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SAND AND GRAVEL OFFSHORE IN THE GREATER NEW YORK METROPOLITAN AREA:

WHAT KIND AND HOW MUCH?

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Scope

This report was prepared as part of a New York State Sea Grant research project concerning "The Impact of Offshore Sand and Gravel Mining on the Availability and Costs of Construction Minerals in the Greater New York Metropolitan Area (G.N.Y.M.A.)". The project's purpose is to provide the data necessary to analyze the economics of mining these minerals in the offshore regions of New York State.

Material included in "The Problem" and "Geologic Setting" sections was obtained from general works dealing with mineral aggregate problems and sediment availability in the G.N.Y.M.A. The survey material on offshore resources was obtained from published reports, personal communication with other researchers, and review of U.S. Army Corps of Engineers' (ACE) data. Reports were obtained, when possible, through regular library channels; however, many had to be obtained from their authors. ACE data were abstracted from core sample reports at their field offices. New York Harbor data, available from the ACE N.Y. District office, consisted of in-house publications on wash borings and vibra-core samples taken off Coney Island, Staten Island, and the Rockaways. Williams' study [69] of South Shore Long Island was procured from the author at the ACE Coastal Engineering Research Center at Fort Belvoir, Virginia.

The data (usually consisting of inventory reports, sewer outfall cores and surficial grab samples) were considered as to the material's suitability for use as fill or construction-grade aggregate. Analysis of suitability required a review of existing construction specifications; those of the New York State Department of Transportation (NYSDOT) and the American Society of Testing Materials (ASTM) were selected. Our understanding

of these specifications was increased through conversations with personnel at NYSDOT and the Office of General Services (OGS). Additional criteria of suitability, from a world perspective, were obtained from Hess's "Marine Sand and Gravel Mining Industry of the United Kingdom" [32].

Throughout this study we maintained almost continuous communication with our consultants: Dr. Leonard Bronitsky, Dr. James Davis and Dr. James Dunn. Their assistance proved invaluable in validating what at times was our "best guess." In addition, we reviewed our approach and tentative results with officials of Construction Aggregates Corporation in New Jersey and Chicago. Of particular importance to us was the cooperation of personnel at OGS, in particular James Marotta, and Sea Grant researchers Dr. Charles Fray and Peter Sanko. We, however, accept all responsibility for our work.

The Problem

The processes of urbanization are creating heavy demands for mineral resources, particularly petroleum fuels and metals. Less publicized but still important are the demands created for sand, gravel, and crushed stone. These materials are required in nearly all types of construction and therefore are vital ingredients in our manmade environment. Conflicts between mineral producers and mineral consumers, or other users of urban space, have increased concern that domestic sand and gravel resources will become scarce [22].

Demand, by volume, for these minerals in the United States is greater than that for all other non-fuel and non-metal resources combined. According to Earney, the United States consumed 913 million short tons of sand and gravel and 792 million short tons of crushed stone in 1972 [22]. By 2000 AD the United States' consumption of sand and gravel and crushed stone is projected by 3,200 and 2,761 short tons, respectively. (See Table 1.)

Table 1

Projections and Forecasts for U.S. Sand and Gravel and Crushed Stone Demand by End Use, 1972, 1985, and 2000

(Million Short Tons)

End use	1972	1985	2000 forecast range: Low	2000 forecast range: High	Probable
Sand and gravel					
Construction					
Highway and street construction	504		1,950	2,740	2,000
Heavy construction, general bldg.	341		805	1,200	1,000
Other end uses	68		145	260	200
Total	913	1,700	2,900	4,200	3,200
Crushed and broken stone					
Construction	723		1,968	3,182	2,576
Other end uses	69		142	228	185
Total	792	1,417	2,110	3,410	2,761

Source: Earney, Fillmore, C.F., "Mining, Planning, and the Urban Environment," CRC Critical Reviews in Environmental Context, April 1977, pp. 53.

This demand is not the entire problem. As noted by Cooper [9], there are other difficulties:

1. Available resources and demand do not match geographically. Some areas have, and will have, more than adequate supplies while others have or expect to have shortages by 2000 AD. It should be noted that this is at least partly due to political considerations.

2. Rapid urban and suburban growth cover or effectively prevent further extraction of sand and gravel and crushed stone from presently available resource areas.

3. The mix of different sizes of sand and gravel in available deposits will seldom match consumer specifications. While coarse material may be crushed, the reverse process is not feasible.

Goodier [30] further emphasizes the gap between demand and reserves by noting that present United States coastal area reserves will be depleted by 1988, given the validity of current demand projections for major growth areas in this region.

Depletion of our onshore reserves of sand and gravel should not be confused with depletion of onshore resources. Long Island, New York alone, has 250 billion tons of glacially deposited sand and gravel, resources enough to supply the region's present and projected market for 22,000 years [22]. However, the mineral aggregate industry requires extensive amounts of land for present operations and future needs. Urban sprawl, highway construction, and land use regulatory laws have restricted or eliminated sand and gravel extraction from many resource sites in the Greater New York Metropolitan Area (G.N.Y.M.A.). Restrictive zoning, increased land values and environmental regulations make extraction of mineral aggregate in metropolitan areas more and more unattractive.

Many aggregate resource sites are "attractive" for urban development because of their suitability for municipal and individual septic systems. Zoning regulations have, therefore, tended to restrict suburban development to these areas, utilizing aggregate resource sites for non-extractive uses. In addition, affluent suburbs, where land is still physically available for mining, are less concerned with the regional economic role of the mineral aggregate industry than with avoiding possibly undesirable environmental impacts of mining. Many such communities have excluded the industry. Little effort has been made towards establishing and enforcing regulations to permit mining activity which could meet the environmental objectives of the citizenry [5,6].

For these reasons, the industry has been forced to move inland, away from urban demand sites. The high-volume, low-value nature of mineral aggregates and the necessity for long hauls make transportation charges a major component of the delivered price. As supply points move progressively farther from demand areas, prices can be expected to increase accordingly. Currently, a hauling distance by truck of 20 miles generally doubles the delivered price of mineral aggregates. Costs become increasingly prohibitive at haul distances of 40-60 miles.

Much longer shipping distances are economically feasible by barge if a suitable water route exists between the supply and demand sites. However, suitable docking facilities are usually located in congested urban areas. This increases hauling time and, therefore, the total cost of transportation to the construction site [53]. These additional costs might provide a cost advantage to producers who haul into the urban area on limited access highways.

Available onshore mineral aggregate resources in the G.N.Y.M.A. are becoming scarce. The pressure and conflicts of urbanization have prevented the opening of any new large-scale sand and gravel extraction operations on Long Island. It has been estimated that the costs of losing these deposits will result in $12,226,000 per year in increased delivery costs and $24,740,000 per year in increased consumer expenditures for fine aggregate alone [7].

