies.

Until 1815 farmers and merchants sent their goods to New York City in sailing skiffs or shallops. These small ships were often becalmed for days. At best the consignee had to wait. All too frequently the cargo rotted. This was changed with the advent of steam. In 1815, steamships began to navigate the Sound.

Until 1889, these steamships were the foremost carriers of freight and passengers between New York and various ports on the Connecticut shore. From Connecticut, passengers or freight moved overland to Boston. Freight haulage by sea from Long Island to New York City and New England markets continued well into the 19th century. Cordwood, for example, was cut on eastern Long Island, loaded aboard schooners at various landings, and shipped to the city on a regular basis.

Industrial and agricultural technology began to have a negative impact on the shipping and fishing industries in the mid-19th century, with the building of the Long Island Railroad in 1844 and the completion of the New York-Boston rail link in 1848. Rail service supplanted waterborne haulage. Improved agricultural production lessened the market for sea products. Discovery and production of petroleum, natural gas, and later, electric illumination reduced the demand for whale oil. Boston and New York City came to dominate the region's commerce.

The gold rush of 1849 played a significant role in the demise of the deepwater fishing industry on Long Island Sound. It was far more profitable, and probably easier, to carry miners around Cape Horn to California than to search for whales or fish. At the end of these voyages, many sailors jumped ship to look for gold.

American shipping suffered a further decline during the Civil War and the succeeding years of the 19th century, when the country's attention was focused on the development of the West. Finally, the coming of the automobile and the modern highway in the 20th century contributed to the dwindling role of Long Island Sound in regional transportation.

The downward trend in commercial fishing and shipping sketched here has not been limited to Long Island Sound. Similar decline has occurred on a national scale. The United States, which as recently as 1957 ranked third among the world's fishing nations in size of catch, ranked sixth after Japan, the U.S.S.R., China, Peru, and Norway in 1972.

SUBURBANIZATION OF LONG ISLAND SOUND

Despite its commercial decline, Long Island Sound still plays an important role for those living on or near its shores. Recreational boating and fishing are now major industries, having replaced whaling, shipping, and commercial fishing. An estimated 227,000 pleasure boats in the area earn for the Sound the title of "the Times Square of Yachting." About 140 yachting and boating clubs and over 100 boatyards and marinas service this weekend armada. Indeed, construction of new marinas to harbor this expanding fleet and of facilities for waste disposal is a sensitive issue in many harbors and bays on the Sound.

The extent and rate of urbanization of the Long Island Sound region within the past half-century has undoubtedly produced a greater and more rapid transformation of the Sound than everything that occurred in the previous 10 millennia. Today the Sound is more completely urbanized than any of the other coastal waters of the United States except perhaps San Francisco Bay.

Long Island Sound was the first of the nation's waterways to be impacted by urbanization and the environmental problems caused by densely populated shoreline areas. Except for small rural areas on its eastern end, the Sound is lined with suburbs and cities. Although other parts of the coastal ocean of the northeastern United States have been affected by incipient urbanization—the innermost sections of Delaware Bay and Chesapeake Bay, for example, have short stretches of suburbs and city—none is as developed or populated as the Long Island Sound region.

The dramatic post-World War II population growth in the United States has been called an "explosion." But the urbanizing process started much before this. During the first half of the 20th century the urban population of the United States increased by 66 million. The influence of large cities extended past their legal boundaries into the surrounding regions. This is commonly referred to as "suburbanization": the outlying areas become suburbs of the cities, and as the process continues, the rural areas surrounding the suburban regions (exurbia) also become suburbs in turn.

This trend has been most apparent along the northeastern seaboard. This was the area of earliest and heaviest settlement, and it contains many large cities in relatively close proximity. When suburbias of different cities converged, the result was an almost continuous urban region 600 miles long, stretching from just north of Boston to just south of Washington, D.C. and known as Megalopolis.*

At the hub of Megalopolis is New York City, the largest urban area in the country. Figure 1.4 depicts the New York region, emphasizing its relationship to Long Island Sound, that is, the nine counties, five in New York State and four in Connecticut, with Sound shoreline.

Table 1.1 indicates the extraordinarily rapid growth that occurred in the region between 1950 and 1960 and the somewhat slower but still significant growth that occurred between 1960 and 1970. The Long Island Sound area's population increased from approximately 5.8 million persons in 1950 to 7.6 million in 1960, a gain of 30.1 percent, and from 7.6 million to 8.8 million in the following decade, a gain of 15.7 percent.

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*Jean Gottman, "Megalopolis or the Urbanization of the Northeastern Seaboard,' *Economic Geography* July 1957: 189-202.

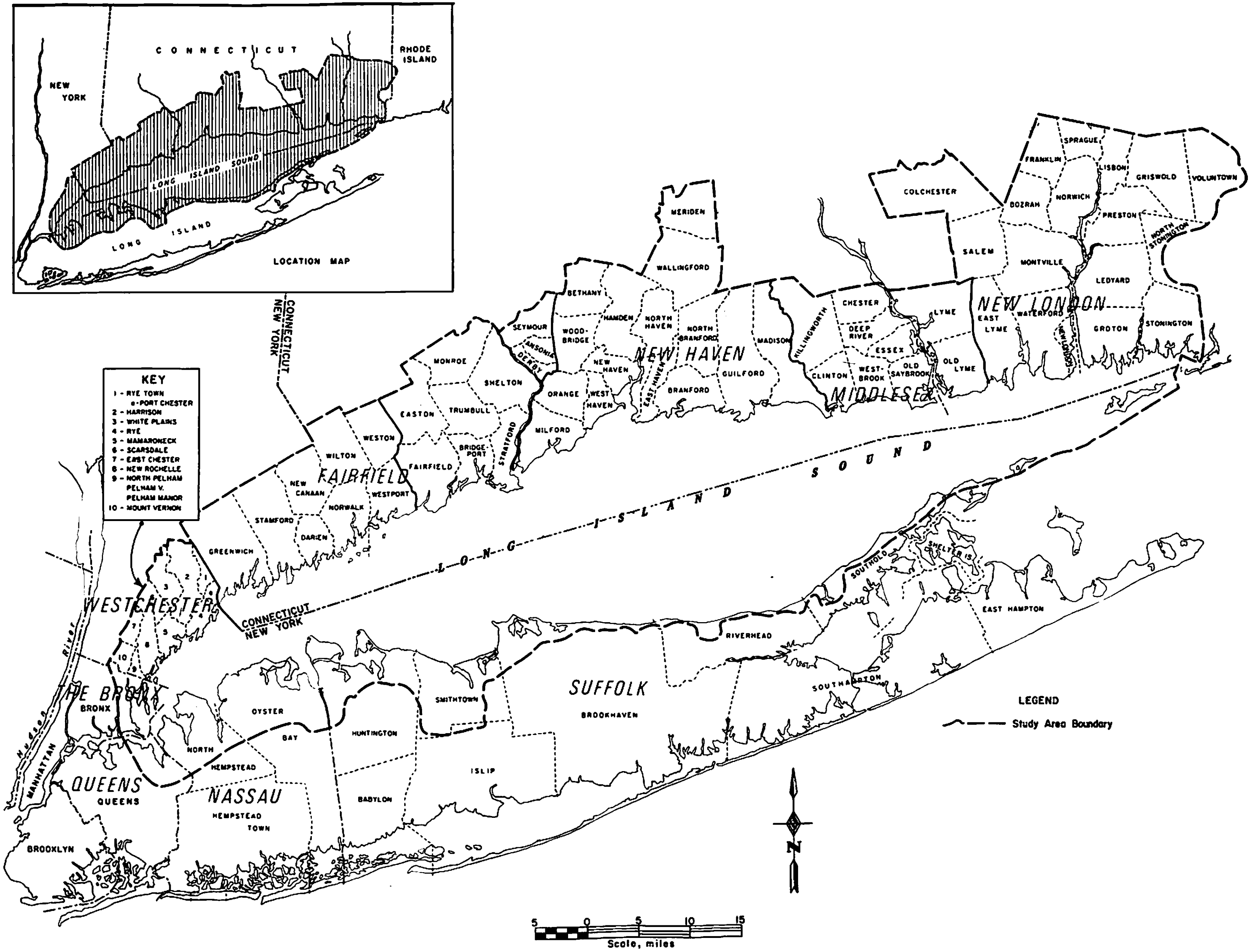

FIGURE 1.4 *The New York metropolitan region and its relationship to Long Island Sound*

TABLE 1.1 *Growth of the Long Island Sound Region, 1950–1970*

	1950	*1960*			*1970*		
	No. of Persons	*No. of Persons*	*Change No.*	*Change %*	*No. of Persons*	*Change No.*	*Change %*
New York							
Bronx	1,451,277	1,424,814	-26,463	-1.8	1,471,686	46,872	3.3
Nassau	672,765	1,300,171	627,406	93.3	1,428,838	128,667	9.9
Queens	1,550,849	1,809,578	258,729	16.7	1,986,470	176,892	9.8
Suffolk	276,129	666,784	390,655	141.5	1,127,030	460,246	69.0
Westchester	625,816	808,891	183,075	29.2	894,100	85,209	10.5
Connecticut							
Fairfield	504,342	653,589	149,247	29.6	792,814	139,225	21.3
Middlesex	67,332	88,865	21,533	32.0	115,018	26,153	29.4
New Haven	545,784	660,315	114,531	21.0	744,948	84,633	12.8
New London	144,821	185,745	40,924	22.0	230,654	44,909	24.2
Total	5,839,115	7,598,752	1,759,637	30.1	8,791,558	1,192,806	15.7

Source: U. S. Census of Population, 1950, 1960, and 1970.

Most of the growth has occurred in the suburban counties around the Sound. In fact, New York City itself lost approximately 110,000 persons between 1950 and 1960 and gained only 113,000 between 1960 and 1970.

The movement to suburbia peaked after World War II for several reasons. During the war, construction of homes was given low priority. After 1945, however, thousands of returning veterans, assisted by federal loans, sought homes for their new families. A serious housing shortage resulted. Developers therefore looked for land where they could undertake mass production of homes. With the major urban centers already built up, their logical choices were the less-developed areas outside the cities, such as the Long Island Sound region.

Urbanization can't be separated from the growth of commerce and the increase in labor specialization. Starting in 1950, the balance between manufacturing and non-manufacturing employment in the big cities shifted in favor of the latter; this shift accelerated with the trend toward specialization. By 1970, non-manufacturing employment accounted for more than five out of every eight jobs in the Connecticut portion of the region and nearly four out of every five in the New York portion.

The increase in white-collar jobs, particularly in New York City, which contains the largest concentration of banks and insurance companies in the country and is the nerve center for advertising, publishing, mass media, and scientific research, meant a larger middle class which had to find a place to live. The residential capacity of the older cities is often saturated; it is difficult for middle-income people to find adequate city housing at reasonable prices. With only slums and expensive high-rise apartments to choose from, many of them were attracted to suburbia, with its open space and nearby recreation.

A view towards Hell Gate looking west from the Throgs Neck area.

The exodus from the cities was made possible by the spread of the automobile and construction of scores of new highways in the 1950s, enabling workers to live a number of miles from their jobs. Many industries also migrated to the suburbs to enjoy expanded facilities and lower costs. The city's growing problems of congestion, crime, and pollution further encouraged people and industry to move out.

Families in the Long Island Sound region are relatively affluent. The movement of middle- and upper-income families to suburban homes, while adversely affecting the income structure of the city, has raised income levels and the amount of disposable income throughout most of the area. According to the 1970 census, the median family income exceeded that reported for the country as a whole in eight of the nine Long Island Sound counties. Table 1.2 shows median income for the United States and for these counties.

Only the Bronx, a central-city county with a sizeable poverty population, reported a median below the national level.

Urbanization is expected to continue. In 1970 there were almost 42 million people—one out of five of the total population of the continental United States—living in the 600-mile eastern seaboard strip between New Hampshire and Virginia, covering only some 54,000 square miles. The average density was almost 800 persons per square mile. No other grouping of communities in the country approaches this figure.

The Regional Economic Analysis Division of the Bureau of Economic Analysis of the US Department of Commerce, which has prepared population projections for the Long Island Sound Study of the New England River Basins Commission, suggests that the population of the region exclusive of the two New York City counties may reach almost 8.0 million by the year 2000. Should this occur, this part of the region will be accommodating an additional 2.6 million or half again as many people as in 1970. The suburban New York counties are expected to grow by as much as 57.1 percent; the Connecticut counties, by 35.7 percent; and New York City as a whole, by 24.9 percent. Suburbanization will undoubtedly continue and perhaps even intensify, converting rural land to exurbs and exurbs to suburbs. Furthermore, suburbanization will probably continue on the two other major estuaries in Megalopolis—Chesapeake Bay and Delaware Bay. It is urgent, therefore, that we understand the effects of the acute growth and spread of population on the coastal ocean and estuaries.

TABLE 1.2 *1969 Median Family Income*

United States	$ 9,590		
Bronx	$ 8,308	Fairfield	$13,086
Nassau	14,632	Middlesex	11,632
Queens	11,555	New Haven	11,303
Suffolk	12,084	New London	10,520
Westchester	13,784		

Source: U.S. Census of Population.

Tracing the growth of communities along the shores of Long Island Sound through statistical and historical data is fairly straightforward work. *Describing the effects of this growth on the waters of the Sound and its bays, however, is not so simple.* The complex relationships between human settlement and natural systems are just beginning to receive scientific study and analysis. The earliest set of scientific data covering the entire Sound dates back only to the late 1940s and early 1950s, with the work of marine scientist Gordon Riley and his associates at Yale. Yet comparing current studies to this work indicates distinct signs of change in the Sound. Change—and perhaps deterioration—is inevitable as the shoreline and waters of the Sound are used for many incompatible purposes like waste disposal, food production, recreation, transportation, and sand and gravel mining.

These competing uses are not new. But whereas the colonial villagers and farmers might never have detected the effects of unplanned and uncontrolled waste disposal operations, today's suburbanite is likely to find that his prized bay has developed some unusual colors in the summer waters, along with intermittent fish kills and unpleasant odors. These are some of the effects of continued disposal of sewage, even after it has been treated in modern, well-run facilities. That such changes are taking place in the Sound, and that they are in large part cumulative, man-induced changes, is clearly shown in the basin itself, in the shores that line it, and in the water that fills it, flowing in and out.

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2 The Basin

INTRODUCTION

An ancient event and a modern practice are the two most distinguishing and interesting characteristics of the Long Island Sound basin. One we have already looked at: the glaciers that scoured the edge of the continent rearranged the landscape so that, when sea levels rose and flooded the ancient freshwater lake from both ends, the main rivers poured into the Sound very near its principal ocean mouth. This very peculiar feature in a body of water otherwise behaving like an estuary has had considerable influence on sediment distribution and bottom topography (as well, of course, as on salinity and other water properties discussed in Chapter 4).

The glaciers also removed most of the soil, leaving little to wash downstream in the rivers as sediment. The result is that human sediment contributions—through the modern practice of dumping solid wastes—far outweigh natural sediment from rivers. In fact, seeing the alteration of the shores and bays by dredging, and noting the solid wastes accumulating on the bottom, we may say that human forces are now the major influence shaping the character of the Long Island Sound basin.

DRAINAGE BASIN

Long Island Sound is the water-filled part of a basin which occupies an area of 39,120 km^2 (15,820 mi^2) northward to the Canadian border and south to central Long Island (Fig. 2.1). From the upland segment of this basin, Long Island Sound receives fresh waters which originally fall as rain or snow over a large portion of New England. Three rivers carry most of this water to the Sound: the Connecticut River, the Housatonic, and the Thames (Table 2.1). No large rivers flow into the Sound from Long Island; streams discharge only about five percent of the amount of rain and snow that falls on the Island each year. The highly permeable sands and gravels forming Long Island permit about half the annual precipitation of 115 cm (45 in) to soak into the ground and reach the Sound as groundwater outflow, rather than as river discharge. Groundwater flows into the Sound through the bottoms of the bays and along the shore. The volume of Long Island Sound is estimated at 61.8 km^3 (14.8 mi^3), and its average depth at 19.4 m (64 ft).

TABLE 2.1 *Major Rivers Draining Into Long Island Sound*

River	*Drainage basin area* *km^2*	*(mi^2)*
Connecticut	29,100	(11,250)
Housatonic	4,050	(1,950)
Thames	3,810	(1,470)
Total Long Island Sound Drainage Basin (includes Long Island portion)	39,120	(15,820)

BOTTOM TOPOGRAPHY

The waters of the Long Island Sound basin hide its complicated bottom topography (Fig. 2.2). Complex small basins and intervening barriers, called sills, affect the circulation of subsurface waters and movement of sediments. There

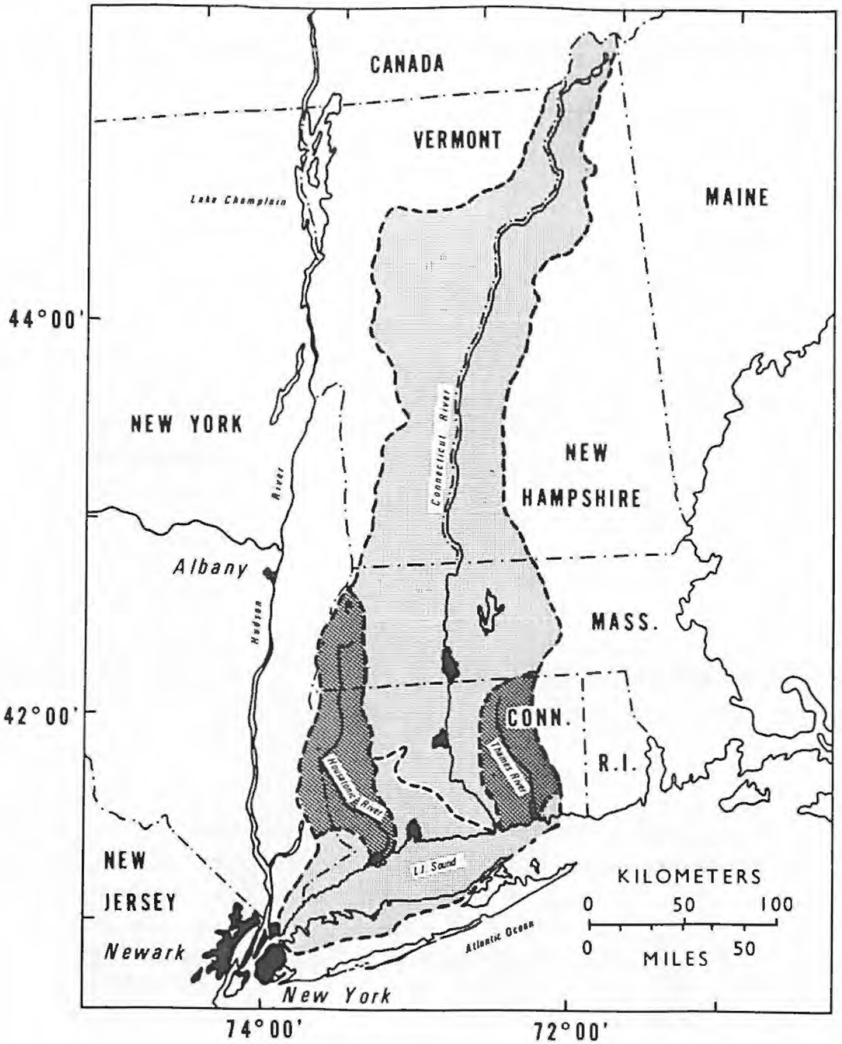

FIGURE 2.1 *The Drainage Basin of Long Island Sound.*

Note that the New England section is drained primarily by the Connecticut River. Long Island has no large streams and most water discharges through the ground into the Long Island Sound.

are three main basins plus the Narrows, which joins the Sound with the East River (Fig. 2.3).

The East River—actually not a river but a tidal strait—is the Sound's link with New York Harbor. This strait's tortuous channel with its many rocks and strong tidal currents has been the bane of small ships and seamen since Europeans first settled the area. Hell Gate—so named for its tidal currents and turbulence—is a rocky sill lying about 35 feet below the water surface at the convergence of the Harlem and East Rivers. Hell Gate forms the western boundary of Long Island Sound so far as water flow is concerned.

The westernmost section of the Sound—the Narrows—extends from Hell Gate to a shoal area, the Hempstead Sill. This sill reaches from Matinicock Point on Long Island to the New York-Connecticut boundary. Water depths along the sill are less than 37 feet, partially isolating the bottom waters in the small basin south of Execution Rock.

The area between the Hempstead Sill and Stratford Shoals, called the Western Basin, is deeper and much wider than the Narrows. Here, too, the bottom is quite irregular. In the middle of this basin is a north-south shoal area extending from Eatons Neck through Cable and Anchor Reefs to Sheffield Island on the Connecticut shore. A narrow, deep passage just south of Cable and Anchor Reefs permits bottom waters to flow into the Western Basin.

Only a few small streams discharge into the Western Basin and the Narrows, although its shores on both sides are deeply embayed with small harbors and ports. The largest harbors on Long Island (Oyster Bay, Cold Spring Harbor, and Huntington Bay) border this section of the Sound.

In the Central Basin, the Sound widens to 21 miles near New Haven, the largest and busiest harbor in the Sound. Both the shoreline and the bottom topography are simpler in the Central Basin than in the western Sound. East of Port Jefferson and Mt. Sinai Harbors, the Long Island coast has none of the large bays that indent the coast to the west. Mattituck Inlet is a small harbor formed by a dredged tidal creek. High bluffs are characteristic of this section of Long Island's north shore; they rise more than 100 feet above the narrow, gravelly beaches. The Connecticut coast has fewer harbors in this section than coastal areas to the east or west. The bottom of the Central Basin is remarkably smooth, sloping southward. The deepest areas lie close to Long Island.

The boundary between the Central and Eastern Basins is a line between Duck Pond Point on Long Island and Hammonasett Point in Connecticut. The boundary is marked on the bottom by Mattituck Sill, whose top lies about 70 feet below sea level. This sill forms a partial barrier to movements of near-bottom waters.

Waters in the Eastern Basin communicate with the Atlantic through the several large passages between islands (Fisher's Island, Plum Island and several smaller ones) that mark the eastern end of Long Island Sound, and separate it from Block Island Sound. These islands are part of the glacial moraine that forms the North Fork on Long Island and extends into southern Rhode Island and Cape Cod.

The Eastern Basin receives the discharge of the Connecticut and Thames Rivers. As we said above, the greatest volume of fresh water and riverborne sediment entering Long Island Sound comes in near its ocean entrance—unlike the usual estuary, where the river enters at the head of the bay.

The bottom topography near the Race is extremely irregular. Glaciers and ancient rivers cut numerous valleys here; later, strong tidal currents through the narrow passes scoured the bottom and may have caused further deepening. Several holes as deep as 330 feet occur in this area.

In the eastern part of the Sound, especially in Fisher's Island Sound, the Connecticut shoreline is marked by numerous small bays. The largest harbors, like New London on the Thames and the towns on the Connecticut River, have played important roles in the maritime history of the region. Long Island's shoreline along the Eastern Basin is devoid of harbors or inlets.

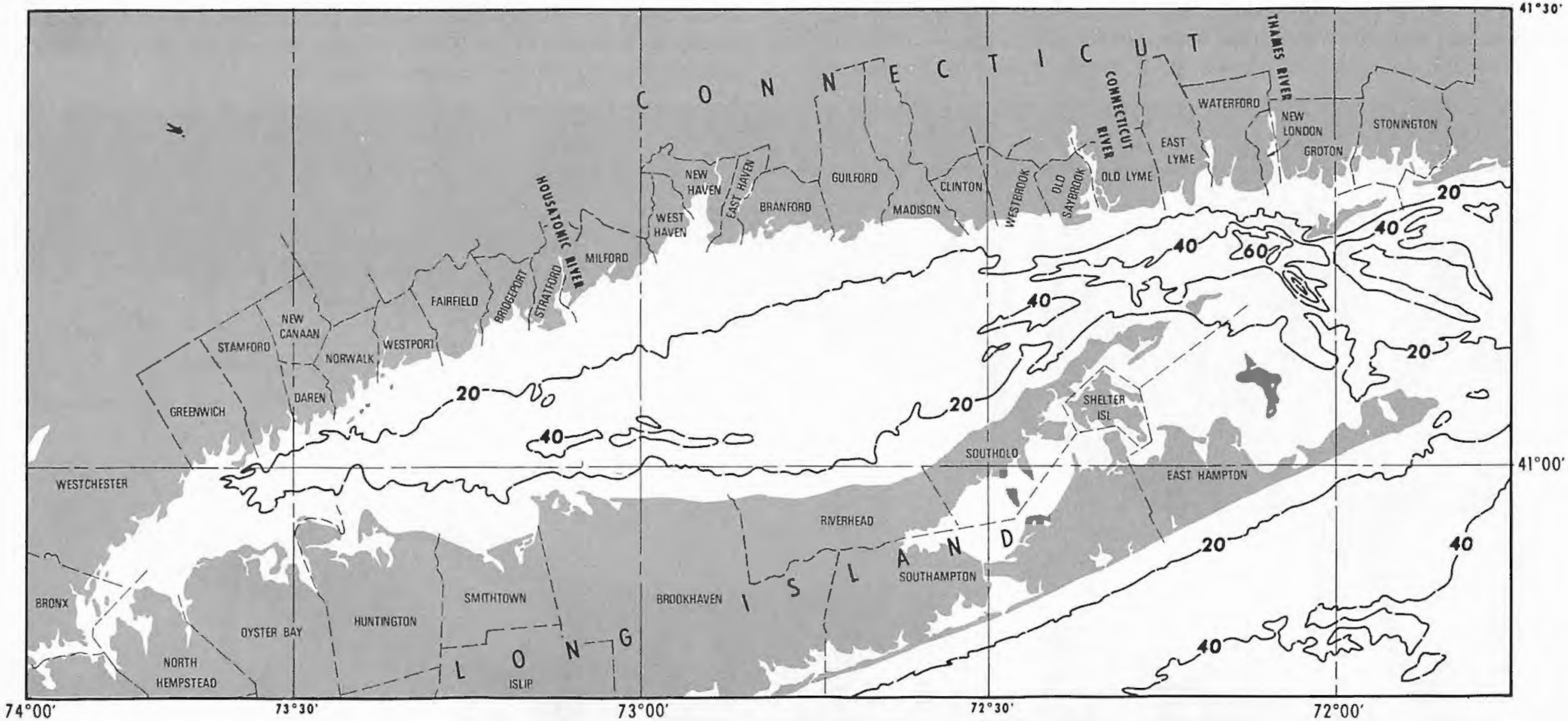

FIGURE 2.2 *Generalized Bottom Topography of Long Island Sound*

(Depth contours in meters.)

SEDIMENTS AND WASTE DEPOSITS

Estuaries trap sediments brought to them by rivers, by wave action along the shore, or by tidal action and storm surges acting on the adjacent continental shelf. This trapping of sediments is one of Long Island Sound's estuarine characteristics. Particles settling out of the water have formed sediment deposits that cover parts of the ancient river-cut, glacier-scoured basin. Sediment deposits are interesting because they record the history of the Sound long before human habitation in the area.

Some unusual features of Long Island Sound profoundly influence the type and distribution of sediment deposited in it. First, there are no large natural sediment sources that discharge into the Sound. As we saw, the glaciers that shaped the Sound also scoured southern New England, leaving little soil to be eroded and carried by rivers to the Sound. Furthermore, these glaciers gouged lakes and left marshy areas in the New England landscape which now act as traps for waterborne particles. This has decreased the amount of sediment carried by rivers. The complicated bottom topography of the Sound remains visible because of the scarcity of sediment sources. The basins would be filled and the ridges (sills) buried if local rivers brought large amounts of sediment to the Sound.

Long Island Sound has, however, large quantities of waste solids deposited in it. This is directly a consequence of the large urban and suburban population in the region. So we must include waste discharges among our sediment sources when we account for the sediments accumulating in the Sound. Indeed, barged waste solids from 1964 to 1968 averaged 1,250,000 tons per year, seven times as much as the estimated 171,000 tons of sediment per year from riverborne sediment and sewage effluents combined (Table 2.2).

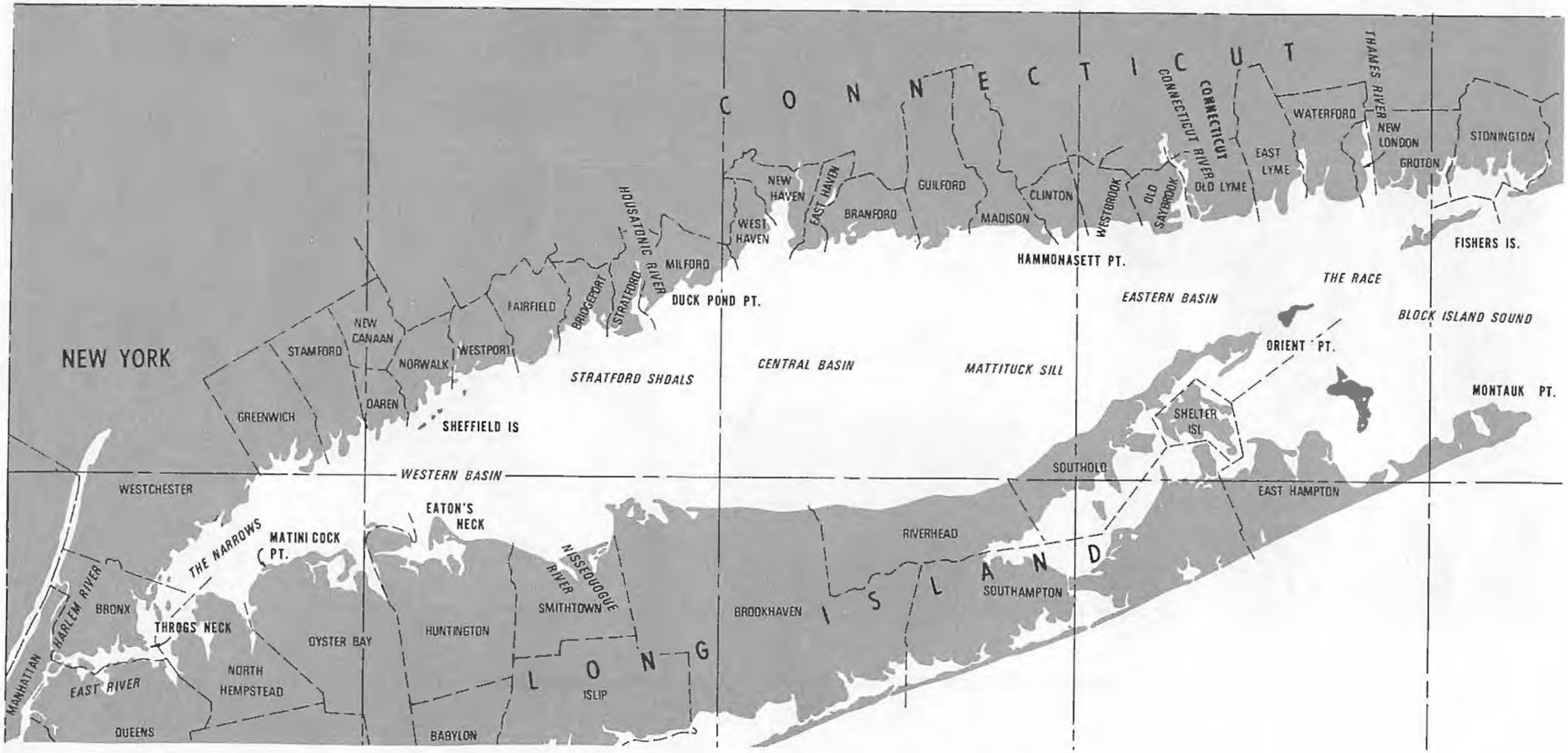

FIGURE 2.3 *Geographic Features of Long Island Sound*

TABLE 2.2 *Estimates of Sediment Sources to Long Island Sound*

Basins	*Riverborne sediment (in thousands of tons/yr)*	*Sewage effluents*[a] *(in thousands of tons/yr)*	*Barged waste disposal*[d] *(in thousands of tons/yr)*	
			1960-63	*1964-68*
East River	—	15[c]	—	—
Western	30[a]	5[a]	400	900
Central		4[a]	60	50
Housatonic River	16[b]			
Eastern		1[a]	100	300
Connecticut River	90[b]			
Thames River	10[b]			
TOTAL	146	25	560	1250

[a] Assumed suspended particle concentration 50 ppm

[b] After Dole and Stabler 1906

[c] Assumed particle concentration 20 ppm in sewage plant discharge of 24.4 m^3/sec

[d] Volumes of waste discharges from Supervisor of New York Harbor, U. S. Army Corps of Engineers; assumed solid concentration 0.5 metric tons/m^3 (see Gross 1970 for details)

Sediment Distribution

Greenish-gray silt is the most abundant sediment in the deep parts of Long Island Sound; silts cover about 510 square miles or roughly one third the area of the Sound (Fig. 2.4). Despite their wide distribution, these silt deposits are rarely seen by people living near or using the Sound; they commonly occur at depths greater than 30 feet. The upper few centimeters of the silt deposits are usually black and smell strongly of rotten eggs, a sure sign of hydrogen sulfide (H_2S). Few organisms can live on such a soft bottom. Unlike Chesapeake Bay or Delaware Bay, the bottom of Long Island Sound is relatively unproductive of food organisms—perhaps a result of this silty bottom. The silt deposits range in thickness from less than 12 feet to about 40 feet.

Silts are very fine-grained deposits. The median grain diameter in the silt deposits ranges from 0.0004 to 0.0008 inches (10 to 20 microns). Clay-sized particles (less than 4 microns) usually comprise less than 10 percent of the sediment by weight. The finest-grained deposits occur in the western part of the Sound, closest to the metropolitan region. To the east, the deposits become progressively coarser-grained, as shown in Figure 2.4.

Coarse sands and gravels along the shores are familiar to most Long Island Sound residents. These common deposits form the beaches and usually extend down to depths of about 30 feet around the margins of the Sound. They also cover the bottom of the eastern portion of the Sound as well as many of the bays and harbors. Much of the Sound's shellfish production is taken from these coarse-grained deposits, which are also highly valued as potential sand and gravel sources for construction purposes.

Fine-grained sands cover the tops of the large shoal areas and sills, and are especially abundant on two large north-south sills, the Mattituck Sill and the Stratford Shoal area.

Sediment Sources

Sediments deposited in Long Island Sound come from the following principal sources:

- Bluff erosion, especially on Long Island
- Rivers
- Continental shelf deposits, chiefly sand, carried into the eastern Sound by bottom currents
- Disposal of waste solids (dredged sediments, rubble, rock)
- Sewage solids, deposited in the Sound after being carried in by tidal currents from adjoining harbors
- Plant debris washed out of surrounding marshes
- Beach pebbles and sand rafted into deep water by sea ice

Space permits us to discuss only the four most important sources.

Bluff erosion, especially on the Long Island side, is locally an important sediment source. On both sides of the Sound, the shores are typically cut into glacial deposits. Exposed to wave action, the sand and gravel bluffs are cut back. Tidal currents carry away the fine-grained fractions to deposit them in deep water. Pebbles and boulders remain near their source, forming coarse-grained deposits at the base of the bluffs.

In some areas erosion of the bottom in shallow waters may have been accelerated by oyster production or commercial dredging for clams. These disturbances of the bottom suspend the deposits, and the fine fractions are transported away from the area by tidal currents.

Rivers, as noted above, are apparently not a major source of sediment to the Sound. If the data from the early 1900s are still valid for the entire drainage

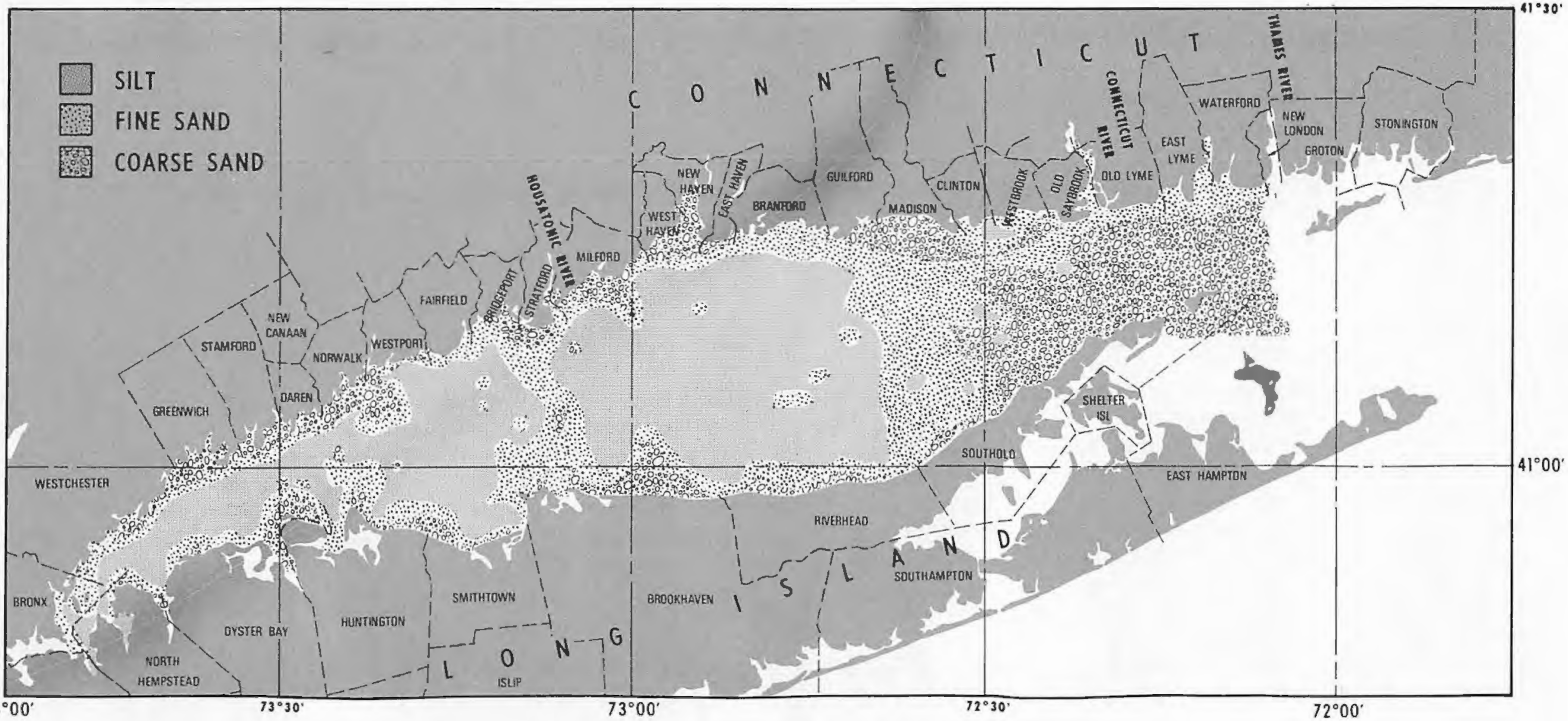

FIGURE 2.4 *Sediment Distribution in Long Island Sound*

basin, we can estimate that the rivers carry about 150,000 metric tons per year to tidewater (Table 2.2). (This estimate ignores the waste load that several of the rivers probably now carry.) None of the rivers around Long Island Sound have built large deltas from their riverborne materials, nor have extensive beaches formed around the mouths of the rivers. Hence, the bulk of the evidence and our knowledge of the action of estuarine systems argue for a limited sediment supply from local rivers during a normal year. Each river mouth acts as an estuary and traps sediment. This sediment-trapping action is usually intensified by dredging of deep navigation channels and construction of port facilities. Although the data are poor, it seems highly probable that the natural sediment load of the rivers of Long Island Sound is initially deposited in the river channels or at their mouths.

Such deposits are naturally removed from harbors during floods or storms. The strong currents associated with flood discharge are probably adequate to scour recent deposits and move them out into the Sound. But in a normal year most of the sediment remains in the harbor. Since these sediments commonly occur near port facilities, docks, or in navigation channels, dredging is required to prevent shoaling from interfering with normal port operations. Barring a flood, most riverborne sediment probably settles and remains in port facilities until it is removed by dredging.

Because of its proximity to the New York metropolitan region Long Island Sound has also been used extensively for disposal of waste solids. These wastes come from the harbors along the Connecticut shore and from the metropolitan region as a whole. Records of waste disposal operations in the Sound go back to 1890. (Waste solids are discussed more fully below.)

Beaches are a seasonally important source of sediment. During late winter, sea ice forms along the shore and incorporates sand and pebbles in it. Under the influence of waves and tides, some of the ice floes are carried offshore. When the ice melts over deeper water, pebbles and sand are released, sink to the bottom, and are incorporated in the sediment deposits.

Sedimentary Environments

Four environments of sediment deposition occur in Long Island Sound. The most familiar is the near-shore area, where sands and gravel accumulate. These sediments usually come from local sources, such as erosion of nearby bluffs, and are usually moved and reworked by wave action. In many areas these coarse-grained deposits are lag materials (left behind when bluffs are eroded by waves and tidal currents); the fine-grained components are carried off to be deposited in deep waters. Scattered boulders remain after the erosion and retreat of the glacial bluffs.

The second depositional environment is found in eastern Long Island Sound. Here, coarse sand and gravel deposits are scoured by strong tidal currents and subjected to waves coming from the adjacent Atlantic Ocean. These currents are strong enough to form giant sand waves, called megaripples, on the bottom. They also remove the fine-grained parts of the sediment deposits.

The shoal areas are the third depositional environment. These deposits lie on top of the north-south sills and on the large submerged banks, such as those around Stratford Shoals or Cable and Anchor Reef. Here strong tidal currents prevent deposition of fine-grained sediment, usually leaving a cover of cobbles, gravel, and sand.

A fourth depositional environment is the bottom of the Central and Western Basins, where tidal currents are apparently weak and wave action does not penetrate deep enough to disturb and rework the sediment deposits. Here the finest-grained silts accumulate, probably derived from suspended sediment from the Hudson River and waterborne wastes from New York City. More than half the City's sewage effluent flows into the Upper East River. This effluent is generally thought to move with the surface waters into Long Island Sound.

Barged Waste Disposal

Waste solids are produced in large quantities around Long Island Sound. In rural areas, these wastes pose little problem because they are usually left in vacant lands where they can be accommodated at little direct cost to those charged with their disposal. Besides, there is often a demand for such wastes in many rural or suburban areas, to fill in a ravine, or a wetland. The growth of the suburbs has reduced vacent land. Moreover, increased concern about the shrinking wetlands has changed the traditional view of "reclaiming" these lands. Consequently, there is a pressing need for waste disposal areas.

Long Island Sound received wastes from its towns and cities for at least 80 years. Garbage, refuse, and floatable wastes are no longer commonly dumped into the Sound because they wash ashore. Now, most floating debris is from small boats and is reported to be a serious problem in many beachfront communities during the height of the pleasure-boating season. Long Island Sound beaches commonly have conspicuous deposits of driftwood mixed with plastic bottles and beer cans.

The largest volume of dumped wastes was sediment and other dredge spoils from harbors, and rock blasted from the bottom during construction of buried facilities, such as pipeline or cable crossings. Small amounts of defective industrial products, building and demolition rubble, and even an occasional derelict ship hull were dumped in federally-designated waste disposal areas in the Sound. There were 19 such areas listed in the Federal Register (Fig. 2.5). One additional site off Little Gull Island in the Race had been used since the the late 1940s for disposal of solid residues from a large pharmaceutical plant at Groton, Connecticut. These sites were established by the Supervisor of New York Harbor under the provisions of a Congressional act of 1888, forerunner of the Refuse Act of 1899. The disposal sites were generally located in waters deeper than 60 feet to avoid interfering with navigation. The sites were located near each of the harbors on the Sound and were apparently established to receive their dredged wastes.

Of the designated sites in Long Island Sound, 16 were used at least once during the period 1960-1971; 8 received more than 100,000 cubic meters of wastes (Table 2.3). The data for all these disposal operations have been grouped for each of the three major basins in Long Island Sound (Fig. 2.6). Except for 1964, the discharges into the Western Basin equaled or exceeded the discharges to the other basins; the smallest volume of wastes went into the Central Basin. The heavy use

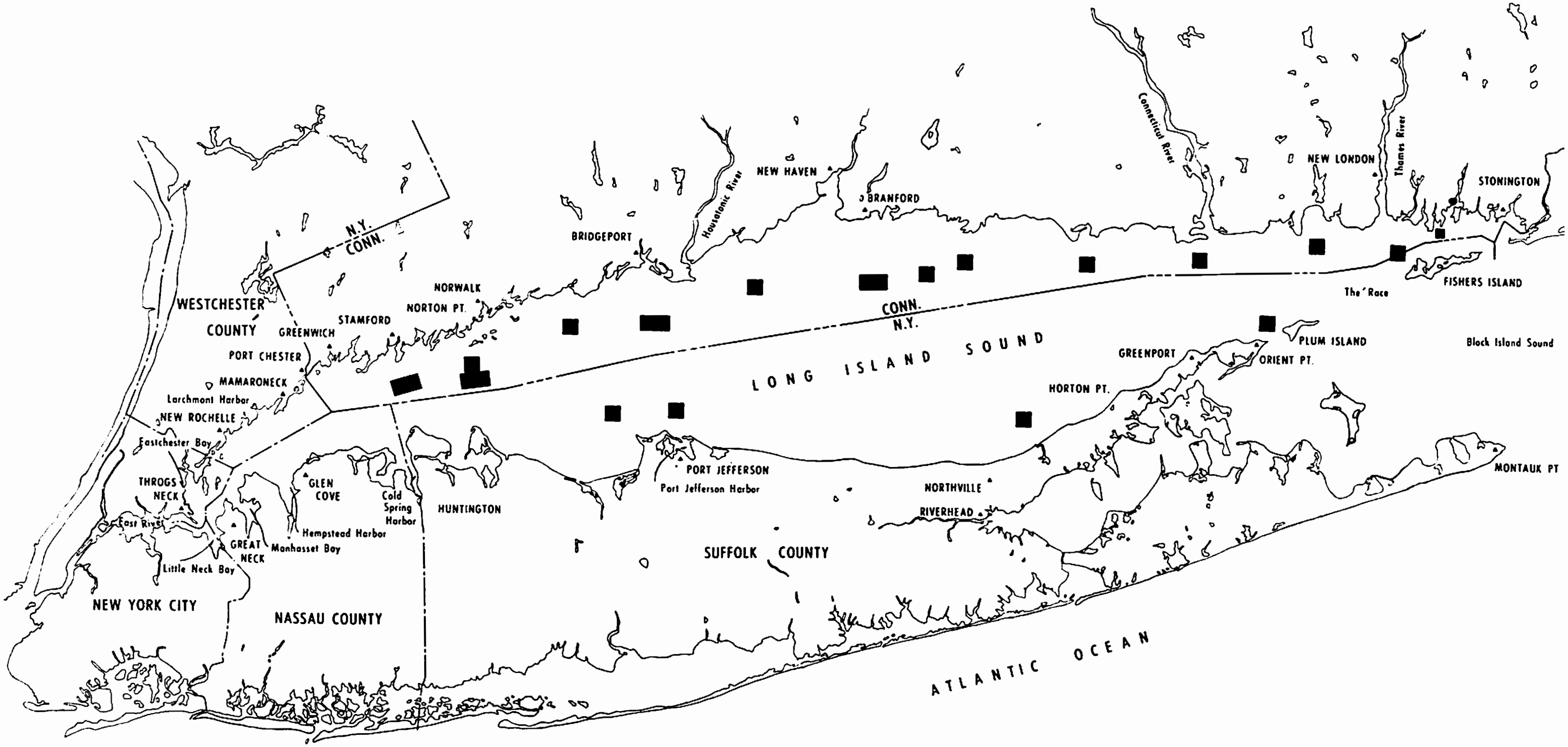

FIGURE 2.5 *Waste Disposal Sites in Long Island Sound*

TABLE 2.3 *Waste Disposal Sites in Long Island Sound and Waste Loads (waste volumes in thousands of cubic meters per year)*

	Location		*Water depth*		*Average waste volumes*			*Years of Use*	*Maximum discharge*	
Disposal Area	*Lat. (N)*	*Long. (W)*	*meters*	*(feet)*	*1960-63*	*1964-68*	*1969-71*	*1960-71*	*and year*	
WESTERN BASIN										
Stamford	40°59′	73°31′	26-40	(87-130)	56	360	140	12	620	(1966)
Eaton's Neck	41°00′	73°26′	31-36	(103-150)	260	1300	150	12	880	(1967)
Norwalk	41°01′	73°27′	22-30	(71-99)	31	71	13	11	93	(1961)
Southport	41°04′	73°17′	18-20	(60-64)	34	12	9	7	140	(1962)
Bridgeport	41°05′	73°13′	20-21	(65-70)	330	110	13	9	1000	(1962)
Smithtown Bay	41°00′	73°16′	25-33	(81-109)	0	0	0	0	—	
CENTRAL BASIN										
Port Jefferson	41°01′	73°06′	30-47	(97-155)	14	13	0.3	7	60	(1964)
Milford	41°07′	73°02′	19-20	(61-67)	10	3.5	3.8	6	14	(1960)
New Haven	41°09′	72°51′	20-21	(64-70)	90	67	38	11	300	(1960)
Branford	41°10′	72°47′	19-22	(63-72)	0.6	26	34	9	210	(1966)
Faulkner Island	41°12′	72°42′	20-23	(64-76)	0	0.3	0.2	2	1.4	(1968)
Mattituck	41°03′	72°34′	23-34	(75-111)	0.05	0.5	0	2	2.3	(1966)
Clinton	41°13′	72°31′	24-35	(79-114)	0	4.1	0	1	20	(1965)
EASTERN BASIN										
Cornfield	41°16′	72°21′	35-37	(87-121)	24	150	6	6	590	(1966)
Orient Point	41°11′	72°15′	36-64	(120-210)	0	0	0	0	—	
Niantic	41°16′	72°11′	26-29	(84-94)	0	0	33	2	54	(1970)
New London	41°16′	72°05′	19-22	(63-72)	150	350	201	12	1100	(1965)
North Dumpling	41°17′	72°00′	19-23	(63-85)	0	0	0	0	—	
Stonington	41°18′	71°55′	19-32	(61-106)	0	0	0	0	—	
Little Gull Island[1]	41°13′	72°06′	27-61	(90-200)	40	43	58	12	70	(1971)

Data from records of Supervisor of New York Harbor, U. S. Army Corps of Engineers.

[1] Not listed in Federal Register; location and water depth approximate.

of Western Basin disposal sites was a consequence both of local dredging activities and of the obvious proximity to the New York metropolitan region.

Between 1960 and 1963, 62.8 percent of the wastes dumped in Long Island Sound went into the Western Basin. This increased to 72.9 percent in the period 1964 through 1967. Waste discharges into the Central Basin have remained rather constant at about 130,000 cubic yards per year. Waste discharges in the Eastern Basin have fluctuated more radically owing to dredging projects in New London Harbor, but a long-term average of about 260,000 cubic yards per year is typical. In the Western Basin, the disposal operations generally amounted to about one to two million cubic yards per year.

Data on the physical properties of the wastes are not readily available. From studies of wastes and waste deposits in New York Harbor, it seems likely that the wastes have an in-place density of 1.4 metric tons per cubic meter with a grain density of 2.65 tons per cubic meter, and contain 40 percent solids by weight. Thus each cubic meter of dredged materials dumped in the Sound would contain about 0.52 metric tons of solids. For the Sound as a whole, this indicates an average total waste solid discharge of about 0.6 million metric tons per year from 1960 to 1963, increasing to 1.2 million metric tons per year from 1964 to 1968.

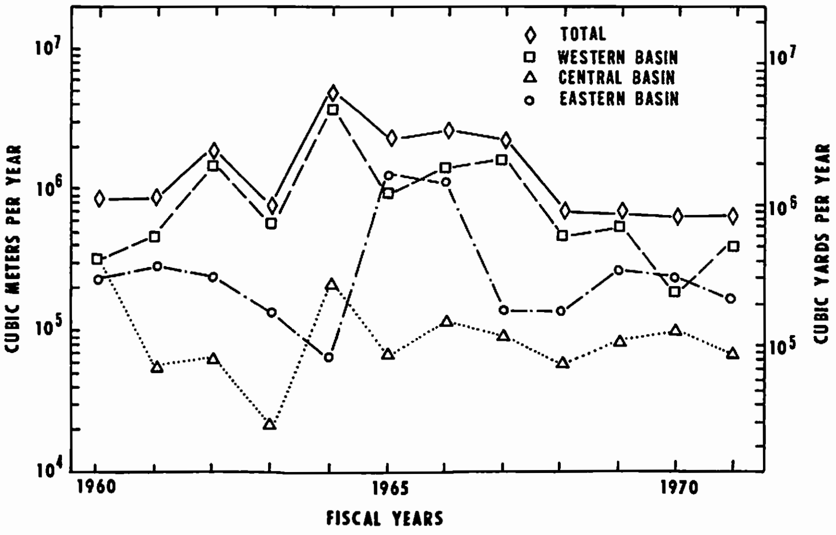

FIGURE 2.6 *Waste Solids Discharged into Long Island Sound, 1960-1971*

Note that most wastes are discharged into western Long Island Sound. Central Long Island Sound receives the least.

The Sound will probably continue to be used occasionally for disposal of some selected wastes. But legislation implemented in early 1973 had greatly reduced overall waste disposal in the Sound, including elimination of most wastes, such as industrial wastes and dredged materials.

LONG ISLAND BAYS

Sediment and water processes in the bays and river mouths around the Sound are strongly interlinked with similar processes in the Sound; each affects the other. Scant research has been done on the sediments and water movements in Connecticut-shore bays; most of what information is available describes bays on the Long Island shore of the Sound.

The eleven Long Island bays and harbors (see Table 2.4) were formed primarily by glacial action and stream erosion when sea levels stood lower. The shoreline has been little altered by marine forces since the sea reached its present level. Except for Mattituck Inlet, all 11 bays are located in the western and central portions of Long Island. The Long Island bays fall into two groups based on their physical characteristics:

- Valleys, slightly modified by marine processes:

  Mattituck Inlet
  Nissequogue River
  Cold Spring Harbor
  Hempstead Harbor
  Manhasset Bay
  Little Neck Bay
  Huntington Harbor

- Broad coastal indentations, partially isolated from the Sound by baymouth bars formed by marine processes:

  Mt. Sinai Harbor
  Port Jefferson Harbor
  Oyster Bay
  Huntington Bay

Long Island's bays are within commuting distance of New York City. Little Neck Bay, closest to the City's central business district in lower Manhattan, is about 15 miles from the Battery. It also has within its watershed the largest population per unit area of the bays mentioned. The other extreme is Mt. Sinai Harbor, which is about 50 miles from the Battery and whose drainage basin is lightly populated and contains primarily agricultural land.

TABLE 2.4 *Hydrographic Data for Bays on the North Shore of Long Island*

Bay	*Mean High Tide Area*		*Mean Low Tide Area*		*High Tide Volume*		*Low Tide Volume*		*Maximum Depth*		*Mean Depth*		*Mean Tidal Range*		*Estimated Shoreline Length*	
	km^2	*(mi^2)*	*km^2*	*(mi^2)*	*millions m^3*	*(billions gal)*	*millions m^3*	*(billions gal)*	*m*	*(ft)*	*m*	*(ft)*	*m*	*(ft)*	*km*	*(mi)*
Little Neck Bay	6.5	(2.5)	5.9	(2.3)	27.0	(7.2)	13.0	(3.5)	3.7	(12.0)	2.3	(7.5)	2.2	(7.2)	12.0	(7.3)
Manhasset Bay	8.8	(3.4)	8.0	(3.0)	45.0	(12.0)	26.0	(6.7)	2.5	(8.2)	3.2	(11.0)	2.2	(7.2)	19.0	(12.0)
Hempstead Harbor	13.3	(5.1)	11.8	(4.5)	93.0	(25.0)	63.0	(17.0)	9.9	(33.0)	5.4	(18.0)	2.2	(7.2)	23.0	(14.0)
Oyster Bay	23.7	(9.1)	21.1	(8.1)	157.0	(42.0)	104.0	(28.0)	25.0	(81.0)	4.9	(16.0)	2.2	(7.2)	50.0	(31.0)
Huntington Bay	27.7	(10.6)	23.6	(9.1)	188.0	(50.0)	126.0	(33.0)	19.0	(61.0)	5.3	(17.0)	2.3	(7.5)	61.0	(38.0)
Huntington Harbor	1.4	(0.5)	1.1	(0.4)	5.8	(1.5)	2.6	(0.6)	6.7	(22.0)	2.4	(7.9)	2.3	(7.4)	9.0	(5.7)
Nissequogue River	2.1	(0.8)	0.6	(0.2)	4.6	(1.2)	0.2	(0.05)	3.7	(12.0)	0.4	(1.3)	2.1	(6.9)	13.0	(8.3)
Stony Brook Harbor	3.4	(1.3)	1.9	(0.7)	7.9	(2.1)	1.6	(0.4)	1.8	(5.9)	0.8	(2.6)	0.19	(6.2)	18.0	(11.0)
Port Jefferson Harbor	6.3	(2.4)	4.5	(1.7)	32.0	(8.5)	20.0	(5.1)	16.0	(53.0)	4.4	(14.0)	2.0	(6.5)	27.0	(17.0)
Mt. Sinai Harbor	1.5	(0.6)	1.4	(0.5)	5.6	(1.5)	2.7	(0.7)	11.0	(35.0)	1.9	(6.2)	2.0	(6.5)	13.0	(7.8)
Mattituck Inlet	0.6	(0.2)	0.3	(0.1)	1.2	(0.3)	0.5	(0.1	2.7	(8.8)	1.6	(5.2)	1.5	(4.9)	12.0	(7.2)

SOURCE: M. G. Gross, D. Davies, P. Lin and W. Loeffler, *Characteristics and Environmental Quality of Six North Shore Bays, Nassau and Suffolk Counties, Long Island, New York,* Technical Report Series #14 (Stony Brook, N. Y.: Marine Sciences Research Center, State University of New York, 1972) Table 2-1, p. 13.

Each bay receives the surface runoff and groundwater discharged from the surrounding land. Drainage basins, determined on the basis of topography, are shown in Figure 2.7. All basin divides, except for the Nissequogue River basin, are bounded on the south by the Harbor Hill moraine. Estimates of the groundwater underflow to the north shore bays are shown in Table 2.5.

Sediment particles come into the north shore bays from various sources: washing in from the Sound on the tide, or from surface runoff, or from human sources. Sediment brought into the bays by littoral drift—wave action moving sand along a beach—is probably not a major factor in the north shore bays because of the limited fetch for locally generated waves and the absence of swell from storms at sea.

In the absence of large natural sediment sources, like rivers, man-controlled sediment sources dominate. Erosion of building sites denuded of vegetation is a significant local source. Where sand and gravel mining has been active, eroded materials from the bare surfaces and silt and fine sand in wash waters from the operations are significant. Materials spilled from sand, gravel and crushed rock barges are probably important sediment sources in Hempstead and Port Jefferson Harbors.

Discharges from sewage treatment plants may be locally significant sediment sources. These contribute solids that settle in areas protected from currents. For example, typical primary sewage treatment plants leave 40 percent of the suspended solids in the waste waters coming out of the plant. Primary combined with secondary treatment typically leaves 10 percent.

Once sediment particles are transported inside a bay, they are likely to be trapped there. Bays tend to fill up with sediment, thus creating shallow waters amenable to salt marsh vegetation. Ebb currents may not be strong enough to scour and suspend the particles brought in by the preceding flood current and deposited during slack water. Furthermore, the estuarine circulation within most bays around Long Island Sound tends to retain particles within the bays. Sheltered from waves, the sediments deposited near the head of a bay are typically finer grained than those that accumulate near the bay entrance where coarse sediments are found. As a general rule, a bay with restricted flow is a better sediment trap than one with unrestricted flow. On this basis, one can predict that Hempstead Harbor and Little Neck Bay are not likely to retain sediment as efficiently as the more restricted harbors, such as Huntington Harbor, Mt. Sinai Harbor, Manhasset Bay and Port Jefferson Harbor.

Many of the Long Island harbors have been substantially altered by dredging, construction of facilities, mining along the bay shores, or discharges of wastes. It therefore seems unlikely that present sediment distributions existed prior to settlement by Europeans. Still, the processes acting in the bays have probably

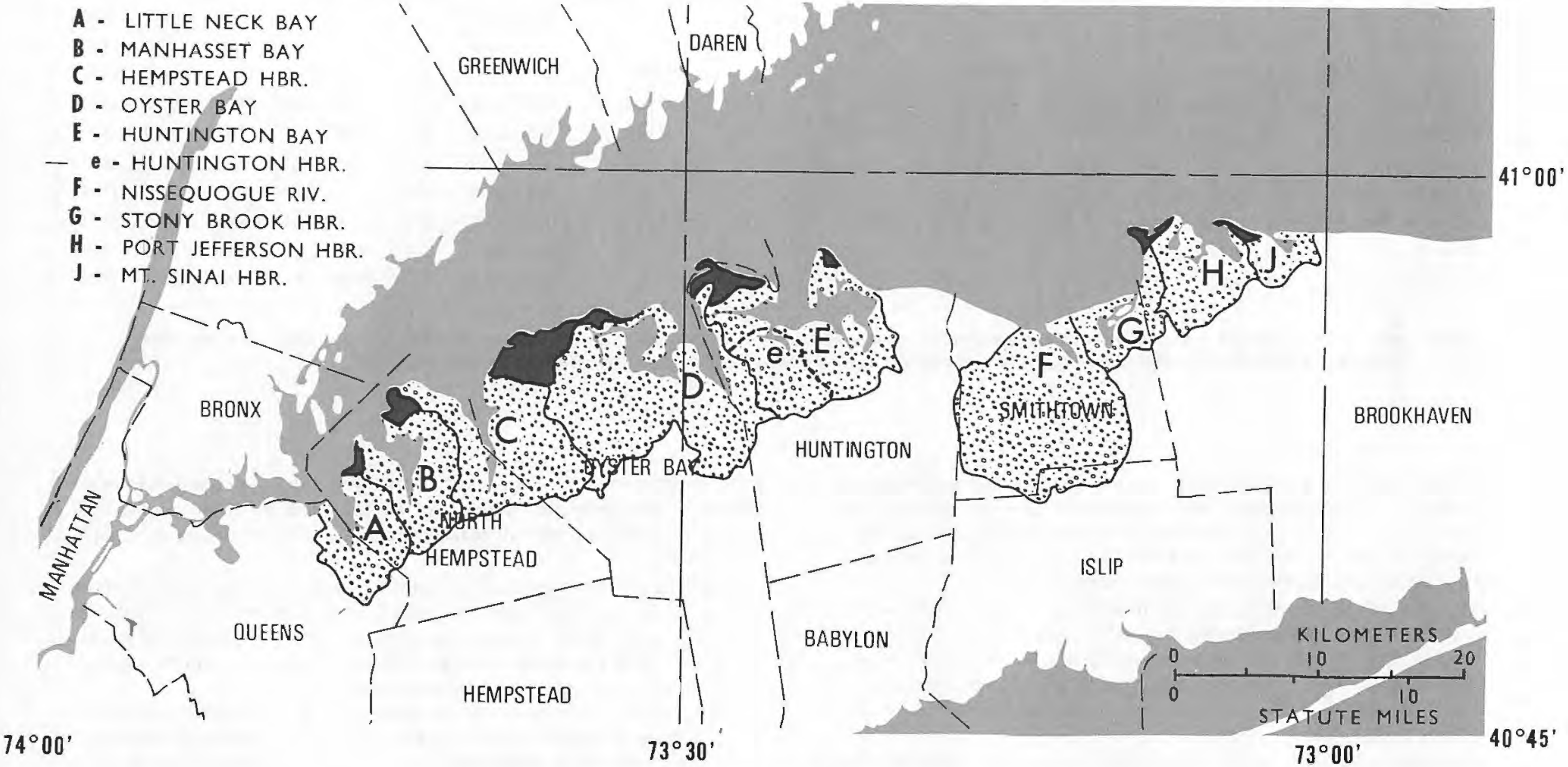

FIGURE 2.7 *Drainage Basins of North Shore Bays*

Shading indicates areas draining directly into Long Island Sound.

Source: Gross *et al., Six North Shore Bays,* p. 14.

not changed drastically. Existing sediment distribution may provide useful information about the deposition of solids that are presently discharged in a bay or likely to be discharged there in the future.

Tidal currents are probably the dominant force controlling sediment distribution within the bays. Such currents are strongest in narrow openings where large volumes of water must pass on each tidal cycle. In a simple situation, the coarsest sediment will accumulate where currents are strongest; the finest sediment will accumulate where currents are weakest. In the presence of strong currents, the fine-grained sediment particles are suspended and moved elsewhere before they can settle out of the water. The second factor is the nearness of major sources of sediment: an eroding hillside, for example. In some bays where no large sediment sources exist, relict sediments (sediments deposited under geologic conditions no longer prevailing in the area) may be the main distribution feature, an initial condition only partially erased by subsequent sedimentation.

Of the six harbors for which information exists, sediment distribution in the first, Port Jefferson Harbor (Fig. 2.8), is relatively simple, apparently controlled

TABLE 2.5 *Drainage Basin Areas and Freshwater Discharge to North Shore Bays*

		Fresh-water discharge, in millions m^3/year (millions gal/day)				
Bay	*Drainage Basin Area (km^2)*	*Ground Water Discharge*[a]	*Gauged Rivers Name*	*Gauged Rivers Discharge*	*Precipitation Minus Evaporation*	*Total Fresh-water Discharge*
Little Neck Bay	29	14 (10)			5.0 (3.6)	19 (14.0)
Manhasset Bay	32	15 (11)			6.7 (4.9)	22 (16.0)
Hempstead Harbor	58	28 (20)	Glen Cove Creek	6.3 (4.6)	10.0 (7.1)	38 (27.0)
Oyster Bay	97	47 (34)	Cold Spring Brook Mill Neck Creek	4.1 (3.0) 8.5 (6.2)	18.0 (13.0)	65 (47.0)
Huntington Bay	58	28 (20)	Stony Hollow Run Mill Creek	1.2 (0.9) 2.8 (2.0)	21.0 (15.0)	49 (35.0)
Huntington Harbor	22	10 (8)	Mill Creek	2.8 (2.0)	1.1 (0.8)	11 (8.8)
Stony Brook Harbor	19	9 (7)			2.6 (1.6)	12 (8.6)
Port Jefferson Harbor	29	14 (10)			4.8 (3.5)	19 (14.0)
Mt. Sinai Harbor	10	5 (3)			1.2 (0.8)	6.2 (3.8)
Mattituck Inlet	14	7 (5)			0.5 (0.3)	7.5 (5.3)

Source: Gross *et al., Six North Shore Bays,* p. 77.

[a] These estimates are minimum values; the actual ground water (subsurface) drainage basins are in some parts larger than the topographic (surface) basins upon which the calculations are based.

by physical processes. Near the harbor entrance, the sediments are coarse sands (median grain diameter 1 to 1.4 mm), probably a result of strong tidal currents carrying away small particles and leaving behind the large ones. Maximum tidal currents in the harbor entrance reach 3 miles per hour (2.6 knots) on the flood and 2.1 miles per hour (1.9 knots) on the ebb. Mud (median grain diameter typically 30 to 40 microns) covers most of the southern half of the harbor except along the western edge. Deposition of fine-grained material occurs as expected in the protected waters near the head of the harbor. The presence of sand along the western margin may be the result of any of these: local dredging, construction,

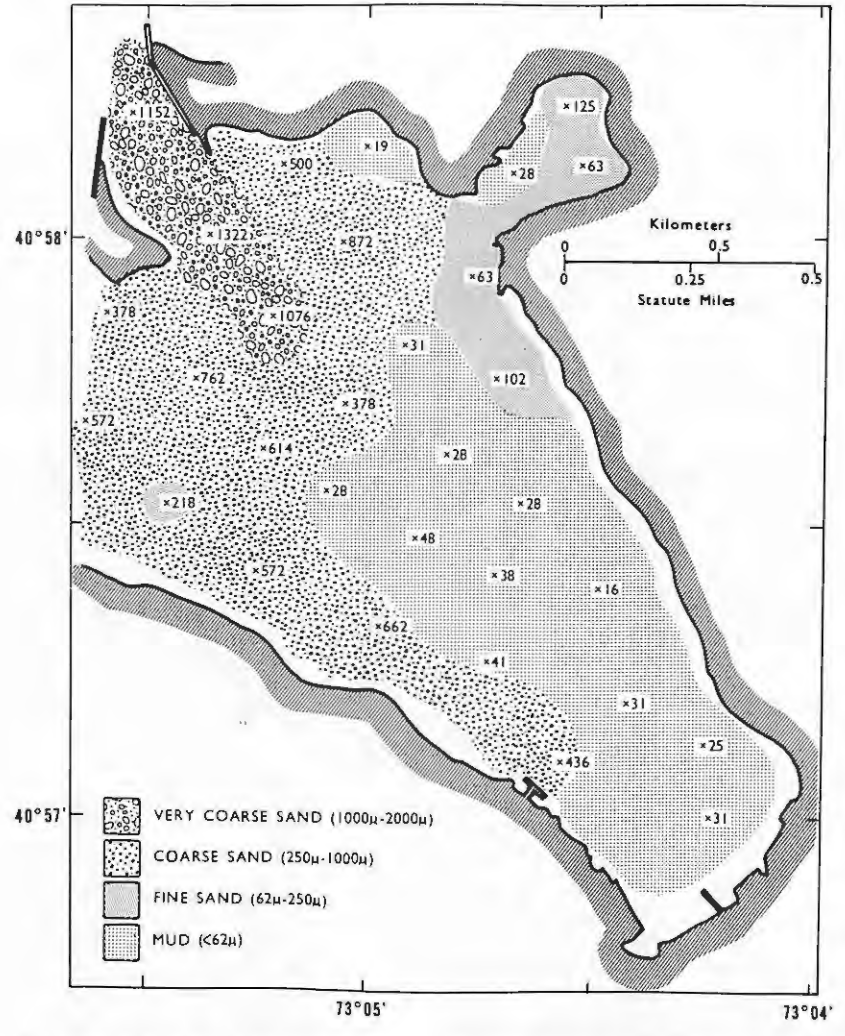

FIGURE 2.8 *Port Jefferson Harbor: Median Grain Diameter (microns)*

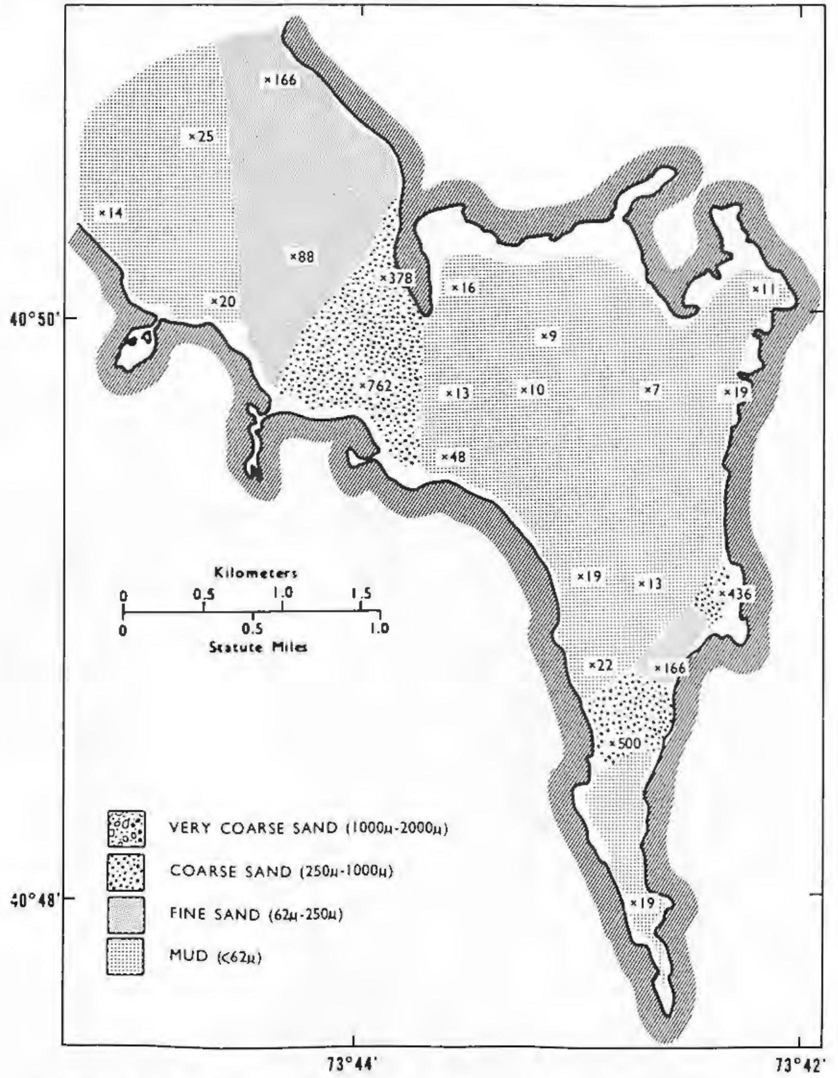

FIGURE 2.9 *Manhasset Bay: Median Grain Diameter (microns)*

materials spilled from local sand and gravel operations, or natural processes such as the exposure of that shore to strong winds associated with winter northeasters. Relatively coarse sands cover the bottom of the outer portion of the harbor.

Manhasset Bay (Fig. 2.9) exhibits sediment distribution patterns typical of a bay with more restricted circulation than Port Jefferson Harbor. Most of Manhasset Bay is covered by muds with median grain diameters of 10 to 20 microns. Sands occur only in the restricted areas around the harbor entrance and in narrow bands at the southern end. Although not as protected as Manhasset Bay, Little Neck Bay (Fig. 2.10) is covered with muds, for the most part with median grain diameters between 20 and 40 microns. Only around the margins are the deposits relatively sandy, probably because of bluff erosion and highway construction.

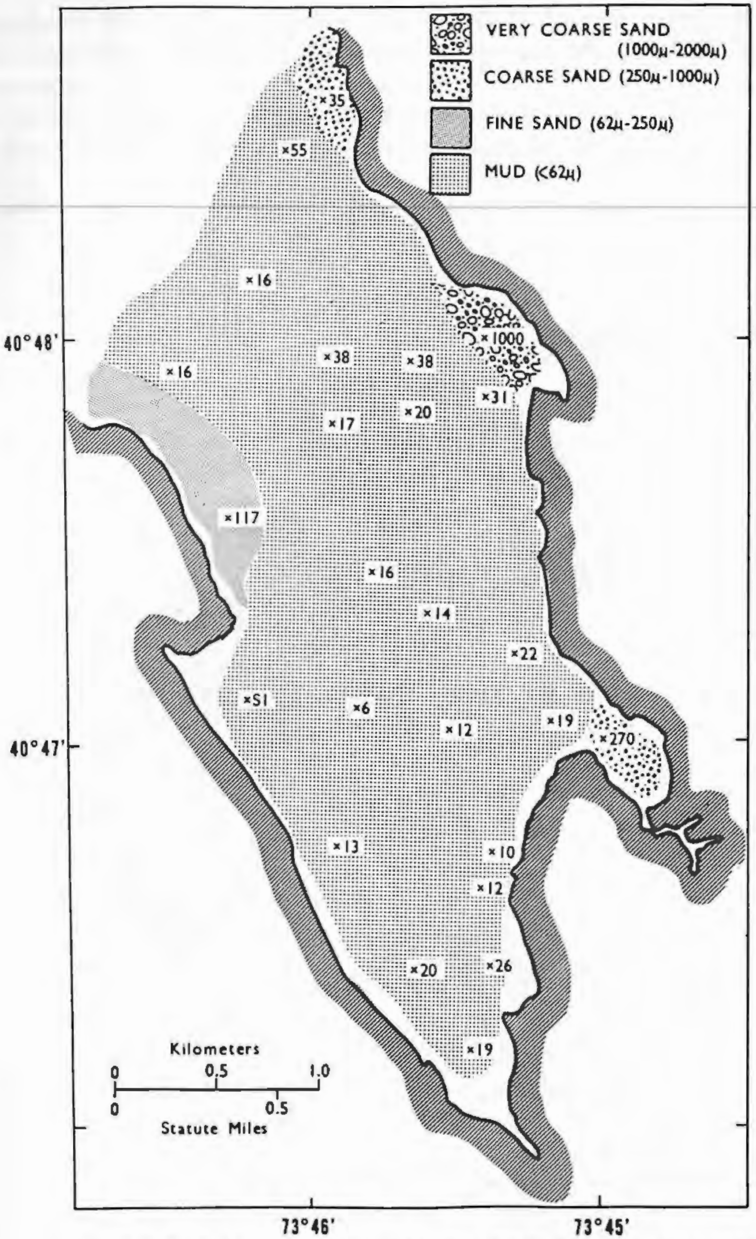

FIGURE 2.10 *Little Neck Bay: Median Grain Diameter (microns)*

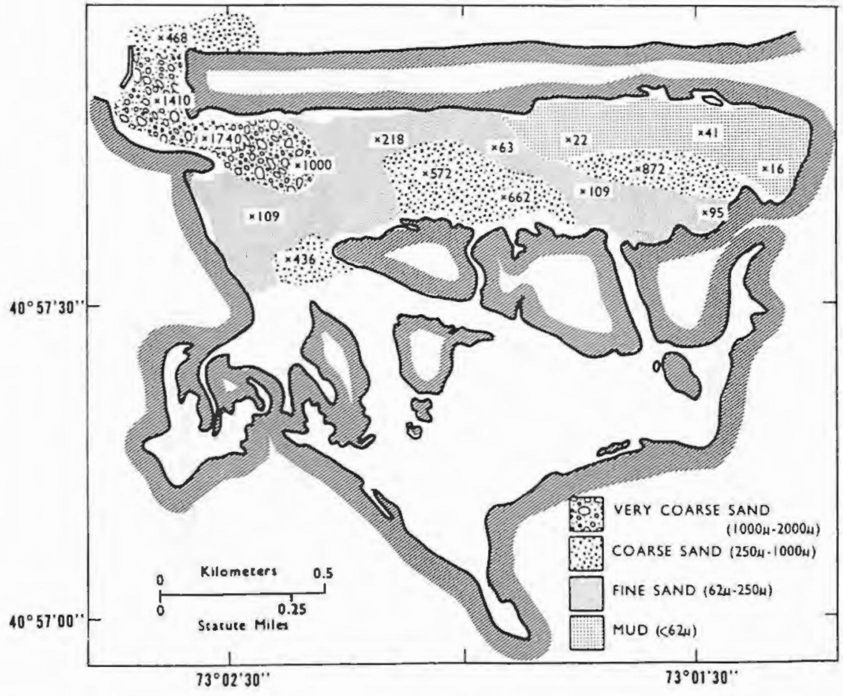

FIGURE 2.11 *Mt. Sinai Harbor: Median Grain Diameter (microns)*

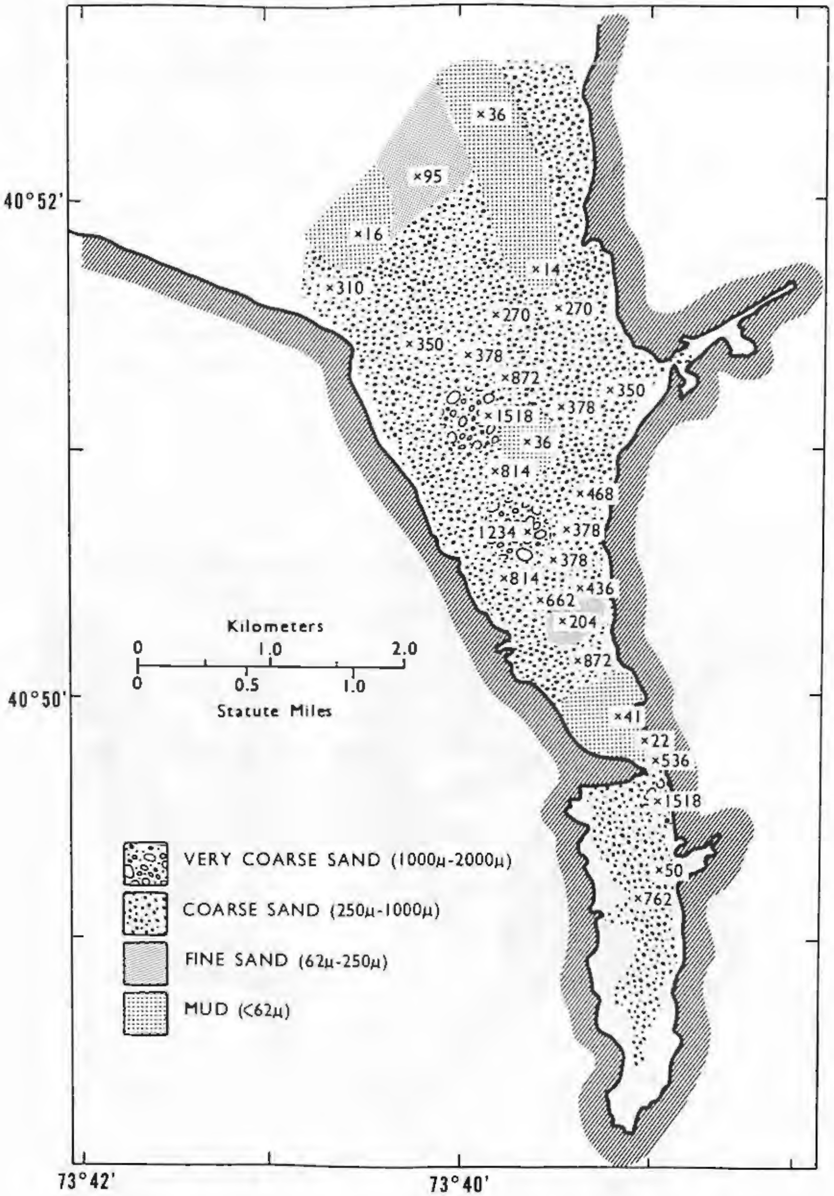

FIGURE 2.12 *Hempstead Harbor: Median Grain Diameter (microns)*

Dredging and industrial activity in Mt. Sinai Harbor (Fig. 2.11), Hempstead Harbor (Fig. 2.12), and Huntington Harbor (Fig. 2.13) are reflected in the complicated distribution patterns of the bottom deposits. Within Hempstead Harbor and Mt. Sinai Harbor the fine-grained deposits occur near the part of the harbor farthest from the entrance, and the coarsest deposits near the entrance.

