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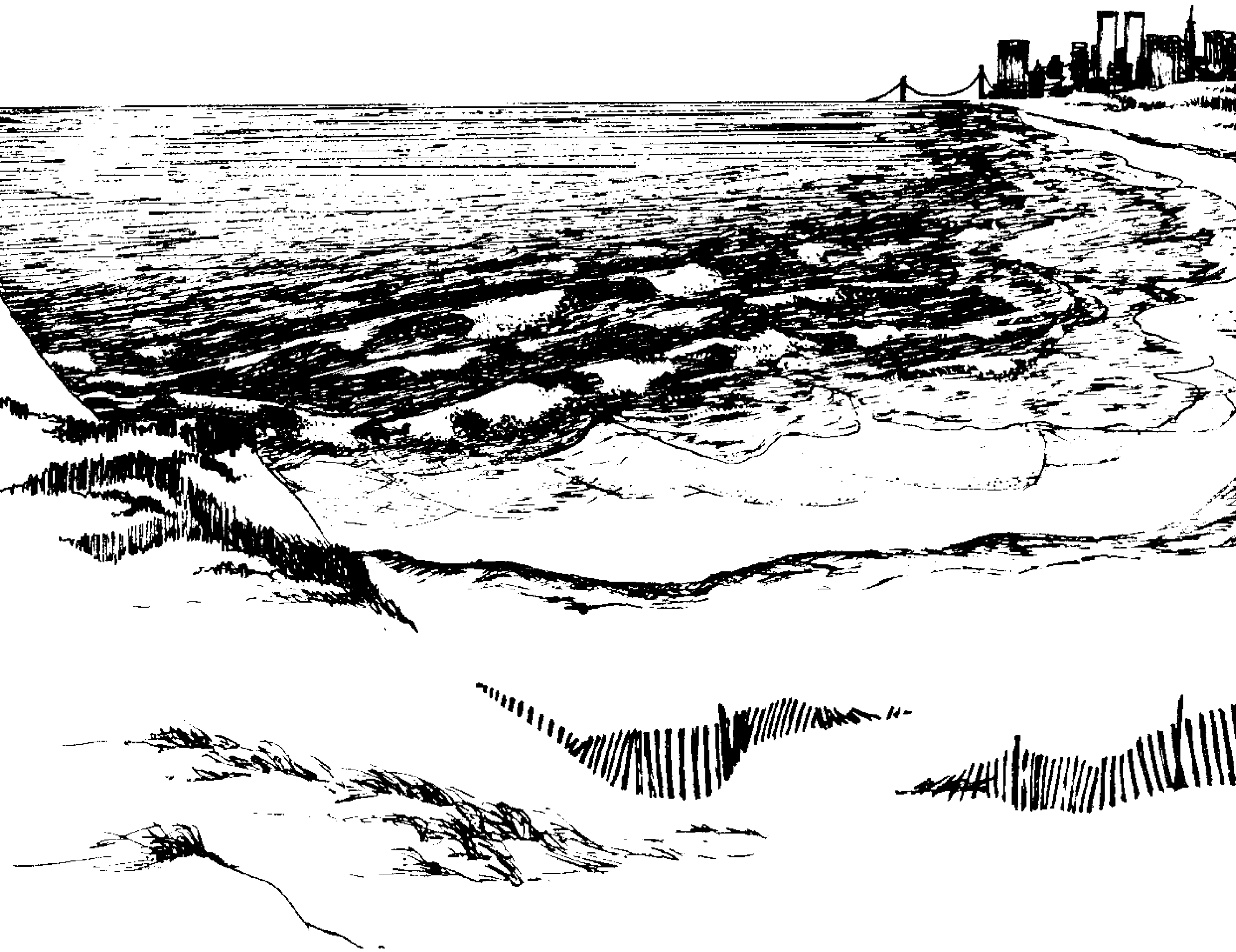
Sand and Gravel

John Schlee with a section by Peter Sanko



MESA NEW YORK BIGHT ATLAS MONOGRAPH 21

The offshore water in the bend of the Atlantic coastline from Long Island on one side to New Jersey on the other is known as New York Bight. This 15,000 square miles of the Atlantic coastal ocean reaches seaward to the edge of the continental shelf, 80 to 120 miles offshore. It's the front doorstep of New York City, one of the world's most intensively used coastal areas – for recreation, shipping, fishing and shellfishing, and for dumping sewage sludge, construction rubble, and industrial wastes. Its potential is being closely eyed for resources like sand and gravel – and oil and gas.

This is one of a series of technical monographs on the Bight, summarizing what is known and identifying what is unknown. Those making critical management decisions affecting the Bight region are acutely aware that they need more data than are now available on the complex interplay among processes in the Bight, and about the human impact on those processes. The monographs provide a jumping-off place for further research.

The series is a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA) and the New York Sea Grant Institute. NOAA's Marine EcoSystems Analysis (MESA) program is responsible for identifying and measuring the impact of man on the marine environment and its resources. The Sea Grant Institute (of State University of New York and Cornell University, and an affiliate of NOAA's Sea Grant program) conducts a variety of research and educational activities on the sea and Great Lakes. Together, Sea Grant and MESA are preparing an atlas of New York Bight that will supply urgently needed environmental information to policy-makers, industries, educational institutions, and to interested people. The monographs, listed inside the back cover, are being integrated into this *Environmental Atlas of New York Bight.*

ATLAS MONOGRAPH 21 presents what we know about the areal distribution of sand and gravel in New York Bight and summarizes data on commercial sand mining in New York Harbor. Schlee says that sand is found over the entire continental shelf in the Bight and that gravel exists only in scattered patches; accurate estimates of the thickness of these deposits have yet to be made. Although sand is being mined commercially in New York Harbor and has been for many years, offshore sand and gravel mining is not yet economically advantageous, nor are its effects on other activities in the Bight well understood.

Credits

Cynthia L. Williams monograph editor
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Erratum

Second line under Credits should read:

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Marine EcoSystems Analysis [MESA] Program
MESA New York Bight Project

Sand and Gravel

John Schlee
with a section by Peter Sanko

MESA NEW YORK BIGHT ATLAS MONOGRAPH **21**

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Peter Sanko, MS, is a regional marine specialist with Sea Grant Advisory Service, Marine Sciences Research Center, State University of New York at Stony Brook. He wrote six volumes of geological and sediment studies of selected areas of the Atlantic and Pacific ocean basins for the Office of Naval Research. He is also the author of *Shoreline Protection Guide for Property Owners.*

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Acknowledgments

Several persons generously made available preprints of papers in press as well as basic data from published papers. D.B. Duane provided his most recent study on the inner New York Bight. G.M. Friedman compiled data from two of his studies on the Atlantic shelf. R.L. McMaster supplied unpublished data collected for the continental shelf around Block Island. D.J.P. Swift furnished preprints of work, including core data, he and his associates have completed for the Atlantic shelf. J.L. McHugh made available the most recent fisheries statistics. Judith and Robert Commeau of the US Geological Survey (USGS) expertly programmed the data to prepare computer printouts in map form.

This monograph's main section by John Schlee was reviewed by R.H. Meade, Jr. and H.J. Knebel of USGS and was authorized by the director of USGS.

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Abstract

Sand and gravel deposits on the continental shelf in New York Bight cover a wide area. Sand is found over the entire shelf; gravel is distributed in patches east of northern New Jersey. The sand exists as a veneer up to several meters thick, covering older shelf deposits. Accurate estimates of the thickness of the sand cover will have to await detailed acoustic surveys coupled to core data. A rough estimate shows that 26,446 million short tons of sand plus gravel occur in a 15,112 km^2 (9,385 mi^2) area of the inner shelf off New Jersey.

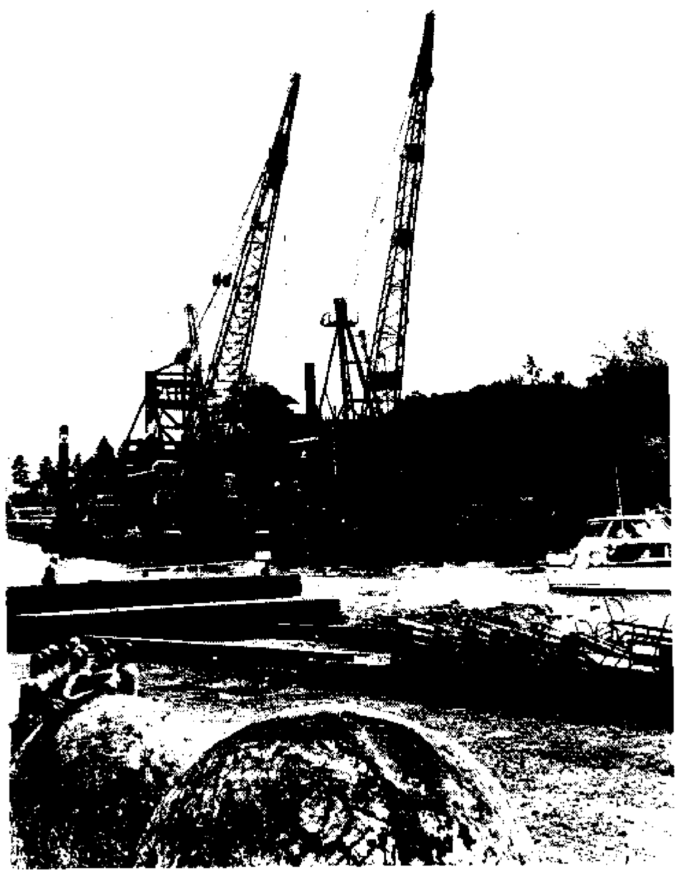
Currently and in the near future, offshore sand and gravel mining cannot compete economically with terrestrial sources for construction aggregate and inland fill; it would require significant new investment of industrial capital.