Since urban growth is greatest in coastal regions and because of economies of scale, the use of offshore mineral deposits may become a viable alternative. Several domestic firms currently dredge offshore for fill materials, but none are mining for fine or coarse aggregate. The major advantages of offshore mining of fill are the large quantities involved and the lack of precise specifications for fill material. Firms can dredge in selected areas where the underwater geology is little known without fear of obtaining subgrade material. Fine and coarse aggregate material, of construction quality, cannot be found so easily.

Before we have extensive offshore mining of both fill and other construction minerals, several issues will have to be resolved. Prominent among them is the need to integrate and/or consolidate governmental policies on offshore mining of these minerals. Producers state that long-term accessibility to offshore resource sites must be guaranteed to allow for necessarily large capital investments. However, present licensing and regulatory procedures by state and federal agencies are short-term in nature. This issue will probably not be resolved until we gain a better understanding of the impact of offshore mining on the marine ecological system.

Market structure also has an impact on offshore mining activities. Dredging for fill is usually done in response to large needs, such as the

New Jersey Meadowlands project, which are difficult to forecast with any reliability. The market for fine and coarse aggregate is typically more dependent on the overall well being of the economy, which directly affects building and highway construction. Modern dredging equipment can extract large amounts of material in a relatively short time. "State of the art" equipment could extract a year's requirement of construction aggregates for the Greater New York region in 12 weeks of production or less [53]. Such capacity would necessitate that a company maintain a large onshore surge (i.e. inventory). Another possibility might be for one company to serve a much greater market area; perhaps including Philadelphia and the Baltimore-Washington areas.

A final concern and the particular thrust of this report is to determine if offshore minerals in the G.N.Y.M.A. are of marketable quality and exist in sufficient quantity to make underwater mining economical. We recognize that a survey of offshore resources suitable for use by industry in determining the exact location of these minerals requires extensive core sampling. Several of the reports and surveys used in compiling our data involved seismic profiles and core samples, while others utilized grab samples and wash borings. However, this lack of detail has not prevented us from determining the economic conditions necessary to make the offshore mining of construction aggregate a viable enterprise.

This report represents a survey of available data on underwater exploration conducted to date. Detailed sampling is presently being conducted in New York Harbor, the results of which will be incorporated in our ongoing investigations.

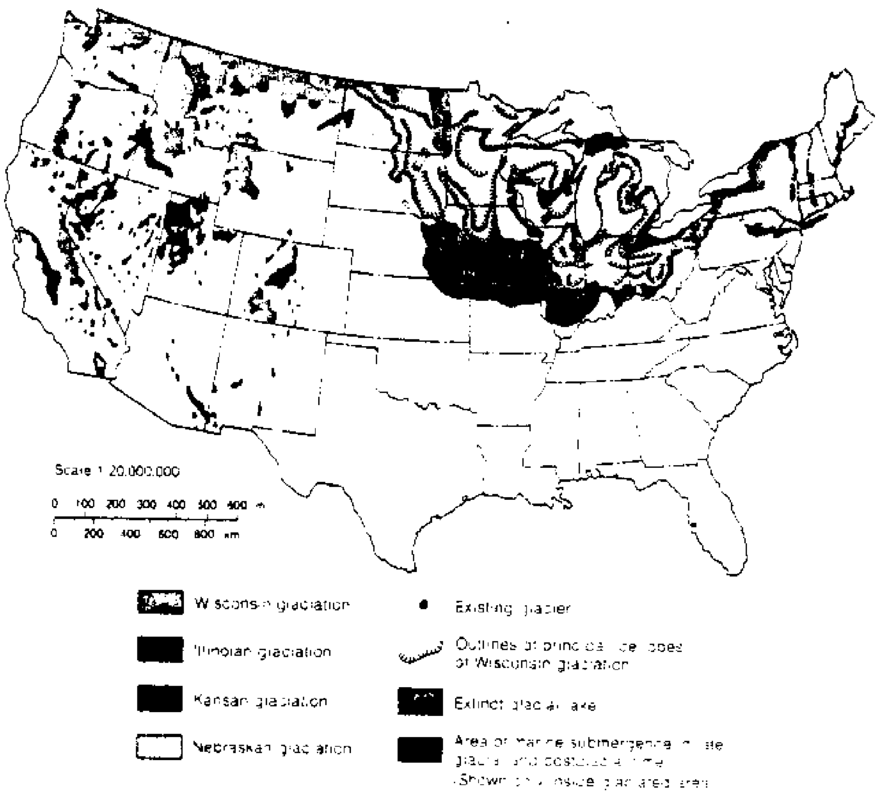
Geologic Setting

Most of the material suitable for offshore sand and gravel mining offLong Island was deposited about 10 to 12 thousand years ago by the southerly advance, and subsequent retreat, of the Wisconsin glacial ice sheet in the Pleistocene Epoch. (See Map 1.) Several types of deposits resulted from glaciation; principally terminal moraines and outwash plains. Terminal moraines are ridges of unsorted glacial till; a mixed, poorly sorted accumulation of material of all sizes. These are deposited by a glacier at the line of its farthest advance. An outwash plain forms in front of a melting glacier containing sediment deposited by meltwater streams; a sorted, stratified, deposit of water transported drift.

Long Island itself is the terminal moraine of the Wisconsin glacial ice sheet. The area south of Long Island was, until the rise of sea level, a large outwash plain. (See Figure 1.) As the glacier melted, the area north of the terminal moraine (Long Island) was less built up by glacial deposits. Subsequently, when the sea rose this area was flooded, creating Long Island Sound. Where the southern shore of Connecticut now exists the glacial retreat stagnated, depositing till and outwash which now form the northern boundary of the Sound. From Table 2 and Figures 2, 3, and 4, once can gain an appreciation for the types of formations underlying Long Island. Most of the aggregate material (e.g. Lloyd Sand, Jameco Gravel) is, both lithologically and underwater, too deep to mine economically.