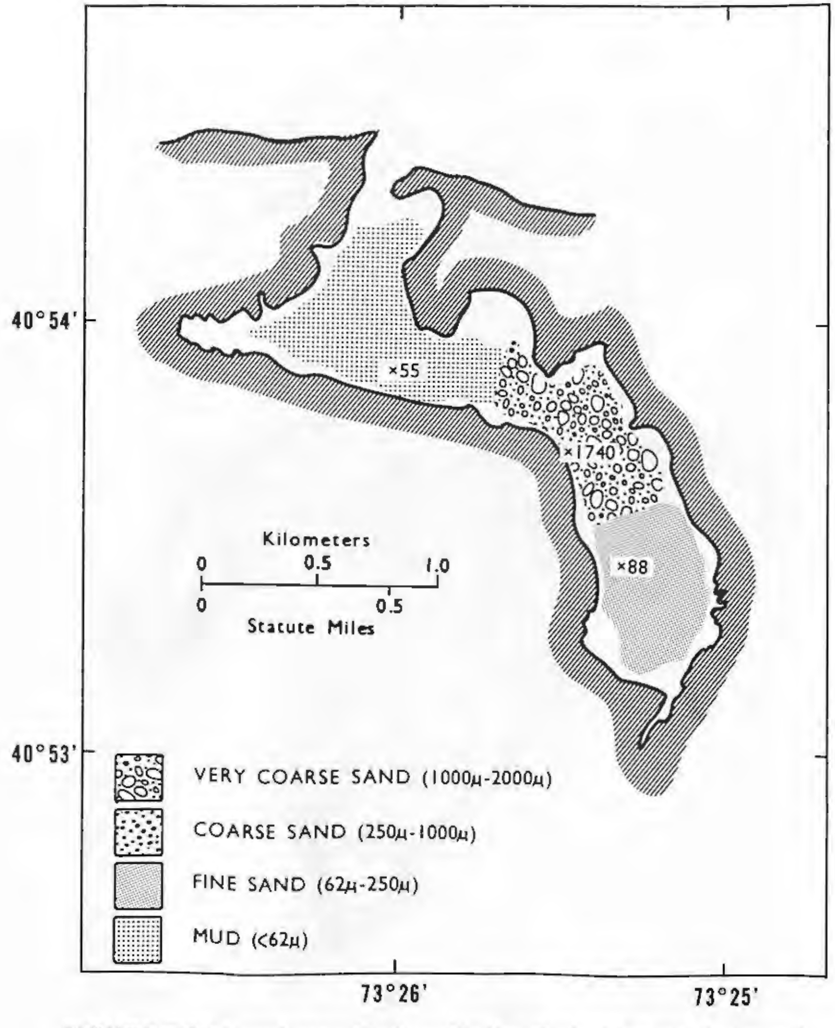

FIGURE 2.13 *Huntington Harbor: Median Grain Diameter (microns)*

SUMMARY

The basin occupied by Long Island Sound is an ancient feature of the New York-southern New England shoreline. Originally formed by erosion of rivers and by the action of glaciers, the basin continues to change slowly as waves, winds, and currents wear away the rocks and the sand of the shores. Even with no humans around, the basin would continue to change, but only gradually.

Since the arrival of the colonists more than three centuries ago, changes in the basin have speeded up. Especially since the Industrial Revolution, human activities have dramatically changed the shorelines, the bays, and the sediments that accumulate in the basin.

Many of these changes were intentional. Efforts to stabilize beaches or to improve the shorelines for transportation have left their mark. But they also served a purpose. Other changes were not intended and went unnoticed until they began to limit uses of the Sound and its bays. One example is the shoaling up of bays by accumulating waste deposits until the bays became too shallow for ships. Effects of these uses and misuses are recorded in the sediment and waste deposits discussed in this chapter.

Changes in the basin will continue as population density increases around the Sound and its waters are more intensively used. The basic principle guiding our future efforts to use and yet protect the Sound and its bays should be: Out of sight does not mean out of mind. Today's inexpensive waste disposal operation may be tomorrow's environmental problem. Undesirable changes in the basin will likely be the last to be noticed and often the most costly to correct.

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3 The Shorelines

INTRODUCTION

The shorelines of Long Island Sound consist of several environmental types. Each responds in its own way to natural forces and human impacts. All too often, man's use of the shoreline and adjacent land has been incompatible with physical forces and has brought on a series of management problems. Natural erosion, for example, has meant trouble in places where buildings or roads are threatened because of long-term shoreline change or short-term effects of severe storms. Sand mining, channel dredging, and shore protection structures have in some places accelerated the rate of erosion of beaches and marshes. Meanwhile, the opposite process, accretion—in the form of silted channels and drifting sands—has raised problems about disposal of polluted dredge soil.

In the urban congestion bordering much of the Sound, the shoreline has become highly prized simply for recreational open space. Wide beaches of suitable grain size for public recreation—not covered with cobblestones or fine, muddy silt—are a scarce resource. Access to the shore is limited. Other uses besides recreation—housing, industrial plants, sewage treatment plants, power plants, docks and piers, oil and cargo transfer facilities, shellfishing—all compete for space along the shore. Each of these modifications has substantial, often conflicting effects.

Of the two broad categories of shoreline—natural and man-made—these are the Sound's natural shores: (1) beaches backed by bluffs or rocky headlands, (2) bars and spits, (3) river-dominated areas, and (4) marine wetlands in bays and coves. Beaches backed by eroding glacial bluffs dominate the eastern half of Long Island's north shore. Rocky headlands and their adjacent coves occur only on the Connecticut side of the Sound. Bars and spits, occasionally with some sand dune development, are associated with eroding headlands, and usually provide sheltered waters behind them in bays, harbors, or coves. River-dominated shores are mainly limited to the Connecticut coast at the mouths of the Connecticut and Housatonic rivers; one small area on the north shore of Long Island is dominated by the Nissequogue River. Coastal wetlands have developed in quiet, shallow places—in bays and coves and along the landward side of bars and spits.

Urban, residential, and recreational development has altered these natural shore environments by the creation of artificial boundaries at the land-sea interface. Examples of man-made shore include (1) structures designed to prevent bank erosion, such as bulkheads and revetments, (2) groins and jetties designed to entrap sand moving along the shore, (3) materials filled in along the shore to create buildable land, maintain beaches, and dispose of solid wastes, and (4) shores affected by the removal of bank or bottom materials for sand and gravel mining, marine construction, or channel maintenance. The altered shoreline still remains subject to natural forces, however; winds, waves, tides, and runoffs tend to establish a new equilibrium as a result of the artificial changes.

It becomes evident in this chapter that the shore's very essence is vulnerability to change. Rising sea levels, in both glacial and historic times, shaped the shore's rough outline: now littoral forces of wind, tide, and wave are constantly remolding it. Meanwhile, storms large and small and the high tides that accompany them make dents in the shore and in any structures built there. People, in their usual way, build and use and change things to suit human purposes, sometimes skillfully adapting to the dynamic processes, more often blundering against them, which ends up costing a good deal of money. The knowledge we need to use and enjoy the shore's resources without running athwart its processes is specified in the chapter's last pages, together with limitations on our expansionist behavior. Although getting them instituted is a political feat, limitations like zoning and building code restrictions could make the knowledge work.

SEA LEVEL CHANGE AND THE SHORELINE

We saw in Chapter 1 that a major factor shaping the Sound's shoreline has been the worldwide rise in sea level since the recession of the ice sheets approximately 10,000 years ago. As the ice melted, the ocean crossed rapidly over the continental shelf south of Long Island. Flooding of the Long Island Sound depression was controlled by several sills.[1] Ridges now submerged at depths of 31 and 33 meters exist in the area between Montauk Point and Block Island, and in Rhode Island Sound. This border region of the Sound was probably flooded by rising seas about 10,000 years ago.

Central Long Island Sound was apparently occupied at that time by a glacial lake. The Connecticut River drainage system was located to the east of the lake. The lake itself was flooded with seawater roughly 8,000 years ago. Drainage of the Sound to the west occurred about 6,000 years ago when sea level rose high enough to flow over the sill near Hell Gate.

As sea level continued to rise, valleys and lowlands cut by rivers on both sides of the Sound were flooded. Although modified by glaciers, the river-cut features are still recognizable in the harbors and coves of Connecticut and western Long Island.

Sea level rise slowed down drastically in the period between 7,000 and 4,000 years ago.[2] From then on, the rate of sea level rise has varied according to locality, with discrepancies attributed to effects of crustal folding (tectonics).[3] Bloom found that sea level during the past 3,000 years along the Connecticut coast has risen at the rate of 0.1 meters per 100 years.[4] This rate corresponds closely to that determined by Newman for the western Long Island area.[5]

For recent years, data are available on the position of mean sea level at selected points along the Atlantic coast from tide observation stations maintained by the National Ocean Survey, NOAA. Long-term records are being kept to determine trends in relative sea level rise that would otherwise be masked by short-term weather effects. Disney has found that for the 60-year period from 1893 to 1953, mean sea level at New York City rose at the average rate of 3.3 millimeters per year, for a total change of about 20 centimeters (8 inches).[6] For the period 1940-1960, Donn and Shaw have found that mean sea level for stations along the Atlantic coast rose at an average rate of 2.4 millimeters per year.[7]

Recent observations suggest a marked increase in the rate of sea level rise during the last decade. During the period 1963-1970, sea level at Willets Point at the western end of the Sound rose at an average rate of 12.5 millimeters per year, for a total change of roughly 100 millimeters (4 inches).[8] Of three main influences on sea level change—meteorologic, tectonic, and eustatic (that is, related to worldwide sea level)—the eustatic rate of sea level rise in the last decade may be responsible: it seems substantially greater than eustatic rates earlier in the century.

Small sea level changes over long periods of time have little effect on erosion/deposition patterns around the Sound. But if sea level continues to rise at the present rate for an extended period, we can of course expect drastic changes in the erosion of the Sound's shoreline. A large rise in sea level would cause the shoreline to move inland.*

SHORELINE DESCRIPTION

Beginning with the Connecticut shoreline, we see (Fig. 3.1) that it is characterized by two types of geologic structure alternating along the coast. The first kind is exposed resistant bedrock—rocky stretches covered in some areas by thin deposits of glacial debris, usually till (intermingled clay, sand, gravel, and boulders). Small pocket beaches occur in rocky coves, their sand eroded from nearby outcrops of glacial deposits. Marshes have developed on the inland sections of some of the larger coves. Three sections of these rocky shorelines occur: the first stretches from the New York-Connecticut boundary to the Norwalk Islands, the second from New Haven to Guilford, and the third from East Lynne to the Connecticut-Rhode Island border.

The second type of Connecticut coast is associated with the large valleys of the Housatonic and Connecticut rivers: a low-lying plain with surficial glacial deposits sloping seaward, lying to the west of the river mouths. Connecticut's largest beaches are located in these areas, and some of the state's most severe problems of coastal instability occur here. The limited evidence about sand movement suggests that littoral drift is eastward along shores trending east/west, and northward along north/south shorelines.[9] More than half the western coast of Connecticut is bulkheaded or filled land.

Looking next at Long Island's north shore, we can divide it into two sections on the basis of topography and shoreline trend. To the west of Port Jefferson, the shoreline is highly irregular, indented by deep harbors and bays. The bays are

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*How far inland would be a distance equal to the product of the rise and the cotangent of the slope angle of the beach and nearshore bottom surfaces.

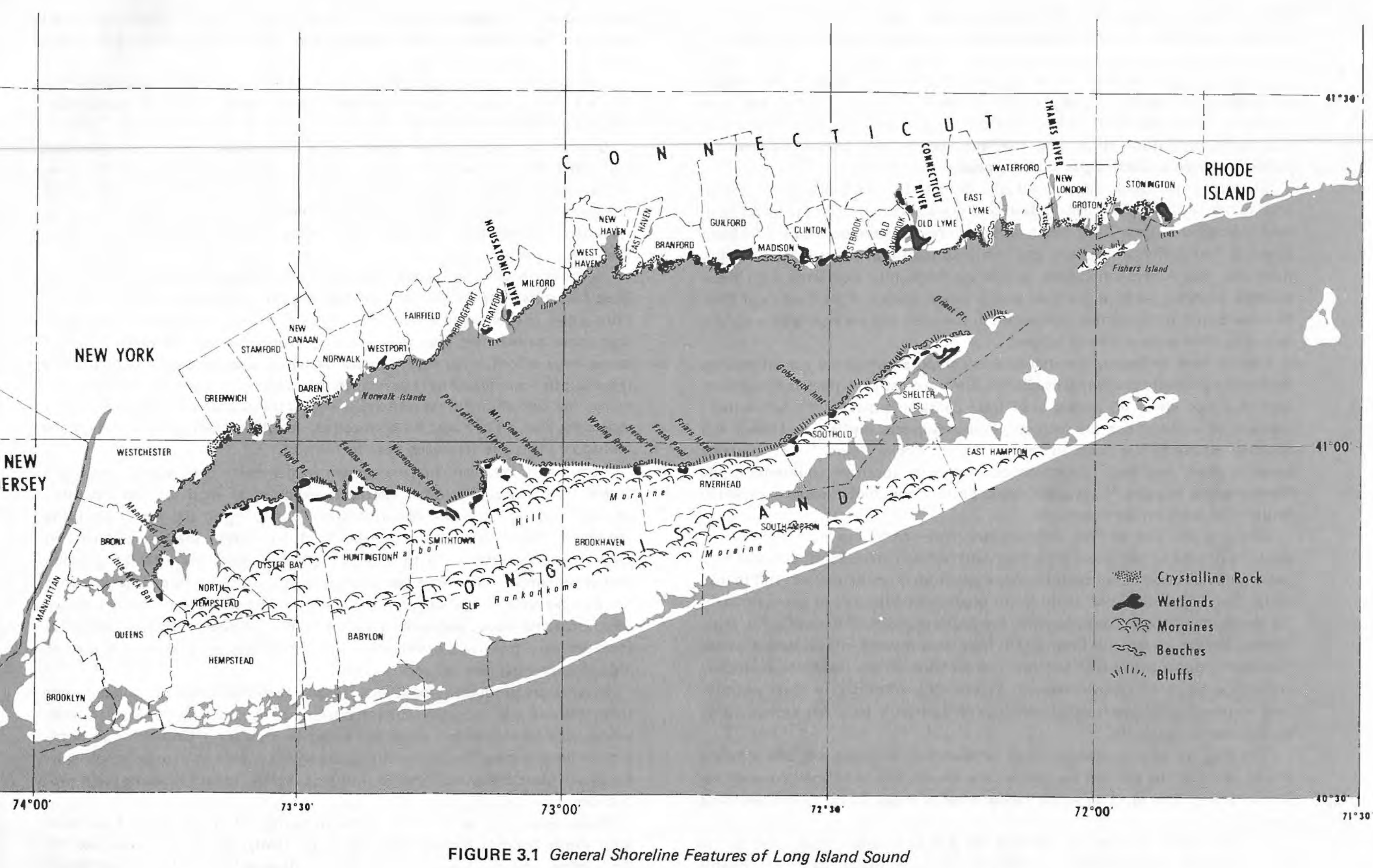


FIGURE 3.1 *General Shoreline Features of Long Island Sound*

separated by peninsulas or necks projecting into Long Island Sound. The necks typically have narrow beaches backed in some areas by bluffs. The bluffs are mainly composed of the Manhasset formation, a combination of till and outwash deposits covered by a thin layer of Harbor Hill till and outwash.[10] Bluff height is roughly 10 meters in the extreme western portion of the Island near Manhasset and Little Neck Bays, and increases to between 23 and 33 meters at Lloyds Point, Eatons Neck, and the Nissequogue area. Pocket beaches are located between projecting points of the necks.

Elevations increase to between 60 and 90 meters in the centers of the necks and at the heads of the harbors. Sand and gravels eroded from the necks have been deposited as spits (West Beach on Eatons Neck), baymouth bars (Old Field Beach at Port Jefferson Harbor), and tombolos (bars that connect islands to the mainland, like Asharoken Beach). Dunes are frequently associated with these beaches. Marshes, such as those at Stony Brook Harbor, Flax Pond, and West Meadow Beach, occupy small depressions in the coast and are separated from the Sound by small spits or barrier beaches.

East of Port Jefferson, the shoreline is composed of gently curved reaches separated by slightly projecting headlands. For the most part, the headlands have high bluffs of up to 40 meters (130 feet) containing clay or till layers more resistant to erosion than the sand or gravel of adjacent bluffs. The Harbor Hill moraine intersects the coast in the vicinity of Rocky Point.[11] This moraine contains more boulders (glacial erratics) than its southern counterpart, the Ronkonkoma moraine.[12] Boulder lag deposits from bluff erosion are often found offshore from the headlands.

Bluffs to the east of Port Jefferson are more continuous than those to the west. They tend to get lower from Port Jefferson to Orient Point. Between Port Jefferson and Herod Point, bluff height ranges from 30 to 42 meters (100 to 130 feet). East of Herod Point, bluff height gradually diminishes to approximately 10 meters near Orient Point. Marshes and beach deposits, like those at Mt. Sinai Harbor, Wading River, and Fresh Pond, have accumulated in depressions where the bluff is discontinuous. Other shoreline sections—Friars Head, for example—are composed of windblown deposits in the form of dunes. In some sections, such as near Sound Beach, wind deflation of bare bluff faces has formed dunes on the tops of the bluffs.

The long line of uninterrupted bluff between Port Jefferson and Orient Point, almost as far as the eye can see, has no counterpart on the Atlantic coast of the United States. One must go to the Pacific coast to Puget Sound to find anything like it.

A word about wetlands as shoreline features is in order. Compared to the South Atlantic coastal states, the margins of Long Island Sound are poorly endowed with wetlands—tidal marshes and submerged flats.[13] Glacial action did not leave large areas of level, shallow land where salt-tolerant plants would flourish; nevertheless, wetlands have established themselves in the quiet waters of bays and coves. Adjacent mudflats and a fringe of upland area above the spring tides are usually included in the definition of wetlands, for management purposes.[14]

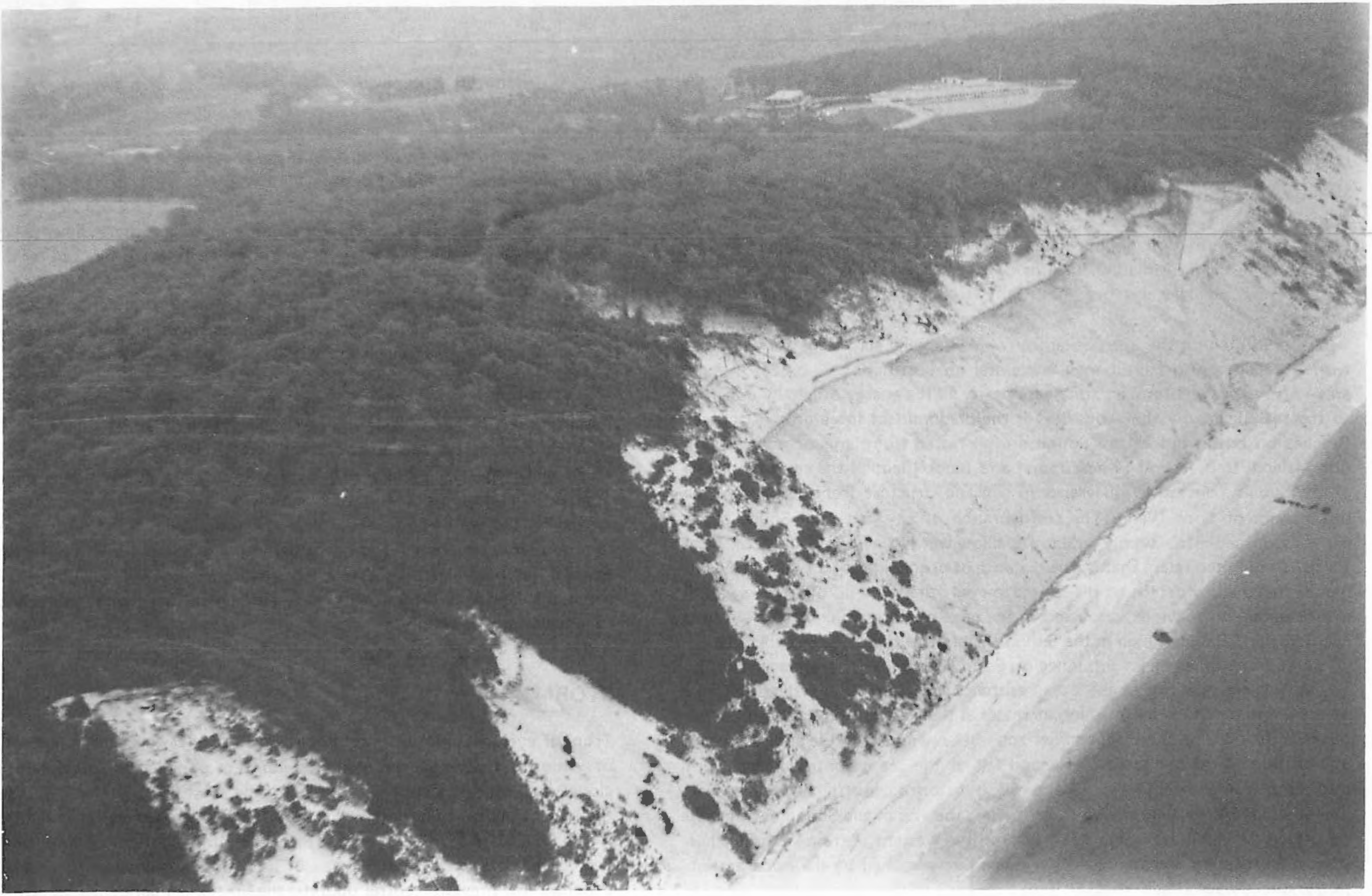
Besides their value as open space and as breeding and feeding areas for fish and other marine animals,[15] wetlands are probably the major traps for fine-grained sediment delivered to the Sound by rivers and runoffs.[16] By trapping sediment, the marsh grasses tend to maintain the marsh surface just above the level of mean high tide. The organic sediments compact as time passes and form thick peat deposits.

In the harsh salt marsh environment, only two species of grass thrive: cordgrass *(Spartina alterniflora)* and salt meadow hay *(Spartina patens)*. *S. alterniflora* grows in submerged areas and along tidal creeks; it is a coarse-leafed plant that grows several feet high in a single summer. *S. patens,* a smaller grass that grows only a foot or so high, prefers higher flats covered only during spring tides. Both these plants have developed mechanisms to cope with the salt in the water, the lack of oxygen in wetland soils, and the abundance of plant nutrients, especially iron. They also have rhizomes, root-like structures from which the individual plant develops each year to full size.

About half the plant material grown in the marsh each year is consumed within its borders. The other half gets exported as food for fish and other animals living in nearshore estuarine areas, or feeding in the marsh but living elsewhere. Marsh grasses are prolific food producers: *Spartina* wetlands in Georgia produce about 10 tons of dry organic matter per acre. Long Island Sound wetlands, with a little less sun, produce about 2.7 tons of organic matter per acre per year.[17] (By comparison, wheat production amounts to 1.5 tons per acre, including leaves and stems.) Continental shelf waters produce about 1.5 tons per acre per year; open ocean water produces only about 0.5 tons of organic matter per acre per year.

Marshes are productive for several reasons. High tide waters bring in nutrients (phosphorous and nitrogen compounds); ebb tidal currents remove organic wastes. Coastal circulation, especially estuarine circulation, tends to retain nutrients in the marshes. The sediment trapped by the grasses also contains nutrients. Decay of plant materials recycles nutrients rapidly, again increasing plant production.

Wetlands also act as erosion buffers for bluffs and upland areas. They minimize storm flooding by spreading the water thinly over a large area, and the dense grass tends to slow down wave action. Because their biological and littoral



Aerial view of bluffs, bluff-face vegetation patterns, and narrow beaches characteristic of Long Island's north shore east of Port Jefferson. The slope angle of the high north shore bluffs ranges between 30 and 35 degrees. At steeper angles, sand and gravel slides are likely.

values have only gradually been recognized, untold acres of Long Island wetlands have been filled in over the years for flat land for airports and housing, and for waste disposal.

LITTORAL FORCES

At the shoreline the ocean's dynamic physical forces are most conspicuous. Waves, tides, storms, all are impelled by enormous energy. Everything is in flux. Beaches are a highly variable landform: energy causes them to erode, or to accrete. They remain stable over time only if material removed equals material added.[18]

Waves formed on the open ocean by winds blowing across the surface travel with little energy loss until they encounter an obstruction—a beach or shoal area—where breakers form and dissipate nearly all the energy originally imparted to the sea surface by the wind. Surf is the predominant force on most coasts. Beaches on both sides of the Sound are protected from large ocean swells by Long Island itself and by Fishers Island and Block Island at the eastern opening of the Sound; hence their difference in size and structure from beaches on the south shore of Long Island. The configuration of any particular Sound beach depends on sediment supply and on shallow-water waves produced by local winds. The limited fetch, that is, the distance of open water over which the wind blows, and shallow depths of the Sound prevent the build-up of large waves,[19] except under storm winds, discussed in the next section, which can raise waves over 2 meters (6.5 feet) high in the Sound's western end near New York City.

Tides are another major influence on Sound beaches. The average range between high and low tide at the ocean entrance to eastern Long Island Sound is about 0.7 meters (2.5 feet), which increases at the western end to about 2.2 meters (7.3 feet). The shore's intertidal zone lies open at low tide and submerged at high tide. Most of the daily rise and fall of the sea is controlled by the attraction of sun and moon (see Chapter 4), but storms can also change sea levels. Storm winds blowing from east to west along the axis of the Sound can increase tide levels as much as 5 meters (15 feet) in the western portion. During these storms, bluffs, spits, and other low-lying areas rarely washed by the water are subject to direct wave attack.

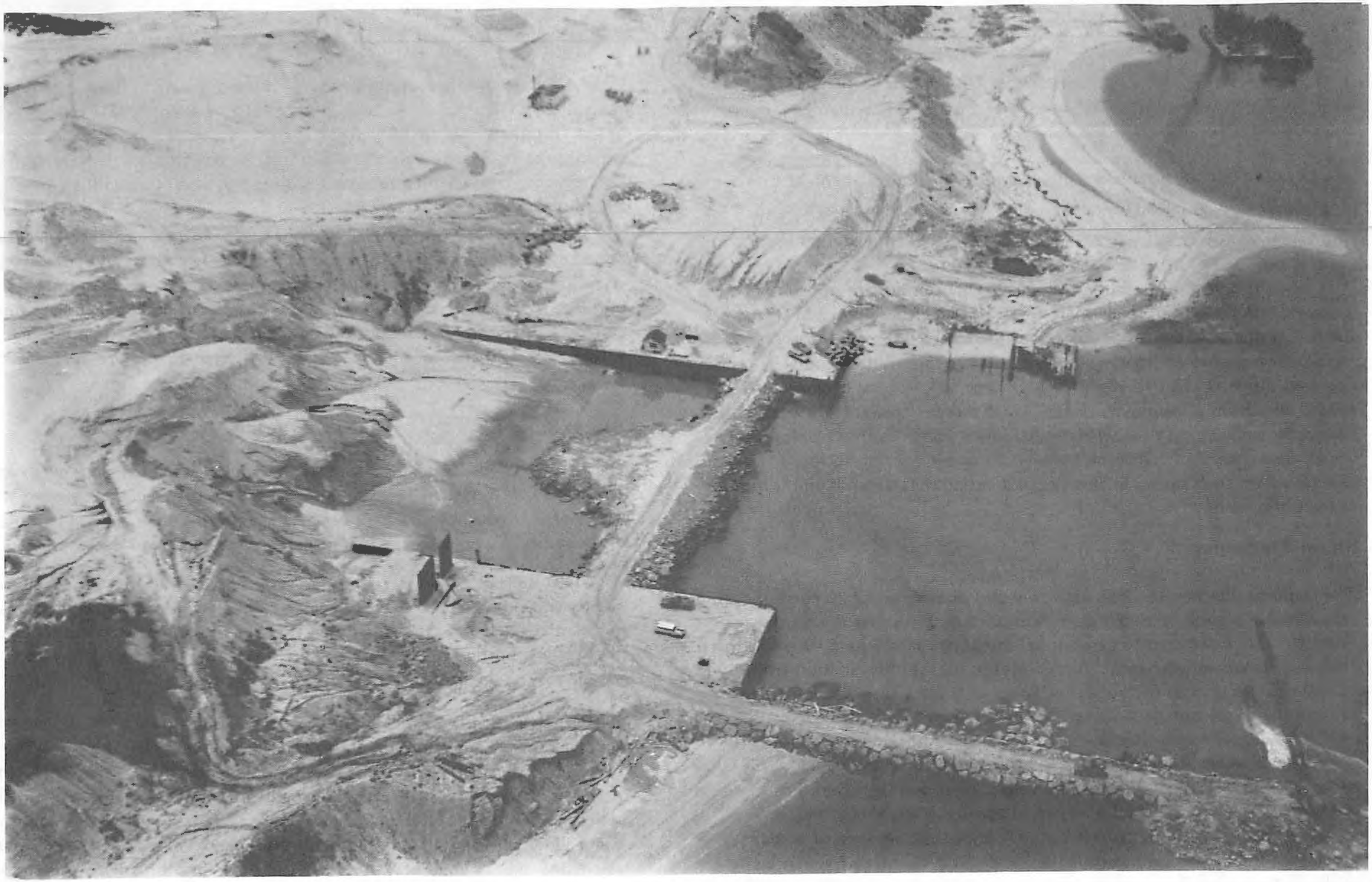
Littoral transport takes place mainly because the energy of waves breaking at the shore moves sand along, although under conditions of restricted flow such as at harbor entrances, tidal currents actually determine the volume and direction of material moving. The direction and rate of littoral transport depend on the angle of wave approach and amount of wave energy at the shore, which in turn depend on the wind characteristics of the area and shoreline configuration.[20] Because of different exposures, three adjacent beaches near the New York-Connecticut border show evidence of sediment movement in different directions.[21] Other factors influencing littoral transport are the available supply of sediment and its grain size distribution.[22] Seasonal wind direction changes also vary the direction of littoral transport.

Littoral transport is the chief supplier of sediment to shore sections without their own local supply from eroding bluffs or riverborne sediment. When an area's supply of sediment brought by littoral transport is blocked by a barrier such as a groin of jetty, the beach of that area will erode; it is no longer receiving sediment nourishment from updrift beaches. The littoral currents washing the eroding beach have become "starved" and tend to remove sediments without depositing updrift material. Narrow beaches at some locations along the Sound can be attributed to this factor. When littoral transport is split in two directions at a headland, beach erosion is often the result. Littoral transport direction is important to the sand budget of a particular stretch of coast.

Waves striking the beach rework and sort glacial deposits. The glacial till of bluffs along the Long Island side of the Sound is a poorly sorted mixture of boulders, pebbles, sand, and fine sediments. The large fragments cannot be moved by the waves and remain near the source. Fine sand, silt, and clay are removed from the beach and deposited in quiet waters of offshore areas, tidal marshes, harbors and bays. Sand and small gravel-sized fragments are moved along the beach as littoral drift; near eroding till headlands, the beaches are usually gravelly or pebbly.

STORMS

Tropical cyclones and extratropical storms (northeasters) are important agents of erosion and cause damage along the shores of Long Island Sound. Tropical cyclones develop over open ocean areas off the coast north of Brazil, just north of the equator, between latitudes of 6° and 10°N, when surface water temperatures are above 26° to 27°C (79° to 81°F), usually in August, September, and October.[23] The counterclockwise vortex of such storms is created by winds blowing toward a low-pressure central updraft; the vortex is maintained by energy from condensation of water vapor derived from the warm ocean surface. As they pass over land masses or cold water, tropical cyclones quickly dissipate because they are deprived of their source of warm, moist air.[23] The path of an individual storm is determined by its point of origin, and by the relative position and strength of low and high pressure centers located in the westerly wind belt and over the Atlantic Ocean.



An abandoned deepwater port/sand mining project at Jamesport, Long Island, 2.5 miles west of Mattituck Inlet. Public pressure and the New York State Attorney General's office forced the Curtis-Wright Corporation to stop operations and to remove two entrance jetties because of their adverse effect on the stability of adjacent shorelines. The current owner of the Jamesport site, the Long Island Lighting Company, is planning to build two 1150-megawatt nuclear power units here by 1983.

Tropical cyclones range in diameter from 80 to 800 kilometers (50 to 500 miles), and are classified according to sustained wind speed. We will use Simpson and Lawrence's classification:[25]

- *tropical storms*—sustained winds exceeding 65 km/hr (35 knots),
- *hurricanes*—sustained winds exceeding 120 km/hr (64 knots),
- *great hurricanes*—sustained winds exceeding 200 km/hr (108 knots).

Northeasters, as they're called, are much bigger storms than tropical cyclones, including hurricanes, and much more frequent. They develop in mid-latitudes in the fall, winter, and spring in response to the interaction of warm and cool air masses along a weather front. They may be more than 1,800 kilometers (1,000 miles) in diameter—two to three times as large as a tropical cyclone.[26] Northeasters also form a counterclockwise spiral directed toward a center of low barometric pressure, but the winds are of lower velocities than tropical cyclone winds. Some gusts of hurricane velocity do occur with northeasters.[27] Wind direction from such storms at a particular area and time depends on the location of the storm center.[28]

Storm Frequency

The National Weather Service's data on storm occurrence in the North Atlantic region show a total of 699 tropical storms and hurricanes during the period 1886-1971.[29] Compared to other areas, the Long Island Sound region has been relatively fortunate, with only 30 to 35 storms in that interval; southern Florida experienced more than 65 tropical cyclones in those years. Table 3.1 describes some of the severe tropical cyclones that have affected Long Island.[30]

Figure 3.2 shows the frequencies of occurrence in a given year of tropical storms, hurricanes, or great hurricanes for segments of coastline about 93 kilometers (50 nautical miles) long between New Jersey and Cape Cod. The frequencies are expressed as probabilities in percentage units, and are not probabilities in the strict mathematical sense. They are the arithmetic averages of actual storm occurrence for the period between 1886 and 1970, based on frequencies determined by Simpson and Lawrence from cyclone tracks during the 85-year period.[31] For the Sound, the frequency of all tropical cyclones is greatest in the central portion, where there is an 11 percent chance of occurrence in any year. In the Cape Cod region, the frequency of tropical cyclones is about twice that of central Long Island Sound. The average intervals between tropical cyclone occurrences for segments 1, 2, 3, and 4 are 25, 9, 17, and 4 years, respectively.

In a frequency study of northeasters affecting the Atlantic coastal margin of the United States during the period 1921-1962, Mather, Adams, and Yoshioka found that there was an 86 percent chance in a given year that a northeaster would cause significant water damage along the coastal areas of New York and Connecticut.[32] Selected extratropical storms that have affected the Long Island Sound region are described in Table 3.2.

Taking together both tropical cyclones and northeasters, the Long Island Sound area experiences a storm causing moderate damage about once every two years. Unusually severe storms are likely to occur, on the average, three times a century. These summary frequencies are Corps of Engineers conclusions from a literature survey of the 204 storms between 1800 and 1962 that affected the Atlantic coast between Maryland and the New Hampshire—Massachusetts border.[33]

Storm Surges

The strong winds associated with both tropical cyclones and northeasters produce storm surges, defined as the "difference between the observed water level and that which would have been expected at the same place in the absence of the storm."[34] Four processes contribute to the buildup of a storm surge:

1. WIND SETUP. Wind stress on the water surface tends to "pile up" water in the downwind direction. Easterly winds in the Long Island Sound region have a substantial fetch and can cause heavy flooding in the low-lying coastal areas at the western portion of the Sound. The wind setup effect is aggravated by decreasing water depths and increasing wind velocity.[35]

2. THE INVERTED BAROMETER EFFECT. The surface of the Sound moves up and down slightly in response to changes in atmospheric pressure. The low pressures associated with severe storms cause a rise in sea level. In the open ocean, a pressure drop of about 34 millibars of mercury (1 inch) will theoretically lead to a sea level elevation of 34 cm (about 13 inches). The constricted water flow through the two ends of the Sound limits the sea level rise by restricting the amount of water that can move into or out of the Sound in response to this pressure effect.

3. WAVE SETUP. Breaking waves transport water into the nearshore zone, thus contributing to storm surge. Wave setup may account for as much as 1 to 2 meters of surge height at a beach.[36] This effect is maximized when waves break parallel to the coast.

TABLE 3.1 *Selected Tropical Cyclones, Long Island*

Date	*Maximum Tides (feet above mean sea level)*	*Comments*
August 15, 1635		Probably the first hurricane historically recorded in New England. The high tides of this storm (14 ft. above high tide at Narragansett Bay, R.I.) no doubt had major effects on Long Island's north shore.[1]
September 22-23, 1815		The "Great September Gale of 1815" was responsible for much damage to shorefront buildings and shipping in the Long Island Sound area.[2]
September 3, 1821		This storm crossed Long Island in the vicinity of Jamaica Bay, causing much damage.[1]
September 21, 1938	13.1 Willets Point	The "New England Hurricane of 1938" was termed America's costliest disaster. The storm passed over central Long Island at a forward speed of 60 mph. Sustained winds of 82 mph were recorded on Block Island. An extreme gust of 186 mph was recorded in Massachusetts. During the period 17-21 September, a total of 10.9 in. of rain fell at Setauket, L.I. Record tides occurred in most parts of the Sound.[3] Damage to the north shore of Long Island amounted to $700,000 (1938 prices).[4]
September 14, 1944	7.0 Willets Point	The "Great Atlantic Hurricane of 1944" hit the Long Island coast at an oblique angle, with the coast to the left of the storm's center. The slow forward speed (25-30 mph) and low tide stages caused less damage than the 1938 hurricane. Sustained winds of 82 mph were recorded on Block Island.[5] Long Island north shore damages amounted to $225,000.[4]
August 31, 1954	9.45 Port Jefferson	Hurricane Carol produced the tide of record along most of Suffolk County's north shore. The north shore harbors were subject to flooding—in some places Route 25A was under 5 ft. of water.[6] North shore damages were estimated at $700,000.[1] The Port Jefferson area suffered severe damage. At the peak of the tide, the bar at West Meadow Beach was under 4 ft. of water. Sustained winds of 90 mph occurred at Block Island. Precipitation amounted to 2.92 in. at Setauket, L.I.
August 29, 1971		Tropical storm Doria was the most recent storm of tropical origin to affect the shores of Long Island. The storm crossed the New York City area with sustained winds of about 60 mph. Tide levels of 5 ft. above normal were reported, but minor flooding resulted as the storm coincided with low tide.[8]

Source: Davies, 1972, pp. 37 and 38.

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[1] D. Ludlum, *Early American Hurricanes, 1492-1870* (Boston: American Meteorological Society, 1963), 198 p.

[2] I.R. Tannehill, "Hurricane of September 16 to 22, 1938," *Monthly Weather Review* 66:286-88.

[3] C. Pierce, "The Meteorological History of the New England Hurricane of September 21, 1938," *Monthly Weather Review* 67:237-85.

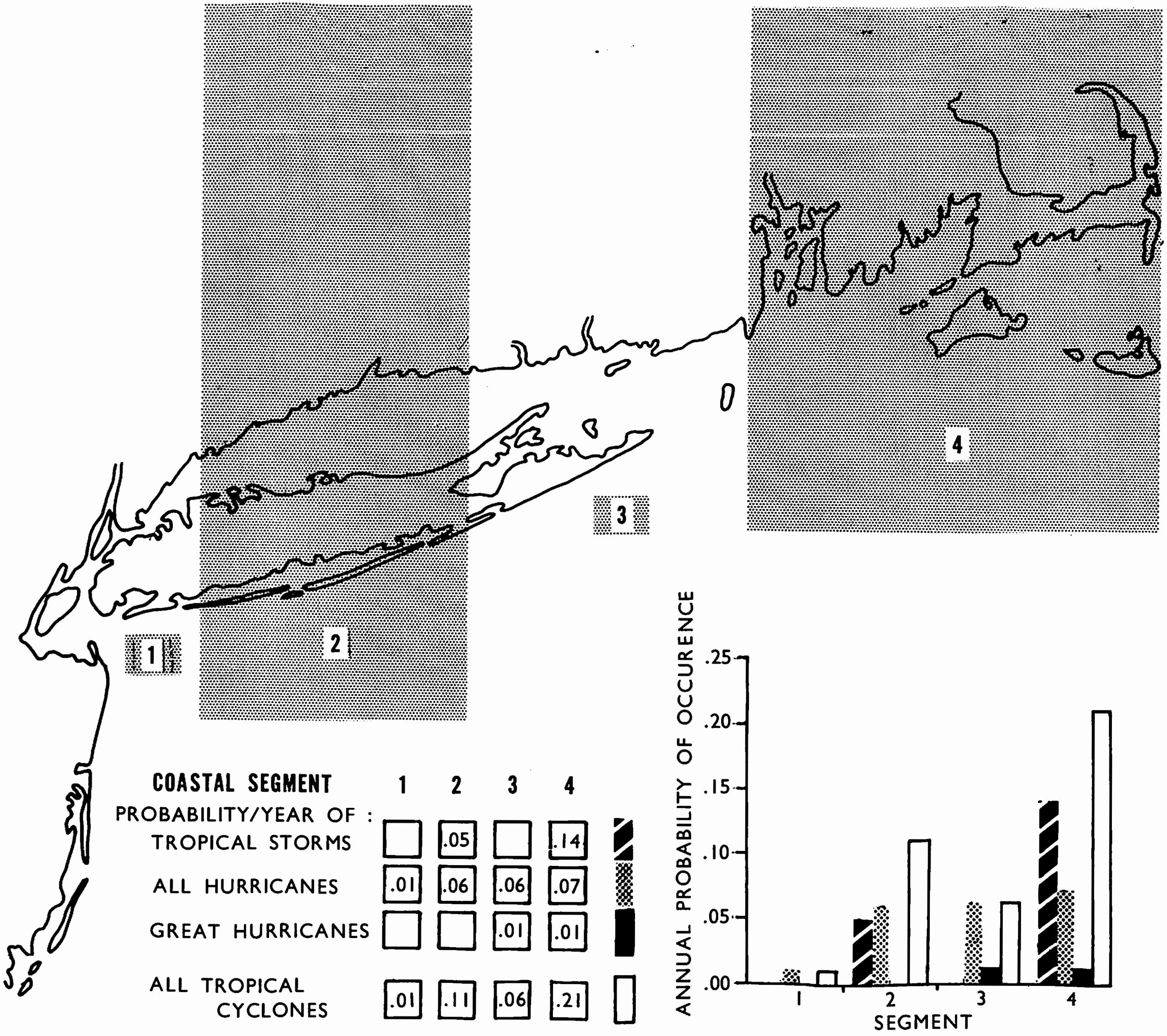
[4] US Army Corps of Engineers, *North Shore of Long Island, Suffolk County, New York, Beach Erosion Control and Interim Hurricane Study* (New York: New York District, US Army Corps of Engineers, 1969), 271 p.

[5] H.C. Sumner, "The North Atlantic Hurricane of September 8-16, 1944," *Monthly Weather Review* 72: 187-96.

[6] *New York Times,* 1 September 1954, p. 20.

[7] *Newsday,* 1 September 1954, p. 3.

[8] R. DeAngelis, "North Atlantic Tropical Cyclones, 1971," *Mariners Weather Log* 16 (1) (1972): 9-20.



COASTAL SEGMENT	1	2	3	4	
PROBABILITY/YEAR OF :					
TROPICAL STORMS		.05		.14	▨
ALL HURRICANES	.01	.06	.06	.07	▒
GREAT HURRICANES			.01	.01	■
ALL TROPICAL CYCLONES	.01	.11	.06	.21	☐

FIGURE 3.2 *Annual Probabilities of Tropical Cyclones in Coastal Segments, 1886-1970*

Source: Davies, Axelrod, and O'Connor, 1973, Figure 2-4.

TABLE 3.2 *Selected Northeasters, Long Island*

Date	*Maximum Tides (feet above mean sea level)*	*Comments*
March 11-14, 1888		The high winds of the "Blizzard of '88" created snow drifts 10-20 ft. high in the Long Island Sound area. Over 44 inches of snow fell in New Haven.[1]
October 24-25, 1897	5.5 The Battery	Tidal flooding separated Orient Village from the rest of the North Fork.[2]
November 25, 1950	9.7 Willets Point 8.9 Port Jefferson	At Brookhaven Laboratory, sustained winds of 73 mph and gusts up to 93 mph were reported. A total of 1.78 in. of rain fell at Setauket, L.I. The barrier islands of the south shore were breached in 16 places. Roughly $500,000 damage was reported along the north shore.[2]
November 6-7, 1953	9.7 Willets Point	The dunes on Fire Island were cut back 10-50 ft. Winds up to 75 mph (average velocity, 5-minute period) were reported on Block Island. Wave heights at the west end of the Sound were roughly 6 ft., while waves in the eastern portions were up to 12 ft. in height. Damages of $300,000 were reported along the north shore.[3]
March 6-8, 1962	8.5 Willets Point 7.1 Port Jefferson	The "East Coast Atlantic Storm" of March 1962 covered a tremendous area. Two low pressure centers coalesced and remained stationary off the Delaware coast. Strong east winds and fetch lengths of 1,000 miles created ocean waves 20 to 30 ft. high. This was one of the worst winter storms in Long Island's history. Abnormally high water levels occurred on 5 successive high tides. Damage on Long Island amounted to $5 million.[2,4,5]

Source: Davies, 1972, p. 41.

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[1] J.J. Brumbach, *The Climate of Connecticut,* Bull. 99 (New Haven: State Geological and Natural History Survey of Connecticut, 1965), 215 p.

[2] US Army Corps of Engineers, *North Shore of Long Island, Suffolk County, New York, Beach Erosion Control and Interim Hurricane Study* (New York: New York District, US Army Corps of Engineers, 1969), 271 p.

[3] US, Congress, House, *Cooperative Beach Erosion Control and Interim Hurricane Study, Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, New York,* 86th Cong., 1960, Document 425, Appendix G, 40 p.

[4] US Weather Bureau, "East Coast Atlantic Storm," *Shore and Beach* 30 (1962): 4-10.

[5] *Newsday,* 8 March 1962, p. 3.

4. RAINFALL EFFECT. Heavy rains can cause flooding in bays and wetlands. This effect depends on local conditions, the existence of streams, and drainage facilities.

Shoreline damage and erosion are directly tied to the maximum tides produced by a storm. The stage of the tide, storm intensity, speed of storm movement, and the angle of the storm track at the shoreline all determine how much storm surge will surpass mean high water.[37] Tropical cyclones and northeasters produce different effects for the last three factors.

A tropical cyclone's strongest winds are located in a narrow band surrounding the eye of the storm.[38] Storm surge peaks and maximum wind velocities are not found at the eye of the storm, however; they are displaced into the region to the right of the storm track. The winds in the right quadrants of the cyclone's counterclockwise spiral are more or less parallel to, and reinforced by, the movement of the storm along its track. This reinforcement can be of considerable magnitude: hurricanes have been clocked at forward speeds over 50 knots. Wind and wave setup effects are maximized in the right or "dangerous" half of tropical cyclones.[39] South-facing coasts perpendicular to storm tracks receive the full impact of the reinforced winds and wave setup. North-facing coasts are somewhat protected. This is one reason why the Connecticut coast of Long Island Sound usually experiences greater surges than the northern Long Island coast. Another factor is the buildup of water along the Connecticut coast because of Coriolis acceleration from the earth's rotation on currents directed into the Sound from east to west.

The dominant effect of shoreline orientation on storm surge is noticeable in storm tracks of major damage-producing hurricanes of the Long Island Sound region, shown in Figure 3.3. If the track of a tropical cyclone passes to the right of a coast, wind and waves will be directed offshore, thus minimizing shore damage from tidal flooding. The hurricanes of 21 September 1938 and 31 August 1954 travelled in paths perpendicular to the shoreline. Figure 3.4 shows the surge heights produced by these two storms in the middle of the Sound. Surge heights in the shallow bays along the coast were considerably amplified (Table 3.3). The 1938 hurricane produced record tides for both the eastern and western Sound. In the central section, the storms' profiles coincide but are of record height here also. Data from tide observations suggest that part of the surge of storms like these hits the New England coast near Rhode Island, and that the surge travels from east to west through Long Island Sound in the form of a large gravity wave.[40] The height of the wave decreases in the wide central portion of the Sound but increases as the Sound narrows near its western end. There is a lag of about two hours between time of storm passage and time of maximum tidal height at Willets Point.

Northeasters also cause storm surges. When an extratropical storm center passes to the west of the Sound area, winds initially blow from the east or southeast. As storm movement progresses, the winds shift to south and then west. This type of storm results in offshore winds for the north shore of Long Island and onshore winds for the Connecticut coast—thus subjecting Connecticut to high wave action from this type of storm, too. If, on the other hand, the storm center passes to the east of the Sound, the initial winds blow from the northeast. Later, the winds veer to come from the north and northwest. This type of storm produces onshore winds along Long Island's north shore, and hence increased wave height and wind setup.

The effect of northeasters on the shoreline depends on their forward speed. If the storm progresses rapidly, variable wind directions over a given fetch prevent the buildup of large storm waves. But if storm progress is delayed by

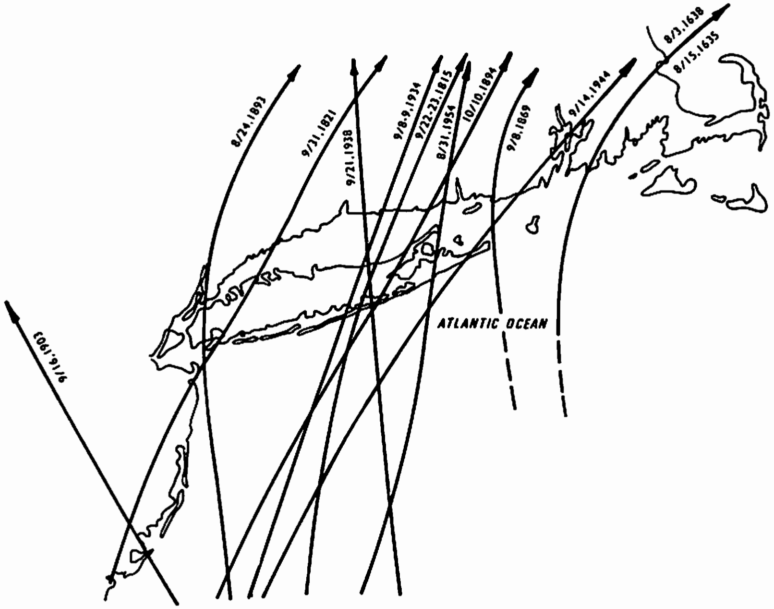

FIGURE 3.3 *Tracks of Major Hurricanes in the Long Island Sound Area*

Source: Davies, 1972.

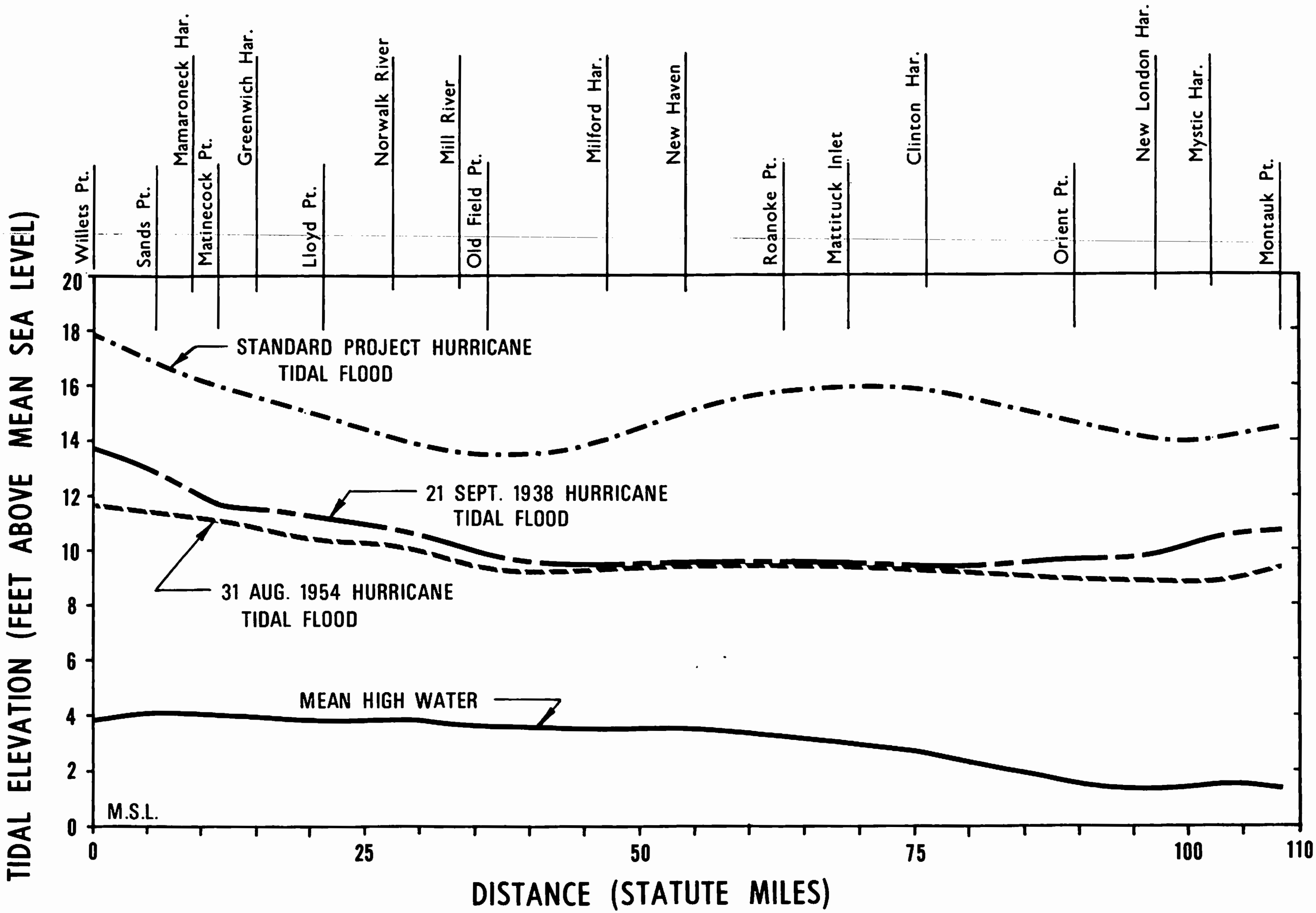

FIGURE 3.4 *Predicted Tidal Flood of the Project Hurricane for the Long Island Sound Region*

The standard project tide, a mathematical projection from the standard project hurricane, is used in designing coast protection construction by the US Army Corps of Engineers. A standard project hurricane is a hypothetical storm that may be expected from the most severe combination of meteorological conditions reasonably characteristic of the region involved, excluding rare combinations.

Source: adapted from US Army Corps of Engineers, New England Division, 1973.

TABLE 3.3 *Storm Surge Heights from Hurricanes in 1938 and 1954*

Location	*21 Sept. 1938* *height above mean sea level* *m*	 *ft*	*31 Aug. 1954* *height above mean sea level* *m*	 *ft*
Connecticut				
New London	2.9	9.7[a]	2.7	8.9[a]
New Haven	2.9	9.5	2.9	9.5
Stratford	2.8	9.2	2.8	9.2
Bridgeport	2.9	9.6	2.8	9.3
Stamford	3.4	11.0	3.1	10.3
New York				
Willets Point	3.9	12.9[b]	3.5	11.4[a]
Port Washington	4.4	14.3	3.6	11.7[c]
Roslyn	3.7	12.1	3.4	11.0[c]
Oyster Bay	3.4	11.2		
Huntington Harbor	3.1	10.1		
Port Jefferson Harbor	2.5	8.2	2.9	9.45[a]
Mattituck Inlet	2.4	7.8		
Orient Point	2.2	7.1	2.6	8.4[a]

[a] US Army Corps of Engineers, *North Shore of Long Island, Suffolk County, New York, Beach Erosion Control and Interim Hurricane Study* (New York: New York District, 1969), 271 p.

[b] B. Bigwood *et al., Hurricane Floods of September 1938,* Water Supply Paper 867 (Washington: US Geol. Survey, 1940), p. 523.

[c] D.L. Harris, *Characteristics of the Hurricane Storm Surge,* Tech. Paper 48 (Washington: US Weather Bureau, 1963), 139 p.

ridges of high pressure, winds from a particular direction have enough time to act on a given wave group to produce waves of maximum height for a specific wind velocity and fetch.[41] The wave heights on an open coast produced by a stationary northeaster of sufficient intensity may equal or exceed those produced by many tropical cyclones. Storms with easterly winds of long duration have the greatest effect on shores of the Sound.

The severe winds and extreme tides of tropical cyclones usually last less than six hours. The wind and wave effects of northeasters, though often less severe, can last up to four or five tidal cycles. Prolonged attack during successive high tides on an eroding beach can lead to substantial dune and bluff recession.[42]

Storms as Geologic Agents

So great is the alteration wrought by hurricanes and northeasters that the shape of the shoreline today is, in fact, mainly the result of storm erosion and deposition. A severe northeaster or hurricane can change the shore in a few hours as much as normal conditions do in a hundred years. The 1938 hurricane that broke all tide records was this kind of storm. The waves and storm surge of this hurricane levelled Rhode Island coastal dunes six meters (19 feet) high—dunes that had been building up since a hurricane of similar magnitude 123 years before on 22 September 1815.[43] The 1938 storm also caused severe bluff erosion: glacial cliffs 15 meters (50 feet) high were cut back over 10 meters (33 feet). The shoreline effects of the hurricane of 14 September 1944 were also severe, despite its northeasterly track angling off Montauk. This storm cut back the bluffs at Shoreham, Long Island, a horizontal distance of over 12 meters (39 feet); by undercutting the bluff base so that the face collapsed, the storm created a vertical cliff 3.3 meters (11 feet) high.[44]

Northeasters, though they produce lower tides than tropical storms, are much more frequent, and the combined effect of two or more northeasters, one right after the other, on beaches that have not achieved full poststorm buildup can be just as devastating as a hurricane. Similar shoreline changes can be expected from a hurricane, a severe northeaster, or several northeasters occurring in a short interval, but the magnitude of change can be expected to be greatest from a severe hurricane, as tidal inundation is the main cause of shoreline damage.[45]

The impacts of the 21 September 1938 and the 14 September 1944 hurricanes on the shore of Long Island Sound have been well documented.[46] These studies indicate that the geologic effects of severe storms depend on the type of shore environment. The effects of hurricane attack on bluffed coasts and bar beaches are outlined in Table 3.4. The most dramatic changes—dune and bluff erosion and inlet formation—are the result of the storm surge, which for a few hours creates a new, submerged shoreline in areas not normally exposed to direct wave and tidal action. Inlets tend to open up in narrow, low sections of barrier bars.[47] Large areas of the bars are completely inundated at the peak of storm surge. Figure 3.5 shows the sequence of changes in beach profile development that would most likely occur as the result of hurricane activity. The net effects are cliff recession and landward migration of bars as they become wider and flatter.

Chute studied bluff recession along the southern Cape Cod coast caused by the hurricane of 14 September 1944.[48] The magnitude of cliff recession was found to be related to several shoreline characteristics:

- Virtually no cliff recession occurred in those areas where the beach was at least 42 meters (140 feet) wide. Cliffs that retreated up to 15 meters (48 feet) as the result of the storm were associated with beaches narrower than 42 meters. The narrow beaches provided less protection for backshore areas.
- High bluffs receded less than low bluffs. This is simply because waves must remove more material from the base of high bluffs to cause a given amount of bluff recession.
- Vegetation and beach ridges at the bases of bluffs retarded bluff erosion.

TABLE 3.4 *Effects of Hurricanes on the Long Island Sound Shoreline*

Bluffed Coast	*Bar Beach*
1. *Beach recession.* Mean high waterline migrates landward as beach deposits are removed and transported offshore.	1. *Beach recession.* Mean high waterline migrates landward as beach deposits are removed and transported offshore. A low, flat "hurricane beach profile" develops.
2. *Bluff recession.* Bluff and headland erodes due to direct wave attack during the peak of the surge flood.	2. *Dune erosion.* Dune scarps (vertical slopes) are formed as a result of wave attack. Overtopping occurs during time of peak surge.
3. *Formation of benches.* Benches are level or gently sloping planes inclined seaward. Formation of wave-cut bench widens the beach. Material eroded from the bluff is deposited on the beach face, and in some instances raises beach elevation above prestorm levels.	3. *Inlet formation.* Beach lowering leads to inlet formation, especially during ebb flow of storm tide.
	4. *Deposition of tidal deltas and overwash fans.* Beach and dune sands are deposited in the bays and on the tidal marshes, increasing bar width.

Adapted from Davies, 1972, Figure 11.

- Bluffs composed of till and clay were more resistant to wave attack than those composed primarily of sands.
- Seawalls were ineffective in curtailing bluff erosion unless they were constructed heavily enough to withstand direct wave impact. The seawalls must also be higher than the height of the storm surge and waves.

These conclusions from Cape Cod fit similar situations in the Long Island Sound region.

Except for the bluffs, which can only remain stable or erode, the shoreline has a remarkable ability to restore itself to prestorm conditions.[49] Material is eventually restored to the beaches from offshore. Some bluff-eroded material remains on adjacent beaches. The berm, the nearly horizontal part of the back beach formed by waves deposits, gradually builds up a convex profile. Dunes do rebuild, though the process requires many years to attain former dune heights, and is often slowed by human interference.

". . . WHO BUILT HIS HOUSE UPON THE SAND"

Beach stabilization, bluff erosion, and property development along the shores of the Sound have in recent years become difficult and heated issues, socially, legally, economically, and politically. A sense of the irony in the term "development," the widespread expectation that the shoreline will for some reason stand still after it's been built on, the rude awakening for developers, houseowners, and commercial builders when they discover the shoreline is not static—all are part of a shoreline "consciousness-raising" that has been making painful headway.

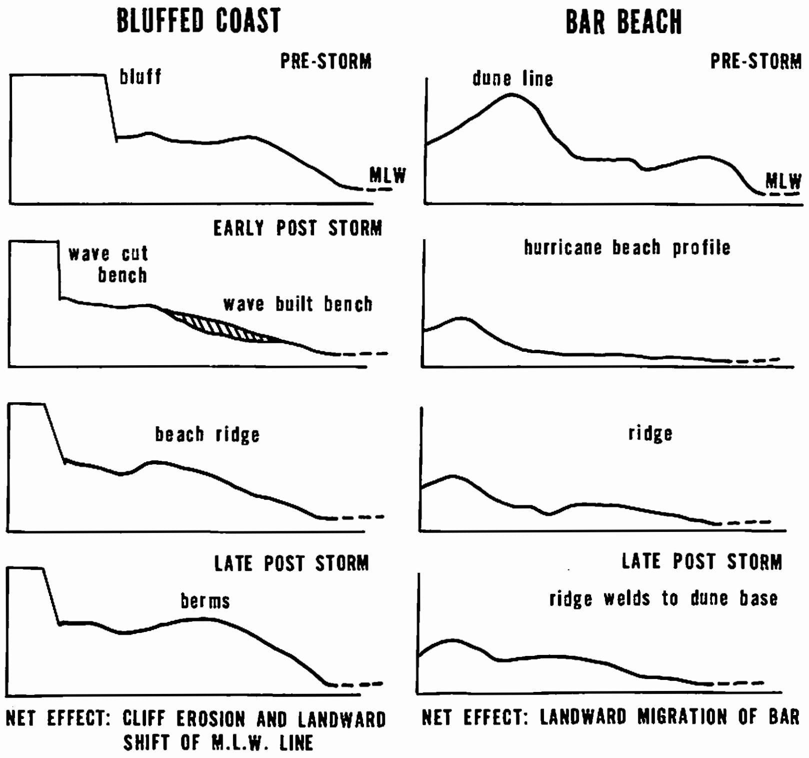

FIGURE 3.5 *Beach Profile Changes From Hurricane Occurrence*
The berm is the nearly horizontal part of the back beach formed by wave deposits.

The US Army Engineer Division has designated 121 miles, or 28 percent, of the Sound shoreline subject to critical erosion[50] (see Table 5.1 in Chapter 5). Most of the critically eroding shores—96 miles out of the 121—are along the north shore of Long Island. The Connecticut shoreline as a whole isn't eroding as fast as the shore across the Sound, although lack of shoreline stability at important recreational beaches has caused management problems; rock outcrops along the shores act as natural erosion barriers. Exposed areas in Connecticut are eroding at a probable rate of one foot a year.[51] (Such estimates of net shoreline erosion or accretion rates come from comparing the same shoreline position on earlier and recent nautical charts or aerial photographs.[52]) The north shore of Nassau County is eroding at rates averaging about half a foot to a foot a year.[53] Suffolk County's north shore is eroding faster, at an average rate of one to two feet a year; small stretches of shore, usually located at bars or spits, gain ground by accretion. Estimates of bluff erosion rates at various locations along the north shore range from 0.8 to 5.2 feet a year, depending on the period of record studied.[54]

Nevertheless, people continue to build along the shore and atop the bluffs. According to the Corps, structures and nourishment are justified in the 121 miles of critically eroding Sound shoreline because of the rate of erosion and the character of building development there. The estimated first cost for shore protection in the critical areas is about $138 million (1971 dollars).[55] This estimate does not include the price of annual beach nourishment. A more economical beach management scheme could perhaps designate certain shoreline areas as eligible for shore protection practices, while other areas, because of their high erosion rates, would be designated ineligible.

Figure 3.6 shows a plot of erosion/accretion rates versus shoreline distance for selected locations on the north shore of Suffolk County. A detailed version of such a plot for a particular stretch of coast can help pinpoint the best locations for attempts to build up or maintain a beach by groins or beach nourishment. The troughs in Figure 3.6 indicate areas where shore protection measures would necessarily be most extensive—hence, most expensive.

The practice of constructing jetties, groins, seawalls and nourishing beaches with fill is being given a hard look these days in terms of cost/benefit. These methods are extremely expensive, and usually effective only in their immediate vicinity. Table 3.5 sets out Corps of Engineers cost estimates, in 1971 dollars, for standard construction and nourishment.

These costs have been paid by private individuals, corporations, beach associations, local municipalities, the state governments of New York and Connecticut, and the federal government. Maximum federal financial assistance for shore

Bluff erosion at Sound Beach, New York. Local residents have attempted to stabilize the 130-foot bluffs by bulkheading and debris dumping. For scale, note the person down on the beach, standing to the right of the bulkhead.

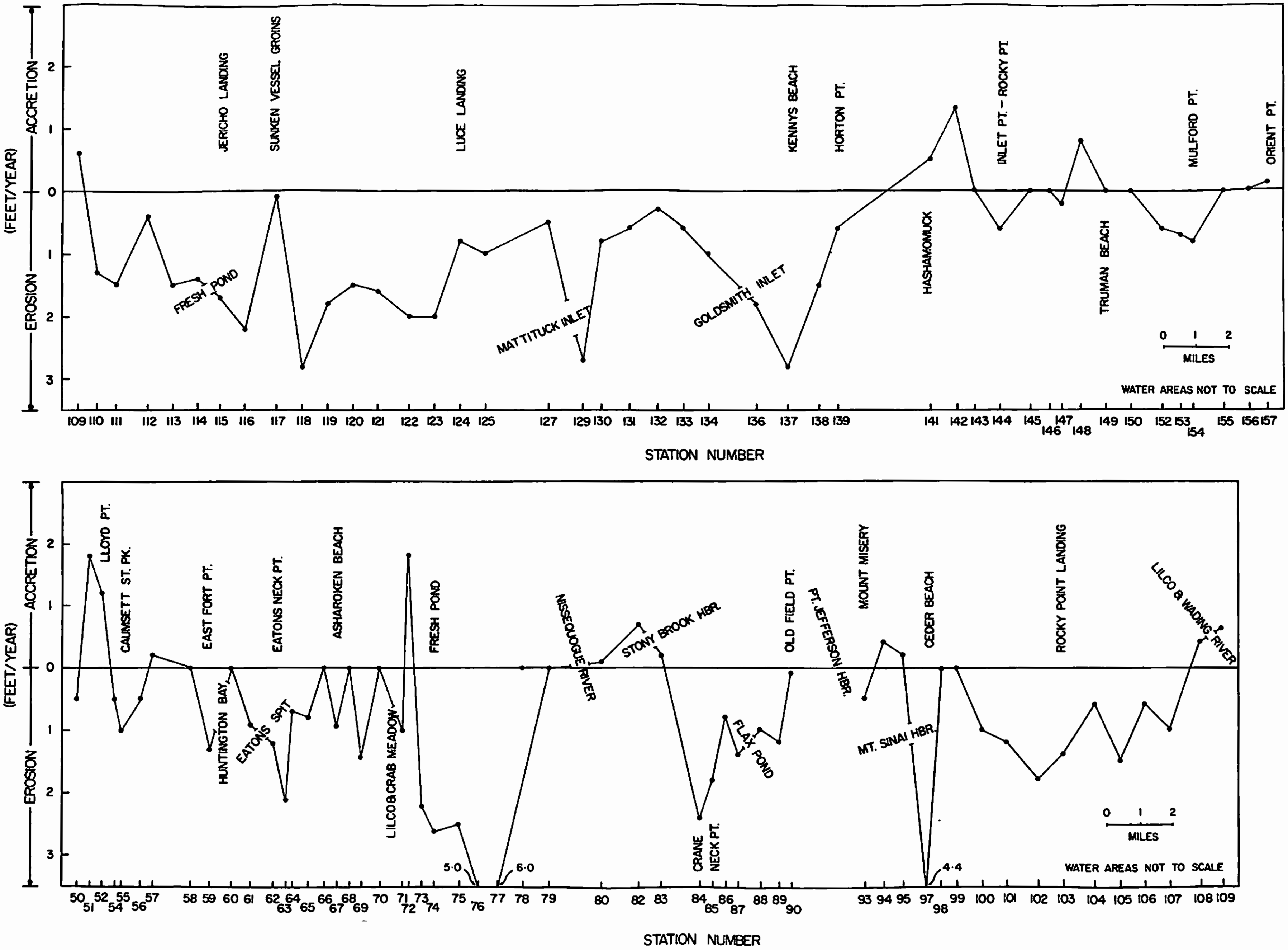

FIGURE 3.6 *Erosion and Accretion Rates at Selected Locations Along Long Island's North Shore*

Peaks on this plot indicate areas which are accreting; troughs on the plot indicate zones of erosion.

Source: Davies, Axelrod, and O'Connor, 1973, Figure 3-31.

TABLE 3.5 *Price Estimates for Shore Protection Structures*

Structure	*Cost per foot of shore protected (1971 dollars)*
Bulkheads	\$ 75 to \$400[a]
Revetments	\$ 75 to \$400[a]
Seawalls	\$200 to \$500[a]
Breakwaters	\$200 to \$500[a]
Groins	\$100 to \$350[a]
Beach Nourishment	\$ 50 to \$300[b]
Periodic Nourishment	\$ 5 to \$ 15[c]

Source: US Army Corps of Engineers, *Shore Protection Guidelines* (Washington, D.C.), 1971), 58 p.

[a] Cost depends on degree of wave exposure, total length and proximity to sources of building materials.

[b] Cost depends on wave exposure, total volume of fill required and proximity to sources of fill.

[c] For beaches at least 2,000 feet long.

protection projects on public land is 70 percent of the construction cost, with the remaining 30 percent assumed by state and local governments. To be eligible, the public beaches must have appropriate facilities to encourage full public use and access. If a shore is privately owned, and there is no public use of the land or benefit in its protection, federal funds cannot be authorized.[56]

The State of New York assists shore protection construction by funding up to 70 percent of the local share for authorized federal projects, and up to 70 percent for state projects built at the request of local government, which must contribute the remaining 30 percent. Nearly all the north shore's major erosion control structures have been built with state funds. Jetties at Port Jefferson Harbor and Mattituck Inlet were part of navigation projects authorized by the federal government, and jetties at the intake canals of Long Island Lighting Company (LILCO) plants at Northport and Shoreham were paid for by LILCO.

The State of Connecticut has been very active in coastal protection. On authorized federal projects, the state contributes 50 percent of the local costs, and on nonfederal projects involving publicly owned land, the state contributes up to 67 percent of the total project cost. Several Connecticut beaches have been restored or expanded. Eighteen different projects involving federal participation were undertaken between 1956 and 1960 at a total cost of \$3.2 million.[57] The federal government in this case assumed one-third the cost; the local or state government provided the other two-thirds. A total of approximately 21 kilometers (13.1 miles) of beach was affected. The largest beach restoration project involved 3 groins, about 3 kilometers (10,000 feet) of beach, and cost \$489,500. Final project costs were about \$150 per meter (\$50 per foot). The most expensive project cost \$390 per meter (\$118 per foot); the least expensive cost \$69 per meter (\$21 per foot).

A monitoring study of one of these restored beaches showed that within three years, all the fill had washed away. Burial Hill Beach, near Westport, Connecticut, restored in 1957 and studied[58] from 1957 to 1960, underwent severe erosion while a nearby natural beach accreted. The beach profile constructed during the project eroded to a profile in equilibrium with the wave regime. This suggests that, rather than just being dumped and bulldozed, the sand should be contoured in the shape of the original profile, and stockpiled on the updrift area of the beach. Littoral transport would distribute the stockpiled sand along the beach.

Despite the expense, shore protection structures have repeatedly been built without adequate knowledge of littoral processes. Unwanted erosion or accretion inevitably results. For example, in 1964 the State of New York built a 310-foot jetty at Goldsmith Inlet in the Town of Southold on Suffolk County's north shore (Fig. 3.7). While the beach to the west of the jetty built up, the beach to the east eroded seriously from the jetty's interference in littoral transport patterns.

Only one beach restoration project has been federally authorized on Long Island's north shore. In October 1972, Congress authorized an improvement project at Sunken Meadow State Park and at neighboring Callahan's Beach. No work on the project has begun.[59] The state periodically nourishes the beaches at Sunken Meadow State Park with clean dredge spoil taken from the mouth of the Nissequogue River.

The Corps of Engineers, New York District, had for several years been studying the feasibility of a small beach restoration project between Matinicock Point and Peacock Point in the City of Glen Cove. Even though Glen Cove citizens requested the study, those at a public meeting on 11 January 1973 were reluctant to give the Corps assurances of local cost cooperation because private beaches benefitting from the project would have to be open for general public use. If private sectors were eliminated from the project, the Corps saw a decrease of recreational benefits and an unfavorable benefit/cost ratio. If the City of Glen Cove voted for beaches open only to city residents, the Corps could not recommend federal funding. The City of Glen Cove has now withdrawn its request for consideration of the project.

We have been considering erosion rates and the costs of modifying that erosion, sometimes futilely, for the sake of the "human configuration" that exists and continues to grow along the shores of the Sound—the buildings, roads, utilities, recreation spots, harbors, and navigation channels. When you add the costs of damage—structural damage, loss of shorefront property, loss of business—from storm wave attack and shore recession, the total costs are very high. Estimates of erosion costs from land loss, repair and maintenance of shore protection devices, and shore cleanup in the Sound area are $4.4 million annually for New York and $1.6 million for Connecticut (Table 3.6). If the hurricanes of 1938 and 1954 were to recur—storms that swept the beaches clean of all human development—this tidal flood of record would cause an estimated $170 million damages (1970 dollars) on the south shores of Nassau and Suffolk

TABLE 3.6 *Annual Shoreline Damages, Long Island Sound Region*

Location	*Land Loss (acres)*	*Monetary Damages (1970 dollars)*
New York North Shore of Long Island and Throgs Neck to Westchester/Connecticut line	42	$4,448,000
Connecticut including Fishers Island	12	$1,552,000
TOTAL	54	$6,000,000

Source: Long Island Sound Study, *Erosion and Sedimentation, An Interim Report* (New Haven: Long Island Sound Regional Study, New England River Basins Commission, November 1973), p. 5.

Note: Since the 54-acre total annual land loss attributed to erosion is spread out over the entire shoreline of the Sound, a monetary value cannot accurately be assigned to the land lost.

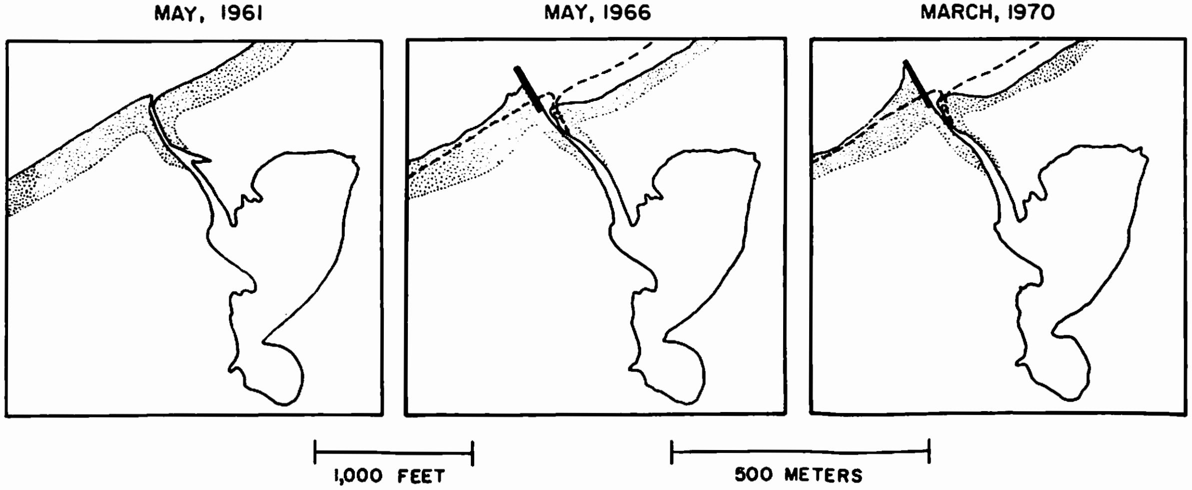

FIGURE 3.7 *Shoreline Changes from Jetty Construction at Goldsmith Inlet*

The shoreline of Goldsmith Inlet, Southold Township, Suffolk County, is shown (left) three years before jetty construction, (center) two years after construction, and (right) six years after construction. Dashed line indicates May 1961 shoreline. Stippled area indicates beach zone. Source: Davies, Axelrod, and O'Connor, 1973, Figure 3-37.

Counties, and $2 million in damages on the north shore and between the eastern forks.[60] Damages for the shore of Connecticut would reach $60 million.[61] Looking back at Figure 3.4, we see that the tides produced by those same two storms did not reach the height of the standard project tide. Within the standard project flood plain mapped for Long Island's north shore, a total of 713 structures were found in 1970.[62] Moreover, flood plains are based on still water elevations; storm damage can occur at elevations 5 to 25 feet above still water because of wave action.[63] Consider, too, the long clusters of cottages and motels on some of the barrier bars in the Sound, many of which are less than 10 feet above mean high water. If so much destruction was wreaked by two storms whose surges were well below the standard project tide, the destruction to be expected from a 100-year storm or a standard project hurricane is very grave, indeed.

The potential shoreline damage from major storms has been increased in recent years by the loss of wetlands through dredging, filling, and waste disposal. Table 3.7 gives estimates of wetland loss—51 percent in Connecticut, 29 percent in Long Island. Wetlands protect adjacent bluffs and upland areas from erosion by absorbing wave energy, stabilizing banks, and serving as storage areas for tidal flood waters. Both the breadth of the marsh and the thick growth of grasses tend to subdue wave action. Structural damages from the 1938 and 1944 hurricanes were severe in areas built on former wetlands. Developments situated behind marshes were less affected.[64]

Several research projects currently under way are studying planting different marsh grasses to stabilize dredge spoil and create wildlife habitats. The US Army Corps of Engineers has designed a comprehensive five-year study on using dredge spoil for controlling marsh erosion and subsidence by distribution of spoil on marshes, and creating new wetlands and spoil island wildlife habitats.[65] Research on the propagation, reproduction, growth rates, and effects of substrate type and elevation on the establishment of *Spartina alterniflora* has also been completed.[66] A private, nonprofit group has restored wetlands in Greenwich, Conn., and has actually created a wetland in Centerport Harbor, N.Y. The Nature Conservancy

TABLE 3.7 *Estimates of Wetland Acreage Remaining in New York and Connecticut*

Location	*1914*	*1954*	*1959*	*1964*	*1968*	*1971*	*Percent Loss, maximum period of record*
Connecticut	23,360[b]	14,744[c]		12,600[b]	11,544[c]		51%
New York		45,395[c]			32,395[c]		29%
Long Island[a]		43,215[d]	37,504[d]	30,508[d]			29%
Nassau County		14,130[d]	11,911[d]	9,495[d]		9,538[e,f]	32%
Suffolk County		20,590[d]	19,208[d]	17,008[d]		12,725[e]	38%

[a] includes Bronx, Kings, Queens, Nassau, and Suffolk Counties.

[b] US, Congress, Senate, Subcommittee on Executive Reorganization and Government Research, *Hearings, Preserving the Future of Long Island Sound,* 91st Cong., 2nd Sess., 1970, p. 144.

[c] George P. Spinner, *A Plan for the Marine Resources of the Atlantic Coastal Zone* (New York: American Geographical Society, 1969), pp. 4-6.

[d] F.A. Smith *et al., Fourteen Selected Marine Resource Problems of Long Island, New York: Descriptive Evaluations* (Hartford: The Travelers Research Corporation, 1970), p. 37.

[e] Joel S. O'Connor and Orville W. Terry, *The Marine Wetlands of Nassau and Suffolk Counties, New York* (Hauppauge, New York: Nassau-Suffolk Regional Planning Board, 1972), p. 6 (corrections added).

[f] discrepancy of 1964 and 1971 figures due to different measurement methods.

is researching the establishment of marshes along sections of eroding shore in Chesapeake Bay. Such experimental marshes may become substitutes for bulkheads as a means of protecting the shore. The results of one study show that marsh stabilization of the shore costs about $13 per linear foot, as opposed to $40 per linear foot for stabilization by riprap or wooden bulkheading,[67] and the even higher costs shown in Table 3.5. Other kinds of vegetation, as well as a terracing technique, have been used to stabilize bluffs along Suffolk County's north shore.[68]

MANAGING THE SHORELINE

The Regional Marine Resources Council, a committee of the Nassau-Suffolk Regional Planning Board, has assessed existing knowledge on coast stabilization and protection, and has formulated research requirements to fill knowledge gaps.[69] The knowledge base was considered *good* for the design of beach protection structures, *fair* for the development of offshore sand mining, and *fair* for understanding the movement of littoral materials. Research requirements applicable to the north shore of Long Island include the following:

- Develop the required technology for economical transfer of sand from deep water to the shore, since shallow-water dredging is prohibited by ecological disturbance and interference in shoreline equilibrium.
- Inventory particular locations on the continental shelf south of Long Island thought to have rich sand and gravel deposits.
- If offshore sand deposits are mined for beach nourishment, study beaches in the vicinity of the mining to watch for abnormal erosion.
- Continue research on innovative design of fixed shore protection structures. Using artificial seaweed, flexible groins, and floating breakwaters, and planting terraces and spoil areas require further investigation.
- Examine the use of wetland fringes to stabilize the landward edge of barrier islands and baymouth bars; study efforts to create new wetlands.
- Analyze littoral transport along the shores of Long Island to determine volumes and sources of the sand, and net flow directions.
- Make model studies of inlets and harbor entrances, and design better systems to transfer sand around them.
- Develop a contingency plan for a catastrophic storm such as Long Island experiences once in every 30 to 40 years, on the average. Planning departments of Nassau and Suffolk Counties would outline emergency procedures to protect life and property, and recommend public condemnation and purchase of certain properties for future public use and for conservation.
- Study the legal, economic, and political aspects of an overall erosion control program—the human dimension of erosion control.

The need for expensive and often ineffective shore protection measures can be reduced by planning and by land-use controls designed to limit potential damages caused by severe storms and normal shoreline regression. Such controls include the following:[70]

- *Floodplain zoning* and land-use management concepts should regulate development of any area that falls within the 100-year-storm floodplain. Only recreation-related structures should be built in the floodplain zone, and should be located behind set-back lines established with an eye to short-term shoreline changes.
- *Bluff hazard zoning* should be implemented in shoreline areas backed by eroding bluffs. Construction of dwellings should be prohibited within 100 feet of the top edge of the bluff.
- *Vegetation* on dunes, bluff faces, and bluff tops should not be destroyed in the process of development.
- *Limited construction of erosion control structures:* only those should be permitted that are backed by knowledge of local littoral processes sufficient to assure that the structure will not increase erosion rates of adjacent property.

These controls will have to be preceded by extensive surveys delineating flood plains on maps scaled to suit use by local planning boards. They'll also require the education and cooperation of village, town, county, and city governments to adopt and put into effect the necessary zoning and building code amendments. Only when the shoreline is treated as a whole, rather than as a series of segments determined by municipal boundaries, will effective shoreline management become a reality.