An average of 5.5 million yd^3/yr of sand was dredged from the Lower Bay of New York Harbor from 1966 through 1974. Most of the mined sand was used as fill and subgrade material in public construction projects and beach replenishment in New York and New Jersey. Since 1973 all sand mining in the harbor has been restricted to maintenance of Chapel Hill North Channel, Swash Channel, and Ambrose Channel.

Introduction

Sand and gravel has been and still is the most important mineral resource in the United States, as measured by dollar value mined per year. Sand and gravel is prosaic but critical. Used for fill, construction aggregate, and a large number of industrial purposes in the New York metropolitan region, it is a resource whose traditional sources – inland pits and quarries – are becoming scarcer and more distant from utilization sites. In the New York region, most sand and gravel is derived from terrestrial sources, but New York Harbor is probably the single largest sand pit in the nation. Fed by littoral drift from the Long Island and New Jersey coasts, the apex of New York Bight has seemingly inexhaustible sand resources. However, the rate at which sand is being removed from the harbor – most of it for fill in the gradual enlargement of Manhattan Island – is very great and in fact may exceed the rate at which it is being renewed by littoral drift.

As terrestrial sand sources become increasingly difficult to find, the economics presently favoring those sources will shift: offshore sand and gravel mining will become more advantageous and more widespread than the biggest present offshore operation, in New York Harbor. That is the situation in Europe. Therefore, the main section of this monograph considers the potential sand and gravel resources in the Bight outside the harbor.



Channel maintenance dredging (Photo by J.M. Hopkins)

Sand and Gravel Distribution in the Bight

John Schlee

Between 1961 and 1971 the demand for sand and gravel in the United States rose from 750 million short tons to 920 million short tons (Pajalich 1973). Production, worth $750 million in 1961 and $1,150 million in 1971, was at its peak in 1970 and fell slightly in 1971 though value continued to rise steadily. In states surrounding the New York Bight area, production and value (Table 1) show a small increase through 1972 – particularly value, up 12.25% from 1971. Because sand and gravel are becoming increasingly important commodities, areas such as Long Island have begun to survey their inland resources and their offshore dredging practices (New York State Office of Planning Coordination, Metropolitan New York District Office 1970; O'Connor 1973).

Table 1. Production value of sand and gravel from inland mining in coastal states surrounding the Bight area

	Production (in thousands of short tons)		Value (in thousands of dollars)	
	1971	1972	1971	1972
New York	23,722	26,722	28,328	36,952
New Jersey	18,511	17,679	38,279	38,020
Connecticut	6,921	6,763	10,262	11,270
Rhode Island	2,252	2,079	3,052	3,336
Delaware	2,205	2,257	2,231	2,660
Total	53,611	55,500	82,152	92,238

Source: Pajalich 1973 and oral communication March 1974

The sand and gravel price change has been evident at the retail level over the past three years. In 1971 Manheim (1972) spot-checked the retail price per ton on concrete-quality sand and gravel in Boston, New York, Philadelphia, and Washington, DC. In 1974 I made a similar survey to see how much the price had changed in three years (Table 2) and found it had risen 25% to 133%.

As price and production increase, some companies have begun to consider the European practice of using the continental shelf as a sand and gravel source. For example, 32 companies are dredging six main areas off the south and east coasts of England (Hess 1971). Of about 20 million short tons of aggregate produced from these areas in 1971, a quarter was sold to the continent, the remainder to Britain. Sand and gravel from the seafloor accounts for 14% of its total production in Great Britain; 25% of the sand and gravel used in London comes from the seafloor.

Table 2. Retail prices of sand and gravel (F.O.B. plant), 1971 and 1974

	1971[a]	1974
Boston	$2.00-3.00/ton	$2.45-3.85/ton
New York	1.50-3.00/ton	3.00-7.50/ton
Philadelphia	1.35-3.50/ton	2.00-6.00/ton
Washington, DC	2.75-3.50/ton	3.85-4.00/ton

[a] From Manheim 1972

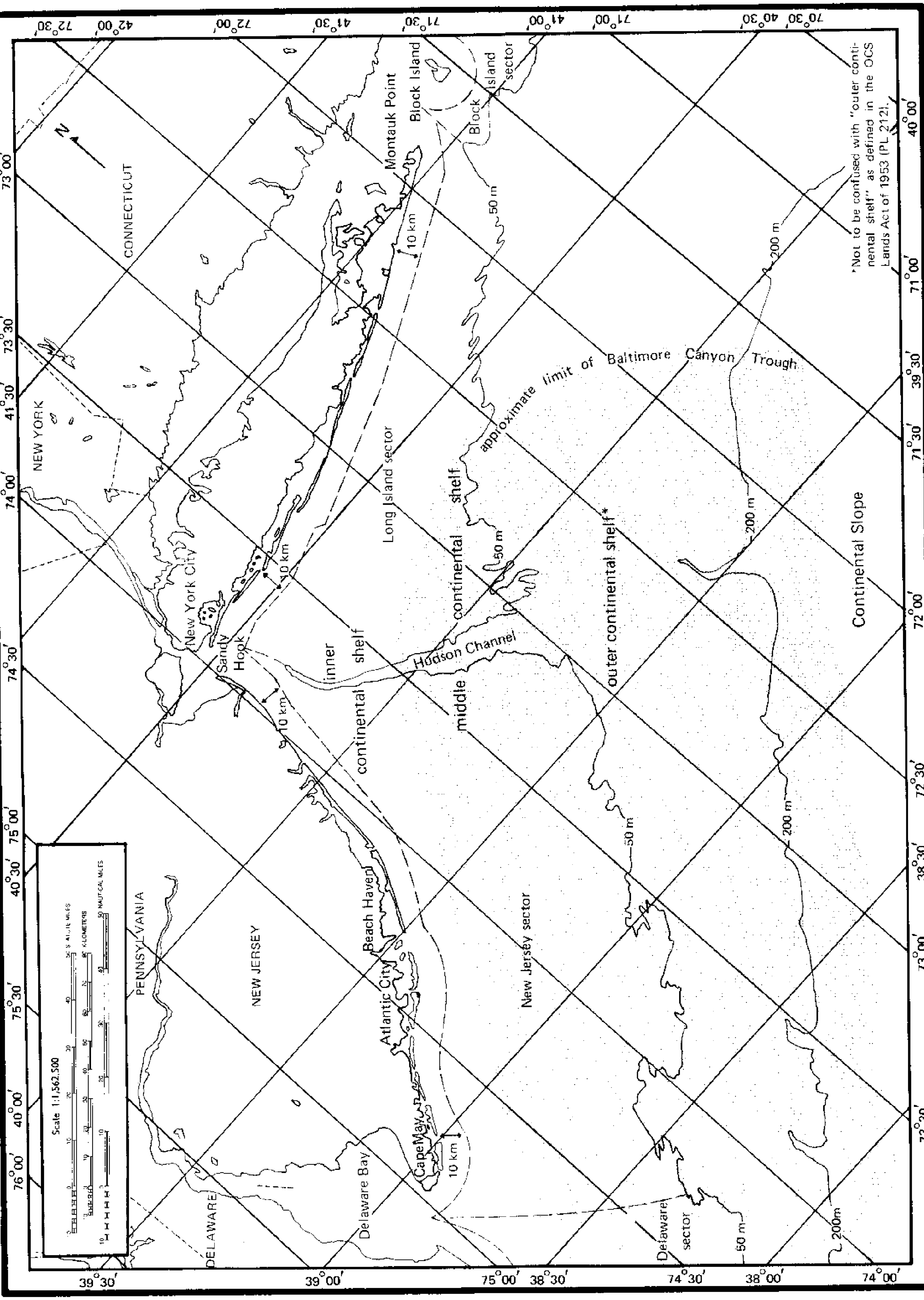
The purpose of this paper is to point out the areal distribution of sand and gravel in New York Bight, to indicate where data are lacking, and to discuss some potential problems in exploitation. Industry's interest in mining sand and gravel in the Bight dates to an article in *Pit and Quarry* pointing out a deposit of sandy gravel on the inner and middle continental shelf off northern New Jersey (Schlee 1964). Several companies obtained permits to explore for sand and gravel in this area, but none have requested the Department of the Interior to put tracts up for lease.