Map 1

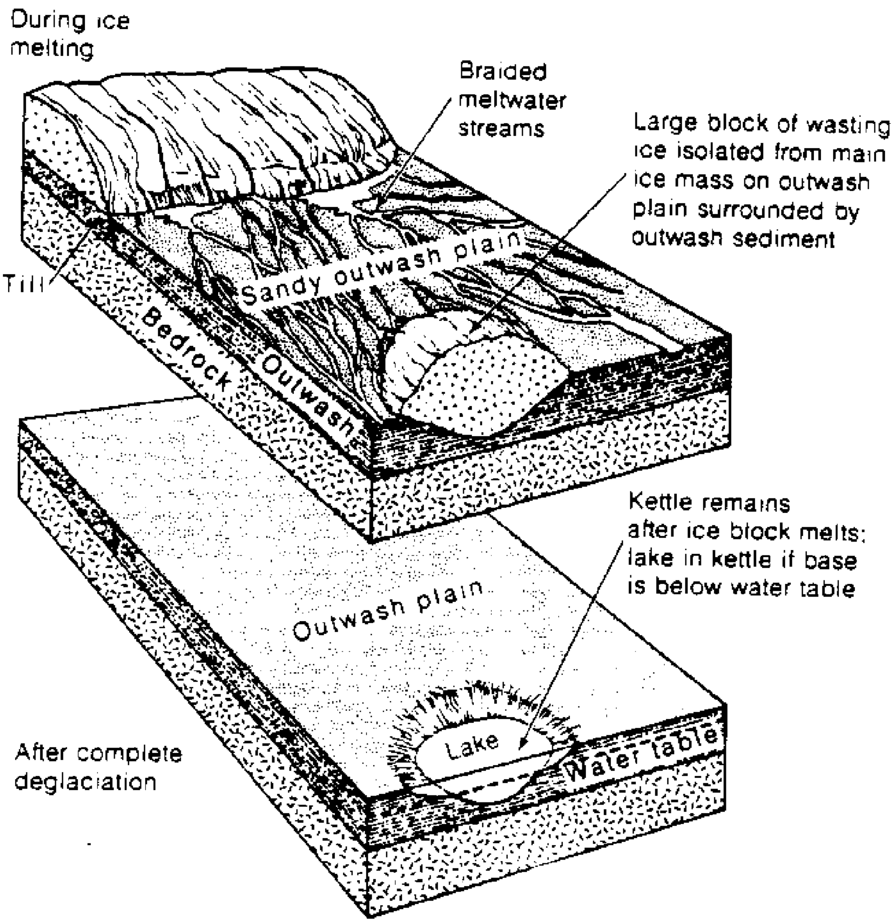
Glacial Geology of the Continental United States



Source: Press, Frank and Raymond Siever, Earth, W.H. Freeman and Company, San Francisco, 1972. [Compiled by C.S. Denny, U.S. Geological Survey.] p. 386.

Figure 1

Evolution of an Outwash Kettle



As a glacier retreats, it may leave behind large blocks of wasting ice that are gradually buried by outwash from the receding ice front. After the front has retreated far enough from the region, outwash sedimentation stops; the ice block melts; and a depression remains which is filled with water if it is deep enough to intersect the groundwater table.

Source: Press, Frank and Raymond Siever, Earth, W.H. Freeman and Company, San Francisco, 1972, p. 382.

Table 2

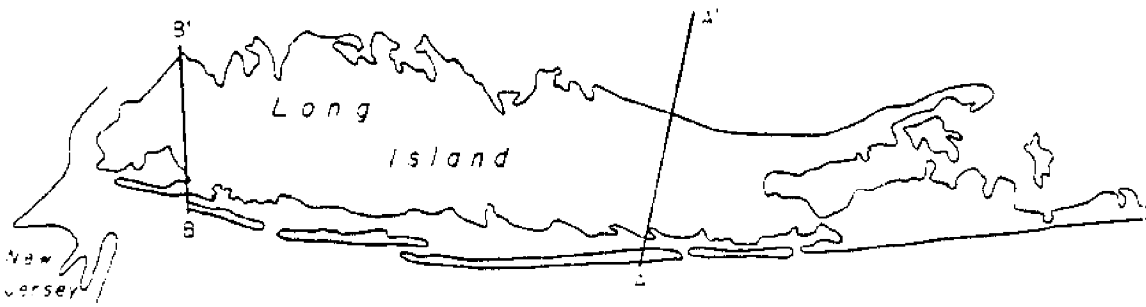
Generalized Stratigraphy of Long Island

Era	Period	Epoch	Unit	Character and origin of deposits
Cenozoic	Quaternary	Holocene		Quartzose sand, beach, and dune deposits and fine-grained, lagoon sediments.
		Pleistocene	Harbor Hill Moraine Ronkonkoma Moraine	Ground and terminal moraine; stratified deposits of sand and gravel, cobbles, and silt and clay.
			20-foot clay	Grayish-green, silty, clayey, glauconitic, fine sand (marine).
			Gardiners Clay	Grayish-green, silty clay (marine).
			Jameco Gravel Mannetto Gravel	Fine-to-very coarse sand and gravel; scattered beds of silt and clay (fluvial or glacial outwash).
Mesozoic	Cretaceous	Upper Cretaceous	Monmouth Group Matawan Group Magothy Formation	Quartzose sand interbedded with silt and clay.
			Raritan Formation Raritan Clay	Silty, sandy, brownish-gray clay with thin beds of sand and gravel.
			Lloyd Sand	Quartzose fine-to-coarse sand and gravel; interbedded clay and silty sand is common.
Precambrian or Paleozoic			Crystalline Bedrock	Undifferentiated, consolidated metamorphic granite.

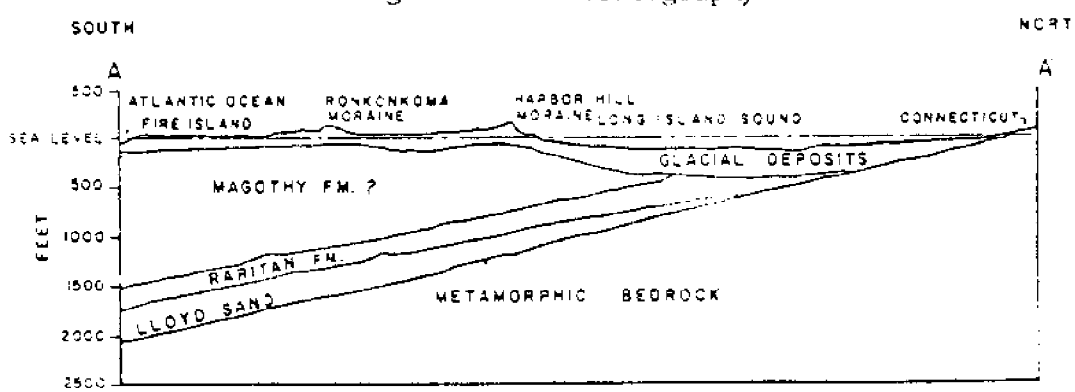
Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure, and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA., TP 76-2, March 1976, p. 18.

Figure 2

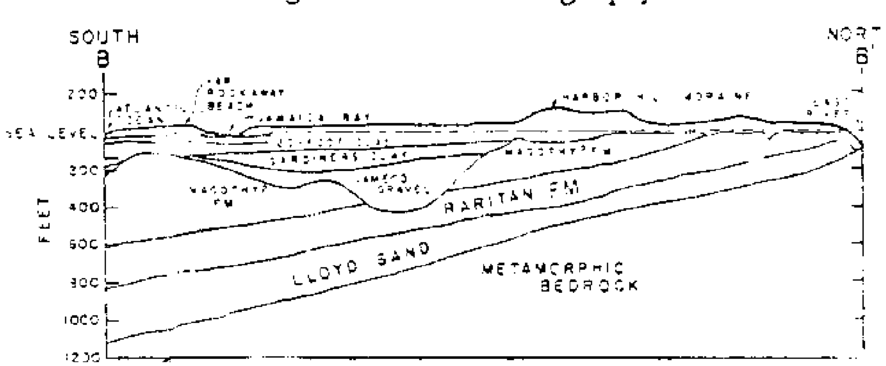
Continental Shelf



Transverse Section of East-Central Long Island
Showing Detailed Stratigraphy



Transverse Section of Western Long Island
Showing Detailed Stratigraphy



Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure, and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., TP 76-2, March 1976, p. 17.