SUMMARY

Worldwide sea level rise has been a major factor in shaping the shores of Long Island Sound since the retreat of continental ice sheets approximately 10,000 years ago. The present-day Connecticut shore of the Sound is characterized by small pocket beaches separated by bedrock outcrops and by river-dominated areas. The western half of Long Island's north shore is indented by a series of harbors and bays; high bluffs and narrow beaches dominate the eastern portion.

Waves, winds, and tides mold Long Island Sound's beach sediments—silts, sands, gravels, and larger fragments—into constantly changing configurations. Changes in beach size and shape are most apparent after a northeaster or a hurricane. Such storms cause moderate damage to the Sound about once every two years; catastrophic storms occur, on the average, three times a century. Shoreline erosion and damage are directly tied to the surge, or the increase in water level, produced by a storm. Storm tides of more than 14 feet above mean sea level have occurred in portions of Long Island Sound. The tides and waves of a severe storm can alter the shore in a few hours as much as normal conditions do in a hundred years. Long-term recession of the shoreline—including dune and bluff recession and barrier bar migration—is mainly the result of severe storms, and thus occurs intermittently.

Shoreline recession rates of up to 2 feet per year have damaged waterfront development. Structural solutions to this problem—groins, bulkheads, beach nourishment—have been hampered because of high construction costs, agency requirements, and experience which indicates that such structures may not perform up to expectations. More research on nearshore circulation and sediment movement in the Sound is needed. Potential damages can be reduced and the public can benefit at the same time if land-use management controls are adopted by local municipalities; we would be adjusting to, rather than fighting against, the Sound's littoral forces.

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4 The Water

INTRODUCTION

This chapter deals with the water of Long Island Sound. We describe how the water is moved by the tides and how its salt content is controlled by exchange with the ocean and by freshwater discharge from the adjacent land. We examine the seasonal change in water temperature, and how heat exchange with the atmosphere alters the vertical density structure of the water, which in turn affects vertical mixing. We describe the distribution of inorganic nutrients, the fertilizers of the sea that control the growth of plant life, and we describe the distribution of dissolved oxygen, essential to animal life.

Long Island Sound is an unusual body of seawater: it has *two* connections with the Atlantic Ocean, an eastern and a western end. In the east the Sound mingles with the fairly unpolluted waters of Block Island Sound. In the west, the Sound communicates with New York Bight through the highly polluted waters of the East River and New York Harbor. Another determinative factor is the significant quantity of non-saline water added to the Sound by the rivers of Connecticut. The temperature of the Sound's water is controlled primarily by heat exchange across the air-water interface. The other water properties—salinity, the concentrations of dissolved oxygen and of the nutrient elements phosphorus and nitrogen—depend primarily on the lateral interconnections in the east and west and on river discharge.

Water motion in the Sound is dominated by the twice-daily lunar tide. The tide in the Sound approximates a standing wave, that is, the tide rises and falls almost simultaneously throughout the Sound. Tidal range (the difference in elevation between high and low water) increases on the average from a small range of 0.7 meters (2.5 feet) in the east to a large range of 2.2 meters (7.3 feet) near the western end of the Sound.

Associated with the rise and fall of the tide are horizontal water movements, tidal currents. These currents are much stronger than the non-tidal currents generated by wind or by inflows of fresh or saline water. In the east, most of the tidal current flows through the Race. In the west, the flow through the East River results from the different tidal regimes of the Sound and New York Harbor. In contrast to the standing-wave type of tide in the Sound, the tide in New York Harbor and the Hudson River is a progressive wave. The tide progresses from the harbor entrance northward into the Hudson River at roughly constant tidal range. Since the East River connects these two different tidal regimes, its tidal flow is determined by the simultaneous difference in elevation between its two ends at Throgs Neck and the Battery. The East River is significantly constricted in depth and width at Hell Gate, giving rise to strong, turbulent tidal currents at that location.

The water in the Sound is subject to a large annual temperature variation, from sea ice conditions in later winter to temperatures in excess of 20°C (68°F) in summer. This corresponds to oceanic conditions ranging from arctic to subtropical. The annual water temperature cycle has a slightly smaller amplitude than the cycle of mean air temperatures and lags behind the air temperature cycle by about one month.

There is abundant precipitation in the area of Long Island Sound. The average annual precipitation amounts to about 110 cm (43 inches) and is distributed fairly evenly through the year. Significant variations in rainfall and temperature occur from year to year. The mean annual temperature has increased by about 1°C (1.8°F) during the first half of the 20th century.

The salinity (salt content) of the Sound is less than that of the ocean, and it decreases markedly as one proceeds from east to west. Whereas average ocean water has a salinity of about $34.5^0/_{00}$ (parts per thousand), the salinity of the

Sound ranges from about $30^{0}/_{00}$ in the east to $20^{0}/_{00}$ by New York City. There are regions of low salinity along the Connecticut shore, where rivers enter the Sound. The average salinity of the Sound varies somewhat with the seasonal and yearly variation of freshwater discharge of the rivers into the Sound.

The density of seawater varies with temperature and salinity: it decreases as temperature increases and it decreases as salinity decreases. Thus the east-to-west salinity decrease in the Sound is associated with a density decrease in that direction, and the seasonal temperature cycle brings an annual variation of density. During the period of surface cooling, from late summer to early winter, there is little vertical density variation: the water is well mixed vertically. During the period of surface warming, from late winter through mid-summer, the surface water, primarily because of its higher temperature, is less dense than the bottom water and stays on top, producing vertical density stratification.

Such stratification inhibits vertical mixing in the water column and results in reduced dissolved oxygen in the bottom water, particularly during the summer when oxygen is less soluble in water anyway because of its higher temperature and when biological uptake of oxygen is more rapid than in winter. Dissolved oxygen is essential to animal respiration; the concentration of dissolved oxygen is therefore a prime indicator of water quality. Water quality standards adopted by the Interstate Sanitation Commission include these minimum oxygen levels:

Class A: dissolved oxygen 5.0 parts per million (ppm)
Waters suitable for primary-contact recreation [e.g., swimming], shellfish culture, and development of fish life.

Class B-1: dissolved oxygen 4.0 ppm
Suitable for fishing and secondary-contact recreation [e.g., boating].

Class B-2: dissolved oxygen 3.0 ppm
Suitable for fish survival, passage of anadramous fish [breeding in fresh water], and for . . . navigation.

Problems of adequate water quality arise primarily in the western end of the Sound and during the summer. For example, on August 9, 1970, in the western end of the Sound, the dissolved oxygen concentration at depth was less than 2 ppm. The surface water, by contrast, was highly supersaturated with oxygen (up to 14 ppm), due to an intense bloom of unicellular marine plants. The bloom of marine algae is due to vertical stratification and a high concentration of inorganic nutrients derived from effluents of sewage treatment plants in the East River.

Unfortunately, people's urge to use the recreational opportunities provided by Long Island Sound is negatively correlated to water quality. Hot, calm weather during the summer, which brings people out to the beaches for relief, also generates intense water stratification, algal blooms, and oxygen depletion in the deeper water, which may lead to fish kills. Further, population pressure on the recreational resources is greatest in the west, where water quality is most degraded. In contrast, water quality is good during winter, particularly in the east, when recreational utilization is at a minimum. Thus the physical, biological, geographical, and seasonal factors converge in a significant conflict between expectation

TABLE 4.1 *Harmonic Tidal Components for Long Island Sound*

Component	*Symbol*	*Period hours*	*Coefficient*	*West: Willets Point*		*East: New London*	
				amplitude (ft)	*ratio**	*amplitude (ft)*	*ratio**
SEMIDIURNAL							
Solar	S_2	12.00	.2120	0.64	3.02	0.214	1.01
Lunar	M_2	12.42	.4543	3.65	8.03	1.14	2.50
Lunar elliptic	N_2	12.66	.0880	0.74	8.41	0.27	3.02
DIURNAL							
Lunisolar	K_1	23.93	.2655	0.34	1.28	0.23	0.85
Lunar	O_1	25.82	.1886	0.20	1.09	0.18	0.96

Source: LeLacheur and Sammons (1932).
*Ratio = amplitude/coefficient.

and reality. The urbanization of Long Island Sound strongly affects its water quality. We shall see in Chapter 5 how water quality reciprocates the impact by affecting further urbanization.

TIDES AND TIDAL CURRENTS

The U.S. Coast and Geodetic Survey has made extensive studies of the tides and tidal currents. Special Publication 174 (LeLacheur and Sammons, 1932) summarizes the findings on Long Island and Block Island Sounds. Information on the tidal exchange between western Long Island Sound and New York Harbor can be found in Special Publication 111 (Marmer, 1935, revised). The Coast and Geodetic Survey also publishes a Tidal Current Chart for Long Island and Block Island Sounds (serial No. 574) and a Tidal Current Chart for New York Harbor.

These studies show that the tidal frequency that dominates the circulation of Long Island Sound is the semidiurnal lunar tide. The tides are generated by the gravitational interaction between the earth, sun, and moon. As a result, tidal motions can be separated into a number of components having periods that correspond to characteristics of the apparent rotation of the sun and moon around the earth. The dominant components are given in Table 4.1, together with coefficients representing the strength of the tide-generating forces, and the response of the tidal amplitudes in Long Island Sound to the particular force components. The ratio of the response in tidal amplitude to the coefficient of the tide-generating force is greatest for the period of 12.66 hours, suggesting that Long Island Sound has a resonance near that period. As a result, the lunar semi-diurnal period of 12.42 hours tends to dominate the tidal motion. Swanson (1971) calculated the resonant period from the geometry of the Sound and obtained a period of 9.77 hours.

The tidal oscillation in the Sound is approximately one-quarter of a standing wave, with the node near the Race and the antinode near the western end of the Sound. The spatial variation of the mean tidal range (Fig. 4.1) increases from about 73 cm (2.4 ft) at the Race to a maximum of 225 cm (7.3 ft) near 73°35′ W and then decreases slightly to 220 cm (7.2 ft) at Throgs Neck.

If the tide were a true standing wave, high and low water should occur simultaneously throughout the Sound. In the central and western portions of the Sound, the tide is close to synchronous (Fig. 4.2); in the eastern portion, however, the tide is a westerly progressive wave.

Given the amplitude and time relationship of the variation in tidal height, it is possible to calculate the mean east-west tidal water motion through any north-south line (meridian) in the Sound. The calculations are given in detail in Appendix A and summarized in Figure 4.3.

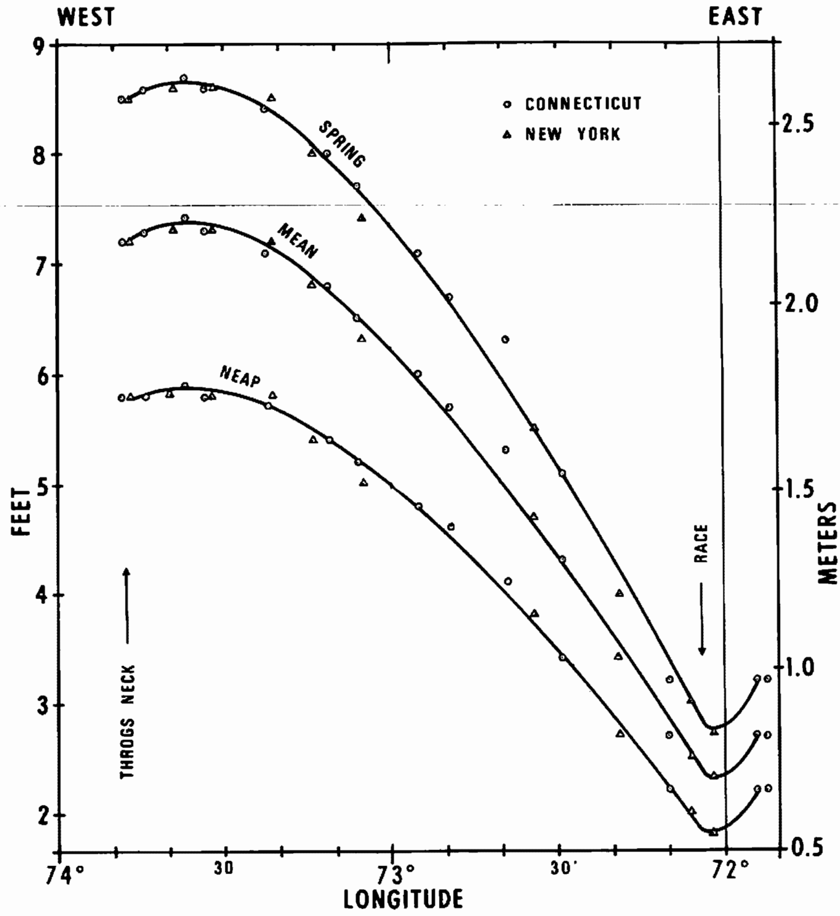

FIGURE 4.1 *Tidal Range*

Measurements of the tidal transport through Plum Gut and Fishers Island are used to obtain tidal transport through the Race by difference. The amplitude of the total mean transport through the eastern passes amounts to about 385,000 m^3/sec. To obtain the total transport during one-half a tidal cycle—the amount of water moving into the Sound during an average flood or moving out during an average ebb—the amplitude of the transport must be multiplied by 14,200 sec. During an average tide, about 5.5 km^3 or about nine percent of the volume of the Sound (62 km^3) is exchanged. During a spring tide, this increases to 6.5 km^3; during a neap tide it declines to 4.4 km^3.

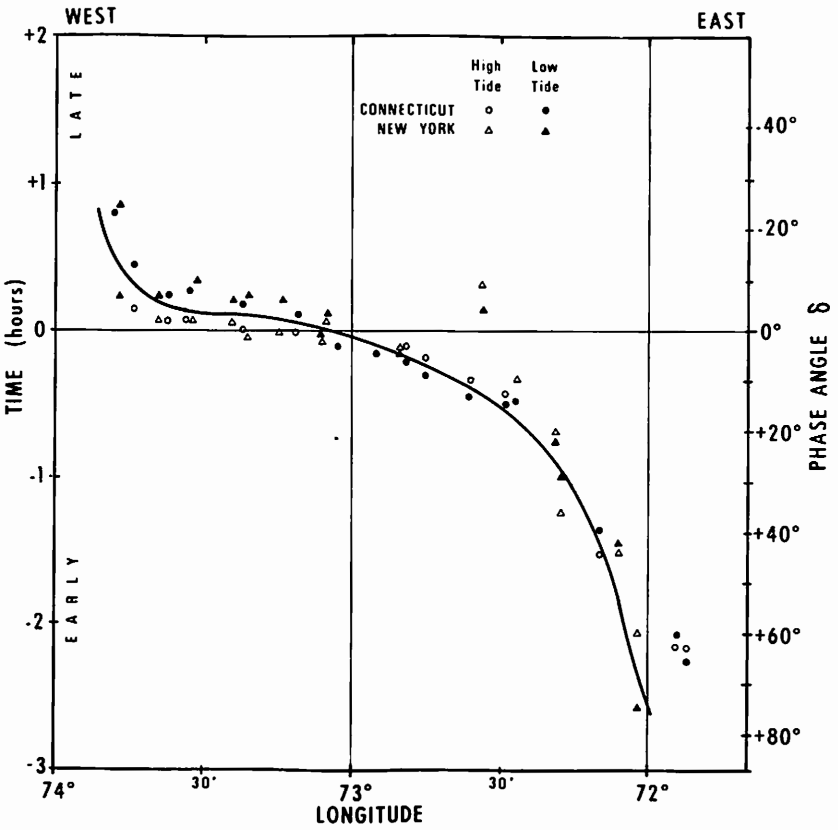

FIGURE 4.2 *Phase of the Tide*

Data from LeLacheur and Sammons (1932). Times of high and low water relative to Bridgeport (about midway in the Sound). If the tide were a true standing wave, the line of high tide-low tide data would coincide with the horizontal line at 0 hour. That the tide progresses somewhat is especially evident in the dip of the line at the eastern end. With few exceptions, the times at a given longitude are almost the same for the Connecticut and the New York shores.

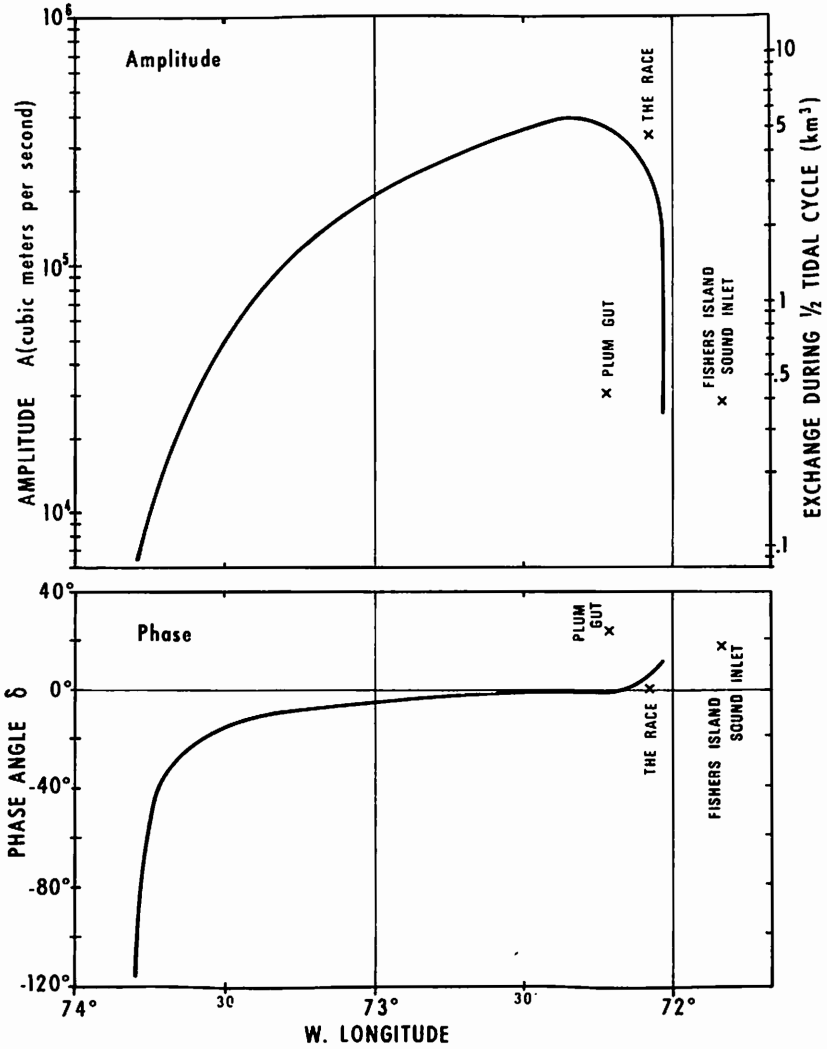

FIGURE 4.3 *East-West Component of Mean Tidal Transport*

Amplitude and phase of the mean tidal transport shown as a function of longitude.

TEMPERATURE AND PRECIPITATION

The climate in the Long Island Sound region is temperate, with a wide annual temperature range and ample precipitation distributed fairly uniformly throughout the year. Table 4.2 shows climatic averages for New York City, New Haven, and Block Island, taken from world weather records. New York City's somewhat higher mean temperature is due to the urban effect; Block Island's annual temperature range is reduced by its maritime location.

Mean monthly temperature averages for the same three locations are shown in Figure 4.4.

A daily cycle with a range of about 8°C (14°F) is added to the monthly temperature cycles. As weather fronts move through the area, the temperature may be displaced as much as 10°C (18°F) above or below the climatological value.

In addition to short-term and annual variations, there are long-term climatic changes. Between 1890 and 1950, yearly figures averaged over twenty-year intervals (twenty-year running mean) for the three locations (Fig. 4.5) show a 1°C (1.8°F) temperature rise over the sixty-year period, from 10°C (50°F) in 1895 to about 11°C (52°F) in 1940. Precipitation, however, declined by about nine percent from 1890 to 1915, leveled off, and then started to rise once more in 1925. The year-to-year variations in average temperature and precipitation are very great, so that the long-term trends become apparent only by averaging yearly values over a fairly long interval. Thus the mean annual temperatures varied between 8.7° and 12.5°C (47.7° and 54.5°F), and the annual precipitation ranged from a low of 86 cm to a high of 142 cm per year (34 in to 56 in), during the period from 1881 to 1959. Such rather marked annual variations must be averaged over two decades to reveal the long-term trends of Figure 4.5.

TABLE 4.2 *Annual Temperature and Precipitation Averages around Long Island Sound*

	Average Annual Precipitation		*Average Annual Air Temperature*		*Annual Temperature Range*	
Location	*cm*	*in*	*°C*	*°F*	*°C*	*°F*
New York City	107.6	42.4	12.5	54.5	24.2	43.6
New Haven	116.9	46.0	10.1	50.2	23.5	42.3
Block Island	102.7	40.4	10.4	50.7	21.5	38.7

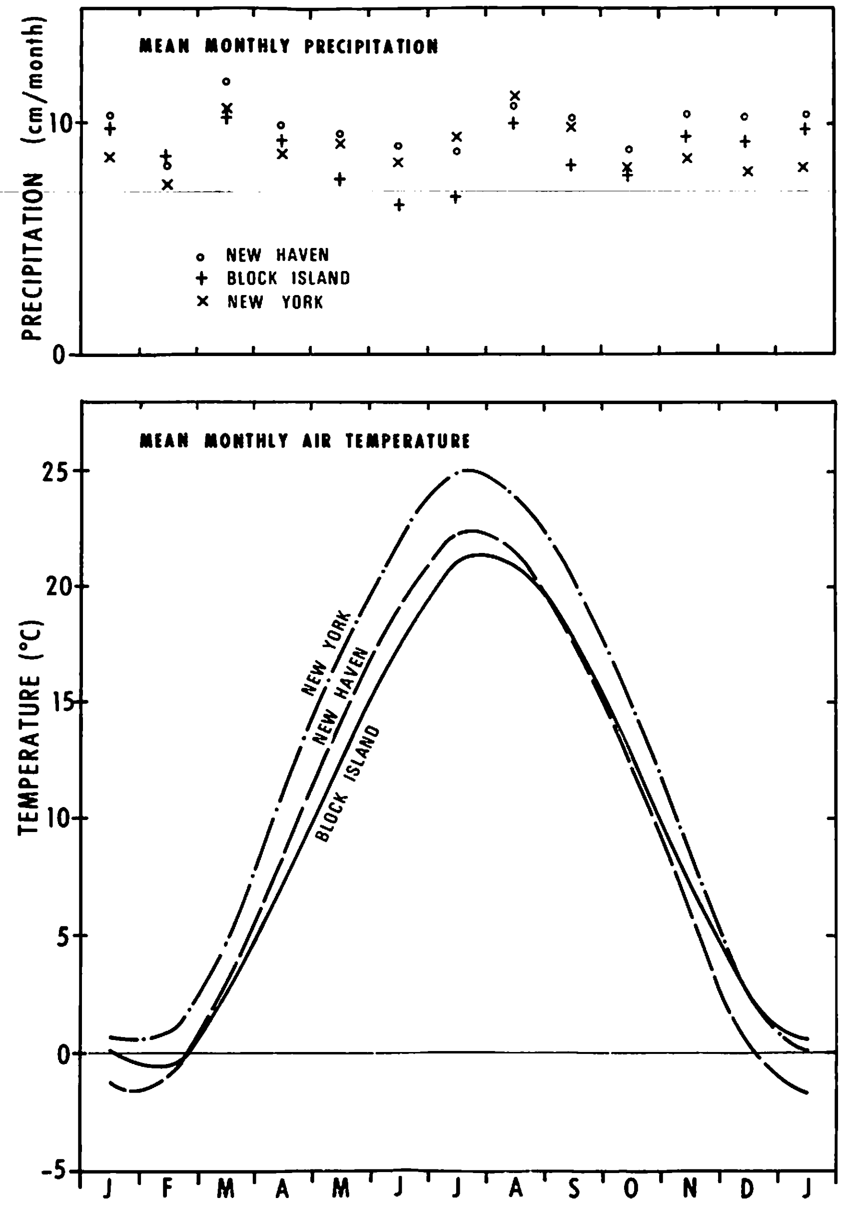

FIGURE 4.4 *Average Monthly Air Temperature and Precipitation*

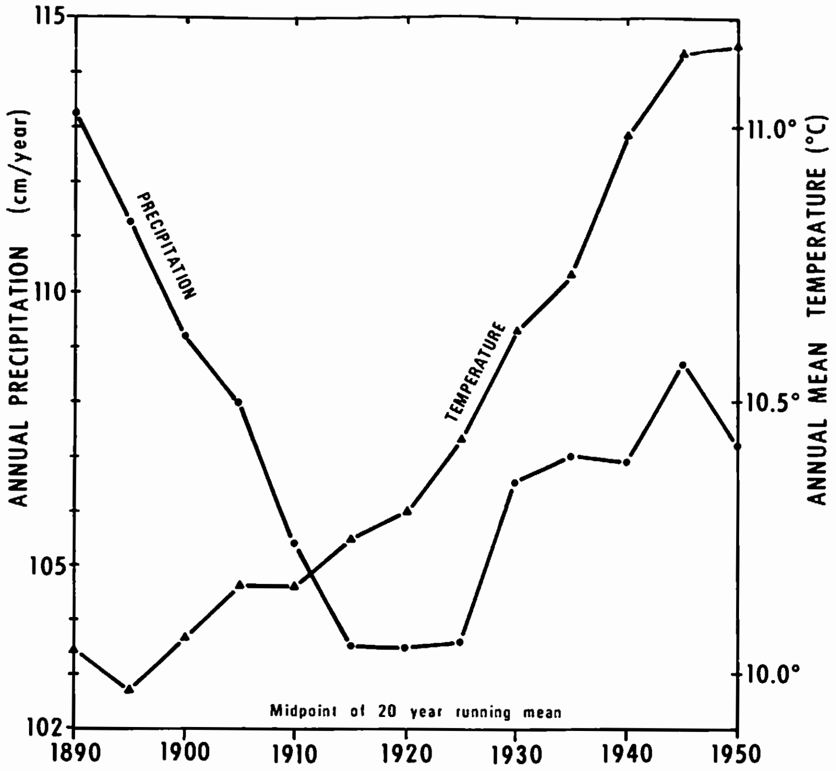

FIGURE 4.5 *Average Annual Temperature and Precipitation, 1890-1950*

Water temperature in Long Island Sound is much more stable than air temperature, which responds to the daily cycle and weather pattern. The main variation in water temperature is in response to the annual cycle (Fig. 4.6). Between March and August when the water is warming, the surface temperature in the central Sound is about 5°C (9°F) warmer than the bottom water. As the water begins to cool in September, the vertical temperature gradient disappears and the water becomes isothermal (constant temperature throughout).

The curve of the surface water temperature is quite similar to the air temperature curve; note, however, that the water temperature cycle lags about one month behind the air temperature cycle.

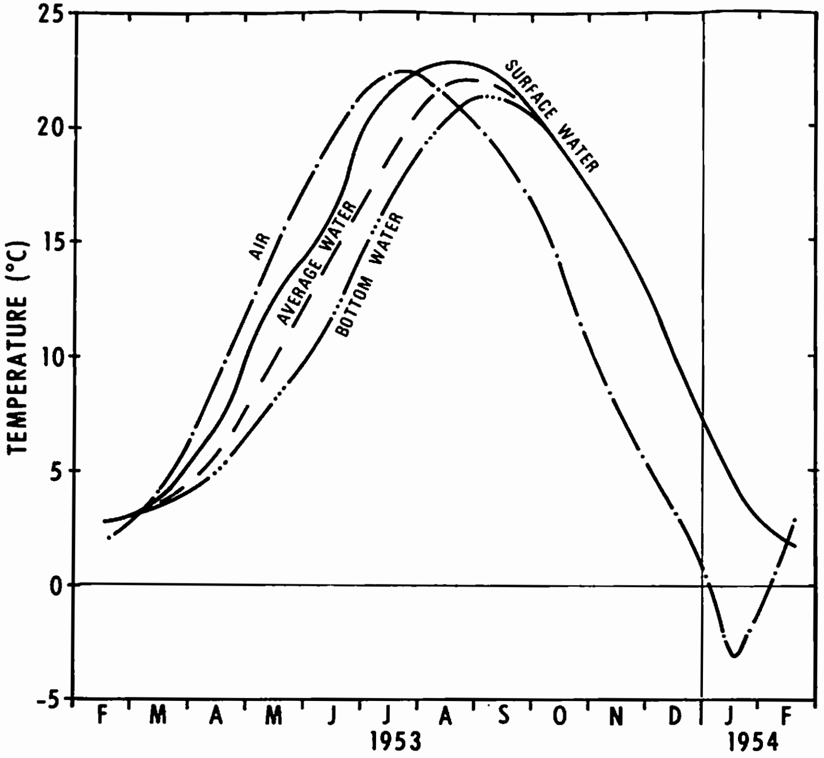

FIGURE 4.6 *Water and Air Temperature, February 1953-February 1954*

Data from Riley (1956, 1959). Water temperatures were taken in the Central Basin of Long Island Sound. Mean monthly air temperatures shown are for New Haven and cover the same period.

To understand that lag, we must take a closer look at the mechanisms that alter water temperature. Working with data from central Long Island Sound, we can ignore the advection of heat by exchange with the East River or Block Island Sound (heat here is not transported in or out by water). The temperature is controlled by the local heat budget (an accounting of heat input and outgo; see Appendix B for a detailed heat budget for the period February 1953-1954). Let us look at the change in mean temperature in a column of water having a cross-sectional area of 1 cm^2 during a period of one month. During this time, the mean temperature changes by an amount we'll call ΔT°C (Δ = difference, change). Since the depth of the water in central Long Island Sound is about 20 meters with a heat capacity of about 1 calorie per cm^3, the change in heat storage in the water is ΔT X 2,000 cal/cm^2. That is, to change the temperature in that water column by 1°C, we'd have to add 2,000 calories.

This change in heat storage results from the difference in *heat absorbed* by the water column and *heat lost* at the air-sea interface. The *heat absorbed* by the water is equal to the incoming solar radiation at the sea surface minus the radiation reflected at the sea surface plus the net infrared radiation radiated by the sea surface. This is known as the radiation balance. *Heat is lost* from the water by sensible heat transfer* from the water to the atmosphere and by the evaporation of water from the sea surface. The heat budget calculations in Appendix B yield an estimate of the amount of water lost from the Sound by evaporation: an annual total of 93 cm of water—about 3 ft over the whole surface of the Sound. Heat storage explains why water temperature peaks about one month after the air temperature, roughly in August and July, respectively.

In shallow water, this heat storage effect is significantly reduced. Surface water there warms up and cools down much more readily than the deep waters. Figure 4.7 shows the difference in surface temperatures for the hypothetical case of no heat storage in shallow water relative to conditions in the deep parts of the Sound. Shallow waters can be expected to fall between this hypothetical situation and the deep-water situation. The shallow-water surface temperature will be warmer between March and August and cooler from September to February than the surface over deeper parts of the Sound.

Figure 4.8 shows surface temperatures as continuously recorded during a cruise on March 19-20, 1972.

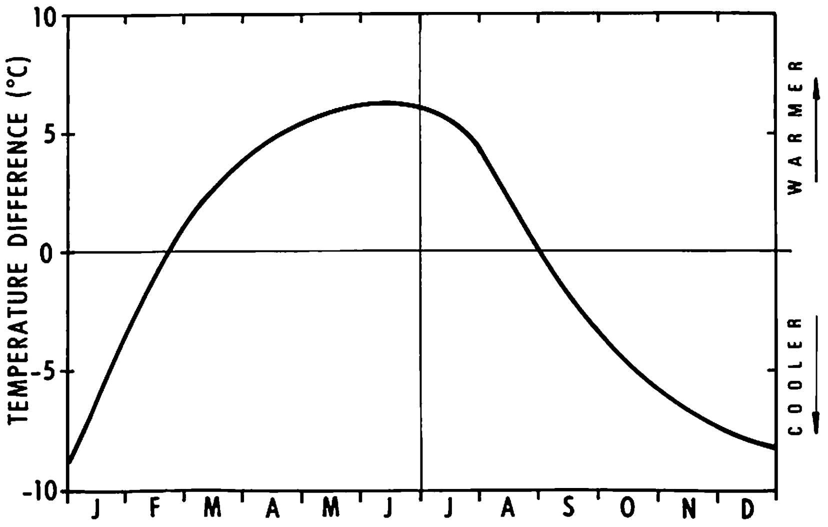

FIGURE 4.7 *Surface Temperature Differences Between Shallow and Deep Water*

Source: Heat budget calculations, Appendix B.

SALINITY

Surface Salinity

A good overall picture of the Sound's salinity pattern is shown in Figure 4.9, with data from Cruise 7202* on March 19-20, 1972. The salinity decreases from $30^{0}/_{00}$ at the Race to less than $20^{0}/_{00}$ in the East River. The longitudinal (east-west) salinity change is slight in the central part of the Sound and great near the two ends. Going west from the Race, the salinity drops by $2^{0}/_{00}$ in the first 15 nautical miles; we then have to move west by an additional 55 nautical miles before the salinity drops $2^{0}/_{00}$ more. In the next 12 nautical miles as we go to Throgs Neck, the salinity drops another $2^{0}/_{00}$. In the East River, the salinity gradient is even steeper, more than $1^{0}/_{00}$ per nautical mile (Fig. 4.10).

Data from other cruises verify this general profile. The salinity at any one point in the Sound, measured at different times, varied by as much as $2^{0}/_{00}$ for cruises from January 1969 to August 1971, but the east-west gradients were always small in the center and steep at either end.

Comparing the Long Island shore with the Connecticut shore (north-south salinity gradient), the surface salinity is lower along the Long Island side from Great Neck to Lloyd Neck—in the western end—than along the Connecticut side. This is due in part to the Coriolis effect caused by the earth's rotation, which makes the ebb current (W-E) stronger on the Long Island side and the flood tide current (E-W) stronger on the Connecticut side. As a result, the low-salinity water derived from the East River contributes more to the southern than to the northern part of the western end of the Sound.

In the central and eastern portions of the Sound, the north-south salinity gradient is reversed due to the freshwater runoff from Connecticut provided by the Housatonic, Connecticut, and Thames rivers. Off the Housatonic and Connecticut rivers, Cruise 7202 encountered plumes of water with salinity less than $20^{0}/_{00}$, and the salinity off the Thames River dropped below $23^{0}/_{00}$ (Fig.

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*Sensible heat transfer warms something; latent heat goes into a phase change, as from liquid to gas—evaporation.

*The Marine Sciences Research Center cruises on R/V *Micmac* have serial numbers; the first two digits designate the year and the last two, the order in sequence.

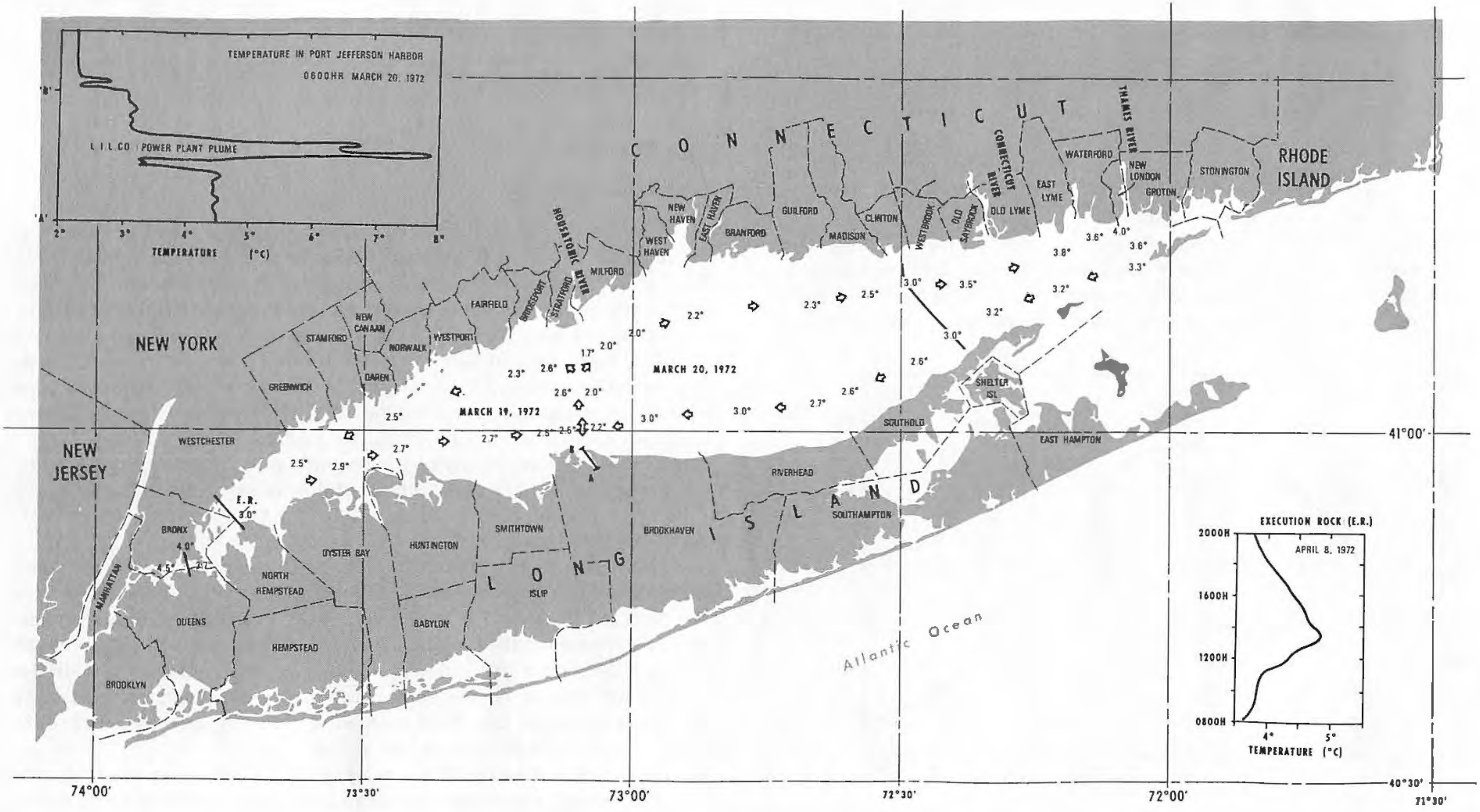

FIGURE 4.8 *Surface Temperatures, March 19-20, 1972*

The record is not truly simultaneous over a broad area (synoptic); it is affected by time-of-day and tidal variations. Thus the morning segments along the Connecticut shore are up to 1 °C colder than during the return trip along the New York shore. For comparison, see the surface temperatures at Execution Rock during a 12-hour period on April 8, 1972, indicating a temperature variation of about 1 °C (*see insert, lower right*). A significant temperature rise is encountered in Port Jefferson Harbor (*see inset, upper left*) due to the thermal effluent from the LILCO generating plant. The temperature also rises significantly in the East River due to the thermal effluents from a large number of steam electric generating plants.

4.9). The edges of the river plumes were at times extremely sharp; at one point salinity dropped practically instantaneously from $28^{0}/_{00}$ to less than $20^{0}/_{00}$. The separation between Sound water and river water was clearly visible because of the turbidity of the river water.

Plume position changes with the tide. On March 20, about two hours before low tide, the plume of the Housatonic extended south and slightly east of the river mouth. On March 19, between one and one and one-half hours after low tide, the plume was found due south of the river, extending about 4 miles to the west.

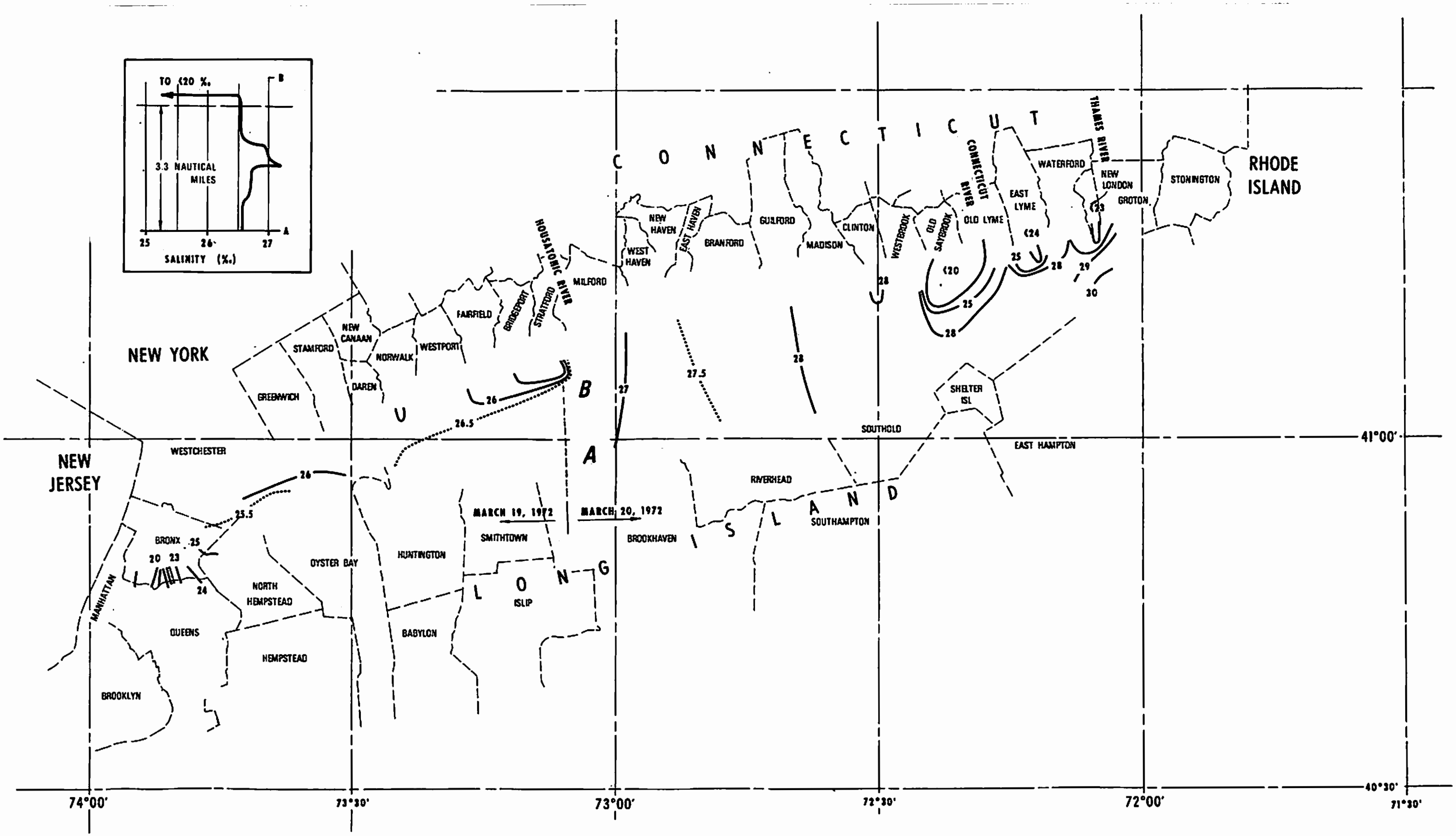

FIGURE 4.9 *Surface Salinity, March 19-20, 1972*

Between the Connecticut and the Thames rivers that same day, Cruise 7202 encountered a fourth plume, probably formed by the discharge from the Connecticut River during the previous tidal cycle.

The configuration of the low-salinity plumes near the Connecticut shore depends on the tide, the amount of river discharge, and the intensity of wind-induced vertical mixing. The values in Figure 4.9 depict plume salinities for that particular cruise only, and cannot be considered typical.

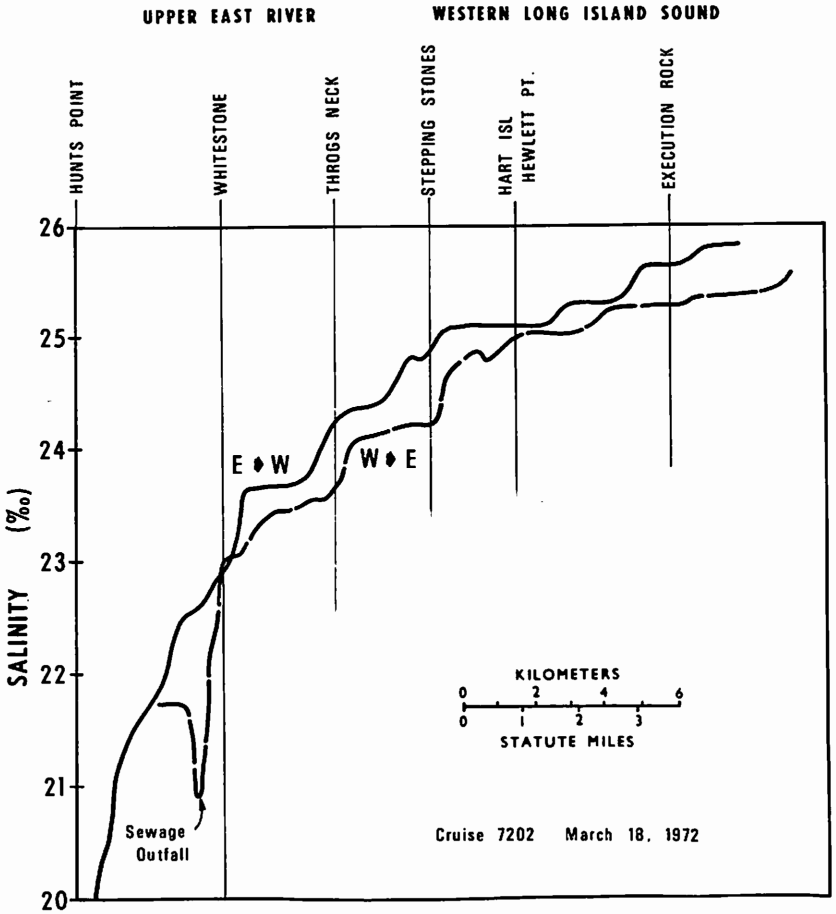

FIGURE 4.10 *Surface Salinity Gradient in the Western Sound*

Water Budget

FRESHWATER DISCHARGE. Approximately 72 percent of the fresh water entering Long Island Sound comes from the Connecticut River, 12 percent from the Housatonic River, and 9 percent from the Thames River (Fig. 4.11).* The remaining surface discharge from Connecticut—for instance, small streams, and surface runoff—is estimated at 5.1 percent of the discharge into the Sound. The surface discharge from mainland New York State amounts to 0.6 percent. The surface discharge from Long Island is estimated at 0.2 percent; added to this is the groundwater discharge from Long Island, estimated at 1.1 percent.

The discharge into the Sound varies considerably from season to season and from year to year. In Figure 4.12, the monthly modes (most frequently recurring amount) for each month through the 41 years from 1929 to 1970 drop to a minimum in August at about 200 m^3/sec, and peak in April at about 2200 m^3/sec—a sizable seasonal difference. In view of the wide span of discharges recorded for any one month, it is not possible to make reliable predictions of discharges.

The variability of the mean annual discharge is significantly less than the variability of the mean monthly discharge. The trend in the mean annual discharge from 1929 to 1971 is shown in Figure 4.13.

EVAPORATION AND PRECIPITATION. Some water is added to the Sound from direct rain: about 17 cm (6.7 in) a year after evaporation. The mean annual precipitation is about 110 cm (43 in), and the annual evaporation rate (from heat budget calculations, Appendix B) works out to about 93 cm (37 in). Over the 3400 km^2 surface area of the Sound, the 17 cm net gain amounts to an average addition of about 20 m^3 /sec or a scant 2.5 percent of the modal annual river discharge.

As we noted earlier, the region's precipitation is fairly uniformly distributed throughout the year. A difference of only 3 cm (1.2 in) separates the maximum and minimum *mean* monthly precipitation at New Haven: 11.7 cm (4.6 in) in March and 8.7 cm (3.4 in) in July. The *actual* monthly precipitation in any one year varies a great deal. During the decade from 1951 to 1960, average monthly precipitation ranged from a low of 1.6 cm (0.6 in) to a high of 27.8 cm (10.9 in).

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*Since September 1928, monthly estimates of the surface discharge into Long Island Sound have been prepared by the U.S. Department of the Interior, Geological Survey, Water Resources Division in Hartford, Conn. This section is based on data supplied by that office.

In contrast to this "uniform-but-unpredictable" precipitation pattern, the evaporation pattern changes regularly with the seasons. Evaporation peaks in summer and drops off during winter. About 74 percent of the total evaporation takes place during the six-month period from May through October. Thus in periods of low precipitation, during the summer we can expect a net loss of water from the Sound, while in winter there will be a significant net gain.

The heat budget calculations (Appendix B, Table B.1) show precipitation exceeding evaporation by 19.2 cm/month (7.6 in) from mid-March to mid-April at one extreme, and evaporation exceeding precipitation by 9.6 cm/month (3.8 in) from mid-August to mid-September at the other extreme. This net flux into the atmosphere and back again of 10 cm/month amounts, over the whole area of the Sound, to 130 m^3/sec or about 16 percent of the modal annual river discharge.

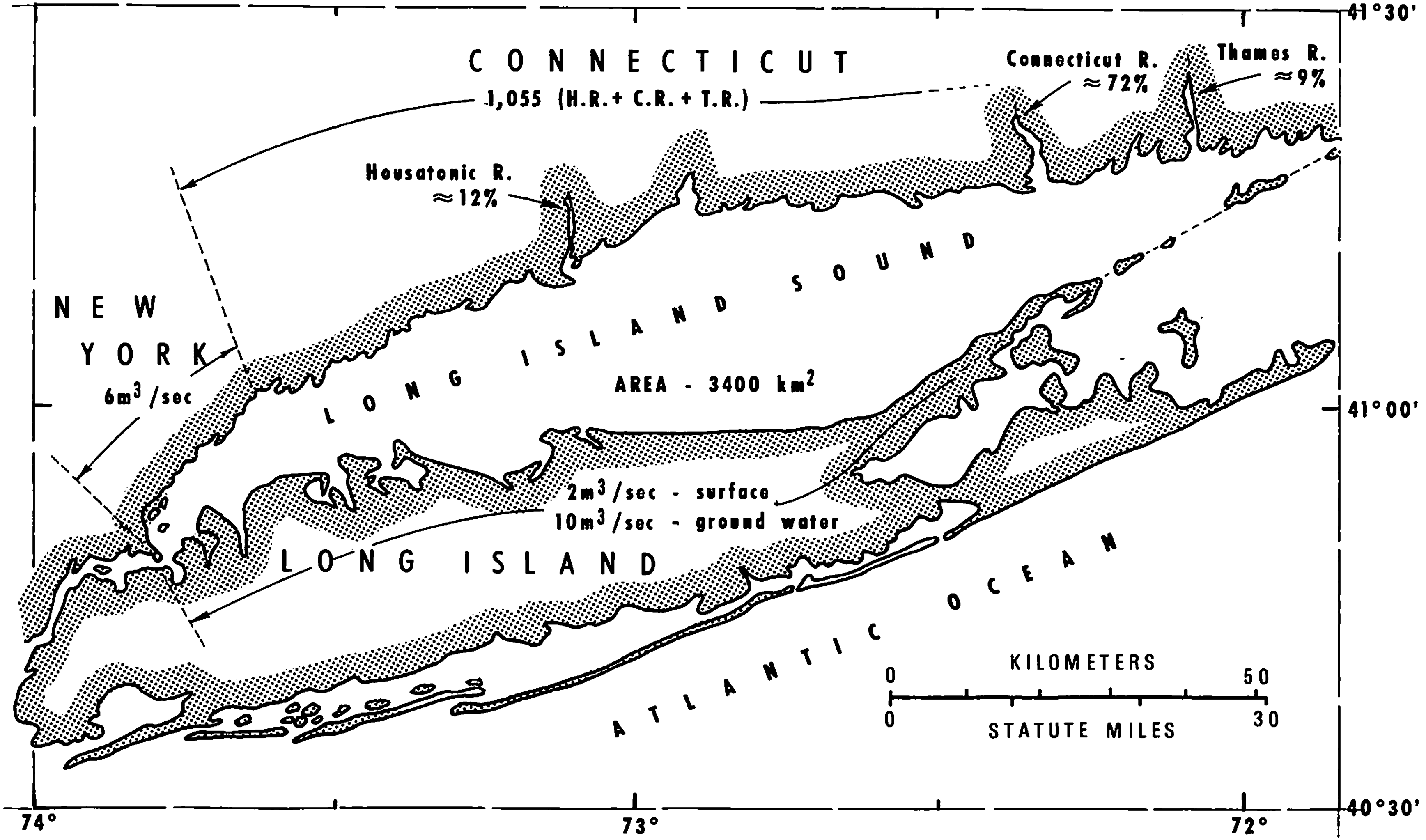


FIGURE 4.11 *Freshwater Discharge into Long Island Sound*

We can conclude that the difference between evaporation and precipitation has but small effect on the water budget of the Sound during periods of high precipitation and hence high surface runoff. During periods of low precipitation and high evaporation, however, the effect on the water budget may become significant. It may also lead to a higher salinity than would be expected from runoff data alone—an important factor to remember when predicting salinity from river discharge, discussed next.

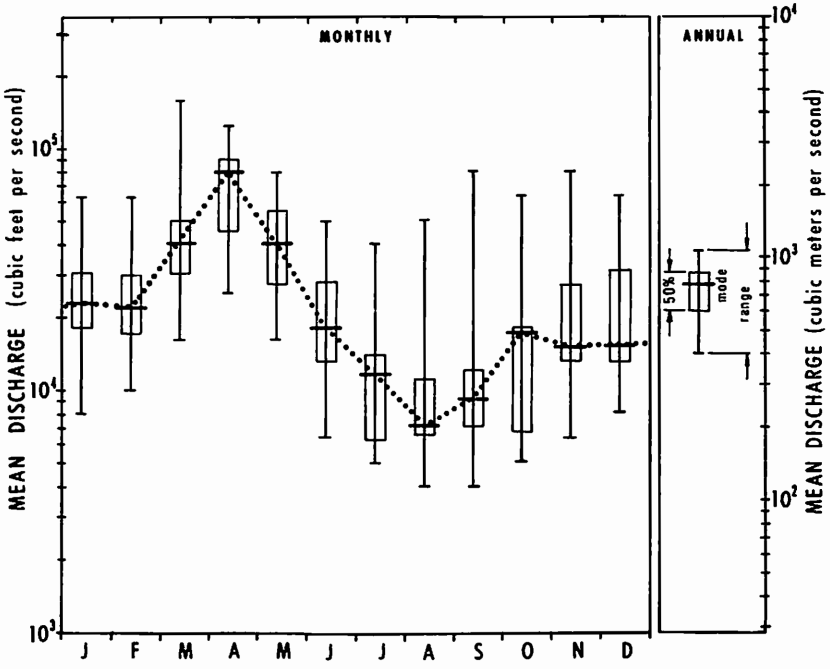


FIGURE 4.12 *Mean Monthly Discharge Rates, 1929–1970*

Note how small the annual range is, compared to monthly ranges.

Predicting Average Salinity from Discharge Data

An increase in the freshwater discharge leads to a decrease in salinity, of course, and a reduced rate of discharge results in increased salinity in the Sound. But by how much?

We can examine the quantitative relationship between freshwater discharge and salinity by comparing the surface salinity data in the central parts of the Sound obtained by G.A. Riley (1956, p. 59) for the period 1952-1955 with the U.S. Geological Survey's freshwater discharge data for the same period. Figure 4.14 shows this comparison. The surface salinity and the two-month running average discharge are plotted as a function of time. Since increasing the discharge will result in a reduced salinity, the salinity scale is inverted. By adjusting the salinity scale so that the salinity $S = 28.6 - 0.00176\,R$, where R is the discharge in m^3/sec, the two become very similar, except that the salinity curve lags about two months behind the discharge curve. Assuming the conditions during the period 1952-1955 were normal, we can use that empirical relationship, $S = 28.6 - 0.00176R$, to predict average surface salinity in the central part of the Sound from discharge data of two months earlier. Thus if the discharge increases by 1000 m^3/sec, the salinity will go down by $1.76^0/_{00}$.

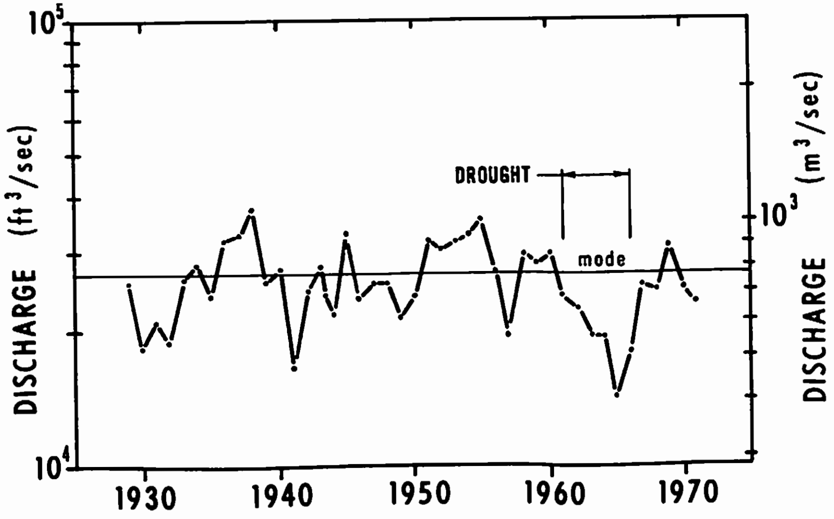


FIGURE 4.13 *Mean Annual Discharge, 1929-1971*

The anomalously low discharges during the period of drought in the northeastern U.S. from 1961–1966 are clearly apparent. Periods of high discharge occurred from 1936–1938 and from 1951–1955.

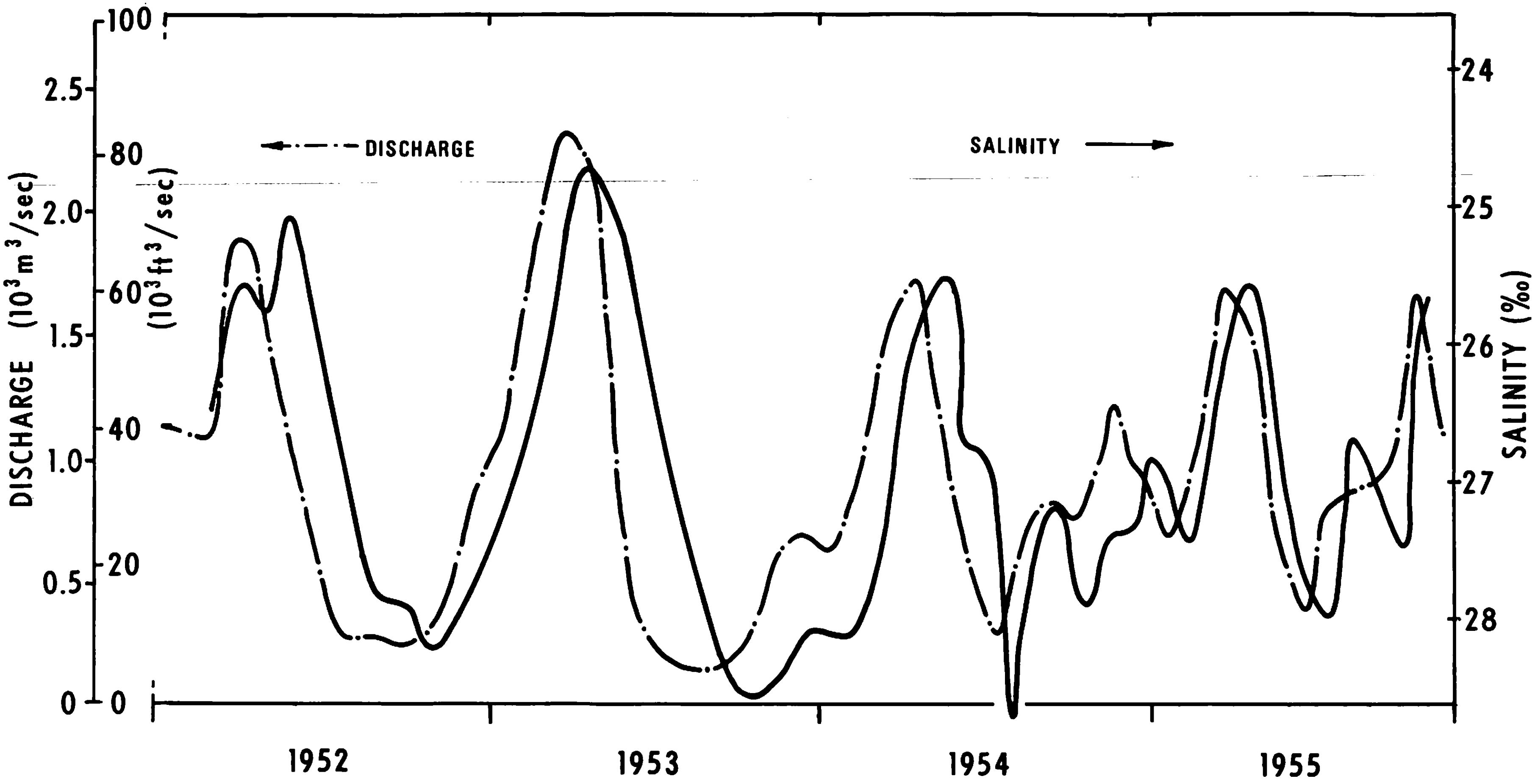


FIGURE 4.14 *Two-Month Running Average Discharge and Surface Salinity, Central Sound.*

Salinity Distribution

Among the factors controlling the salinity distribution in the Sound, estuarine circulation is prominent. There are important similarities and differences between the behavior of a classic or typical estuary and the behavior of the Sound.

A typical estuary is shown schematically in Figure 4.15. At the landward margin of the estuary, fresh water enters from one or more rivers. Toward the mouth of the estuary there is usually a vertical salinity gradient, with the fresher, less dense water on top. Averaged over a tidal cycle, there is a net inflow of saline water into the estuary near the bottom, and a net outflow of less saline water at the surface. The saline bottom water is gradually mixed upwards into the fresh water to form the surface discharge.

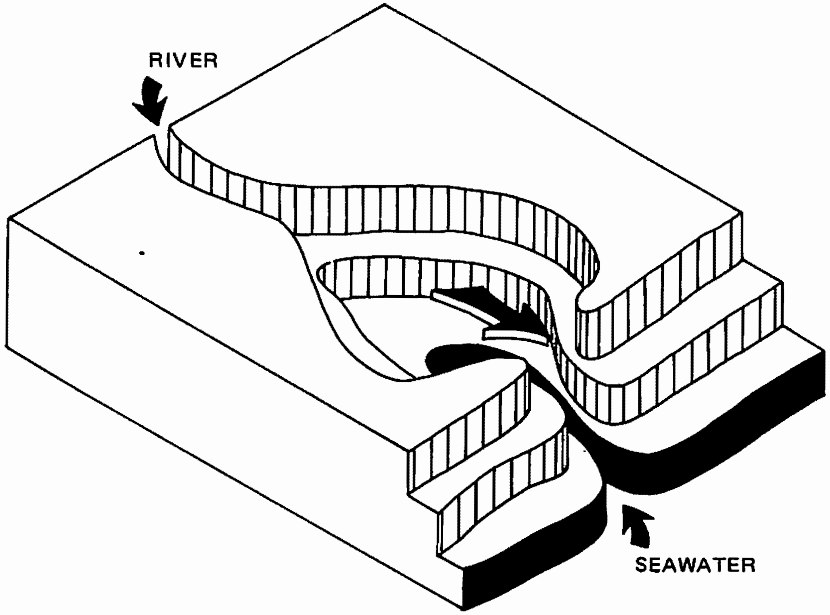


FIGURE 4.15 *Flow in an Estuary*

The geometry of Long Island Sound differs from that of a typical estuary, since the Sound is connected to the ocean at both ends. Figure 4.16 is a block diagram of Long Island, Block Island, and Rhode Island Sounds at three levels, with the topography turned upside down to show off the geometry of the basins. Depressions appear as hills.

Starting in the east with the deepest parts, we can see in the figure the connections between the eastern end of Long Island Sound and the other two sounds. The controlling sill depth for the connection to the open Atlantic via Rhode Island Sound is 35 m (115 ft). There is also a narrow connection through Block Island Sound at a slightly shallower sill depth of 33 m (108 ft). The comparative importance of these passages for bottom water flow into Long Island Sound has yet to be determined. The passage west of Block Island is shorter but narrower and slightly shallower, whereas the deeper, wider passages east of Block Island are more circuitous.

We know something of the salinity influence of Rhode Island Sound water on eastern Long Island Sound water from seasonal hydrographic data for the deep part of Rhode Island Sound collected by Shonting *et al* (1966). Results from seven cruises during an annual cycle for their station #9 at 41°08′N 71°21′W are shown in Figure 4.17. In winter, the water is well mixed vertically. During the warming season, vertical gradients appear, first because of lowered surface salinity and then from rising temperatures. The salinity gradient is likely to differ significantly from year to year due to variations in runoff; the temperature regime can be expected to be more regular. The two variables—salinity and temperature—are linked in action, however. The presence of a vertical temperature gradient stabilizes the vertical density structure and thus reduces vertical mixing; freshwater runoff then tends to remain in the surface layer, resulting in a vertical salinity gradient.

The vertical density gradient between the surface and 40 m (131 ft) is most pronounced in early summer and then decreases due to surface cooling in the fall. Thus, the estuarine type of circulation, which introduces cool, saline water into the bottom of Long Island Sound from the east, will be most significant in summer and will be reduced in winter.

In the Eastern Basin proper, the complex topography (Fig. 4.18) complicates salinity patterns. Deep water enters from Block Island Sound via the Race. A continuous channel with depths of at least 34 m (112 ft) extends to about 72°30′W, where it runs into Mattituck Sill, separating the Eastern from the Central Basin. The maximum depth of the sill is about 22 m (72 ft); it is divided by Six Mile Reef into a narrow northern gap and a broad southern one (see inset in Fig. 4.18). To determine the relative importance of the overflow of bottom water across these two segments of the sill, detailed studies of bottom currents through a complete tidal cycle will be needed. The Coriolis effect of the earth's rotation would favor the narrow northern channel. Figure 4.18 shows salinity data obtained on MSRC Cruise 7102 in August 1971, when there was significant vertical density stratification; these data give a rough idea of the supply of bottom water to the sill. Salinity just east of the northern gap was significantly greater ($29.64^{0}/_{00}$) than near the southern gap ($28.94^{0}/_{00}$). This suggests more rapid inflow at the northern gap. Just on the other side of the sill in the eastern extreme of the Central Basin, salinity was $28.60^{0}/_{00}$, suggesting considerable dilution of the overflow, if in fact it came through the northern gap. Further observations will be needed to settle this question.

Along the southern axis of Long Island Sound, from the eastern to the western end, the vertical salinity structure shows clear seasonal variations (Fig. 4.19). In winter (January cruise) the water is well mixed vertically, with very little variation in salinity so that the isohalines (lines of constant salinity) are almost vertical. In summer (July cruise) there is a significant vertical salinity gradient, which

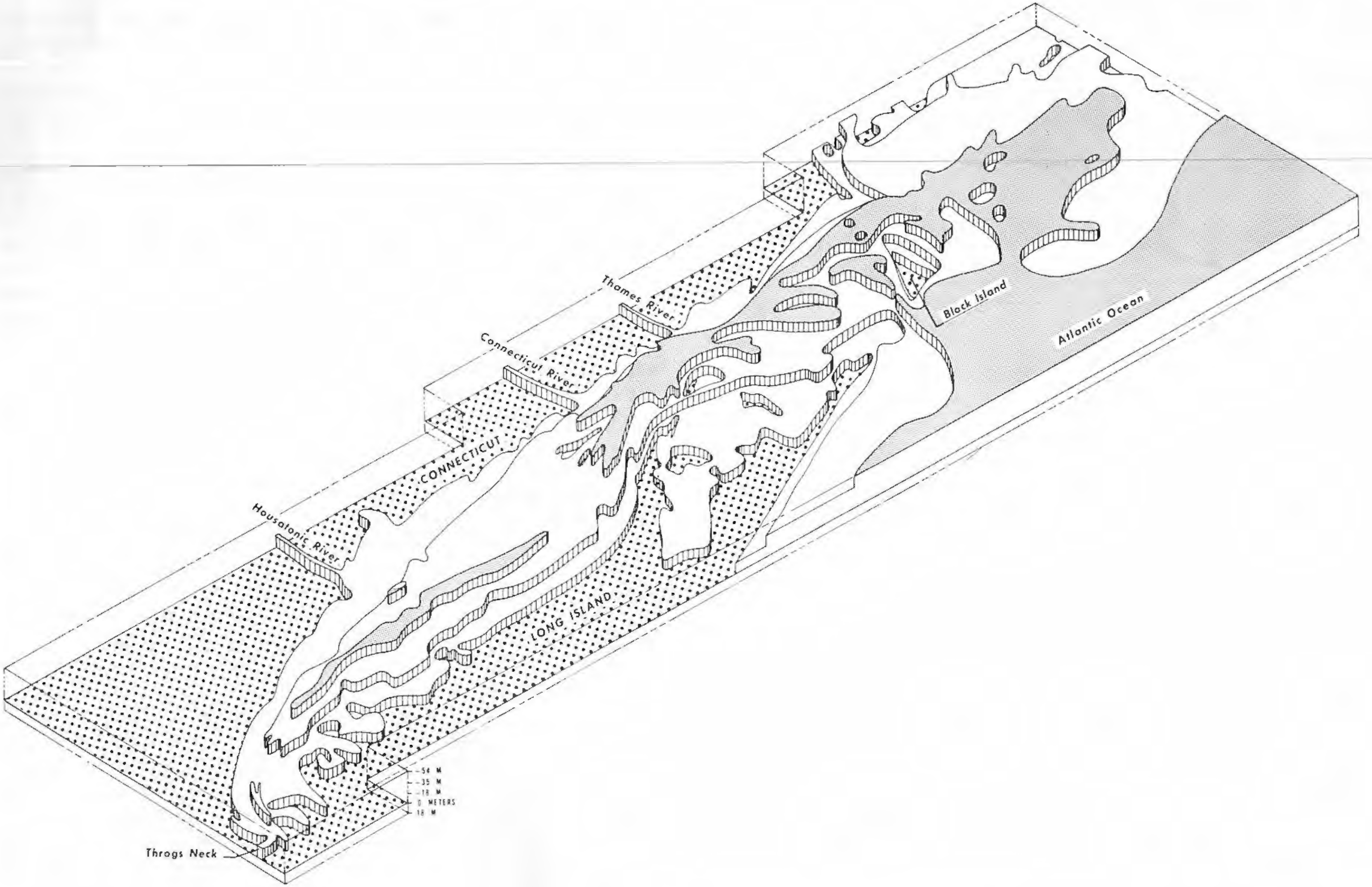


FIGURE 4.16 *Depth Diagram of Long Island, Rhode Island, and Block Island Sounds*

The topography has been inverted so that depressions appear as heights. Mean sea level and depths below the surface of 18m (10 fathoms) and 35 m (19 fathoms) are shown.

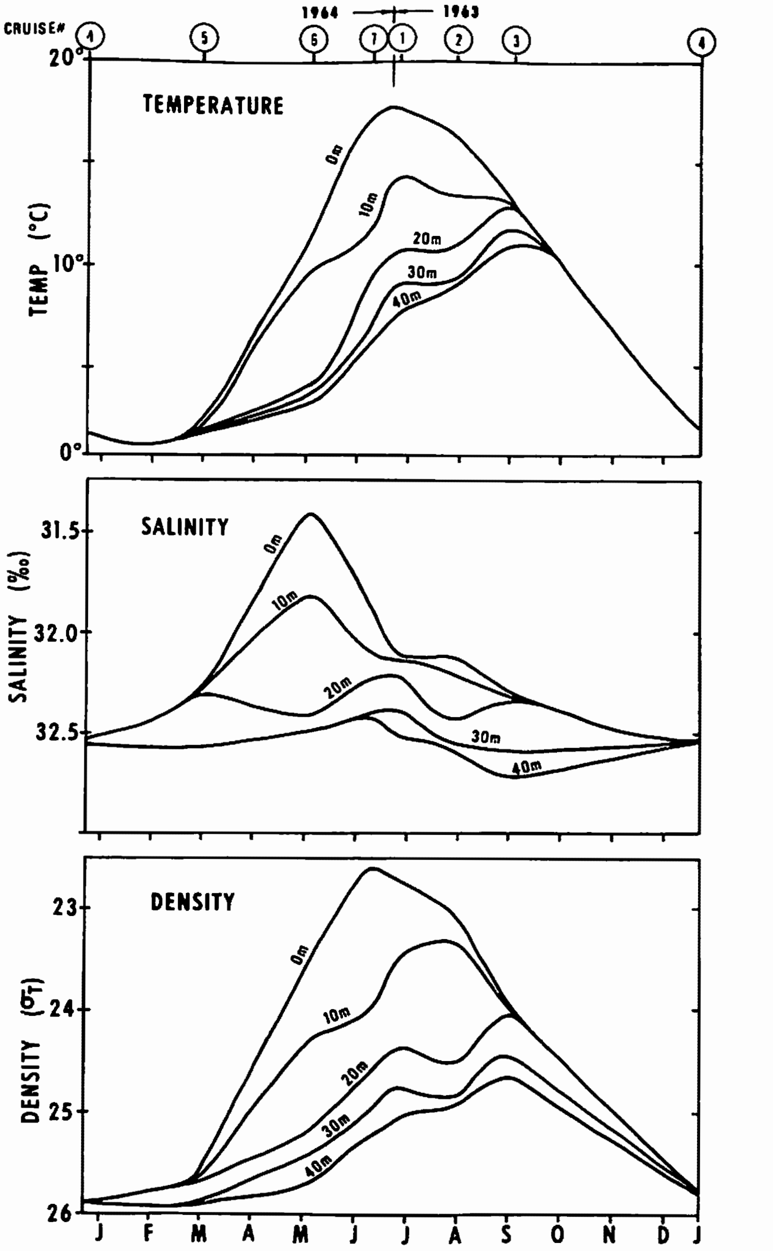


FIGURE 4.17 *Rhode Island Sound: Annual Cycle of Water Temperature, Salinity, and Density*

Source: Shonting *et al* (1966), Station No. 9, 41°08'N 71°21'W.

decreases in the fall (October cruise). At all times of the year, we find large horizontal gradients in salinity at either end of the Sound, and a small gradient in the Central Basin. The salinities in the regions of large horizontal gradients change markedly during a tidal cycle; the data in the figure do not take this into account, but represent observations taken over a period of time without regard to the tidal cycle.

The estuarine circulation leads to a westward spread of saline bottom water; this general trend is counteracted by turbulence from tidal motion and by vertical mixing from surface cooling. The effect of mixing by tidal turbulence is evident in a small region of higher surface salinity found just east of Middle Ground during Cruise 7202 on March 19, 1972 (see Fig. 4.9). This patch of more saline water was sharply bounded north and south; it could only have been produced by an admixture of saline water from depth through vertical mixing, undoubtedly the result of turbulence from rapid shoaling. Thus Middle Ground and other hazards to navigation play an important role in vertical mixing by inducing turbulence. Removal of such shoal areas would have the effect of reducing vertical mixing and aggravating stable vertical stratification. That in turn would be adverse for the dissolved oxygen situation.

Having discussed the salinity distribution in the eastern and central Sound, let us now consider salinity in relation to the interchange of water with New York Harbor in the west. In Figure 4.20, an inverted block diagram showing the interconnection of Long Island Sound with New York Harbor and the Hudson River, the constriction of the East River in depth and width is evident at Hell Gate, where the relatively small channel of the Harlem River also enters and forms a separate connection with the Hudson River. The sill depth at Hell Gate is only about 11 m (35 ft), and the complex geometry of the channels here produces rapid currents and much turbulence, resulting in thorough mixing of the water column. We saw that elevations of the water at the two ends of the East River are controlled by the tidal regimes of the Hudson and the Sound—the one a progressive wave, the other a standing wave. The resulting elevation differences at Throgs Neck and the Battery give rise to hydraulic tidal currents (flowing in response to level differences). Because of the constriction near Hell Gate, a large fraction of the total hydraulic gradient occurs here, producing rapid currents. The gradient in the relatively wide, deep upper East River is much smaller.

The tidal diagram of the East River (Fig. 4.21) indicates that during the last two hours of the ebb of the Hudson, low-salinity river water flows north into the East River. Near the end of the Hudson flood, when the water is more saline due to inflow from the ocean, the flow in the East River is southward. As a result of these phase differences in the currents, the East River at its southern end takes in water that on the average is less saline than the water in the Hudson

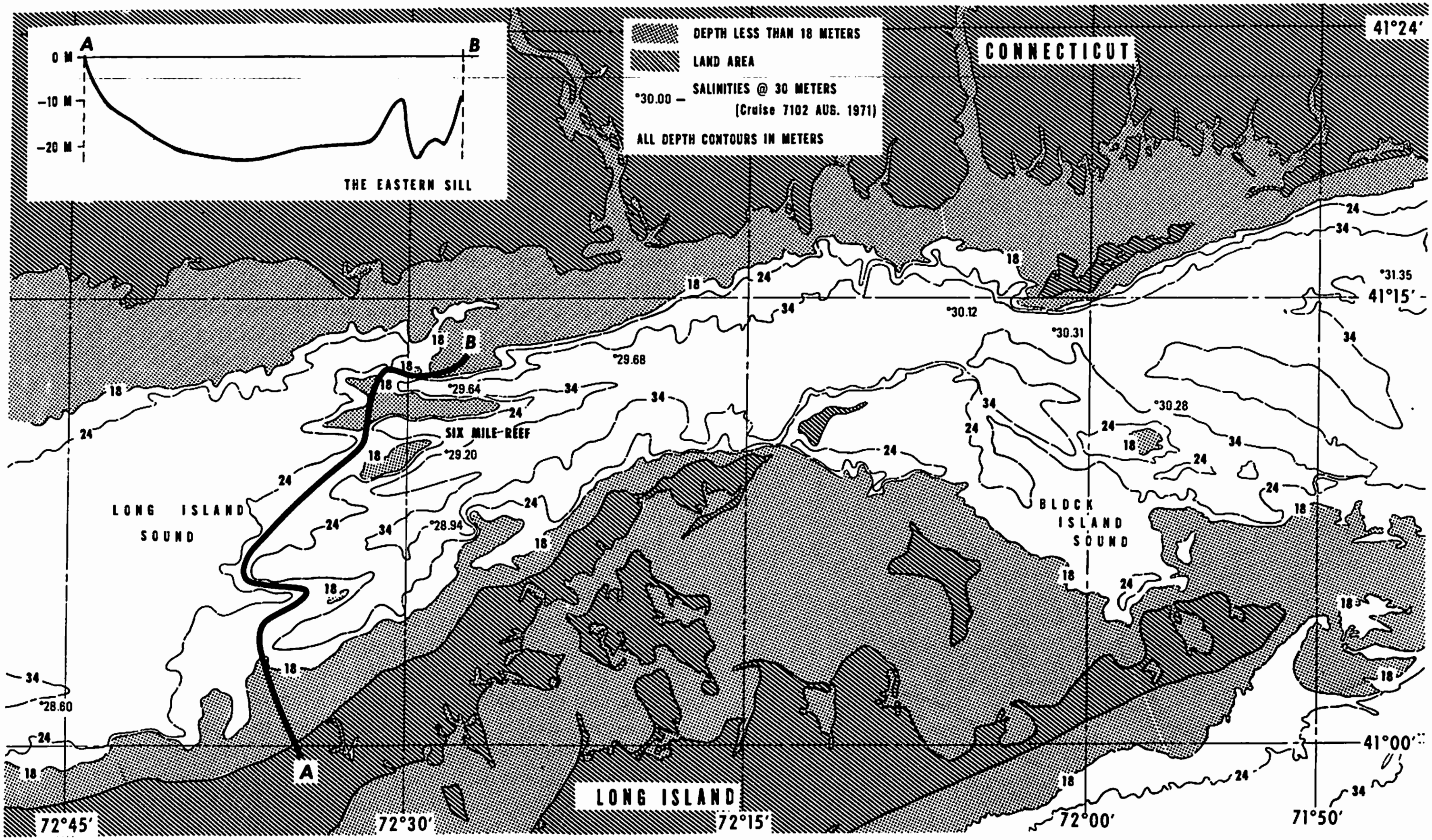


FIGURE 4.18 *Bathymetric Chart of Eastern Long Island Sound*

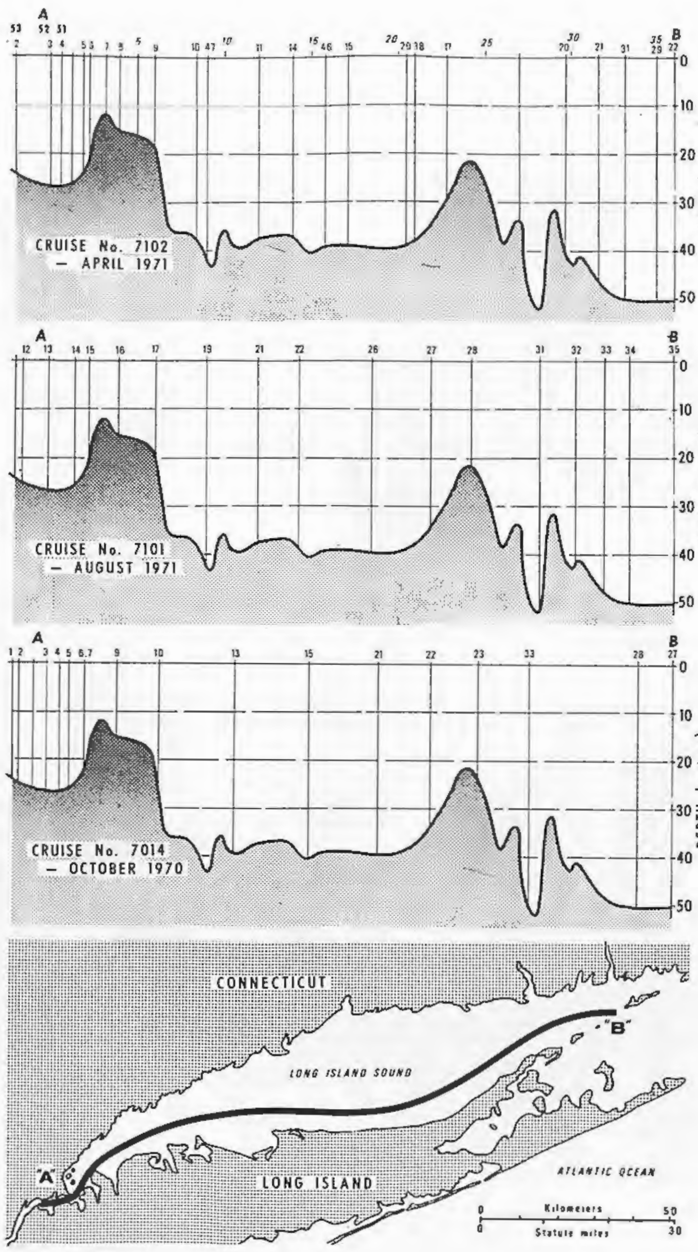


FIGURE 4.19 *Vertical Salinity Structure*

Salinity in parts per thousand.

at the Battery. A detailed study of the complex relationship between salinity and the tides in New York Harbor has recently been carried out by the Marine Sciences Research Center and is being prepared for publication.