The study area has been expanded to include the continental shelf from Block Island to Delaware. Map 1 shows shelf and slope sections and features discussed in the text.

Previous and Present Studies

Previous sediment studies of the northeastern US continental margin – reviewed by Schlee (1973) and Milliman (1974) – span the past century but most were made within the last 40 years. Shepard and Cohee (1936) collected over 700 samples on the continental shelf between Martha's Vineyard and

Map 1. General locator



Transverse Mercator Projection

Delaware Bay. They could find no systematic change to finer-grained sediment farther offshore (such as might occur if finer and finer sediment settled out in deeper water). Hence they concluded that the sediment covering the continental shelf was *relict,* that is, formed during an earlier phase of sedimentation unlike the present. Studies made along selected profiles by Stetson (1939) and by Donahue et al (1966) showed clay below a thin sand cover and further indicated the nonsystematic change in sediment grain size across the shelf.

The most recent studies of sand and gravel distribution off the coast from New Jersey to Nova Scotia cover relatively large areas and show that most of the shelf here is sand-covered (Schlee 1968; Manheim 1972). The few exceptions are the Gulf of Maine, a sandy-silt area on the outer shelf south of Rhode Island and Massachusetts, and gravelly areas off New Jersey, Nantucket Shoals, and northern Georges Bank. These maps are based on several hundred grab samples, on a 16 km (10 mi) spacing, collected by the Woods Hole Oceanographic Institution (WHOI), the US Geological Survey (USGS), and the National Marine Fisheries Service (NMFS). Several large-scale studies, completed either before or after the USGS-WHOI program, add knowledge to the sediment distribution pattern in the Bight. G.M. Friedman and students (McKinney and Friedman 1970; Frank and Friedman 1973; Frank et al 1972; Friedman and Sanders 1970) collected approximately 333 samples in two strips – one extending seaward from the Long Island coast to the upper slope, the other extending seaward from the New Jersey coast near Atlantic City. They found an almost complete lack of fines in samples taken off New Jersey, whereas the sands on the Long Island shelf did contain appreciable amounts of silt and clay (5% to 10%) seaward of the 64 m (210 ft) isobath.

McMaster and students (Garrison and McMaster 1966; McMaster and Garrison 1966, 1967; McClennen and McMaster 1971; McClennen 1973) studied the continental shelf south of Massachusetts–Rhode Island and off New Jersey. On the shelf south of New England are wave-cut terraces at water depths of 24 m (79 ft), 82 m (269 ft), 119 m (390 ft), and 146 m (479 ft), and relict beach ridges at 64 m (210 ft). Much of the sand was brought there by rivers during the late Pleistocene (see Table 3). Off New Jersey paired linear ridges and depressions connect with Holocene erosional surfaces at 24 m (79 ft), 37 m (121 ft), 46 m (151 ft), 54 m (177 ft), 64 m (210 ft), 69 m (226 ft), 79 m (259 ft), and 108 m (354 ft).

Table 3. Major stratigraphic and time divisions in use by the US Geological Survey

Erathem or Era	System or Period	Series or Epoch	Estimated ages of time boundaries in millions of years
Cenozoic	Quaternary	Holocene	
		Pleistocene	2-3
	Tertiary	Pliocene	12
		Miocene	26
		Oligocene	37-38
		Eocene	53-54
		Paleocene	65
Mesozoic	Cretaceous	Upper (Late) Lower (Early)	136
	Jurassic	Upper (Late) Middle (Middle) Lower (Early)	190-195
	Triassic	Upper (Late) Middle (Middle) Lower (Early)	225
Paleozoic	Permian	Upper (Late) Lower (Early)	280
	Carboniferous Systems: Pennsylvanian	Upper (Late) Middle (Middle) Lower (Early)	
	Carboniferous Systems: Mississippian	Upper (Late) Lower (Early)	345
	Devonian	Upper (Late) Middle (Middle) Lower (Early)	395
	Silurian	Upper (Late) Middle (Middle) Lower (Early)	430-440
	Ordovician	Upper (Late) Middle (Middle) Lower (Early)	500
	Cambrian	Upper (Late) Middle (Middle) Lower (Early)	570
Precambrian		Informal subdivisions such as upper, middle, and lower, or upper and lower, or younger and older may be used locally.	3,600+

Source: ***Strategraphic nomenclature in reports of the US Geological Survey*** by G.V. Cohee, 1970 (Internal USGS document)

Current meters placed near the bottom for several days during calm weather measured velocities as great as 40 cm/sec (15.7 in/sec) – more than sufficient to rework the sand cover (McClennen 1973). Such velocities are averaged values, collected over a maximum 2.5 minute time interval, every 5 or 10 minutes.

The landward edge of the shelf in the Bight, particularly near the entrance to New York Harbor, has been studied intensively by Cornell University, the US Army Corps of Engineers, and the National Oceanic and Atmospheric Administration (NOAA). Because of multiple activities in this area, the studies considered a large number of sediment properties. Investigators from Cornell University (1953) collected several hundred grab samples and cores along two tracks converging on the harbor entrance (Map 2); the closely spaced samples indicated variability in amounts of gravel, sand, silt and clay. The sand inventory program of the Corps of Engineers (Duane 1969) attempted to locate and assess quantities of sand immediately offshore, not only in the Bight but along the entire Atlantic coast. Recently, the Corps diversified the program to include shallow seismic reflection profiling and coring farther offshore (Williams and Duane 1974). Their program is designed to evaluate sedimentary processes acting on the inner shelf and the potential for support of man-made structures on the shelf.

As part of a Marine EcoSystems Analysis (MESA) project, Swift and his associates are investigating seafloor topography, shallow structure, currents, sediment texture and mineralogy on the shelf in the Bight, with an eye to working out the regional sediment budget (see Freeland and Swift, in press).

A program to determine the movement and characteristics of bottom sediments within the Baltimore Canyon Trough area is currently being conducted by the USGS (Knebel, oral communication, June 1974). This study is concentrating on three subareas on the middle and outer shelf off New Jersey and Delaware. The shallow subbottom structure was determined in each subarea by high resolution seismic profiling. The bottom sediment was sampled extensively in the subarea south of central Hudson Channel.

Areal Distribution

Data presented on Maps 3, 4, and 5 show concentrations of *sand* – material between 0.062 and 2 mm (0.002 and 0.078 in), *gravel* – material coarser than 2 mm (0.078 in), and *silt and clay* – material finer than 0.062 mm (0.002 in). In a general way, the maps indicate some areas where commercial deposits of sand and gravel may be found following detailed exploration. Data are a compilation from Cohee (1937), the USGS-WHOI project (Hathaway 1971), Friedman and students (McKinney and Friedman 1970; Frank and Friedman 1973), the Cornell University study (1953), and unpublished data provided by R.L. McMaster (Narragansett Marine Laboratory, University of Rhode Island). I used a sediment map prepared by Williams and Duane (1974) to refine the contours in the vicinity of the inner Bight.