Longshore Drift and Current

Longshore drift and current are important to offshore mining, particularly off South Shore Long Island and New Jersey. These phenomena are caused by the movement of sediment along the shore by wind and wave action. In areas other than river channels, they are major components of resource replenishability.

Longshore drift is the movement of sediment along the shore by the swash (roll up) and backwash (fall back down) of waves. Waves have enough force to move particles of sand and sometimes large pebbles along the shore. The net movement of the material is in one direction, because the waves break at an angle to the shoreline. The swash moves particles at this angle into the shore, while the backwash pulls the material down at right angles; this results in a zig-zag motion down the shoreline.

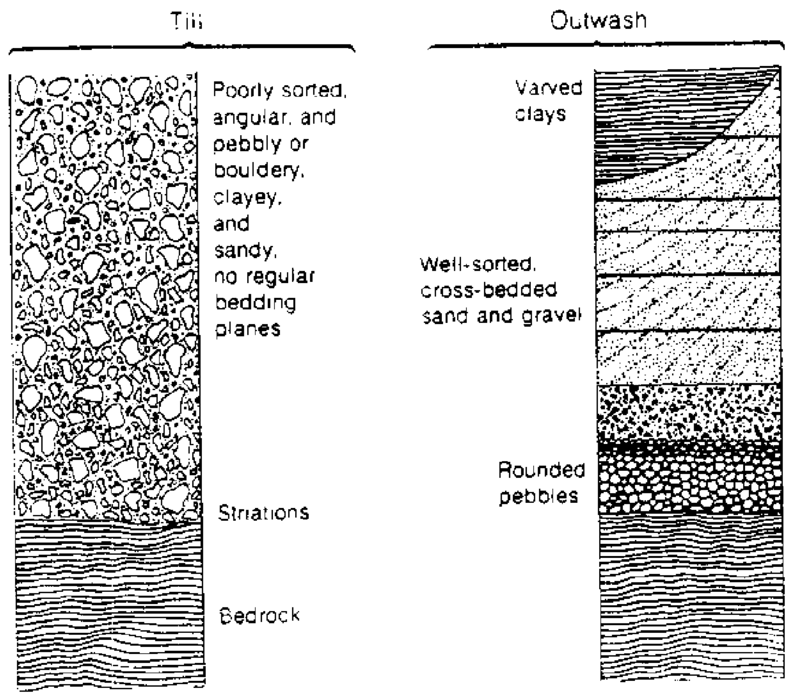
Longshore current is the net movement of water by the same method described above. This movement of water creates a current which carries the material on the bottom in the direction of the wave action.

Wind generated waves hit South Shore Long Island from the south and southeast, resulting in an east-to-west longshore drift and current. Seasonal weather conditions affect the volume of sediment moved. On the average the net volume of sand moved by longshore drift is estimated at 229-458 x 10^3 cubic meters per year (.391-.783 x 10^3 yds^3). There is no predominant longshore drift or current in Long Island Sound because of erratic wind and wave action along the north shore of Long Island and the south shore of Connecticut. There are, however, sketchy patches of east-to-west movement.

Because of its well-defined longshore drift and current patterns, most of the South Shore Long Island area is composed of glacial outwash with scattered outcrops of gravel and coarser material. By contrast, Long Island Sound is mainly a combination of glacial outwash and till. The differences between the two are shown in Figure 5. In subsequent sections, we will elaborate on these conclusions through examinations of cores and samples taken from the study region.

Figure 5

Comparison of Generalized Sections of Glacial Till and Outwash



Source: Press, Frank and Raymond Siever, Earth, W.H. Freeman and Company, San Francisco, 1972, p. 381.

Resource Suitability

To evaluate the "worth" of a sand and gravel resource, one must determine its suitability to standards for use as concrete, aggregate, construction aggregate, and fill [4,45]. An area may have abundant, clean (i.e., homogeneous) sediment which is unuseable because it cannot meet applicable product specifications.

Several associations and agencies publish specifications for mineral aggregate;* the most important to this study are:

1. American Society for Testing Materials (ASTM), typically used for private building projects; and

2. New York State Department of Transportation Standard Specifications for Construction and Material (NYSDOT). All New York public building and highway construction projects use these specifications.

Specifications are either exclusionary or inclusionary: exclusionary meaning that certain elements, compounds, or materials must be either absent from or limited in a product; and inclusionary meaning that the specified product must include certain elements, minerals, or aggregate-particle-size distributions.

Some exclusionary factors considered in these specifications include the content of shells, sodium cloride (NaCl), coal, clay, and chalk. The most troublesome elements, from the perspective of offshore sand and gravel, are shell and NaCl content. The NYSDOT and the U.S. Federal Highway Administration agree that corrosion and spalling can occur when the NaCl content in concrete exceeds 200-350 parts per million (ppm) [12].** The concrete is

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*The Greater London 93 Standards were evaluated, but they are not relevant to our study area.

**NYSDOT Specifications: Fresh concrete 100 ppm, coarse aggregate 200ppm, fine aggregate 350 ppm.

unusable when the shell content exceeds one percent in coarse aggregate and five percent in fine aggregate.* ASTM specifications do not consider NaCl and shell content but do publish limits on the other materials mentioned. Exclusionary standards on coal, chalk, etc., will not present problems for offshore construction aggregate producers in our study area as the quality of the G.N.Y.M.A. resource is superior [44]. Problems posed by NYSDOT NaCl specifications may not be severe. The residual salt content of well-drained, dredged fine aggregate is not expected to exceed 300 ppm before fresh water washing [20]. The NYSDOT has stated that it believes coarse aggregate is extremely limited in the G.N.Y.M.A. and that the shell content for the area "fines" (<1mm) is unlikely to exceed two percent [46].

The inclusionary aspects of ASTM and NYSDOT specifications deal with the geologic materials and particle-size distribution which must be present in the mineral aggregate, for use in certain products. These specifications are too numerous and complicated to reproduce in this report, particularly those of NYSDOT. Primarily they call for particular particle size distributions by weight of coarse gravel (greater than 4mm), gravel (>2mm), and sand (.125-2mm). Some latitude is permitted within these distributions to allow for the inherent variability of natural aggregate. The sources most critical aspect of inclusionary specifications is a requirement for gravel (>1mm), which most typically exceed 50 percent by weight of the product aggregate. Most products used in highway and building construction require large percentages of gravel. Some products which do not are mortar and highway curbs. Since the G.N.Y.M.A.'s offshore mineral aggregate consists mostly of coarse-to-fine sand, these product specifications will pose severe suitability problems. Offshore producers of sand and gravel

*These are NYSDOT specifications.

in the G.N.Y.M.A. would need to provide extensive and expensive onshore processing to provide a suitable end product.

Of the specifications applicable to the G.N.Y.M.A., the NYSDOT specifications are the most detailed. They are typically used for all publicly funded highway and building construction in New York State. For other construction, the much less stringent ASTM specifications are used. This report does not deal directly with the types of rock which must be included in materials, as this is not perceived to be a severe problem.