The interchange of water between the East River and the western Sound affects the salinity situation there. The tidal currents through the crucial section from Throgs Neck across to Willets Point were measured by H. C. Denson in July 1922 (reported in Marmer, 1935, p. 190). During this time of year, the water in the western Sound is stratified and the measurements show the effect of this stratification. The tidal displacements during the ebb and flood obtained at various depths at three stations are shown in Figure 4.22. To convert the measurements to a tidal displacement (the distance the water would move during an ebb or flood), each half tidal cycle is assumed to be approximately a sine wave, so that the displacement in nautical miles is equal to the maximum velocity in knots times the duration of the ebb or flood in hours multiplied by $0.637 = 2/\pi$. Figure 4.22 shows that the easterly displacement from the East River to the Sound is strongest near the surface and decreases with depth. In contrast, the westerly flow from the Sound to the East River is minimal at the surface and increases downward. This estuarine circulation results in a net inflow of lower-salinity surface water into the Sound and a net outflow of more saline bottom water out of the Sound.

Unfortunately, the data cannot be used to calculate the ebb and flood fluxes—the net transport through—because the directions of the currents were not determined. The large curvature of the channel at this location prevents assumption of a simple reversal in direction. The curvature tends to increase the flow at the outside of the bend near Willets Point; on the other hand, the Coriolis effect causes the westerly currents to be stronger near Willets Point.

Rough estimates of net transport are possible, from measurements also carried out in July 1922 along a straighter portion of the upper East River near the present location of the Whitestone Bridge (Marmer, 1935, p. 189, Stations 50, 53, 54). The detailed calculations are given in Appendix C. The flow of water during a tidal cycle can be considered as a sum of three terms: an alternating flow, an easterly surface flow, and a bottom flow to the west. By far the largest is the alternating flow, with an amplitude of 6300 m^3/sec. Averaged over a tidal cycle, this flow results in no net transport of water. The easterly surface flow of fresher water into Long Island Sound has a velocity of about 1000 m^3/sec, and the westerly bottom flow of more salty water out of the Sound has a velocity of about 500 m^3/sec. Adding up the three terms gives a net flow *into* the Sound with an estimated velocity of 500 m^3/sec. Since this is only about 10 percent of the dominant alternating component, the reliability of this estimate is very low. To obtain a salt budget would require reliable estimates of the three flows, plus data on the variation in salinity across the section.

The net transport situation is even more difficult to calculate at the eastern margin of the Sound. Here the alternating flow amounts to about 300,000 m^3/sec. The net *outflow* to the east—the result of river discharge—is only on the order of 1000 m^3/sec, or less than one percent of the alternating flow.

The effect of the flow through the East River on the salinity of the Sound depends in part on the difference between the discharge of the Hudson River and the river discharge from Connecticut directly into the Sound. If during a particular time the discharge of the former were much greater than the latter, one would expect a significant dilution of the salinity of the Sound by the East River connection. Conversely, conditions of low Hudson River discharge and high discharge from Connecticut might lead to a reversal of the salinity gradient in the East River and a gain of salt for the western Sound. The actual discharge data (Fig. 4.23) show a positive high correlation between the two discharges—that is, when one is high, the other is usually high, and vice versa. Whereas the amounts of the mean monthly discharges of the Hudson and the Connecticut rivers vary by a factor of 20, their ratio varies much less. For a series of ten years,

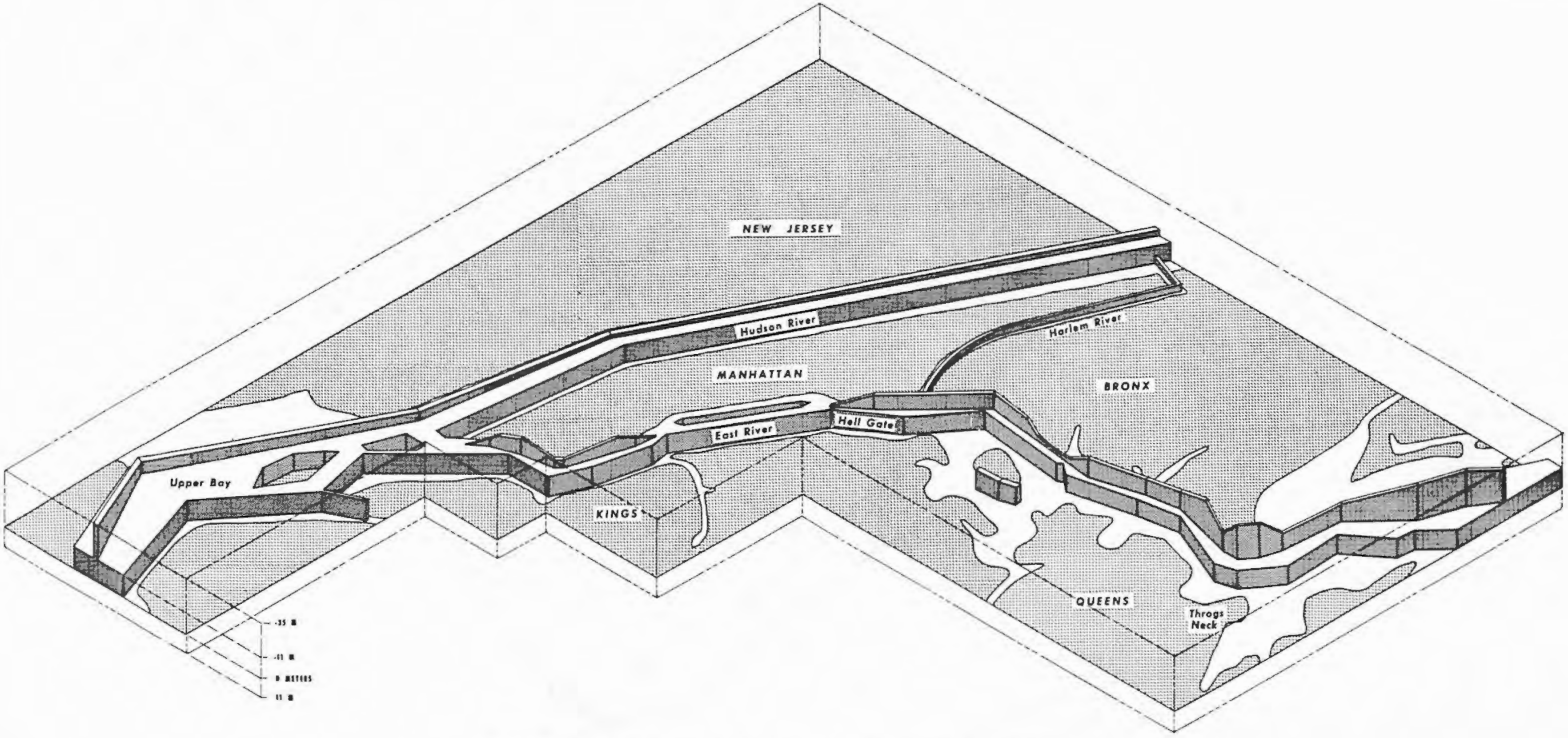


FIGURE 4.20 *Schematic Bathymetric Diagram of East River*
The topography has been inverted so that depressions appear as heights.

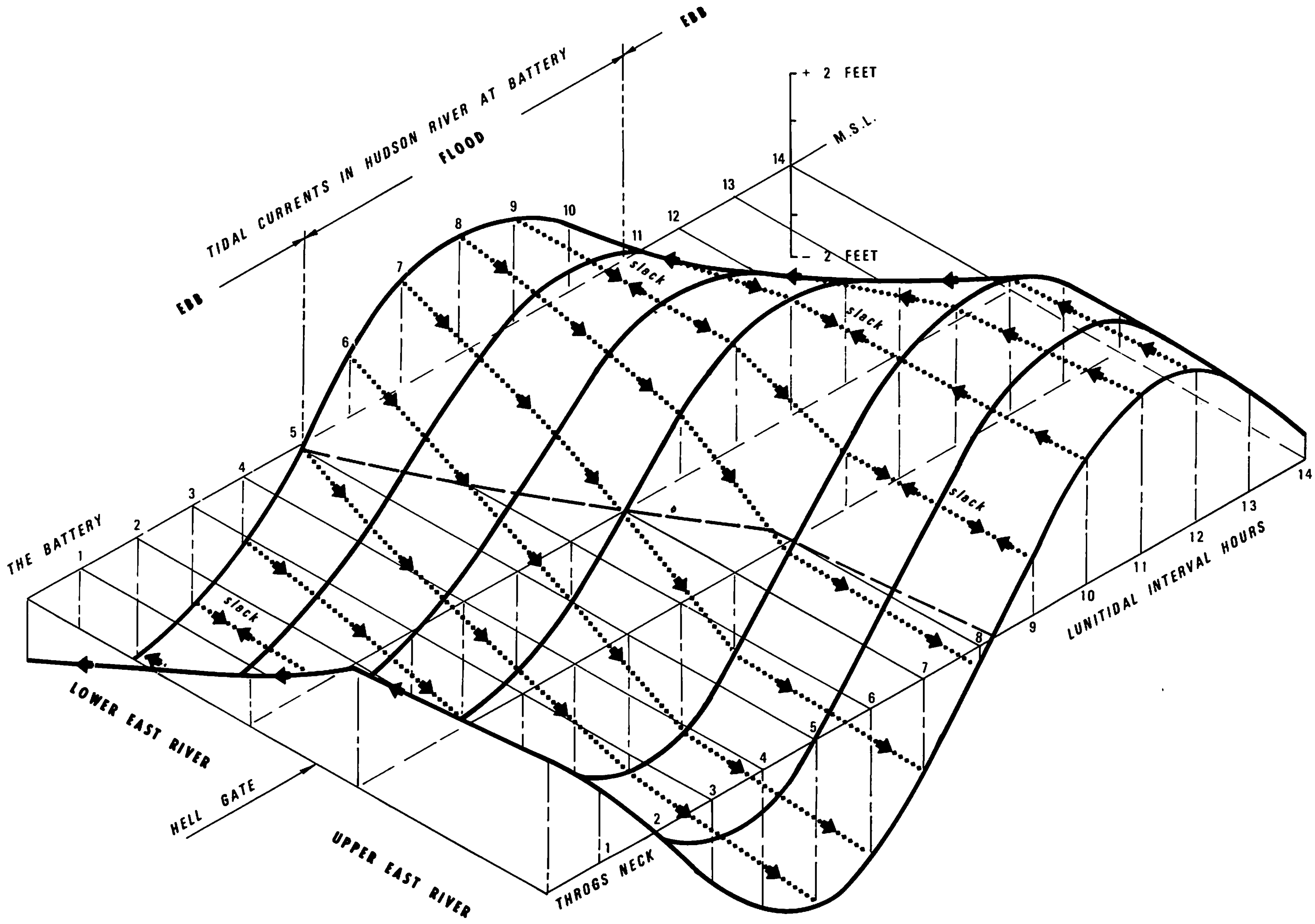


FIGURE 4.21 *Tidal Level and Currents from Throgs Neck to the Battery*

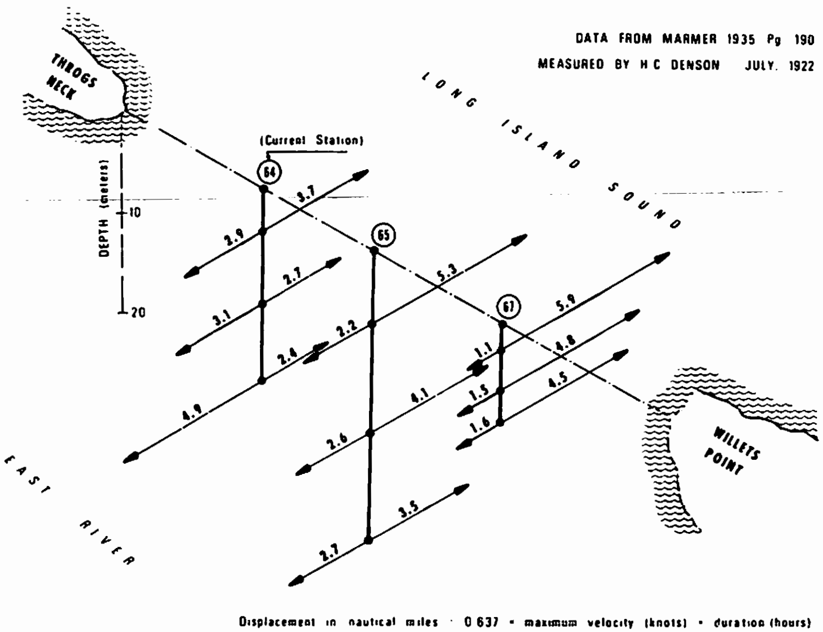


FIGURE 4.22 *Tidal Displacements at East River/Long Island Sound Interchange*

covering extreme conditions of runoff, the ratio of the Connecticut runoff into the Sound to that of the Hudson varied only from 0.72 to 3.0, a factor of 4, with the great majority of the months giving ratios between 1 and 2. This high correlation is the result of similar weather patterns for the two drainage areas. Because of the similarity in discharge, the effect of this factor on the salinity distribution in Long Island Sound is probably minor, although it may become significant on rare occasions.

DENSITY

The density of seawater depends on its salinity, temperature, and pressure. The pressure of the water increases with depth at a rate of approximately one atmosphere per 10 meters (30 feet). Long Island Sound is sufficiently shallow for us to ignore the effect of pressure on density there. We shall therefore consider only the effect of temperature and salinity on density at a standard pressure of one atmosphere. Since the density of seawater is very close to 1 gm/cm^3,

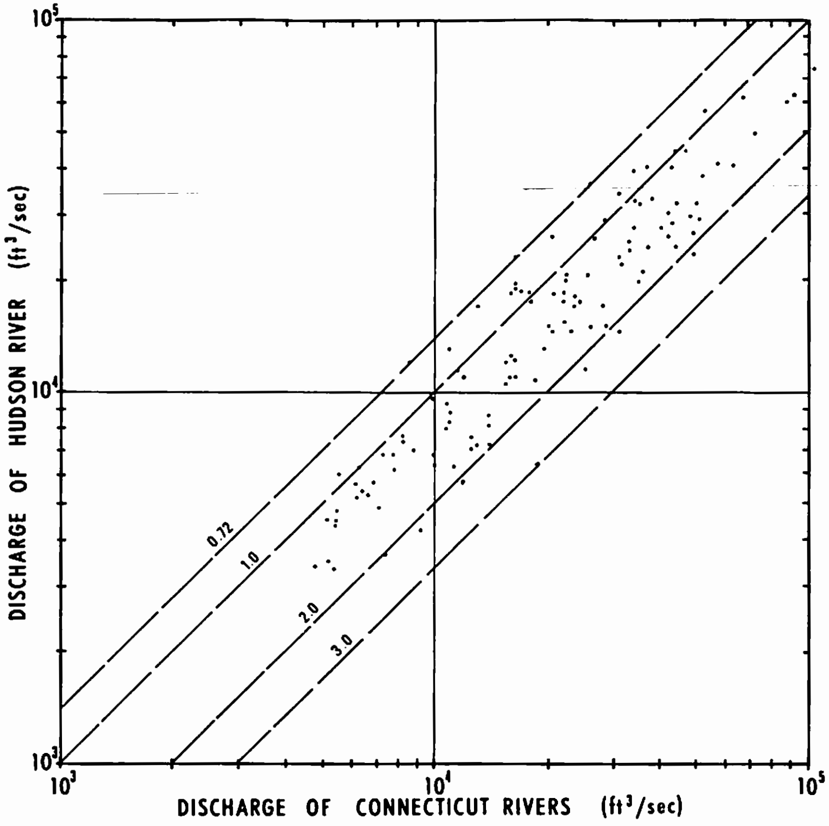


FIGURE 4.23 *Discharge of Hudson River at New York City and of the Connecticut rivers into Long Island Sound*

Numbers on lines indicate the ratio of the discharge into Long Island Sound to that of the Hudson River.

oceanographers designate the density of seawater at one atmosphere by its sigma-T (σ_T) value. Sigma-T is the density minus one multiplied by 1000, so that a density of 1.020 gm/cm^3 is equal to a sigma-T value of 20.

The value of density (sigma-T) over the range of the Sound's temperature and salinity is shown in Figure 4.24. We noted in earlier sections that salinity varies from about 20$^0/_{00}$ to 30$^0/_{00}$ and temperature ranges from approximately -2°C (28°F) to 25°C (77°F). Note that density is approximately linear with salinity but nonlinear with temperature. The thermal expansion of seawater is

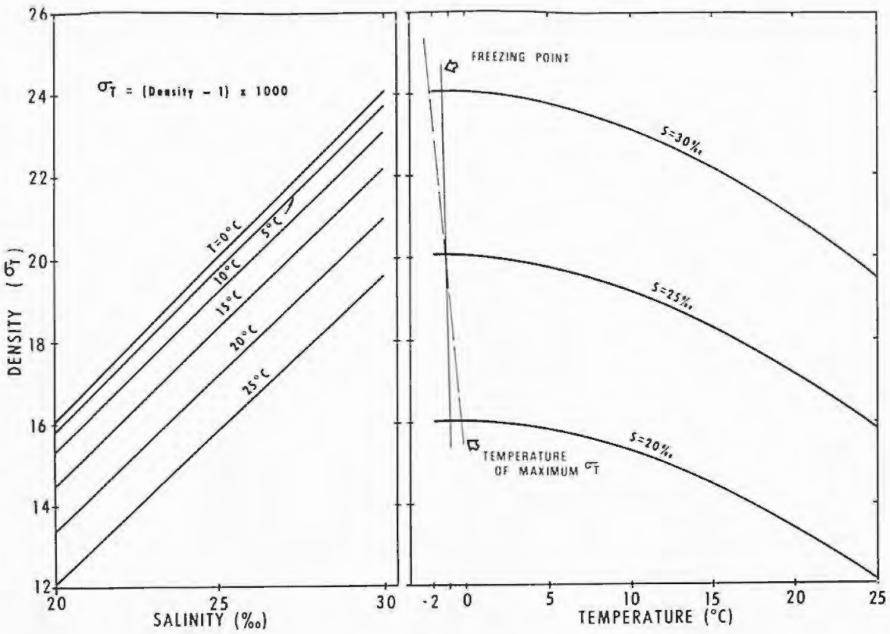


FIGURE 4.24 *Density (σ_T) Related to Salinity and Temperature*

very small near the freezing point and increases greatly as the temperature rises; hence, the effect of temperature on density is small in winter but becomes significant in summer.

We saw that the surface temperature in the Sound varies relatively little with space but has a large annual cycle (Fig. 4.6). In contrast, the salinity has an annual variation of $2^0/_{00}$ to $3^0/_{00}$ (Fig. 4.14) and increases by about $5^0/_{00}$ at any one time as one goes from west to east (Fig. 4.19). As a result, surface density increases from west to east in response to the horizontal salinity gradient, while its measured value goes through a seasonal cycle in response to temporal variations in temperature and salinity.

Of much greater importance than surface (horizontal) density structure is the variation of sigma-T with depth, vertical density structure. The estuarine circulation and vertical mixing both depend on the vertical density distribution rather than on the separate variables of salinity and temperature. This is because the stability of a water column to vertical overturning depends on the vertical sigma-T gradient. (1) When sigma-T is independent of depth, vertical mixing requires merely enough energy to overcome the viscous resistance of the seawater. (2) When sigma-T increases with depth, the stably stratified column has less potential energy than a well-mixed water column, since mixing would raise the center of gravity of the water column. As a result, a much greater expenditure of energy is required to mix a water column whose sigma-T increases with depth. (3) If sigma-T decreases with depth, such a column of water is "top-heavy" or unstable; since vertical mixing lowers the center of gravity in this instance and so decreases the potential energy, the excess potential energy is spontaneously transformed into the kinetic energy of mixing. Vertical mixing can be started either by a loss of heat from the water surface, or by a loss of water by evaporation, resulting in an increase in salinity. On the other hand, the water column becomes stabilized if the surface temperature rises due to heating or the surface salinity decreases due to precipitation.

Vertical density patterns in the Sound are significantly affected by the east-west salinity gradient: the change of about $5^0/_{00}$ corresponds to a difference of about 4 sigma-T units. This is a much greater density difference than could be generated by surface cooling; Figure 4.24 indicates 4 sigma-T units would require a temperature drop of something like 24°C (43°F). One would expect the Sound to be stratified during the entire year, therefore, with low-salinity water from the East River overlying the saltier water from the eastern passes (Fig. 4.25). Actually, we find that, though salinity does increase from

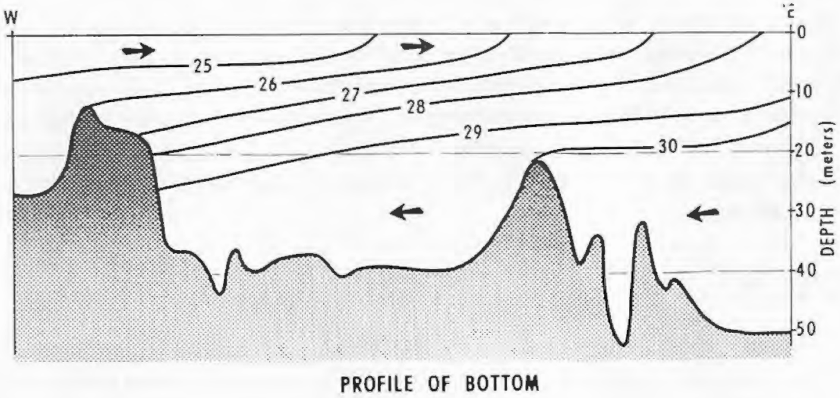


FIGURE 4.25 *Hypothetical Stratification Pattern*

Compare to actual patterns in Figure 4.19.

west to east, the salinity difference from top to bottom is much less than that from west to east, even during July when there is a maximum of stratification (Fig. 4.19). The natural tendency of the Sound to become stratified in salinity is counteracted by the strong tidal currents. The irregular topography of the Sound also aids in converting a significant fraction of the tidal flow into turbulent eddies, whose dissipation causes vertical and horizontal mixing. Additional energy for vertical mixing near the sea surface is provided by the wind. As the wind blows over the Sound, it generates surface waves at the air-water interface. The dissipation of these waves results in turbulence. Tidal mixing, which predominates, varies mainly with location, whereas wind mixing varies with the weather: nonexistent during periods of calm, important as storms pass through the area.

Long Island Sound is always subject to significant vertical mixing. Changes in the density structure depend on the turbulent energy available, on whether the density of the surface layer is increasing or decreasing, and on the previous density stratification. Figure 4.26 shows variations through a year of the density difference between the bottom and various depths at one location in south-central Long Island Sound. More detailed hydrographic time series, combined with studies of the heat budget and weather patterns, are needed to understand the quantitative annual changes in density stratification.

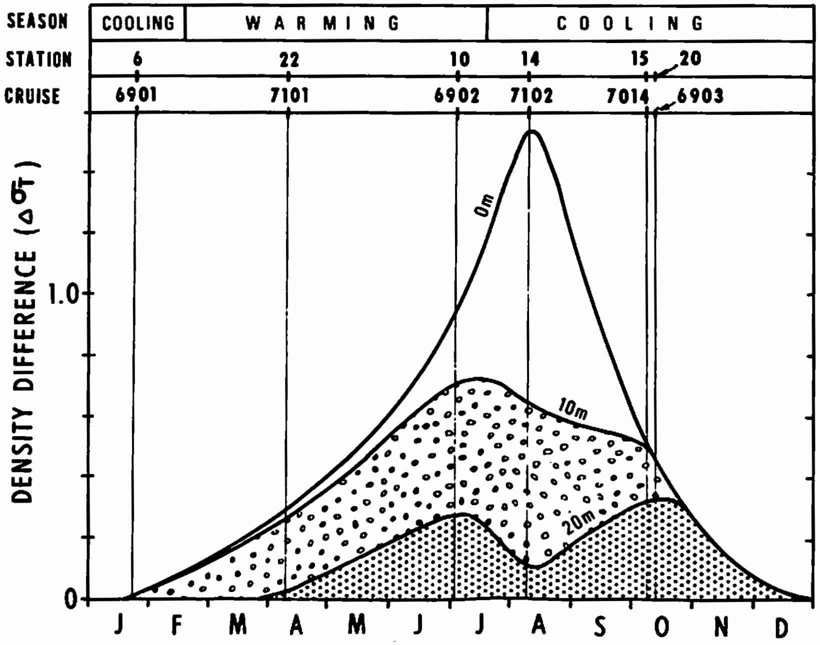


FIGURE 4.26 *Annual Variation of Density Differences Between the Bottom and Various Depths.*

DISSOLVED OXYGEN DISTRIBUTION

Density stratification and its effect on vertical mixing are crucial to an understanding of the distribution of dissolved oxygen. Dissolved oxygen is an important link between the physical and biological processes in the water.

To get an idea of the basic amount of oxygen in the water, let us consider the hypothetical case of no biological activity: the level of dissolved oxygen in the water would be controlled only by the exchange of oxygen at the air-water interface. The concentration of dissolved oxygen would correspond to the solubility of atmospheric oxygen at the pressure of one atmosphere.

The solubility of oxygen in seawater decreases markedly with increasing temperature and slightly with increasing salinity (Fig. 4.27). Photosynthesis by

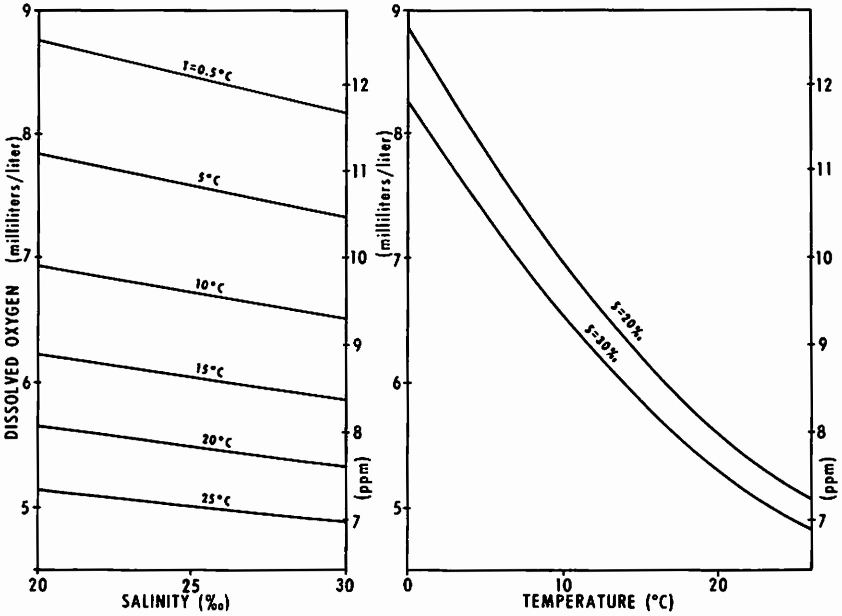


FIGURE 4.27 *Solubility of Atmospheric Oxygen in Sea Water.*
Source: Carpenter (1966).

plants in the presence of sunlight converts dissolved carbon dioxide in the water into oxygen and organic matter. Respiration by bacteria and animals reverses this reaction by converting dissolved oxygen and organic matter back to carbon dioxide. Oxygen-generating photosynthesis can take place only in the illuminated surface layer of the water, whereas respiration takes place at all depths and on the sediment surface.

Biological activity thus tends to produce a vertical gradient of dissolved oxygen. There is an excess production of oxygen near the surface and oxygen in the deeper water becomes depleted. The actual amounts of dissolved oxygen depend on the relative rate of the biological processes that produce the gradient and on the physical processes of vertical mixing and equilibration with the atmosphere that tend to dissipate the gradient.

Effluents and solid wastes added to the water from human processes have the effect of stepping up the rate of the biological processes, thus aggravating the vertical oxygen gradient and the depletion of dissolved oxygen from the deep water. These are some of the operating factors:

- The turbidity of the water is increased by dredging and by the discharge of particulate matter from sewage treatment facilities. The downward penetration of sunlight is thus reduced, and photosynthesis becomes limited to a very thin layer near the surface.
- Secondary sewage treatment breaks organic matter down to inorganic nutrients (e.g., phosphates, nitrates), which are discharged into the surface waters. These nutrients increase the growth rate of phytoplankton, leading to phytoplankton blooms, which add to the turbidity of the water and further restrict the penetration of sunlight. Photosynthesis by the masses of phytoplankton leads to high oxygen supersaturation of the surface layer.
- Primary sewage treatment facilities discharge large quantities of organic matter that is oxidized by animals and bacteria at all depths and on the bottom, bringing about a rapid rate of oxygen consumption throughout the water column. Phytoplankton sinking out of the illuminated surface layer add organic matter.
- The discharge of low-salinity sewage water and heated effluent from power plants increases the vertical stability of the water column and so reduces the rate of vertical mixing. As a result, the natural rate of oxygen replenishment from the sea surface is reduced.
- Pollutants such as petroleum and sewage sludges contain large amounts of reduced carbon. After sinking to the sea floor, such pollutants are in part oxidized by bacteria and other organisms, leading to a high rate of oxygen consumption at the sediment-water interface.
- Surface-active contaminants (e.g., water softeners, oil) reduce the rate of oxygen exchange between the atmosphere and the seawater by changing surface tension.

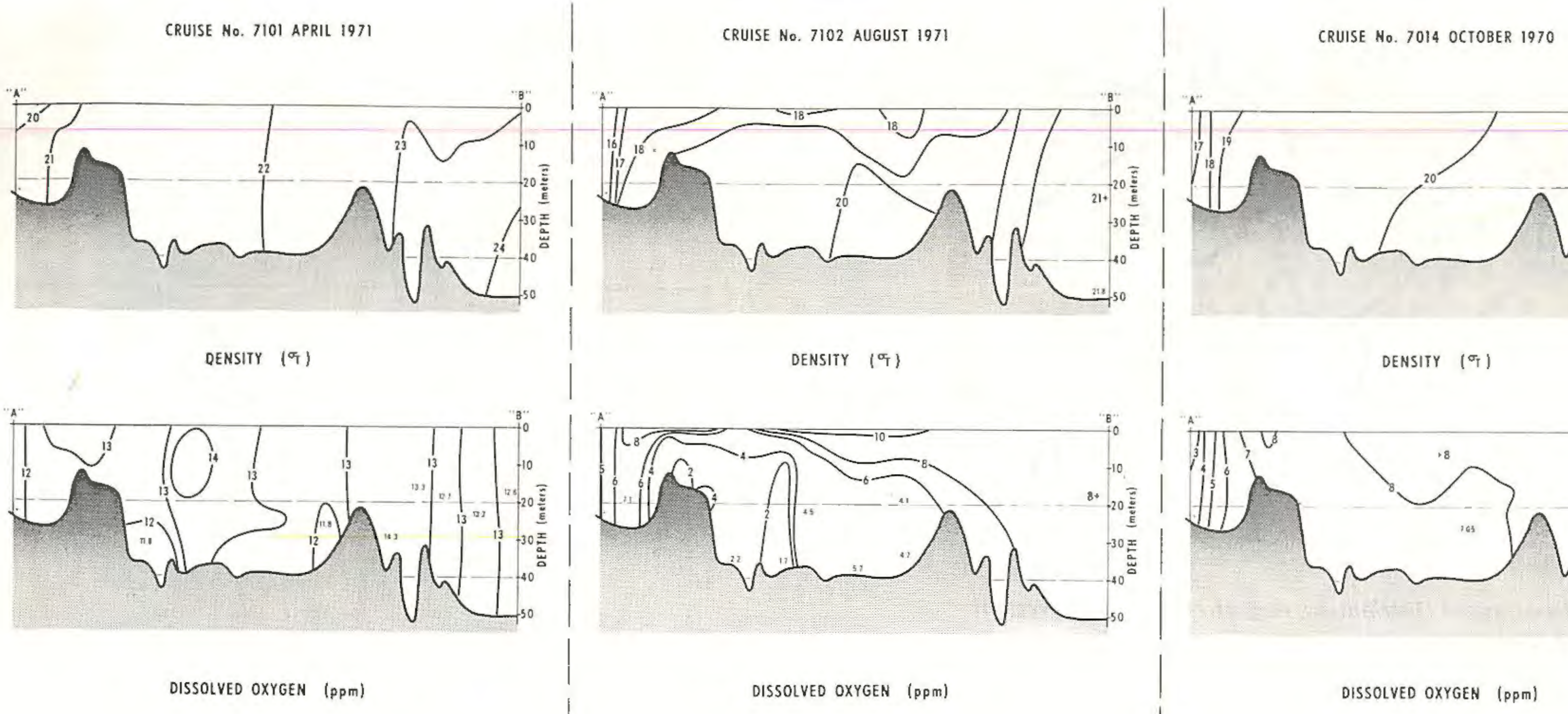
The seasonal change in the oxygen and density distribution is illustrated by a series of west-east sections of the Sound (Fig. 4.28), using data for April and August 1971, and October 1970. In April, the dissolved oxygen level is close to saturation everywhere. In August, some surface water is supersaturated and much of the bottom water, particularly in western parts of the Central Basin, is seriously depleted in dissolved oxygen. By October, the oxygen has increased to acceptable levels, except in the East River.

Thus, oxygen depletion is primarily a summer problem. These are the reasons: (1) in summer, the temperature is near its maximum and the solubility of oxygen in the water is therefore at its annual minimum (Fig. 4.27); (2) in summer, vertical density stratification is also at its maximum, reducing vertical mixing (Fig. 4.26); (3) the rate of respiration by bacteria and cold-blooded animals (e.g., fish) increases as the temperature increases. Therefore the rate of respiration is at a maximum in summer. In addition, many species of fish migrate into the Sound during the warm months and further increase the summer respiration rate.

This summer-season, western-Sound condition was extensively studied in August 1970 by the Marine Sciences Research Center (Hardy and Weyl, 1971). The surface distribution of oxygen saturation on August 7-8 is shown in Figure 4.29. Surface oxygen levels ranged from less than 25 percent of saturation in the East River to 200 percent or twice saturation near Execution Rock—an extreme variation.

The surface waters east of Great Neck (Fig. 4.30, B and C) also showed a high oxygen supersaturation. Large patches of brownish water—intense blooms of phytoplankton—had developed because of the high nutrient concentration and the stable density stratification. Their high rate of photosynthesis drove the dissolved oxygen up to twice saturation.

For three stations (A, B, and C), the variation of oxygen concentration with depth is shown in Figure 4.30 for August 9 and 13. Observations on August 9



CRUISE No. 7101 APRIL 1971

CRUISE No. 7102 AUGUST 1971

CRUISE No. 7014 OCTOBER 1970

DENSITY (σT)

DISSOLVED OXYGEN (ppm)

FIGURE 4.28 *Distribution of Density and Dissolved Oxygen*

See locator map on Figure 4.19.

show very low oxygen levels below the surface layer. By August 13, the amount of dissolved oxygen in the deeper water had increased significantly. This was undoubtedly due to a storm which blew through the area on August 11. The vertical density distribution for the two days is also shown. On August 9, there was a steep density gradient between 1 and 5 meters. By August 13, the region of steep gradient had been displaced downwards (A and C) or the gradient had been reduced (B).

These observations illustrate how much the dissolved oxygen concentration depends on the weather. Extended periods of calm weather during the summer can lead to high oxygen supersaturation in the upper few meters of the water and extremely low values of dissolved oxygen in the deep water. During periods of calm weather the rate of loss of the excess oxygen to the atmosphere is slow and the vertical density stratification reduces the rate of downward diffusion to the depleted underlying water. A brief period of strong wind can materially raise the oxygen level in the deeper water by enhancing vertical mixing.

Interpretation of the observational data is complicated because of the many variables that affect oxygen concentration. At any one point there can be changes due to tidal displacement, the daily illumination cycle affecting photosynthesis, and the previous weather, which determines the present density stratification. The studies to date do clearly indicate, however, that the waters in western Long

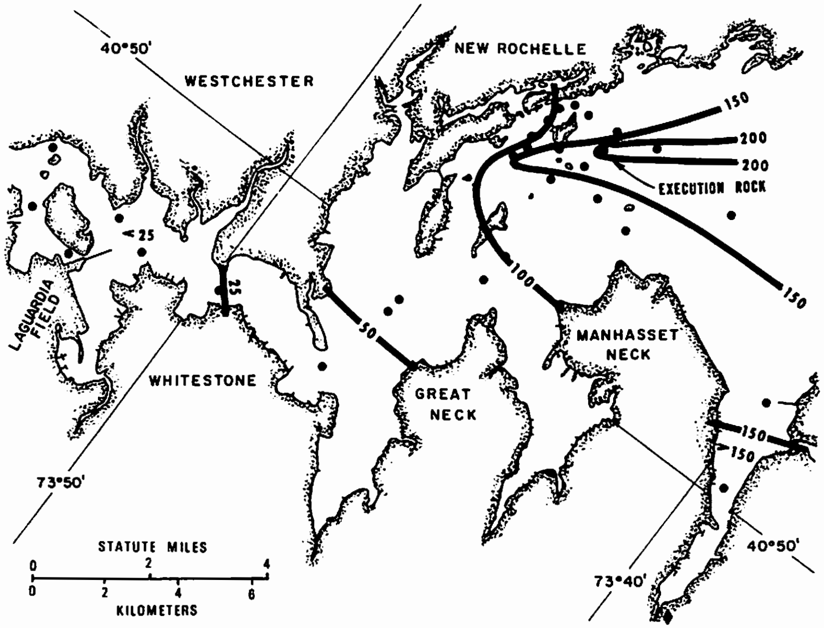


FIGURE 4.29 *Surface Oxygen Distribution, August 7–8, 1970, in Western Long Island Sound*

The numbers indicate the percentage of dissolved oxygen saturation.

Island Sound have dissolved oxygen levels in August that are well below the water quality standards established by the Interstate Sanitation Commission. Further work is required to determine the steps that would have to be taken to raise water quality to those standards.

INORGANIC NUTRIENTS

Animal life in the sea ultimately depends for its sustenance on photosynthesis by plants—the basis of the sea's primary productivity. Primary productivity depends not only on the presence of light and carbon dioxide for photosynthesis, but also on the availability in suitable molecular form of other essential elements, the inorganic nutrients. Of particular importance are the nutrient elements nitrogen and phosphorus, essential constituents of protein and other organic compounds.

Measuring the amounts and distribution patterns of nitrogen and phosphorus is considerably more complex than measuring salinity or oxygen, and the variables

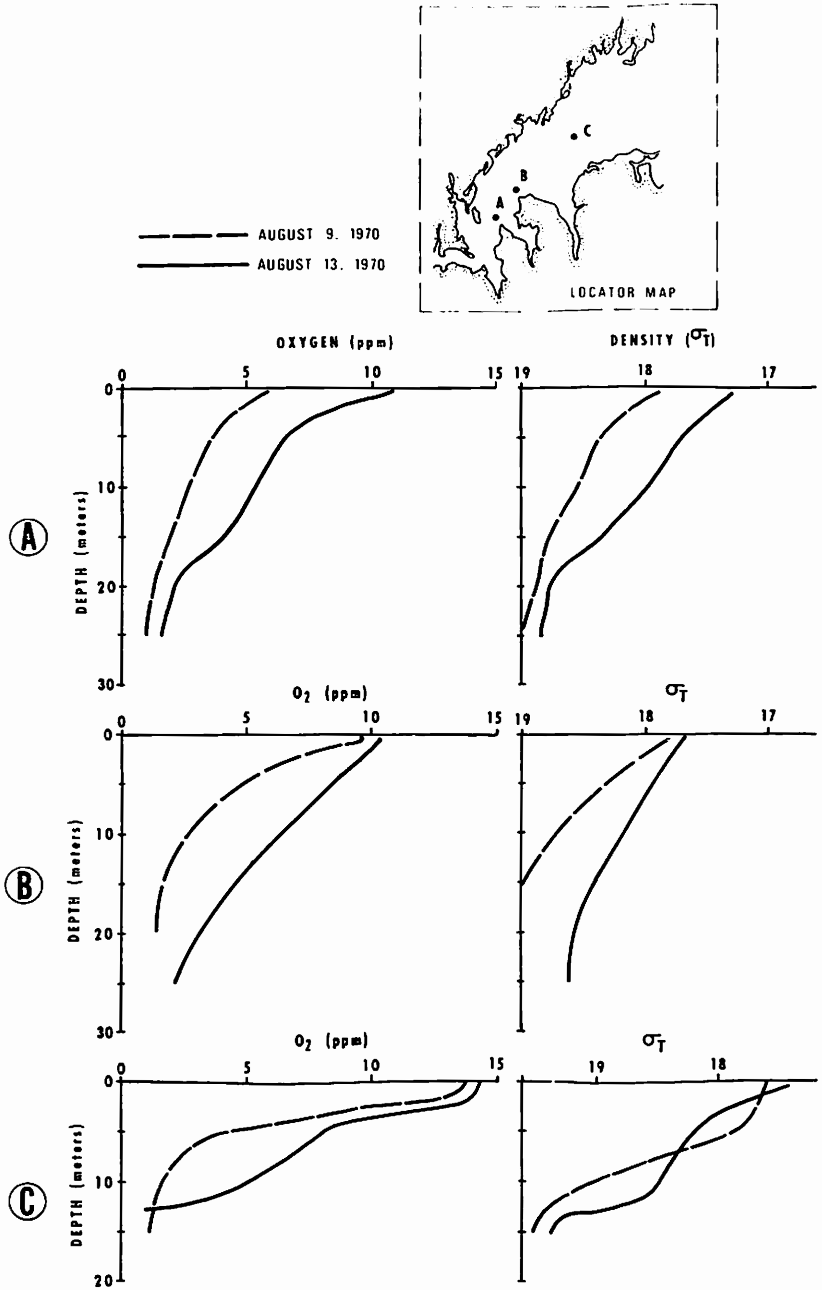


FIGURE 4.30 *Oxygen and Density in the Western Sound, August 9 and 13, 1970*

are more intricate. A nutrient budget, to begin with, must take into account the nitrogen and phosphorus tied up in organic matter as well as that in the water itself.

Harris and Riley (1956) have analyzed the nitrogen and phosphorus content of organic matter in collections of phytoplankton taken from Long Island Sound during various seasons of the year. Their results, shown in Figure 4.31, indicate that nitrogen and phosphorus account for approximately 7.5 percent and 1 percent respectively of the weight of the organic matter (dried phytoplankton).

Also indicated is the weight percent of chlorophyll, which is not a nutrient but a pigment responsible for photosynthesis. Whereas the content of nitrogen and phosphorus from January to August is relatively constant, the concentration of chlorophyll shows a small increase during February and decreases significantly during the summer. This decline is due to the greater intensity of sunlight, which permits the same rate of photosynthesis to be supported by a smaller quantity of pigment.

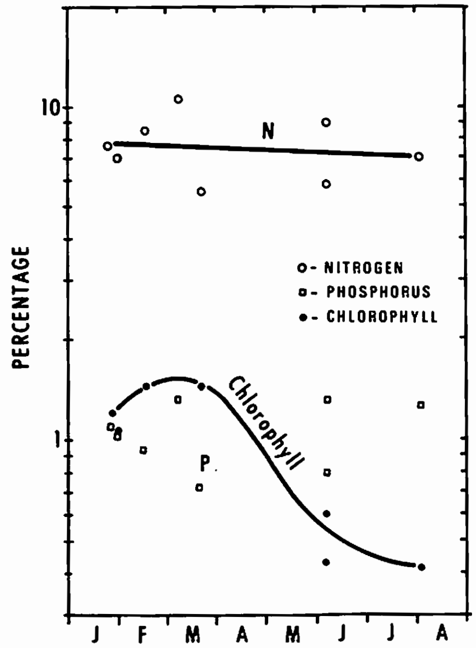


FIGURE 4.31 *Nitrogen, Phosphorus, and Chlorophyll Content of Phytoplankton from Long Island Sound*

Data from Harris and Riley (1956). Weight percent of organic matter.

Concentration of phytoplankton can be estimated by measuring the chlorophyll content of the surface water—the method used on Marine Sciences Research Center cruises. To arrive at a nutrient budget one must therefore know the nutrient-to-chlorophyll ratios. Figure 4.32 shows the nitrogen/chlorophyll

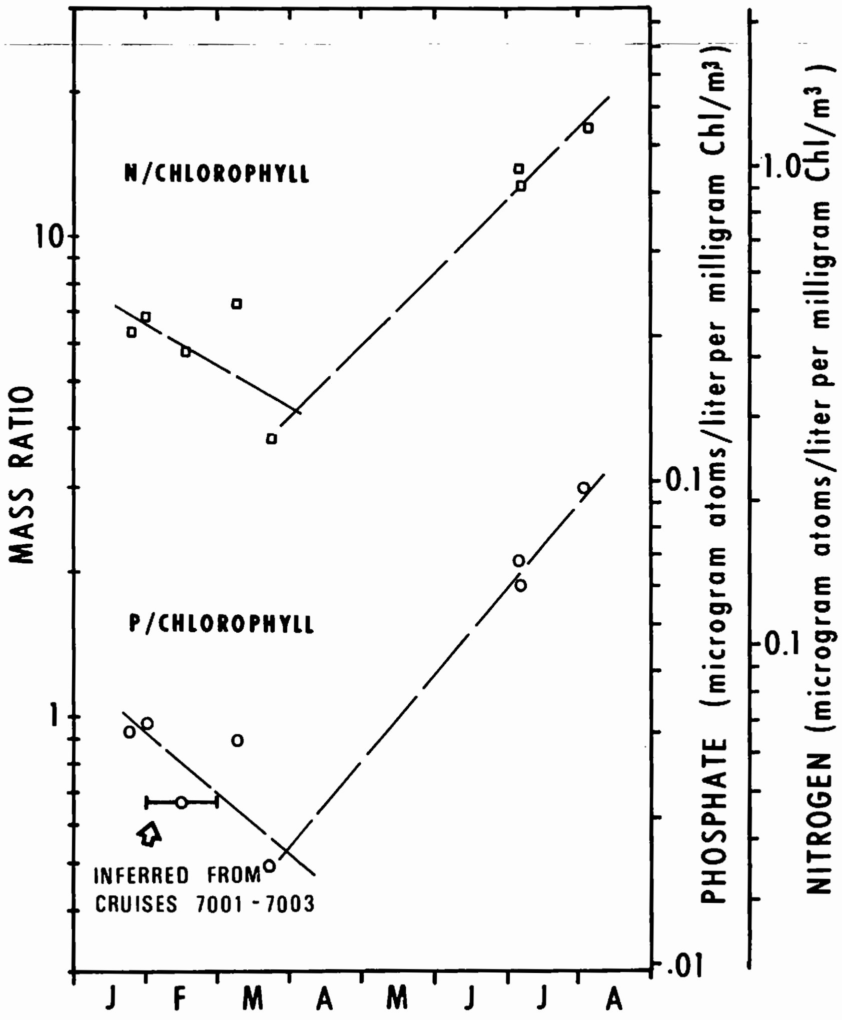


FIGURE 4.32 *Nutrient/Chlorophyll Ratios in Phytoplankton*

Data from Harris and Riley (1956).

ratio and phosphorus/chlorophyll ratio calculated from the data of Harris and Riley. These ratios show a significant seasonal variation, primarily due to the seasonal variation in chlorophyll concentration discussed above.

A number of very large secondary sewage treatment plants are located along the East River (see locator map in Fig. 4.34). They discharge large quantities of phosphorous and nitrogen compounds into that body of water. From there, the nutrients are dispersed into the western end of Long Island Sound and into lower New York Harbor. The sewage plants and their characteristics are listed in Table 4.3.

TABLE 4.3 *East River Sewage Plants, 1971 (all secondary treatment)*

Plant	*Discharge (in millions of gallons/day*)*	*People Served (in millions)*
Tallmans Island	59.7	0.25
Hunts Point	145.9	0.77
Bowery Bay	105.3	1.00
Wards Island	245.5	1.47
Newtown Creek	169.0	0.5
Total East River	725.4	4.0

Source: Interstate Sanitation Commission.
*A million gal/day = .044 m^3/sec; 725 million gal/day = 32 m^3/sec.

Unfortunately, we have no data on the nutrient content of these discharges; however, we can make estimates based on data for other cities. A National Academy of Sciences study (1970) gives estimates on the combined discharges in 1968 from Los Angeles County and the City of Los Angeles. The total discharge was 700 million gal/day for a population of about seven million. The daily discharge rate amounted to 165 tons of total nitrogen and 100 tons of phosphate. Converted to parts per million, concentrations were 57 ppm nitrogen and 34 ppm phosphate. In terms of atoms of nitrogen and phosphorus, the concentration of sewage effluent amounts to 4050 and 360 microgram atoms per liter respectively.

On an atomic basis, we find that the Los Angeles discharge of nitrogen is about 11 times that of phosphorus, not greatly different from the 7.5-to-1 ratio found in phytoplankton. Other references cite significantly smaller nitrogen-to-phosphorus ratios. Determining ratios and weighing their reliability is complicated by the fact that nitrogen in sewage effluents occurs in a number or chemical forms, some of which are not analyzed for by one investigator or another. Table 4.4 lists concentrations given by Weinberger *et al* (1966).

TABLE 4.4 *Nutrient Species and Concentration in Secondary Sewage Discharge*

Species	*Formula*	*Molecular Weight*	*In Secondary Sewage* *ppm*	*In Secondary Sewage* *microgram atoms/liter*
urea	NH_2CONH_3	60.06	not analyzed	
nitrite	NO_2^-	46.01	1	22
nitrate	NO_3^-	62.01	15	242
ammonium	NH_4^-	18.03	20	1109
total nitrogen	N	14.01		1373
phosphate	PO_4^{3-}	95.03	25	263
Ratio total nitrogen/phosphate				5.2

Source: Weinberger *et al* (1966).

Because of the complications of nitrogen chemistry, our discussion of nutrients will concentrate mainly on phosphate. At the end, we will present our data for nitrogen and indicate some of the problems requiring further study.

Nutrient Distribution and Phytoplankton Blooms

In Long Island Sound, the microscopic unicellular plants that float in the water undergo a population explosion during the summer and winter. The increase in plant density is accompanied by a decrease in the nutrient content of the water, as phosphorus and nitrogen are incorporated into the organic matter making up the plants. To study the relationship between the winter flowering of phytoplankton and the nutrient concentration, two cruises went out in early 1970, in January and in February (Hardy and Weyl, 1970). Data from these cruises, combined with cruise data from January 1969 and April 1971, give a general picture of the overall variation in space and time of the nutrient distribution.

Estimating the concentration of plants by measuring the concentration of the plant pigment chlorophyll, as mentioned above, investigators on the first cruise (7001, January 28–29) found chlorophyll levels in the water of the western Sound to be only 2.5 milligrams/m^3. By February 25 (Cruise 7003), the chlorophyll content of the water had increased to over 30 milligrams/m^3. During the same period the concentration of inorganic phosphate went down. Comparing the loss of phosphate with the gain in chlorophyll for a series of locations near the western end of the Sound yields an inferred phosphorus-to-chlorophyll ratio of 0.67 in phytoplankton, a ratio in close agreement with the data of Harris and Riley (Fig. 4.32).

Because of the large horizontal variations in nutrient content in the western end of the Sound at any specific location, one can expect significant changes due to the tidal oscillations. Unfortunately, because of limited resources, it was not possible at the time to study these temporal variations. However, the tidal effect in the data can be partially overcome by characterizing the water by its salinity rather than by the location from which the sample was taken. Salinity provides an independent variable that moves with the water mass during its tidal displacement.

Figure 4.33 is a graph of the phosphate concentration against salinity. The phosphorus content of the plants themselves was a very small fraction of the total during Cruise 7001 in January, but had become a significant fraction during Cruise 7003 in February. Data for January of the previous year (Cruise 6901, which covered the entire length of the Sound) show the same small phosphorus amounts in plant cells.

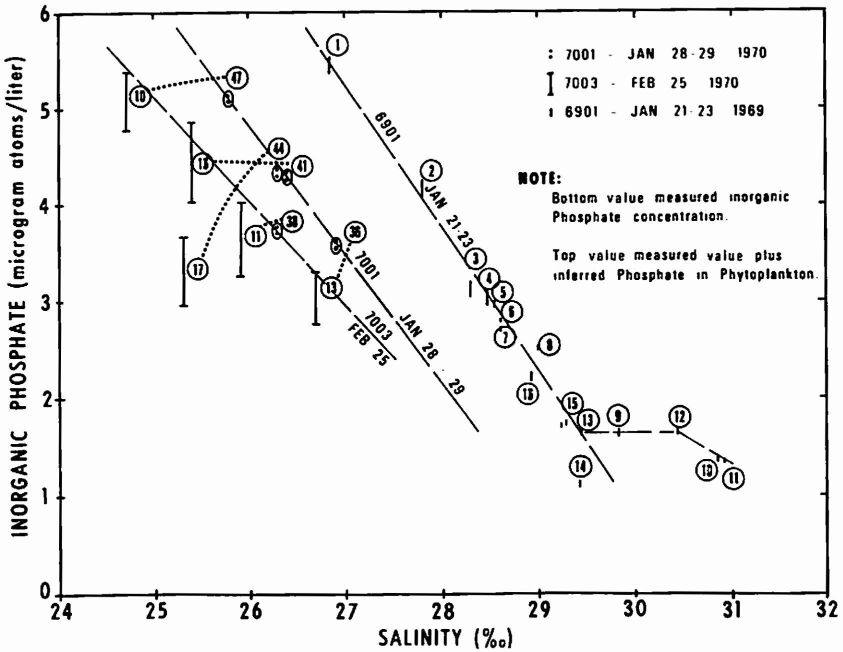


FIGURE 4.33 *Phosphate Concentration and Salinity*

Double symbols are used for phosphate: the lower value represents the measured concentration in the water, whereas the top value includes the inferred phosphorus content of the phytoplankton, obtained by using the phosphorus/chlorophyll ratio. Comparable locations on Cruises 7001 and 7003 are linked with a dotted line.

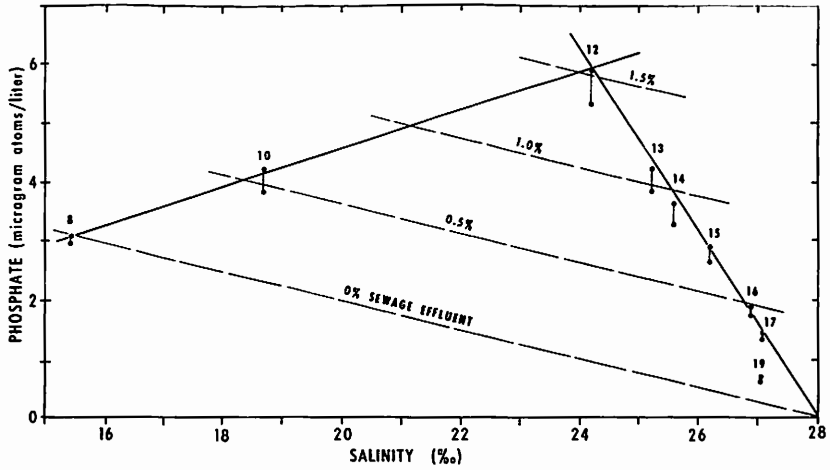
The three lines of data show that, except for the easternmost stations (salinity greater than 29.5$^0/_{00}$), the phosphate content of the water is a linear function of the salinity, that is, the lower the salinity the higher the phosphate. This linear trend in the total phosphorus content is what one expects if the waters of the central Sound are in fact a mixture of low-salinity, high-phosphate water from the west with high-salinity, low-phosphate water from the east. This simple mixing model breaks down in the eastern portion of the Sound.

Further nutrient data acquired during Cruise 7101 on April 9, 1971 encompass the Upper Bay of New York Harbor, the East River, and the western end of Long Island Sound. The phosphate-salinity relationships, including the amount of phosphorus tied up in the phytoplankton, are shown in Figure 4.34, along with a locator map. The data allow a rough estimate of the contribution of sewage effluents to the waters of western Long Island Sound, as follows: The total phosphorus values, plotted against salinity, fall on two straight lines that intersect in the upper East River at a salinity of 24.2$^0/_{00}$, and at a phosphorus content of 5.9 microgram atoms/liter. We can explain these phosphorus-salinity relationships by assuming that we are dealing with a mixture of three hypothetical water types: water from the Upper Bay, a hypothetical Long Island Sound water containing no phosphorus and having a salinity of 28$^0/_{00}$, and effluent water from the sewage plants located on the East River. The sewage effluents will have essentially zero salinity and we shall assume their phosphate content at 300 microgram atoms/liter, intermediate between the Los Angeles and the Weinberger data. With these assumptions, the water at Station 12 consists of 1.54 percent sewage effluent, 26.7 percent water from the Upper Bay, and 71.8 percent Long Island Sound water. The percent of sewage effluent at the other stations is estimated from the diagram and shown with dotted lines on the locator map (Fig. 4.34).

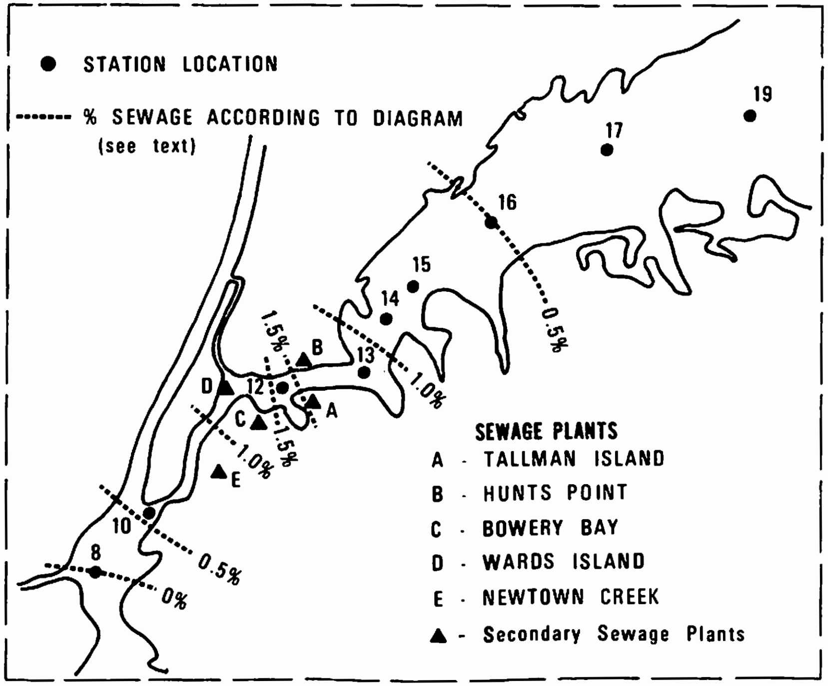
The true percentages of sewage will be slightly higher or lower than the estimates above because the phosphate content of the sewage differs from the assumed value of 300 and because the water in the Upper Bay (Station 8) already contains some sewage. If all the phosphate in the water at Station 8 were due to sewage, then the water at Station 12 contains 5.9/300 = 2.0 percent sewage, not 1.54 percent. On the other hand, we have slightly overestimated the effect of sewage since we have assumed mixing with a hypothetical Sound water of zero phosphate content.

These estimates, while not definitive answers, do show the proportion of sewage effluents in the waters of western Long Island Sound; the highest percentages

FIGURE 4.34 *Phosphate-Salinity Relationships in Western Long Island Sound and the East River, April 9, 1971*



LOCATOR MAP *(Cruise 7101)*



correspond, not surprisingly, to the location of clustered sewage treatment plants on the East River. To refine the estimates will require more detailed data on phosphate and chlorophyll distribution, on their ratio in the phytoplankton, and analytical data on the phosphate content of the sewage effluents.

The annual variation of chlorophyll and phosphate is shown for three locations in western Long Island Sound in Figure 4.35. The two blooms, winter and summer, are dramatically evident in the chlorophyll data. At all times of the year, the inorganic phosphate content of the water decreases from Throgs Neck in the west to Cable and Anchor Reef in mid-Sound north of Eatons Neck. The chlorophyll content, however, tends to increase from Throgs Neck to Execution Rock and then to decrease once more to the east. The annual cycle of chlorophyll varies from year to year; Figure 4.35 masks this feature somewhat by combining data

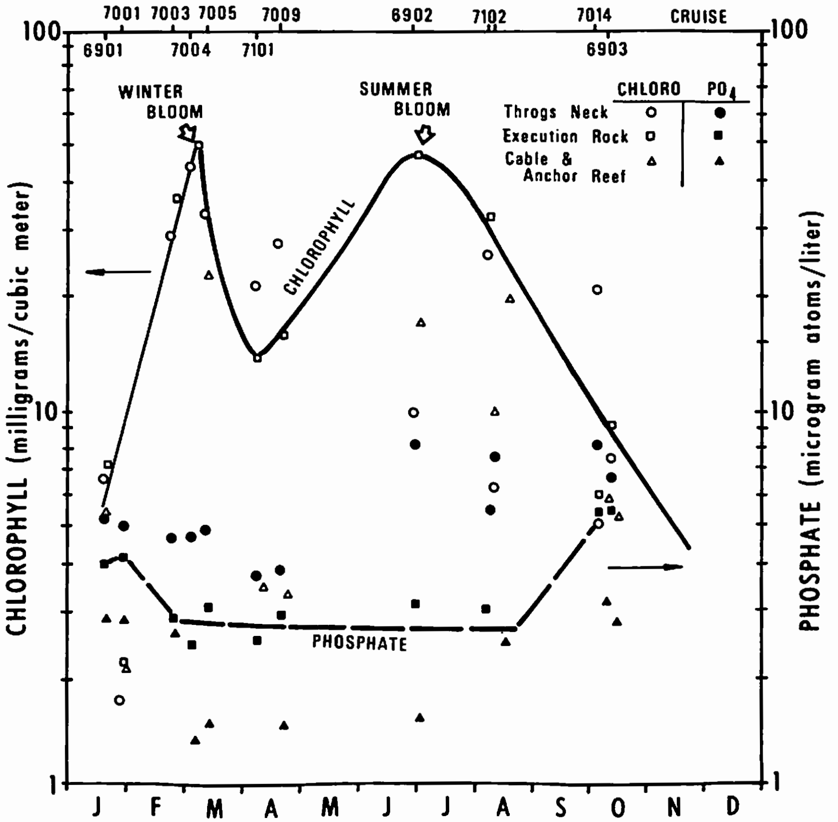


FIGURE 4.35 *Annual Variation of Chlorophyll and Phosphate, Western Long Island Sound*

from three years (1969, 1970, 1971). Chlorophyll concentration shoots up during the winter bloom in February, followed by a decline, with a second peak during the summer. Observations by Conover (1956) during 1952-54 show a winter bloom between mid-February and early March and a summer bloom in late August of 1952 and mid-June of 1953. It is important to remember, when looking at the chlorophyll curve, that the amount of actual organic matter per unit chlorophyll increases by a factor of four from March to August: although the summer bloom has lower chlorophyll values than the winter bloom, the plant biomass is greater. As we said above, the sun's intensity in summer permits the same rate of photosynthesis to be supported by a smaller quantity of pigment.

Figure 4.35's complex data clearly show the need for detailed study and thoughtful conclusions regarding the space-time variation of phytoplankton in Long Island Sound.

Finally, let us examine the distribution of nitrogen. Figure 4.36 is a salinity-nitrogen plot from the data of Cruise 7101, similar to Figure 4.34. Unfortunately, nitrate (NO_3^-), a major nitrogen species, was not determined during that cruise. During Cruise 7009 in April of the previous year, however, data for nitrate (NO_3^-) and ammonia (NH_3) for the western Sound produced an average ratio of 0.63, with a range from .98 to .41 (after eliminating one station with an anomalously high value of 2.7). Assuming that the sum of $NH_3 + NO_3^-$ is equal to 1.63 times the determined value for NH_3, and knowing that the ratio of microgram atoms N/liter to grams of chlorophyll/m^3 is about 0.3 for that time of year (Fig. 4.32), we obtain the data shown in Figure 4.36. If we ignore the anomalously large nitrite (NO_2^-) contribution at Station 8 in the Upper Bay, we obtain mixing relationships not too different from phosphate in Figure 4.34, that is, nitrogen and phosphorus follow about the same mixing pattern. The nitrogen values are approximately 10 times the phosphorus values and nitrogen tends to disappear somewhat more rapidly than phosphorus toward the east. Whereas the phosphorus mixing curve in the Sound indicated an admixture of zero phosphorus water with a salinity of $28^0/_{00}$, the corresponding salinity for zero nitrogen is between $26^0/_{00}$ and $27^0/_{00}$. Further observations are clearly needed to reconcile the nitrogen and phosphorus mixing models. Unfortunately, incomplete analysis prevents accurate calculation at this time of the total nitrogen/phosphate ratio. Roughly, this ratio ranges from 10 to 3.

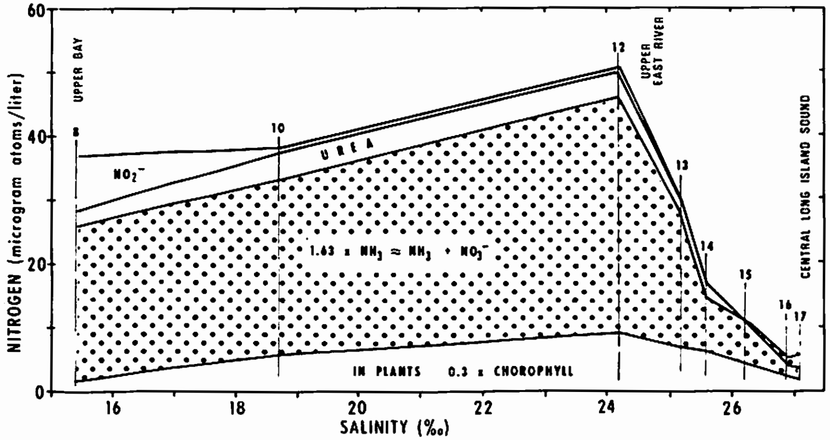


FIGURE 4.36 *Nitrogen-Salinity Relationships in Western Long Island Sound and the East River, April 9, 1971*
See locator map in Figure 4.34.

The annual variation of the nitrogen species near Throgs Neck and Cable and Anchor Reef is shown in Figure 4.37. Due to the input of nutrients from the East River, the concentrations are always highest near Throgs Neck. The nitrogen species decline in concentration in spring. More detailed time series are required to work out the seasonal cycle.

Several severe complications are inherent in working out a nitrogen budget and nitrogen species distribution.

- The different nitrogen species are utilized at different rates by the phytoplankton.
- Bacteria transform one nitrogen species into another.
- Nutrient/chlorophyll ratios in the nutrient-laden waters of the western Sound may differ significantly from the values determined by Harris and Riley in the central Sound.
- Nitrogen's marked seasonal variability—much greater than that of phosphorus (Fig. 4.35)—suggests that nitrogen may be a growth-limiting nutrient during part of the year.
- In addition to nitrogen supplied to the water by sewage discharges, the atmosphere may be a significant source. The Los Angeles study (NAS 1970) gives a daily emission rate of 165 tons/day of nitrogen in sewage and a surprising 950 tons/day of nitrogen oxides into the atmosphere—mostly from automobiles and trucks. The transfer of this atmospheric pollutant into the local waters depends critically on the weather, and provides a highly variable and possibly important additional source of nitrogen nutrients.

SUMMARY

The waters of Long Island Sound are strongly affected by the semidiurnal lunar tide, which approximates a standing wave. The water temperature undergoes a large annual variation from near-arctic conditions in winter to subtropical

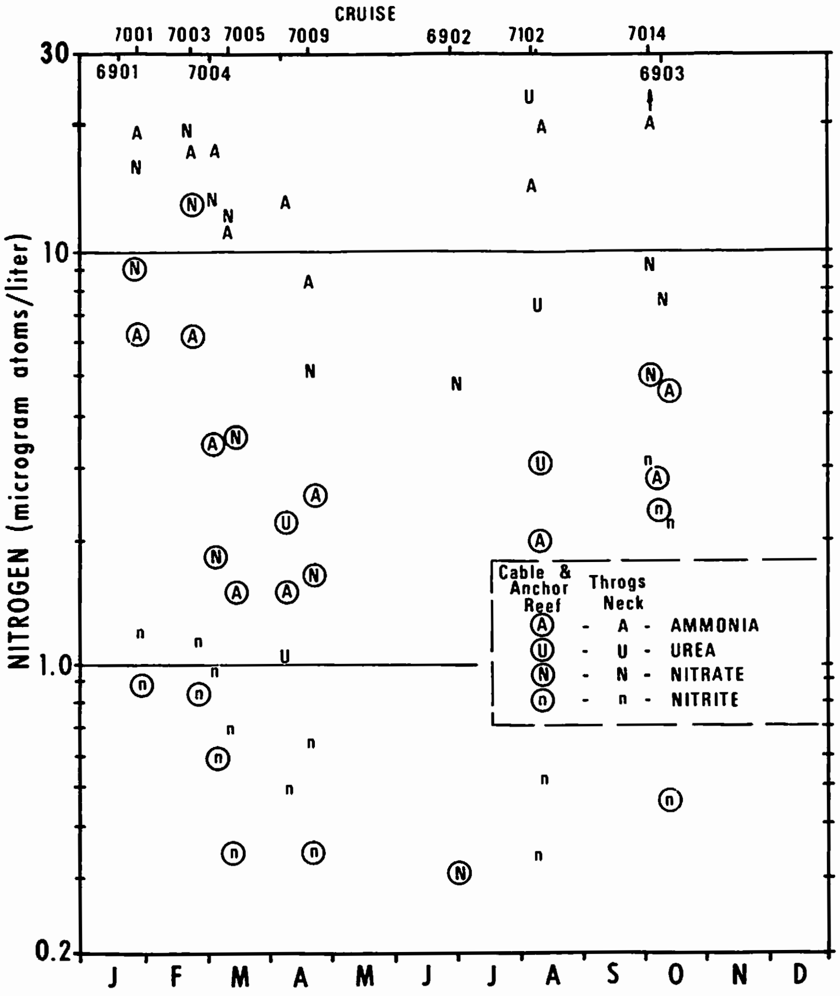


FIGURE 4.37 *Annual Variation of Nitrogen Species, Western Long Island Sound*

temperatures in summer. The salinity of the Sound increases significantly from west to east, and the average salinity varies with the rate of river discharge. The water is well mixed vertically in winter and becomes stratified in summer, particularly during long periods of calm. In winter the dissolved oxygen concentration differs little from saturation. In summer, however, particularly in the west, the surface waters become supersaturated due to intense phytoplankton blooms, while the deeper waters are depleted in dissolved oxygen. There is a strong negative correlation between water quality and recreational use. The nutrient elements nitrogen and phosphorus are greatly enriched in western Long Island Sound, due to the discharges of secondary sewage treatment plants in the East River. There are two phytoplankton blooms a year, in winter and in summer. The densest blooms occur not where the nutrient levels are at their maximum—in the East River—but rather, further east near Execution Rock.

Conditions in the Sound change significantly, not only with the seasons but also from year to year, due to variations in river discharge. On a much shorter time scale, significant variations occur in summer in the western end of the Sound in response to changing weather conditions. As a result of this variability, adequate studies of long-term trends in the water quality of Long Island Sound will require detailed observations over at least a decade.

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Part Two

Administrative Aspects

5 Uses and Misuses

INTRODUCTION

The human impact on basin, shore, and water profoundly affects the complex whole. To the natural or scientific descriptors of the system, e.g., sediments, water and salt budgets, and beach profiles, should be added man's uses and abuses of the marine environment. The real drama is in understanding the day-to-day interactions that take place on, in, and around this marine environment as the result of burgeoning urbanization.

Ever-increasing numbers of people and ever-expanding uses of the water affect, and are affected by, the presence and condition of the Sound. It is reasonable to assume, for example, that future use of the shoreline for fishing, swimming, and tourism is in jeopardy. The greater the population, the greater its recreation demand, and the greater the impact on the natural resource and its capacity to fulfill the demand. Present trends that spoil the natural environment can be offset, however, by adopting sound conservation practices. Conservation is the key to maintaining and enhancing the marine environment. The introduction to a report to the Regional Plan Association of New York points this out:

> An . . . instance of dangerous tampering with nature concerns the wetlands. These are the key to an adequate water supply, the basic component in a natural system of flood control, and a vital biological element in marine productivity. . . .Without its tidal marshes, Long Island's fishing industry would be practically non-existent. Yet we permit our swamps, marshes, and bogs to be dredged, drained, filled and polluted with the mistaken notion that man-made works are somehow superior to these biological natural features which subtly perform a great, continuous task free of any capital or maintenance charge.[1]

The essence of conservation is *ecological balance,* the totality of relations between organisms and their environment. It is true that as the culture has become urbanized, people have given little attention to conservation—perhaps partly because overwhelming technological achievements tended to dwarf other considerations. When the nation's prime objectives were "taming the wilderness" and converting natural resources into material goods—buildings, bridges, roads—the tradition that was developed was "man against nature." Natural laws cannot be violated with impunity. When the natural balance is upset by, for example, introducing a new predator, by controlling pests chemically, or by removing ground cover, some segment of natural life will suffer. If the resulting imbalance is severe enough, the entire ecological complex can disintegrate.

Man's inexpert tampering is evident: air and water pollution, potable water shortages, loss of arable lands, drastic reduction of some fish and shellfish, and disappearance of recreation areas.[2] It is from our sheer ignorance of land-water-air interrelations, as the late Aldo Leopold, one of the nation's leading conservationists, made clear:

> We know that engines and governments are organisms; that tampering with a part may affect the whole. We do not yet know that this is true of soils and water. Thus men too wise to tolerate hasty tinkering with our political constitution accept without qualm the most radical amendment to our biotic constitution.[3]

It is not merely the wild community of plants and animals that stands to gain by intelligent consideration of ecological balance. The human community also stands to benefit. Man is an animal; ergo, man should conserve the natural environment for his own well-being. Experimentation has shown that animal species survive to their maximum effectiveness when they utilize approximately 50 percent of their natural surroundings.[4] Overutilization causes deprivation, waste, and ultimate decline. Of course, because of cultural evolution, man differs from other organisms in his ability to adapt; but a healthy human community is possible only in a healthy environment. For example, protection of water supply and air from pollution is basic to sound planning. This is as true for the suburbs as for the largest city. Commenting on the deleterious effects of city life, Lewis Mumford noted the need for preserving natural environments:

> The rhythm of the seasons disappears, or rather, it is no longer associated with natural events, except in print. Millions of people grow up in this metropolitan milieu who know no other environment than the city streets: people to whom the magic of life is represented, not by the miracles of birth and growth, but by placing a coin in a slot and drawing out a piece of candy or a prize. This divorce from nature has serious physiological dangers that the utmost scruples of medical care scarcely rectify. For all its boast of medical research, for all its real triumphs in lessening the incidence of disease and prolonging life, the city must bow to the countryside in the essentials of health: almost universally the expectation of life is greater in the latter, and the effect of deteriorative diseases is less.[5]

Yet ecological balance is among the least understood and least applied considerations in the planning process.

The conservation of a marine environment favorable to wildlife can also be justified in economic terms favorable to people. There is no question but that marine-based activities strongly affect the whole economic picture of the Sound region—and have done so from pre-colonial times to now. The 1971 value of marine recreation industries alone is estimated at more than $700 million[6] for just Long Island. The same pollution controls necessary to make boating and swimming enjoyable can serve to ameliorate water conditions for fish and shellfish. What *is* the question is the size, stability, vitality, methods, and mutual tolerance of the activities that constitute the Sound's marine economy. Specifically, in view of past performance, present limitations, and future potential, what is the status of the marine economy? The answers to all phases of this question are not completely available, but partial information, set forth in this chapter, does at least indicate reasonable trends—some up, some down.

Certain activities have been more carefully documented than others, either because they are intrinsically more susceptible of analysis or because government agencies are concerned with their regulation or operation. For example, a tremendous amount of work about and for the fishing industry, nationally and locally, has been carried out by the United States National Marine Fisheries Service and the New York State Department of Environmental Conservation. This includes annual record-keeping of the species, location, weight, and value of fish caught; research into better methods of operation ranging from fish production to fish processing; and the operation of hatcheries for production purposes.

Much less quantitative information is available about other activities: perhaps they are not unionized, or sell a service rather than a product, or consist mainly of individual unregistered entrepreneurs who run their businesses on a cash basis, or are activities not regulated or evaluated in a consistent fashion by any level of government. It is difficult to assess the relative importance of these activities. A good example is tourism, whose economic importance for Long Island Sound is measured in millions of dollars per year, but whose statistics are, to put it mildly, unevenly distributed.

Nevertheless, one thing is clear, a common thread running through all phases of the marine economy: *pollution damages every industry.* Sound conservation practices obviously will help individual and collective economic viability.

When one begins to look at how the coast is used, and tries to do it without bias—that is, without starting off as a "conservationist" or any other "-ist" except perhaps "pragmatist"—two things quickly become evident. First, that certain conflicts are built in between one use of water or shore and another use; competition is inescapable. There's just so much shore and so much water, and no more. Second, that pollution has a directly damaging impact on shellfish and recreation industries, and an indirectly damaging impact on most marine activities. A sound marine economy rests on a properly conserved marine environment. The loss of wetlands, for whatever reasons, results in attrition for the entire ecosystem. A substantial improvement in the marine environment could mean an increase in commercial and sport fishing, tourism and recreation, shellfish production, and boating of at least an additional $200 million to $250 million annually.[7] Full development of Long Island Sound's marine potential could yield a total value many times that amount. Conversely, a substantial deterioration of the environment could lead to a corresponding decline of the economy.

If conservation of the natural environment is so important, one might reasonably ask, "What is the problem? Why aren't good practices put into force?" A fast inventory of uses of the marine environment brings into focus the fundamental fact that each use by itself can individually be validated; conflict arises when one use impinges on another. For example, the desire to maintain wetlands conflicts with other uses, such as sand and gravel mining, solid waste disposal, or residential development. From an economic point of view these are legitimate competing uses. Yet one must assess full economic costs, including social costs like public taxes for pollution control, in order to choose intelligently among competing uses.

To make use of the marine environment one must have access to the sea. The access required depends on use, and ranges from deep-draft harbors to the natural shoreline. Use of the sea can be passive, as in *transportation* or *recreation.* Or it can consist of *extraction* from the sea or *insertion* into the sea. An extracted product may be a food for man or animal derived from the biosphere, or it may be a mineral derived from sea water, from the sea floor, or from beneath the sea floor. Much of the waste from our economy ends up being "inserted" into the sea, either directly or by secondary transport through rivers and ground water. Liquid effluents dumped in the sea include industrial wastes, sewage outflows, and oil spills. Solid wastes are, for example, sewage sludge, chunks of cement, and dredge spoils. In addition, coastal waters receive waste heat from industry, primarily from electric generating plants. The flow pattern of each of these four major use categories—recreation, transportation, extraction, and insertion—is summarized in Figure 5.1.

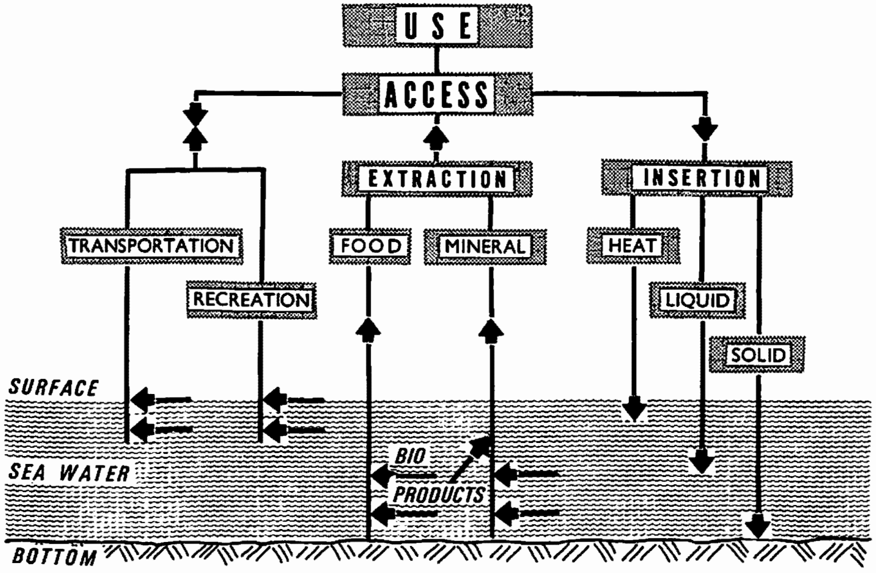

FIGURE 5.1 *Access and use of the sea*

RECREATION

Fewer working hours and increasing prosperity have led to increased demands for outdoor recreation. Recreation stands fourth on the list of expenditures, after food, housing, and transportation.[8] At the same time urban problems, particularly the "hot summer" phenomenon, draw attention to the need for increased recreational facilities for the urban poor. Both salt water and fresh water are, of course, natural playgrounds. In 1968, 112 million Americans participated in marine-oriented recreation activities, and spent $14 billion.[9] The numbers are climbing much more rapidly than the population as a whole.* The demand for water recreation is soaring.

Water recreation ranges from a casual stroll on the beach to a vacation at an ocean resort or a world cruise. Swimming is the number one outdoor recreational activity around Long Island Sound,[10] and of all Americans over twelve, 28 percent participate in fishing, 23 percent participate in boating, and 7 percent waterski. It is no surprise that an important part of Long Island Sound's economy is providing recreational goods and services, especially marine-oriented. Such activities as boat building, sales and services of fishing gear and boat rentals, party boat operations, swimming and diving equipment sales, and the rental of housing to vacationers are all strongly growing business areas.

This marine-oriented business depends directly upon the survival of a healthy marine environment for its prosperity. The growing number of people participating in coastal and offshore recreational activities places increasing pressure on our limited coastal resources. Already deteriorating due to industrial development and pollution, the coast is now sustaining further impact from the recreational activities themselves and from the commercial developments to service them.

Here we face the crux of the problem, as we saw before: conflict among competing uses. Recreational use of the shoreline conflicts with other uses and can actually change the marine environment. Parking lots, boat ramps, and docking facilities alter the shoreline. Beachfront owners and commercial resorts wish to limit access to their shoreline, whereas the public desires free access. People walking around or camping may destroy the delicate plant life in dune areas, salt marshes, and tidal pools. Commercial collecting of live organisms for sale to tourists may devastate natural populations of organisms. Power boats release oil and gas. Raw sewage from boats, beach facilities, and coastal resorts is often discharged straight into the water with no treatment. Sport fishing may deplete some species past the point of maximum sustainable yield and so lead to decreasing resources. Recreational boating does not mix well with commercial shipping.

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*It is projected that swimmers alone will increase by 72 percent between 1965 and 1980, while population as a whole will increase by 29 percent.

Playland Recreation Area, Westchester County, New York

On top of all that is the heavy demand for safe and clean swimming areas: remember that swimming is the region's most popular outdoor sport.

Swimming

It is important to note that there is a certain amount of conflict or competition even within one use category. Swimmers, for example, must stay in a separate area from power boating for their own safety; fishing is incompatible with water skiing. Different uses have different maximum densities for safe enjoyment. The order of decreasing permissible density runs from sunbathers to swimmers to fishermen in slowly-moving boats to waterskiers. As the density of users increases, the problem of safety becomes more acute.

How many sunbathers can a mile of beach accommodate? Some estimates say about 2,000.[11] On a hot Saturday or Sunday at Coney Island, however, it's more like 300,000 per mile, or about one million people for the 3.4 miles of beach. At that density, the total population of the United States could be accommodated at the presently existing public beaches at one time, providing the mass transportation system to carry them there were available, and provided they didn't mind the crush. The waterfront actually available for public recreation varies greatly from state to state. Michigan and Oregon have about 10,000 inhab-

TABLE 5.1 *Physical Characteristics and Ownership of the Long Island Sound Shoreline (in miles)*

Reach	*Total Shoreline*	*Beach*	*No Beach*	*Non-Critical Erosion*	*Critical Erosion*	*Public Ownership*	*Private Ownership*
North Shore of Long Island, Suffolk County, New York	87	80	7	0	87	16.2	70.8
North Shore of Long Island, Nassau County, New York	16	10	6	7	9	3.6	12.4
Shore of New York City along Long Island Sound, Westchester County to Throgs Neck	18	9	9	18	0	11	7
Westchester County, New York along Long Island Sound	41	4	37	41	0	9	32
Connecticut (Fairfield, New Haven, New London and Middlesex Counties)[a]	270	145	125	240	25	55	215
Total, Long Island Sound	432	248	184	306[b]	121	94.8	337.2

Source: U.S. Army Engineer Division, North Atlantic Corps of Engineers, *National Shoreline Study, Regional Inventory Report, North Atlantic Region* (New York, 1971), Vol. I, p. 102.