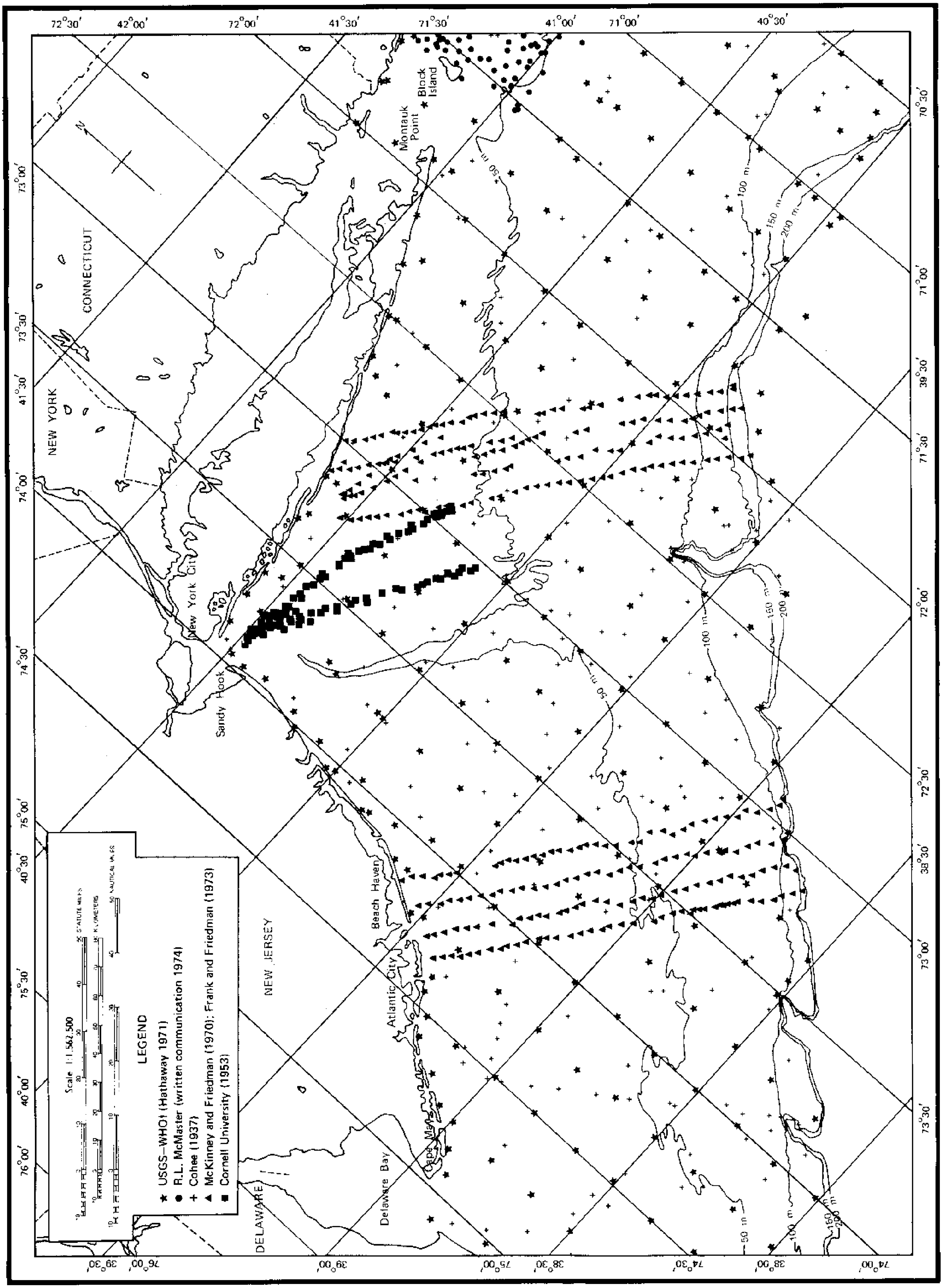
The maps give a two-dimensional view of sediment distribution in the Bight area – a spotty view because of differences in sampling density. Samples are closely spaced – approximately 1 km (0.6 mi) apart – east of the New York Harbor entrance and widely spaced – 16 km (10 mi) apart – on certain sections of the shelf (Map 2). Differences in sample density as well as in sampling methods presented some difficulty in contouring the data. Frank, McKinney, and Friedman (1972) found almost no fine detritus beyond 64 m (210 ft) in the transects across the shelf along Long Island and found no fines out to the shelf edge off New Jersey. However, samples collected by other investigators in the same area show as much as 18% silt and clay off New Jersey. Friedman used a Phipps Underway Sampler, which may not have penetrated the bottom as deeply as the Campbell Grab or the telegraph snapper that the other investigators used to collect their samples.

The contours of sediment values took into account broad bathymetric features such as channels and shoals. I used the set of charts that Stearns and Garrison (US Coast and Geodetic Survey and US Bureau of Commercial Fisheries 1967) compiled on a scale of 1:125,000 and contoured on a two-fathom interval. Even where these bathymetric charts were used, sediment contours tend to be broad where the data are widely spaced and tightly curved where the data are closely spaced. The distribution patterns that emerge are somewhat analogous to looking at the moon with a low-power telescope. Some patterns will appear (maria and lunar highlands), but a powerful telescope or a satellite in orbit around the moon will show more and more, and the patterns will be more intricate than at first surmised.

As the predominant shelf sediment, sand is distributed over the entire shelf but is concentrated along the sand-wave-dominated inner shelf south of Long Island and the entire shelf off southern New Jersey (Map 3). Admixtures of gravel are mainly on the inner shelf off New Jersey; admixtures of silt occur on the outer shelf south of Massachusetts–Rhode Island and in a few scattered spots elsewhere on the shelf.

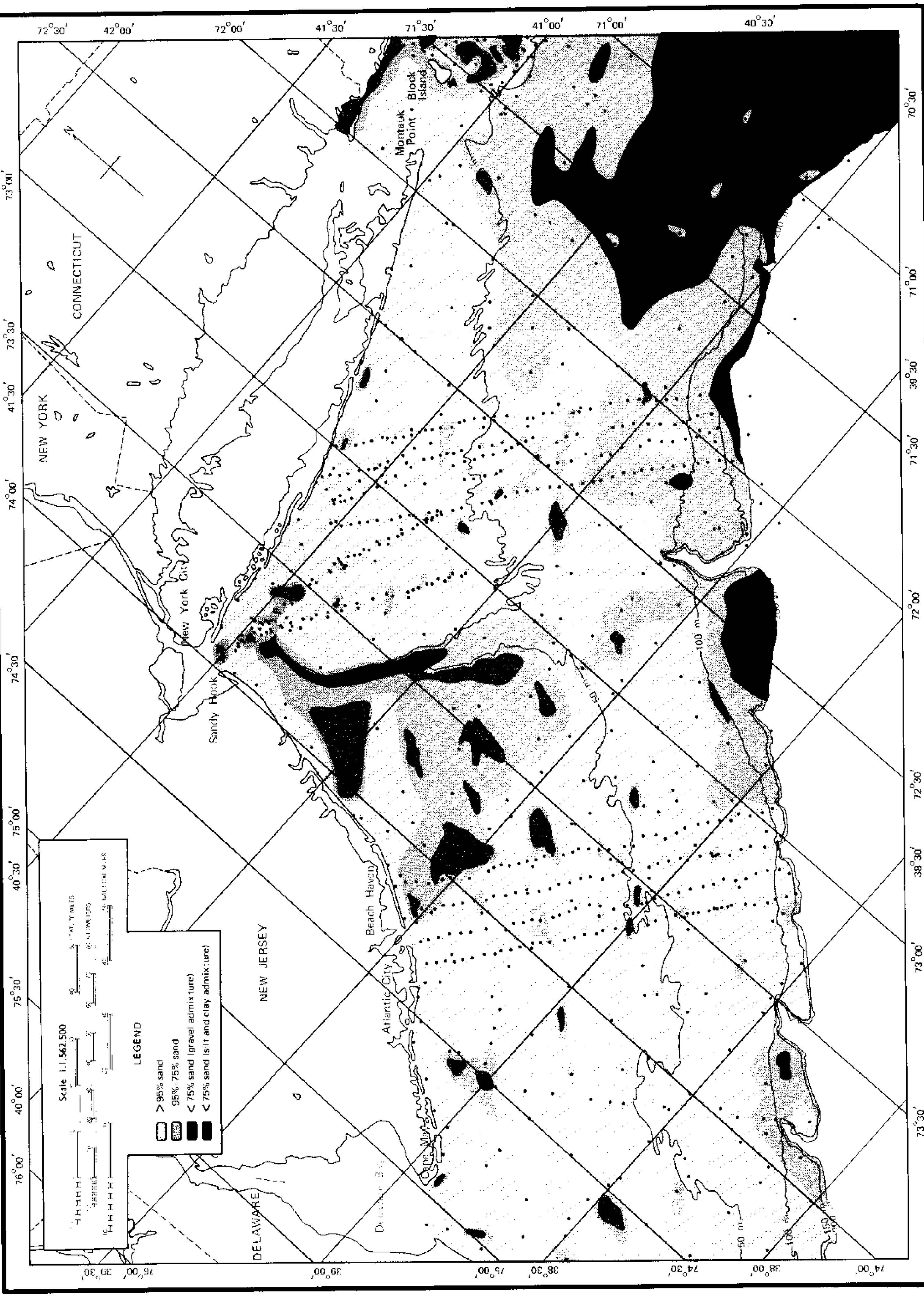
The shelf sand is coarse- to fine-grained and dusky yellow (Schlee 1973; Milliman 1972). It contains less than 5% calcium carbonate and this is mostly echinoid and mollusk fragments (Milliman et al 1972). The sand consists of 94% to 100% quartz and feldspar (Trumbull 1972); glauconite is spotty in occurrence but is abundant near Sandy Hook and on the middle of the shelf off southern New Jersey (Trumbull 1972; Milliman 1972). The feldspar/feldspar-plus-quartz ratio ranges from 10% to more than 25% in the Bight (Milliman et al 1972). Ratios in excess of 25% are associated with the relict fluvial channels that cut across the shelf off Chesapeake Bay, Delaware Bay, Hudson River, and south of Block Island. Milliman et al (1972) speculated that the