Specifications for fill are much less stringent than those for construction aggregate. They are published for individual project uses: by the state for public uses and by private contractors for non-public uses. The main concern in obtaining fill is to insure that the aggregate is sufficiently fine. The specifications used by the New Jersey Turnpike Authority are typical for most fill uses and are shown in Table 3. The focus of these specifications is clearly to limit the amount of silt to less than 2-10 percent by weight, and to exclude large pebbles and rocks.

Table 3

New Jersey Turnpike Specifications For Fill Sand

Special Subgrade Material Grade A

Sieve Size	Total % Passing thru the Sieve by Weight
7.62 mm	100%
.297 mm	8-65%
.074 mm	0-6%

Special Subgrade Material Grade B

Sieve Size	Total % Passing thru the Sieve by Weight
7.62 mm	100%
.297 mm	8-65%
.074 mm	0-10%

Sand Blanket

Sieve Size	Total % Passing thru the Sieve by Weight
9.51 mm	100%
2.38 mm	30-100%
.23 mm	0-20%
.074 mm	0-2%

Common Embankment

Sieve Size	Total % Passing thru the Sieve by Weight
.074 mm	0-10%

Source: Construction Aggregates Corp., "New Jersey Turnpike Specifications for Fill Sand," furnished by James Marotta.

Sand and Gravel Distribution Offshore of the G.N.Y.M.A. and Interpretation by Area

The area offshore considered appropriate to satisfy the G.N.Y.M.A.'s demands for sand, gravel, and fill stretches from Atlantic City, New Jersey, to the western border of Rhode Island. Included are Long Island Sound, New York Harbor, and South Shore Long Island (see Map 2).

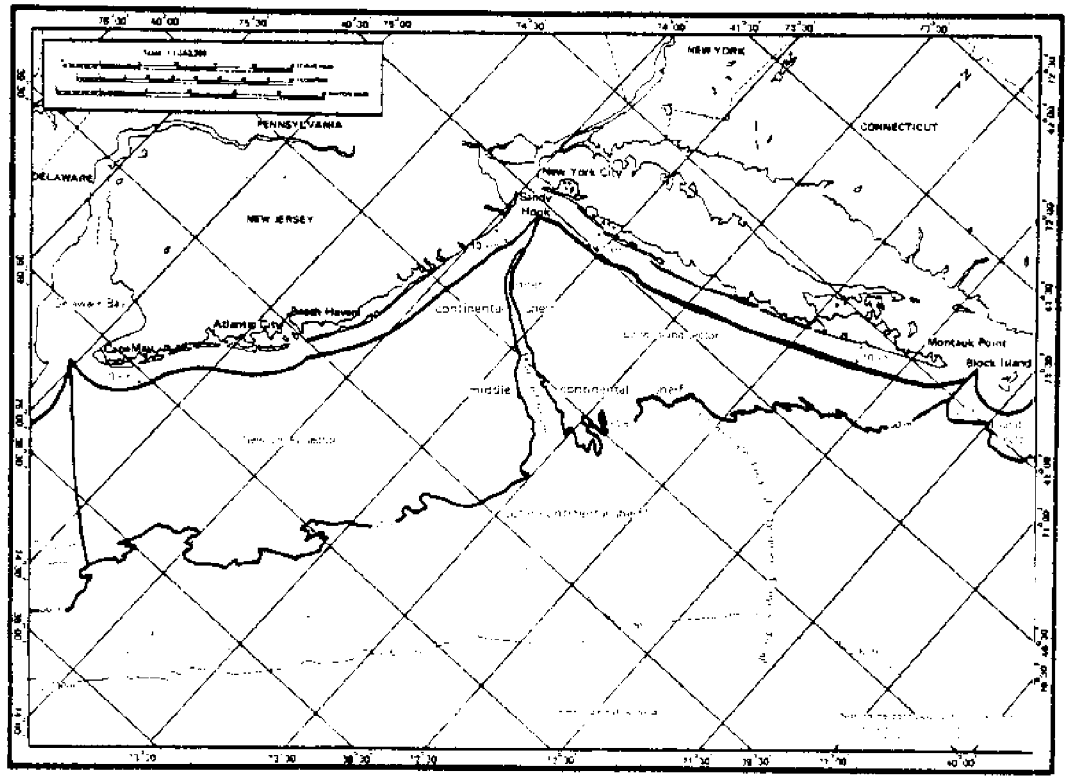
Data are presented and considered out to the 600-foot depth contour although current economical dredging depths are 0-100 feet. The lower limit is variable, established by the dredging vessel's loaded draft. The upper limit, is a function of the actual dredging mechanism's design. Typical hydraulic suction dredges operate in depths between 30 and 100 feet, although Hydrojet and air-lift dredges can operate at depths of 200' and 1,500' respectively (see Figure 6). Currently, the most favorable conditions for mechanical dredging are deposits near shore in less than 30 feet of water [41].

Hydraulic suction dredges are currently favored over air-lift and hydrojet dredges because of their economical capital investment, manageable maintainence costs, low energy costs, and large production outputs. Air-lift and hydrojet barges are the products of more recent technology and have not been completely recognized by the world dredging community.

Data in the following sections are presented at a level of detail sufficient for a regional economic analysis. More detail and quantitative structure would be necessary to induce the large-scale investment required to mine offshore for a mineral aggregate market other than fill. A survey format has been used, including data collected from grab samples and seismic/vibra-cores. Because of the differences between these two methods, areas of resource potential lack clarity of exact special qualifications

Map 2

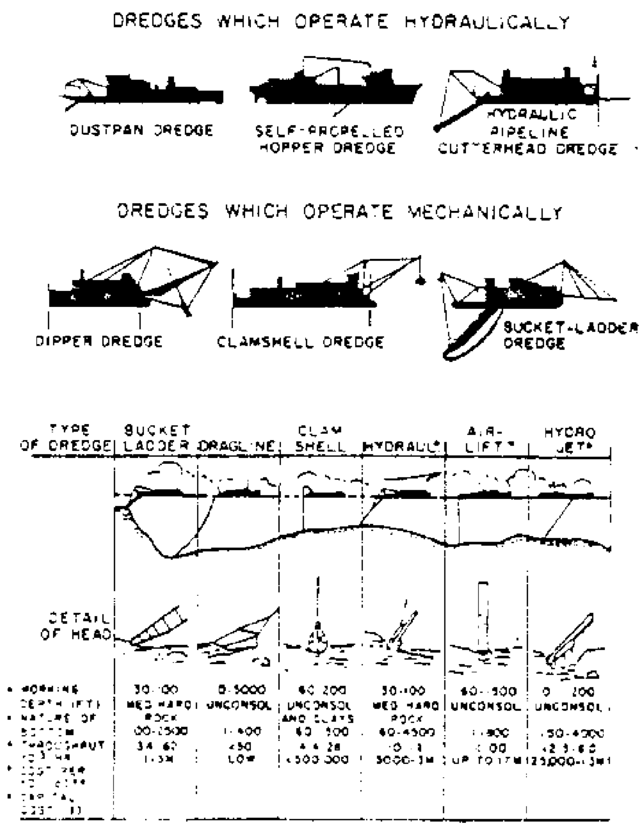
"General Locator" Map of New York Bight Study Area



Source: Schlee, J. and P. Sanko, "Sand and Gravel," New York Sea Grant Institute, MESA New York Bight Atlas Monograph 21, July 1975, p. 9.