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[a] Includes Fishers Island

[b] Includes 5 miles of non-eroding beach in Connecticut

View of Orchard Beach, Bronx, N.Y., looking north itants per mile of public shore; Louisiana and Virginia have more than 1 million inhabitants per mile. New York and Connecticut each have about 16,000 inhabitants per mile of public coastline.*

Approximately 57 percent of Long Island Sound's linear shoreline of 432 miles can be considered beach area (see Table 5.1). An estimated 16 million visits are made annually to these beaches, with heavier usage along the Connecticut shore. Sunken Meadow and Wildwood State Parks on Long Island account for 2.2 million visits (see Table 5.2). Figure 5.2 depicts the location of the major public beaches. Annual sales of swimming, diving, and beach equipment is an important business to the Long Island Sound area, totaling $2 million to $3 million.[12]

The demand for public swimming facilities is projected to double over the next decade and perhaps triple by the turn of the century.[13] This could generate an economic return in excess of $40 million total for the Long Island Sound region—if rational compromises among competing uses are reached and if deterioration of water quality is checked. To supply beach facilities for the multiplying demand means acquiring land and providing transportation facilities to bring the people to the beaches. Because of the high user density permitted by swimming and sunbathing, beach facilities could be provided for all potential users.[14]

TABLE 5.2 *Number of Persons Per Year Visiting Beaches at Various Parks in Long Island Sound Region, 1970*

Orient Beach State Park	111,300
Wildwood State Park	434,200
Sunken Meadow State Park	1,766,700
Caumsett State Park	undeveloped
Local government parks, Suffolk County	70,000
Local government parks, Nassau County	600,000
Orchard Beach	3,017,400
Glen Island Park	135,000
All Connecticut State and municipal beaches	10,000,000
Total	16,134,600

Source: U.S. Army Engineer Division, North Atlantic Corps of Engineers, *National Shoreline Study, Regional Inventory Report, North Atlantic Region* (New York, 1971), Vol. I, passim.

Boating

The space required for boating is much greater than that needed for swimming. Docking or launching facilities must be provided on the shoreline, as well as parking spaces for cars and boat trailers. The number of boats that can safely use nearshore water is limited; as more people become affluent enough to buy boats, the demand for boating space will rapidly exceed the available areas. For dock space, a waiting list of four and five years is common in most marinas in the region, and the high density of boats on weekends already limits enjoyment of many parts of the Sound. There is great danger that the proliferation of boats will choke the urban marine areas as the automobile has the cities. The problem is how to allocate limited boating resources equitably among an exponentially-growing population of boat owners. Shore facilities should be limited to the capacity of the offshore area.

Boating is a major industry on Long Island Sound. Long Islanders spend a total of something over $59 million per year on boat upkeep, dock rentals, and operating costs, as well as the purchase of new boats. One item in operating costs—12 million gallons of gasoline a year—costs about $4 million. Sale of new boats is about half the total, an estimated $30 million.[15] Over four percent of the total registered power boats in the United States can be found on Long Island Sound (see Table 5.3). An estimated 175,000 pleasure boats were in the water in the Nassau-Suffolk region in 1970, including inboard and outboard motor boats and sail boats. An additional 60,000 motor boats are registered in Connecticut. This number is expected to multiply rapidly since most boat-owners are from families earning $10,000 to $15,000 a year.[16] In the Long Island Sound area, construction costs for a permanent berth average $1,000. An average launching ramp with parking represents a $20,000 investment. Rentals of a slip can vary from $5 to $70 per month, depending upon services offered and location. In 1972 the average cost was about $1 per foot per month; in other words, $30 per month for a 30-foot slip.[17] The boating industry with all its ancillaries is clearly a growth industry, and a prosperous one. The outlook is for more growth, due not only to population increase but to the rising popularity of sailing and motor boating.

Growth, but with a caveat: the boating industry's health depends directly upon the maintenance of relatively clean waters and clean channels. Unfortunately, pleasure boats often work against themselves; they dump garbage and human wastes into bays and harbors. Toilets that discharge at sea or toilets without holding tanks or shore facilities to accept wastes are particularly obnoxious where inadequate tidal circulation in a harbor causes concentration of their wastes in the water and upon the bottom. The result is further nutrient and bacterial pollution of these areas.

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*If current proposals for the Gateway National Seashore, Tock's Island, Mohawk Valley, and Suffolk County beach acquisitions become reality, New York should have at least one mile of public shore per 8,000 inhabitants.

CODE	NAME	CODE	NAME	CODE	NAME
1.	Pelham Bay Park	13.	Goldsmith Inlet County Park	25.	Hammonasset State Beach
2.	Rye Beach Playland	14.	Great Pond County Park	26.	Plum Bank State Fish & Wildlife Area
3.	Glen Island Park	15.	Greenwich Point Park	27.	Selden Neck State Reserve
4.	Sands Point County Park & Preserve	16.	Longshore Country Club Park	28.	Lords Cove State Fish & Wildlife Area
5.	Hempstead Harbor County Park	17.	Sherwood Island State Park	29.	Great Island State Fish & Wildlife Area
6.	Garvies Point Preserve	18.	Seaside Park	30.	Rocky Neck State Beach
7.	Glen Cove City Park	19.	C.E. Wheeler Fish & Wildlife Area	31.	Harkness Memorial State Seashore Reserve
8.	Sagamore Hill National Historic Site	20.	Silver Sands State Park	32.	Fort Shantok Historic Site
9.	Caumsett State Park	21.	Osbornedale State Rec. Area	33.	Bluff Point State Seashore Reserve
10.	Crab Meadow Beach & Park	22.	East Shore Park	34.	Harley Farm State Seashore Reserve
11.	Sunken Meadow State Park	23.	Cockaponset State Forest	35.	Barn Island State Launching Site
12.	Wildwood State Park	24.	East River Fish & Wildlife Area		

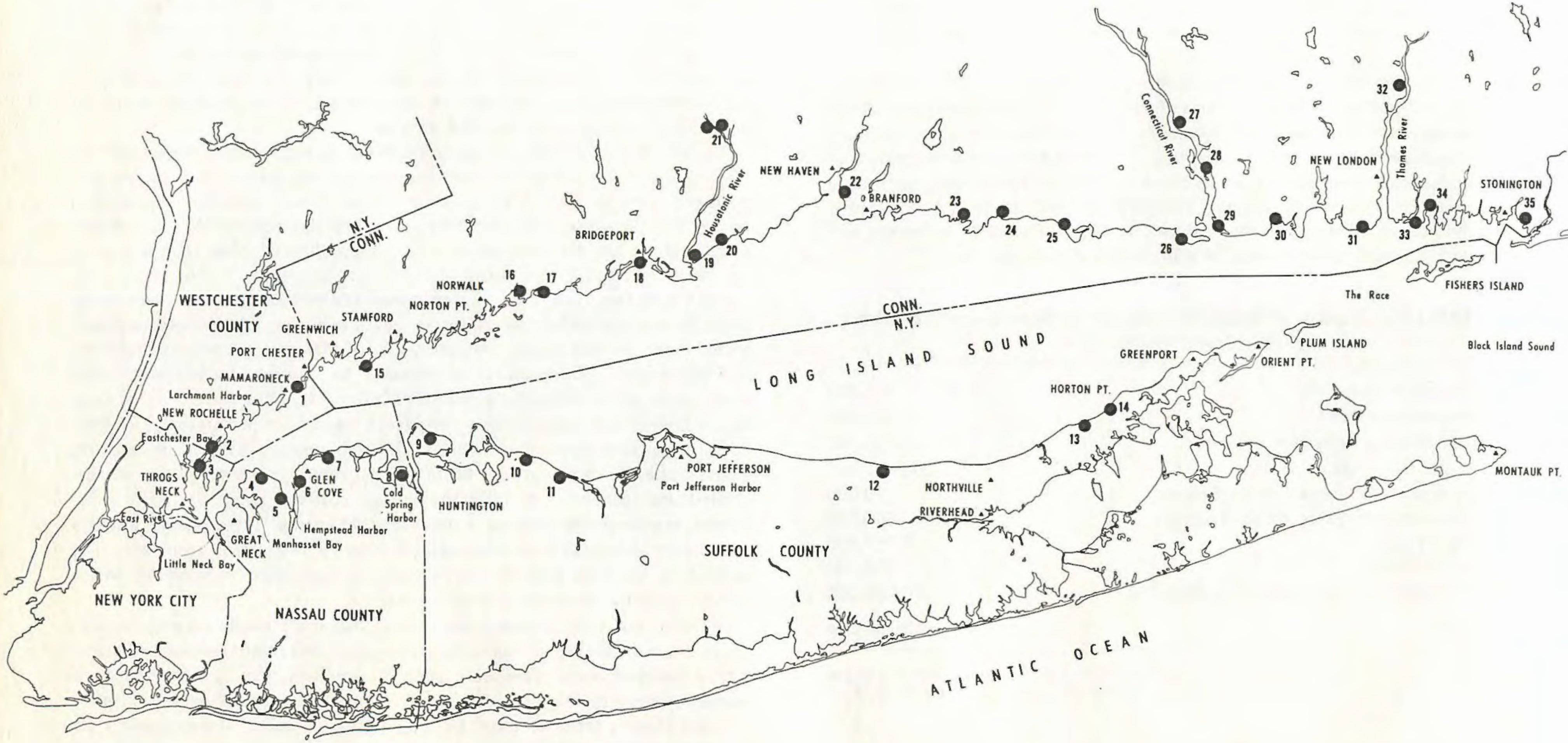

FIGURE 5.2 *Major Public Beaches*

TABLE 5.3 *1970 Motor Boat Registrations, Long Island Sound Region*

Nassau[1]	43,632
Suffolk[1]	57,802
Westchester	13,662
Metropolitan Area[2]	31,154
Connecticut[3]	60,000
Total	206,250
Total U.S. registration[4]	4,868,885

Source: Edward Bevelander, Regional Supervisor, Melville, N.Y., Division of Marine and Recreational Vehicles, Department of Environmental Conservation.

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[1] Approximately 40 percent of the boats registered in Nassau and Suffolk are based on the north shore of Long Island; the remainder are based on the south shore.

[2] Richmond, Manhattan, Kings, Queens and Bronx Counties.

[3] Connecticut State Department of Environmental Protection, Bureau of Administration, Licensing and Revenue Section, Hartford, Conn.

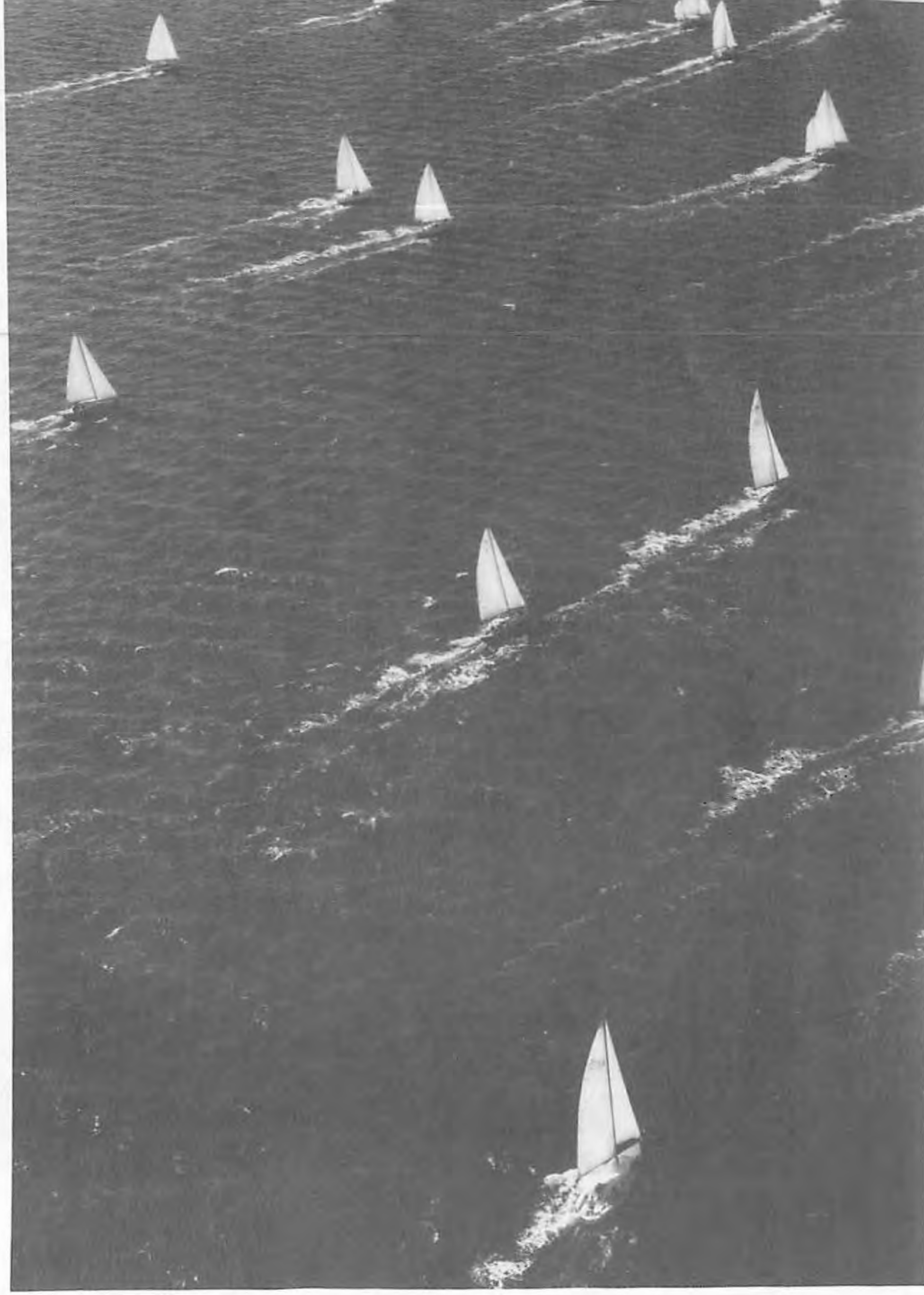
[4] National Association of Engine and Boat Manufacturers, *Recreational Boating Registration Statistics* (Greenwich, Conn., 1972).

Sport Fishing

Sport fishing is closely tied to the boating industry and shares its dependence on water clean enough to support marine life. It is a major pastime for Long Island Sound people. Sales of fishing tackle and bait, operation of party and charter boats, and other fishing activities amount to at least $45 million a year for the Long Island area.[18] Continuance of this sport depends largely upon water quality in the bays and harbors where most sport fishing is done, and upon navigable channels. For many occasional and serious anglers who do not have the means or desire to fish from boats, facilities such as fishing piers can provide access to the water.

Housing

The marine environment has an important though indirect bearing on the real estate industry. People build and rent houses in the Long Island Sound region partly because the water is there, near enough for recreation and enjoyment.



Sailing Regatta on Long Island Sound

View of marina and harbor, Housatonic River, Stamford, Connecticut

Access to harbors and bays usually increases property values substantially: the most desirable and valuable house sites are along the shore of the Sound. The tremendous and increasing demand on available waterfront land complicates the choice between development of new home sites and protection of natural resources. It often means filling in irreplaceable wetlands. Any kind of waterfront land is a valuable asset for the developer and for the people who live nearby.[19] Water frontage creates low-maintenance open space, provides many kinds of recreation facilities, and is so popular that it increases surrounding land values up to five or ten times normal value.* Apartments in Columbus, Ohio rent for $15 more per month if they have a view of a seven-and-a-half-acre "lake" the builder developed from an abandoned sand pit. On Long Island, waterfront plots can command a premium of $5,000 to $15,000 over non-waterfront plots, according to Richard D. Schoenfeld of the Long Island Builders Institute.[20] As a result, many areas have been under heavy pressure for development. Most of the loss of wetlands over the past 20 years has occurred from bulkheading and filling marshes to make construction sites for residential or commercial property.

The 1972 NYS Tidal Wetlands Act, if implemented, should protect the remaining wetlands from irresponsible filling and home building. Fortunately, builders on Long Island have generally been a progressive group. They have supported planning innovations like clustering, buffer strips, and planned unit development, in which environmental conservation is integrated by planning a whole community at once. Most Long Island builders are aware of and act to preserve aesthetic and productive aspects of the marine environment, setting aside waterways and natural features. Sound land planning practices can provide waterfront access while preserving large marsh areas as open space. Mr. Schoenfeld writes:

> It is essential that while compatibility between marine environment interests and builder interests could be achieved, it must be remembered that builders are people-oriented as opposed to any other orientation. Popular demand and availability of suitable land to accommodate increased population is the builder's first concern. In no event does the average builder wish to see the marine environment unnecessarily deteriorate or destroyed in any fashion and will work toward the accomplishment of these objectives. Swimming, boating, visual beauty, and to some extent fishing are perhaps the major aspects which are quickly brought to mind by the average builder's reflection upon the worth of marine environment to his own property.[21]

In seasonal housing particularly, a progressive attitude among builders can make a critical difference. Construction, sale, and rental of seasonal houses and apartments contributes $50 million annually to the regional economy. According to the 1970 census, there were 37,900 seasonal housing units in Nassau and Suffolk Counties, 31,285 of which were in Suffolk County. Seasonal houses even more than year-round houses are located where they are because of the satisfactory marine environment: still another example of the economic worth of keeping the marine environment healthy.

TABLE 5.4 *Seasonal Housing, Long Island Sound Region*

	Number of Units
Connecticut	6,615
New York State: Nassau, NYC, Westchester	58,186
Suffolk	31,285
Total	96,086

Source: U.S. Bureau of the Census, 1970.

WATER TRANSPORTATION

Until the development of railroads, water transportation was the only economical method for moving heavy goods over great distances. To move goods over land required the tremendous effort of roadbuilding, to smooth out the irregularities of the land and to provide a bearing surface for wheels. The sea has the advantage of being flat, and displaced water supports the load of the vessel. The only construction involved is the building of ports at either end of the route to permit the transfer of goods from the land to the ship.

Most large cities in the United States were originally ports. The harbor was the action center of the city, for employment, recreation, marketplaces, and parks. There is no more dramatic example of the impact of technological change than the transformation of the waterfront from what it was a hundred years ago to what it is now. Then it was the focus of the excitement of ships; now it often is rotting wharves, pockets of filth, and a dangerous place to be, day or night. It is not nostalgia but such unacceptable conditions that motivate the rehabilitation of urban waterfronts.

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*Waterfront building lots in Suffolk County had an average price of $300 per front foot in 1972, or $35,000 per acre. Inland acre building lots start at $3,000.

They will not be rehabilitated to do their old job, however. Transoceanic passengers going by airplane, increases in vessel size, and cargo containerization have drastically altered requirements for port facilities. Fewer, larger, and more automated port facilities are replacing the numerous wharves that once were required to handle the multitude of small vessels, which were unloaded by methods not significantly different from those used in Phoenician times. Thus, most U.S. ports are a mixture of efficient modern facilities and semi-abandoned older piers. New York Harbor is a striking example. Despite substantial increases in cargo tonnage, therefore, we actually need less urban waterfront. The President's Council on Recreation and Natural Beauty recommended in 1968 "that Federal agencies be authorized to conduct, in cooperation with State and local governments, a coordinated program of urban waterfront restoration that would emphasize recreational, scenic, and aesthetic values, including physical and visual access."[22] This is a major challenge for both urban and marine environmental planners.

Each of the two main developments in water transportation—larger vessels and containerization—has meant certain changes in the marine environment. The larger the ship, the deeper it rides in the water, and the deeper the harbor has to be to accommodate it. The advantages of an increased capacity are lower costs for fuel, capital, and labor per unit weight. The tendency towards larger ships has been particularly marked for tankers. In 1945, the standard tanker was the T-2 tanker with a dead weight (total carrying capacity) of 16,460 tons. The upper practical limit for supertankers of 1 million dead weight tons will probably be reached by 1990. Freighters and bulk carriers are also increasing in size, though less dramatically. In 1970, the maximum size for freighters and bulk carriers was 25,500 and 105,000 tons respectively. As the capacity of the vessel increases, its draft increases roughly as the cube root of the tonnage. In 1972 the maximum draft for New York Harbor was 45 feet, which limited ships entering the harbor to a tonnage of about 70,000 dead weight tons. New Haven Harbor had only 35 feet of water in its entrance channel. To maintain the harbors even at their present depth requires dredging to remove sediment and waste deposits. For supertankers and big bulk carriers, existing harbors will have to be deepened or new harbor facilities provided.[23] Harbor maintenance and deepening affects the ocean in four ways: dredging (1) modifies water movements in the harbor which in turn causes (2) changes of salinity and (3) altered sediment transport; and (4) the dredge spoils, often polluted, are usually disposed of at sea.

Containerization for handling miscellaneous cargos has meant a move to different facilities—sometimes refurbishing old ones, sometimes abandoning them and building a brand new port. Miscellaneous products are packed into a standardized container by the originator, sent by truck or rail to the port, and then lifted into a container ship. At the destination of the cargo, the process is reversed. In this manner, the dockside handling of the cargo can be automated because the containers are standard sizes, regardless of their contents. Handling of bulk cargo, liquid or solid like oil or sand, is also automated, using pumping, suction, or other bulk handling methods. Dockside storage tanks must be provided to hold the cargo until it can be sent to the consumer. These streamlined, large-scale methods are having a major impact on the nature of the urban waterfront.

Shipping in Long Island Sound

Long Island Sound's 16 major and 8 minor seaports (Fig. 5.3) handle mainly petroleum products, crushed and broken stone, and sand and gravel—bulk commodities for which specialized port facilities are most suitable (see Tables 5.5, 5.6, and 5.7). The region also imports much of what it consumes in food and other raw materials; these come in by truck and rail, mostly, rather than by water. Still, both major and minor ports have many facilities for handling goods other than the bulk commodities (Tables 5.5 and 5.6). Most Sound ports have been growing over the past ten years (Table 5.8), some markedly. New London Harbor on the Connecticut shore and Port Jefferson Harbor on Long Island's north shore both have added to their already-large capacities, particularly in petroleum handling. Northville Oil Terminal, one of the few Sound ports able to accommodate tankers directly from the Gulf states or Venezuela, has experienced a growth of 500 percent during the past 10 years.

Further expansion for seaports is beset with problems, however. Forty-two firms on Long Island were queried on their expansion plans. Two stated they had expansion plans, one was presently expanding, and the rest did not have any plans. The reasons given for failure to expand were: lack of room on the site or adjacent to the site, restrictive zoning regulations, and strong citizen opposition. Petroleum product firms, in particular, lack expansion room or face public opposition.

At present, the metropolitan (tri-state) region does rely rather heavily on waterborne commerce: almost one-third of its freight traffic moves by water (see Table 5.9). As noted above, this water freight is chiefly bulk commodities like stone, sand, or oil. The pipelines mentioned in Table 5.9 are also widely used to transport bulk commodities and may be a useful alternative to transport by water, especially as port expansion around Long Island Sound is in conflict. Pipelines constructed in the Sound region are for petroleum products. Two facilities use pipelines to transfer petroleum products from marine vessels to storage tanks. One is operated by Consolidated Petroleum Terminal, Inc., which maintains a dock in Port Jefferson Harbor with storage tanks inland in South Setauket and Holbrook. The other, that fast-growing Northville Oil

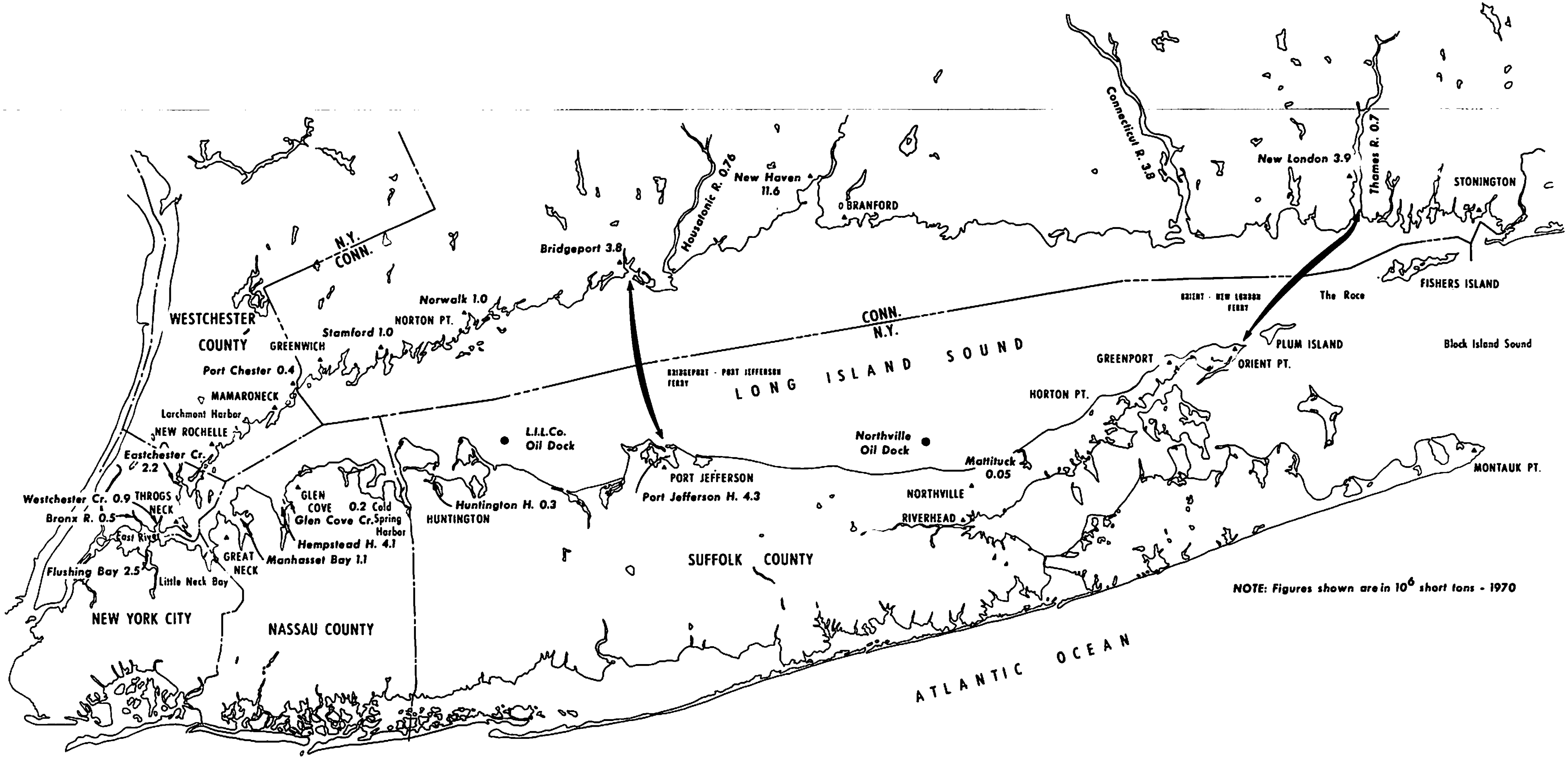


FIGURE 5.3 *Major and Minor Seaports*

Winter view of New Haven Harbor – showing oil terminals and adjacent highway, rail, and aviation linkages

TABLE 5.5 *Terminals on Waterways by Type of Waterborne Commerce, 1970 (showing number of facilities or companies)*

	Oil Terminal	Sand, Gravel, Crushed Rock	Asphalt	Fisheries	Other	Total
Connecticut Shore, Major Ports						
New London Harbor	8	–	–	2	26	36
Conn. River below Hartford						n.a.
New Haven Harbor	18	1	1	1	19	40
Housatonic River	2	–	–	–	11	13
Bridgeport Harbor	13	4	–	–	12	29
Norwalk Harbor	3	3	–	4	13	23
Stamford Harbor	10	2	–	–	8	20
Port Chester Harbor	4	3	–	–	1	8
East Chester Harbor	13	8	–	–	3	24
Westchester Harbor	4	3	–	–	–	7
Connecticut Shore, Minor Ports						
Greenwich	1	–	–	–	1	2
Guilford Harbor						n.a.
Westport Hbr. & Saugatuck River	–	1*	–	–	–	1
Larchmont Harbor	–	–	–	–	3	3
Mamaroneck Harbor						n.a.
Connecticut Shore, Total	**76**	**25**	**1**	**7**	**97**	**206**
North Shore–Long Island, Major Ports						
Hempstead Harbor	7	7	–	–	8	22
Manhasset Bay	6	1	–	–	23	30
Oyster Bay Harbor						n.a.
Glen Cove Creek	2	1	1**	–	4	8
Port Jefferson Harbor	5	2	–	–	6	13
Huntington Bay and Harbor	2	–	–	–	5	7
North Shore–Long Island, Minor Ports						
Northport Harbor and Bay	1	1	–	–	5	7
Mattituck Harbor	1	–	1	–	7	9
Greenport Harbor	1	–	–	3	15	19
North Shore–Long Island, Total	**25**	**12**	**2**	**3**	**73**	**115**
Grand Total	**101**	**37**	**3**	**10**	**170**	**321**

Data supplied by New York District Office and New England Division, U.S. Army Corps of Engineers.

*sand and gravel and petroleum facilities combined

**sand and gravel and asphalt facilities combined

TABLE 5.6 *Principal Commodities Handled by Seaports on Long Island Sound, 1970 (percent distribution by weight)*

	Major Ports		*Minor Ports*		*All Ports*		
	Conn. Shore	*L.I. Shore*	*Conn. Shore*	*L.I. Shore*	*Conn. Shore*	*L.I. Shore*	*Long Island Sound*
Fresh Fish	0.0	0.0	0.0	3.0	0.0	0.0	0.0
Shellfish	0.0	0.0	3.4	0.6	0.0	0.0	0.0
Crushed & Broken Stone, Sand & Gravel	5.0	45.5	65.4	55.8	5.2	45.5	15.9
Petroleum Products	84.5	53.4	31.0	40.4	84.3	53.3	76.1
Other	10.5	1.1	0.2	0.2	10.5	1.2	8.0

Source: U.S. Army Corps of Engineers, *Waterborne Commerce of the United States, 1970,* Part I, Waterways and Harbors, Atlantic Coast, 1972.

TABLE 5.7 *Distribution of Waterborne Freight Tonnage in the Long Island Sound Region (percent of 1970 Commerce)*[1,2]

	Connecticut	*New York*[3]	*Nassau-Suffolk*
Petroleum	56	20	14
Sand, Gravel & Crushed Rock	1	15	12
Coal	3	0	0
Other	4	0	0

Data from U.S. Army Corps of Engineers, *Waterborne Commerce of the United States, Calendar Year 1970,* Part I, Waterways and Harbors, Atlantic Coast, 1972.

[1] Percentages rounded to nearest percent.

[2] Total 1970 commerce: 40,273,108 tons.

[3] Includes Nassau-Suffolk ports.

Terminal in the town of Riverhead, uses a dual submarine pipeline to connect its storage tanks behind the bluff overlooking the Sound to a mooring about 7,000 feet off shore. The Nassau-Suffolk Regional Comprehensive Plan (see Chapter 7) recommends the eventual creation of an island-wide pipeline network to eliminate oil shipments and storage from most Long Island harbors.

Shipborne Commodities

Fish and shellfish, crushed and broken stone, sand and gravel, and petroleum products constitute the main waterborne commerce on Long Island Sound. Table 5.6 shows proportions of each for 1970.

Clearly, shellfish and fresh fish constitute less than 0.1 percent of the cargo volume handled by the major Sound ports; these are more important in some smaller ports. (The value per seaport of fishery commodities cannot be determined since the statistical records of fishing catches are kept on the basis of

TABLE 5.8 *Long Island Sound Waterborne Commerce, 1961–1970 (in millions of short tons)*

Port	*1961*	*1970*	*Low Year 1961/70*	*High Year 1961/70*	*% Change[1] 1961/70*
Connecticut Shore, Major Ports[2]					
New London Harbor	1.12	3.87	.81/64	3.87/70	+246
Conn. River below Hartford	2.77	3.81	2.76/61	4.35/69	+ 38
New Haven Harbor	8.37	11.63	8.34/62	11.63/70	+ 39
Housatonic River	.96	.76	.76/70	1.14/67	– 21
Bridgeport Harbor	2.31	3.84	2.31/61	3.85/69	+ 66
Norwalk Harbor	.68	1.06	.68/61	1.86/69	+ 56
Stamford Harbor	.72	1.02	.72/61	1.06/69	+ 41
Port Chester Harbor[3]	.45	.41	.32/64	.47/68	– 9
East Chester Harbor[3]	1.83	2.20	1.83/61	2.26/68	+ 43
Westchester Harbor[3]	1.25	.90	.67/63	1.25/61	– 28
Connecticut Shore, Minor Ports					
Greenwich	n.a.	.08			n.a.
Guilford Harbor	n.a.	.00			n.a.
Westport Harbor and Saugatuck River	n.a.	.01			n.a.
Larchmont Harbor	n.a.	no commerce rep.			n.a.
Mamaroneck Harbor	n.a.	.01			n.a.
Connecticut Shore, Total	**20.45**	**29.63**			+ 45
North Shore–Long Island, Major Ports					
Hempstead Harbor	4.81	4.15	3.53/65	5.59/62	– 14
Manhasset Bay[3]	.80	1.14	.63/65	1.38/68	+ 42
Oyster Bay Harbor	.28	.49			+ 76
Glen Cove Creek	.29	.17			– 39
Port Jefferson Harbor	1.57	4.33	1.45/63	4.33/70	+176
Huntington Bay and Harbor	.44	.28	.28/70	.63/62	– 37
North Shore–Long Island, Minor Ports					
Northport Harbor and Bay	n.a.	no commerce rep.			n.a.
Mattituck Harbor	.11	.05			– 58
Greenport Harbor	.02	.02			+ 19
North Shore–Long Island, Total	**8.37**	**10.64**			+ 28
Grand Total	**28.77**	**40.27**			+ 40
Port of New York	**144.76**	**174.01**	**144.76/61**	**174.80/68**	+ 20

Data from U.S. Army Corps of Engineers, *Waterborne Commerce of the United States, Calendar Year 1970,* Part I, Waterways and Harbors, Atlantic Coast, 1972.

[1] Percentages rounded to nearest percent.

[2] Major port defined as having a total commerce of greater than 100,000 tons/year.

[3] Included in totals for Port of New York.

TABLE 5.9 *Freight Traffic Movement, Tri-State Region, by Mode of Transport, 1970 (in percentages)*

Freight Mode	*Into the Region*	*Within the Region*	*Out of the Region*	*Total Movement*[2]
Water[1]	46.5	21.2	24.0	29.8
Truck	23.8	76.3	56.2	56.5
Rail	16.0	1.0	9.7	7.1
Oil Pipelines	13.5	1.5	9.4	6.5
Air[1]	0.2	—	0.7	0.2

Source: *Freight Traffic of the Tri-State Region, Interim Technical Report 4293-2505* (New York: Tri-State Planning Commission, April 1972).

[1] Includes domestic and foreign.

[2] Total freight movement amounted to 647.1 million tons.

large geographical areas.) Over the past decade, the amount of fish landed has declined by almost 29 percent, but the dollar value has more than doubled, as shown in Table 5.10. The shellfish industry, as is well known, has gone down in both weight landed and dollar value of the catch.

Since fresh fish and shellfish are highly perishable, they are processed immediately and shipped to market. Many fisheries have limited storage facilities and therefore catch only what the processing plants can hold. Most of the catch is shipped by truck to local and metropolitan markets, although some products, like oysters, are distributed nationwide. Fish oil and fish meal are distributed throughout the mid-Atlantic states and as far west as Ohio by truck and rail.

Crushed and broken stone, sand and gravel—aggregates, as they are called—account for 15.9 percent of Long Island Sound's waterborne commerce. This commodity is important to the construction industry, primarily for making concrete. In 1970, 6.4 million tons of aggregates were handled in Long Island Sound ports. Most of this tonnage was shipped to the Port of New York, the rest going to Connecticut and Hudson River points. Most sand and gravel mines are located on or near the water, minimizing the need for storage facilities; the product is shipped directly on demand. Crushed and broken stone is imported, also on demand, and stored temporarily until trucked to its destination.

TABLE 5.10 *Long Island Sound Commercial Fish and Shellfish Landings, 1960–1970*

	Finfish[1]		*Shellfish*		*All Species*	
Year	*Pounds*	*Value*	*Pounds*	*Value*	*Pounds*	*Value*
1970	4,304	$880,000	2,307	$1,809,000	6,611	$2,689,000
1969	4,579		2,669		7,248	
1968	4,692		2,327		7,019	
1967	3,941		2,726		6,667	
1966	4,128		2,837		6,965	
1965	4,310		2,508		6,818	
1964	3,907		2,645		6,552	
1963	4,245		3,986		8,231	
1962	5,043		4,528		9,571	
1961	5,380		3,921		9,301	
1960	5,521	$420,000	2,915	$2,000,000	8,436	$2,420,000

Data for Area 9 (Long Island Sound), New York Marine District from the following sources: (a) New York Landings, Marine District, U.S. Dept. of the Interior and N.Y.S. Conservation Dept., annual summaries 1960-1969. (b) 1970 shellfish statistics were supplied by Walter Henry, N.Y.S. Dept. of Environmental Conservation, Stony Brook, N.Y. (c) 1970 finfish statistics were supplied by Churchill Smith, National Marine Fisheries Service, Patchogue, N.Y.

Data for Connecticut landings supplied by: (a) Fishery Statistics of the United States, statistical digest numbers 53 to 62, U.S. Dept. of Commerce. (b) 1969 and 1970 statistics by William Murphy, National Marine Fisheries Service, Newport, Rhode Island.

[1] Finfish totals are based on LIS landings and do not include fish caught in LIS and landed in ports of other areas.

Petroleum products constitute three-quarters of all shipborne commerce on the Sound, and are obviously significant to the region's economy. Fuel oils and gasoline accounted for approximately 96 percent of the total petroleum products coming into the listed seaports in 1970; gasoline was 23 percent of the total. Petroleum products were 30 to 40 percent of the minor seaports' volume in 1970 (see Table 5.6). Asphalts, tars, and petroleum distillates used in road construction comprised 16 percent of the total petroleum products brought into Mattituck Harbor.

Since almost 90 percent of New York State's gasoline now comes in via ports on the Sound, and since per-capita consumption of petroleum nationwide and statewide is climbing steeply, those ports can reliably be expected to do more petroleum volume in the future. National annual per-capita demand for petroleum was 14.2 barrels in 1949, rose to 19.4 barrels in 1959, and was projected to increase to 26.4 barrels in 1975. The per-capita gasoline consumption in New York State in 1967 was 242 gallons, up 19.2 percent over the 1958 rate. The U.S. Army Corps of Engineers report on Port Jefferson Harbor estimated that the average per-capita consumption in Suffolk County in the 1958-1964 period was 17 barrels annually, projected to go up to 19 barrels by 1970 and to 24.5 barrels by the year 2020. What does all this mean? It means what you see near the shore at port facilities specialized for oil: large round storage tanks, one after another. After coming in at the seaport by tanker or barge, the petroleum products are stored until they are distributed by truck. Table 5.11 indicates present and projected petroleum storage capacities at the various major ports.

TABLE 5.11 *Petroleum Volumes by 1990: Anticipated Accommodation Increases (volumes in millions of tons)*

Facility	*1970 Volume*	*1985 Volume*	*Increase Over 1970*	*1990 Volume*	*Increase Over 1970*
Port Jefferson[1]	2.0	12.8	240.0%	14.2	610.0%
Northville[1]	0.8	5.1	537.5%	5.7	612.5%
New Haven	6.0	8.0	33.3%	9.8	62.3%
Port of N.Y.	50.6	68.3	35.0%	77.0	52.2%

Source: Tri-State Regional Planning Commission, *The Tri-State Region's Fuel Needs,* Interim Technical Report 4239.2150, February, 1972.

[1] The sharp gains in volume shown for Port Jefferson and Northville are based on operators' expansion plans.

It is this potential for expansion, and citizen opposition to it, that concerns oil shippers most. Other problems for them are inadequate depth of some harbors and waterways, forcing shippers to use small tankers and half-laden barges, thereby adding to delivery costs; heavy winds, which can cause inlets to shoal or make vessel handling difficult in narrow channels; and pleasure boats, which in some places interfere with or restrict vessel movement by gradual enlargement of marinas.

Ferries

Two commercial ferries (shown in Fig. 5.3) provide interstate service between Long Island and Connecticut, on a seasonal basis only. These lines are the Island's only relief from its dead-end condition: New York City is the only land link or interface between island and mainland, except for these two ferries carrying automobiles. Since they're seasonal, they are not a continuous part of the transportation pattern.

The Port Jefferson-Bridgeport Ferry, established in 1883, operates from late May to mid-October. Its principal activity is carrying passengers and automobiles, but it also charters moonlight trips and excursions. The other ferry runs between Orient Point and New London. This line carries a much greater volume than the Port Jefferson-Bridgeport Ferry, partly because of a longer operating season, from late March to early January. This line also provides excursions and tour service. (Connecting smaller islands to the Connecticut mainland are several short ferry runs, not shown in the figure.) Table 5.12 depicts the use of both ferries in 1971-1972.

TABLE 5.12 *Long Island Sound Ferry Traffic, 1971–1972*

Item	*Bridgeport-Port Jefferson Ferry*[1]	*Orient Point-New London Ferry*[2]
Automobiles[3]	22,728	55,808
Trucks and Trailers[4]	–	4,313
Passengers	78,769	130,636
General Cargo	3 tons	–

Source: Arthur Tooker, The Bridgeport-Port Jefferson Steamboat Co., 102 West Broadway, Port Jefferson, New York.

[1] 1972 figures; operates from May 25 through October 15 only.

[2] 1971 figures; operates from March 24 through January 2 only.

[3] Toll rates based on passenger car toll of $9.50 for one-way trip (including driver).

[4] Passenger toll rate for one-way trip is $2.50.

EXTRACTION

The use of the sea for extracting resources–from water, from underlying sediments, and from subsurface deposits–is both profitable and necessary, but can, like other uses, be distorted to misuse. The products of extraction are conveniently grouped into living and non-living resources. First let us examine the non-living resources.

From the Water: Desalinated Water

The water demand of coastal areas is rising much more rapidly than over the country as a whole, a reflection of intensive urbanization taking place along the seaboards. At present, these demands are being met from surface or subsurface sources. Connecticut, for example, obtains its supply entirely from stream-fed reservoirs (75 percent) and groundwater sources (25 percent). But New York City and the Long Island communities must pay special heed to alternative sources. New York City now obtains its water supply from upstate New York, including some from Delaware River Basin sources. The U.S. Army Corps of Engineers has studied the feasibility of tapping the Hudson River.

On Long Island the water supply problem is especially acute. Nassau County is approaching the balance between demand and safe yield of its underground reserves. In fact, the demand may already be excessive, as evidenced by lowered water levels in surface waters such as Hempstead Lake. If rainwater doesn't replenish the groundwater supply, the delicate balance between sea water and fresh water at the shore's edge may be disturbed. It is this dynamic boundary, formed by pressure of fresh groundwater against seawater, that prevents the landward intrusion of salt water.[24] When groundwater pressure is reduced past the balance point, by pumping too much water out of the ground into the town water supply, or by discharging too much sewage (which is, after all, fresh rather than salt water) into the ocean, seawater begins to seep in under the land and infiltrate the groundwater. Brooklyn and Queens lost their groundwater supply this way a number of years ago. This delicate balance Nassau County is now approaching or may even have reached. Suffolk County, although it has an ample groundwater supply now, should prudently consider supplemental sources.[25] One potential supplemental source is known to be inapplicable for Long Island: fresh water from sources beneath the continental shelf or from submarine fresh water springs.

There is a potentially infinite source of fresh water: seawater converted by desalinization. At the end of 1967 there were, worldwide, 625 desalting plants in operation or under construction, with a total capacity of over 200 million gallons per day. They use any of three methods: distillation, membrane processes, or freezing. The cost of desalting water is dropping. In 1952, desalted seawater cost more than $4.00 per thousand gallons. By 1967, this cost was reduced to about $1.00 per thousand for a plant with a capacity of a million gallons a day. This cost doesn't compare favorably with groundwater costs yet; however, in plants larger than a million gallons, or in plants using brackish water of 6 parts per thousand salinity—far less salty than seawater—the costs can be reduced to 65¢ and 35¢ per thousand gallons respectively.[26]

Desalinization is no panacea. Seawater desalination plants take in seawater and discharge hot brine at about twice the salinity of seawater. The disposal of hot brine can have deleterious effects on the nearshore environment: since it is denser than seawater, the brine could fill topographic depressions near the shore and form a stable layer of saline water near the bottom, impeding water circulation. Eventually, this would result in depletion of dissolved oxygen in bottom waters and destruction of all life except sulphate-reducing bacteria. Before desalination plants are built in the Sound region, submarine topography near the proposed outfalls must be carefully considered, and diffusers to mix the effluent may have to be installed.

From the Sea Bottom: Sand and Gravel

Sand and gravel are among the most important mineral resources taken from the ocean. In 1967 sand and gravel was valued at $1 billion for the United States.[27] Sand and gravel in Long Island—its only mining—in that same year had an annual value of about $8 million[28] (see Table 5.13). During 1967 Suffolk County produced 4.6 million tons of sand and gravel and was the largest producer in New York State. Nassau County was second with 4 million tons. Table 5.14 shows the quantity and value of aggregates in the tri-state region. About 90 percent of the sand and gravel produced comes from upland mining operations, often located adjacent to harbors, since for this large-volume, low-cost industry, transportation costs are what's critical. One-third of the sand and gravel sold to New York City construction-industry customers is barged by water, the rest goes by truck.

TABLE 5.13 *Production of Sand and Gravel,*
Nassau and Suffolk Counties, 1970

	No. of Operations	*Tons in thousands*	*Value in thousands*
Nassau County	5	3,987	$3,788
Suffolk County	17	4,641	$4,471
Bi-County Area	22	8,628	$8,259

Source: New York State Office of Planning Coordination, *Long Island Sand and Gravel Mining* (New York: Metropolitan New York District Office, 1970), p. 4.

TABLE 5.14 *Quantity and Value of Sand and Gravel and Stone, Tri-State Area, 1970*

State	*Sand and Gravel*		*Stone*	
	Quantity[1]	*Value*[2]	*Quantity*[1]	*Value*[2]
Connecticut	6.8	$ 9.2	8.3	$16.9
New York[3]	35.5	$38.8	37.6	$68.1
New Jersey	16.7	$31.6	15.2	$40.6

Source: Frank T. Manheim, *Mineral Resources Off the Northeastern Coast of the United States* (U.S. Geol. Survey Circ. 669, 1972), p. 14.

[1] Quantity in millions of short tons.

[2] Value in millions of dollars.

[3] f.o.b. plant prices in New York: sand $0.75-$1.50/short ton; gravel $3.00/short ton.

In urban coastal areas, marine deposits will be sought after for an increasing fraction of the sand and gravel requirements, for two good reasons. As land deposits are exhausted, operators will first exploit nearshore deposits in protected waters before mining deeper deposits in exposed waters. Second, many zoning controls now prevent opening up new sand and gravel pits, due to the unsightly land scars they leave behind. Consequently, harbor improvement and channel deepening, yielding sand and gravel as a by-product profitable for construction, are favorite operations for the industry. Since bottom lands are in the public domain, dredging operations for sand are usually part of town or county public improvement, where the prime purpose is to dig a channel, improve a beach, or modify the circulation of a bay or harbor.

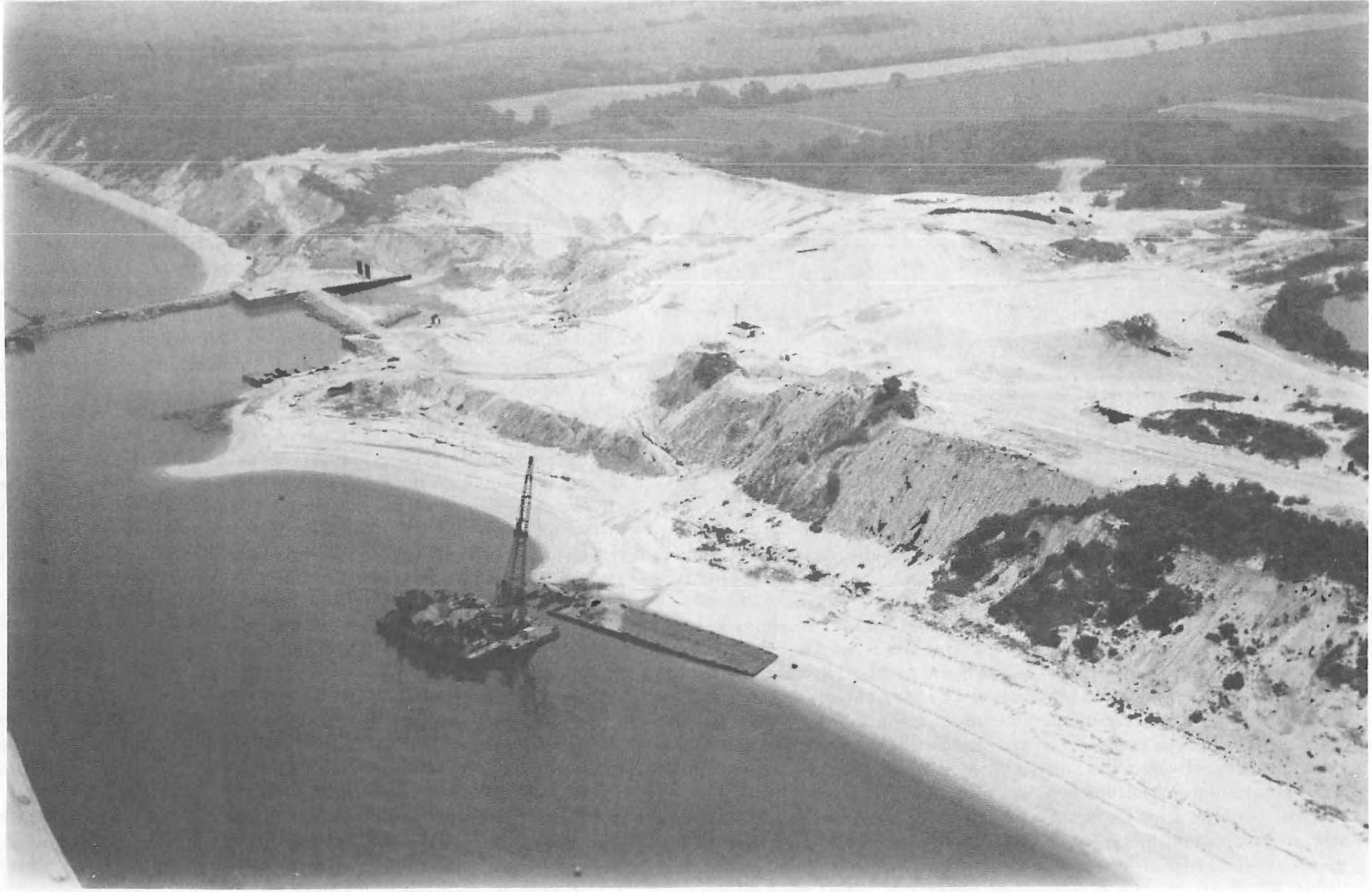
Sometimes, regard for the public benefit is negligible or even non-existent; then the dredging usually becomes a major controversy. Potential ill effects of sand and gravel production near shore include bluff erosion and loss of beach. Neither is likely to be acceptable to shoreline property owners and local residents. However, the public interest may be well served by combining a dredging project with a mining operation. For example, instead of requiring governmental expenditures for harbor improvements, the usual Long Island township practice is to allow commercial dredging. The town gets the work done and also receives a royalty for each ton of sand and gravel taken. The improvement of Huntington Harbor would have cost $2 million; because the bottom consisted of usable sand and gravel, the town was able to sell the privilege of mining this resource and realize half a million dollars profit.[29]

Profit is not the last word on the subject. Controversy over the Huntington Harbor dredging focuses for us once again the crux of the problem of uses and misuses: competition among different kinds of uses of the marine environment. On the one hand, dredgers claim that through their operation in 1965 the harbor bottom was rehabilitated and should become a more productive area for shellfish than it was before.[30] On the other hand, shellfish companies claim that 90 percent of the area dredged had been shellfish-producing area of the best quality and that at least a portion of this area will not be conducive to shellfish growth for a long time.[31] These areas were capable of producing an estimated one-half million dollars worth of shellfish annually.

What *does* dredging do to marine life and the shape of the shore? We don't really know some of the essential information. Much of the heat in present debate comes from lack of light on such issues as: bottom rehabilitation through dredging, the effect of dredging on salt water intrusion, pollution control versus salinity control, how dredging inlets affects their stabilization, the use of groins for erosion control and beach stabilization, and where to dump dredging spoils.

Meanwhile, it is argued, on the one hand, that wetlands are more important to marine life-cycles than sand and gravel deposits. Since offshore dredging does not affect wetlands directly, the ecological loss is less than, say, filling in wetlands. Furthermore, mining operations clean up an ecologically useless "mucky" bottom and leave behind fine-grained materials after removing the sand and gravel. This silt blanket resettles and new bottom growth eventually covers it again. Finally, it is said that if dredging improves water circulation in polluted harbors, ecological conditions in these bays and harbors may be enhanced rather than damaged.[32]

The answering arguments, on the other hand, focus on two adverse consequences of dredging. First, sand and gravel operations disturb the living balance in the dredged area; the silt blanket covers the bottom, making it unfit for many desirable organisms like oysters, which grow better on a sandy bottom. The turbid water caused by the silt blocks out sunlight, killing off plants by ending photosynthesis. This stops not only the food supply of finfish and shellfish but also one of their major sources of oxygen—photosynthetic oxygen. Furthermore, the decay of any aquatic animals killed off in the process produces noxious gases detrimental to other life forms and consumes oxygen present in the water.[33] Dredging operations have had devastating effects on the shellfish in Northport Harbor, Oyster Bay, Mount Sinai, and Wading River. Conservationists and baymen agree that most bottom lands dredged to date were not "mucky" bottoms originally. They were hard or sand bottoms that were detrimentally affected by dredging. In addition, the so-called "mucky" bottoms are not ecologically useless.[34] They provide a decomposition zone under a photosynthetic one. In other words, digging up the decomposition zone buries the nutrients



Sand and Gravel Dredging, Town of Riverhead, 1970. This project was stopped by the Attorney General of the State of New York necessary for the growth of all the marshland vegetation instead of allowing the nutrients to recycle back into the system.

The other objection is that controls on dredging operations have often been sloppy or non-existent. Contractors have dug deeper channels than called for, or dredged areas not within their contract, or left large, deep holes in the bottom. These deep holes accumulate waste deposits which gradually degrade water quality or cause odor problems in hot weather. Some of the dredges used in the sand and gravel operations are equipped to dig deeper than 16 feet, often with an endless chain of dippers. The dredged material is sorted into gravel, sand and silt, and the marketable aggregates are shipped to local or New York construction markets. Between 1955 and 1968 Mount Sinai Harbor was dredged by a private contractor.[35] More than 3 million cubic yards of sand and gravel were taken from the harbor's bottom.[36] When the operation began, the top of the wetlands south of the beach was removed to a depth of 40 feet, for the sand underneath. The dredges were to backfill to a finished grade of 12 feet below water level. Not only was the backfill ineffective to restore any wetland growth, but there still are deep holes in the harbor. The dredgers exceeded boundaries set for the east and also went into the south where no boundaries or check points had been established. Approximately 60 percent (140 acres) of the former wetlands was destroyed.*

The dredge problem is further illustrated where dredges contracted to remove the sand bar off Center Island Beach in Oyster Bay were supposed to dig to a depth of about 18 feet below mean low water (mlw). They in fact went as deep as 33 feet below mlw. Conflicts arise due to the lack of controls in existing legislation, in which adverse consequences of dredging are not articulated. Use of dredging for speculative real estate development or make-work projects involving political patronage rarely is in accord with desirable conservation or public-interest objectives.**

Other areas besides bays or harbors may be useful sources of sand and gravel. The several mid-Sound sills and the eastern basin have sand in great abundance. The distance from densely populated centers is likely to reduce the level of local opposition to the dredging operations. Many of these areas are not known to be valuable shellfish-producing areas or nursery grounds for fish or other organisms. If production of sand and gravel can be combined with projects to improve circulation in the Sound, dredging may be acceptable.

The point is that dredging can be beneficial, but must be planned for compatible use, and must be supervised. Harbors do silt in and do require circulation channels. Navigation and mooring channels are also necessary. We do need dredging to build up ground for shoreline roads, waterfront power plants, and fuel storage tank sites. Moreover, there is no question that sand and gravel mining is a necessary industry: construction requires these aggregates for the manufacture of concrete. At the present time, offshore mining appears to be the most economical method. However, certain compromises will have to be reached if ecology and beauty are to be served as well. Up to now, Nassau and Suffolk Counties' public works departments and the U.S. Corps of Engineers have used navigation as the sole criterion for dredging. Recently, the President's Science Advisory Committee made a heartening suggestion:

> We recommend that issuance by the United States Army Corps of Engineers of permits for dredging, and decisions concerning the Corps' own operations, be continued on the anticipated effect on all resources, not on effects on navigation alone.[37]

It is possible with good planning and proper control to use dredging intelligently and at the same time preserve the marine environment.

From Beneath the Sea Floor: Oil and Gas

By far the most important economic resource from the continental shelf is petroleum and natural gas. Between 1850 and 1950, U.S. fuel consumption increased by a factor of 14.7; per-capita consumption increased by a factor of 2.3. Not only is the total energy demand going up, but the type of fuel has shifted markedly. Around 1850 wood was the dominant fuel. By 1885 coal was dominant, losing its place to oil and gas by 1947. Because of limited supplies, however, oil will probably be replaced before the year 2000. Coal is one possible replacement, but even this resource can last only a few hundred years; ultimately the world's energy demands will be met by nuclear fuels or other energy sources. For the present, the profits of oil production offset the short life expectancy of oil as a dominant fuel, and oil companies continue to invest in new exploration, especially offshore. In 1971 about 16 percent of the United States oil and gas production was from beneath the sea; 25 percent of world production, excluding the United States, was from the sea.[38] As continental resources are depleted, the fraction of offshore production is likely to increase.

The production of petroleum from under water presents a number of environmental problems. Withdrawal of oil and gas in a nearshore area can lead to subsidence of the land. The extensive extraction of oil from Lake Maracaibo in Venezuela has dropped the shorelines so much that dykes have had to be constructed to prevent inundation.

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*This estimate is based on various testimony presented to the Oceanographic Committee of the Nassau-Suffolk Regional Planning Board.

**Article I of the Suffolk County Charter, adopted by referendum, November 1970, requires county agencies to submit statements of environmental impact of certain projects to the Suffolk County Council on Environmental Quality for review.

Some spillage of oil is common during offshore drilling, but extensive pollution can result when blowouts occur. During drilling, the weight of the mud in the hole being drilled (drilling mud) must be carefully adjusted to equal the pressure of the oil reservoir. Oil formations are usually sealed by impervious clay layers and may be at abnormally high pressures; when such reservoirs are encountered unexpectedly, the reservoir pressure may exceed the weight of the drilling mud. Blowout preventers on the drill tubing, if properly installed, should forestall accidents, but blowouts from human error do occur. When a well blows out, the drilling mud is expelled and oil and gas pour out of the hole. Often a well catches fire, and the fire has to be extinguished by explosives before attempts can be made to bring the well back under control. To control a blowout, another hole is drilled at a slant to intersect the "wild" well. When contact is made, cement is injected to form a seal in the "wild" well. It takes weeks, usually, to control the well; during this time an enormous amount of oil may be discharged. On February 10, 1970, a Chevron production platform 10 miles off the Louisiana coast caught fire. It took two months and 300 pounds of TNT to extinguish the fire, but then the well began discharging water with a 5 percent oil content—2000 gallons per minute. Eighty-four ships were employed in an attempt to contain the oil slick that formed.

Even without such catastrophes, offshore oil production poses problems. The offshore production platforms are potential hazards to navigation. Drilling and production operations may reduce the aesthetic values of the seashore[39]—aesthetic values which, as the recreation discussion made clear, are worth hard, cold cash. The noise of oil drilling may adversely affect wildlife; seismic exploration for subsurface structures has been blamed for fish kills.

The facts remain that the nation uses more energy than ever, and that oil and gas are at present the best available energy sources. This puts considerable impetus behind solving underwater production problems like subsidence, blowouts, navigation, aesthetics, and damage to wildlife. It is no longer at a distance, "over there in California" or off Louisiana shores; it is a major challenge for the whole Atlantic seaboard for the 1970s.

Food From the Sea: Fish and Shellfish

The living resource of food extracted from the sea has a long history around the Sound, and is the subject of much folklore and nostalgia. Lately, though, the decline in both fishing and shellfishing industries has caused some concern. A review of Table 5.10 highlights the main picture over the past decade.

The United States per-capita consumption of fish for food has been remarkably constant at about 11 pounds per year. As is well known, fish is high in protein; food values of typical 3-ounce portions of fish are given in Table 5.15.

TABLE 5.15 *Food Values of Fish (3 oz. portion)*

Food	*Percent Water*	*Energy Calories*	*Protein grams*	*Fat grams*	*Carbohydrate grams*
Bluefish	68	135	22	4	0
Clams, raw	80	70	11	1	3
Crabmeat	77	9	14	2	1
Mackerel	62	200	19	13	0
Salmon, canned	70	120	17	5	0
Shrimp	66	110	23	1	—
Tuna, canned	60	170	25	7	0
Beef steak	*39*	*375*	*19*	*32*	*0*
Daily recommended dietary allowances at age 25 (NAS 1958)					
Men		3200	70		
Women		2300	58		

Source: U.S. Department of Agriculture, *Food Yearbook of Agriculture* (Washington, D.C.: U.S. Government Printing Office, 1959), pp. 245-248 and pp. 228-229.

Long Island's 1970 fish catch (Table 5.16) was worth a total of $2.4 million dock-side, of which food fish was $2.3 million.[40] The balance represents industrial fish not used for direct human consumption. The Long Island area produces about 0.7 percent of the total fish caught in the nation.[41]

The food fishery concentrates on winter flounder, bluefish, mackerel, eel, whiting, striped bass, porgy, blackfish and others. The industrial fishery concentrates on menhaden. Industrial fish are used to make fishmeal and fish oil. Ground-up whole fish produces a fishmeal of 60 to 74 percent protein content. The use of fishmeal in the poultry industry has reduced costs and growing time of chickens and has given the United States the competitive edge in world markets in broilers and fryers. Fishmeal is also used to feed cattle, mink, hogs and other animals, and even trout. Fish oil has many uses, particularly as a cooking oil. However, substances made from whole unviscerated fish cannot yet be used as ingredients in products for human consumption in the United States. In Canada fish oil can be used to make margarine and cooking oils.

Given the consumption of fish and its nutritive value both for people and for

TABLE 5.16 *Commercial Fish Landings From Long Island Waters (New York Marine District) 1970*

Species	*Pounds (millions)*	*Value (millions)*
Food Fish	15.38	$2.32
Industrial Fish	1.06	$0.06
Total	16.44	$2.38

Source: U.S. Department of Commerce, NOAA, in cooperation with The Bureau of Marine Fisheries, N.Y.S. Dept. of Conservation, *New York Landings, Annual Summary 1970,* Current Fisheries Statistics No. 5611, 1971, p. 1.

animals, it is clearly not slackening demand that is bringing down the fishing industry. One of the main reasons is fewer fish. Fishing is a form of hunting and gathering; it is quite unlike meat production. Cattle growers control the feeding, breeding and killing of livestock in order to maximize the meat yield: nearly all the meat produced can be consumed by man. The only reduction in yield results from loss of livestock by disease and occasional predators. In contrast to the farmer, the fisherman has very little control over his stock, and, rather than increasing it, he preys upon it—along with other fish predators. Fish species have a natural distribution with climatic and self-induced variations. The population dynamics produce a certain age distribution for each species so that, on the average, the population is in a steady state. If fish are removed at a constant rate below the maximum sustainable yield, a new steady state is established: a smaller population with fewer old fish. This is perfectly tolerable. But if the rate of fishing is high, beyond the maximum sustainable yield, the standing stock will drop drastically and may become unprofitable for fishing. For many species the maximum sustainable yield is between one-third and one-half the natural standing stock.

This is a significant part of the conflict between commercial and sports fisheries. Each claims the other is overfishing; each alone is a legitimate use; but between them both, some species have been fished beyond the maximum sustainable yield and almost cannot be found in Long Island Sound.

In addition, various types of pollution and the destruction of wetlands reduce the available stocks. The vitality of the fish industry is intimately tied to the health of the wetlands. Wetlands produce food and serve as a spawning and nursery area for the growing fish.[42] Menhaden, for example, spawn in the ocean or Long Island Sound. When the young fish are about one inch long they swim to the wetlands, where they find food and protection from larger fish. After spending about eight months in the nursery areas, the young menhaden return to the ocean during the winter and may migrate to the south. By this time they have been transformed from slender, transparent larvae into deep-bodied juveniles resembling adult menhaden.[43] Many of the fish caught by local fishermen mature in the wetlands of Long Island and Connecticut. Preservation of these wetlands is essential for the preservation of the industry. Without these tidal wetlands, the life cycle of the menhaden, as well as flounders, fluke and other fishes, would be broken.

A wetland partly or completely filled in for housing sites is a wetland partly or completely useless to fish. But even without fill, much wetland productiveness has been poisoned by waste discharge from homes, boats, industries, farms, and municipal sewers. Furthermore, dredging operations and ditching to eliminate mosquitoes have damaged or destroyed wetland production of basic food chain organisms. Hence, wetlands that do still exist often show very marked reductions in productivity.

Other problems faced by the fishing industry of Long Island Sound are of broader scope than can be treated in this study, as they are of an international or national character. Russian trawlers operate within 25 miles of the American coast; they are developed, owned, and operated by the Soviet government. United States fishermen have few boats big enough or similarly equipped to compete with the Russians, or a source of labor willing to venture out to the fishing banks for weeks at a time.[44] The American fishery industry is also hampered by a lack of international controls over many fisheries, obsolete crew requirements on large boats, and lack of training programs, government subsidies, or financing enjoyed by other countries.[45]

One improvement in fish products—potentially a great boon to the fishing industry, and offering year-round employment as well—is presently hampered by rules of the Food and Drug Administration against using whole fish for human consumption. An improved type of fishmeal called fish protein concentrate (FPC) can be produced from industrial fish. This product is odorless and tasteless and can be stored indefinitely without spoilage, since all of the fish oil has been removed. A plant processing FPC was recently established in Greenport, entailing an investment of over $1 million.[46] Unfortunately, odors from the plant, together with a shortage of fish, have forced it to close. An FPC industry on Long Island has good potential, if adequate standards are instituted to prevent nuisance factors and if the menhaden stocks revive. An FPC industry could also lead to the development of ancillary food packaging and processing on Long Island. The Food and Drug Administration recently changed its position on FPC and now allows sale of one-pound packages of FPC made only from hake species. FDA does not allow the sale of products containing FPC as an ingredient.

Hammonasset River at Hammonasset, Connecticut. Note ditching of the wetlands surrounding the harbor.

Thus far, we've been discussing commercial fishing for finfish. Actually, of course, there is little economic difference between finfish and shellfish, but there is enough difference in their problems, conditions, and methods to warrant treating the two phases of commercial fishing as separate topics.

The shellfish industry has a long history on Long Island. Its many saltwater bays fed by small freshwater streams are highly favorable for shellfish farming (see Fig. 5.4). Such trade names as the Blue Point oyster have made Long Island world-famous. All the more startling, then, to confront statistics like these: In 1904, Long Island produced 20 million pounds of oysters.[48] By 1950, production had fallen to 8.8 million pounds a year, and by 1970 to 0.5 million pounds. At its peak at the turn of the century, the oyster industry employed 3,000 people and produced a crop worth $50 million at today's prices.[49] The 1970 crop was worth $1 million, representing only one percent of the nation's total oyster production, and employed only a few hundred persons.

The hard clam industry has fared somewhat better, with production increasing in the last several years to put New York first among states. In 1970, Long Island's clam industry produced 7.9 million pounds, valued at $8.9 million—a large share of Long Island's total 1970 shellfish crop value of $12.8 million.[50] The decline in the oyster industry has been partially offset by this increased concentration on hard clams.

Nevertheless, the shellfish industry as a whole is troubled. As with fish, the problem is not reduced demand—quite the contrary. Growing and marketing shellfish is still potentially one of the most profitable natural industries in the region. The nutritive content of shellfish is highly desirable: shellfish contain twice as much iron, pound for pound, as sirloin beef. Shellfish is rich in copper, phosphorus, calcium, iodine, and vitamins A, B, C, and D—and low in calories. Shellfish growing can also be highly productive: one acre of good shellfish producing ground can hold 500 bushels of marketable shellfish.[51]

What's the explanation, then, especially for the deterioration of the oyster industry? First, a brief look at how shellfish grow, and then a consideration of four key elements to their health. It's true you can harvest 500 bushels of oysters or clams from one acre, but it takes five to eight years to grow them to harvest size. In the case of oysters, there is a seeding stage (natural or by hatcheries) and a cultivating stage. In the natural setting, mature male and female oysters in spawning beds emit sperm and eggs into the water. A mature oyster lays about 100 million eggs a season. Fertilization takes place in the water; the resulting larvae swim freely for approximately 10 days to three weeks. Eventually, they fasten or "set" on shells, rocks and other suitable material on the bottom of an open-water floor of a seed bed, usually in a bay or harbor. Bays around Long Island Sound are brackish enough (not too salty) to permit natural oyster setting. The best natural sets occur in Connecticut waters. During the cultivating stage, the oysterman shifts the baby oysters, or "spat," from the seeding beds to the growing beds, and then to shaping beds and finally to fattening beds. During this growing period steps must be taken to eliminate or control the oyster's natural enemies—starfish, drills (a kind of shellfish), and conches. Finally, the oysters can be harvested and sold, maybe eight years after the seeding. Hard clams are harvested by baymen working with tongs, or with hydraulic harvesters.

Four elements are necessary for successful shellfish farming: (1) adequate sources of shellfish seed, (2) control of predators, (3) well-managed underwater and shorefront property, and (4) areas of unpolluted clean waters with an ample food supply.

SOURCES OF SEED. Seed from natural set in Long Island Sound is in danger. A catastrophic storm in November, 1950 virtually wiped out natural oyster seed and spawning beds in Long Island Sound, especially on the Connecticut shore. A number of oyster firms went out of business after the storm; that also reduced the fight against predators. A cooperative study by Connecticut and New York and a development program to achieve the restoration of natural seed areas might provide some answers to this pressing problem. So far, no such study or program is underway. An alternative approach is controlled production of oyster seed by special pond culture or hatchery techniques.[52] Pond culture is used extensively in Europe and Japan but has not been significant in the Long Island Sound region. Several ponds on Long Island could be adapted to seed production under these techniques, though in summer only. An experimental use of Japanese techniques in a pond on Fisher's Island produced over $100,000 of seed oysters in one summer. A better prospect is the development of more year-round hatcheries or greenhouses where seed can be produced under an environment of controlled temperatures and food supplies; existing hatcheries are too small to supply all the seed needed to revive the oyster industry. The shellfish industry is trying to help itself through research and good resource management techniques, but in its weakened economic state is unable to support the level of basic and applied research necessary to solve the seed supply problem.[53]

CONTROL OF PREDATORS. In past years, natural enemies of oysters have multiplied alarmingly. There has been an unprecedented rise in the oyster drill population in Gardiner's Bay particularly, and in all Long Island waters in general, including the Sound. A highly prolific and fast-growing barnacle that sets in early spring, covering and smothering seed oyster crops, has been flooding into Gardiner's Bay and Shelter Island areas. Finally, a very rapid increase of starfish in Long Island Sound is spreading into Huntington and Oyster Bay Harbors.[54] One starfish alone can consume 200 to 400 seed oysters a year—and there are

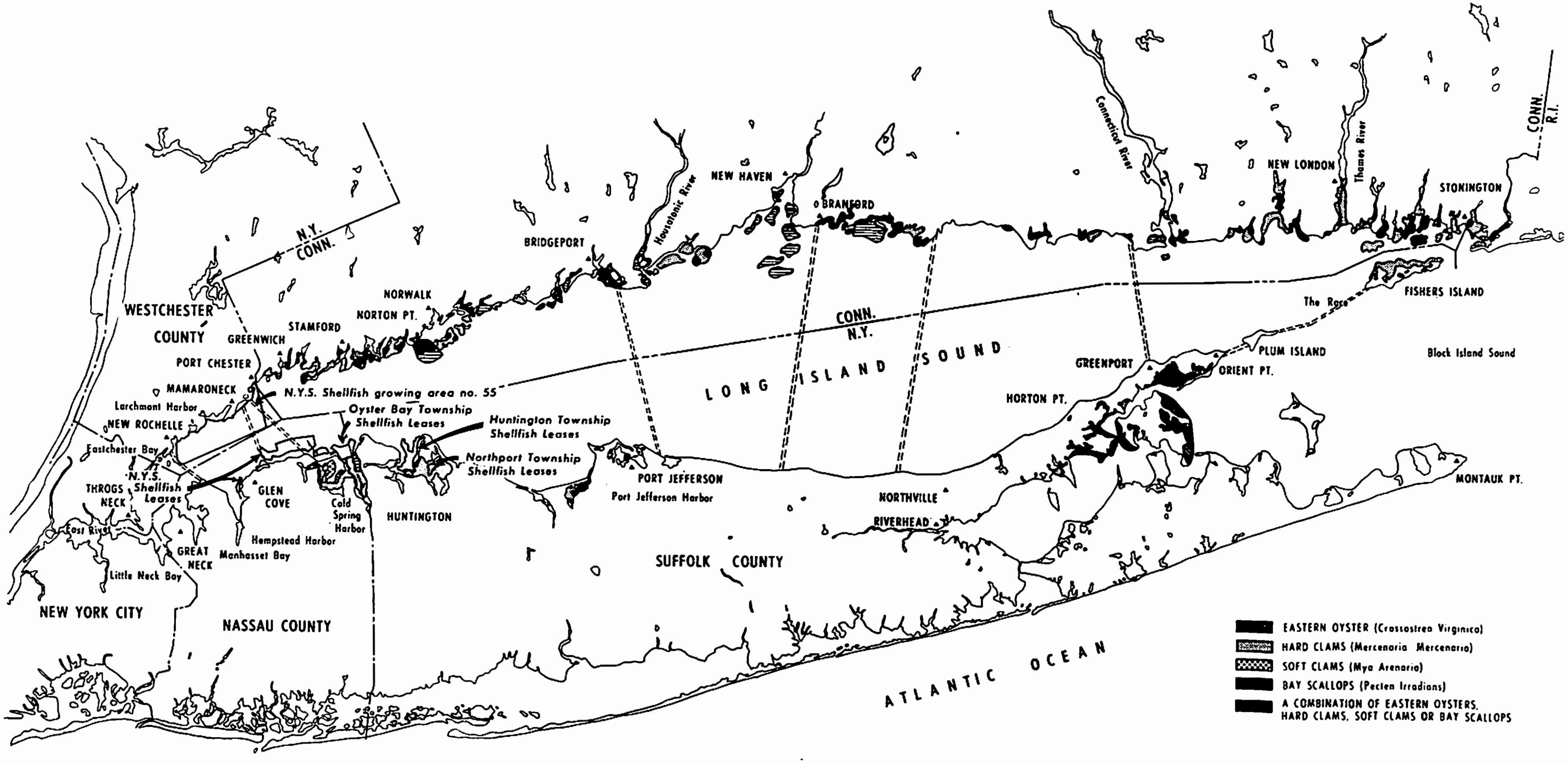

FIGURE 5.4 *Shellfish Grounds — Location and Species*

probably millions of starfish in Long Island Sound in any normal year. Using high frequency sound waves and chemicals like lime to eliminate these predators has been confined mostly to laboratory experiments.[55] In fact, no effective, wide-scale method to stop the growth or influx of oyster drills or barnacles or starfish has been found. Oyster farmers are simply at their mercy, for now.

The combined impact of storms and predators has been much harder on oyster production than on the clam—mostly, it seems, because of location. The Connecticut shore is where oysters have thrived best, and that's where storms have hit hardest and industrial pollution is the closest. Hard clams, on the other hand, seem to be doing better than ever before in Great South Bay on Long Island's ocean side. Gradual changes have taken place in salinity and water conditions there, and the bay is somewhat protected from storms. Added to that is a good market price for hard clams in recent years.

UNDERWATER AND SHOREFRONT PROPERTY MANAGEMENT. Long Island Sound has over 300,000 acres suitable for shellfish farming (see Fig. 5.4).[56] Only 40,000 acres are presently leasable for oysters, and only a small percentage of that is actively farmed* because of the lack of seed oysters. Existing leasable acreage is estimated as capable of producing a crop of oysters valued at $100 million annually.[57] The unused land represents a vast untapped natural resource. Leasing land rather than relying on natural propagation is essential to encourage scientific farming. In the towns of Oyster Bay, Huntington, and Brookhaven, where a balanced farming program between baymen and farmers has been initiated, shellfish propagation is on the upturn.

The shellfish industry also needs adequate shore establishments to support its landbased phase: adequate docking and unloading facilities for shellfish vessels, and shorefront areas with clean waters to establish shellfish hatcheries. In some cases the shellfish industry must compete for clean-water locations with other businesses not even related to water or the shore; this adds to overhead expenses because of high land acquisition costs and taxes.

CLEAN WATERS AND FOOD SUPPLY. Shellfish can grow only if there is adequate food in the waters they inhabit, and they can be marketed only if these waters are free from toxins. Wetlands are the main food source for shellfish; landfill in many wetlands has pinched the food supply. A growing population around Long Island Sound has discharged increasing amounts of sewage wastes. Sewage has at least three different potentially ruinous effects on shellfish. First, its pathogenic bacteria (e.g., coliform) can contaminate and ruin a harvestable crop—which has taken five to eight years to grow, as noted above. Second, the nutrients in sewage and in farmland and duckfarm runoff can cause overfertilization and algae blooms, which decay on the bottom where the shellfish are, using up the oxygen. Third, sewage can contaminate potential shellfish farming areas and prevent their future use.

At present, 17 percent or approximately 82,000 acres of New York Marine District waters in Long Island Sound are closed to the harvesting of shellfish—plus approximately 43,000 acres of estuarine waters in Connecticut. These 125,000 acres are almost half the growing waters. Figure 5.5 depicts the areas closed, and Table 5.17 lists the acreages. Since polluted grounds are very fertile, the shellfish do grow well. This unfortunately creates a law-enforcement problem, since there are unscrupulous individuals who, if given the opportunity, will harvest this crop from the closed areas and sell contaminated shellfish to unsuspecting buyers.

TABLE 5.17 *Areas Closed to Shellfish Harvesting, Long Island Sound, New York Marine District, 1972*

Code	*Area*	*Acres Closed*	*Total Bay Acreage*
	Nassau County		
1	Little Neck Bay	entire bay closed	
2	Manhasset Bay	2,725	2,725
3	Hempstead Harbor	3,465	3,465
4	Oyster Bay Harbor	350	5,040
5	Cold Spring Harbor[1]	95	1,325
	Suffolk County		
6	Huntington Harbor	165	340
7	Centerport Harbor	130	400
8	Northport Harbor	300	410
9	Smithtown Bay	500	22,000
10	Port Jefferson Harbor	815	1,550
11	Northville	5,170	
12	Greenport	300	
13	Fishers Island	900	

Source: Robert Schneck, Environmental Control Unit, N.Y.S. Dept. of Environmental Conservation, Stony Brook, N.Y.

[1] Includes that portion of Cold Spring Harbor in Suffolk County.

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*This does not include spawning beds in the wetlands, where the critical fertilization process takes place.

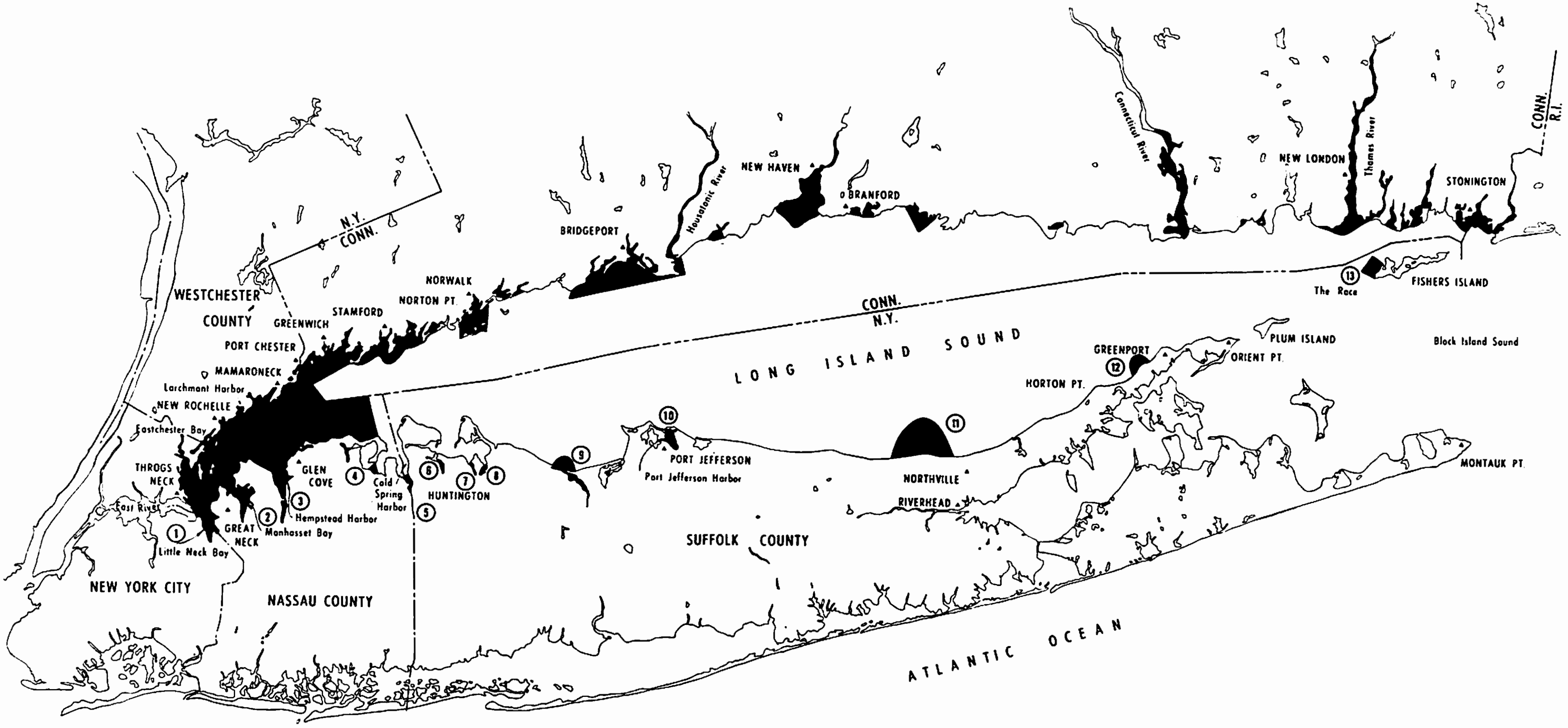


FIGURE 5.5 *Closed Shellfish Grounds on the Sound, 1972*

INSERTION

The prior discussion illustrates typical problems with the most generally recognized substance we insert into the ocean—sewage. Wastes have to be disposed of somewhere, and in some form. Both sewage wastes and solid wastes like rubbish, garbage, and dredge spoils have been undergoing some transformations before they are dumped—inserted—into the water. They are compressed or separated mechanically or treated biologically or chemically, for instance. But we still are finding exactly how much impact these metamorphoses really make on the water chemistry, how much of the ocean floor is covered by which wastes, and what that means for bottom plant and animal growth, to list a few areas of research. Other substances we insert into the ocean are beginning to be dealt with as having priority for research and management. The quantity and effects of pesticides on ocean life are virtually unknown. The effects of heated water pouring out of such industrial plants as electric power generating facilities are presently under research.