Map 2. Samples: location and source



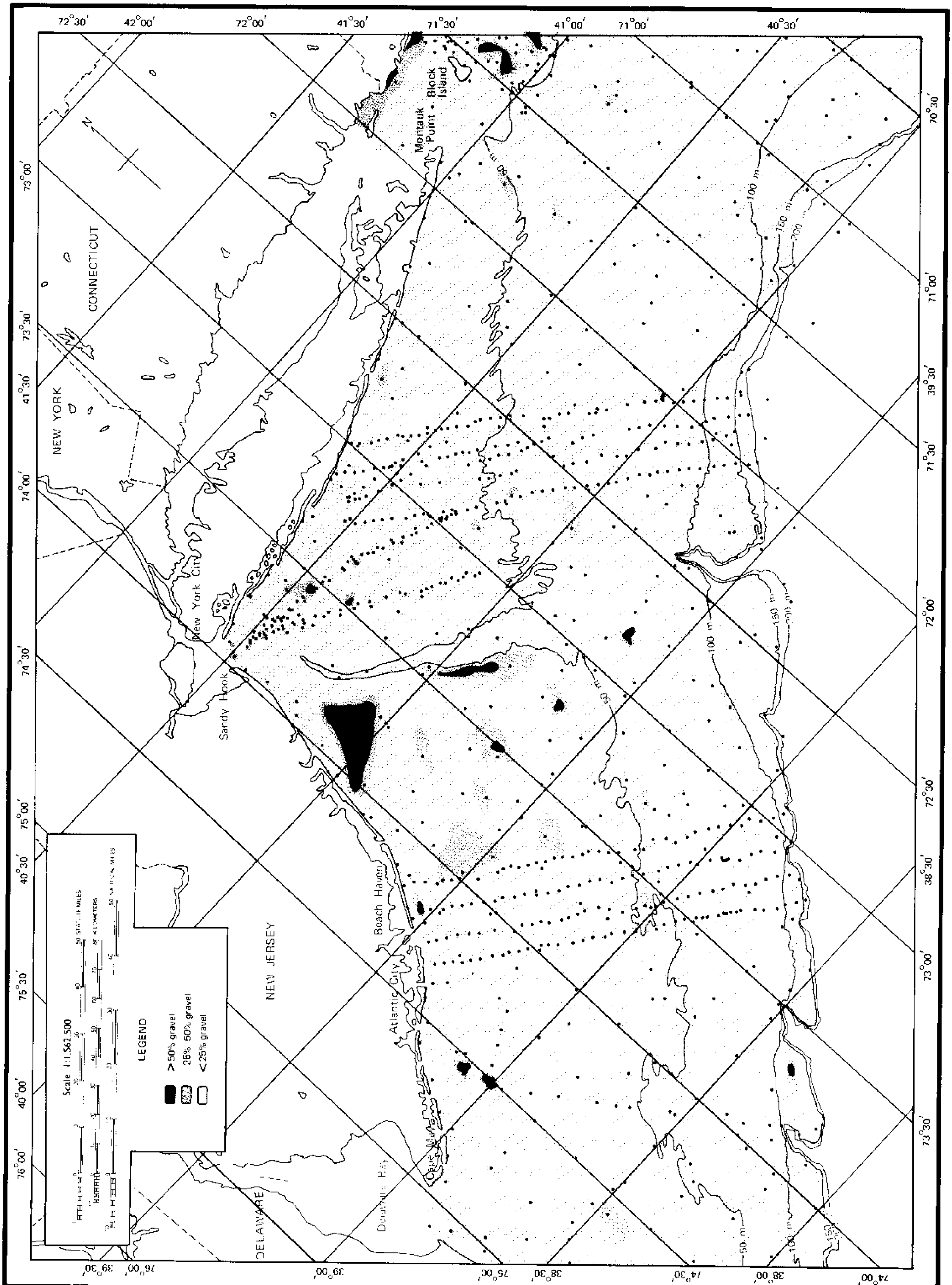
Transverse Mercator Projection

Map 3. Sand distribution



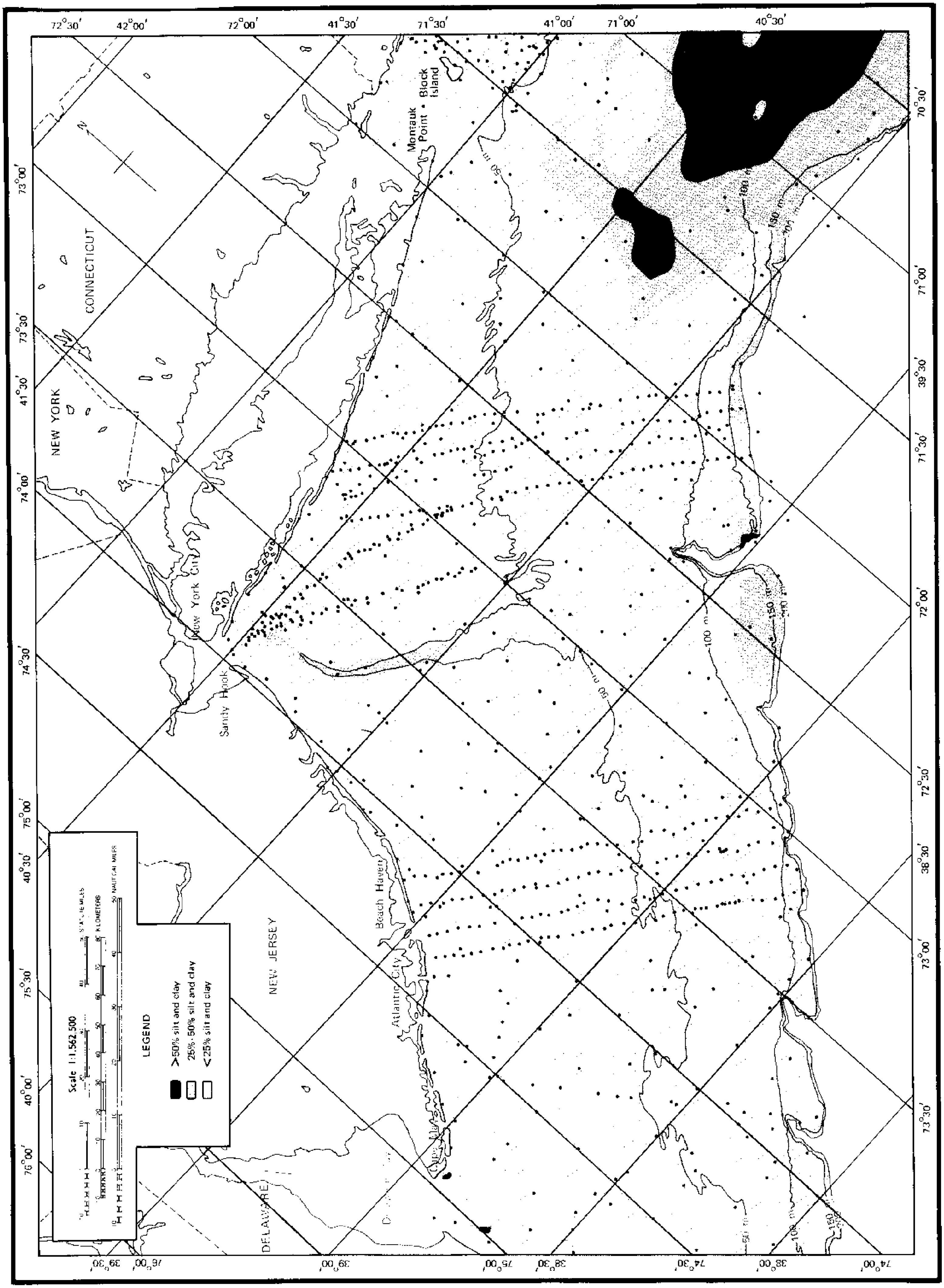
Transverse Mercator Projection

Map 4. Gravel distribution



Transverse Mercator Projection

Map 5. Silt and clay distribution



Transverse Mercator Projection

increased amounts of feldspar were brought there by meltwater streams that drained across the emerged shelf during lowered sea level associated with advances of the Pleistocene ice sheets.

Gravel and gravelly sand is distributed in patches off northern New Jersey (Map 4). The deposits are nowhere as continuous as indicated by Schlee (1964). They are mainly between the 25 and 50 m (82 and 164 ft) isobaths off northern New Jersey, as far south as Atlantic City; in this area, gravel is mostly in troughs between broad, low, sand ridges. Gravel mixed with sand occurs in a few areas seaward of Cape May. Small patches of gravel are located north of the Hudson Channel, bracketing the 25 m (82 ft) isobath. Patches of gravelly sand on the middle of the shelf, between the 50 and 75 m (164 and 246 ft) isobaths, off both New Jersey and New York may be part of a relict terrace deposit associated with a Holocene strand line (Schlee and Pratt 1970). The coarse gravel near Block Island is glacial debris deposited during the Pleistocene (Schafer and Hartshorn 1965). Subsequent reworking during a sea-level still-stand in the Holocene redistributed this glacial debris to produce a spit-lagoon-headland complex southeast of Block Island at a present water depth of 25 to 27 m (82 to 89 ft) (McMaster and Garrison 1967; Grant 1973).