Figure 6

Basic Dredge Types and Methods of Marine Ore Exploitation



*Each of these systems may be used with or without a cutter head

**Costs are for actual operations at less than 200-foot depths.

Source: Grant, Malcolm J., Rhode Island's Ocean Sands: Management Guidelines for sand and gravel extraction in state waters. University of Rhode Island Marine Technical Report No. 10 Narragansett, R.I., 1973, p. 10, Reprinted from Mero, John L. Review of Mineral values on and under the ocean floor. Exploiting the Ocean, Washington, D.C.: Marine Technology Society.

(i.e., grab samples indicate only surface sediment, while seismic/vibra-cores yield sediment characteristics with depth and clues to sediment structures within an explored geographic area). The definition by size of terms used is given in Table 4.

Table 4

Terminology

Sediment	Size (mm)
gravel	>2
very coarse sand	1.0 to 2.0
coarse sand	0.5 to 1.0
medium sand	0.25 to 0.5
fine sand	0.125 to 0.25
very fine sand	0.0625 to 0.125
silt and mud	<0.0625

Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure, and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., TP 76-2, March 1976, p. 87.

Long Island Sound

Donohue and Tucker [16] explored the largest resource area known in Long Island Sound by vibra-core sampling and seismic profiles. Forty-seven vibra-cores were taken across the sound (see Map 3). Each core was considered for its economic potential in terms of heavy metals and sand and gravel. This economic potential was assessed from "particle size distribution and mineral composition" [16]. Table 5 summarizes their results for each core.

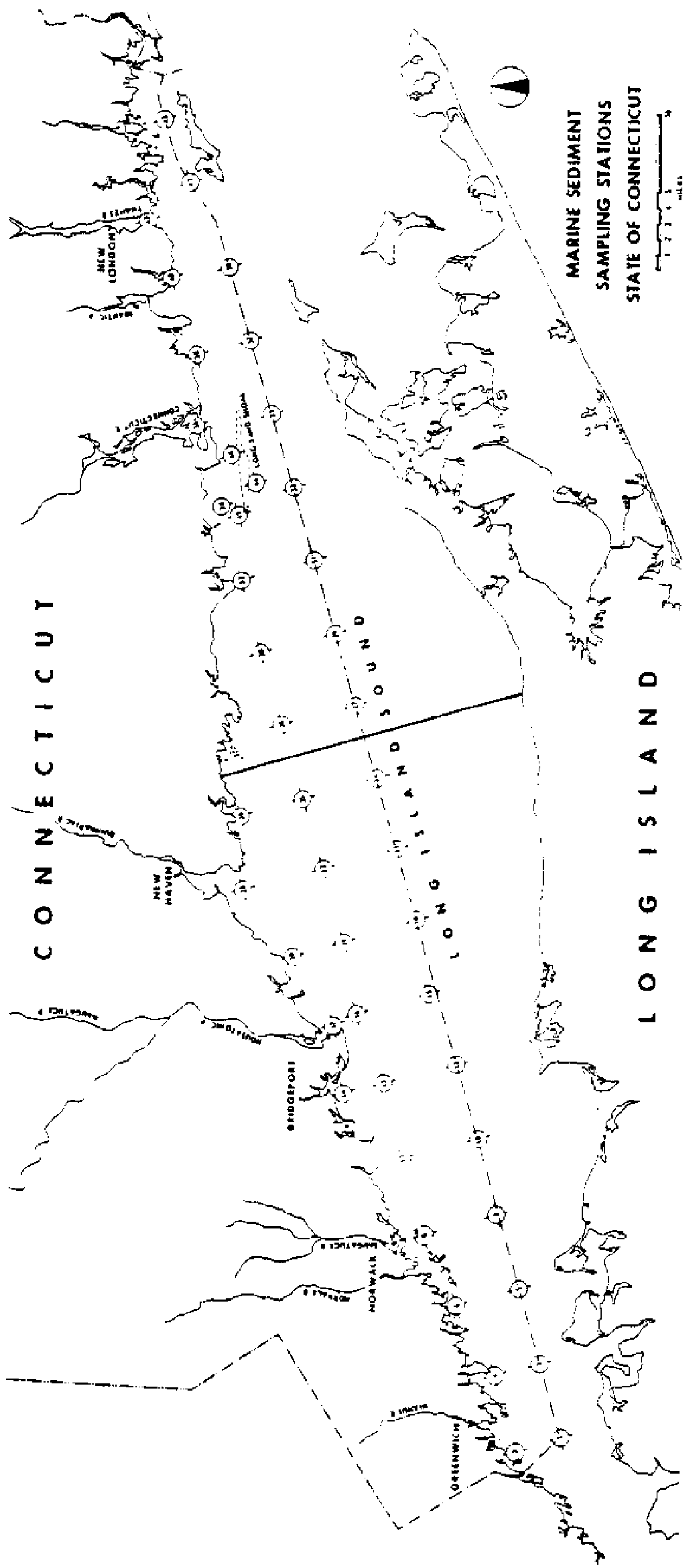
Donohue and Tucker divided the Long Island Sound study into two sections, east and west, for the purpose of generalized interpretation. The east section consists of core samples 27-46, east of Indian Neck, Connecticut, and the west section consists of cores samples 1-26, west of Indian Neck.

The western section consists predominantly of mixed sand with silt and/or clay. Clean sand with mean grain-size diameters less than 2mm exists in a pocket offshore from Bridgeport, Connecticut, to New Haven. This sand contains little silt and/or clay and can be mined at depths which are economical. Isolated pockets of gravel occurring within this area are sufficiently large to support offshore production of construction-quality gravel. This aggregate, while abundant and with low shell content, is not by itself suitable for most construction uses because of its low mean grain-size diameter. This sediment would be suitable for industrial use, supplemental sand for construction use, beach replenishment, and fill.

The eastern section is much like the western section. The area consists mostly of mixed sand with silt and/or clay. A pocket of

Map 3

Study Area of Donohue and Tucker



Source: Donohue, J.J., and F.B. Tucker, "Marine Mineral Identification Survey of Coastal Connecticut." United Aircraft Research Laboratories under a grant clean sand stretches along the shoreline from New Haven to Mystic, Connecticut. This sand seems to possess the same characteristics as the clean sand pockets within the western exploration section. Isolated pockets of sparse gravel located in this area are not sufficient to warrant special extraction methods.

Detailed summary results for Donohue and Tuckers cores are given in Appendix A.