Human Sewage

Most of Long Island Sound's waters are clean, attractive, and relatively unpolluted.[58] Thousands of residents and visitors still swim and fish without fear for their health in most places. But evident signs of sewage pollution have begun to appear in Long Island Sound coincident with the increasing population. The problem was first obvious and is now most critical in western Long Island Sound, near New York City.[59] It is by no means confined to that area. For example, the Suffolk County Health Department has observed through its beach inspection program a slow but steady deterioration in water quality in the less populated areas of the eastern Sound.

Overflow from cesspools, seepage of polluted ground water, and illegal direct discharges of sewage are finding their way into the surrounding water. Boats polluting directly into the water need to be stopped by enforcement of regulations, a good education program, and convenient dock-side evacuation facilities. Between 1960 and 1970 the Suffolk County Department of Health found it necessary to refuse swimming permits for a small number of beaches on both the north and south shores and on some inland lakes.[60] Furthermore, a joint survey by the United States Geologic Survey and the Suffolk County Water Authority indicated the presence of ABS (synthetic detergents) in the ground water and in most of the streams tested.[61] This is a positive sign that sewage is finding its way not only into the waters of the Sound but also into the drinking water supply on Long Island.

One reason for the present situation is the long-accepted assumption that the subsoils of Long Island are adequate to cleanse raw sewage for an infinite population. Approximately 95 percent of the sewage in the towns along Long Island's shore of the Sound is flushed into individual subsurface disposal systems, that is, septic tanks or cesspools. In areas where population densities are light (land zoned for half-acre or more) and the subsoils consist of medium to coarse sands and gravels extending to depths of 100 or more feet, cesspools are effective. But in much of Long Island, neither the population nor the geology meets those ideal conditions.

Purification of water occurs naturally. But the natural process requires time and is limited by the amount of dissolved oxygen in the water. Oxidation of organic matter by micro-organisms proceeds fairly rapidly when enough dissolved oxygen is in the water. It stops when dissolved oxygen is absent. An important parameter is therefore the amount of oxygen required to oxidize the organic matter. This is usually expressed as the *biological oxygen demand* (BOD): the mass of dissolved oxygen used up when a specified amount of effluent is held for five days at a temperature of 20°C in a closed bottle. During the five-day incubation, about 70 percent of the organic matter in the water can be oxidized (destroyed). The BOD is expressed as parts per million (ppm) or gm/ton.

The self-cleaning ability of a body of water depends on its oxygen content, the BOD of the sewage-water mixture, and the rate at which oxygen is transferred from the atmosphere to the water. The solubility of oxygen in fresh water depends strongly on water temperature: it decreases as the water temperature is increased, that is, the warmer the water, the less dissolved oxygen it can hold. As we saw in Chapter 4, the greatest problem arises when waters are warmest, usually in late summer. The dissolved oxygen in the water is lowest then, and oxygen uptake (by decaying algae, etc.) is most rapid. In addition, under these conditions, the body of water may have a thermocline (a region in which temperatures change rather abruptly with depth, from the warmth of the sun-warmed surface zone to the cold, deep zone). A stable thermocline inhibits vertical mixing of the water, and therefore reduces the rate of reoxidation of bottom waters even further.

Water at 20°C (a temperature within normal range for the Sound) is considered saturated when it contains 9 ppm of oxygen; sewage would have to be diluted 20 times for the oxygen content of the water to satisfy the BOD. Dilution is thus not the answer to sewage pollution at medium or heavy population densities. Water of a quality safe for health is going to require sewage collection, treatment, and disposal.[62] Individual family cesspools simply cannot protect either ground waters or nearby marine waters. And sewage treatment techniques themselves are going to need marked improvement; right now even treated sewage seriously degrades water quality.

Solid Wastes

The municipal refuse pile of the United States grows by about 200 million tons each year. Collection and disposal of refuse costs $4.5 billion or an average of $28 per ton. The yearly trash pile includes 46 billion cans, 26 billion bottles, 30 million tons of paper and 4 million tons of plastic. With rising populations in coastal areas, management of this waste has become increasingly difficult and expensive. Every present disposal method creates new problems. Large metropolitan areas, many of them coastal, are caught in a dilemma of unacceptable alternatives and face the immediate crisis of being buried in their own rubbish.

The major method of rubbish disposal is sanitary landfill operation. The rubbish is piled on the ground or in an excavation and is covered daily with a few inches of fresh soil. Coastal communities have long used wetlands for landfill. Consequently, valuable wetlands are destroyed and the filled area is later developed as real estate or parkland. About 10 percent of New York City is built on former disposal sites; San Francisco Bay is still being filled in. Landfills also adversely affect nearby marine waters by leaching. Rainwater seeps into the ground, dissolves materials from the wastes in the fill, and loses its oxygen through oxidation of the organic matter. This new ground water may contaminate other ground waters or be discharged to nearby marine waters. In short, the material in a landfill may be out of sight, but should not be out of mind, since it is not removed completely from the system.

Two other answers to waste disposal—burning or dumping at sea—also have spin-off problems. Approximately 70 percent of rubbish is burnable; but reducing the trash pile by incineration causes air pollution. That can be more expensive than landfill, what with all the regulations and regulators that are needed to keep air pollution down.

Dumping wastes at sea has a frustrating aftermath: the floatable components are carried ashore by surface currents. New York City used to barge refuse to sea for dumping, but a significant part was redeposited on the New Jersey and Long Island shores. A U.S. Supreme Court decision in 1933 stopped the practice. Other cities have had similar experiences. Various schemes to compress rubbish and garbage to increase its density and so avoid the flotation problem have been developed, but not enough to be put into practice.

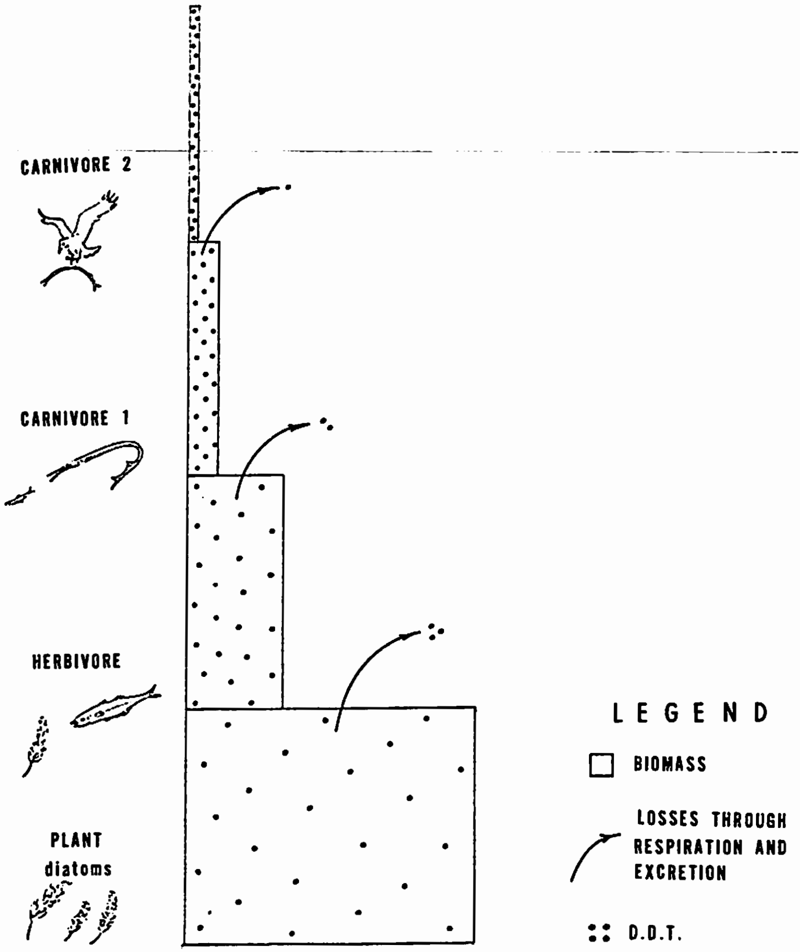
Solid wastes other than rubbish are regularly dumped at sea in disposal areas designated by the Corps of Engineers. Obsolete military hardware and ammunition debris, old cement and slabs of macadam from excavations, dredge wastes, sewage sludges, and chemical wastes, all are going down to the sea bed daily. For example, each year between 1964 and 1968, about 0.8 million tons of waste solids were dumped in western Long Island Sound and 4.6 million tons in New York Bight.

The problems posed by the solid wastes depend on their composition and quantity. At the very least, they cover bottom-dwelling organisms; after dumping ceases, organisms adapted to the new substrate can become established. At worst, the waste deposits may have a large oxygen demand, or toxic components may leach into overlying waters. Wastes may remain within disposal sites or may be spread by bottom currents. Wastes from dredging are extremely variable in composition. In industrialized harbors, the dredged materials consist of municipal and industrial wastes and usually resemble sewage sludges. Petroleum is common in these wastes. In other areas the dredged material may be clean sand, useful for construction or landfill. At present, oil-soaked muds and clean sands are often dumped together with no organized effort to use the sand (because dumping it may be less expensive than shipping it, and sand is less desirable than gravel for construction). A major advance toward acceptable sea-dumping practice would be classification of wastes and intelligent disposal based on their probable environmental effects.

Pesticides

Pesticides are causing serious and widespread problems among marine organisms and among animals that feed on them, especially birds. Large amounts of chlorinated hydrocarbons (DDT) and similar pesticides are used for crop control on the uplands, and for mosquito control in the salt marshes, tributary streams, and catch basins. Through seepage, groundwater flow, and direct contact, these persistent pesticides find their way into bays or the ocean. Since they are relatively insoluble, they are taken in undiluted by the microorganisms in the water and enter the food chain. As they move up the food chain, they become concentrated; appreciable amounts are being found in fish, fish-eating birds, and other carnivores.[63] Figure 5.6 illustrates how DDT becomes more and more concentrated as the food cycle reaches larger marine animals. Table 5.18 indicates the amount of DDT residues found in organisms living in or near the sea.

Unfortunately, little detail is known about pesticide effects on marine life. It is clear that some species die, become sterile, or don't survive the embryonic stage, resulting in reduced populations of higher forms like fish.[64] This in turn allows excessive growth of algae and further pollution from the unconsumed algae dying and decomposing on the bottom. From the fact that broad correlations do exist between DDT concentrations and mortality, it seems patently obvious that pesticides serve no beneficial purpose in the marine environment. In fact, the damage may be more insidious and complete than from any other source now threatening the marine ecological system. DDT affects entire species on a world-wide basis rather than a single population, and may well wipe out those varieties by eliminating reproduction.[65]



SOURCE:- Scientific American March 1967. Vol. 216 . NO. No. 3. P.30

FIGURE 5.6 *The transfer of DDT through a simple food chain of marine animals to birds*

TABLE 5.18 *DDT Residues in Samples of Plants and Animals (in parts per million wet weight of the whole organism)*

Sample	*DDT Residues (ppm)*
Plankton, mostly zooplankton	.04
Shrimp	.16
Crickets	.23
American Eel (immature)	.28
Hard Clam	.42
Sheepshead Minnow	.94
Black Duck	1.07
Summer Flounder	1.28
Common Tern	3.15
Green Heron (immature, found dead)	3.51
Herring Gull (immature)	3.53
Osprey (one abandoned egg)	13.80
Ring-Billed Gull (immature)	75.50

Source: Adapted from *Science* (Vol. 156, May 12, 1967), Table 2, p. 822.

Alternatives are needed, like the development of new pesticides which rapidly decompose into relatively harmless components. Some areas around Long Island Sound are experimenting with biological control schemes. Most of Nassau County's mosquito control work is being done by irrigation and water control with ditches or small channels to improve water flow and eliminate breeding areas, and by encouraging organisms that feed on mosquitoes or mosquito larvae. Along the New Jersey coast, upland marshes have been flooded to flush out larvae, and biological controls have been introduced: natural balance is eliminating the mosquitoes. Using chemical pesticides other than DDT can bring great improvement. Spraying in Nassau County is done with malathion. Where biological management is not effective or possible, fuel oil emulsions are used as a larvicide. A very thin layer of oil, one molecule thick, is enough to kill larvae. Most salt marsh mosquitoes have thus been eliminated in Nassau; the remaining pests come from stagnant fresh waters. Since the long-range effects of the various alternatives are unknown, research in this field is obviously indicated. We need not wait for research results, however, to act against DDT. The Suffolk County Mosquito Control Commission stopped using DDT in 1970 after recognizing its operations were causing widespread pesticide contamination. DDT was used in Nassau over a four-year period but was discontinued because it brought poor results relative to cost. New York State banned the use of DDT on January 1, 1971.[66]

Thermal Discharges

Many industrial processes—involving chemicals or metals, for example—require dissipation to the environment of large amounts of heat. Long Island Sound people are quite familiar with one particular such process: electricity generation. There are 17 electric generating plants using oil or coal (fossil fuels) around the Sound, and 7 more proposed (Fig. 5.7).

In an electric generating plant using steam to turn the turbine, steam is heated to a high temperature and pressure by burning a fossil fuel or by heat exchange with a nuclear reactor. The steam then drives a turbine connected to the generator which produces the electricity. The low-temperature, low-pressure steam leaving the turbine must be condensed to water; condensation reduces its pressure and maintains flow. This water is then returned to the boiler to be reheated to steam.

The condensing stage requires great amounts of water to cool the steam. Cooling water flows through miles of tubing surrounded by steam, absorbs the heat, and then is discharged back into the river or ocean whence it was pumped ("once-through" cooling). Alternatively, the water may be cooled by evaporation in cooling towers and recirculated through the plant. To illustrate the great amounts of water involved and the proportion used by the electric industry: in 1964, United States industry used about 50 trillion gallons of water for cooling; 81 percent of that was used in the generation of electricity.

There has been considerable improvement through the years in using steam efficiently, and thus the cooling water "goes farther" these days. Efficiency is expressed in terms of the *heat rate*, the thermal energy in BTU (British Thermal Units) required to generate one kilowatt hour of electricity (3413 BTU = 1 kilowatt hour). The heat rate (efficiency) has improved from a 1925 United States average of 25,000 BTU/kwh to 8588 BTU/kwh for the best plant in 1962. The reduction in heat rate has been achieved by increasing the temperature and pressure of the steam produced in the boiler. Of the heat rate, 3413 BTU are converted to electrical energy; the rest are dissipated to the environment. This means that in 1925, about 21,500 BTU/kwh were going into the water as waste heat; in 1962 only about 5000 BTU/kwh were dissipated. Fossil-fuel plants use less cooling water per kwh than nuclear facilities, however; "going nuclear" is no improvement from the water's point of view. In a fossil-fuel plant, about 40 percent of the heat (the 8588 BTU/kwh) is converted to electricity; of the 60 percent waste heat, about 15 percent goes into the atmosphere by stack gases and by losses from the plant, and the remaining 45 percent goes into the cooling waters. In a nuclear plant there are no stack losses of heat and about 5 percent of the heat is dissipated from the plant to the atmosphere; since in nuclear plants 32 percent of the heat converts to electric energy, that leaves 63 percent going as waste heat into water. Because of lower operating temperatures, heat rates of nuclear plants are somewhat lower than those of the most efficient fossil-fuel plants.

Efficiency overall is better, yes. But much more electricity is being generated now, and individual plants are larger than before, hence the total amount of water running through is much greater. Finding good, available water in massive quantities is already problematical. Areas of high electric load density are usually also areas of water shortage or poor water quality. Heating water further reduces water quality by lowering dissolved oxygen and raising oxygen uptake. The maximum demand for electricity also comes when flows are usually low, either in late summer or in midwinter.

It becomes clear, then, why the Long Island Sound area has 17 generating facilities operating and 7 more proposed. The vast quantities of water required make shore locations convenient. Because fresh water is preferred to salt water (which corrodes the pipes), power plants have built on estuaries, with their intakes close to the surface. But the heated water exacerbates adverse effects of other pollutants, and the quantities of water demanded by expanded electricity needs are causing industry planners to look offshore. The generating plants presently located around the Sound use more than 2.1 billion gallons of cooling water daily; this demand can be expected to increase more than eightfold over the next two decades. Table 5.19 lists the existing and proposed plants by type and location.

Since siting power plants right on the seashore will compete with recreational and other uses of the beach, we can expect in the future to see large power plants, nuclear-fueled, located near shore or on platforms offshore. The effect of heated water discharges depends on numerous variables, so it will be essential to develop adequate safeguards against potential damage to the marine environment of the Sound.

Long Island Lighting Company nuclear power generating station under construction at Shoreham, L.I.

TABLE 5.19 *Major Electric Power Plants on Long Island Sound*

			Installed Capacity (megawatts)	*Planned Capacity (megawatts)*	
*Code**	*Name of Plant*	*Location*	*1967*	*1970*	*1990*
○	*Steam*				
1	Long Island Lighting Co.	Port Jefferson	467	483	483
2	Long Island Lighting Co.	Northport	387	403	403
3	Long Island Lighting Co.	Glenwood Landing	307	1567	1567
4	Connecticut Light & Power Co.	Norwalk Harbor	326		
5	United Illuminating Company	Steen Point Bridgeport	156		
6	United Illuminating Company	Bridgeport Harbor	261	655	1155
7	Connecticut Light & Power Co.	Devon, Housatonic River	479	470	445
8	United Illuminating Company	English, Mill River, New Haven	146		
9	Connecticut Light & Power Co.	Montville, Thames River, New London	176	176	

*Code**	*Name of Plant*	*Location*	*Proposed Capacity (megawatts)*	*Scheduled Completion Date*
◊	*Nuclear*			
1	Long Island Lighting Co.	Shoreham	849	1975
2	Long Island Lighting Co.	Lloyd Neck	1000	Mid 1980's
3	Consolidated Edison Co.	Welfare Island	3000	Proposed
4	Consolidated Edison Co.	Davids Island (Ft. Slocum)	4000	1978
5	Connecticut Yankee Atomic Power Company	Haddam Neck	567	In Operation
6	Northeast Utilities	Millstone Point	828	1975

Source: *Proceedings, Conference in the Matter of Pollution of the Interstate Waters of Long Island Sound and its Tributaries—Connecticut—New York,* April 13-14, 1971, New Haven, Connecticut. (Washington, D.C.: Environmental Protection Agency, 1971) Volume 1, Tables A-1, A-2, pp. 137-139.

*Refers to numbers on Figure 5.7

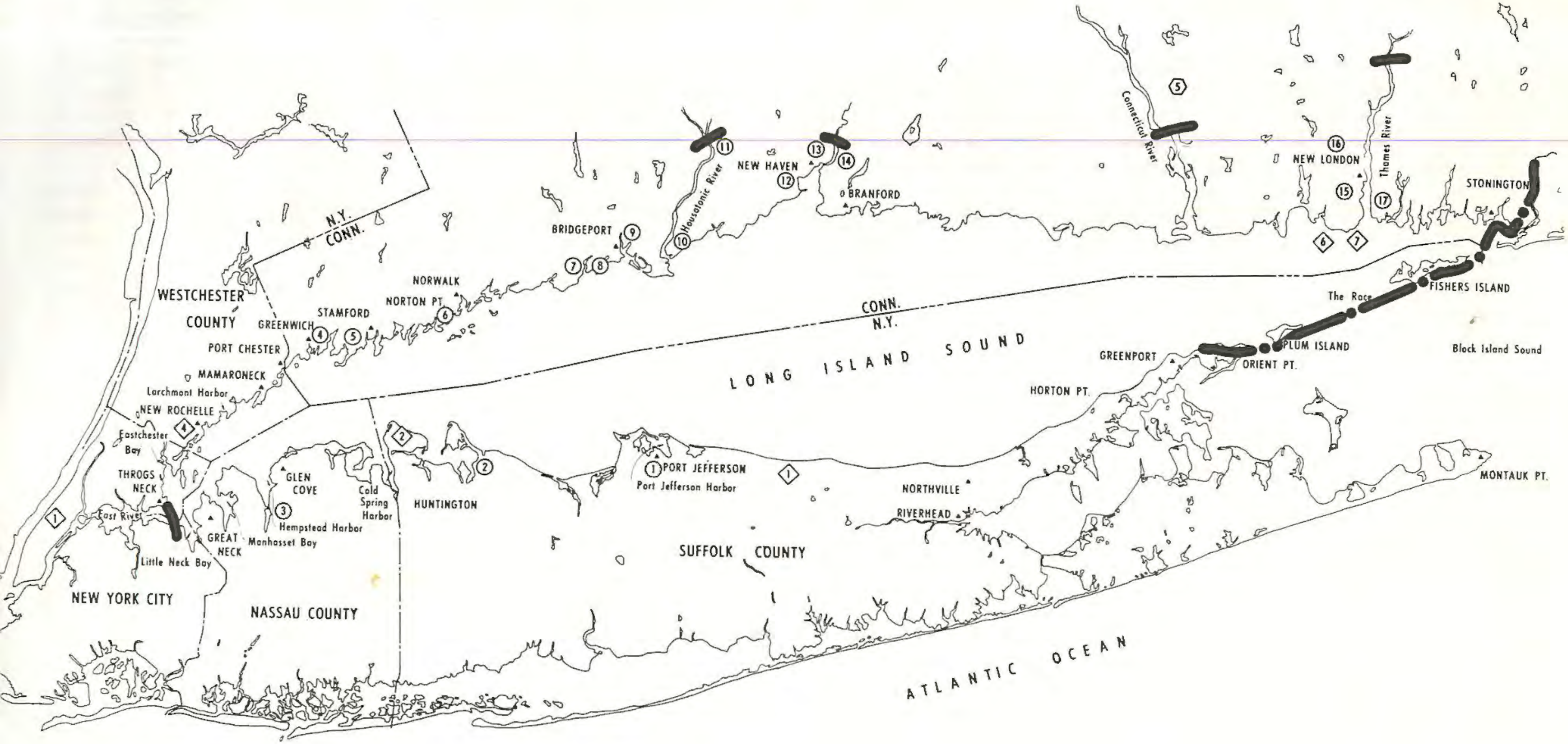


FIGURE 5.7 *Power Generating Plants*

SUMMARY

Conflicts among uses, competing demands made on the waters and shores of Long Island Sound, are the crux of the present situation. What the Sound will be like in the future—economically and aesthetically—hangs precariously on how well the environment itself is served now, when competition created by rapid urbanization is balancing this way and that. Protection and conservation of the Sound are essential if swimming and boating, fishing and clamming are to continue. But competing with those uses are dredging to get sand and gravel for construction or to clear navigable channels, and extracting and shipping oil. An intractable and direct conflict exists over wetlands: the need for preservation *as is* for fish and shellfish life cycles, versus the need to fill them in and build them over with the rubbish and residences of an expanding population.

There's more involved than just competition for space or use, however. Actual misuse is evident, that is, a use whose methods are unacceptable and undesirable. On-shore practices like agricultural fertilization, pesticide use, and the disposal of human and animal sewage have been and are depreciating the value of Long Island Sound by pollution. Thermal pollution from generating plants in the western Sound aggravates already-severe oxygen depletion and overfertilization stemming from sewage treatment plants and the character of tidal flow there. Dredging that exceeds its boundaries and depths wreaks irreparable havoc.

Some of the conflicts may be resolved by public awareness and financial support for conservation programs. Some of the conflicts can be ameliorated by stringent enforcement of existing rules and regulations. Some of the conflicts will yield only to energetic coastal planning and management. We already know a great deal about the marine environment, and have some good laws; putting knowledge and laws to work effectively depends now on active and concerned citizens.

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6 Government and the Sound

INTRODUCTION

The United States is the only industrialized western nation that has not developed a national plan, or even a set of national priorities, for the allocation of natural resources or the direction of urban growth. This is partially a reflection of the pioneer syndrome that persists well past the closing of the frontier. The Articles of Confederation and the Constitution were both written as strong expressions of the authors' intense distrust of government in general, and of centralized government in particular. The right of property was established as a basic principle. As a result, land ownership and land use were largely relegated to the private sector. Yet urbanization—the by-product of the industrial revolution—brought an awareness that some control over land development was necessary to protect the rights of private landowners from conflicting land-use actions of their neighbors. The limited exercise of "police power" to control land-use decisions has been almost exclusively a local government function, with a few notable exceptions of state control in Hawaii and Alaska (California, Florida, and Maine have enacted limited review procedures).

Another factor that contributed to fragmented and unregulated growth was the availability of seemingly unlimited resources. In effect, Americans adhered to the legal concept of *feri naturi,* i.e., the commodities of nature are free to all. Unfortunately, the uncontrolled practice soon became a perversion. Fresh air and clean water should be free commodities for everyone, but they are not. The imbalances produced by industrial and urban pollution have indeed raised the cost of these essentials to life.

Land resources have been similarly exploited to provide for the insatiable appetites of a rapidly growing and urbanizing population. The coastal zones have been subjected to the most intensive uses—and abuses. This is understandable: the natural interface of land and water has allowed for the most diverse support for human settlement. Transportation of all kinds, ample protein food, strategic military position, recreational opportunity, and commercial development were and are some benefits of living near the coasts. It is not surprising that the great majority of Americans lives in or near the four major coastal zones, i.e., the Atlantic, Pacific, Gulf Coast, and Great Lakes regions. Population projections made at all levels of government agree that this trend will continue, thereby increasing the demands on the natural environment and exacerbating the conflicts over access and usage.

Other problems, including the array of ecosystem degraders generally referred to as pollution, e.g., sewage and thermal and chemical contamination, exist in part because of governmental inertia in carrying out enforcement procedures. And some problems are perpetuated by the conflicting philosophies and goals of public agencies, compounded by the absence of a comprehensive approach to managing the marine environment. It is hoped that the Coastal Zone Management Act of 1972 will contribute greatly to the creation and implementation of broad-based management policies and programs to overcome the present deficiencies. More will be discussed of this legislation in this and the next chapter.

Long Island Sound is bordered by numerous villages, towns, and cities. Each municipality controls its own destiny in matters of planning and zoning for land use. Therefore, the pattern of development adjacent to and into the marine waters is currently decided locally. But pollution problems are a county, state, interstate, and federal concern. Channel improvements, beach protection and stabilization, and other dredging projects must be approved by the US Army Corps of Engineers. Other enterprises possibly affecting the Sound may also be subject to review and control under the National Environmental Protection Act. The marine environment is therefore controlled in some degree by each shoreline municipality as well as the counties and states on the Sound and the federal government. Table 6.1 shows the number of governmental units that share an interest in the use and control of Long Island Sound.

At the present time there is no coordinated system among the various municipalities for managing the marine environment. Problems created by one municipality but affecting other municipalities have no regular means of solution other than through the courts. Nor is there coordination among the various federal agencies that exert control or influence over the marine environment of Long Island. And unfortunately, there are no effective research programs to help maintain a desirable and productive marine environment. It is true that efforts have been made by some organizations and citizens' groups to achieve a balanced ecosystem, but these have been limited in scope—either geographically or substantively—with no attempt at relating the consequences of individual group actions on the total system.

At the very least, it appears that coordination is necessary at the federal, state, and local levels of government to protect, improve, and enhance the marine environment. Nevertheless, problem-solving at the most local level of government has great appeal to many of the region's citizens. Support for home rule is based on a long history of political activity in the states of Connecticut and New York.[1] A clear understanding of basic home-rule philosophy is essential to full consideration of administrative proposals, including the likelihood of their implementation. The political reality of multiple governmental units kept alive by the supporters of home rule tends to further limit the opportunities for cooperative action.

TABLE 6.1. *Governmental Units With Active Interest in the Long Island Sound Marine Environment**

Governmental Level	*Number of Jurisdictions*	*Number of Agencies, Bureaus, or Authorities***
Federal	1	10
State	3	7
Cities	18	–
Counties	4	9
Towns	59	–
Villages	64	–
SUBTOTALS	**149**	**26**
TOTAL		**175**

*Also see Fig. 6.1.

**This table does not include local conservation advisory committees, marine water trustees, or municipal operating agencies.

The exercise of home rule is valid for problems manageable at the local level. Yet Chapter 5 shows that in cases of pollution, wetlands conservation, and conflicts among different users, the problems of the marine environment are not neatly separable into discrete units of manageable size by jurisdictional boundaries. This poses a significant question: what administrative vehicles can be devised that can take into account the home-rule philosophy and can at the same time solve problems in a comprehensive fashion? An examination of the two current attempts in this direction should offer some insight. Both efforts are advisory and primarily concerned with developing a planned approach to the Sound and adjacent lands; both have considered the vital questions of plan implementation and management requirements. The first example is the Nassau-Suffolk Regional Planning Board and its Regional Marine Resources Council. The second is the New England River Basins Commission and its special study of the Long Island Sound.

THE NASSAU-SUFFOLK EXPERIENCE

The Nassau-Suffolk Regional Planning Board was established in January 1965 to prepare a comprehensive development plan for the two suburban counties of Long Island. The completed plan, released in August 1970, included the traditional components of land usage, transportation networks, and community facilities.[2] Yet it was unique in that the underlying model, called "Clusters, Corridors, and Centers," reflected the realization that the natural environment is not infinite—the number of people that can reasonably be accommodated is limited by environmental constraints on air, water, and soils.

The board recognized the special character of the area with its varied marine environment. Consequently, one of the first decisions was to focus on the opportunities and problems that go along with urbanization of the marine environment. The impetus for this approach, at a time before "Earth Days," Sea Grant programs, and environmental protection became firmly established in the public consciousness, came from the dogged determination of a gifted individual with a mission.

In the spring of 1965, the late Dr. Mark A. Frey, president of Unified Research, Inc., came to the Nassau-Suffolk Regional Planning Board offices to

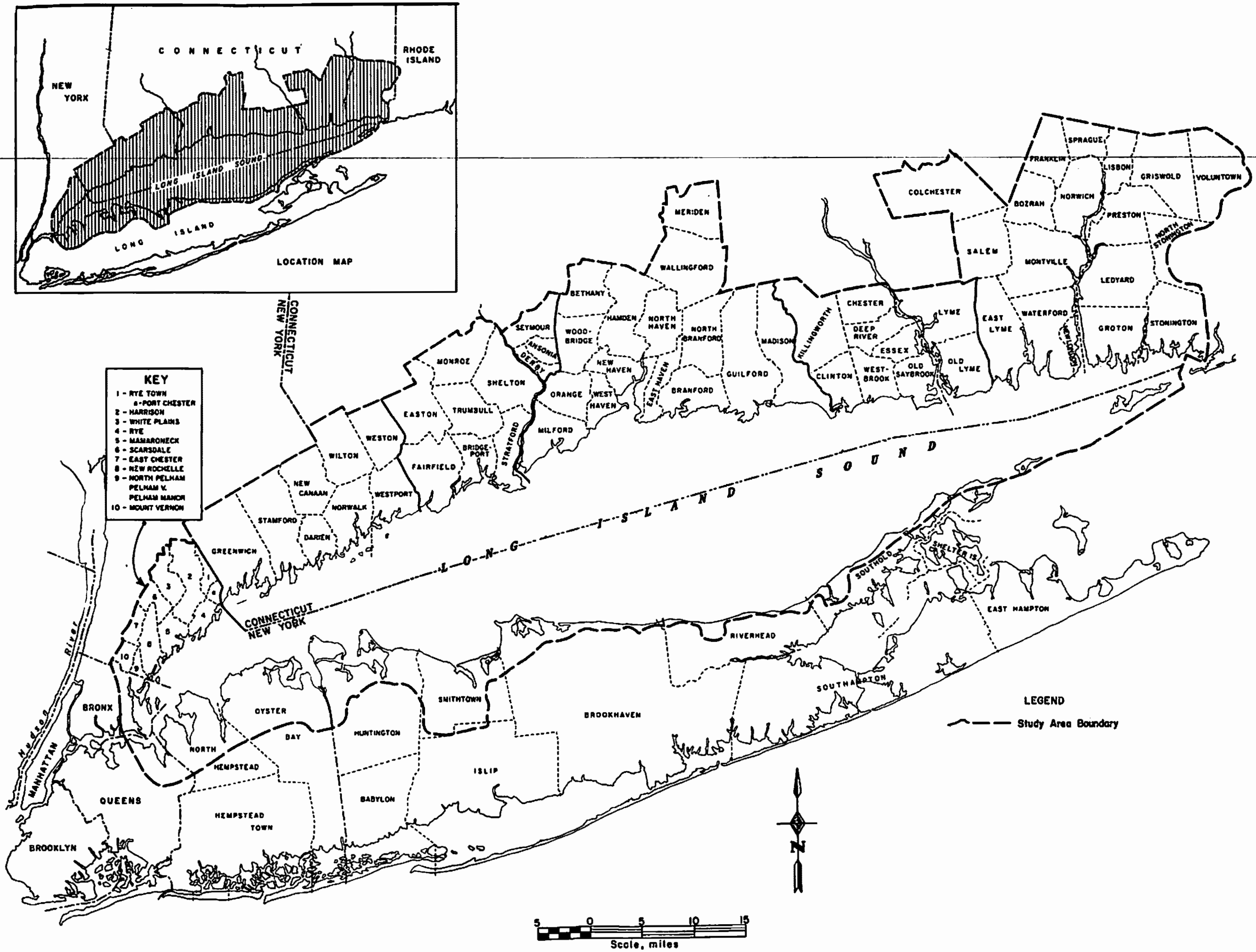

FIGURE 6.1 *Governmental units with active interest in the Long Island Sound marine environment (excluding villages)*

talk about the development of oceanographic activities on Long Island, in light of the increased national attention to oceanography. The federal government had funded numerous grant-in-aid programs to stimulate research and development in this field, and it seemed probable that the myriad activities that make up the broad term "oceanography" would constitute the leading national industry in the coming decades. He pointed out that Long Island, with its miles of shorefront and diversity of marine resources, would be a desirable area for the development of such water-oriented activities.

At his own expense he commissioned the New York firm of Tamlyn and Brown to prepare a detailed report with recommendations to implement this development[3] The firm proposed the establishment of a multi-purpose center on Long Island, with educational, research, industrial, and recreational functions.

Since Dr. Frey felt that such an endeavor would require the cooperation of the various governmental units on Long Island, he requested the support of the Nassau-Suffolk Regional-Planning Board. His proposal was placed before the board at its April 1965 meeting, and it was received favorably.

To pursue Dr. Frey's proposal and to examine further the role that Long Island should play in oceanographic development, the board announced the creation of a task force called the Oceanographic Committee. The board instructed its staff to recommend leaders in the fields of oceanographic engineering, education, marine fisheries, boating, conservation, agriculture, and government (the seven areas selected as representative of the major interests in the marine environment). Two members from each field were to be appointed to the task force—one from Nassau and one from Suffolk. This was the only concession to political pragmatism. Chairman of the Board Leonard W. Hall also recommended that the task force be chaired by a nationally recognized authority in the field of oceanography. Obviously, residency could not be a criterion. The search was a relatively easy chore, since the number of qualified individuals didn't add up to a baker's dozen. Within a month's time, the board appointed Admiral Edward C. Stephan, former oceanographer for the US Navy and then president of the Marine Technology Society, to serve as chairman.

At first, it appeared to the committee that there were two separate areas of interest to be examined: 1) the opportunities on Long Island to participate in the growing national oceanographic and ocean engineering programs; and 2) the oceanographic problems growing out of the effects of population expansion on Long Island's marine environment. However, as the work of the committee progressed, it became evident that the two areas were inseparable.

The committee found that the complex marine environment, with its extreme sensitivity to the effects of population expansion, was a factor of overriding importance in the development and growth of Long Island. Population expansion on the Island has caused serious deterioration of the once-delightful marine environment which was a major factor in the Island's attractiveness and consequential growth.

To gain an understanding of the complex relationships within the marine environment, the committee launched a two-pronged investigation, simultaneously covering natural and man-made conditions and conflicts. Of course, these were not mutually exclusive; the interaction of human activities with the natural environment and the consequences of each action was the essence of this investigation. Preparation of a management plan was beyond the scope of the initial work.

The methodology employed involved the basic techniques of research, namely, data gathering, data refinement, analysis, and finally, synthesis.

The data were gathered through weekly meetings to which specialists in the various fields of the marine environment were invited. Tape recordings were made of each meeting. It was explained to the speakers that the function of the task force was to gain a clear understanding of the status and potential of the marine environment relative to each of their interests. Specifically, the task force needed information on current activities and the past history of these activities, with the attendant problems and the economic return. Each guest was requested to file a brief incorporating the major points of his presentation and any additional information that might be pertinent to the interests of the task force. The guests were also asked to state their industries' views as to the solution of existing problems and conflicts. More than 3,500 pages of testimony and briefs were entered into the record between September 15, 1965 and October 12, 1966. The staff conferred regularly with the members of the committee in the drafting of a summary report. The document, "The Status and Potential of the Marine Environment of Long Island," was submitted to the Regional Planning Board on December 7, 1966.[4]

This report summarized the information then available on the Nassau-Suffolk region in terms of the value and economic potential of its marine resources. It considered not only the direct commercial aspects, but also those that were more subtle and indirect. There are a number of important industries on Long Island directly related to the marine environment; these include shellfisheries, commercial and sport fishing, boating, swimming, and almost the entire Long Island tourist business. Generally, all of these businesses are enhanced by any improvement in the marine environment. The large residential real estate industry of Long Island has been and will continue to be favorably affected by the maintenance of an attractive marine environment, as illustrated by the great value of shore properties. Development of non-marine industry is also enhanced by the advantage afforded employees of living near a recreation-laden marine location. The report concluded that if Long Island were to continue to grow as a desirable and attractive place in which to live and work, the trend towards deterioration of the estuarine and shore environment had to be reversed. The report identified such activities as dredging, landfill, and pollution by human, industrial, and agricultural wastes as management problems that must be solved to insure proper development for the area.

Improved sewage systems, particularly in areas close to the shore where direct discharge and seepage to the marine environment occurs, and the safe disposal of effluents and solids from sewage reduction plants were considered top priority. Storm runoff containing insecticides, herbicides, fertilizers, and automobile wastes is another serious source of contamination of the Long Island Sound. In addition, despite the picturesque and pleasant image of boating, the ever-growing number of boats and marinas contributes to pollution with the dumping of raw or chemically treated sewage into the marine environment.

The report recognized the pressing need for greater knowledge of the effects of population expansion on the marine environment of Long Island before such problems could be properly solved. It stressed that extensive research programs would be required to understand adequately how the various contaminants reach the waters and their effects on marine biology and chemistry. The report recommended emphasis on developing an educational capability oriented towards understanding the local marine environment, with the various local universities and colleges cooperating in the assembly of staff, facilities, and a central library.

Dr. John C. Baiardi, formerly with C.W. Post College of Long Island University, and a member of the committee, supported this recommendation by creating the New York Ocean Science Laboratory at Fort Pond Bay in the Town of East Hampton. He was successful in obtaining a cooperative response from most of the major institutions on Long Island and in New York City to participate in the consortium effort. The laboratory, created in 1967, has been conducting marine research in Long Island Sound and adjacent waters. In addition, the State University of New York established a Marine Sciences Research Center at its Stony Brook campus for the express purpose of undertaking applied research on the impacts of urbanization on marine waters. Both agencies have made significant contributions to the research on Long Island Sound. (See Appendix D, Annoted Bibliography for listing of reports.)

The study indicated the need for establishing an ongoing agency to coordinate a continuous regional approach to the management and enhancement of the Long Island marine environment. In response, on December 7, 1966 the board set up the Nassau-Suffolk Regional Marine Resources Council as a regular adjunct arm. The council was assigned, but was not limited to, the following responsibilities:

1) Formulate a comprehensive plan for the management of the marine environment.
2) Resolve conflicts affecting the marine environment.
3) Initiate a coordinated university approach to the study of the marine sciences and ocean engineering.
4) Initiate industrial participation in the research and development pertinent to the Long Island marine environment.
5) Initiate a research program on the problems and potential of the marine environment.

The council was composed of voting members from the private sector, representing the academic, commercial, environmental, and industrial communities. In addition, advisory members from federal, state, and local agencies having a direct interest in the management and supervision of the marine resources were represented.

In 1967 the council began a study to identify the knowledge required. The study was structured into a series of steps, as shown in Figure 6.2. The steps in the left column represent the detailed activities required to develop the information to complete the planning procedure. These five steps culminate in resource data and information collection.

Developing the marine resource planning and management procedure (Step 6) actually takes place at the same time as the functional steps shown on the left of Figure 6.2 and should be considered one of the functional steps. This step derives its initial structure from the information developed in Functional Step 1—the classification of the marine resource problems. The procedure is made operational by incorporating existing information with projections of the results of future research and data collection. The procedure is recursive, and as the knowledge base continues to grow, it will be used to:

1) Predict environmental conditions.
2) Assess impact of conditions on marine-related activities.
3) Evaluate costs and benefits of these conditions and their impacts.
4) Identify alternatives.
5) Recommend optimal and priority actions.

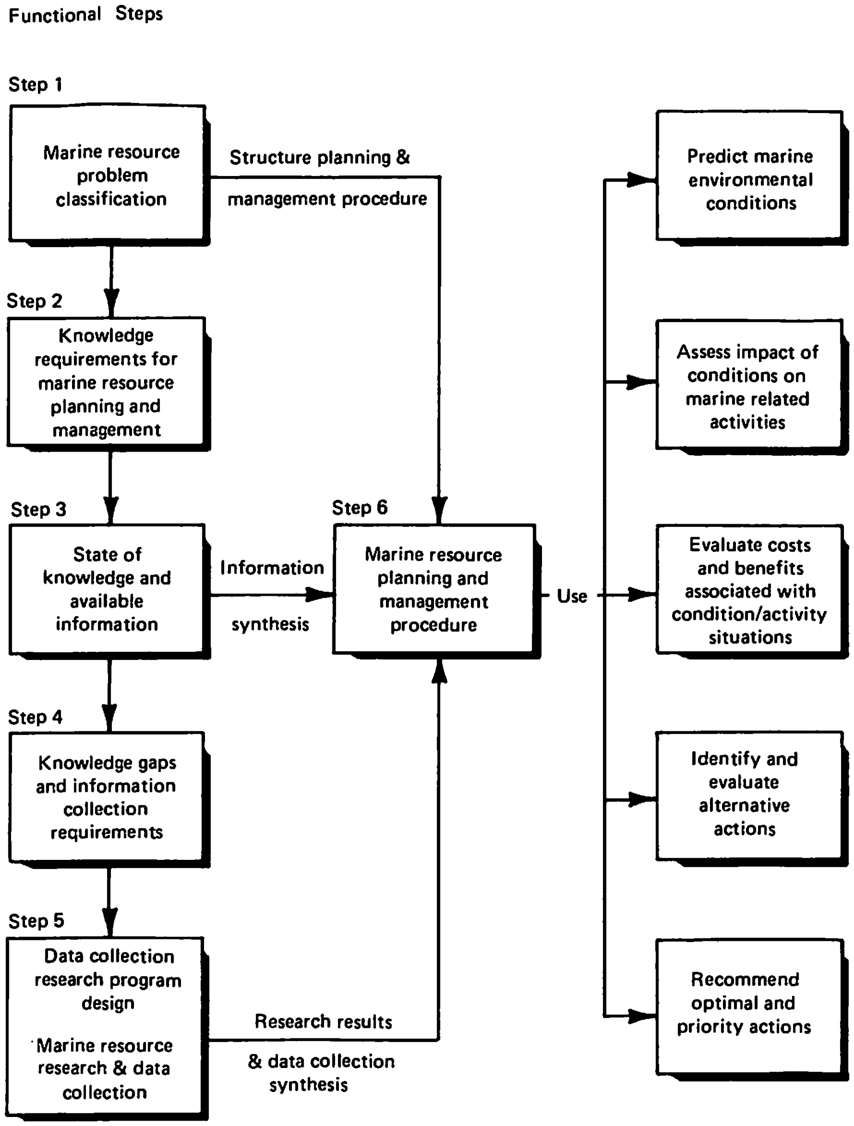

FIGURE 6.2 *Summary of the Marine Resources Council Research Program*
Source: Nassau-Suffolk Marine Resources Council

The principal objective of Functional Step 1 is to provide a framework for describing and classifying problems related to marine resources. Such a framework consists of eight sets of descriptors or dimensions which, when filled in, give the salient features of a particular problem:

1) Cause-environment condition-effect relationships: identifies the activities responsible for dissatisfaction with the marine environment and the activities adversely or beneficially affected.
2) Natural environmental characteristics: describes the physical attributes of the marine environmental problem, its physiographic location, and affected biota.
3) Reasons for individual or group dissatisfaction: identifies such reasons, and whether they are ethical, aesthetic, or economic.
4) Incidence of costs, damages, or dissatisfaction: identifies who is affected, adversely or beneficially, the location of the affected parties, and their income groups.
5) Intensity or severity of problems: describes the available objective evidence that a problem actually does exist.
6) Geographic locations and areal extent: describes the location and areal extent of problem cause and problem incidence.
7) Temporal pattern: specifies the temporal or chronological patterns related to the problem (e.g., cyclical trend, random).
8) Governmental-administrative jurisdiction: identifies the governmental bodies having decision-making authority affecting the problem and the agency functions related to the problem.

A list of 17 problems that appeared to be of greatest concern was compiled after reviewing the literature on Long Island and its marine environment, and after discussions with members of the Regional Marine Resources Council and other informed citizens. They included:

1) shellfish production
2) depletion of sport and commercial fisheries
3) control of insects and related pests
4) disposal of solid waste
5) wetlands management
6) development of marine industries
7) coast stabilization and protection
8) dredging and dredge spoil disposal

9) control of eelgrass
10) wastewater disposal
11) boat pollution
12) oil spill pollution
13) limited shoreline recreation facilities
14) duck waste pollution
15) saltwater intrusion
16) thermal pollution
17) preservation of sites of natural and/or historical value.

Note: The 17 problems are not listed in any particular order or ranking.

The approach formulated to analyze the problems focused upon the "cause-environmental condition-effect" relationships that existed—namely, a dissatisfaction with some environmental condition or set of conditions. The development of a plan to manage coastal zone resources necessarily includes the discovery of such cause-effect links in the environmental conditions that affect the desired uses of the resources.

Each identified marine-related activity draws upon certain attributes of the marine environment or, in other words, requires a certain combination of environmental conditions. And the existing set of environmental conditions stems from a combination of influences—both natural and man-made. Consequently, analysis can find a series of links, or a network of activities altering environmental conditions which, in turn, influence other activities. Such analysis for the major problems on Long Island has formed the basis for further research into the state of existing knowledge and data pertinent to the significant relationships.

In lieu of implementing a computer-based information system for marine resource management, the council thought it best to establish planning and policy guidelines in five high-priority problem areas: coast stabilization and protection, dredging and dredge spoil disposal, integrated water supply and wastewater disposal, wetlands management, and shellfish production.[5] The council held public seminars, in conjunction with various federal and state agencies, to assess the latest technological innovations in these areas. Topics discussed included shellfish culture (cosponsored by the Bureau of Commercial Fisheries, US Department of the Interior, and NYS Department of Environmental Conservation), advanced wastewater treatment and disposal (cosponsored by the US Environmental Protection Agency and the US Geological Survey), wetlands management (cosponsored by the National Oceanic and Atmospheric Administration), and dredging/dredge spoil disposal and coast stabilization (cosponsored by the Office of the Chief of Engineers, US Army Corps of Engineers). The council has also maintained a close relationship with the New York Sea Grant Institute, and has used technical advice of faculty at the Marine Sciences Research Center, Stony Brook, New York.

While the council was establishing planning guidelines for the marine environment, there was a parallel, but much larger, effort under way to prepare the Comprehensive Development Plan (CDP), for Nassau and Suffolk counties. It became clear that the next logical step was to bring the two activities together by applying the concepts and framework developed in the marine-related research program to the CDP; this would link coastal zone planning with comprehensive regional planning, using Long Island as a prototype for the testing and refinement of the methodology. In other words, the CDP became a test model for integrating coastal zone research with the general planning process. The specific objectives of this project were:

1) Determine the impact of the regional plan and the mix of activities proposed therein on the coastal zone of Long Island and, conversely, the influence of the conditions of this marine environment on the proposed activities or land uses shown in the plan.
2) Identify and recommend alternatives, modifications, or additions to the plan based on the environmental impact determinations.
3) Recommend administrative mechanisms for implementing the plan, based on environmental impact assessment and consideration of social, political, and economic factors in the region.
4) Evaluate the Nassau-Suffolk experience for general transferability to other coastal regions of the country.
5) Prepare a report and guidelines for the integration of marine resource and comprehensive planning to assist planners and decision-makers in other areas.

Real cases such as the CDP, coupled with the Marine Resources Council's procedure for studying problems of the coastal zone, developing the necessary information for planning, and incorporating this information into the planning process, provide an opportunity for the development and demonstration of a total process for regional and environmental planning in a coastal zone region. Documentation of the process is intended so that it can be used as a model in other regions of the country.[6] Eventually, it can be used in the "second generation" updating of the general planning for the entire Sound developed by the

New England River Basins Commission. (This recent planning and the need for additional work is discussed more fully in the next chapter.)

The relation of the research program to the overall planning effort can be seen graphically in Figure 6.3. The research segment is shown within the dotted lines. The first seven steps will form the basis for knowledgeable coastal zone management decisions by the public or its representative. The last step of implementation or action will hopefully result in changes in the current or projected environment to meet the stated goals or needs. This may result in revisions to the original goals or the creation of new goals, based on a more thorough understanding of the environment of Long Island Sound and its adjacent communities.

This leads to the next obvious issue. Implementation implies an administrative system for carrying out the conclusions and objectives of the planning effort. What is the desired form of agency or related agencies to actually administer the coastal zone management program? In fact, on this issue hangs the fate of the entire future of the Sound. Undoubtedly, the permanent mechanism will be the result of an incremental and evolutionary system of trial and error—coupled to competing forces vying in the political arena — similar to the current competition among the myriad users of the Sound.

The last segment of this chapter discusses alternatives in an effort to initiate the coming debates on a more rational footing.

CONGRESSIONAL ENVIRONMENTAL ACTIONS

The same year the Nassau-Suffolk Regional Planning Board was established, Congress passed two acts significant to the management of Long Island Sound. One deals with water quality, the other, with water resources planning.

The provisions of the Water Quality Act of 1965 created a new agency, the Federal Water Pollution Control Administration, which assumed the duties formerly assigned to the Public Health Service.[7] This act received the strong support of President Johnson. In his State of the Union message in 1965, he said that the federal government would seek additional legal powers to prevent water and air pollution, adding that water quality has to be measured in terms of beauty and recreation as well as in terms of health factors.

Federal financing of local pollution control projects was increased, but more important was the inclusion of a strong enforcement section which stated:

> In the case of pollution of waters which is endangering the health or welfare of persons in a State other than that in which the discharge or discharges . . . originate, may request the Attorney General to bring such a suit on behalf of the United States to secure abatement of pollution.[8] [*sic*: does not specify who may so request]

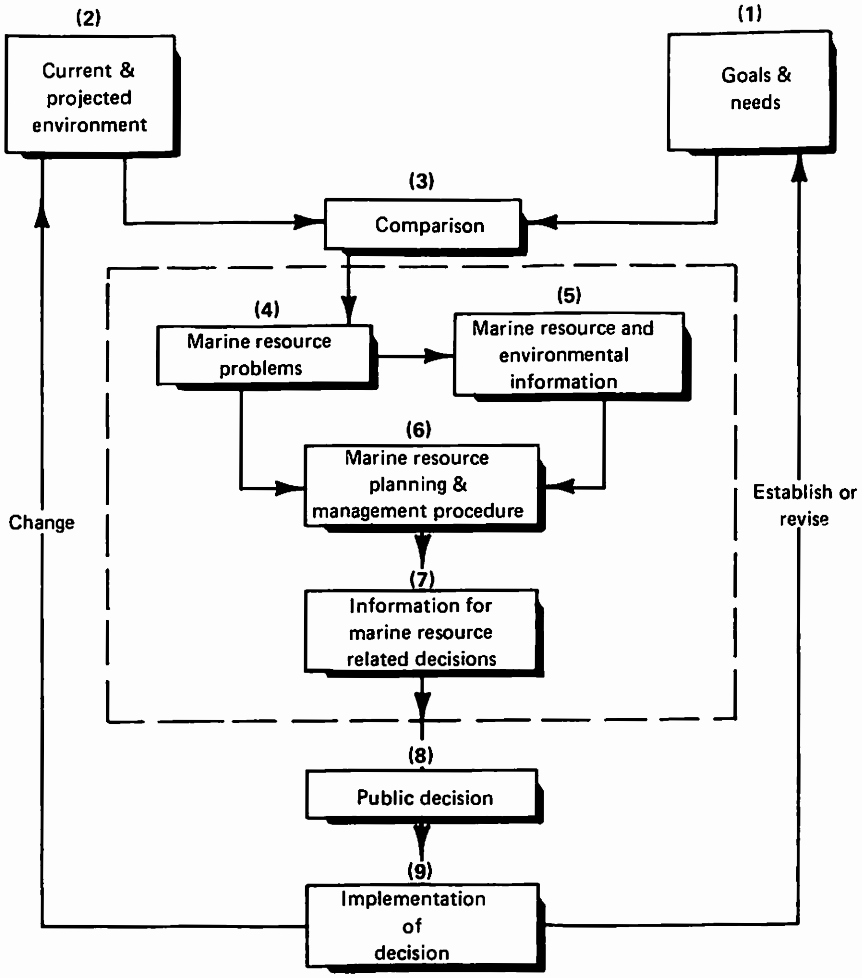

FIGURE 6.3 *Coastal Zone Management Sequence*
Source: Nassau-Suffolk Marine Resource Council

One significant observation about this act is that for the first time in water quality matters, the federal government had become a catalyst for initiating local action through use of financial incentives,[9] the route followed in welfare, highway construction, airport aid, open space acquisition, comprehensive planning, education, and health. Federal participation has also improved the quality of public service by tying financial aid to performance standards: if a locality wishes to reap the fiscal benefits, it must subscribe to federal standards.

A second and more important observation is that with problems of general neglect and local inaction that are not responsive to solution by voluntary means, regardless of incentive, action by the higher responsible level of government is mandatory. The federal government must therefore assume a general responsibility for enforcement of those programs deemed in the national interest.

Water pollution control is starting to be considered in light of the second observation—far different from the "study and advise" approach prevalent in earlier legislation. The old federal programs of grants, information dispersal, and enforcement as a last resort are now recognized as inadequate by the Congress and the public.[10]

Since 1966 the states have had the authority to set water quality standards and to establish programs to meet them. The basic concept in water management was to maintain pollution levels within "acceptable" levels in lakes and rivers by regulating the amounts of discharge by polluters; the federal government had the right of approval over the standards and programs. Drawbacks to this approach soon became apparent. First of all, allowing states to initiate standards meant that there might be states without any water quality standards. (In fact, less than half the states have taken action.) Second, the economic definition of "acceptable" levels of pollution may not be ecologically sound. The evidence seems to point to this,[11] although long-term evidence of tolerable carrying capacity (the amount of contamination that waters can absorb and still maintain ecologically acceptable standards) has not been adequately evaluated.

Congress responded to these deficiencies by passing the Federal Water Pollution Control Act of 1972.[12] The significance of this legislation was its intent to control pollution at the source, with the overall goal of total elimination of pollutants, to be achieved in two phases. Industrial plants must use "the best practicable" technology control by 1976, and cease all discharges by 1983 unless this is impossible even with "the best available" technology, considering "economical achievability." All discharges are to be terminated by 1985.

Under the new act jurisdictional problems could be avoided—theoretically. First, the permit-issuing authority would be transferred from the Corps of Engineers to the Environmental Protection Agency. The permit power would also cover municipal wastes, industrial wastes, outfalls into the ocean, and agricultural wastes from livestock. The agency could transfer the permit function to the states when their programs met federal standards. However, the agency would retain the powers to cancel state programs not in accord with the act, to veto any state dumping permit issued to private industry, and to sue violators if the state failed to act.

In practice, however, kinks in the jurisdictional "to-and-fro" haven't yet been worked out. One major New England chemical company has been dumping wastes into Long Island Sound for more than two decades, with the routine permit approval of the US Army Corps of Engineers.[13] The discharge of 12 million gallons of residue wastes from the manufacture of penicillin and other antibiotics is a violation of New York State's water quality standards. The Environmental Protection Agency exerted pressure on the company to find alternative solutions. The company response was a suggestion that instead of dumping into the Sound, it be permitted to dump into the ocean. The Corps of Engineers tentatively agreed to issue permits even though Congress currently leans towards severe limits on ocean dumping.

The act was overwhelmingly passed by the Congress, only to be vetoed by President Nixon.[14] Congress demonstrated the strength of its intent by overriding the veto, but Nixon thereupon issued orders to the Environmental Protection Agency not to release funds as called for in the legislation on the grounds that the expenditures would be inflationary.[15] President Ford has reversed this posture. New York State, for example, is now eligible for $16 million for planning grants under the act. The Nassau-Suffolk Regional Planning Board received $5.2 million in 1975 for studies on Long Island and surrounding waters.[16]

In addition to wanting to protect fresh and salt waters from the ravages of pollution, Congress recognized the need for action on a broader scale, by passing the Water Resources Planning Act, the second act of 1965 with important implications for Long Island Sound management. Pollution from point sources is only one aspect of the complex patterns resulting from the impacts of urbanization on the natural environment. Comprehensive planning approaches had to be taken if truly rational management decisions concerning water and land were to come about.

Such Congressional awareness actually goes back to the 1930s, when the Natural Resources Planning Board was created, and to 1949, when the Housing Act was passed, providing assistance to municipal governments for comprehensive land-use planning.[17] The unique feature of the Water Resources Planning Act of 1965, however, was its emphasis on water boundaries rather than municipal ones. For the first time the planning areas were to be defined by watershed or river basins. The act provided for the creation of river basin commissions to "serve as the principal agency for the coordination of federal, state, interstate, local and non-governmental plans for the development of water and related land resources.[18]

THE NEW ENGLAND RIVER BASINS COMMISSION

The governors of the six New England states and New York supported the creation of the New England River Basins Commission in accord with the act. (The commission was established on September 6, 1967 with the Presidential signing of Executive Order 11371.) The essential reason for such multistate cooperation was the fact that six of the major watershed or river basin areas include portions of two or more states. Although the commission is primarily New England-based and oriented, New York joined because of its interests in Long Island Sound (New York did not participate directly until 1968—one year after the agency was created). The Sound is an integral segment of the lower Connecticut river valleys and coastal edge, since it serves as a sink or receiving basin of the shore runoff and estuarine flows from the Thames, Housatonic, Connecticut, and other rivers. It is similarly affected by the quality of the East River—the strait connecting the Sound with the New York Bight—and various runoffs from Long Island. What is interesting, though, is why a coastal zone study was assigned to a river basin agency. After all, the Sound is not a river basin, nor strictly speaking can it be defined as a watershed. Its relationships to the various river basins are not as crucial as the impacts of pollution on the Sound from the land and the choice and management of various land uses in estuarine areas.

Another interesting question is: how or why do programs come into being without statutory sanction?[19] The official literature of the New England River Basins Commission is vague: "The lands and water of Long Island Sound were singled out for a comprehensive study primarily as a result of public demand and the urgings of the Governors of both New York and Connecticut."[20] Cries of "save our Sound" have long been heard around the shores of the Sound without much effect. Just what was that public demand? Therein lies the story.

In 1968 when New York joined NERBC, the state initiated action to have parts of Long Island included in the official territory of the New England River Basins Commission. In 1970 the commission, at the urging of the states, organized an approach to a comprehensive joint planning program. And in July of that year, Senator Abraham Ribicoff of Connecticut held hearings in the region for his bill calling for a major study of Long Island Sound, the end product to be a management plan for the Sound's future conservation and development. Congressmen Lester Wolff of Long Island and Thomas Meskill of Connecticut had introduced similar legislation in the House.[21] Support for a coordinated and comprehensive study and action plan for the entire Sound is certainly apparent. But such support was not manifested by any philosophical or intellectual upswelling from the "masses." On the contrary, it is almost a precept of American politics that regardless of how meritorious an issue may be, action by elected officials rarely occurs unless and until a crises arises—potential or real.

What galvanized public attention to the Sound was the proposal in 1965 by Robert Moses, chairman of the Triborough Bridge and Tunnel Authority, to construct a bridge across the Sound from Bayville in Nassau County to Rye, New York (in Westchester County).[22]

Initially there was some support for the structure. The construction unions perceived its value in jobs. Motorists favored the potentially easier travel from Long Island to New England. Former County Executive Eugene Nickerson anticipated its economic advantage to Nassau County in terms of jobs and industrial location. Some supported it because of their faith in its proponent.

Opposition was local and limited. Originally, the span was to traverse Manursing Island, near the Connecticut border. It was claimed that an access highway on the island would obliterate the only Frank Lloyd Wright residence in New York State. Plans for the route were then changed to have the northern terminus at a recreational complex, known as Playland, in Rye. By this time the opposition began to mount with increasing ferocity and geographic distribution. Although the bridge would lie entirely within the jurisdictional boundaries of New York State, it was clear that it would have an impact on Connecticut by increasing the automobile traffic on that state's limited arterial network. But it was the residents from the North Shore villages in the Town of Oyster Bay who led the battle. They filed several lawsuits, convinced their local state assemblymen to introduce bills in the state legislature to stop the bridge (all vetoed by the governor), and then in 1968 received the Town's support in offering more than 3,000 acres of wetland to the United States Department of the Interior for use as a wildlife refuge. The strategy was simple: in exchange for the donation, the Interior Department had to prevent the bridge.

From the onset of the controversy, the bridge opponents called for an overall plan for the Sound before any action was taken. Granted that this call was viewed as a delaying tactic, even by those who supported it, it was backed by the local congressmen and by Senator Ribicoff.

By the summer of 1970, congressional hearings on the Ribicoff bill were completed and $100,000 was appropriated by Congress for the preparation of a work program. The project, referred to as the Long Island Sound Study (LISS), was assigned to the New England River Basins Commission.

An ambitious work plan was detailed by August of 1971. Thirty separate studies to be carried out by a variety of regional, state, and federal agencies would provide the basic inventory of existing uses and characteristics of the Sound and the lands surrounding it (see Appendix F for an annotated bibliography of NERBC reports). Work commenced in January 1972. This multiagency participation was in keeping with the basic intent of the river basins legislation and reflected the adopted policy of the New England River Basins Commission. Theoretically, this approach should allow the best talents to participate; in practice, however, most efforts of this sort soon resemble the classic camel—a horse put together by a committee. It is difficult to administer a massive research effort centrally when the participants are voluntary and not liable to sanction except from their respective organizations. Some of the weaknesses of this approach became apparent during the plan formulation stage,[23] but early recognition of problems is actually a positive result of the project. This is the only way that later strength can be built in. And the Long Island Sound Study *is* a prototype—following a limited budget and limited timetable of three years, from January 1972 to January 1975.

The planning aspects of the study are reviewed in the next chapter. But one segment of the implementive portion is management related and is included in the following pages along with an alternative approach used in Suffolk County. Both models represent an effort to overcome the defects of uncoordinated, unrelated, fragmented, and often non-existent municipal control — within the mythology of local planning and control. They are of further interest since they respond to the management formats required in the Coastal Zone Management Act of 1972.

COASTAL ZONE MANAGEMENT ACT OF 1972

A Congressional report prepared by the Interagency Committee on Oceanography and submitted in July of 1963 first defined the national objectives in oceanography, and offered a list of priorities and action recommendations.[24] This led to recommendations for creating a national oceanic and atmospheric entity to serve as the principal agency for federal programs in these fields, and for passing a Coastal Zone Management Act.[25] The act was passed in 1972, after three years of consideration.[26] President Nixon commented at the signing of the act that it "recognizes the need for carefully planned, comprehensive management programs to ensure the most rational and beneficial use of the coastal zones."

The act bears particular relevance to the needs of the Long Island Sound as expressed by the Marine Resources Council and the New England River Basins Commission, and builds upon the ongoing efforts to create development plans for the Sound. Neither agency is in the regulatory or operational business, and presumably, the life of the Long Island Sound Study terminated with the completion of the plan. Thus, no current mechanism exists to manage the Sound comprehensively and effectively and implement plans for it.

Although compliance with the act is entirely voluntary—fortunately, Connecticut and New York have elected to participate—it provides both the incentives for planning *and* the means to carry out the plans, to be accomplished in the traditional pattern of matching-grant fiscal support, and in a novel procedure that amounts to a cross-endorsement policy: moneys can be used to develop the management programs *and* to operate approved programs.

If applied to the Sound, this can ensure continuity of the management process. Since most of the planning work has already been carried out, the Long Island Sound region could be one of the first in the nation to be eligible for operational funding. But even more important than funding is the significance of program approval. Once the Secretary of Commerce approves the coastal states' program, an immediate limitation is placed on all federal actions in that area. (Section 3507 of the act assigns responsibility for the Coastal Zone Management Program to the National Oceanic and Atmospheric Administration of the US Department of Commerce.) For example, the issuance of any permits or licenses by any federal agency must be consistent with the approved program. This commitment by the federal government is indeed a powerful and useful control device for protecting the integrity of the states' efforts. The act does require that proposals include a description of the governmental structure to administer the program and the methods to be used for controlling land and water uses within the defined coastal zone. Choosing a form of control is at the option of the state, within three broad categories specified in the act: direct regulation by the state, local regulation consistent with state-established standards, and local regulation subject to state review. The LISS recognized the need for an ongoing agency and has prepared recommendations to help meet this need.

RECOMMENDED LEGAL AND INSTITUTIONAL STRUCTURE

A Bi-State Approach

New York and Connecticut have almost equal lengths of shoreline on Long Island Sound. A bi-state authority with comprehensive and conclusive powers over all aspects of land and water uses in the Sound would be the ultimate in simplicity, since there is only one structure to be defined. Yet if all the historical, geographical, and political nuances were addressed, simplicity would soon yield to an exponential growth of administrative variations. This discussion is an attempt to identify some of the constraints in moving towards a set of attainable and workable entities. In a sense, this is a conscious attempt to sound a pragmatic note. "Ideal" solutions that require massive functional or structural changes in the organization of the two states should be omitted from consideration. Thus, the field is immediately narrowed.

Home rule, current laws, departments of state government with mandated powers and interests in the Sound, and a variety of regional planning bodies and local governments that exercise advisory and regulatory land-use controls in and around the coastal zone are the major constraints to any coordinated management program. To deal with these constraints and move towards a solution, the following questions must be answered about the nature and scope of the proposed governmental structure: Is a bistate authority feasible? If not, how will coordination be achieved between Connecticut and New York on mutual problems? Which of the three control options in the act should be followed? Are there any new or creative aspects included in the choice? And finally, what actions are required by the states to enable the new management structure to work?

A single agency with comprehensive regulatory and planning powers over the Sound would be logical from a geographical standpoint. If the entire region were located in one state, it might even prove feasible. In this situation, however, the existing jurisdictional controls over the region are distributed among several federal agencies, two states, the City of New York, and numerous units of local government. The difficulty in creating a unitary approach is further compounded by the internal differences in state-local relationships in the two states, and the limitations—both administrative and legal—of interstate authorities.

Connecticut has a two-tiered structure (town-state), whereas New York's is three-tiered, with the counties, particularly in the downstate area including the Sound, assuming an increasing degree of administrative responsibility. The manner in which land-use controls in the two states are implemented reflects these differences.

There are other pragmatic concerns as well. The only successful examples of bistate or compact agencies have been those with a single or limited function. Furthermore, most of the land-use problems that affect the Sound are internal to one or the other state. The few issues of truly bistate interest or requiring bistate action, e.g., a Sound-crossing ferry or bridge linkage, can be resolved by alternative means, such as the use of an existing authority—the Metropolitan Transportation Authority—which would avoid the necessity of creating another level of government.

The consultants for the Long Island Sound Study rejected the idea of creating a bistate authority for these and many other reasons. They also recommended against the take-over of all land-use controls by a state agency. The long history of enabling legislation that has placed zoning, subdivision control, and official mapping powers at the discretion of municipal governments cannot be reversed, except for certain limited purposes.[27]

The experience of the Urban Development Corporation in New York State bears stern testimony to the established ability of local governments to protect their feifdoms. The law provided that the corporation could override local zoning powers when the exercise of these powers prevented specific housing programs in a community. Attempts to sponsor projects in Suffolk County received sufficient local opposition to engender legislative retribution. The override clause was summarily repealed.[28]

Towns in Connecticut are even more firmly viewed as the basic subadministrative elements of the state, so much so that counties were abolished in 1962. There are so-called regional planning agencies, but they are only advisory and subject to local control. Hence, only two general options are possible given the *realpolitik* of the situation: local regulation in accord with state standards, or local regulation subject to state review with only a limited transfer of controls to the state. The consultants opted for the latter. Because of unsuccessful past experiences in trying to manage an ecosystem as large and complex as the Sound through a plethora of local governments, they determined that the new structure must be capable of melding state and local participants into a regionwide body with broad scope and powers. Thus each state could establish a coastal zone management group (CZMG) and tailor its constituency and functions to respect its unique political and administrative customs and laws.

Initially, the two state groups would agree to a general statement of purposes and goals that apply to the entire program. Each state group would also develop a set of standards, guidelines, and criteria to be adhered to by the local or regional implementation agencies. The latter material would be tailored to the unique needs of each state with uniformity necessary only in those instances where an activity crossed over or affected both states.

Discounting direct state exercise of regulatory powers, save those already in existence, the consultants proposed that delegate agencies be designated to accomplish suitable control and coordination of local actions, thus insuring the integrity of the state interests, while maintaining a closer relationship to local governments. In Connecticut this function could be assigned to the five advisory regional planning boards by means of legislative enactments. In New York the responsibilities could be assigned to the county planning commissions that already have such enabling legislation. On Long Island the bi-county regional board would be suitable since it already is the designee for all comprehensive regional and water-related planning.

Land development and conservation plans would be a mandatory requirement for the local units of government. These plans, which could be updates of existing ones or entirely new ones, would have to be in accord with the established standards. To ensure proper management, such plans, which are currently advisory, would now have the weight of control, and all actions affecting the coastal zone would be subject to them. State financial aid would be made available to local agencies to overcome any lack of local resources. In addition, the state CZMG would be empowered to review the plans and require modifications if necessary to achieve conformity with state purposes.

In the interim period, until plans were adopted, the CZMG could set a moratorium on any developments not consistent with state purposes. Furthermore, the delegate agencies would be empowered to prepare plans for local entities that defaulted on plan preparation requirements, and to supplement any of the plans with elements of a regional nature. The delegate agencies would be the permit issuers on all development matters beyond purely local concerns and those specific actions reserved to the states under specific legislation, e.g., control of wetlands, and power plant siting. The permit process would also be in conjunction with local review. Any development denied by local governments for nonconformance with local plans or regulations would not be issued a permit. Each state CZMG would act as the appellant agency for disputed matters. Suitable time periods would have to be built into the model to assure adequate response time and protection of private rights.

Initially, quarterly meetings are recommended between the two state CZMG's to achieve overall coordination. Figure 6.4 depicts the generalized bistate model. Obviously this can be expanded for multi-state adoption.

The Suffolk County Experience

Since 1965 the Suffolk County Planning Commission has participated in a bi-county regional planning effort for the creation of a comprehensive land-use development plan with specific attention addressed to coastal zone planning. Incorporated within the overall work was the development of detailed guidelines for management of the coastal zone.

The planning effort also recognized the need for an effective management mechanism to accomplish control over coastal zone development, and implementation of the development plan's objectives. In a sense, the Coastal Zone Act of

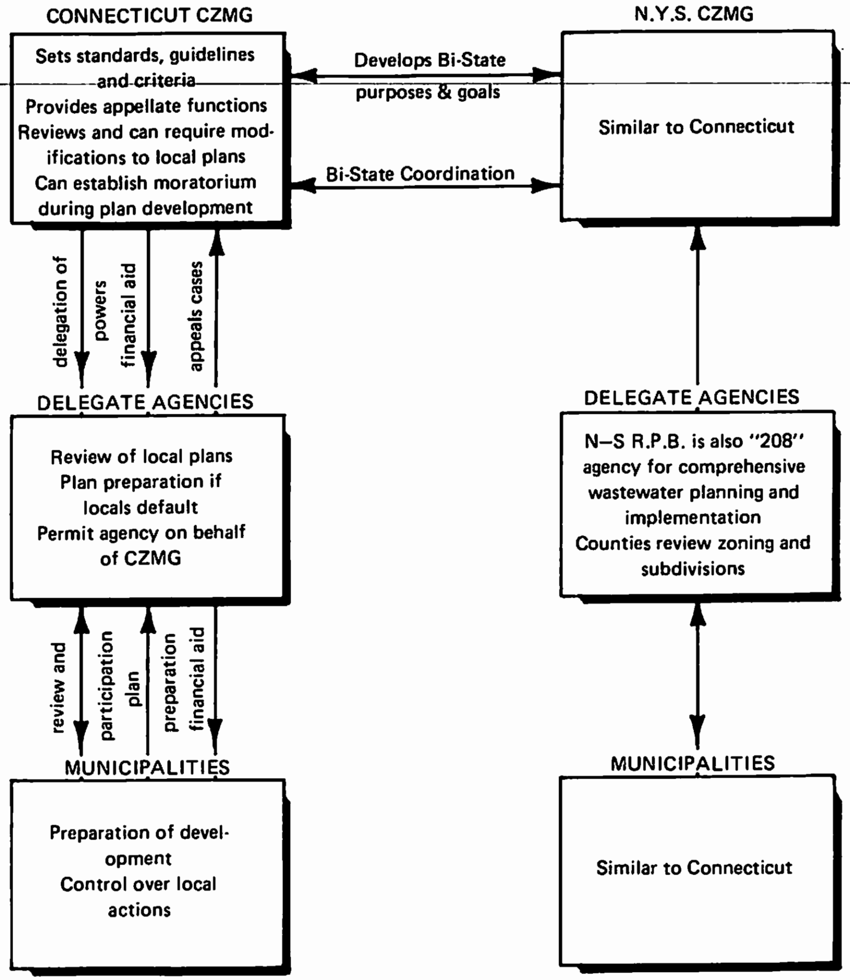

FIGURE 6.4 *Bi-State Model*

1972 was anticipated. The approaches developed provide a prototype of a local (county-municipal) development plan, with various regulatory procedures to be enacted by the local governments, in the main, in accordance with locally designed guidelines and criteria and applicable state standards. The local coastal zone work has been coordinated with the overall state responsibilities for coastal zone planning and represents the Nassau-Suffolk portion of the state plan.

In effect, the county-regional role is an example of development control powers being shifted upwards from the municipal governments. This model provides an incremental alternative to state assumption of zoning powers. Various public referenda between 1959 and 1972 have transferred from the municipalities to the county planning agency zoning and sub-divisions powers including review of all such matters within 500 feet of the shoreline, all major highways, county and state facilities, and municipal boundaries.[29] In the last case the county's action is conclusive. Critical areas, such as power plants and airports, are subject to county review for a distance of one mile from the proposed project.

The State of New York currently exercises a variety of discrete operational and regulatory activities. These activities are handled by three separate state agencies, each independent of the others. These activities all funnel through the county planning agency. The initial needs of a management mechanism could be met by the adoption of an executive order of the governor, or legislative statute, pulling together the separate operations under the aegis of a state board (perhaps the state agency responsible for the statewide coastal zone plan development). In practice, however, the local model used in conjunction with specific state functional powers offers a viable alternative. Figure 6.5 depicts this choice.

Either of the two basic models is sufficiently flexible to provide a working framework for any coastal state in the nation, without requiring significant structural or even functional changes in the federal system of intergovernmental relations or in the basic internal workings of the states. The respect paid to incremental improvement in the regulatory process should prove generally acceptable — and more importantly — provide the means for achieving adequate management programs for the coastal zones of the country.

SUMMARY

The effects of particular acts--dredging a channel, dumping wastes offshore, building a power plant--have fuzzy boundaries, and the impact of such acts diminishes geographically as one moves away from the locus. This diminishing may be very rapid or very slow--some acts may have even a global effect. Jurisdictional boundaries, on the other hand, must and should always be sharp. The problem is how to match the sharp and varied political boundaries to the fuzzy impact boundaries. We do not want the United Nations to worry about every septic tank; nor do we want a village to regulate a nuclear power plant affecting the county or state.

In earlier, less urban times, home rule was proper. As industries and urban areas have grown, they have greatly increased the degree and extent of economic and environmental interaction. As a result, local political entities are no longer able to cope with the situation--particularly the need for planning at workable government levels.

Planning carried out at several levels cooperatively could help move us from adversary decisions on "Do we or do we not build this plant?" to examination and action on the options before us. Planners take into account the access to basic data that must be allowed and encouraged for all groups to assess possible impacts on their interests. Lead time in planning should be related to the longevity of a proposed action's consequences. Given the political reality of the strength of local governmental control, we *can* devise a workable structure empowered both to act in the present and to plan competently for the long range.

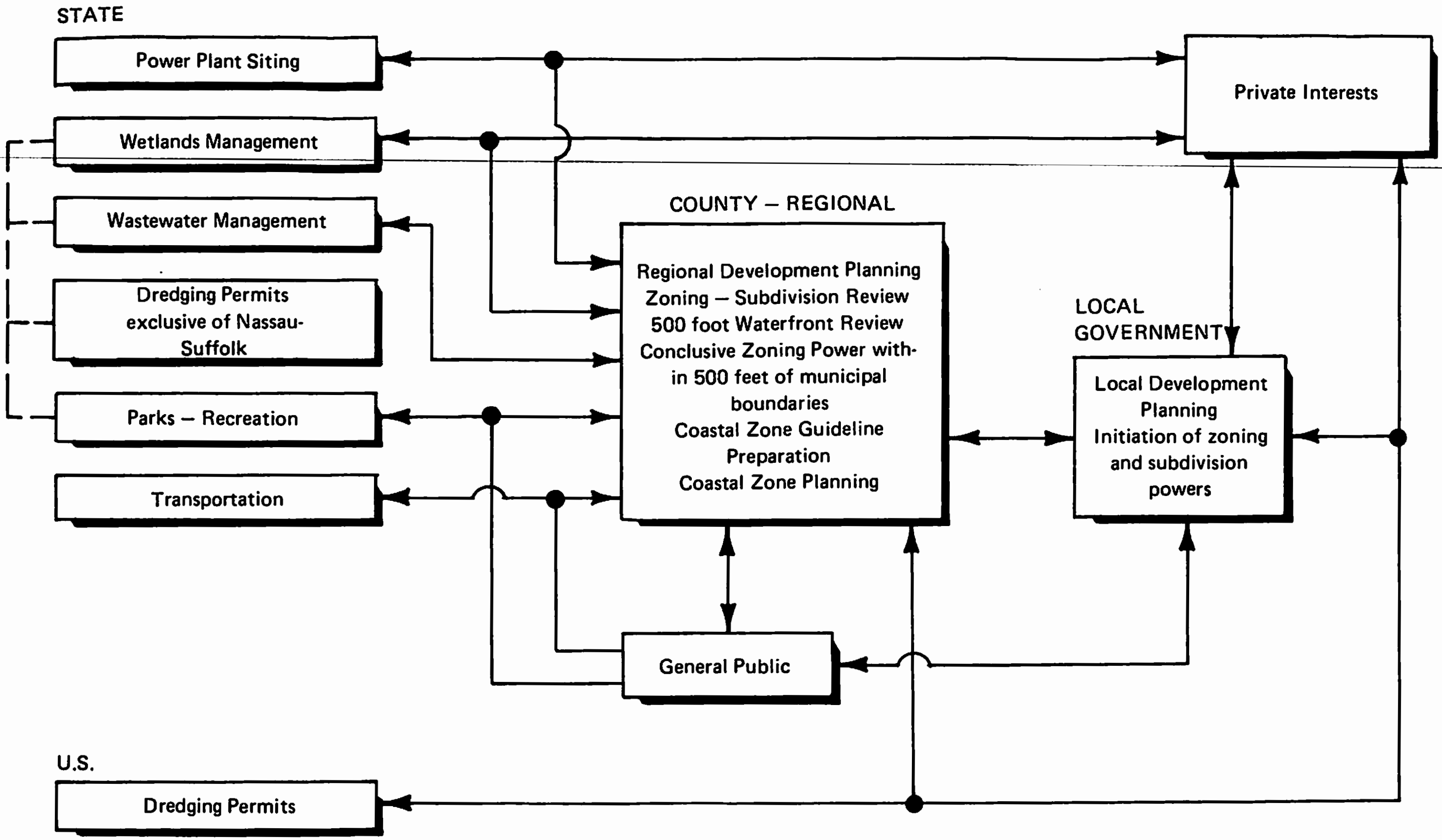

FIGURE 6.5 *Local Plan Development and Regulation Subject to State Standards and County Criteria and Guidelines*

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[22] R. Cassidy, "The Long Island Sound's Troubled Waters," *Planning: The ASPO Magazine* (Chicago: American Society of Planning Officials), July 1973, 39 (6):14.

[23] H. Pearson, "L.I. Sound Survey: Confusion, Delays," *Newsday*, Friday, February 2, 1973, p. 15A; K. Grossman, "42 Months of Nonplanning: The Undoing of L. I. Sound?" *Long Island Press*, March 27, 1974; and K. Grossman, "Foes Dunk Sound Plan as Too Little, Too Late," *Long Island Press*, March 28, 1974.

[24] Interagency Committee on Oceanography, "Oceanography, The Ten Years Ahead, A Long-Range National Oceanographic Plan, 1963-1972" (Washington, D.C., July 1963).

[25] J. Stratton, *Our Nation and the Sea* (Washington, D.C.: The Marine Science Commission, January 9, 1969). For a further reading of the Congressional history on oceanography, see the draft (the final report is greatly abridged) on the *Coastal Zone Management Annual Report for Fiscal Year 1973* (Washington, D.C.: NOAA, US Department of Commerce).

[26] 1966 Marine Resources and Engineering Development Act, Title III, signed into law by President Nixon on October 27, 1972 as Public Law 92-583.

[27] This discussion is taken from a draft entitled "Recommended Legal and Institutional Structure for Coastal Zone Management in the Long Island Sound Region," prepared for the New England River Basins Commission's Long Island Sound Study by Raymond, Parish, and Pine, Inc. (White Plains, N.Y., August 6, 1974), 24 pp. The excerpts do not reflect the views of the commission at this writing.

[28] McKinney's Unconsolidated Laws, NYS Urban Development Corporation Act, Section 6265, Subdivision 5, effective June 5, 1973. Session Laws-L. 1973, Chapter 446 Section 3, added subdivision 5.

[29] Sections 1323-1330 of the Suffolk County Charter.