The gravel in the Bight consists mainly of rounded quartzose rock types (Schlee and Pratt 1970). Pebble counts in the 8 to 16 mm (0.3 to 0.6 in) class show that "vein quartz" and quartzite predominate; diabase, granite, gneiss, schist, and sedimentary rock are also present. The sedimentary rock fragments are sandstone, claystone, and siltstone, which probably were partly derived from erosion of formations of the Atlantic Coastal Plain. Dominance of resistant rocks, their rounding, and the location adjacent to the Hudson Channel all indicate that gravel was brought there by the ancestral Hudson River (Schlee 1964). The prevalence of quartzose rock shows that either the source area was deeply weathered or that conglomerates of Tertiary and Cretaceous age from formations beneath the Coastal Plain supplied the pebbles. The feldspathic content of associated sands is lower (10% to 25%) in the gravelly areas off northern New Jersey than it is in the presumed meltwater channel ways. The main phase of gravel deposition off northern New Jersey probably preceded introduction of the feldspar-rich detritus in the Pleistocene and the gravel was deposited on the shelf in response to falling sea level at the onset of Pleistocene glaciation.

Silt and clay deposits are confined to estuaries, the continental slope, and the outer shelf south of Rhode Island and Massachusetts (Map 5). Fine detritus has accumulated in a few closed depressions, the largest of which is the Hudson Channel. Some of the spot anomalies may be connected with the many small closed depressions on the shelf (US Coast and Geodetic Survey and US Bureau of Commercial Fisheries 1967). Inner-shelf studies by Duane et al (1972) and Swift et al (1973) described fine sediment in troughs between linear sand ridges; lag gravels were also found there.

The large sandy silt area in the northeastern section of the Bight is part of a larger shelf deposit extending to the 70° meridian. The deposit appears to have formed during a lowered sea level in the Holocene (Schlee 1973).

Thickness and Volume Estimates

Most of the sediment samples collected in the Bight are grab samples scraped from the seafloor. Hence, the patterns that emerge are two-dimensional. However, some gravity cores, Vibracores, and shallow borings have been taken, showing that the surficial sediment is only a veneer.

Much of the deeper borehole data is summarized by Emery and Uchupi (1972, Figures 78, 85). The records of foundation borings for US Coast Guard light towers and one Texas Tower show mainly coarse- to fine-grained sand at the surface, giving way to silty clay or gravel a few meters below the seafloor. Williams and Duane (1974) give a more detailed description of some of the cores shown by Emery and Uchupi, and they also correlate the stratigraphy from these cores (plus 61 Vibracores) to 716 km (445 mi) of seismic reflection profiles taken off the approaches to New York Harbor (647 km^2 [250 mi^2] area). Williams and Duane show that the seafloor is covered by a few meters of fine- to medium-grained sand (coarse-grained to gravelly in some places) inferred to be Holocene in age; this surficial sand sheet covers Pleistocene fluvial sand ranging from 10 to 45 m (33 to 148 ft) thick. Williams and Duane believe that some of the gravel is derived from erosion of Coastal Plain formations and that some of it was brought there by meltwater streams draining the front of the Pleistocene ice sheets.

Over 300 gravity cores taken in the Navy-sponsored study done by Cornell University in 1953 indicated that grain size generally increased with core depth. I used 99 analyses of surficial sediment from these cores for Maps 3, 4, and 5. Records of 115 additional cores, ranging from 0.25 m (0.8 ft) to nearly 1.5 m (4.9 ft) long, were studied for grain-size trends. Grain size tended to increase with core depth in 53% of the cores; the reverse occurred in 15%. Usually grain size increased irregularly from sand to slightly pebbly sand at depth.

Of 18 cores collected by Donahue et al (1966) from the shelf off central New Jersey, 13 showed a thin sand cover with clay, peat, or shells 15 to 60 cm (6 to 24 in) below the seafloor. Donahue and his associates concluded that the thin sand cover was in equilibrium with "contemporary dynamic processes," i.e., present currents acting on the ocean bottom, and that the fine sediment and shells date from an earlier phase of sedimentation.

Stahl et al (1974) reached a similar conclusion for the inner shelf off Beach Haven, NJ. Here they drilled up to 92 m (302 ft) below the seafloor, through an underwater sand ridge 3.6 m (11.8 ft) high and 1.8 km (1.1 mi) long. From the borings, they found the thickness of surficial sediment to be about the same as the relief of the ridge – 3.6 m (11.8 ft); the ridge was built over Holocene clays inferred to be lagoonal and back-barrier facies.

Farther offshore in the same area, Stubblefield et al (in press) took four Vibracores on a trough-ridge complex. They found approximately 20 cm (8 in) of Holocene sand covering Pleistocene silty clay in the trough and more than 2.4 m (7.9 ft) of Holocene sand on the ridge and upper flank of the trough. The ridge relief is 13.5 m (44.3 ft).

This brief review of core-sediment studies shows the complex relation between the surficial sand cover and relict deposits beneath. Where ridge and swale topography has formed, the sand or gravelly sand appears to have built over a substrate of older fluvial, lagoonal, or barrier deposits. If such topography were widespread over the shelf and if Holocene lagoonal clays were always found in the troughs of these systems, then the thickness of the sand blanket could be estimated from the relief of the sand ridges. However, the ridge-trough system is not uniform on the shelf; it occurs on broad terraces formed during fluctuations in the post-glacial rise in sea level (McClennen and McMaster 1971). Hence the geometry of the sand sheet is stratigraphically complex.

Accurate estimates of the thickness of sand and gravel deposits will have to await closely spaced shallow core data tied to high resolution seismic reflection surveys. The proving up of a deposit is done by a company interested in a lease tract under an exploratory permit from the government. The closeness of corehole spacing and sonic profile tracks depends on the areal extent of the deposit. One such survey was made off eastern Massachusetts in a two-step operation. A broad-gauge survey covering 700 km^2 (270 mi^2) used a sonic line spacing of 0.5 to 1.8 km (0.3 to 1.1 mi) and collected Vibracores from 2 km (1.2 mi) to several kilometers apart (Massachusetts Department of Natural Resources, Division of Mineral Resources 1974). Within this area, NOAA contracted for an intensive survey of one deposit 3.7 km (2.3 mi) long, 2.2 km (1.3 mi) wide and as much as 6 m (20 ft) thick (Setlow 1973). Here a 150 to 300 m (492 to 984 ft) sonic line spacing was used, and 31 additional cores were collected. The format and density of the Massachusetts study give an idea of what will be necessary to prove up areas of high concentration of sand and gravel.

Without many such thorough surveys, only general estimates of sand plus gravel can be made for sectors of the shelf. These estimates are presented in Table 4. I delineated four sectors, using shelf valleys or their inferred extensions as boundaries between sectors (Map 1). As an inner-shelf boundary, I chose a set distance of 10 km (6 mi) from the coastline, and as an outer boundary, I chose the 50 m (164 ft) isobath. In picking the inner boundary I followed a practice used by the British of leasing well away from the shore, to stay out of that part of the inner shelf they consider the zone of most active sediment transport. Beyond 10 km (6 mi), dredging vessels would be hardly visible from land, thus minimizing aesthetic objections. Though the 50 m (164 ft) outer limit is slightly beyond the depth at which dredges currently work, improved technology may increase their capabilities in the future.

The estimates in Table 4 are several hundred times the yearly consumption of the coastal states

Table 4. Estimates of sand plus gravel on the inner shelf of the Bight

	Area mi^2	Area km^2	Short Tons (in millions)
Delaware	550	1,424	2,492
New Jersey	5,833	15,112	26,446
Long Island	2,680	6,942	12,148
Block Island	249	645	1,129
Total	9,312	24,123	42,215

NOTE: Average assumed dredging depth, 1 m (3 ft) below the seafloor; dry weight, 1.75 short tons/m^3 (assuming a 40% porosity) (compare Table 1). The figures are considerably below those given by Manheim (1972) because I used a smaller area than he did and because he assumed a dredging depth of 3 m (10 ft) below the seafloor. The values for Delaware and Block Island are low because those sections are limited by the boundaries of our study area (Map 1).

Even the estimates given in Table 4 are probably optimistic so far as concrete-grade sand and gravel are concerned. For this use alone, a closer estimate would be gained from considering only the gravelly areas seaward of New Jersey's northern and central coast – eight irregular areas between the coast and the 50 m (164 ft) contour and mainly north of 39°15'N. Together these areas cover approximately 1,300 km^2 (502 mi^2) and could contain 2.2 billion short tons of sand and gravel, assuming the same conditions given in Table 4.