Dr. David B. Duane [17] of the U.S. Army Coastal Engineering Research Center conducted a study off Bridgeport, Connecticut, in 1966-1969, which utilized seismic reflection profiling supplemented by coring of the marine bottom. This was undertaken as part of a sand inventory program for New England.

The Bridgeport "grid" (study area) extended along the Connecticut Coast from Stratford Point west to the Saugatuck River, and approximately 1-6 miles offshore (see Map 4). Duane found two significant deposits of sand. One conforms approximately to the locations of Donohue and Tucker's core samples #16 and #17, thus confirming the identification of sand deposits there. The other deposit is off Norwalk, Connecticut, east of the Saugatuck River (near Donohue and Tucker's Core #5). Donohue and Tucker reported that they believed a heavier concentration of sand and gravel existed in this area than was shown by their core samples.

These two deposits are separated by an area of fine sands, silts, and clays. The Norwalk deposit averages nearly nine feet thick and is composed predominantly of medium-to-coarse-grained quartz sand (.25-1.0 mm), with isolated gravels. The Bridgeport deposit consists of similar sediment without any gravel but larger in area and volume.

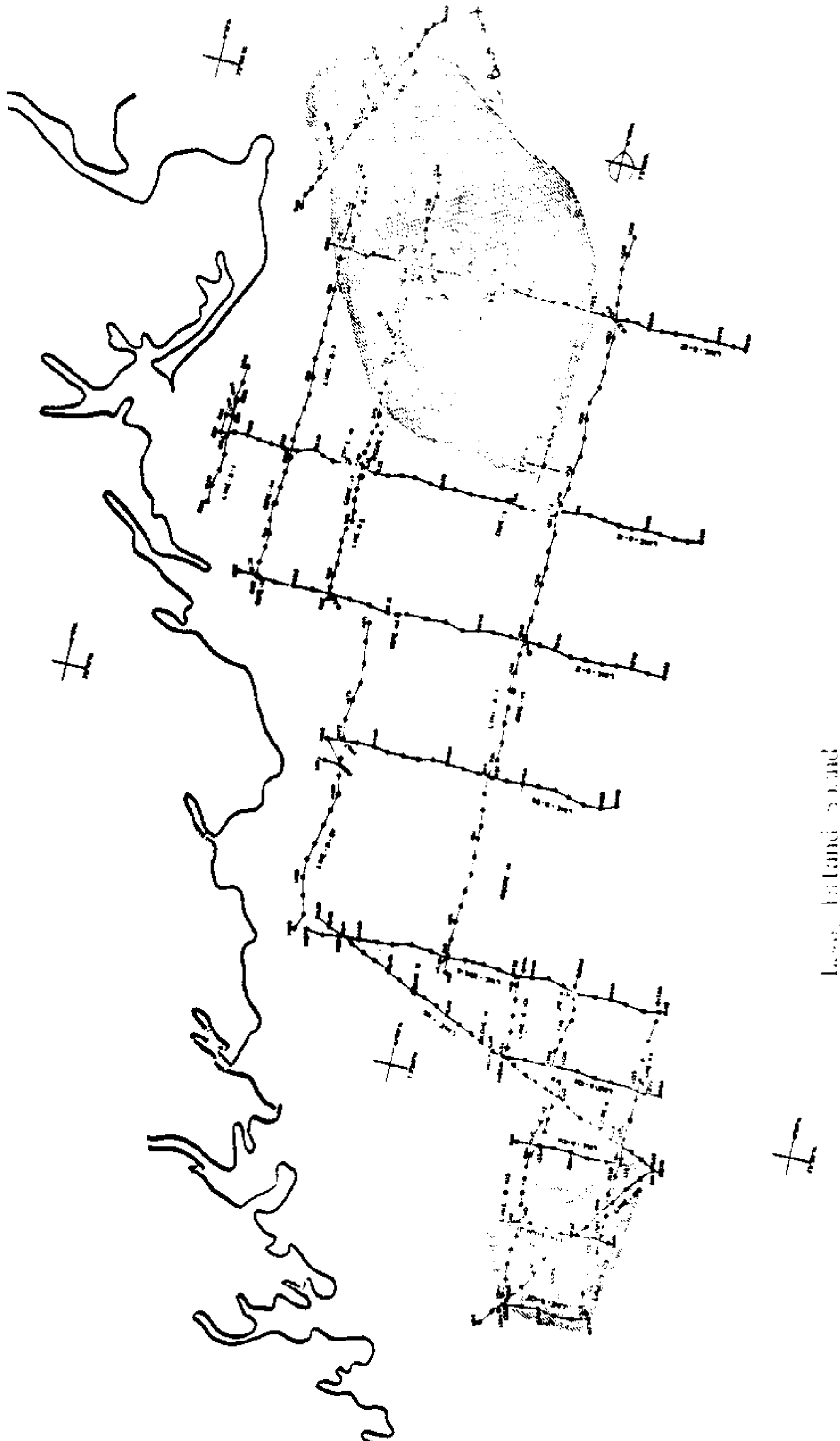
The sediments identified by Duane and later confirmed by Donohue and Tucker [16] are characterized by small mean grain-size diameter and lack of suitability, by themselves, for nearly all construction uses. Therefore, like the material in the western section such sediments are suitable for beach replenishment, fill, supplemental sand for construction uses, and some industrial uses.

Reports by Island Complex Offshore New York/New Jersey *(ICONS) entitled "Quick-Look Report of Long Island South-Bridgeport, Connecticut, Area" and "Quick-Look Report of Norwalk Islands Area-Long Island Sound" are supportive of the findings of Duane and Donohue and Tucker. These provided reports provided core data taken by ICONS off Norwalk Islands and Bridgeport, Connecticut. Summary results are given in Appendix B.

The bottom of the Norwalk Island Shoal is smooth and dips gently southward. All of the cores taken in this area contain some sand which appears to be continuous but is covered locally by mud or muddy sand. When observed vertically, layers of sand, silty sand, and pebbly sand alternate and do not correlate from core to core. The greater part of the sand recovered from these cores contained a large volume of particles with diameters around .400 mm, which is desirable for beach fill, but the overall mixture is either much finer or much coarser. The most uniform sand in this area was found in Core 9, with a median diameter of .425 mm. From geophysical records, this core appears to have been taken at the inshore end of a low southward projecting ridge. If the uniform, gray sand characteristic of Core #9 is the material making up the ridge, then the ridge area could contain a volume of approximately 5.2×10^6 cubic yards of uniform sand, suitable for beach replenishment. All

Map 4

Study Area of Duane



Source: Duane, D.B., "Sand Inventory Program-A Study of New Jersey and Northern New England Coast Waters," Shore and Beach, Vol. 37, No. 2, 1969, p. 38.

of the sediment in this area, by itself, is unsuitable for almost all types of construction due to uniformly small grain-size diameters.