7 Coastal Zone Management: A Planned Approach

INTRODUCTION

The preceding chapters have shown an exciting potential for expanding and developing Long Island Sound marine activities. But much of this potential is being dissipated through outright waste and negligence. Preservation and wise management of wetland areas are vital to commercial and sport fishing and shellfishing, recreation, and tourism, but thermal, bacteriologic, and chemical contamination continues to have adverse effects. The consequences of dredging, the significance of the wetlands, and the various kinds and degrees of contamination are just some of the things that must be thoroughly understood if a planned marine economy is to evolve from a series of unrelated, uncoordinated, unregulated, and generally exploitative ventures.

Urbanization on Long Island Sound, as in other suburban coastal zones of the country, is destroying land and water resources. Open spaces that once provided aesthetic enjoyment, wildlife protection, and recreational opportunities are being lost to the homes, schools, factories, highways, commercial centers, and other manifestations of an urban society. This has been the pattern on Long Island Sound in the past decades; it will surely continue if growth is left solely to the workings of the market. What is economically best for the community does not equal maximum economic efficiency in real estate terms. To act in the public interest, a third party, the government, must intervene between buyer and seller.

But how can government decide what is in the public interest better than the private citizen can? How can government provide for long-term development without ignoring immediate needs? Planning deals with these questions.

Planning is a process. It starts with knowledge already available, and then determines needs or desired goals, develops an answer or set of alternative answers, describes the consequences of each, and finally, offers a means of implementation for the selected solution. The aim of planning is balanced, orderly community growth. The planner attempts to structure governmental action to help meet this aim. His philosophy is that the "good life" can be achieved through proper ordering of land uses, community facilities, and transportation networks in an aesthetic setting.[1]

In the first stage, or information period, the planner gathers all relevant data about existing conditions and past trends in the area, and he projects population growth to estimate future spatial and service needs. He also formulates general goals and objectives.

In the next phase, he draws up alternative proposals, each showing projected growth, development of policies and programs necessary for its implementation, and its own set of end objectives and consequences.

In the third stage, the planner chooses the alternative that reflects the overall objectives most closely. Physical and economic data are relatively easy to measure and, in *realpolitik* terms, easy to use in defining goals. The major obstacles to comprehensive planning, however, are the more abstract social and environmental components, which lack a methodological base and are not as widely accepted at the firing line.

Often, the planner has to act as a surrogate for the "people." How accurate the planners have been to date is perhaps epitomized in the brief plea, "Dear Lord, help us to help the people by making them want what we know they need."[2]

Goal formulation is one of the weak links in the planning process; a selected goal is supposed to reflect the general consensus of the people, but it cannot help but be a value judgment. Even where an apparent consensus exists, there is always a discrepancy between general goals and more specific plans of attack.

General goals can best be characterized as "motherhood" issues: there *should* be a program of park acquisition, there *should* be strict conservation of Long Island Sound, there *should* be an efficient transportation network, there *should* be full employment.

Just as data are converted into information, and information converted into plan alternatives, there is also a transformation of goals from the general to the specific. When one or more workable comprehensive plans evolve, and the consequences of each plan are fully enunciated, then the plan or plans are ready for implementation. It is at this stage that the issue of goals again becomes of paramount interest. As each alternative is developed and detailed, the end objectives become less abstract. In place of "There should be an efficient transportation network," the planner may now say, "A six-lane, grade-eliminated highway is required to cut diagonally through the towns of X, Y, and Z."

We then pass very quickly from motherhood to oxgoring, and from the safety of technical seclusion to the political arena. This juncture usually marks the end of the planning process. Technical responsibilities end with the transmittal of the plan to the official decision-makers. The planner retires from the ring, so that elected representatives can assume the role of matador, since final decisions based on planning objectives are truly political.

There are two types of constraints on the implementation of planning objectives: inner-oriented and outer-oriented. Inner-oriented indicates planner-to-planner relationships; outer-oriented refers to planner-to-politician-to-public relationships. In the former category, implementing objectives has been limited by planning deficiencies. These include technical failings, such as the lack of operational theories and the uneven quality of information input—partially due to inadequate funding, but more often to a varied sophistication in data on urban and ecological systems. Other inner-oriented constraints are deficiencies in methodology and differing goals among planning agencies that share responsibilities for the same area.

Among the outer-oriented deficiencies is the short-sightedness of many planners, who do not view planning in socio-political-economic-ecological terms. There is a great need for communication between the planner and the politician. It is all too easy to rationalize the ineffectiveness of planning by blaming the politician for being unresponsive. Until the planner recognizes that all public agency programs must be politically acceptable as well as technically sound, it is doubtful that planning objectives will become political realities.[3] Impaired communication between planner and politician is not the story of the good guys *v.* the bad guys but a generation gap. The planner often fails to realize that while *his* generation may be the next two to four decades, the generation of the elected official is his current term of office. While the planner talks of the year 2000, the politician wants to discuss and solve what are yesterday's problems—from the planner's point of view. And the politician's constituency is very real—particularly at the polling booths. Any proposals that cannot stand testing in the crucible of political heat are almost assured of defeat, decline, or impotence:

> Finally, any act of management of the environment, any intervention in the relationship between man and his surrounding milieu. . . implies decisions of a political nature. . . .Environmental decisions are, hence, ineluctably political. . .and, thus, whoever wishes to pursue the achievement of a sound environment must be prepared to deal with the relevant political factors.[4]

If the politician realizes that the planner is not attuned to the crisis issues of the day, he relies on input from other sources, especially in the field of social planning. The new concept of "advocacy planning"—in which planners stand outside the power structure—means that the politician hears from segments of the constituency that the institutionalized planning office has not dealt with.[5] Therefore, the need for dialogue between planner and politician has become more important to the planner than to the politician.

Planning objectives can only become political realities when the planner does the following:

1) Addresses the public and not just fellow planners.
2) Considers the problems that face the politician.
3) Educates the public.
4) Establishes a working liaison with the array of decision-makers who effect any degree of control over planning.

Communication obstacles can be overcome. The prime impetus must come from the planner. But there are obstacles to implementation beyond the planner's reach. These arise out of governmental inertia resulting from structural and functional limitations. Control spread among multiple governmental units—a manifestation of home rule—is a major barrier to attaining regional planning objectives.[6] Many problems and solutions apply to fiscal or legal jurisdictions broader than the municipalities involved. Little can be done unless the general public and their elected representatives are willing to support shared or regional controls by relinquishing some local powers. Of course, inertia can also be the result of unwillingness of elected officials to exercise leadership, or in some cases, just plain venality.[7] Such deficiencies are rarely addressed, let alone rectified, in American domestic affairs except in response to a real or perceived crisis.

Fortunately for Long Island Sound, increasing public attention has been focused on potential threats like growing pollution, proposed bridges, fuel desulfurization plants. Strong constituencies have emerged in the last decade. In striving to prevent real crises, these groups have lobbied for and supported regional planning efforts. In fact, the relatively untrained but committed citizens have often shown more courage and vision than have the professional planners. Until recently, with few exceptions, the planning efforts undertaken in the Long Island Sound region have been based on general trend analyses with predetermined objectives. Such efforts result in highly constrained, almost deterministic views of the future. Considering growth a "given" reduces the planning process to a holding action at best, or a charade in most cases. Sops to citizen requests for reform and rationality in governmental decision-making no longer suffice. Increased citizen interest and action have given birth to increased sophistication—both in technical knowledge and in political astuteness.[8]

The Nassau-Suffolk Regional Planning Board and the New England River Basins Commission (NERBC) have been working towards developing a comprehensive and multidisciplinary management plan. Their efforts have not yet produced a final acceptable plan, but two key factors have emerged: an understanding of 1) the process and methodologies used in planning, and 2) the administrative mechanisms necessary to implement the recommendations of a plan. The techniques used and standards derived from developing a management plan for Long Island Sound will undoubtedly serve as models for other areas with similar concerns.

THE LONG ISLAND SOUND STUDY

The Long Island Sound Study, begun in August 1971, was released for public scrutiny and comment at the end of 1974. NERBC staff then reedited the various drafts during the spring of 1975. The final report is an amalgam of ten broad interest areas that are meant to make up the plan for Long Island Sound.[9] Each area—land use, water management, shoreline appearance and design, erosion and sedimentation, flood damage reduction, recreation, fish and wildlife, marine transportation, minerals, and power and the environment—is essentially a mini-plan. (See Appendix F for an annotated bibliography of selected functional studies.) Intensive inventories were prepared, problems identified, short-term and long-term projections of need made, goals chosen, alternative solutions developed, and finally, a set of recommendations drawn up.

A 30-member Citizen Advisory Committee (CAC) was appointed by the chairman of the NERBC and the governors of New York and Connecticut. The CAC was specifically assigned the task of deciding the broad goals of the program.[10] They also participated in the various technical work groups set up to carry out the individual functional studies. A similar 30-member Research/Planning Advisory Committee was appointed from the academic and scientific communities to provide the technical equivalent of the CAC.[11]

The general goal of the study was "to produce a plan of action by the Spring of 1975 which balances the needs to protect, conserve and wisely develop the Sound and its related shorelands as a major economic and life-enriching resource for the 12 million people who live near it."[12]

Unfortunately, the Long Island Sound Study did not achieve its stated goal. Yet even its failures are a contribution, in the sense that latent pitfalls were revealed in planning for a system as complex as the Sound and its surroundings.[13] Current efforts to complete the planning process for the Sound region, discussed later in this chapter, were able to avoid the shortcomings and build on the strengths instead. For example, it is now obvious in retrospect that the CAC did not succeed in the important and elusive task of becoming the intermediary between the planners and the citizenry. If it had, much of the criticism of the plan could have been avoided. Perhaps the absence of broad support at the public hearings—which clearly demonstrated that the NERBC failed to capture the imagination of the person in the street—was due in part to the manner of selecting members of the CAC.[14] An official appointment tends to taint the designee as being part of the government. The NERBC could have taken its cue from the War on Poverty legislation, requiring that citizens organize and select their own representatives.

One other general observation is in order. It appears that the NERBC promised much more than it could reasonably have been expected to produce, given the time and money constraints set by the federal government. Although some of the planners, economists, and environmental scientists and engineers recognized these limitations, it was never made clear to the public that the overall goals were too high. "Promise less but deliver more" is a motto that should be stressed in planning schools as vigorously as the classic saw, "Planning is a continuous process."

Despite the shortcomings of the Long Island Sound Study, several aspects of the plan are innovative and should be given serious consideration. These include the Long Island Sound Heritage proposal, the segment on shoreline appearance and design, and the proposals for administrative agencies to implement the management programs. (A discussion of the management program proposals appears in Chapter 6.)

Long Island Sound Heritage

The aim of the work group on recreation was to enable more people to enjoy the pleasures of the Sound. But most of the shoreline and the access to it are either privately owned or controlled by municipalities that restrict use to its residents. The Long Island Sound Heritage proposal strongly urged that New York and Connecticut create an expanded system of public beaches and parks, and specifically nominated 16 sites for acquisition or expansion.[15] Figure 7.1 depicts the locations. The proposal also recommended removing restrictions on bus transportation to state parks, instituting a recreational ferry service to link the various parks, and opening beach fronts now inaccessible to vehicular traffic.

Shoreline Appearance and Design

Aided by a consultant landscape architect, the work group on shoreline appearance and design concentrated on scenic preservation, removal of debris, and public education programs on visual pollution.[16] Despite some criticism that there was too much emphasis on this segment of the plan, the work group produced a valuable and professional assessment of the aesthetic problems and solutions to them. Their recommendations could lead to a new sense of public awareness, an appreciation not only of the many and varied beauties in the coastal zone but also of the importance of proper management.

The more valid criticisms of the Long Island Sound Study relate to its organization. Most of the almost $3 million invested in the program went to the 20 federal agencies that conducted the bulk of the work. The CAC's staff had virtually no quality control over the agencies. This fragmentation carried over to the final package, more an aggregation of pieces than a coherent plan. The Long Island Sound Task Force noted that the most significant issues of growth policies for the region were avoided:

> Any plan for managing growth around the Sound which leaves the question of limiting growth up to the Federal government, which discusses transportation only as marine transport and recreational access, and energy only in terms of power generation, is clearly suffering from a failure of nerve. This report handles the easy questions in many cases very well; it does not tackle the really hard ones at all.[17]

Once committed to the limited, subject-by-subject approach, the CAC planning staff also missed an opportunity to utilize ongoing or prior work of other agencies until the end of the project.[18] In a sense the Long Island Sound Study was administered in a partial vacuum: a decade of planning and research experience on the Long Island side of the Sound was largely ignored—until public criticism prodded the CAC to cooperative action.

THE NASSAU-SUFFOLK COMPREHENSIVE DEVELOPMENT PLAN

Rapidly urbanizing coastal areas of the United States, such as Nassau and Suffolk counties, are confronted with a triad of concerns that require urgent attention: 1) planning for urban and surrounding metropolitan communities; 2) planning for outlying rural areas and their interactions with metropolitan areas; and 3) planning for the adjacent marine environment. Typically, planning has ignored the marine environment and its interactions with adjacent land uses. *Truly comprehensive planning for the management of coastal areas requires the blending of all three concerns.*

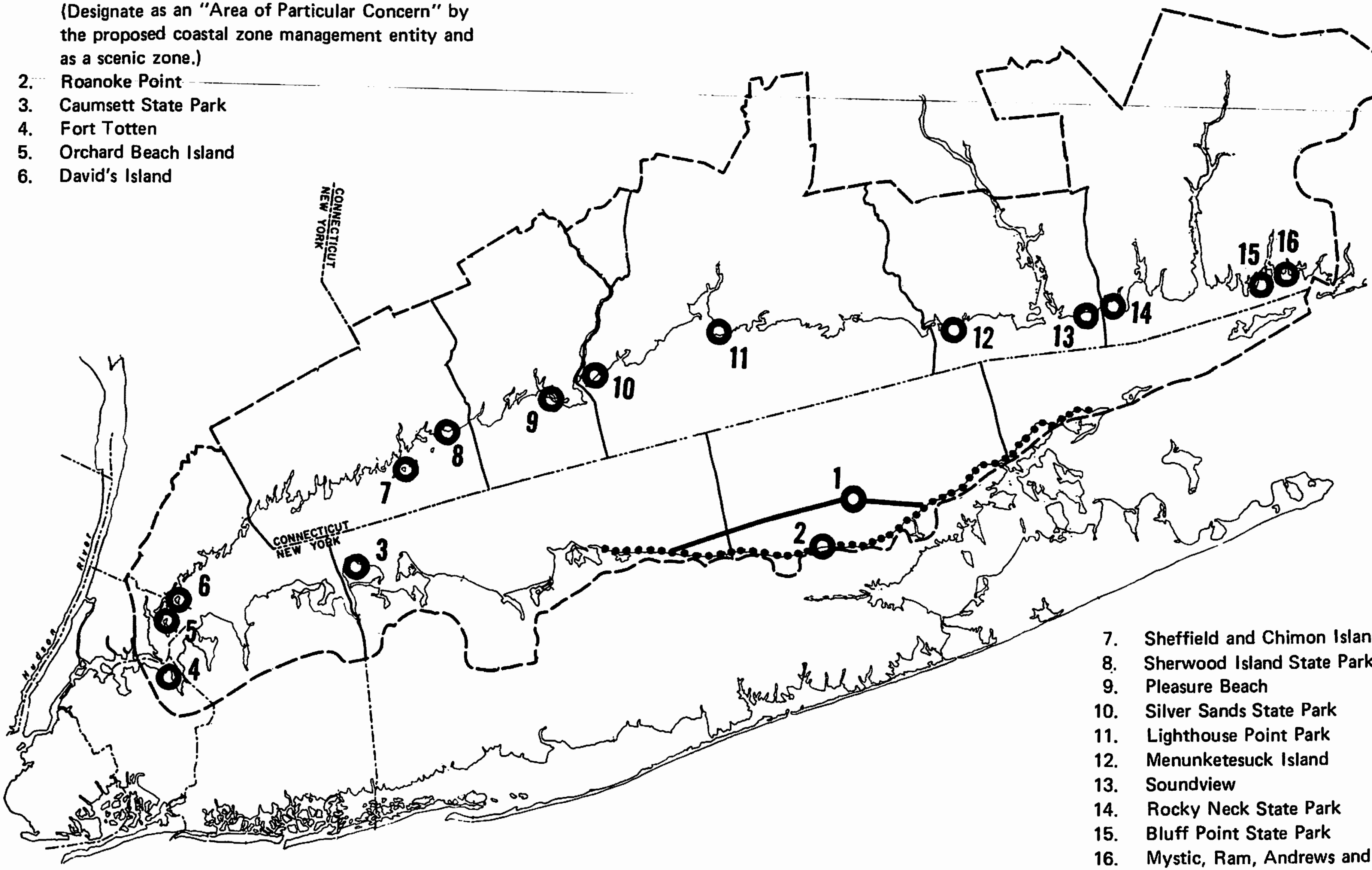
Nassau and Suffolk counties contain all elements of these planning concerns—from heavily urbanized westernmost Nassau, through the rapidly suburbanizing central part of the Island, to the rural, agricultural eastern Suffolk, all of which are surrounded by the marine environment. Their 1970 population of 2.5 million is ten times what it was a half-century ago. Projections to the year 2000 estimate another 1.5 million people, with particularly heavy growth in Suffolk County. Even Suffolk's easternmost reaches are undergoing urbanization. This process is evidenced directly by changes in land uses and increased population, and indirectly by industrial and utility sites (such as nuclear power generating facilities) required to service urban communities.

In response to mounting pressure from the news media, the Nassau and Suffolk Boards of Supervisors formed the Nassau-Suffolk Regional Planning Board in 1965 to develop an overall plan for the use of resources in the two counties. One of the board's principal accomplishments to date has been the creation of the Nassau-Suffolk Comprehensive Development Plan (CDP) (August 1970). Backed by numerous staff and consultant studies, and financed through US Department of Housing and Urban Development Section 701 Program support, the plan analyzed extensively such land uses as transportation, housing, recreation, industry, commerce, and education. The board gave priority to four broad goals:

1) Direct the pattern of development and the rate of growth.
2) Provide adequate housing and jobs linked by a balanced transportation system.
3) Eliminate deteriorating or obsolete housing.
4) Preserve open space and the natural environment.

LEGEND

1. North Shore Bluffs
   (Designate as an "Area of Particular Concern" by the proposed coastal zone management entity and as a scenic zone.)
2. Roanoke Point
3. Caumsett State Park
4. Fort Totten
5. Orchard Beach Island
6. David's Island



7. Sheffield and Chimon Islands
8. Sherwood Island State Park
9. Pleasure Beach
10. Silver Sands State Park
11. Lighthouse Point Park
12. Menunketesuck Island
13. Soundview
14. Rocky Neck State Park
15. Bluff Point State Park
16. Mystic, Ram, Andrews and Dodges Islands

FIGURE 7.1 *Long Island Sound Heritage Proposal*

More specific goals have emerged since the plan was drawn up, as the result of the increased knowledge of the planners and, more important, the interactions with a host of private citizens and organizations. One important question that came up: How many people should the plan provide for? Obviously, statistics on resource use, land-use intensity, infrastructure investments, fiscal requirements, and environmental quality rest on demographic input. One can argue that since New York City supports a resident population of 8 million, the balance of the Sound basin could support 32 million (New York City is one-fourth the size of Nassau and Suffolk counties). Similarly, if Nassau County sustains a population of 1.5 million on a land area of 300 square miles, then Suffolk County should be able to support 4.5 million people on 900 square miles. These, of course, are absurd statements. Aesthetic and economic considerations alone mandate against such thinking.

What, then, is the correct number? The criterion is not land availability; it is rather the "carrying capacity"—a vague term which includes the number of people, organisms, trees, etc., that can be sustained *in balance* by any particular environmental setting. The one clear constraint to growth is water supply. Long Island's entire supply is derived from groundwater sources. Continuing the patterns of development prior to the creation of the CDP clearly would soon outpace the water supply.

Overuse is evident in the Brooklyn-Queens history: overpumping dried-up surface streams caused saltwater intrusion and forced these boroughs to seek water from upstate New York.[19] Furthermore, after lengthy Supreme Court battles, New York City is now allowed to tap into the Delaware River basin. The message is plain: Water management, an absolute necessity, constrains the development of Long Island. With no available external water supply, the region must be continually self-sufficient.[20]

In the early stages of plan development, the board apprised all local governments that the zoned capacity of vacant land could theoretically accommodate double the population that could be supplied with water.[21] Such a dangerous possibility, coupled with increasing pressure to limit population because of the rising cost of government, produced a ready response by the local governments. Through a series of upzonings (changes to lower density), the potential population was brought into line with the estimates of safe yield.

The concept of carrying capacity was considered so vital to the entire planning process that the Suffolk Board of Supervisors, on recommendation from the board, commissioned an intensive hydrologic survey[22] to verify and update an earlier study.[23] Symptomatic of its significance: the overall cost of preparing the regional plan was almost matched by the cost of the water study.

Both studies were timed so as to dovetail. The final results verified the earlier work but also pointed out severe ecological limitations that weren't readily apparent then. Although Suffolk County has a "safe" yield—a water supply adequate for 3 million persons, there would be a price: as the population approached this number, the water table would drop and surface waters would disappear. Without adequate recharge the lakes, rivers, and estuaries would suffer. These limitations were recognized and reflected in the CDP. Initial projections indicated a potential 1985 Suffolk County population of 2.25 million. Nassau was projected to grow to 1.75 million. Considering the time necessary to research and install suitable recharge equipment, the plan recommended slowing the growth rate to a total of about 3.3 million for the two counties by 1985. Current zoning reflects this recommendation.

Nassau and Suffolk counties have almost 1,000 miles of shorefront; woods, fields, ponds, clean air and waters; moderately priced housing, good schools and community services, and accessibility to New York City. Today, these attributes, which have attracted more than 2.7 million residents, are threatened. Beaches and parks are overcrowded; fresh and marine waters are increasingly polluted; woodlands and fields are giving way to developments; old downtown areas are declining; and travel to New York City is frustrating, whether one uses the Long Island Railroad or the Long Island Expressway. Although the vast majority of residents live in well-built homes, there is a housing problem—a shortage both in numbers and quality—for blacks, Puerto Ricans, and Indians, for welfare clients and migrant workers, for the young, the aged, and the large families of moderate income.

Residents are familiar with the land-use pattern of detached single-family houses served by large shopping centers, with offices and industrial parks scattered along the highways. Such urban sprawl wastes the open land and spreads houses, jobs, and shopping so thinly that private cars must be used for every errand, no matter how trivial. Almost all housing is beyond the means of the poor and middle-income people. This is the antithesis of a rational development pattern, one that would preserve open space, encourage the elimination of deteriorating or obsolete buildings and facilities, and provide adequate housing linked to jobs and shopping by a balanced transportation system.

The Nassau-Suffolk Comprehensive Development Plan is responsive to future population demands and reflects the knowledge that the natural environment is not limitless. The number of people that can be accommodated is restricted by the environment, the lack of mass transportation, and the need to preserve open space and shorefronts for conservation and recreation.

The plan is not a static document. To remain relevant, it is adaptable to changing conditions and values. With public support, such a plan will contribute to the proper development of existing and new communities and the preservation of the Island's assets.

Priorities

There are fewer than 15,000 acres of vacant land in all of Nassau County. This is only six to seven percent of the county's land area and is insufficient to satisfy all of the projected needs. The land-use priorities in the CDP are based on a determination of which of Nassau's needs must be met within the county, either on vacant land or through rebuilding on underutilized land, and which of these needs can be met by spilling over into nearby areas of Suffolk County.

Suffolk, with 41 percent of its land vacant, has sufficient land to satisfy its own needs, absorb some of Nassau's, and still preserve the open character of the eastern towns—but only if development is carefully planned and controlled.

Land for parks and conservation has been accorded the first priority in both counties. This land must be acquired in anticipation of need—once graded, paved, and built upon, open land is lost forever. Excess open acreage can always be released later for other uses, but it does not work the other way around. Therefore, whenever there is a choice of use involving land areas suitable for recreation, they should be so used. Existing open space, even when privately owned, should be carefully preserved. In both counties, sufficient recreation land should be provided in new communities through the clustering of development.

The open-space priority will be tempting to ignore since, unfortunately, the most valuable recreation land is frequently the best for home sites as well. Land set aside for conservation appears to cry out for improvement, and taxpayers are anxious to attract revenue-producing facilities.

The CDP gives land for apartments the second priority in Nassau County. In fact, no residential land should be rezoned to industrial, commercial, or office use unless it appears certain that the land is unsuitable for parks or open space, or for development of multi-family units. Not all construction of such units should take place on vacant land. New apartments should be located in the older business districts of both counties, where rebuilding at increased densities would stimulate economic revitalization and encourage greater use of mass transit.

If these priorities are followed, parks, conservation, and multi-family housing will preempt Nassau County's vacant land. Providing the open space and apartments needed in Nassau County will require great determination, resistance to more attractive tax assets, and a willingness to permit greater apartment densities than most Nassau County communities have accepted in the past.

Beyond these two highest priorities in Nassau County, it will be necessary, as well as desirable, to locate as much new commercial and office space as possible in the existing central business districts. This course is dictated by the shortage of land and the needs to revitalize these older centers and to decrease dependence on the automobile. New office space should be strictly limited to the projected need. If construction of large office parks continues at the current rate, Nassau County will soon have a surfeit of office space.

Industry is another large user of land. Much of the new industry that will employ Nassau residents should locate in Suffolk County, where many accessible sites, along major highways and the railroad, are available to meet the needs of both counties.

Because Suffolk County has more than enough land to accommodate both its projected 1985 needs and the spillover from Nassau, it is not necessary to establish rigid priorities there, except for preserving open land. Suffolk County must, however, avoid the danger of overzoning for revenue-producing land uses—much of its land is already being used for commerce and industry.

Corridors, Clusters, and Centers

Three concepts—corridors, clusters, and centers—are the essence of the Nassau-Suffolk Comprehensive Development Plan.[24] In judging the merits of a specific proposal, each community should be guided by these concepts.

Not every new development will conform fully to the corridors, clusters, and centers concepts. In fact, even if these concepts were rigorously applied starting today, they would not substantially change the appearance of the western third of the Island over the next 15 years, except in the heart of some of the larger centers. Nassau County and western Suffolk are already almost fully developed. About half of the new housing in Nassau will be single-family homes on scattered lots. Such infilling will merely accentuate the present development pattern. But over time, the CDP, if followed, will accommodate necessary growth while respecting the needs of the people and their environment, conserve the Island's natural resources, and encourage the use of mass transit by placing greater densities of housing, jobs, and shopping within walking distance of mass transit facilities.

CORRIDORS Consider the geography of Nassau and Suffolk counties: long, narrow, attached at one end to one of the world's major cities, surrounded everywhere else by water. Clearly, the most valuable recreation land is at the waterfront; the best location for housing is adjacent to the recreation land. Equally clearly, the most logical location for industry and other businesses is along the center spine of the Island, close to the major transportation facilities. In such a location, equidistant from the north and the south shores, jobs would be most accessible to residents, yet the inevitable harmful effects of industry—noise, traffic—would be minimized in residential and recreational areas. Existing limited-access highways, together with rapid and efficient rail service coordinated with a network of feeder bus lines, would provide transportation to work, shopping, and other activities.

There would be two broad residential corridors, one near the north shore, one near the south shore. These corridors, each fairly well served by its own highways and rail, would be within easy reach of both the central employment-transportation spine and the parks and seashore. Residential densities would be lowered along the shore, increasing towards the central spine.

CLUSTERS New development should be clustered wherever possible. The concept of clustering is simple: suppose that instead of placing 50 homes on 15,000-square-foot lots, you placed them on 10,000-square-foot lots—saving 5,000 square feet per parcel. The 250,000 square feet thus saved could then be used for playgrounds, greenways, and other community open space. Both the original house purchase price and the annual taxes might be lower than under the old system, yet the value of the house could be greater because of the enhanced quality of its environment.

Clustering should apply to entire neighborhoods. Local streets would serve only those structures within the neighborhood. Collector streets would delineate neighborhoods while linking them with the community center or downtown.

Clustering also allows for the combining of town houses and apartments with single-family detached houses while maintaining the overall original permitted density. This is important because apartments can help ease the critical housing shortage in the two counties and slow the rapid rise in the cost of construction. Single-family homes in established neighborhoods may become available when the present occupants of these homes retire to nearby apartments. Apartments relieve the mounting cost to the community of public services, because the cost of public utilities, fire and police protection, and roads is lower per unit for apartments than for single-family dwellings. In addition, new apartments on Long Island are a tax asset to schools: apartment-dwellers generally pay more than three times as much in taxes as it costs to educate their children.

Clustering can be one of the most effective tools for open-space preservation at no acquisition cost to the community. By clustering adjoining developments and setting aside contiguous acreage, alert communities can acquire extensive open-space systems. Linear parks so created can be valuable as watershed protection; they can also provide recreation space (for hiking, horseback-riding, cycling, and "passive recreation"), preserve spots of particular scenic beauty or ecological significance, and articulate and delineate communities. The Smithtown-Islip greenbelt is one such linear park.

CENTERS The centers concept is an extension of the idea of clustering. The centers discussed in the plan are of two types: the single-use center, exemplified by an educational institution (State University of New York at Stony Brook), a government center (at Hauppauge), and a grouping of industrial establishments (along the Long Island Expressway in Plainview), and the multi-use center such as those proposed for Mitchel Field and the revitalized downtowns along the major east-west transportation routes. Such centers can be large or small—plans range from a regional center at Mitchel Field to a local center in Southold—but in every instance they will include housing and shopping, and in all but the local centers, they will also include other facilities—employment, education, transportation, special services (like medical centers, concert halls, and libraries), and recreation.

Many of the central business districts have deteriorated because they cannot compete with the new shopping and office centers; ease of access and ample parking space have lured customers out of the older, traffic-clogged downtowns to new, convenient shopping centers along the major roads. Low-income residents have moved into the aging and decaying housing bordering the business districts. The tremendous investment in railroads and public utilities is underutilized, while roads, water mains, sewers, and power lines are extended to serve new commercial and residential growth in outer areas.

Every effort should be made to transform the old business districts near the major transportation routes into activity centers. Better access to the downtown areas and improved parking, together with a substantial increase in permitted densities, will stimulate private renovation, provide needed new housing, and promote economic and social integration.

Activity centers can be formed by revitalizing and expanding an existing nucleus such as an old central business district or by creating an entirely new center as the focus of a planned new community.

But new activity centers should be planned only for the portions of the Island that are presently undeveloped and where it is not possible to expand existing small concentrations of nonresidential uses. Three such new centers are proposed for eastern Brookhaven—at Middle Island, Yaphank, and Manorville.

To serve the traffic that the major employment centers will generate along the Island's central corridor, transportation centers are planned for Mineola, Hicksville, East Farmingdale, Ronkonkoma, Yaphank, and Calverton. These are to be at the points where the main line of the railroad crosses major north-south highway routes.

Activity centers should encourage the use of mass transportation. The central line of the railroad should be improved to provide high-speed transportation. This would bring more services near the railroad stations which would, in turn, reinforce the economic justification of creating the high-speed line. Concentrating a large proportion of the projected population increase in centers would permit the remainder of the Island to retain its open character.

Water Transportation Excerpts

In many ways the Nassau-Suffolk Comprehensive Development Plan is germane to the management of the southern half of the Sound. The Long Island land mass, at least from the glacial moraine northward, can be considered an integral part of the coastal zone in watershed terms. Obviously, all land-use activities near the shoreline are by definition "coastal uses." Furthermore, most marine-oriented activities have direct or indirect impacts on inshore concerns. These relationships are most evident in the water transportation segment of the plan.

The bi-county region is dependent upon several highly specialized seaports for the import of petroleum commodities and crushed and broken stone, and the export of sand and gravel. Tremendous quantities of sand and gravel were once mined near natural harbors along the north shore. Since World War II, the development of adjacent residential areas has subjected these mines to political pressures that have prevented their expansion. Therefore, most of these facilities will be phased out as the supply of material on the site becomes exhausted. Harbor dredging, once a prime source of sand and gravel, is declining because of concern over ecological damage.

The bi-county region has three choices regarding the commercial use of seaports. Commercial use can be eliminated, it can continue in a haphazard fashion, or it can continue based on a program of coordinated, planned development.

Some people wish to see all commercial activities in the harbors eliminated, with a return to recreation and conservation uses. Others reflect a laissez faire entrepreneurial approach, partially because they want to attract industry and broaden the tax base. Strict adherence to either alternative would lead to a waste of resources. The former would mean that other types of transportation would have to bring in bulk products, at considerably higher expense—in shipping and additional highway construction. The third alternative is to plan for development, abandoning some seaport facilities and modifying or building up others in coordination with auxiliary projects like pipelines. Figure 7.2 depicts the major water transportation recommendations and related suggestions.

PETROLEUM Bi-county seaports are beset with a number of problems that reduce the efficiency of petroleum product delivery, e.g., narrow, shallow channels and shoaling of inlets. These factors limit the shipments to half-laden barges and tankers on a rising tide. On the average, most harbors are only eight or nine feet deep at mean low water. The T-2, a tanker commonly used in Long Island Sound until the late 1950s, carried approximately 16,600 deadweight tons (DWT). The T-2 drew 30 feet 2 inches, exceeding most of the channel depths. The tankers more generally used today are those in the 40,000 to 60,000 DWT classes. They are much more efficient, and they require a crew of 45, compared to the T-2's complement of 41. The newer vessels require greater channel depths; the 35,500 DWT tanker, for example, has a loaded draft of 35 feet 7 inches. Even these large tankers are gradually becoming outmoded by the supertankers.

Once, nearly all terminals were located in sparsely developed areas that are now hemmed in by intensive land development. Consequently, expansion plans are met with heavy opposition and restrictive zoning code requirements. Truck routes out of the terminals pass through residential developments where there used to be open land. In some cases the roads out of the harbors are narrow with steep grades, making them dangerous and slow.

One solution to the problem lies in consolidating terminal facilities and using pipelines with inland tank farms as distribution centers. In certain instances this is already being done, as in the Town of Brookhaven.

Nassau County north shore oil terminals are located at Hempstead Harbor, Glen Cove Creek, Manhasset Bay, and Oyster Bay Harbor. Hempstead Harbor holds one of the greatest possibilities for modernization, cleanup, and consolidation with a coordinated development of recreational facilities. The west side of the harbor includes a tract of approximately 1,000 acres. Presently, this tract is used for sand and gravel mining, due to terminate in 1990. Plans have been made for three major types of land use: 215 residential acres, 240 industrial acres, and 500 park acres. This site could consolidate some of the scattered terminals on the harbor. At the north end of the tract, an offshore mooring facility could unload all tankers and barges now docking throughout the harbor, thereby keeping ship activities out of the head of the harbor. The mooring facility will require a deeper channel and a turning basin of sufficient depth to accommodate the larger tankers. A buried pipeline will be required along the shore to go to a tank farm at the south end of the tract. Consolidating the tanks at the south end will place them near major highway accesses.

Manhasset Bay can be used primarily for recreation, once the oil industry is concentrated in Hempstead Harbor and all commercial and industrial uses are phased out.

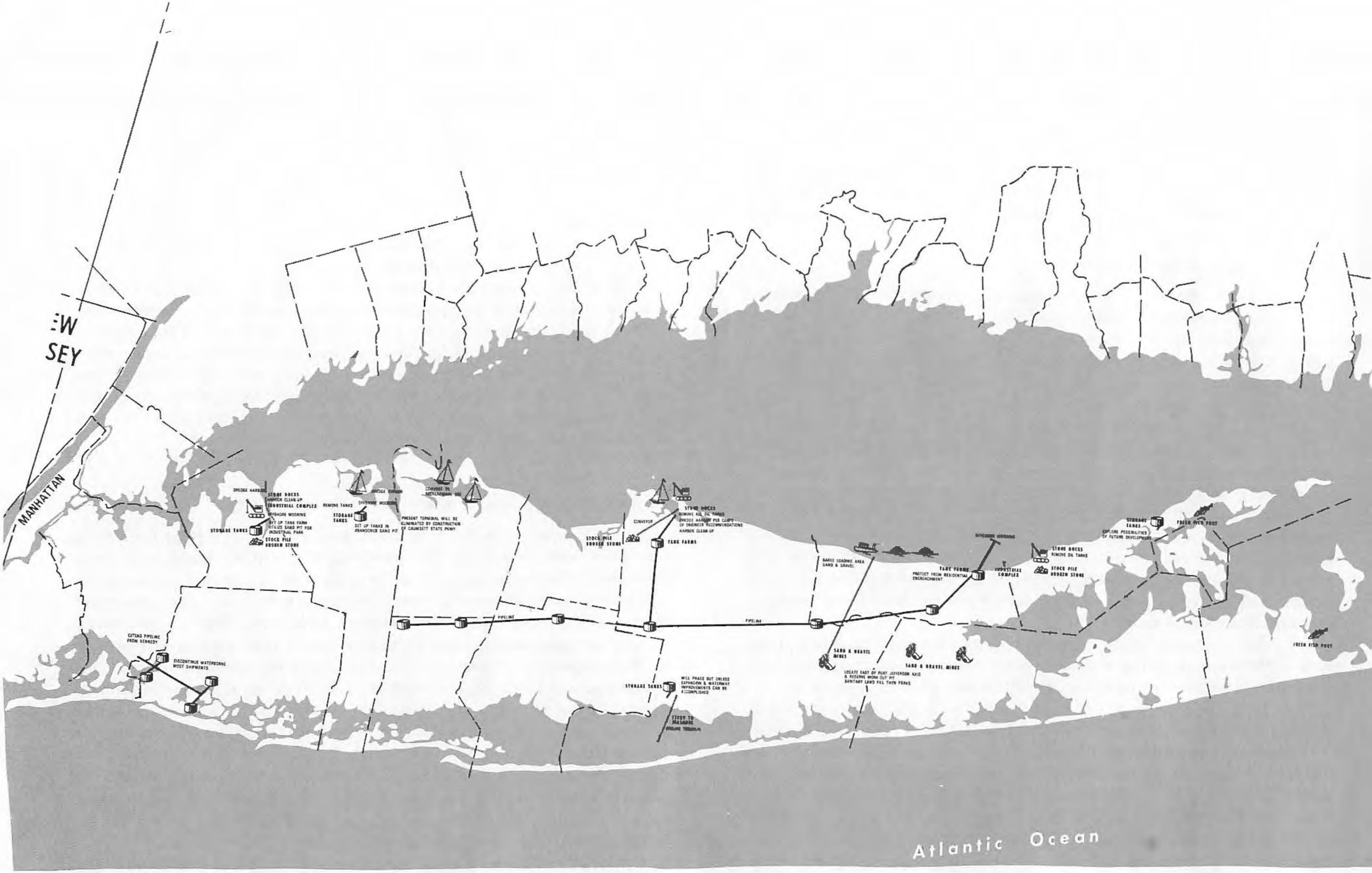
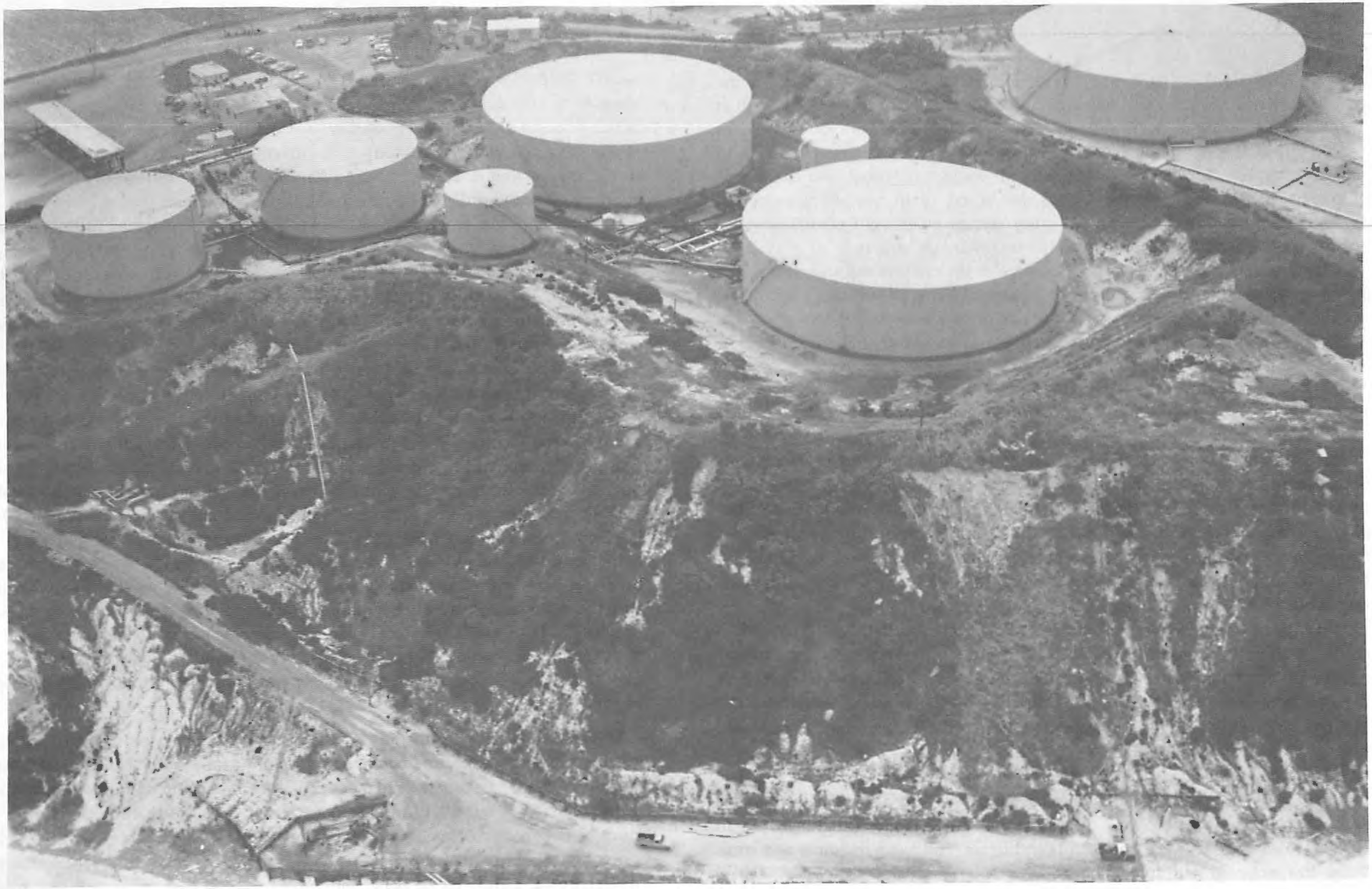


FIGURE 7.2 *Pipelines, Shipping, and Recreation: Recommendations on Water Transportation*



Northville Industries storage tanks for petroleum products, located on shoreline bluffs in the Town of Riverhead. Total storage capacity is 126 million gallons. The complex is connected by pipeline to an unloading platform 1.3 miles offshore in water 60 feet deep.

Oyster Bay Harbor has one oil terminal which should be removed and the harbor converted to park and recreational uses. Oil delivery could be handled at an offshore mooring or dock. Instead of shorefront storage, the tanks could be moved inland to the sandpit on Pine Hollow Road. This pit is now a source of sand and gravel. Delivery to the tank farm would be through buried pipeline from the harbor. Trucks would then deliver oil to homes and commercial buildings. In the future, individual utility service pipes from community distribution tanks would reduce truck traffic on residential streets.

Glen Cove Creek is intensively used for both commercial operations and pleasure boating, resulting in occasional conflict. The oil terminals should be consolidated with those proposed for the sandpit in Hempstead Harbor.

As for Suffolk County, Cold Spring Harbor has an oil terminal on its east side. This terminal may be eliminated if the proposed parkway to the state park on Lloyd Neck is constructed. Rather than relocating the terminal at another spot on the harbor, it should be moved to another harbor and consolidated with a terminal there.

Northville Oil Terminal and Port Jefferson Harbor are the two major areas on Suffolk's north shore for importation of petroleum products. The Northville terminal is an offshore loading facility with tanks located in back of the bluffs. Plans for a pipeline from this facility to the central corridor of the Island and thence to the Nassau-Suffolk line should eliminate a large amount of trucking from the terminal. Tank farms situated along the pipeline would act as distribution centers.

Existing tanks should be removed from Port Jefferson Harbor. All petroleum deliveries should come into one unloading facility on the west side of the harbor and be pumped through a pipeline to the tank farm in South Setauket. This pipeline now extends to the Holbrook distribution center and eventually will be extended through the Island to similar distribution points, according to company plans.

The purpose of concentrating the receipt of petroleum products at a few major deepwater ports is to provide more economical delivery. These products are presently received on New Jersey shores, where they are transferred to smaller vessels for delivery to Long Island ports. The extra handling and small vessel size, coupled with increasing labor costs, means high delivery costs. These can be offset by using larger vessels, which would require a proportionately smaller crew and so would make fewer trips into the harbor to deliver the same quantity of fuel. If the recommended ports are developed in conjunction with tank farms and inland distribution terminals utilizing pipelines for supply, the smaller terminals can be phased out, and the harbors can then be used for recreation.

SAND AND GRAVEL Sand and gravel operations should no longer take place in or near the marine environment. The natural beauty of the shoreline is a prime resource and must be preserved. Yet for economic reasons, the bi-county region may not wish to abandon this industry. To preserve the shoreline and retain the economic benefits of the sand and gravel industry, inland mining, coordinated with solid waste disposal, should be considered.

Future sand and gravel pits and mines would best be located in the central part of the Island, east of Port Jefferson. These areas at present are sparsely inhabited, lightly developed, and mostly covered with scrub, pine, or oak. Such sites should be set aside for sand and gravel mining. Once abandoned, the pits can be used for sanitary landfill, with eventual reclamation for use as public parks or industrial sites.

Since these pits would be located inland, the problem of transporting the material to the waterways would be considerable if only trucks were relied upon. This problem could be solved by using pipelines from the pit to the offshore loading facility. Through improved technology such as the slurry—a thin mixture of water and an insoluble material like clay, pipelines are beginning to be used for transporting many products besides petroleum and natural gas. Coal, nickel-copper concentrate, limestone slurry, wood chips, and pulp are already handled in some areas by using pipelines. In addition, pipeline transportation is being considered for slurried gravel, sugar cane, sand, wheat and rice, and several other products including melted metals.[25] A shore facility would be required to sort the material and store it temporarily. Barge loading could be done at a pier or wharf in fairly shallow water. If barges become uneconomical to use, specially designed carriers could be developed to carry the sand and gravel to New York City.[26] Larger vessels would require deeper water, mandating an offshore loading facility.[27]

GENERAL CARGO General cargo is virtually a nonexistent part of the bi-county region's waterborne commerce. It is unfortunate that this type of transportation cannot be greatly expanded. As the Oceanographic Committee of the Nassau-Suffolk Regional Planning Board put it, the "deep water ports offer a potential economic base. . .in fostering greater use of waterborne cargo."[28] Seaports contribute to the economy of the area served, in wages to the workers and payments to banks, forwarders, and others. It has been estimated that bulk cargo contributes as little as $1 to $2 per ton to the community, while a ton of high-value general cargo contributes $8 to $12 or more. However, proximity to New York City and its extensive port facilities poses a major competitive limit. Even the Port of Boston has been declining due to the influence exerted throughout New England by the Port of New York. Approximately 80 percent of the exports produced in New England are shipped out of New York City.[29]

In addition, the volume of freight is becoming less, as industry turns to lighter products and services. Little effect on port activity can be expected from coastal shipping. This is due to the decline of the coastal fleet during World War II; it has never been rebuilt, because of high construction costs and competition from rail and truck transportation. Prospects for the revival of this form of transportation are not encouraging unless there are changes in rate structures. In bulk movement, small differences in the overall cost of transporting goods make a big difference and will affect the choice of a port. However, high transportation costs become unimportant when the value per pound of the commodity is high, as with electronic equipment. In such cases, air freight shipping has become important. Today's ports are, therefore, extremely sensitive to technological and economic change.

Among various proposals to develop Long Island's economy has been one to create deep-water ports at Port Jefferson and Greenport for handling general cargo. But there is no indication that establishing either as a general cargo port is feasible. The major problem is inability to attract sufficient tonnage to warrant development.

Although the bi-county region should not attempt to build any general cargo seaport, it should consider developing two seaport-industrial complexes. These complexes should be designed so that the material loaded or unloaded could be utilized on site by an industry needing large bulk shipments. Such ports would, of course, be special-purpose, geared to a minimum of diversity. They could offer a significant opportunity for industries such as motor vehicle assembly.[30]

BROKEN AND CRUSHED STONE In Nassau County, Hempstead Harbor receives a considerable amount of crushed and broken stone and bulk cement. This operation should continue, as these materials are essential for building and highway construction, and the harbor provides distribution throughout the county.

In Suffolk, Port Jefferson Harbor serves as a distribution center from Huntington to Riverhead. However, Port Jefferson is hampered by limited expansion space and highway access. Roads leading into the harbor are narrow, dangerous, and slow. Distribution, trucking, unloading, and storage should be concentrated on the west side of the harbor next to the storage tanks and petroleum unloading dockage. A conveyor system could remove storage heaps of aggregates around the harbor. A conveyor car system or belt system constructed in an enclosed conduit along the Long Island Lighting Company right-of-way would be well suited for this, as it would pass through a large, industrially zoned tract of land in South Setauket. This tract, appropriate for a storage, sorting, and distribution center, is near the Nesconset-Port Jefferson State Highway. This would eliminate the need to truck stone products out of Port Jefferson Harbor.

FERRY FACILITIES There is little change anticipated in the growth pattern, use, and general organization of ferry service in the bi-county region. This can be attributed to the specialized, recreational use of the ferry lines. The recreation-oriented services have been able to adjust to changes in demand and should be capable of doing so in the future.

COASTAL ZONE PLANNING

The corridor concept of the Nassau-Suffolk Comprehensive Development Plan commits the overwhelming majority of the strip of land along northern Long Island to low-density residential use and assorted open space uses like recreation, conservation, and agriculture. This most conservative policy for the Long Island Sound coastal zone is in sharp contrast to the recommendation for a transportation-industrial corridor in the central part of the Island. The plan thus provides for population growth as well as other needs, without sacrificing the unique coastal edge.

The Suffolk County Legislature formally adopted the CDP in 1971 and has taken notable actions to implement significant aspects.[31] The NYS Office of Planning Services also included it as the Nassau-Suffolk portion of the NYS Development Plan.[32] The Suffolk County Charter was amended by public referendum to grant the Suffolk County Planning Commission zoning and subdivision review powers within 500 feet of the shoreline. Furthermore, Senator Bernard Smith, chairman of the NYS Senate Committee on Conservation and a close supporter of the regional planning effort, successfully introduced legislation for wetlands control.[33] Nassau County, without formally adopting the CDP, is implementing it. In short, the trend for turning planning objectives into realities appears promising.

Using the CDP, the Nassau-Suffolk communities can build a secure and proper growth pattern. It is only necessary to maintain civic and governmental interests. Two current programs, aside from short-term or special projects, are being developed by the Nassau-Suffolk Regional Planning Board; these insure the continuity of the planning process and should improve management prospects for the Sound immeasurably. They have grown out of the Coastal Zone Management Act of 1972 and the Federal Water Pollution Control Act of 1972.

Updating the Comprehensive Development Plan

In cooperation with the NYS Division of Planning (the successor to the Office of Planning Services), the board is reexamining and updating the 1970 CDP. The coastal segments will be submitted to the US Secretary of Commerce for approval, in accord with the 1972 Coastal Zone Management Act. This will probably be the first segment to be finalized in the state coastal plan.

Work began in May 1975 with a public meeting convened by the board. It reviewed the past history of coastal zone planning and the desirability of updating the regional plan as new environmental knowledge is acquired. During the summer and fall of 1975 the ad hoc citizens' group met regularly and, in caucus with their community organizations, formulated a detailed set of goals for coastal management. This valuable work enabled the planners to reassess the CDP, as well as existing and proposed county and state laws and administrative procedures. Nine broad goals were set forth:

1) Forestall the acceleration of shoreline destruction and erosion.
2) Preserve and protect water resources.
3) Maximize the public benefit while minimizing environmental damage.
4) Identify, preserve, protect, and restore areas of historic and cultural significance.
5) Enable the public to enjoy the amenities that the coastal zone has to offer.
6) Provide for compatible water-dependent uses (like fishing and ports) and water-enhanced uses (like home sites).
7) Preserve, protect, and develop community infrastructure sites (like utilities, parks, ferry terminals) related to the coastal zone.
8) Restore and enhance, wherever possible, degraded natural or developed areas.
9) Develop legal and administrative mechanisms to implement the updated CDP.[34]

A set of detailed objectives accompanied each goal. Prior CDP planning addressed all of these goals—but not always to the degree called for in the newly defined objectives. In particular, the second and third goals identified the major shortcomings of the CDP in coping with specific critical areas and issues. They are cited in full because they demonstrate public awareness of complex problems and because the planners, fortuitously, were able to provide an immediate response.

Goal 2 Preserve and protect water resources.

Objective A

Dispose of wastewater without appreciably diminishing the quality and quantity of groundwaters and fresh surface waters and the quality of marine waters.

Encourage continuance of experimental research of wastewater disposal as is done at Wantagh Sewage Treatment Plant, the advanced wastewater treatment plant at Hauppauge, and the Brookhaven Town Project Advisory Committee at Brookhaven National Laboratory.

Consider advances in wastewater treatment technology, such as reuse of wastewater through spray irrigation, and the merits of different water management schemes, such as a dual water supply system, a nonaqueous waste disposal system, and treatment of water supply at the wellhead, in the design of new water supply systems.

Require adequate treatment for all sewage plant effluents discharged into estuarine or any other confined waters, to maintain acceptable marine water quality.

Continue the present program of installing sewage collection, treatment, and disposal systems in densely populated areas for handling domestic and industrial wastewater, pending the development of satisfactory alternatives.

Continue ocean disposal of wastewater, subject to treatment producing an effluent with acceptable quality for ocean discharge. However, it must be recognized that this system lowers groundwater levels. When water supplies can be successfully augmented by recharging treated wastewater of sufficient quality, ocean disposal of wastewater should be phased out.

Design storm water systems that will reduce contaminant flows into the marine environment and replenish groundwater aquifers.

Establish no-discharge zones in selected marine areas where the water quality is excellent for fishing and recreation.

Require source pretreatment of toxic and hard-to-treat industrial wastes if such substances are incompatible with effective and economical treatment in municipal treatment plants.

Require holding tanks on vessels for wastes, and require adequate onshore facilities for the treatment and disposal of vessel wastes.

Goal 3 Maximize the public benefit while minimizing environmental damage.

Objective A

Minimize alteration of natural landforms and native vegetation.

Objective B

Maintain living natural resources of high biologic productivity and importance, and preserve and protect their habitats.

Undertake research/management programs to determine appropriate harvest yields for shellfish and finfish.

Consider the net effects on hard clam resources and other marine life when considering: 1) upgrading the treatment process of those sewage plants which presently discharge their effluents into shellfish-producing waters; 2) expanding existing sewage treatment plants or constructing new plants that discharge effluents into shellfish-producing waters; and 3) constructing sewage outfall pipes that traverse shellfish beds.

Encourage New York State, pertinent local governments, and private agencies to acquire at the earliest practical date the fee simple or lesser property interest in as much of the remaining privately held wetlands as possible, with a view toward preserving them in perpetuity. Grant tax and other incentives to individual wetland owners who assure preservation and enhancement of their properties, as initiated by Nassau County in 1974.

Take measures for the rapid containment and cleanup of oil spills.

Endorse national regulation and management of migrating species.

Objective C

Encourage research to increase the knowledge base necessary for understanding how man affects the environment.

Objective D

Identify, preserve, and protect unique geologic formations.

Objective E

Identify, preserve, and protect areas of scenic beauty.

Comprehensive Areawide Wastewater Management Planning[35]

The Nassau-Suffolk Regional Planning Board was preparing an areawide wastewater management program at the same time that the citizens' group set forth its goals. Therefore, the board was able to include many of the citizens' requests. Although narrower in scope than the coastal planning work, the program is far more scientifically rigorous and will be the linchpin in the entire effort to update the CDP.

The wastewater study will provide the environmental criteria and standards upon which planners can base community development and coastal zone management. Coordinating the wastewater study and the CDP updating has been easy at the technical level, since the board is conducting both. Citizen participation, though, was independently established for each study. Because public input is voluntary, the board made no effort to appoint the citizen members of the advisory committees. Quite by chance a partial duplication in membership has occurred. Thus far, the reporting between citizens' groups has been productive. The wastewater study has generally adhered to the requirements of the Federal Water Pollution Control Act of 1972, and specifically addresses itself to:

1) Feasibility of groundwater recharge, in terms of method, site, cost, and treatment required.
2) Determination of groundwater, fresh surface water, and marine water constraints.
3) Identification of both point and nonpoint sources of marine water pollution and the magnitude of such sources.

These water quality problems are extremely complex because of the interactions between marine waters, fresh surface waters, and groundwater. In fact, the first task that faced the planners and their citizen advisers was specifically identifying the problems. Listed below are those chosen for detailed study.

1) Fresh Surface Water and Marine Water Problems
    a) Contravention of marine water quality standards—closure of approximately 25 percent of the waters of the New York marine district which were once deemed suitable for the growth of shellfish; closure of bathing beaches because of high bacteria counts in the marine waters of Nassau County.
    b) Adverse ecological impacts of nutrient loadings discharged into marine surface waters and fresh surface waters.
    c) Alteration of bay salinity regimes as the result of decreases in stream flow and groundwater seepage, caused in turn by low groundwater levels.
    d) Eutrophication of bay marine waters.
    e) Disposal of inadequately treated wastewater and storm water overflows by the City of New York into the East River. This impacts the surface waters of Long Island Sound and the north shore harbors of Nassau County.

f) Disposal of untreated urban storm water runoff directly into fresh surface waters and the marine environment.

2) Groundwater Problems

a) Deteriorating water quality in the upper glacial aquifer and the Magothy aquifer as the result of discharges from cesspool and septic disposal systems in the urbanized portions of Nassau and Suffolk counties.

b) Deteriorating water quality as the result of land management practices associated with agriculture (overfertilization of farm land) and residential land uses (runoff and contamination from sewers, cesspools).

c) Deteriorating water quality as the result of industrial waste discharges and the recharge of untreated urban storm water runoff by means of basins and sumps.

d) Pollution from sanitary landfill leachates (the liquid that has percolated through landfill).

e) Pollution from saltwater intrusion.

f) Stream flows and lake levels that are too low for recreational and fish and wildlife needs.

g) Decrease in groundwater levels as the result of extensive sewering that discharges treated effluents into marine surface waters.

h) Negative effects on quality of usable groundwaters, due to sewering of different areas.

i) Time lag in influencing groundwater quality significantly in areas where sewers are, or are not, planned or installed.

3) Development Problems

a) Extensive and uncontrolled development along watercourses and shorelines. This has resulted in increased urban runoff and deteriorating stream water quality.

b) Loss of groundwater recharge because of increase in impervious surfaces of highways and buildings.

c) Canalization of bay shorelines resulting in poor water circulation and impaired water quality.

d) Nassau-Suffolk dependence on groundwater for their entire water supply.

e) Population growth and greater demands on a limited groundwater resource. Water supply deficits are predicted if conservation measures are not implemented.

f) Seasonal wastewater disposal problems in eastern Suffolk County as the result of summer migration to the area.

4) Management Problems

a) Problem of how to manage and dispose of treatment plant, agricultural, and industrial sludge.

b) Inadequate treatment levels in many public and private municipal treatment plants.

c) No structural or nonstructural solutions to meet wastewater treatment needs in the urbanized portion of Nassau-Suffolk; no adequate nonstructural abatement strategies in the rural portion of Suffolk.

d) Inability to predict the quality and quantity response of Nassau-Suffolk groundwater supplies when subject to stress in the form of water withdrawal, treatment, and disposal strategies.

e) Inability to predict the chemical and biologic impacts of alternative waste discharge schemes on Nassau-Suffolk marine waters.

f) Nonintegrated, piecemeal approaches to the solution of water supply and wastewater disposal problems.

g) No management programs for storm water disposal.

h) No management of irrigation water.

These problems are all addressed in the wastewater study, designed in part to do the following:

1) Identify required treatment facilities for point and nonpoint sources of pollution, including 5-year, 10-year, and 20-year construction priorities, costs. Designate authority for the construction and operation of such facilities.

2) Identify required facilities, regulatory programs, and land management procedures for the control of nonpoint pollution sources related to agricultural and construction activities, saltwater intrusion, and urban storm water runoff.

3) Describe a program to regulate the growth and the construction of new facilities in the Nassau-Suffolk region that will result in a decrease in pollution loadings.

4) Describe a program for controlling the disposal of solid wastes and hazardous substances and thereby minimizing deleterious impacts on groundwater and surface and marine waters.

5) Identify the scheme for implementing the wastewater management plan.

6) Describe the tradeoffs, and select various structural and nonstructural alternatives to achieve water quality goals in terms of costs, benefits, and environmental impacts.

SUMMARY

The preceding chapters have identified and described the issues, assets, conflicts, and deficiencies that constitute the status and potential of the marine environment of Long Island Sound. Although no preconceptions conditioned the results of the study—other than the rather obvious bias that the geophysical interrelationships of shorefront communities and the marine environment must be understood as an integral part of the planning process—two concepts became preeminent as the study progressed: 1) wetlands conservation and pollution control are essential to maintaining a healthy ecosystem, and 2) we need greater knowledge and new administrative approaches to achieve and implement rational policies and programs for the planned use of the marine resources. There are two prerequisites to a coordinated and comprehensive management of the marine ecosystem: 1) research and education as the means to acquire additional knowledge, train personnel, and disseminate information that will create public understanding of the marine environment, and 2) a review and evaluation of administrative mechanisms that may be used to implement a planning and management program.

Lest the reader be misled to assume that the discussion of needs and preferred solutions is tantamount to problem-solving, let it be emphasized that the end of this recital is only the beginning. Adopting a comprehensive management plan and devising the means for implementing it for the Long Island Sound region are still to be achieved. And the selection or development and testing of the administrative agency or agencies required to make a plan operational is yet to be accomplished. Each of these elements is the subject for additional work.

The unique feature of the Long Island Sound region is its marine environment. Few communities have been endowed with such a handsome but delicate gift. Well managed, it will continue to serve as its greatest asset. Unmanaged or mismanaged, it will become a costly and dangerous liability.

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[35] Nassau-Suffolk Regional Planning Board, *Work Plan and Scope of Services: Application for Federal Assistance for Areawide Waste Treatment Management Planning,* Section 208 (Hauppauge, N.Y., May 1, 1975).

The panorama of Long Island Sound, looking east from Throgs Neck

Appendixes

Appendix A Calculation of Mean Tidal Transport

The tides in Long Island Sound are mainly semidiurnal lunar, and the amplitude and phase of the tide depends primarily on the longitude. Thus the height of the water H depends on the time t and the longitude x according to the following expression:

$$H(x,t) = 0.5\, R_x \cos(\omega t + \delta_x)$$

where R_x is the mean range of the tide and δ_x is the phase at longitude x (Fig. 4.1, 4.2). The angular frequency ω is 1.405×10^{-4} sec^{-1}, corresponding to the principal lunar period of 12.42 hours. The phase angle δ is chosen to be zero for Bridgeport, so that $t = 0$ corresponds to high tide at that location.

We divide Long Island Sound into 14 segments, bounded by meridians as shown in Figure A.1. The area of each segment was obtained by planimetry and is indicated in Table A.1. We now represent the rise and fall of the tide in each segment by its mean amplitude and phase. During a tidal cycle, the volume of water within the segment changes, and, because of conservation of water, the change in volume of the segment must be equal to the difference in transport across the boundaries of the segment.

Consider first the westernmost segment (1) between 73°48′W and 73°43′W. This segment has a surface area A_1 of 88.4 km^2 or 88.4×10^6 m^2. The tidal range R_1 is 2.17 meters, giving an amplitude $H_1 = 0.5\, R_1$ of 1.085 meters, and the average phase angle for the tidal height for the segment δ_1 is -12°. The time rate of change of water volume W due to the change in tidal height is:

$$\begin{aligned} dW/dt = A_1\, dH/dt &= -A_1 H_1\, \omega \sin(\omega t + \delta_1) \\ &= -13.5 \times 10^3 \sin(\omega t - 12^\circ)\ \text{m}^3\ \text{sec}^{-1}. \end{aligned}$$

The flux of water into Long Island Sound through the section Throgs Neck-Willets Point, minus the increase in volume in segment 1, must equal the eastward flux of water through 73°43′W, the eastern boundary of the segment. Each of these fluxes is sinusoidal with the frequency of the lunar semidiurnal tide; however, since the phases differ, we must resort to a vector addition.

We shall adopt the convention that a positive transport is from west to east and that it is represented by a sine wave with phase angle δ. The time when $\omega t + \delta = 0$ thus represents zero transport (slack average current) before the water ebbs from the Sound through the Race. As before, high tide at Bridgeport corresponds to zero degrees on the vector diagram, Figure A.2. The change in volume in segment 1 is represented by a vector with a magnitude of 13.5×10^3 m^3 sec^{-1} and a phase angle of -12°. The phase of the tidal transport undergoes a large change from -117° at Throgs Neck to -39° at 73°43′W (estimated from current measurements reported in Le Lacheur and Sammons, 1932*). Since the sum of the vectors for the tidal change in segment 1 and the transport at Throgs Neck must equal the vector of transport at 73°43′, we can obtain the magnitudes of the latter two transports. We find that the tidal transport through Throgs Neck-Willets Point has an amplitude of 6.3×10^3 m^3 sec^{-1} (see Fig. A.2). We can compare this value with the flow rate obtained by multiplying the maximum surface tidal current by the area of the cross section at Throgs Neck. The tidal current tables list mean maximum flood and ebb currents as 1.0 and 0.6 knots respectively, giving an average of 0.4 m sec^{-1}. The cross-sectional area of the channel is about 18×10^3 m^3, resulting in an amplitude for the tidal transport of 7.4×10^3 m^{3}sec^{-1}, assuming that the velocity is uniform in the channel. This is somewhat larger

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*References in Appendixes A, B, and C are given in full following Chapter 4.

than the derived transport (6.3 X 10^3) and therefore in reasonable agreement, since the average velocity should be smaller than the surface velocity.

Next we consider the change in the tidal prism in segment 2 and add this vector to the transport across boundary 1-2 to obtain the transport through the boundary between segments 2 and 3. The various data are shown in Table A.1. We proceed in like manner until we reach segment 12. In this segment we must consider the transport through Plum Gut as well as the transports through the meridional boundaries and the change in the tidal prism. Similarly, we must consider the transport through the Race in segment 13, and the transport through Fishers Island Sound Inlet in segment 14.

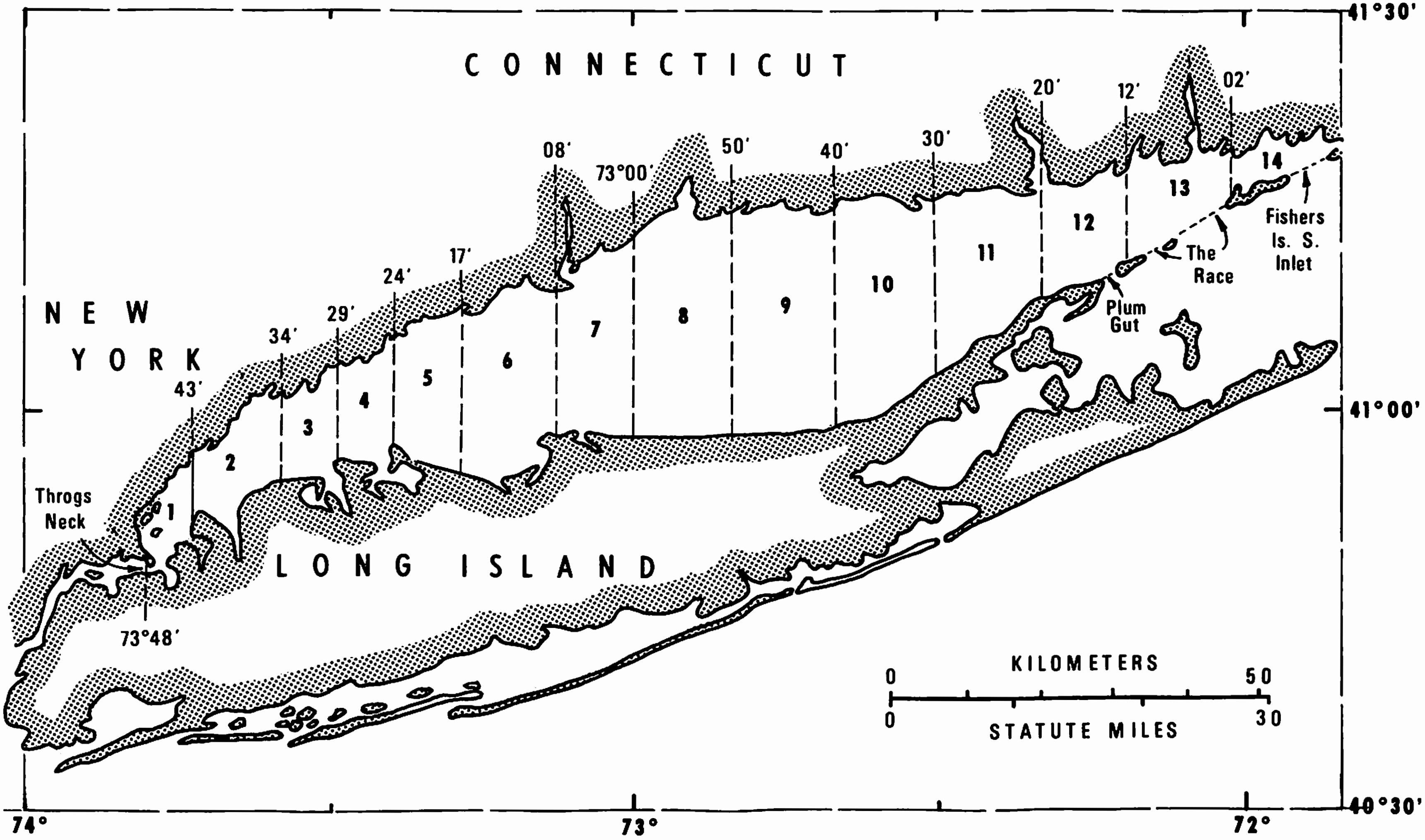


FIGURE A.1 *Location of Segments of Long Island Sound.*

TABLE A.1 *Data for Segments of Long Island Sound*

		Segment				Boundary		
			Tidal Prism dW/dt				Transport	
Nr	Area $A\ (Km^2)$	Tidal Height Amplitude $H\ (m)$	Amplitude* $10^3 m^3 sec^{-1}$	Phase δ	Longitude	Name	$10^3 m^3 sec^{-1}$	Phase
					73°48′	Throgs Neck	6.3	-117°
1	88.4	1.085	13.5	-12°				
					43′		13.3	- 39°
2	154.8	1.10	23.9	- 6°				
					34′		35.8	- 19°
3	112.3	1.10	17.4	- 6°				
					29′		52.9	- 14°
4	122.0	1.09	18.7	- 4°				
					24′		71.5	- 11°
5	192.6	1.075	29.1	- 4°				
					17′		100.4	- 9°
6	318.1	1.045	46.7	- 3°				
					8′		146.9	- 7°
7	281.0	1.00	39.5	0°				
					73°00′		186.1	- 6°
8	454.8	.935	59.7	+ 2°				
					72°50′		245.5	- 4°
9	448.6	.83	52.3	+ 6°				
					40′		297.1	- 2°
10	406.5	.74	42.3	+ 7°				
					30′		338.9	- 1°
11	293.9	.605	25.0	+17°				
					20′		362.8	0°
12	164.1	.485	11.2	+31°				
						Plum Gut	30	+ 24°
					72°12′		345.0	- 1°
13	183.9	.38	9.8	+53°				
						Race	326.7	0°
					72°02′		24.8	+ 12°
14	81.0	.37	4.2	+55°				
					71°50′	Fishers Is. Sound Inlet	28	+ 18°

*Amplitude = $AH\omega$

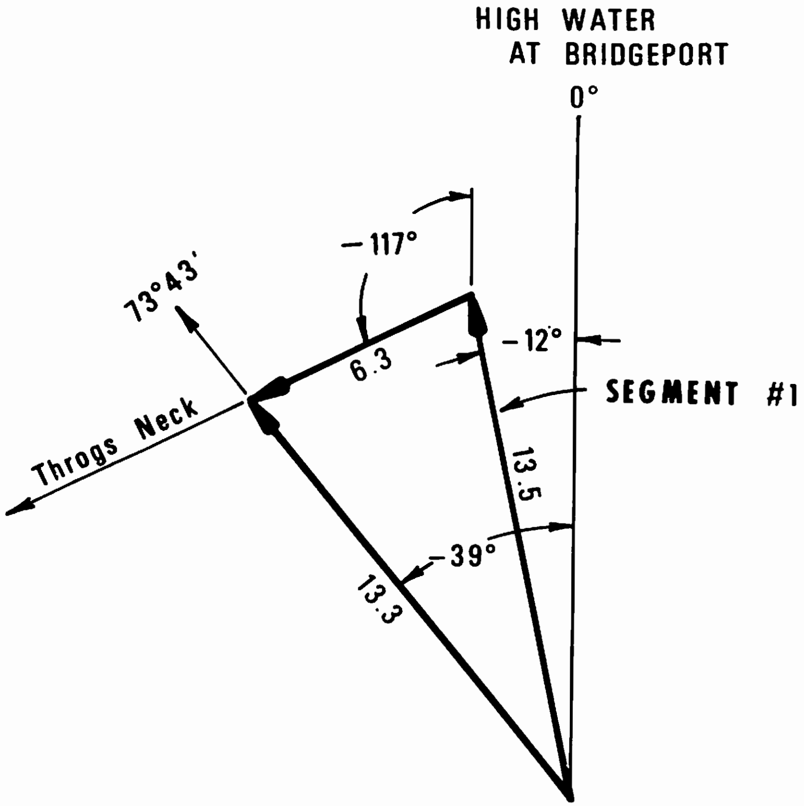


FIGURE A.2 *Vector Diagram of Mean Tidal Transport for Segment #1*

Of these three, the transport through the Race is by far the largest, much larger than the transport through Plum Gut or through Fishers Island Sound Inlet. We shall therefore estimate the two smaller transports from tidal current data and then obtain the transport through the Race by vector addition. The flux through the Race is about 10 times that through either Plum Gut or Fishers Island Sound and is therefore insensitive to errors in the estimates of the latter transports. The estimates are given in Table A.2. Using these estimates, we can complete the calculation and obtain the transport through the Race (Table A.1).

TABLE A.2 *Tidal Current Data for Plum Gut and Fishers Island Sound Inlet*

	*Plum Gut Table #1680**	*Fishers Island Inlet Table #1610**
Cross-sectional Area $10^3 m^3$	15	28
Average max current		
flood knots	3.5	1.7
ebb knots	4.3	2.2
average m sec^{-1}	2.0	1.0
Transport		
amplitude $10^3 m^3 sec^{-1}$	30	28
phase (degree)	+24°	+18°

*Ref. LeLacheur and Sammons 1932.

Appendix B Heat Budget for Central Long Island Sound

We can arrive at an approximate heat budget for the central part of Long Island Sound by using mean monthly insolation data for 1953-54 obtained at Brookhaven National Laboratory, Upton, New York (data courtesy of Miss Constance M. Nagle, B.N.L.). The details of the heat budget calculations are given in Table B.1.

Line 1 in Table B.1 lists the mean monthly insolation in cal cm^{-2}day^{-1}.

TABLE B.1 *Heat Budget for Central Long Island Sound*

											1953														*1954*		
Line	*Units*		*F*		*M*		*A*		*M*		*J*		*J*		*A*		*S*		*O*		*N*		*D*		*J*		*F*
①	cal cm^{-2} day^{-1}	Insolation	205		287		404		430		653		583		490		444		297		182		156		145		258
②	cal cm^{-2} day^{-1}	Reflection	22		23		30		28		46		42		35		37		28		21		21		18		28
③	cal cm^{-2} day^{-1}	Back radiation	70		87		116		101		115		118		115		120		139		101		77		48		67
④	cal cm^{-2} day^{-1}	Radiation balance ① - (② + ③)	113		177		256		301		492		423		340		287		130		60		58		79		163
⑤	°C	T mean water	3.0		3.7		6.2		10		14		18.7		21.7		21.3		18.7		14.7		9.5		4.0		1.5
⑥	cal cm^{-2} day^{-1}	Radiation balance		145		216.5		278.5		396.5		457.5		381.5		313.5		208.5		95		59		68.5		121	
⑦	cal cm^{-2} day^{-1}	Change in heat storage		47		167		253		267		313		200		-27		-173		-267		-347		-366		-167	
⑧	cal cm^{-2} day^{-1}	Heat loss at surface		98		49.5		25.5		129.5		144.5		181.5		340.5		381.5		362		406		434.5		288	
⑨	°C	T water – T air		0		-1.5		-2		-3		-2.5		0		2.2		4.5		7.0		7.0		6.5		3.0	
⑩	°C	ΔT effective		1.3		0.6		0.2		0.1		0.2		1.3		2.5		4.5		7.0		7.0		6.5		3.2	
⑪	cal cm^{-2} day^{-1}	Sensible heat loss		39		18		6.0		3.0		6.0		39		75.5		136		212		212		197		95	
⑫	cal cm^{-2} day^{-1}	Latent heat loss ⑧ - ⑪		59		31.5		19.5		126.5		138.5		142.5		265		245.5		150		192		237.5		193	
⑬	cm month^{-1}	Evaporation		3.0		1.6		1.0		6.4		7.0		7.2		13.5		12.5		7.6		9.8		12.1		9.8	
⑭	cm month^{-1}	Precipitation		17.8		20.8		11.7		7.4		11.5		6.3		3.9		6.2		9.8		11.8		9.9		5.1	
⑮	cm month^{-1}	P-E ⑭ - ⑬		14.8		19.2		10.7		1.0		4.5		-0.9		-9.6		-6.4		2.2		2.0		-2.3		-4.7	
⑯	cal cm^{-2} day^{-1}	Total heat loss surface ⑧ + ③		176.5		152		135		237.5		261		298		458		511		482		495		497		345.5	
⑰	°C	T water surface		3.0		5.8		10		14.3		20.0		22.3		22.7		20.3		17.0		12.0		7.0		2.3	
⑱	°C	ΔT no storage		+1		+3.6		+5.4		+5.7		+6.7		+4.2		-0.6		-3.7		-5.7		-7.4		-7.9		-3.6	

Next the reflected radiation (line 2) and the infrared back radiation (line 3) are estimated, using the method of James (1966). We then obtain the mean radiation balance for each month by subtracting the reflected and back radiation from the insolation (line 4). Averaging the surface and bottom temperatures observed by Riley (1956), we obtain mean temperatures for each month (line 5).

Next we obtain a heat budget from the fifteenth of one month to the fifteenth of the following month. The first item is the mean radiation balance for the time interval (line 6) obtained by averaging adjacent monthly values (line 4). Next we must consider the change in the heat content of the water in the Sound. Using a mean depth of 20 meters, we obtain the change in heat content by multiplying the temperature change over the 30-day interval by 2000/30 = 66.7 to obtain the change in heat content in cal $cm^{-2}day^{-1}$. Assuming that no heat is advected into the central part of Long Island Sound, the radiation balance minus the change in heat content must then be equal to the non-radiative loss of heat from the sea surface (line 8).

Next we separate the heat loss into two parts: a sensible part due to a change in air temperature, and a latent part due to the evaporation of water from the sea surface. Under open ocean conditions, the air over the water is close to saturation with water vapor and the ratio between sensible and latent heat (the Bowen ratio) can therefore be estimated from the air-water temperature difference and the vapor pressure differences corresponding to these temperatures. For Long Island Sound, however, the relative humidity of the air can vary widely depending on whether the air mass over the Sound is derived from the adjacent land mass or from the North Atlantic. We shall therefore estimate the sensible heat loss directly and obtain the latent heat loss by difference.

If the water is warmer than the air, the air above the water becomes thermally unstable and a natural convection ensues. If, on the other hand, the water is colder than the air, a stable stratification is set up at the air-sea interface, and heat transfer from the air to the water is inhibited.

Laevastu (1960, p. 54) gives formulas for the two cases. Water warmer than air (unstable stratification):

$$Q = 30.24\,(T_w - T_a)\ \text{cal cm}^{-2}\text{day}^{-1}.$$

Air warmer than water (stable stratification):

$$Q = 0.432\,(T_a - T_w)\,V\ \text{cal cm}^{-2}\text{day}^{-1}$$

$$V = \text{wind speed in m sec}^{-1}$$

Thus at a windspeed of 18 knots, the heat gain by the water is only 10 percent of the heat loss for a corresponding temperature difference of opposite sign.

The temperature differences ($T_w - T_a$) isted in line 9) are mean temperatures, averaged over the diurnal temperature cycle. While the water temperature varies relatively little over a 24-hour cycle (we obtained a range of 0.9°C on August 14-15, 1970 near Execution Rock), the air temperature has a significant diurnal variation of the order of 8°-10°C.

Thus, although the mean water temperature is less than the mean daily air temperature, as long as the mean difference is less than one-half the diurnal air temperature range, the water will be warmer than the air for part of the time, resulting in a net heat loss from the water to the air. To compensate for this effect, one can replace the average water-air temperature difference by an effective temperature difference. If we assume a sinusoidal diurnal temperature variation with an 8° range, we obtain the effective temperatures shown in line 10, Table B.1. Multiplying the T effective by 30.24 cal $cm^{-2}day^{-1}\,{}^{\circ}C^{-1}$, we obtain the sensible heat loss values in line 11. Next we obtain the latent heat loss (line 12) by difference. The annual variation of the components of the heat budget is shown in Figure B.1.

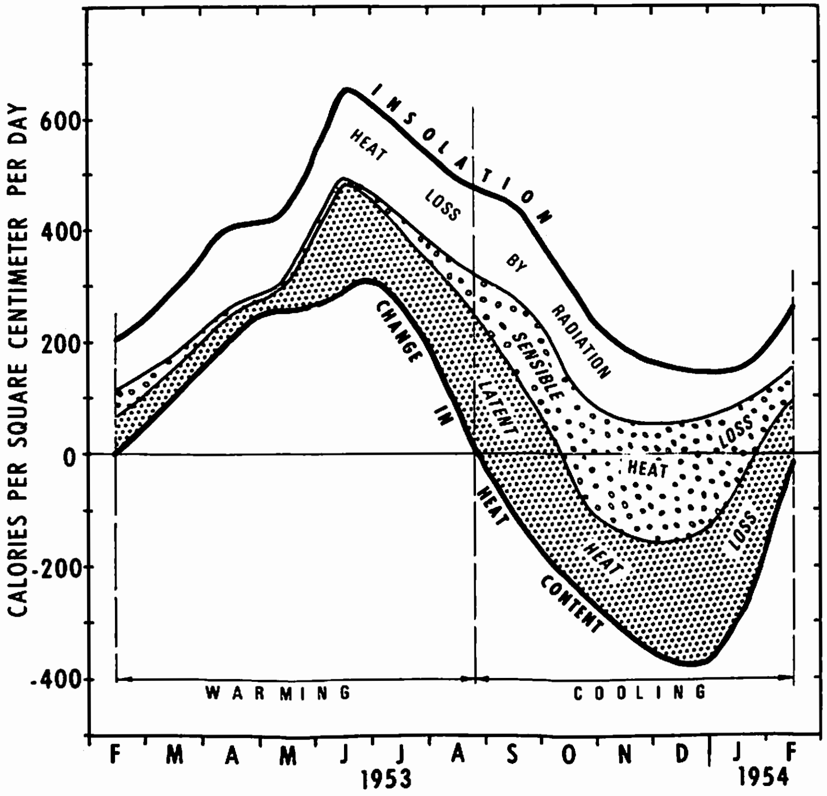


FIGURE B.1 *Annual Variations of the Components of the Heat Budget*

TABLE B.2 *Annual Heat Flux, Feb. 1953 – Feb. 1954*

	cal cm^{-2} day^{-1}
Incoming solar radiation	359
Reflected radiation	30
Back radiation	101
Radiation balance	228
Change in heat storage	-8
Sensible heat loss	87
Latent heat loss (by difference)	150
Annual evaporation	93 cm

By the procedure above, we have obtained a rough estimate of the annual variation of the heat budget for central Long Island Sound. As a check, we can average the monthly values in order to obtain an annual budget for the interval February 15, 1953 to February 15, 1954 (Table B.2). As before, we shall express the flux in cal cm^{-2} day^{-1}.