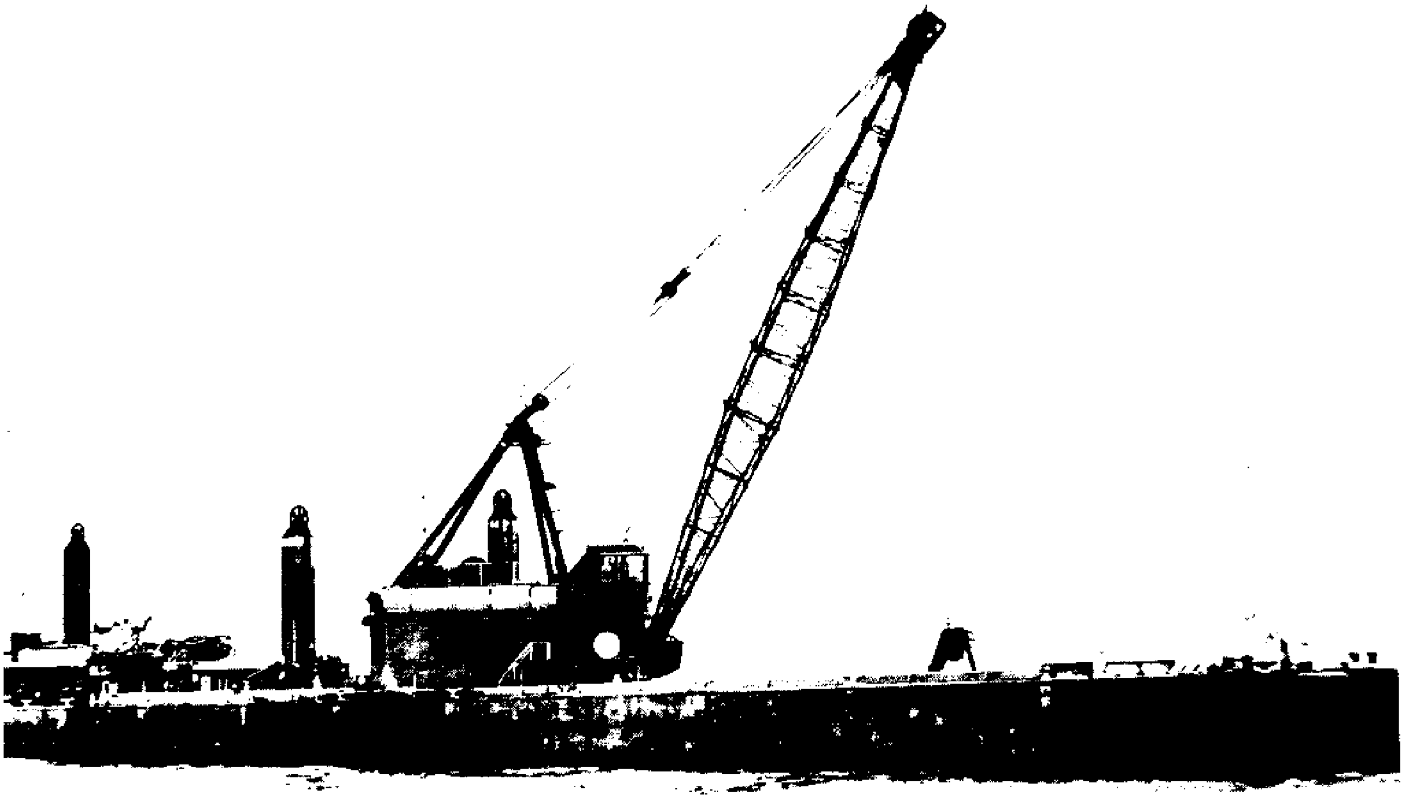
Constraints

Future development of sand and gravel deposits in New York Bight will have to be considered in light of existing and proposed activities in the area. Prominent among the present seafloor activities are a surf clam and scallop fishery, and ocean dumping. Further, the deposits are athwart some of the main shipping lanes and cable routes into New York and New England (Grant 1973). Potential future uses of the inner shelf include a proposed offshore power plant near Atlantic City and an offshore supertanker terminal. The most directly competing use is the fisheries, hence they merit examination to consider their magnitude and economic trends.

Though the Bight does support a finfishery (McHugh 1972; Saila and Pratt 1973; Deuel 1973; Freeman and Walford 1974), the bottom-dwelling animals are of particular concern here because they are likely to be disturbed in any dredging activity. Two forms, surf clams and sea scallops, are commercially important. Data supplied the author by Dr. J.L. McHugh (McHugh and Williams, in press) show that the major catches in pounds of meat landed are surf clams, and these are dredged mainly off New Jersey. Catches of both clams and scallops have been declining in recent years. Combined figures for New Jersey and New York show an eight-year decline in the surf clam catch from 20,436 metric tons of meat in 1966 to 11,308 metric tons in 1973; approximately 90% of the catch was made off New Jersey. The sea scallop harvest has decreased throughout the past decade and a half; during the past eight years, the catch has fallen from 1,148 metric tons of meat in 1966 (combined figure for New York and New Jersey) to 256 metric tons in 1973, with most of the decline in the catch off New York. The combined value of the catch for the two states was $5,788,000 in 1968 (Saila and Pratt 1973); surf clams accounted for 62% of this amount. These fishery figures are important because they show magnitudes and trends in recent years. The resource is renewable and with wise management could give a more bountiful yield than at present.

How sand and gravel dredging will influence this harvest is not fully known. Potential effects as discussed by Grant (1973) for Rhode Island waters include turbidity, sedimentation and resuspension (possibly clogging the gills of shellfish near the dredge site), and destruction of shellfish beds. To assess this fairly, data pertinent to conditions as they presently exist need to be collected. How have the ongoing activities of dredging for shellfish and dumping wastes altered the biota and water quality? Where are the prime shellfish beds, how large are they, and how has their yield changed with time? How adequately understood is the circulation of shelf waters in the area (Knebel 1974)? Complementing baseline studies, a small-scale pilot project to monitor the effects of sand and gravel mining could anticipate problems that may occur on a large scale. Applying the experience of offshore mining elsewhere along with a good understanding of the Bight environment could minimize conflicts of use where they occur and forestall hazards before they arise.

Except for cable lines and certain navigation lanes, other activities would appear capable of accommodating a seafloor mining industry at present. Dumping is concentrated mainly near the inner Bight; hence it should have small impact on mining unless the sites are expanded. Cables are charted, so the linear areas occupied by them will have to be zoned "off limits." Main navigation channels at the approaches to New York Harbor likely will have to be avoided as mining sites in the interest of safety. Away from these channels, dredging vessels probably can mine just as they do off Britain. Indeed, the British experience offers hope that seafloor mining can coexist with other ocean activities, having done so for many years. With the collection of adequate, environmentally sensitive data on seafloor sediment, biota, and water quality and circulation, with a fair assessment of the priorities for seafloor use, and with proper regulations, it may be possible to accommodate offshore sand and gravel mining in the Bight.



Maintenance dredging in New York Harbor (Photos by P. Sanko)

Gilgo Beach (Long Island) replenishment (Photo by P. Sanko)

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Sand Mining in New York Harbor

Peter Sanko

Sand deposits in the Lower Bay of New York Harbor have been the largest single source of commercial sand for the New York City metropolitan area since 1963. Records maintained by the New York State Office of General Services (OGS), which administers licensing of commercial sand and gravel dredging on state-owned underwater lands, show that an average of 5.5 million yd^3/yr (8.3 million short tons/yr) of sand was dredged from the Lower Bay from 1966 through 1974 (Table 5). Prior to 1958 commercial sand mining was small scale, in response to demand, except between 1950 and 1952. OGS estimates that the volume of sand mined from the harbor may reach 10 million yd^3 (15 million short tons) in 1975.

Table 5. Average short tons of sand mined in Lower New York Bay, 1950-1974

	Million yd^3/yr	Million short tons/yr
1950-1952	1.1	1.65
1953-1957	0.3	0.45
1958-1962	1.1	1.65
1963-1965	4.5	6.75
1966-1974	5.5	8.25

These production statistics do not represent the absolute total amount of sand mined. Those for 1966 through 1974 are probably accurate to within 0.5 million yd^3/yr (0.8 million short tons/yr) because the US Army Corps of Engineers and OGS have tried in recent years to control more closely the mining activity in New York Harbor. However, statistical reliability decreases progressively from 1966 into the past. Many old dredging permit records reflect only the approximate amount of sand proposed to be dredged; they show neither the actual amount dredged nor whether any sand was in fact dredged. As many as seven commercial dredging companies may apply for permits and licenses to mine sand during any year, as is currently the case. If records do not indicate how much sand was mined under a given permit, each company must be contacted; but because many companies involved in marine mining in the 1950s and prior years either no longer exist or are no longer active in this field, these data are not always available. Thus production figures were computed from known volumes of sand mined and represent only the minimum – not the absolute total – amounts mined.

Uses of Mined Sand

Almost all sand mined from New York Harbor has been used for fill and subgrade material in public and semipublic construction projects in New York State and New Jersey. Such projects, requiring millions of cubic yards of sand, include Newark Airport, Ports Elizabeth and Newark, New Jersey Turnpike, and two now under construction – New Jersey Sports Complex and Manhattan's Battery Park City. For Newark Airport 15 million yd^3 (23 million short tons) of sand was used, for Port Elizabeth 12 million yd^3 (18 million short tons), and for Battery Park City 3.5 million yd^3 (5.3 million short tons) will be used.