Our annual heat budget indicates that the annual evaporation from Long Island Sound amounts to 93 cm of water. The mean annual lake evaporation for the region of Long Island Sound as derived from evaporation pan data is 75 cm year^{-1} (United States Weather Bureau Technical Paper 37). Because there is greater wave energy over the Sound than in an evaporating pan, one would expect the Sound's evaporation to be greater. The annual rate of evaporation from the North Atlantic at 40° north latitude is estimated as 94 cm (Sverdrup *et al*, 1942, p. 123), in close agreement with our heat budget data. Thus, we conclude that our rough estimate of the heat budget gives a reasonable value for the annual evaporation.

Using the monthly precipitation data for New Haven (Table B.1, line 14) and the monthly evaporation derived from our heat budget (line 13), we can estimate the monthly difference between precipitation and evaporation (line 15). We obtain a range from a positive water balance of about 19 cm month^{-1} from March 15 to April 15, 1953, to a negative water balance of about 10 cm month^{-1} net evaporation between October 15 and November 15 of the same year. Because of the year-to-year variations in the heat budget, and the even greater variations in monthly precipitation, the seasonal water balance will vary significantly from year to year.

Heat storage in the water of the Sound has the effect of causing the temperature extremes in the water to lag about one month behind the peaks in air temperature. In shallow water, along the northern and southern shorelines of the Sound, the effect of heat storage will be significantly less than in deep water. We can estimate the surface temperature variation in the absence of heat storage. Since the back radiation depends on the surface temperature of the water, we must consider how the total heat loss by sensible and latent heat and infrared radiation varies with surface temperature and the air-sea temperature difference. The total surface heat loss is given in line 16. This term varies with surface temperature T and the air water temperature difference ΔT according to the following linear approximation:

$$\text{Heat loss from surface} = 185 + 40\Delta T + 6.5T, \ \text{cal cm}^{-2}\text{day}^{-1}.$$

A surface temperature increase of 1°C therefore leads to an increase in heat loss of 46.5 cal cm^{-2} day^{-1}°C^{-1}. Using this ratio we can calculate the temperature change required to compensate for heat storage in the Sound (line 18 and Fig. 4.7).

Appendix C Transport at the Boundaries of the Sound and Salt and Nutrient Budget

The properties of the waters of Long Island Sound depend to a large extent on the exchange of water, salt, and nutrients across the western and eastern boundaries. Of prime importance is the exchange with the East River to the west and with Block Island Sound through the Race in the east. The matter has been discussed in a general way in the body of Chapter 4; here, however, we wish to take a more quantitative approach. We will examine the general theory and apply it to some available data. The purpose here is not to provide a final answer, since much of the needed information is not available. Rather, we are interested in obtaining a first approximation as a guide to future efforts.

Consider the flow across one of the boundaries of Long Island Sound—for example, a N-S section in the East River just west of Throgs Neck. Let the x coordinate be horizontal across the section and let the z coordinate be measured vertically downward from the instantaneous water surface. The component of the water flow velocity perpendicular to the section v will vary with time t during a tidal cycle and its value will also depend on x and z; $v(x,z,t)$. Let C be the concentration of some constituent in the water such as salt or phosphate, where the concentration is given as a mass per unit volume. C will also vary with x, z, and t so that we have $C(x,z,t)$. Let the sign of the velocity be positive if it is into the Sound and negative if the flow is out of the Sound. The average rate of mass transport F of the constituent into the Sound between time $t = 0$ and $t = T$ is obtained by integrating the product of velocity and concentration across the section and over the time interval, and dividing this by the elapsed time:

$$F = \frac{1}{T} \int \int \int_0^T v\,(x,z,t)\; C(x,z,t)\; dx\, dz\, dt.$$

To obtain the flux requires, therefore, that both the normal velocity component and the concentration of the constituent be measured continuously throughout the time interval, as a function of x and z. The number of grid points in x and z at which measurements would be required depends on the space variability of v and C. Such a detailed series of measurements is clearly out of the question and we must therefore replace the functions $v(x,z,t)$ and $C(x,z,t)$ by approximations.

First consider the velocity $v(x,z,t)$. Considering the transport from the East River to the Sound, we cannot use the data in the sections Throgs Neck-Willets Point (Fig. 4.22) because the large curvature in the channel makes it impossible to obtain the component normal to the section from the measured speed of the water. However, data are available further to the west near the Whitestone Bridge, where the channel is relatively straight, so that the measured speed is a reasonable approximation of the normal component v. We shall use the measurements in July 1922 reported in Marmer (1935), p. 189, stations 50, 53, and 54. For each station and at a number of depths, the velocities are given for the ebb and flood strength, as well as the duration of the flood and ebb. The tidal currents in the East River are approximately sinusoidal with the period of the semidiurnal lunar tide, 12.42 hours. The tidal variation of the velocity v at a point x,z can be approximated by the following equation:

$$v(x, z, t) = v_1\,(x, z) + v_2\,(x, z) \cos \omega t,$$

where v_1 and v_2 are the amplitude of the net and the alternating current respectively. See Figure C.1.

The relationship between the components of the velocity v_1 and v_2, and the velocity for the strength of the flood and ebb v_F and v_E, and the duration of the flood and ebb D_F and D_E, are shown in Figure C.1. The durations are constrained by the fact that their sums must equal 12.42 hours, so that we have three independent data to determine the two components v_1 and v_2. The difference in the period of the flood and ebb is likely to be more accurate than the difference between the velocities v_F and v_E. We shall therefore use the following equations to find the components of v:

$$v_2 = \frac{1}{2}(v_F + v_E)$$

$$v_1 = +v_2 \sin \alpha$$

$$\alpha = (D_F - 6.21)\ 14.5^\circ$$

The values of v_1 and v_2 obtained from current stations 50, 53, and 54 in the upper East River near the Whitestone Bridge are shown in Figure C.2. Note that the direct component v_1 is positive (that is, into the Sound) near the surface and negative at depth. As a result of the Coriolis effect, the current into the Sound is stronger on the south side of the channel, whereas the current out of the Sound is stronger to the north.

Having obtained the distribution of the velocity components in the cross section, we next integrate the alternating part of the tidal velocity v_2 over the channel, to obtain the alternating components of the tidal transport T_2:

$$\iint v_2\ (x, z)\ dx\ dz = T_2$$

We find that $T^2 = 6.3 \times 10^3\ Tm^3\ \mathrm{sec}^{-1}$, in agreement with the value determined by a different method in Appendix A (see Table A.1).

Since the direct component v_1 changes sign with depth, we must proceed differently. Integrating v_1 with respect to x, we obtain a transport term W_1 in m^2 sec^{-1} as a function of z (Figure C.3):

$$\int v_1\ (x, z)\ dx = W_1\ (z)$$

W_1 is positive near the surface, goes through zero at about a depth of 9 meters and becomes negative below that depth. Integrating the positive and negative portions separately with respect to z, we obtain a surface transport T_s of 1020 m^3 sec^{-1} into the Sound, and a deep transport T_d of 540. The difference of these two transports gives a net flow of 480 m^3 sec^{-1} into the Sound.

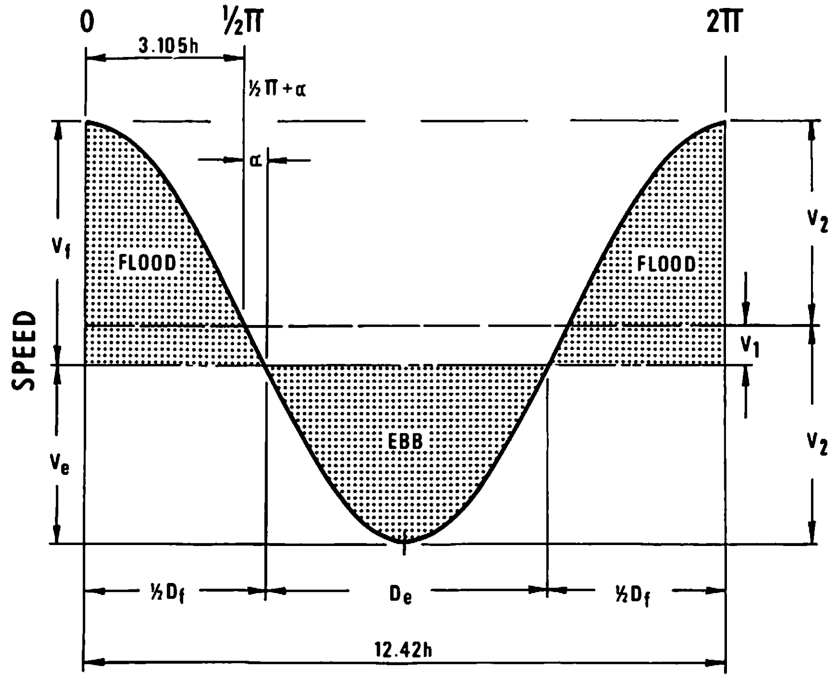
To simplify matters further, it is best to resolve the direct transport W_1 into an advective part W_a, which is uniform over the depth of the channel, and an estuarine part W_e, which gives rise to a surface transport T_e into the Sound and an equal and opposite bottom transport out of the Sound. The relationships are shown in Figure C.3b. $T_a = T_s - T_b = 480\ m^3\ \mathrm{sec}^{-1}$ and T_e is 850 m^3 sec^{-1}.

The estuarine transport T_e consists of a couple of equal and opposite flows with a surface inflow at an effective depth z_s and a deep outflow at an effective depth z_d. In the example the effective depths are approximately 3 and 14 meters respectively. The tidal transport through the cross section thus consists of three terms: a time-varying sinusoidal component with amplitude T_2, an advective component T_a, and an estuarine couple T_e having equal and opposite-directed flows at depths z_s and z_d.

Next we must consider the concentration of the component being transported, $C(x,z,t)$. In analogy with the transport, we approximate the variation in concentration by three terms: the average concentration C_a, a time-varying part that changes sinusoidally over a tidal cycle C_2, and a vertical variation characterized by the average difference in concentration between the effective depth of the surface estuarine transport z_s and the deep transport z_d: $C_e = \overline{C(z_s)} - \overline{C(z_d)}$.

The sinusoidally varying part of the concentration is taken as a sine function; however, we must add a phase angle δ, since the time when the sinusoidally varying part of the concentration goes through zero while increasing does not necessarily correspond to the peak transport velocity into the Sound. As a first approximation, to obtain the flux of a component averaged over a tidal cycle, we need only multiply the parts of the transport with their corresponding concentra-

FIGURE C.1 *Tidal Current Diagram*



$$v = v_1 + v_2 \cos wt$$

$$\alpha = (½D_f - 3.105h)\frac{90^\circ}{3.105h} = (D_f - 6.21)\ 14.5^\circ$$

tion terms and integrate, since the products of non-similar terms average to zero. We find:

1) An advective flux F_a equal to the product of the advective transport T_a times the average concentration C_a

$$F_a = T_a C_a$$

This term is positive if the transport is into the Sound.

2) An estuarine term equal to the product of the estuarine transport T_e times the vertical concentration difference C_e

$$F_e = T_e C_e$$

T_e is positive if the surface flow of the couple is into the Sound and C_e is positive if the surface concentration is greater than the deep concentration.

3) A term due to the phase shift between the alternating parts of the transport

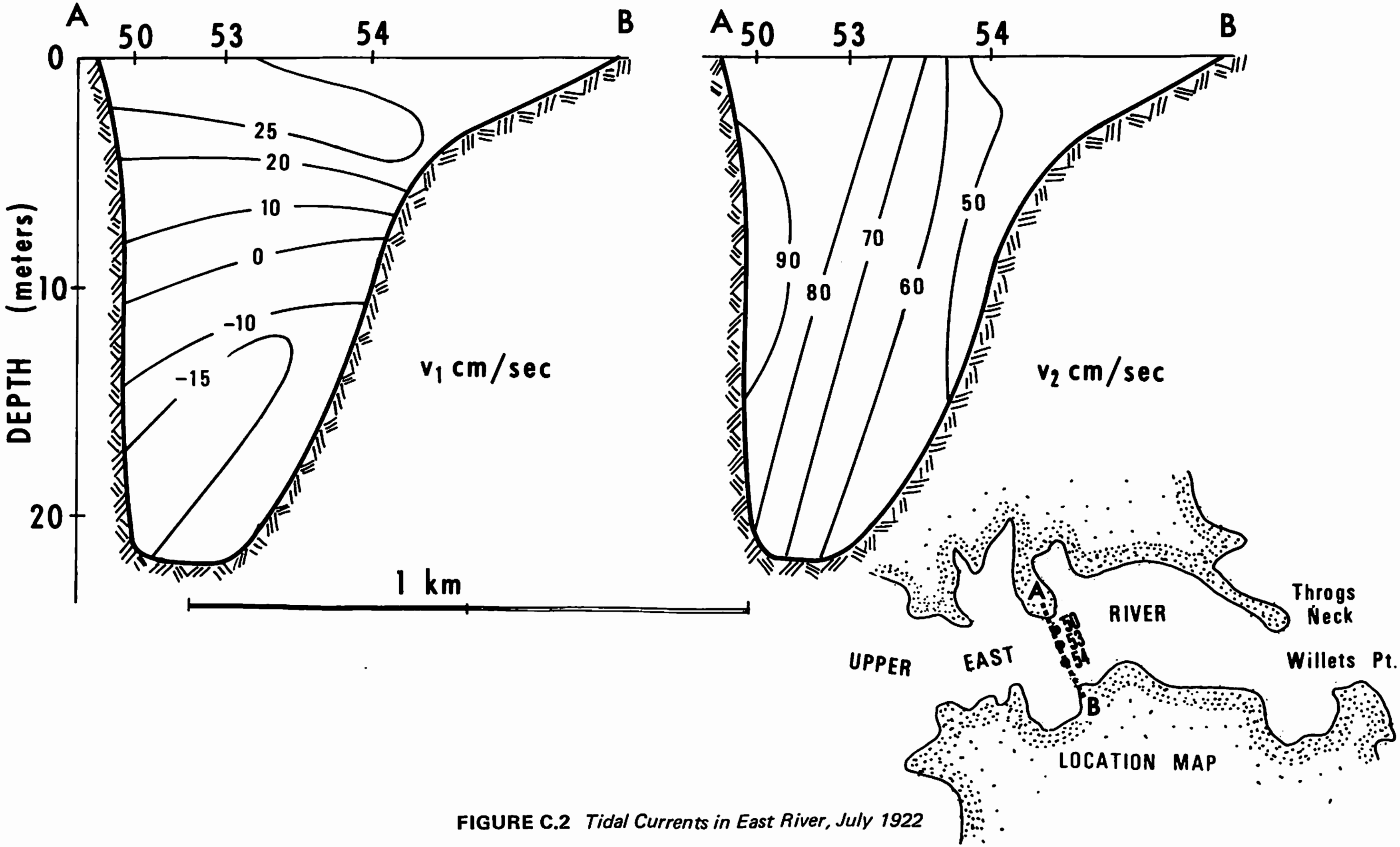


FIGURE C.2 *Tidal Currents in East River, July 1922* and the concentration F_2. Averaging over one tidal cycle we obtain the following:

$$F_2 = \frac{\omega}{2\pi}\int_{t=0}^{\frac{2\pi}{\omega}} T_2 \cos\omega t\, C_2 \sin(\omega t+\delta)\, dt = \frac{T_2 C_2}{2} \sin\delta$$

Thus if the phase shift is zero, there is no transport by this mechanism. The phases of both the current and the concentration change with depth and across the channel. To evaluate the proper effective phase shift δ, one has to average the local phase shifts $\delta(x, z)$ over the cross section.

From the measurements near the Whitestone Bridge in July 1922, we have estimated the following fluxes:

$$F = 0.48\, C_a + 3.15\, C_2 \sin\delta + 0.85\, C_e \times 10^3 \text{ tons sec}^{-1}$$

if the concentration C is given in tons m^{-3} or gm cm^{-3}. Within a channel, if there are no sources or sinks, the flux must be conserved. Further, if the average water level in the channel is to remain constant, the advective transport in the absence of sources or sinks must also remain constant.

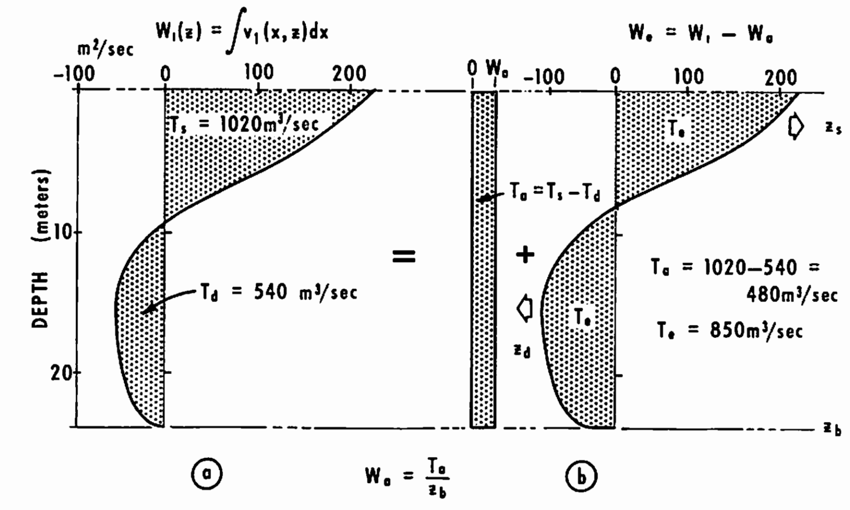


FIGURE C.3 *The Estuarine and the Advective Transport*

Turbulent mixing in the channel, however, may drastically alter the vertical stratification and hence the estuarine part of the transport term T_e. As a result, as the estuarine transport is decreased, we would expect an increase in the absolute value of the phase angle δ. In the East River we would therefore expect a larger phase shift near Hell Gate, where there is little vertical stratification, than near Throgs Neck, where the water is stratified.

In winter, when there is essentially no stratification, the flux will be exclusively due to the advective and the phase shift term.

Next consider the transport through the eastern passes. Here the alternating term T_2 is about 350 X $10^3 m^3 sec^{-1}$, compared to 6.3 X $10^3 m^3 sec^{-1}$ in the west. To maintain the water balance in the Sound the advective term T_a is equal to minus the sum of T_a in the west plus the rate of freshwater discharge into the Sound or about $-(0.5 + 0.3) \times 10^3 m^3 sec^{-1}$, approximately $-10^3 m^3 sec^{-1}$. Because the alternating term T_2 is much larger than T_a it is not possible to obtain T_a from current measurements. To permit such measurements, it would be necessary to measure the instantaneous velocity distributions across the eastern passes with an accuracy of better than 0.1 percent. Such measurements are clearly beyond the present state of the art of current measurements.

To obtain an estimate of the order of magnitude of T_a and T_e we can proceed as follows: the average concentrations of salt in the west and east are 24‰ and 30‰ respectively. The advective part of the budget is therefore $0.5 \times 24 - 1.0 \times 30 = -18$ tons of salt sec^{-1}. Advection thus results in a net loss of salt to the Sound, since the advective loss in the east exceeds the net advective gain of salt in the west. The diffusive transport of salt must on the average have an equal and opposite value of +20 tons sec^{-1} and this corresponds to the contributions by the estuarine terms and the terms $T_2 C_2 \sin\delta$.

In winter, there will be no estaurine term, so that the diffusive flow is carried entirely by the phase shift in the tidal transports. The amplitude of the tidal salinity variations at the ends of the Sound is on the order of 1‰ and the effect will be to remove salt by tidal mixing in the west and to add it in the east. The approximate balance in the absence of estuarine transport is therefore:

$$20 \text{ tons sec}^{-1} = -3 \sin\delta_w + 325 \sin\delta_e.$$

The first term is clearly negligible so that

$$\sin\delta_e = 20/325 = 0.06 \text{ and } \delta_e = 3.5^\circ.$$

Thus the phase shift in the east is at most 3.5° corresponding to a time difference of only 7 minutes.

If on the other hand we have extreme stratification, so that the salt balance is entirely maintained by the estuarine component, we obtain the following: C_e, the vertical salinity difference, is about −0.4‰ at both ends, the minus sign arising from the fact that the salinity is less at the surface. In the west, T_e is approximately $+10^3 \mathrm{m}^3 \mathrm{sec}^{-1}$ since the surface water is flowing into the Sound, and T_e in the east will be negative since the net surface flow at the Race is out of the Sound. We find:

$$20 \text{ tons sec}^{-1} = -0.4 + 0.4\ T_e.$$

Thus T_e in the east is at most about $50 \times 10^3 \mathrm{m}^3 \mathrm{sec}^{-1}$, or about one-seventh of the alternating component. Riley (1956) has estimated the estuarine component near the eastern end of the Sound to be about $15 \times 10^3 \mathrm{m}^3 \mathrm{sec}^{-1}$.

If, instead of salt, we consider the budget of a nutrient such as phosphate, the situation is quite different. Here the values and gradients are very large in the west, whereas the values and gradients are very small in the cleaner eastern waters. We are thus mainly confronted by an addition of nutrients in the west that are converted to organic matter in the Sound. Typical estimates of the concentration terms in microgram atoms per liter are $C_a = 6.5$, $C_e = 1$, $C_2 = 1$. The flux into the Sound from the East River is therefore approximately:

$$F = (3 + 3 \sin \delta + 1) \text{ gm atom sec}^{-1}$$

for the advective, the tidal mixing, and the estuarine terms respectively. The flux of phosphorus thus amounts to about 5 gm atoms sec^{-1} or 150 gm sec^{-1}, which equals about 13×10^6 gm day^{-1}. Per person, the phosphate load in sewage amounts to about 3 gm day^{-1} so that the influx into the Sound corresponds to the output of about four million people. The above estimate is very crude; the fact that we obtain reasonable numbers, however, is encouraging. The data suggest that the largest fraction of the nutrient input into the Sound is probably due to advection. More detailed studies will be required to confirm this tentative conclusion.

Appendix D Annotated Bibliography

Regional Marine Resources Council Publications

This bibliography is in three parts: I. an alphabetical listing of marine resource reports prepared by or for the Regional Marine Resources Council and the Nassau-Suffolk Regional Planning Board; II. an alphabetical listing of those reports prepared under the Sea Grant project, *The Development of Methodologies for Planning for the Optimum Use of the Marine Resources of the Coastal Zone;* and III. Nassau-Suffolk Regional Planning Board publications used for comprehensive planning, listed by date of publication.

I. Regional Marine Resources Council — Nassau-Suffolk Regional Planning Board Marine Resource Reports.

Cok, Anthony E. and Sirken, Leslie A. 1973. *Investigation of Surface and Subsurface Sedimentary Deposits in Offshore Environments of Southern Long Island.* Garden City, N.Y.: Adelphi University Institute of Marine Science.

> Describes methods used and results of research on geomorphology, sedimentology, and stratigraphy in surface and subsurface sediments in the near and offshore regions of southern Long Island — the Ridge and Swale topography. Bibliography 6 items (18 pp).

Davies, D.S., Axelrod, W. and O'Connor, J. 1973. *Erosion of the North Shore, Long Island, New York.* Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, Technical Report Series No. 18.

> Describes beaches and bluffs of north shore of Long Island; inventories natural characteristics and man-made structures, character and effects of dynamic beach processes catalogued with recommendations to minimize damage to persons and property. Maps show station locations and erosion and accretion rates. Bibliography 99 items (101 pp).

Gross, M. Grant; Davies, DeWitt; Lin, Paul; and Loessler, William. 1972. *Characteristics and Environmental Quality of Six North Shore Bays, Nassau and Suffolk Counties, New York.* Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, Technical Report Series No. 14.

> Describes physical characteristics, results of surveys of water quality, sediments and waste deposits of six bays. Develops three environmental quality indicators (present, integrative and predictive) used to rate the six bays. Recommends further studies for better evaluation of bay environmental quality. Bibliography 109 items (98 pp).

Gross, M. Grant; Davies, DeWitt; Lin, Paul; and Loessler, William. 1972. *Survey of Water Quality and Sediments in Six North Shore Bays, Nassau and Suffolk Counties, Long Island, New York (Appendix to Technical Report No. 14).* Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, Technical Report Series No. 15.

> Describes sampling procedures, analytical techniques, data for water quality and sediment survey, with maps of the six bays showing location of sampling stations. Bibliography 6 items (29 pp).

Hair, Malcolm E. and Buckner, Stuart. 1973. *Assessment of the Water Quality Characteristics of Great South Bay and Contiguous Streams.* Garden City, N.Y.: Adelphi University Institute of Marine Science.

> Describes procedures and results of bi-weekly measurements of salinity, temperature, dissolved oxygen, dissolved phosphorus, particulate phosphorus, nitrate, nitrite, ammonia, and chlorophyll at 39 stations in Great South Bay over a seven-month period. Comparison with previously available data with estimate of stability of various areas of the bay. Bibliography 33 items (59 pp) plus three appendices containing raw data.

Hardy, Charles, D. 1972. *Hydrographic Data Report: Long Island Sound — 1970 Part II.* Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, Technical Report Series No. 13.

> Data on single three-day survey of L.I. Sound on salinity, temperature, dissolved oxygen and nutrients. Bibliography 4 items (20 pp).

Oceanographic Committee of the Nassau-Suffolk Regional Planning Board. 1966. *The Status and Potential of the Marine Environment.* Hauppauge, N.Y.: Nassau-Suffolk Regional Planning Board, December 1966.

> Report on Committee findings on the marine resources of Long Island and their relations to industry, conversation, research, and education; its

recommendations on the formation of a Regional Marine Resources Council, with notes on sources of information on problems. Bibliography 100 items (91 pp).

O'Connor, Joel. 1973. *Dredging and Spoiling on Long Island.* Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, Technical Report Series No. 19.

Evaluates dredging and spoiling activity in Nassau and Suffolk counties during the period 1961-1971 in terms of motivation, sponsor, and location. Contains recommendations for improving and monitoring dredge-spoil activity. Bibliography 42 items (34 pp).

O'Connor, Joel and Terry, Orville. 1972. *The Marine Wetlands of Nassau and Suffolk Counties, New York – 1972.* Hauppauge, N.Y.: Nassau-Suffolk Regional Planning Board.

Inventories and classifies wetlands of Nassau-Suffolk counties, estimates changes in acreage since 1964. Identifies locations (by maps), area, and physical and ecological functions of wetlands necessary for planning and management decisions, such as governmental acquisition, definition of zoning regulations, and recreational development. Bibliography 58 items (99 pp).

Regional Marine Resources Council. 1971. *Proceedings of the Conference on Shellfish Culture.* Hauppauge, N.Y.: Regional Marine Resources Council.

Papers on state-of-the-art of shellfish culture, i.e., algae culture, molluscan embryology and physiology, culture methods–present and future, and techniques and problems in commercial shellfish farming (106 pp).

Regional Marine Resources Council. 1972. *Proceedings of the Seminar on Advanced Wastewater Treatment and Disposal.* Hauppauge, N.Y.: Regional Marine Resources Council in cooperation with U.S. Environmental Protection Agency and U.S. Geological Survey.

Papers on state-of-the-art in wastewater treatment, groundwater management experience, and new projects for treatment and recharge (167 pp).

Regional Marine Resources Council. 1973. *Guidelines for Long Island Coastal Management.* Hauppauge, N.Y.: Nassau-Suffolk Regional Planning Board.

Suggests management guidelines or generalized procedures to be followed in process of policy planning, decision and action at the local level, representing the integration of scientific information and local political, social, and economic realities in the four areas of coast stabilization and protection, dredging and dredge spoil disposal, integrated water supply and wastewater disposal, and wetlands management. Bibliography 30 items (42 pp). (Reprinted as Appendix E in this book)

Regional Marine Resources Council. 1973. *Proceedings of the Wetlands Management Seminar.* Hauppauge, N.Y.: Regional Marine Resources Council in cooperation with the National Oceanic and Atmospheric Administration.

Papers on the values of wetlands, both natural and managed, the state-of-the-art for wetland management, present guidelines for wetland management – federal, state, and local levels, and research needs for wetland management (131 pp).

Regional Marine Resources Council. 1974. *Guidelines for the Management of Long Island Hard Clam Resources.* Hauppauge, N.Y.: Nassau-Suffolk Regional Planning Board.

Describes the history and problems of Long Island's hard clam *(Mercenaria mercenaria)* industry. Develops scientific research requirements, administrative research requirements, and planning guidelines for scientific management of hard clam resources (25 pp).

Regional Marine Resources Council. 1974. *Proceedings of the Seminar on Dredging/Dredge Spoil Disposal and Coast Stabilization/Protection.* Hauppauge, N.Y.: Regional Marine Resources Council in cooperation with U.S. Army Corps of Engineers.

Papers on dredging technology, regulatory procedures, dredging and spoil disposal activities on L.I., research activities, state-of-the-art on beach erosion and stabilization, notes on the National Shoreline Study, and federal beach erosion activities on L.I. (125 pp).

Regional Marine Resources Council. 1974. *Proceedings of the Seminar on Energy Alternatives for Long Island.* Hauppauge, N.Y.: Regional Marine Resources Council.

Focuses on the following topics: energy conservation measures and programs for buildings and various modes of transportation, use of solar heating and cooling, energy from winds and thermal gradients, energy from solid wastes, and federal energy legislation (124 pp).

Regional Marine Resources Council. 1975. *Proceedings of the Seminar on Oil Spill Prevention, Containment, and Clean-up Technology,* held August 27, 1973. Hauppauge, N.Y.: Regional Marine Resources Council.

Focuses on a variety of topics: the nature of the oil spill problem, environmental effects of oil spills, oil spill regulation, contingency plans, authorities, equipment to contain and remove spilled oil from the sea surface, research and development projects to improve the capability of handling spills, and reactions of local officials to proposed Atlantic Outer Continental Shelf oil production activities (131 pp).

Weyl, Peter K. 1974. *The Pollution Susceptibility of the Marine Waters of Nassau and Suffolk Counties, New York.* Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, Technical Report Series No. 20.

Describes a new parameter of the coastline, pollution susceptibility. This is the average concentration in the water near the coast that would result from a unit rate of discharge of a conservative pollutant that is miscible with the water. For potential continuous discharges in restricted bays, a second parameter, steady-state pollution susceptibility, is developed. This is the average concentration that would result from a unit rate of discharge after the bay has come to a steady state with the pollutant (21 pp).

II. Regional Marine Resources Council — Research Reports of Sea Grant Project, *The Development of Methodologies for Planning for the Optimum Use of the Marine Resources of the Coastal Zone,* the Center for the Environment and Man, Inc., Hartford, Conn. (formerly the Travelers Research Corp.)

Bartholomew, F.L. and McGuinness, W.V., Jr. 1972. *Coast Stabilization and Protection on Long Island.*

Description of shore topography and usage, erosion mechanisms, possible means of coast stabilization and management, solutions, need for further research, and suggested guidelines for controlling use. Bibliography 34 items (47 pp).

Cheney, Philip, B. 1970. *Functional Step Two, Knowledge Requirements.*

Categorization of knowledge requirements for development of marine resource planning into those pertaining to location and time-specific information in the form of descriptive data, and those pertaining to the understanding of environment (31 pp).

Cheney, Philip B. 1970. *High-Priority Research and Data Needs, Interim Functional Step Four.*

Preliminary method of selection and list of high-priority research and data collection programs considered vital to the solution of L.I. coastal problems and management of the coastal zone. Bibliography 8 items (14 pp).

Dowd, Richard M. 1972. *Dredging on Long Island.*

Dredging motivation, processes, environmental conditions changed, and implications of the changes, suggested controls for managing dredging needs in acceptable manner. Bibliography 32 items (43 pp).

Ellis, R.H.; Cheney, P.B.; Smith, F.A.; Davies, R.M.; and Brush, R.D. 1969. *Functional Step One, The Classification of Marine Resource Problems of Nassau and Suffolk Counties.*

The concept of the Marine Resources Council program, the definition and scope of marine resource problems, and method used for classifying problems identified in this first step, and an example of analysis and synthesis necessary in the next functional step of the program. Bibliography 21 items (65 pp).

Ellis, R.H.; Cheney, P.B.; Ball, J.T.; and Sweeton, E.R. 1972. *The Design of a Management Information System for Coastal Resources Planning.*

A management system with five components, i.e., data storage and retrieval, environmental relationships, analytical design, synthesis and analysis, and executive control. Description and use of matrices in relation to L.I. coastal zone management. (113 pp).

Green, Ralph F. 1972. *Wetlands on Long Island.*

Wetlands characteristics, natural functions, uses by man, and natural and man-made changes, experience with various techniques for wetlands management and suggested guidelines for L.I. Bibliography 54 items (80 pp).

McGuinness, W.V., Jr. 1972. *State of the Art for Selected Marine Resources Problems on Long Island.*

Assessment of adequacy and availability of data and knowledge most relevant to planning and policy formations for four high-priority marine resource problems: integrated water supply and wastewater treatment and disposal; coast stabilization/protection; dredging/dredge spoil disposal; and wetlands management. Bibliography 175 items (72 pp).

McGuinness, W.V. Jr. and Pitchai, R. 1972. *Integrated Water Supply and Wastewater Disposal on Long Island.*

Examination of natural hydrological systems, man's water supply and wastewater system and its effect on water quantity and quality, now and projected into the future. Development and analysis of alternative solutions regarding water supply/wastewater disposal problems. Bibliography 59 items (180 pp).

McGuinness, W.V. Jr.; Pitchai, R.; and Northrop, G.M. 1973. *Technology Transfer in the Marine Environment of Long Island.*

Description of the activities of the Center for the Environment and Man during 1972 and early 1973 in providing the MRC with briefings on analyses and findings regarding the four high-priority research areas, and their assistance to the MRC committees in developing planning guidelines. (51 pp).

Ortolano, Leonard. 1970. *Quality Standards for the Coastal Waters of Long Island, New York.*

Legal and other bases for water quality "standards," use in classifying L.I. waters, possibilities for refinement, recommendations for new sets of standards for marine resource management. Bibliography 15 items (26 pp).

Ortolano, Leonard and Brown, Philip S., Jr. 1970. *The Movement and Quality of Coastal Waters: A Review of Models Relevant to Long Island, New York.*

Description of hydrodynamic, hydraulic, and water quality models, state-of-the-art of such models, and possible application to L.I. coastal waters. Bibliography 48 items (88 pp).

Pitchai, R. and McGuinness, W.V., Jr. 1972. *A Proposed Problem-Oriented Marine Research Program for Long Island.*

Summaries of 77 research projects specifically relating to the solution of four high-priority marine resource problems: integrated water supply and wastewater treatment and disposal; coast stabilization/protection; dredging/dredge spoil disposal; and wetlands management, with indicated costs and priorities. Bibliography 15 items (119 pp).

Smith, Frank A.; Ortolano, L.; Davies, R.M.; and Brush, R.O. 1970. *Fourteen Selected Marine Resource Problems of Long Island, New York: Descriptive Evaluations.*

Identification and systematic description of 14 outstanding marine resource problems with indication of information needs. Bibliography 191 items (121 pp).

III. Nassau-Suffolk Regional Planning Board Publications.

Republic Airfield, 1966.

A study of the feasibility of converting a privately owned airport into a publicly owned general aviation facility.

Special Report: Proposed Bayville—Rye Bridge, 1966.

A study to determine the advantages and disadvantages of a proposed Long Island Sound crossing between Nassau County and Westchester County.

North Shore Transportation Corridor, 1967.

A study of the need to create a major roadway along the north shore of Nassau and Suffolk counties which would eliminate the need for widening state and county roads in the area.

Residential Market Analysis, Volume 1, 1967.

An inventory of the regional housing stocks; surveys of substandard units and the housing of welfare recipients.

Suffolk County Inventory of Existing Bus Systems, 1967.

An inventory of Suffolk County's private bus network and an evaluation of its major deficiencies.

The Economy of Long Island, 1967.

A survey of employment and economic trends in Nassau and Suffolk counties.

A Look Ahead at Long Island Employment, 1968.

A projection of employment demand in the Long Island area to 1985.

Existing Land Use, 1968.

An inventory of land uses in the bi-county area. This report includes land use summaries for all cities, towns, villages and school districts, along with a projection of total population saturation for these areas if they are developed according to existing zoning.

Housing — Better Homes for Better Communities, 1968.

A summary of housing conditions in the area along with projections of housing needs and ways to meet these needs.

Inventory of Public Lands and Facilities, 1968.

An inventory of recreational lands, school facilities, health facilities, and public buildings in the area.

Projected Employment and Occupational Mix, 1968.

A projection of the types of industries and related jobs that will be necessary to accommodate the population increase anticipated in the region.

Residential Market Analysis, Volume 2, 1968.

A summary of housing costs and needs to 1985. The report also includes an analysis of the existing multi-family housing market in the bi-county area.

Sales Tax Study, 1968.

A report recommending the establishment of a sales tax for both Nassau and Suffolk counties to reduce the dependency on the property tax for financing governmental projects.

Population, 1969.

A summary of population trends for municipalities along with projections to 1985 for major municipalities and school districts.

Soil Interpretations – Inventory and Analysis, 1969.

An inventory of all of the soils in Suffolk County and recommendations on how these soils can best be used in the future.

Utilities – Inventory and Analysis, 1969.

An inventory of existing water, sewer, electrical, and waste disposal systems with an evaluation of the drainage areas on Long Island.

Comprehensive Development Plan – Summary, 1970.

A summary of all elements of the bi-county plan in a version that can be widely distributed to the general public.

Housing Code Enforcement, 1970.

A summary of housing codes and their enforcement, with a recommendation for a county-wide system of housing inspections on a regular basis.

Transportation Plan, 1970.

An inventory of existing air, water, road, and rail transportation networks on Long Island. An analysis of these networks and a recommended overall transportation plan.

Zoning – Inventory and Analysis, 1970.

An inventory of existing zoning ordinances in each of the 108 municipalities in the bi-county area, with an evaluation of the ordinances and recommendations for a model zoning ordinance.

The Long Island Economy – Anatomy of Change, 1971.

A survey of changing economic conditions in the bi-county area.

On Planning and its Uses in Government, 1971.

A theoretical report identifying essentials of the planning process, relationships to programming and budgeting practices, and opportunities for cooperation with others through better job specification and organization.

U.S. Census '70, Volume One – Number of Inhabitants, 1971.

An analysis of total population change for all minor civil divisions and places and census tracts in the two counties.

U.S. Census '70, Volume Two – Color and Race, 1972.

A report detailing racial changes in the decade to 1970.

U.S. Census '70, Volume Three – Age, 1972.

An analysis of the age composition of the bi-county area population.

U.S. Census '70, Volume Four – Housing, 1972.

An analysis of conditions and changes relating to housing, tenure, vacancies, and type of units in the 1960-1970 decade.

U.S. Census '70, Volume Five – School District Population, 1972.

A report presenting 1970 census data for each school district in Nassau and Suffolk counties.

U.S. Census '70, Volume Six – Income, 1972.

A report indicating the changes in median family income in the last decade, with the location of high-income and poverty areas.

U.S. Census '70, Volume Seven – Senior Citizens, 1973.

A report indicating the amount and rate of growth and the geographic distribution of the elderly component of the population, and the social and economic characteristics of the persons who constitute this frequently overlooked minority.

Long Island Economic Trends – A Profile of the Nassau-Suffolk Labor Force, 1973.

This report summarizes 1970 census information on employment status, occupations, incomes, and journey-to-work patterns of Nassau-Suffolk residents. Its purposes are to promote an understanding of Nassau-Suffolk labor market functions and to provide a reference manual for those charged with guiding local economic development.

The Demand for Higher Education in the Nassau-Suffolk Region, 1974.

This document estimates enrollment and facilities needed for the balance of the century.

Inflation and Economic Activity: The Nassau-Suffolk SMSA. Long Island Economic Trends, second quarter report, 1974.

This paper examines the history and impact of inflation on the Long Island economy.

An Economic Profile of Commuter Relationships: The Nassau-Suffolk SMSA. Long Island Economic Trends, third quarter report, 1974.

This brochure examines the economic dimensions of commuter flows between Nassau-Suffolk and New York City, and between Nassau and Suffolk counties themselves. It analyzes the incomes and occupations of cross-commuters as well as their geographic origins and destinations. Its purposes are to develop a more precise understanding of the economic linkages between a suburban labor market such as Nassau-Suffolk and its parent labor market, the New York Metropolitan Region, and to establish to what extent the Nassau-Suffolk labor market has become economically self-sufficient.

Income Levels and Purchasing Power: The Nassau-Suffolk SMSA. Long Island Economic Trends, fourth quarter report, 1974.

This article analyzes the purchasing power of the Nassau-Suffolk workers, the potential for consumer spending within Nassau-Suffolk SMSA, and Long Island's changing industrial structure.

U.S. Census '70, Volume Eight – Nativity, County of Origin, and Mobility of the Population, 1974.

Volume Eight deals with the place of birth, ethnic origins, and interregional and intraregional migrations of the population. These data are useful in planning for the delivery of health and other social services in marketing.

The Nassau-Suffolk Economy: A Status Report. Long Island Economic Trends, first quarter report, 1975.

This report analyzes the pattern of economic activity within the Nassau-Suffolk area during 1974 in the context of regional and national economic trends. Its purposes are to determine what impact the national recession has had on the Long Island economy, and to assess the potential for recovery, given Nassau-Suffolk's unique economic base.

The Pattern of Worktrips to Major Employment Centers: The Nassau-Suffolk SMSA. Long Island Economic Trends, second and third quarter report, 1975.

This report analyzes the patterns of commuter flows to Nassau-Suffolk's major employment centers, to develop information about the spatial linkages between people and their jobs within a suburban labor market. Worktrip origin and destination data from the 1970 decennial census are the basis for analysis.

Appendix E Guidelines for Long Island Coastal Management

Regional Marine Resources Council, a committee of
the Nassau - Suffolk Regional Planning Board

1973

INTRODUCTION

During the process of formulating a comprehensive development plan for Long Island, the Nassau-Suffolk Regional Planning Board (the Board) recognized that existing knowledge was insufficient to deal effectively with problems related to multi-purpose use of the marine environment. The Board lacked the planning tools necessary to determine how the coastal zone could be compatibly or exclusively used by such competing interests as residential housing, commercial and public recreation facilities, commercial fisheries, marinas, power plants, sewage treatment facilities and petroleum suppliers. The available knowledge, even when translated into a form useful to local government officials, planning boards and the general public, was all too often exploited by special interest groups or its meaning was obscured due to a lack of information concerning the structure of government operations in respect to the marine environment. The Board was advised by its Oceanographic Committee in 1966 that if Long Island was to maintain its desirability and attractiveness as a place in which to work and live, the trend of estuarine and shoreline deterioration had to be reversed. To help bridge the information gap and to provide a rational basis for solution of marine environmental problems, the Board established the Regional Marine Resources Council (the Council) in 1967.

The Council was charged with the responsibility of advising the Board on matters of marine concern and designing a research program aimed at organizing knowledge and data into a planning framework that would permit both rational and efficient decision making. The ultimate objective of the Council research program has been, and continues to be, the optimal utilization of the natural resources found in Long Island's coastal zone. The research program has been conducted over a period of five years with financial support from the Board and the National Sea Grant Program of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Consultant reports, seminars, briefings, as well as input from the voting members representing environmental groups, academic institutions, and marine industry and the responses of advisory members appointed from various Federal, State and local agencies, have contributed to the information base of the research project.

The results of the project are being transmitted to the public in the form of suggested guidelines or generalized procedures to be followed in the process of policy planning, decision and action at the local level. The guidelines themselves represent the integration of scientific information and local political, economic and social realities in order to provide a means of managing the future use of the marine resource base from a posture which stresses environmental considerations, yet is realistic in terms of past and future pressures exerted by a growing metropolitan region.

In keeping with its role as a sounding board for discussion of local marine oriented research, the Council has evaluated the existing knowledge base in terms of its adequacy for the solution of environmental problems in four major areas of concern—*coast stabilization and protection; dredging and dredging spoil disposal; integrated water supply and wastewater disposal; and wetlands management.* This assessment of the state of the art in the four major areas was used to outline research requirements designed to serve as a guide for directing research efforts to fill identified knowledge gaps. The unique aspect of the Council approach to coastal management is the linking of research needs based on knowledge assessment with the planning guidelines.

Planning guidelines have been developed in the four subject areas. The guidelines are flexible and not static. They not only suggest public policy, but also make specific recommendations by which individual courses of action can be weighed and decided upon. The resources of the Council will be used in the future to update the guidelines from time to time, as necessitated by changes in technology and in development patterns. However, the Council believes that on the basis of current knowledge, the guidelines are adequate for the process of controlling and directing development.

The guidelines are designed for use at the county, town and village levels. They provide a perspective useful in formulation of public policy and decision-making. Thus, the guidelines should be helpful to planning commissions in their review of subdivision design and in municipal planning, to zoning boards in their formulation and amendment of zoning ordinances and building codes, and to conservation advisory councils in their review of both public and private development projects to assure the maintenance of an aesthetic balance between man and the natural environment. Government agencies in charge of projects which can have significant effects on coastal resources should use the guidelines during the design phase of such activities to lessen possible adverse environmental impacts. The Nassau-Suffolk Regional Planning Board will use the guidelines as a basis for integrating marine environmental considerations into the comprehensive planning process, and for creating a coastal zone management scheme for Long Island. The general public can also benefit from the guidelines, by using them to help evaluate proposed bond issues, and to monitor the performance of public officials charged with the allocation of coastal resources.

The future work of the Council will be aimed at implementation and interpretation of the guidelines, as well as the formulation of guidelines in other areas, e.g., management of the shellfish industry, and the prevention and cleanup of oil spills. The guidelines will be forwarded to the Nassau and Suffolk County Executives and the appropriate legislative bodies at the county level for consideration. An effort will be launched to convince the 107 cities, towns and villages of the Nassau-Suffolk region, which retain basic land use powers, to endorse and use the guidelines as a basis for decision-making.

COAST STABILIZATION AND PROTECTION

Various shoreline management problems have resulted from man's use of the shoreline and adjacent land. The natural erosion of the shore has become a problem where permanent structures, buildings or roads are threatened with destruction, either because of long-term shoreline changes, or the short-term effects of hurricanes and "northeasters." Sand mining, channel dredging, stabilized inlets, and shore protection structures have created situations where the natural rate of erosion affecting both beaches and marshes has been increased.

People's memories are also short. They fail to remember, take into consideration, or perhaps are not informed of the devastating shoreline destruction—beaches were literally swept clean of all human development—caused by the 21 September 1938 and 31 August 1954 hurricanes. Loss of life is also a potential hazard; 45 people were killed or listed as missing on the south shore of Long Island as a result of the 1938 hurricane. Extensive development of Long Island's shorelines has occurred without due consideration for the dynamics of shoreline topography. The result of this disregard of natural process has been increased shoreline damage on an annual basis. The recurrence of the record storm tidal flood in our area would cause 170 million dollars (1970 dollars) in damages on the south shores of Nassau and Suffolk Counties, and 2 million dollars in damages on the Long Island north shore and the eastern forks.

Shoreline damage caused by wave and tidal action has resulted in the construction of shore protection devices and beach fill. Such projects have been financed by private individuals, beach associations, local municipalities, the State of New York and the Federal government, and have often been constructed on a piecemeal basis without a comprehensive evaluation of their potential effects on large segments of the shore. The practice of constructing groins, seawalls, and bulkheads, as well as the re-building of beaches by filling with dredged materials is extremely expensive. The U. S. Army Corps of Engineers estimates that the initial cost for beach restoration by sandfill is roughly 157 million dollars for the south shores of Nassau and Suffolk Counties, and 59 million dollars for the shore between Orient and Montauk Points, and about 103 million dollars along Long Island's north shore. Unless care is taken during the design of shore protection devices, they could interfere with the natural equilibrium of coastal processes, and hence may adversely affect nearby shore areas by diminishing their supply of sands; they are also inherently dependent on the dynamics of the littoral zone, and may not perform their intended function.

Future development of Long Island's shorelands should be controlled to lessen the need for coast stabilization measures. Land use planning should be based on an understanding of the processes affecting the configuration of the shoreline, as well as the factors which cause the need for shore protection. Even though the findings of research conducted by the New York State Sea Grant Program on the shorelines of Peconic and Gardiners Bays are not yet available, the guidelines developed here should be applied to the appropriate segments of these shores on a site-by-site basis. [Those findings are now available. *Ed.*]

A. Knowledge Base

1. *Good* in design of beach protection structures.
2. *Fair* in development of offshore sand mining.
3. *Fair* in understanding the movement of littoral materials.

B. Research Requirements

1. Continue research on the innovative design of traditional, fixed shore structures. The use of artificial seaweed, flexible groins and floating breakwaters and planting to stabilize spoil areas requires further investigation.

2. Model study inlets and harbor entrances, and design better sand transfer systems for utilization at these littoral barriers.
3. Examine the use of wetland fringes for stabilization of the landward edge of barrier islands and baymouth bars. Such research could be coupled with efforts to create new wetlands.
4. Continue research on the dynamics of natural barrier beaches recently started by the U.S. Department of Interior in North Carolina, and couple the results of such research with land management techniques for use in areas with similar environmental characteristics.
5. Analyze littoral transport along the shores of Long Island to determine volumes, sources of the sand, and net flow directions.
6. Even though studies have shown the existence of vast sand and gravel resources on the continental shelf to the south of Long Island, inventories on a more local basis are needed to assess the physical, ecological and economic feasibility of using offshore sand to maintain major Long Island beaches.
7. In the event that offshore sand deposits are mined for the purposes of beach nourishment, studies should be undertaken so as to indicate whether or not such removal will promote erosion of adjacent beaches.
8. Analyze the feasibility of creatively employing inlet development and stabilization techniques to enhance the environment of the south shore bay system. Develop models to determine the relationship between the size and location of inlets and selected physical/chemical characteristics of the interior bays.
9. Define and map the Intermediate Regional Tidal Flood Plain for the shores of Suffolk County. (A flood plain mapping project for the shores of Nassau County has been completed by the U.S. Army Corps of Engineers.)
10. Create a research team to study the legal, economic and political aspects of an overall erosion control program that is designed to limit barriers hindering effective action.
11. Because Long Island experiences a catastrophic storm which occurs on the average once in every 30 to 40 years, the planning departments of both counties should develop a contingency plan for such a disaster. Such a plan would: a. outline emergency procedures for the protection of life and property and b. recommend public condemnation and purchase of certain properties for future public use and for conservation.

C. Planning Guidelines

1. Control development on those lands contained in the *Intermediate Regional Tidal Flood Plain** by use of *flood plain zoning,* land use management concepts and other regulatory tools. Uses other than those requiring shorefront locations and those related to recreation, as well as the expansion of existing uses, should be discouraged. *Non-conforming use* status should be applied to existing development. Necessary future construction on the flood plain should be located in accordance with the establishment of sufficient *set-back lines,* so as to avoid damage from short-term shoreline changes. Such construction on the flood plain should include, as a minimum, elevation of first floors of such structures above the Intermediate Regional Tidal Flood Plain level, and floodproofing of utilities and equipment serving such structures. Consult the National Flood Insurance Program as amended by the Flood Disaster Protection Act of 1973 for flood plain insurance eligibility, floodproofing, and land use management requirements.
2. Prohibit construction on *primary dune* lines.
3. Adopt *bluff hazard zoning* in those shoreline areas, especially along the north shore of Long Island, which are backed by eroding bluffs. Discourage construction in the zone 100 feet landward from the top seaward edge of the bluff defined by an abrupt increase in slope.
4. As a general rule, discourage expenditure of public monies for the design and construction of shore protection work and beach nourishment on private lands unless substantial benefit to the public or public lands can be substantiated.
5. Accept the natural, long-term shoreline regression that is occurring along Long Island's north shore as a phenomenon that is beyond man's present capability for practical, effective control. Maintain heavily used beaches and recreation areas and, when the need exists, establish new beach areas by means of sand nourishment techniques in locations where historical records indicate either accretion or low to moderate erosion of the shore. Maintain existing navigation channels connecting major embayments with the Long Island Sound.
6. Emphasize dune stabilization and beach nourishment techniques, compatible with natural processes, as the primary means of minimizing storm breaching of the Long Island south shore barrier islands, and thus protect the environments of the south shore bays from sudden short-term changes.
7. Prohibit dredging of sand from the outer *bar* and from any area between the bar and the beach.
8. Support research designed to develop the required technology for economical transfer of sand from deep water sources to the shore for beach nourishment purposes.
9. Stabilize existing south shore inlets (East Rockaway, Jones, Fire Island, Moriches and Shinnecock) at approximately their current dimensions and

*See Glossary for definition of italicized terms.

locations. Permit drastic changes in the inlet characteristics only when explicitly justified by analysis of consequent changes such modifications will produce in the bays.

10. Advocate the implementation of Federal projects for *sand bypassing systems* at Shinnecock, Moriches and Fire Island Inlets.
11. Prohibit the construction of *groins* and other shore protection devices either by government or private persons unless it can be demonstrated that such structures will not adversely affect adjacent property.

DREDGING AND DREDGE SPOIL DISPOSAL

Growth in the region's population and economy has generated pressures for development of marine resources in differing ways, such as waterfront housing, marinas, channel dredging and recreation facilities. Some types of development have required the dredging of bay bottoms and shorelands, and the subsequent disposal of the dredged materials, by such methods as filling low-lying areas, creating spoil banks and artificial islands, and nourishing eroding beaches. Alteration and destruction of the valuable natural habitats found along the shores and bay bottoms of the Nassau-Suffolk region have occurred in the past without due regard for the functions these habitats play in the maintenance of environmental quality, lifestyles and diverse recreational opportunities. Today we are aware that even small scale alterations over widespread areas may have a cumulative effect on the region's ecology, and thus should be regarded with as much scrutiny as a major project alteration in a localized area. Thus, the issue of dredging can be stated in two parts: 1. determination of which dredging projects are essential, and are in the best interests of the public, and 2. how to design and implement such projects in a manner which is not environmentally counter-productive.

Dredging activity is executed for various reasons—channel and inlet maintenance, removal of polluted sediments, beach nourishment, pier and bulkhead construction, new channels, marinas, sand and gravel mining, and development projects (such as parking lots and housing sites). In terms of the volume of sediments removed, government agencies dominate dredging activity in the Long Island region. The State of New York accounted for 46.4 percent of the total volume of 7,184,234 cubic yards of material removed from Long Island waters during the period 1970-72, while Suffolk County activity amounted to 26.9 percent. Private interests removed 3.5 percent. Dredged materials were disposed in upland sites (64.6 percent), as beach nourishment (20.1 percent) or in government dumping grounds and offshore ocean areas (15.3 percent).

Dredging activity can produce damage to marine resources by: 1. removing beneficial *substrates* and destroying aquatic life; 2. increasing turbidity and sedimentation which can be deleterious to water quality and marine life, depending on the type and life stage of the species involved; 3. changing the topographic conditions of the sea floor which can lead to alteration of circulation patterns, shoaling and subsequent changes in water quality; and 4. destroying wetlands and wildlife habitat. The complex relationships of marine ecosystems often make it difficult to predict the consequences of a specific dredging project. However, recent research in Moriches Bay has shown that bottom dwelling organisms are less abundant in dredged channels than in other bottom types with different characteristics. It has been suggested that dredging and shoreline development associated with small bays be subject to a moratorium until long-term effects can be assessed. However, there appears to be little, if any, damage associated with the maintenance dredging of existing projects, provided the spoil from such projects is disposed of in an acceptable way.

Dredging and dredge spoil disposal is unique among the four high priority problem areas discussed in this report in that these activities are subject to certain permit procedures, approvals and reviews. These involve some or all of the following:

a. Local governments with rights over certain wetlands and bay bottoms have dredging and/or grading ordinances which require review of proposed dredging projects by local conservation advisory councils or commissions before permits for such work are issued. In Suffolk County, the Council on Environmental Quality reviews dredging projects involving the expenditure of Suffolk County funds.
b. Before a dredging project can commence, the New York State Department of Environmental Conservation must certify that work on the project will not cause violation of water quality standards. Areas subject to moratorium permits issued by the Department under the New York State Tidal Wetlands Act (Article 25, Environmental Conservation Law) enacted in September, 1973 include not only tidal wetlands, but also lands within 300 feet of such wetlands which are less than 10 feet in elevation above sea level. The Department also must approve the installation of piers and floats, with the exception of work performed by municipalities exempted by law.
c. The Department of the Army, Corps of Engineers, is the Federal government permit granting agency for dredging, filling and installation of structures in navigable waters; other Federal agencies such as the U. S. Department of the Interior and the Environmental Protection Agency as well as the general public, are given the opportunity to review and comment on permit applications.

A. Knowledge Base

1. *Good* in shallow water dredging for navigation channel maintenance.

2. *Fair* in deep water sand dredging for various purposes.
3. *Poor* in environmental and ecological effects of dredging and dredge spoil disposal.
4. *Poor* in dredging to maintain desired circulation, flushing, and salinity in bays and harbors.

B. Research Requirements

1. Develop predictive models to determine the effect of new or modified inlets and/or channels on the physical and chemical characteristics of estuarine areas, particularly for the south shore bays of Long Island. Such models predicting changes in current patterns, flushing rates, salinity and temperature, and the effects of contaminants introduced through stream flow, runoff, and waste disposal would enable more rational decision making regarding the desirability of dredging operations.
2. Continue research to determine the effects on marine life and productivity caused by physical and chemical alterations of the bays.
3. Develop a management scheme to facilitate decisions on specific dredging operations using proposed criteria to evaluate the magnitude of the potential impact, and to determine the extent of permit application evaluation.
4. Develop and evaluate methods of offshore dredging for use in beach nourishment and sand mining.

C. Planning Guidelines

1. Consider each dredging proposal on the basis of its merits by evaluating need, environmental effect, socio-economic advantage, monetary cost, and cost in committing, consuming, or otherwise destroying natural resources.
2. Evaluate environmental costs and benefits of dredging projects and their potential impacts on natural resources by considering:
   a. the effects of the removal of bottom material in the area to be dredged;
   b. the dredging operation's effects on turbidity and sedimentation in adjacent waters;
   c. the timing of the proposed dredging activity;
   d. the modifications of flushing rates, salinity and oxygen levels caused by channelization;
   e. the location where dredged material is to be placed as either fill or *spoil* and its effect on the environment;
   f. the alternative use of spoil to create or improve wildlife habitats, such as waterfowl nesting areas; and
   g. the degree of temporary and permanent effects, including the induced effect of increasing boat traffic and the demand for shoreline development.
3. When temporary incursion of wetland areas is deemed essential, such as for the construction of sewer pipeline, provide for restoration of disturbed areas in accordance with permit procedures described in Wetlands Guidelines.
4. Avoid dredging that in any way cuts into or otherwise affects the fresh water *aquifiers*.
5. The following areas are particularly sensitive to the effects of dredging and/or deposition and should receive special evaluation:
   a. inlets;
   b. channels that can affect back bay current patterns;
   c. important shellfish areas;
   d. locations where induced sedimentation and turbidity can be widespread, causing shoaling and/or deterioration in water quality, as in the removal of duck farm sludge or other wastes, and in long-term sand and gravel mining projects;
   e. areas where dredge spoil is polluted to the extent that it exceeds Federal criteria for open water disposal; and
   f. areas not previously subject to dredging, including the enlargement of existing channels and the creation of new channels.
6. Determine the motivation and need for the project. Project motivations can be grouped under the general categories of:
   a. navigation improvements;
   b. shoreline construction and landfill;
   c. substrate removal;
   d. beach nourishment; and
   e. miscellaneous, such as the development of new wetlands.
7. Consider the following specifics when determining whether a project is in the best interest of the public:
   a. preservation of resources;
   b. project economics;
   c. project aesthetics;
   d. historic values;
   e. fish and wildlife values;
   f. tidal flood damage;
   g. land uses;
   h. navigation;
   i. recreation;
   j. loss of water supply;
   k. bay water quality;

  - l. aquaculture;
  - m. shoreline erosion; and
  - n. the desirability of alternative locations and methods.

8. Provide for a public notice and a hearing to determine whether there is any public reaction to a proposal. This may be accomplished by establishing a mechanism for processing the application at the local level (i.e., county, town and village) as follows:
   - a. Develop local law covering dredging and construction in or bordering on waterways and provide an appropriate permit application form. Include in such regulations the procedures necessary for handling emergency repair situations.
   - b. Designate the person, department or agency to process applications.
   - c. Provide for a public notice and, if objections are raised, a public hearing on the project.
   - d. Approve or disapprove the application. If approval is given, application is converted to a permit issued by the local level within 30 days from issuance of permit by Department of the Army.
9. Advise the public regarding state and Federal procedures to be followed when applying for permits to dredge and fill. The procedures include the following:
   - a. New York State Department of Environmental Conservation
     - i. Applicant must apply for certification of assurance that work will not violate water quality standards. Such certification should be forwarded to applicant and Department of the Army within 60 days from receipt of all required information.
     - ii. Applicant must apply for a wetlands moratorium permit, if the project will alter a tidal wetland, or lands within 300 feet of a tidal wetland which are under 10 feet in elevation.
   - b. U.S. Army Corps of Engineers
     - i. Upon receipt of permit application and water quality certification the U.S. Army Corps of Engineers publishes a public notice describing the application.
     - ii. The Environmental Protection Agency, the Department of the Interior, and the New York State Department of Environmental Conservation may comment favorably or unfavorably on the public notice. In the event of public objection to the project, the U.S. Army Corps of Engineers should hold a public hearing on the application. If, after the public hearing, the Corps of Engineers District Office cannot reach a decision, the case may be referred to the Secretary of the Army for final action.
10. Provide adequate inspection of all projects to insure compliance with the terms of permits. The local and/or Federal permit issuing agency should administer the inspection process.

INTEGRATED WATER SUPPLY AND WASTEWATER DISPOSAL

The present population of the Bi-County region—2.66 million people—is larger than that found in 26 of our states. Population projections indicate that an additional 1.4 million people (the population of the City of Detroit) will be living in the Nassau-Suffolk area by the year 2000. Concomitant with this population growth is the transformation of vacant land to built up uses. In 1966 only 17,000 acres of land remained vacant or in agricultural use in Nassau County, while 336,000 acres of such land existed in Suffolk County.

Urbanization and its by-products—sewage treatment plant effluent, leachates from septic tanks and cesspools, and storm water runoff—have caused both surface water and groundwater quality deterioration. At present, 17 percent, or roughly 205,000 acres of New York Marine District waters are closed to the taking of shellfish for culinary purposes. In 1904, production of oyster meats in New York marine waters peaked at over 20 million pounds; in 1971, production was only 778,000 pounds. Yet, Long Island's estuarine waters remain highly productive for other species. In 1971, commercial shellfishermen in Suffolk County produced 8.1 million pounds of hard clam meats, or 47 percent of the total hard clam production in the United States. Compatible, multi-purpose use of Long Island's marine environment in the future will depend heavily on the strategies employed for water supply and the treatment and disposal of domestic and industrial wastewaters and street runoffs.

Consumptive water usage in Nassau County will amount to 328 MGD (million gallons per day) by the year 2020; *permissive sustained yield* of the aquifers in Nassau County is only 151 MGD. Thus, Nassau County will have a future water supply deficit of 177 MGD. Suffolk County, however, has a permissive sustained yield of 466 MGD, and a projected consumptive water use of 381 MGD for the year 2020. Thus, Suffolk will have a water supply surplus of 85 MGD at this future date.

Permissive sustained yield estimates are based only on factors which would adversely affect the public water supply, such as *salt water intrusion*. They do not include ecological, aesthetic or recreational constraints. Utilization of the permissive sustained yield would permit groundwater levels to eventually be reduced as much as 75 percent below present levels within the interior of the *water budget area*. The development of the permissive sustained yield is also predicated on the assumption that groundwater will not be contaminated by cesspool wastes and other pollutants to the extent that it cannot be used for human consumption.

Nassau and Suffolk Counties must solve the problem of how to meet the requirements for water supply and wastewater disposal in an economically, sociologically and environmentally acceptable way. Current decisions involving various management schemes have to be made with cognizance of future population and land use projections, as well as changes in technology. An integrated system of water supply and wastewater disposal consists of the following components: acquisition, transmission, treatment, distribution, and use of fresh water; and collection, treatment and disposal of wastewaters. The selection of the system servicing a particular area depends on economic and political considerations, the results of future research, and value judgments in terms of potential effects on surface water resources and the quality of marine waters. Implementation of mixed strategies involving: 1. importing water from New York City; 2. installation of both sanitary and storm water sewers; 3. continued use of *secondary treatment* and the disposal of effluents via ocean outfall; 4. groundwater recharge with effluent subject to *advanced wastewater treatment*; 5: *injection barriers* to limit salt water intrusion; and 6. cesspools or individual waste treatment systems, will no doubt be executed in the Bi-County region because of different patterns of land use, population, and variation of hydrologic conditions.

A. Knowledge Base

1. *Good* in quantitative understanding of groundwater resources and surface water resources.
2. *Good* in the technology for desalinating sea water.
3. *Good* in wastewater treatment and rapidly improving as a result of ongoing research and development.
4. *Poor* in wastewater disposal, primarily because of lack of knowledge as to what receiving waters can assimilate without damage to the marine environment.
5. *Fair* in understanding of process for recycling of water into the ground by injection, collection basin or infiltration.

B. Research Requirements

1. Determine the physical, chemical and biological characteristics of wastewater to be discharged into: a. ocean waters, estuaries and their tributaries; and b. the ground by agricultural irrigation, for augmentation of the groundwater supply and as barriers to salt water intrusion.
2. Evaluate and standardize effective water quality indicators.
3. Investigate the movement of contaminants into and out of Long Island's estuaries, including contaminants from sources adjacent to the area, as well as the flushing requirements necessary to maintain acceptable water quality.
4. Investigate the movement of contaminants in groundwater with regard to the requirements of maintaining an acceptable quality as it influences marine resources.
5. Ascertain the optimum salinities for shellfish, and determine the flushing requirements needed for the maintenance of such salinities.
6. Evaluate the adequacy of existing beach closure standards, and improve them if necessary.
7. Improve knowledge of the cumulative effects of toxic material in food chains, and if necessary, modify waste disposal policies.
8. Establish suitable restrictions on the use of cesspools and septic tanks adjacent to ocean waters, estuaries and their tributaries.
9. Continue research on the following aspects of water resources which bear directly or indirectly on coastal zone management because of the interaction of ground and surface waters with the marine environment: a. water usage; b. onshore and offshore geology; c. groundwater levels; d. groundwater contaminants; e. industrial water supply and discharge; f. infiltration processes; g. groundwater outflow into the marine environment; h. methods of groundwater recharge using wastewater subject to various degrees of treatment; i. advanced wastewater treatment; j. area or individual unit wastewater treatment equipment; k. use of treated wastewater for water supply; l. the necessity and feasibility of a *dual water supply* for potable and general purpose use; and m. contaminants contained in agricultural and urban runoffs, particularly asphaltic and other hard surface runoffs.

C. Planning Guidelines

1. Continue the present program of installing sewage collection, treatment and disposal systems in densely populated areas for handling domestic and industrial wastewater until better water supply and wastewater disposal schemes are developed.
2. Permit access over wetland areas only where necessary for the efficient and economic installation of important equipment. Take measures to minimize ecological disruption during installation and to restore damaged areas after construction activities are completed.
3. Require adequate treatment for all sewage plant effluents discharged to estuarine or any other confined waters, in order to maintain acceptable marine water quality.
4. Continue ocean disposal of wastewaters subject to treatment producing an effluent with acceptable quality for ocean discharge. However, it must be

recognized that this system lowers groundwater levels. When water supplies can be augmented by recharging treated wastewater of sufficient quality, ocean disposal of wastewater should be phased out.

5. Design storm water systems so as to reduce contaminant flows into the marine environment.
6. Evaluate new sources of water, such as connection with mainland surface water supplies and desalinization, for the purpose of improving existing water supply systems.
7. Consider advances in wastewater treatment technology such as renovation of wastewater through land disposal by spray irrigation, and the merits of different waste management schemes, such as a dual water supply system, a *non-aqueous waste disposal system,* and *treatment of water supply at the well-head,* in the design of new water supply systems.
8. Require installation of sewers, wastewater treatment facilities, and controlled public water supplies as a condition for approval of development plans in areas designated as intermediate or higher in population density (greater than five people per acre) in the Nassau-Suffolk Comprehensive Development Plan.
9. Consider the net effects of population densities on the carrying capacity of existing groundwater supplies when designing or amending zoning regulations.
10. Require flood-proofing of existing and new sewage collection, treatment and disposal systems handling domestic and industrial wastewater which are located in special flood hazard zones or in areas susceptible to groundwater flooding.
11. Dispose sewage and duck waste sludges by utilizing methods which will minimize contamination of fresh water supplies and the marine environment.

WETLANDS MANAGEMENT

Marine wetlands have been considered as either valuable, productive natural habitats, or as worthless swamps offering opportunity for creating buildable land for various types of development. The difference in these two perceptions of the role wetlands play in Long Island's coastal zone has created conflicts between developers and preservationists. Public outcry for wetlands protection has increased in recent years due to more awareness of the natural functions of wetlands and the amenities they provide, as well as the fact that wetlands have become a diminishing resource in the Long Island area.

In response to public demands, local communities have adopted legislation regulating the use of tidal wetlands. The New York State Tidal Wetlands Act (Article 25, Environmental Conservation Law) enacted in September, 1973, authorizes a moratorium on the alteration of tidal wetlands until a program of land use regulations governing wetlands is established. During the moratorium, the Commissioner of the New York State Department of Environmental Conservation may issue permits for wetlands alteration in certain hardship cases, and/or where it can be shown that no significant and lasting damage will occur. This new law, however, is not applicable to any lands appropriated now or in the future by New York State or any of its departments under the power of eminent domain. Attempts at wetlands management have been complicated by the creation of a plethora of rules and regulations. Streamlining and the elimination of conflicts and duplications appear to be necessary for effective management.

Several functions are performed by marine wetlands in their natural state. Such natural functions include: 1. protecting adjacent mainland areas by acting as natural breakwaters which buffer the impact of storm waves; 2. providing essential habitat for many species of fish and wildlife; 3. producing food and nutrient materials for use in the wetland environment and coastal estuarine waters; 4. acting as a sediment trap for the removal of silts, organic matter and pollutants from both tidal waters and upland runoffs; 5. transforming waste products into useful nutrient materials by both chemical and biological processes; and 6. serving as a storage area for storm tidal waters and upland runoff. Man has used wetlands in a number of different ways, e.g., recreational pursuits, such as bird watching, hiking, hunting and fishing; aesthetically pleasing open spaces; and various educational and research activities. However, other uses have either destroyed or altered wetlands by filling, channel dredging, bulkheading, and pollutant loading.

Wetlands management involves the problem of how to recognize, preserve and enhance the usefulness of wetlands for ecological and human purposes. Drastic reductions in Long Island's wetlands inventory have occurred in recent years. In 1954, there were 14,130 acres of wetlands in Nassau County; by 1971, 9,538 acres remained—a 32 percent loss of the existing 1954 acreage. In Suffolk County, 1954 wetlands totalled 20,590 acres, and by 1971, 12,725 acres remained—a 38 percent loss. Thus, for the Bi-County region as a whole, 12,457 acres of wetlands were destroyed during the 17 year period, 1954 through 1971. The effects of this destruction are obvious in terms of loss of open space, but they are not so apparent when dealing with ramifications for estuarine and oceanic ecology. However, it is known that 90 percent of the species comprising the marine fishery sport catch of the Atlantic coast are estuarine dependent during some portions of their life histories, and that 63 percent of the species comprising the Atlantic coast commercial fish catch are considered to be estuarine dependent.

Control of the remaining Nassau County wetlands is virtually assured in that

96 percent of these wetlands are owned by some level of government. The situation is potentially much more serious in Suffolk County, because between 34 and 47 percent of Suffolk's wetlands are in private ownership, and hence, may be optioned for future development.

A. Knowledge Base

1. *Fair* in amount and quality of wetlands required to meet various functions of wetlands, such as ecological support for shellfish, coastal finfish, deep water finfish, and for storm protection, recreation, and aesthetic values.
2. *Fair* in understanding means by which wetlands can be created, restored, or enhanced.
3. *Fair* for both qualitative and quantitative inventories of the remaining marine wetlands in the Nassau-Suffolk area. For wetland inventory information, the Regional Marine Resources Council has adopted the report entitled, *The Marine Wetlands of Nassau and Suffolk Counties . . . New York 1972,* as amended, compiled and published by the Marine Sciences Research Center of the State University of New York at Stony Brook. (Note: The New York State Department of Environmental Conservation is currently preparing an inventory of tidal wetlands, their extent, vegetative communities and ownership as authorized by the Tidal Wetlands Act. This inventory should be completed by mid-1975.) [As of December 1975, the inventory was near completion. *Ed.]*

B. Research Requirements

1. Continue to design and develop a management-oriented wetlands classification system.
2. Expand the inventories of each wetland unit in both counties on the basis of the characteristics established in the above classification scheme.
3. Establish the value (quality) of each major wetlands complex according to the degree with which it fulfills a set of delineated natural functions and human uses. Determine the acreage necessary to support such functions and uses.
4. Identify and evaluate wetlands management techniques.
5. Support the development of a comprehensive wetlands management plan that integrates the inventory data on wetland characteristics, the quality evaluation, and the management techniques into a coherent plan for the Island's wetland system as a whole, and for its individual wetlands complexes.
6. Develop criteria for the environmental assessment of proposed actions which will alter marine wetlands. The degree of competency required to author such assessments should be established.
7. Continue to research and field test means of wetlands restoration, creation and enhancement.

C. Planning Guidelines

1. Consider all remaining wetlands in the Nassau-Suffolk area worthy of preservation in the public interest. Any proposed wetlands alteration must, for approval, be shown to be of over-riding public necessity.
2. Encourage New York State, pertinent local governments and private agencies to acquire at the earliest practical date a *fee simple* or lesser property interest in as much of the remaining privately held wetlands as possible, with a view toward preserving them in perpetuity. Grant tax and other incentives to individual wetlands owners who assure preservation and enhancement of their properties.
3. Establish uniform wetlands regulations, consistent with the New York State Tidal Wetlands Act, within the two counties and each town, city and village having such lands within their respective jurisdictions, yet recognize the fact that individual tracts of wetlands vary widely from each other in the degree of encroachment that they can absorb without substantial damage. Include in such regulations, applicable to both public and private owners alike, a permits system (analogous to building permits) which requires that an authoritative environmental assessment accompany each permit application. The regulations should be consistent with guideline one above.
4. Support the artificial establishment of marine wetlands.
5. Utilize the resources and capability of the Regional Marine Resources Council to assist units of local government in wetlands planning and management activities.

GLOSSARY

I. Coast Stabilization and Protection

Intermediate Regional Tidal Flood Plain – those lands covered by a tide having an average frequency of occurrence on the order of once in 100 years, although the tide may occur in any year.

flood plain zoning – regulations designed to limit or reduce damage from flooding; such zoning regulations could establish:

a. stringent use restrictions for high hazard areas subject to wave or erosion action or without access during times of flood;
b. use restrictions for other areas to allocate lands to uses with low flood damage potential;
c. elevation requirements;

d. beach setbacks; and
e. special provisions for dune or beach protection.

non-conforming use — pre-existing land use that does not conform with present zoning regulations; present zoning regulations take effect upon termination of the non-conforming use.

set-back lines — required horizontal distance between a building, road or other form of construction and a beach, dune, shoreline or similar flood prone area, designed to establish a buffer to limit flood or erosion damage.

primary dune — the ridge or mound of loose, wind-blown material, usually sand, located immediately landward of the beach berm.

bluff hazard zoning — the use of zoning ordinances to control land uses adjacent to eroding bluffs for the purposes of:
a. minimizing community expense for construction of shore protection structures;
b. preventing erosion-related damage;
c. preventing the acceleration of bluff erosion; and
d. preventing the victimization of unwary purchasers of property fronted by eroding bluffs.

bar — an offshore ridge or mound of sand, gravel, or other unconsolidated material lying a short distance from and usually parallel to the beach; it results from the removal of sediments from the beach because of storm turbulence.

sand bypassing systems — technique utilizing land-based dredge plants, floating dredges and/or mobile land-based vehicles for the purpose of artificially nourishing the shore downdrift from inlets to improve its stability; nourishment is accomplished by using the available littoral supply from updrift sources.

groins — shore-protective structures designed to maintain or build a protective beach by trapping littoral drift. Groins are usually constructed perpendicular to the shore and extend from a point landward of possible shoreline recession into the water a sufficient distance to stabilize the shoreline.

II. Dredging and Dredge Spoil Disposal

substrates — the sea or bay bottom and its characteristics which are dependent on grain size distribution.

spoil — waste materials resulting from the dredging process.

aquifers — bodies of earth material that readily yield economically significant amounts of groundwater to wells.

III. Integrated Water Supply and Wastewater Disposal

consumptive water usage — uses of water which ultimately result in a net loss of water in available supplies, e.g., evapotranspiration of irrigation water and discharge of treated sewage to the sea.

permissive sustained yield — the "safe yield," or rate at which water can be withdrawn from an aquifer without producing an undesired result.

salt water intrusion — the movement of salty groundwater into areas previously occupied by fresh groundwater.

water budget area — that area which covers about 760 square miles, bounded on the west by the Nassau-Queens border; on the east by an imaginary north-south line that separates the eastern forks from the main part of Long Island; the northern boundary follows roughly, but with local departures, the northern shoreline; and the southern boundary is a curved line that joins the streamflow measuring stations on the major streams that drain into the bays along the south shore.

secondary treatment — a combination of processes, including screening, gravity separation, biological flocculation and precipitation capable of producing an 80-95% reduction in BOD, 85-90% reduction in suspended solids and 95-98% reduction in bacteria.

groundwater recharge — the addition of water to the groundwater reservoir via injection or infiltration.

advanced wastewater treatment — a term employed to describe a variety of techniques which may be applicable to improve performance in conventional waste treatment in order to produce an effluent of very high quality by substantially removing refractory organics, dissolved inorganics, and phosphorus and nitrogen compounds from wastewater.

injection barriers — the creation of an artesian pressure ridge parallel to a shore by means of recharging renovated wastewater in a line of injection wells, for the purpose of limiting salt water intrusion.

dual water supply system — a water supply system with two components; one component supplies water of high quality for culinary purposes, while the other supplies water of lesser quality for such purposes as domestic waste disposal.

non-aqueous waste disposal system — system which utilizes substances other than water for the handling and conveyance of domestic wastes.

treatment of water supply at the well-head — concept of treating water at its source before it is used, rather than before its disposal; requires the continued use of cesspools as a means of waste disposal.

IV. Wetlands Management

marine wetlands — those lands inundated and re-exposed by mean high and mean low spring tides, respectively, at least monthly and characterized by predominant growth of either cordgrass (*Spartina alterniflora*) or salt meadow hay (*Spartina patens*) or both, but including a protective fringe of uplands above mean high spring tide level, and any adjacent mudflats. The upland fringe will vary among separate tracts of marine wetlands, but will usually be characterized by growths of black rush *(Juncus Gerardi)*, sea myrtle *(Baccharis halimifolia)*, seaside goldenrod *(Solidago sempervirens)*, bullrush *(Scirpus)*, marsh elder *(Iva frutescens)*, cattails *(Typha)*, and reed *(Phragmites communis)*.

fee simple — a fee without limitation or restrictions on transfer of ownership; the maximum possible ownership in real estate.

Appendix F Long Island Sound Regional Study Reports

New England River Basins Commission

MAIN REPORTS

A Plan for Long Island Sound: Vol. 1, Summary. July 1975.

Highlights of the plan and a brief discussion of the rationale leading to recommendations (76 pp).

A Plan for Long Island Sound: Vol. 2, Supplement. July 1975.

A more comprehensive planning document; enumerates the major alternatives considered in formulating the recommendations, together with an explanation of how the plan was prepared, who did the work, and background information organized both by subject matter and by geographical sub-region of the Study Area (224 pp).

PLANNING REPORTS

Each of the 10 planning reports was developed by a "Work Group" chaired by a federal agency, with the active participation of state and local agencies, other federal agencies, and citizen and scientific advisors. These reports incorporate data (originally published in a series of Interim Reports, July 1973–March 1974) estimating people's demands for the resources of the Sound region, the requirements to meet those demands, the existing capacity of the region to meet the requirements, and any deficiencies noted. The second half of each planning report develops solutions by stating objectives in terms of satisfying defined needs; suggesting alternative ways to achieve the objective; evaluating each alternative by environmental, economic, and social criteria; developing economic, environmental, and composite plans; and making recommendations.

Federal Power Commission, New York Regional Office. *Power and the Environment.* [undated] 84 pp. + 2 appen.

Ralph M. Field and Associates, for the U.S. Dept. of Housing and Urban Development. *Land Use.* February 1975. 60 pp. + 4 appen.

U.S. Dept. of the Army, Corps of Engineers. *Marine Transportation.* February 1975. 66 pp. + 3 appen.

U.S. Dept. of the Army, Corps of Engineers and the U.S. Dept. of Agriculture, Soil Conservation Service. *Erosion and Sedimentation.* January 1975. 64 pp. + 4 appen.

U.S. Dept. of the Army, Corps of Engineers and the U.S. Dept. of Agriculture, Soil Conservation Service. *Flood Damage Reduction.* January 1975. 62 pp. + 8 appen.

U.S. Dept. of the Interior, Bureau of Mines. *Mineral Resources and Mining.* May 1975. 44 pp. + 8 appen.

U.S. Dept. of the Interior, Bureau of Outdoor Recreation. *Outdoor Recreation.* January 1975. 78 pp. + 5 appen.

U.S. Dept. of the Interior, Fish and Wildlife Service and U.S. Dept. of Commerce, National Marine Fisheries Service. *Fish and Wildlife.* February 1975. 56 pp. + 5 appen.

U.S. Dept. of the Interior, National Park Service and Roy Mann Associates, Inc. *Shoreline Appearance and Design.* February 1975. 60 pp. + 4 appen.

U.S. Environmental Protection Agency and the States of New York and Connecticut. *Water Management.* March 1975. 130 pp. + 4 appen.

OTHER REPORTS

Roy Mann Associates, Inc. for the U.S. Dept. of the Interior, National Park Service. *Shoreline Appearance and Design: A Planning Handbook.* April 1975. 293 pp. + maps package.

Recommended management procedures for protecting and enhancing the region's scenic resources.

U.S. Dept. of Agriculture, Economic Research Service and U.S. Dept. of Commerce, Bureau of Economic Analysis. *An Economic Perspective.* July 1974. 36 pp. + 3 appen.

An examination of the economic and demographic trends in the region, with data upon which all projections in the Study were based.

U.S. Dept. of Agriculture, Soil Conservation Service. *Soils.* September 1973. 14 pp. + 4 appen.

An inventory and analysis of soil composition in the region.

U.S. Geological Survey, Water Resources Division and U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration. *Sources and Movement of Water.* October 1973. 45 pp. + 5 appen.

A summary of the hydrology and climate of the region.

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