Proposed projects needing sand as fill include beach replenishment and highway construction. Present plans call for about 4 million yd^3 (6 million short tons) of sand to replenish Rockaway Beach in 1975, with another 4 million yd^3 (6 million short tons) to be added in 1976. Other planned beach replenishment programs, specifically for Coney Island and Staten Island beaches, may require 7 to 8 million yd^3 (11 to 12 million short tons) of sand. If the proposal to rebuild Manhattan's West Side Express Highway on landfill along the Hudson River is realized, approximately 13 million yd^3 (20 million short tons) of sand will be needed from 1976 to 1978 for fill in this project alone. Based on current replenishment and construction proposals, the demand for sand throughout the remainder of the 1970s will probably exceed 8.5 million yd^3/yr (12.8 million short tons/yr).

Small amounts of marine sand were used for concrete aggregate in the past but none is being used for this purpose now. Although inland sand sources – especially those close to New York City – for concrete and asphalt aggregate have become scarce, offshore sand costs are still higher than costs of inland sand. According to the Empire State Sand and Gravel Association, sand used for aggregate material in New York City's five boroughs amounts to about

2.7 million yd^3/yr (4.0 million short tons/yr). This sand, most originating in quarries in New Jersey and on Long Island, sells for about \$3.85 to \$4.25/yd^3 (\$2.54 to \$2.81/short ton), processed and delivered to a concrete plant. Sand from the Lower Bay now averages about \$2.90 to \$3.00/yd^3 (\$1.91 to \$1.98/short ton), delivered; no processing is required for its present uses. Washing and screening the sand, necessary for use as concrete and asphalt aggregate, would raise the total cost by about \$1.50/yd^3 (\$0.99/short ton). As inland sand prices increase because of depleted sources, restrictive zoning laws, and higher taxes and property values, use of offshore sand for concrete and asphalt aggregate may become not only economical but essential if suitable sand substitutes cannot be found. Producing sand from pulverized rock is now economical on a small scale, and in the New York metropolitan area crushed rock has all but replaced natural gravels as aggregate material.

Dredging Areas

Prior to 1968 there were virtually no restrictions on commercial dredging in the Lower Bay, other than those pertaining to navigation interference and authorized depth limits. Between 1968 and 1973 dredging was limited to a depth of 35 ft (11 m) below mean low water (MLW) and to a distance no closer than 4,000 ft (1,220 m) from the Staten Island shoreline. During these years the West Bank was the preferred dredging area (Map 6). It is generally believed that West Bank sediments are of glacial origin and are not being replenished by littoral drift. In 1973 dredging was restricted in this area because of its adverse effects on beach erosion, water quality, water circulation, and shellfish and finfish.

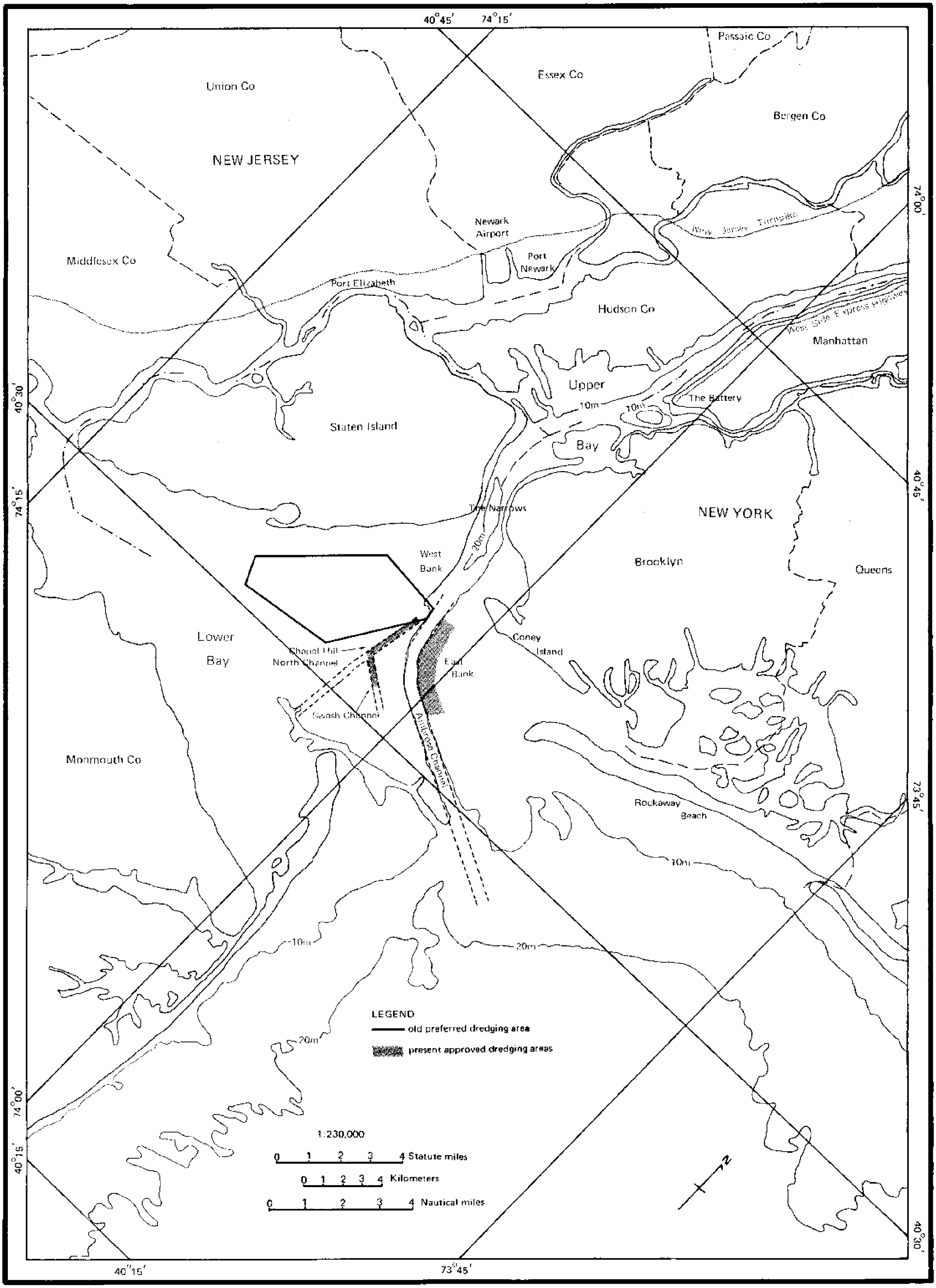
Since 1973 all sand mining in New York Harbor has been restricted to maintenance and widening projects in Chapel Hill North Channel, Swash Channel, and Ambrose Channel (Map 6). If the dredged sand is to be sold rather than removed to dumping grounds, the dredging companies are not paid for their work but instead pay a royalty to New York State for every cubic yard of sand removed. Thus, much of the required channel maintenance in the bay is accomplished at no cost to the federal government, and the dredging industry has a source of sand in an area with the least environmental objections.

The currently approved dredging areas are suitable sand sources only as long as the supply meets the demand. In view of the present and projected demand for general fill sand and of the current dredging limit of 45 ft below MLW, these areas may be depleted of sand in two to three years. Also, all sand now mined here is fine-grained – about 80% passes through the No. 50 sieve (grain size to .297 mm) – with almost no silt; it consists of 94% quartz, 2% each of muscovite and biotite, 1% shell fragments, plus traces of heavy minerals and rock fragments. Although this material is suitable for general fill, it is not coarse enough to be used, in most cases, as subgrade material for highway construction, beach replenishment, or concrete and asphalt aggregate. The need for coarser sand than that obtained in the approved locations will necessitate dredging outside those areas.

The East Bank is now the preferred dredging area because it is replenished by the westward littoral drift of sand along the south shore of Long Island. The Corps of Engineers estimates that about 1.5 million yd^3 (2.3 million short tons) of new sand enters the East Bank every year. Recently the Corps of Engineers and New York State authorized sand removal from East Bank areas outside Ambrose Channel for replenishment of Rockaway Beach. A borrow site in New York Bight directly opposite Rockaway Beach was preferred but the cost of dredging in the open ocean environment, especially during storms, proved to be prohibitively expensive. If ocean dredging cannot be combined with alternate site dredging in reasonably protected waters – the latter used during bad weather – then ocean bottom sand could cost three times as much as sand mined in a bay (personal communication, industry sources).

Up to now, there has not been sufficient demand or need for ocean bottom sand mining in the United States. Hence the nation's dredging industry is not equipped for this purpose, unlike the dredging industries of coastal European countries where sand has been mined offshore for many years. The seven major dredging companies active in the New York Harbor area have about \$70 million invested in equipment, according to current replacement costs (personal communication, industry sources). The gross value of all sand mined in the harbor in 1975 may reach \$30 million. Despite these impressive figures, private industry probably will not invest in equipment needed for ocean mining until they are certain it can be used on a sustained and profitable basis.

Map 6. Sand mining in Lower New York Bay



Transverse Mercator Projection

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