The Bridgeport Shoal is three nautical miles wide at the base and extends about three nautical miles south from this base to a triangular apex. Depths over this shoal range from 0-35 feet at mean low water. The shoal is a sandy body of varing thickness (0-30 feet with the southern one-third being the thickest) with its edges overlapped by muddy sediment. The sand in this shoal is typically light brown, medium-to-coarse (.250-1.00mm) quartz sand with sparse shells and local areas of up to 15 percent small gravel (>2mm). The sand is clean, without mixtures of silt and/or clay, and exists in relatively homogeneous pockets throughout the shoal. Typical uses for sediment from this area might be fill, supplemental construction sand, and beach replenishment. Although local areas of gravel do occur the quantity does not appear sufficient to special mining for construction-grade gravel.

Conclusions: Long Island Sound

From the exploratory studies already completed, it is evident that clean sand exists predominantly in two areas: off Norwalk Islands and off Bridgeport, Connecticut. Clean sand with little silt and/or clay may also exist close to shore from Bridgeport to New London, but this is substantiated only by Donohue and Tucker. Separating these zones, and predominant throughout the rest of the study area, is sand mixed with high concentrations of silt and/or clay. Material containing silt must be washed to produce particle sizes suitable for most construction or beach fill purposes. Production of suitable construction aggregate also would require the addition of coarser material to satisfy ASTM and NYSDOT standards.

One economic way of obtaining construction quality aggregate would be offshore production, returning the unused material, predominantly fines, to the water. It has been found, however, that significant washing operations on board dredging equipment would introduce deleterious turbidity, excessive release of nutrients, or anoxic conditions associated with the release of silt material [41].

American dredging firms currently do not have the dredging facilities to economically mine the clean sediment which exists at depths in excess of 100 feet. They would be most interested in the near-shore, shallow-water deposits (<30' water) occurring near Bridgeport and Norwalk Islands and near shore from Bridgeport to New London. However, a major part of the Connecticut shore west of the Connecticut River and out to the 40-foot depth is unavailable for mining because it is legally set aside for leased oyster beds [41].

A summary of our findings is given in Table 5.

Table 5

Summary Results Of Exploration In Long Island Sound

Area	Sub-Area	Composition	Volume	Discussion
Western		Medium-to-coarse sediment intermixed with silt and clay.	N/A*	Material except for areas outlined below is suitable for commercial dredging.
	Bridgeport Shoal	Light brown, medium to-coarse quartz sand, sparse shells and local gravel.	150M yds	Homogeneous patches of material exist which would be suitable for commercial dredging for fill and low grade aggregate product
	Norwalk Ridge	Uniform, medium, (.425mm) grey sand.	5.2m yds^3	Suitable for beach fill; little value in construction uses other than for supplemental fine-medium sand.
	Norwalk Islands	Non-uniform sand, coarse to fine with local patches of silt.	130m yds	Discontinous non-uniform mixtures would not be ideal for large-scale commercial extractio
Eastern	none	Sand mixed with silt and/or clay.	N/A*	Possible clean sand existing near shore from Bridgeport to New London, Connecticut, but unsubstantiated and unavailable due to oyster beds.

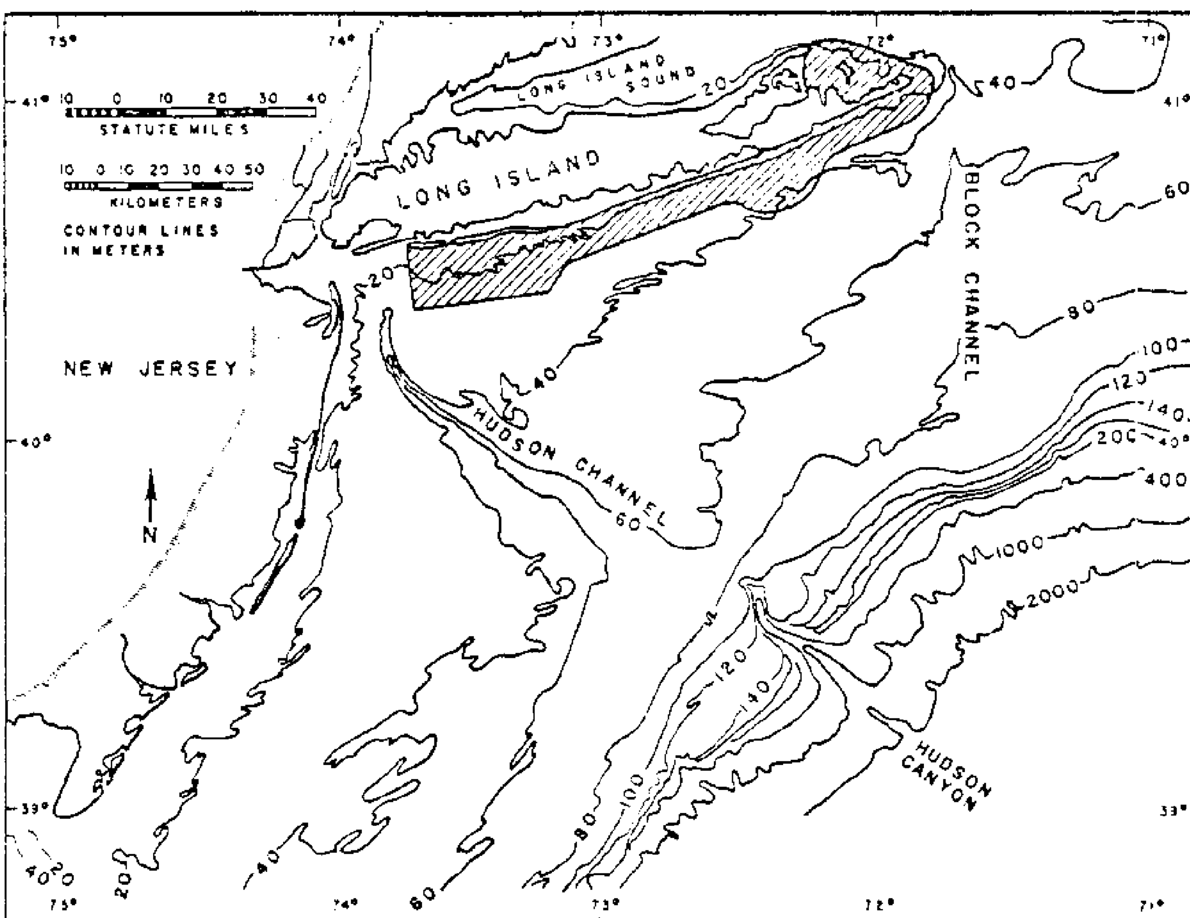
*N/A sampling was not complete enough in these areas to yield suitable volume estimates.

South Shore Long Island

Williams [68] has compiled the most complete report available on sediment resource availability off the South Shore of Long Island. 735 miles of high-resolution continuous seismic profiles and 70 vibra-cores were obtained. In addition, data were analyzed from 82 sediment cores and 225 seismic records. The vibra-cores and continuous seismic profiles were undertaken by the Coastal Engineering Research Center, while the sediment cores were taken along proposed sewer outfall lines in Nassau and Suffolk counties. The study area is displayed in Map 5.

Map 5

New York Bight Study Area



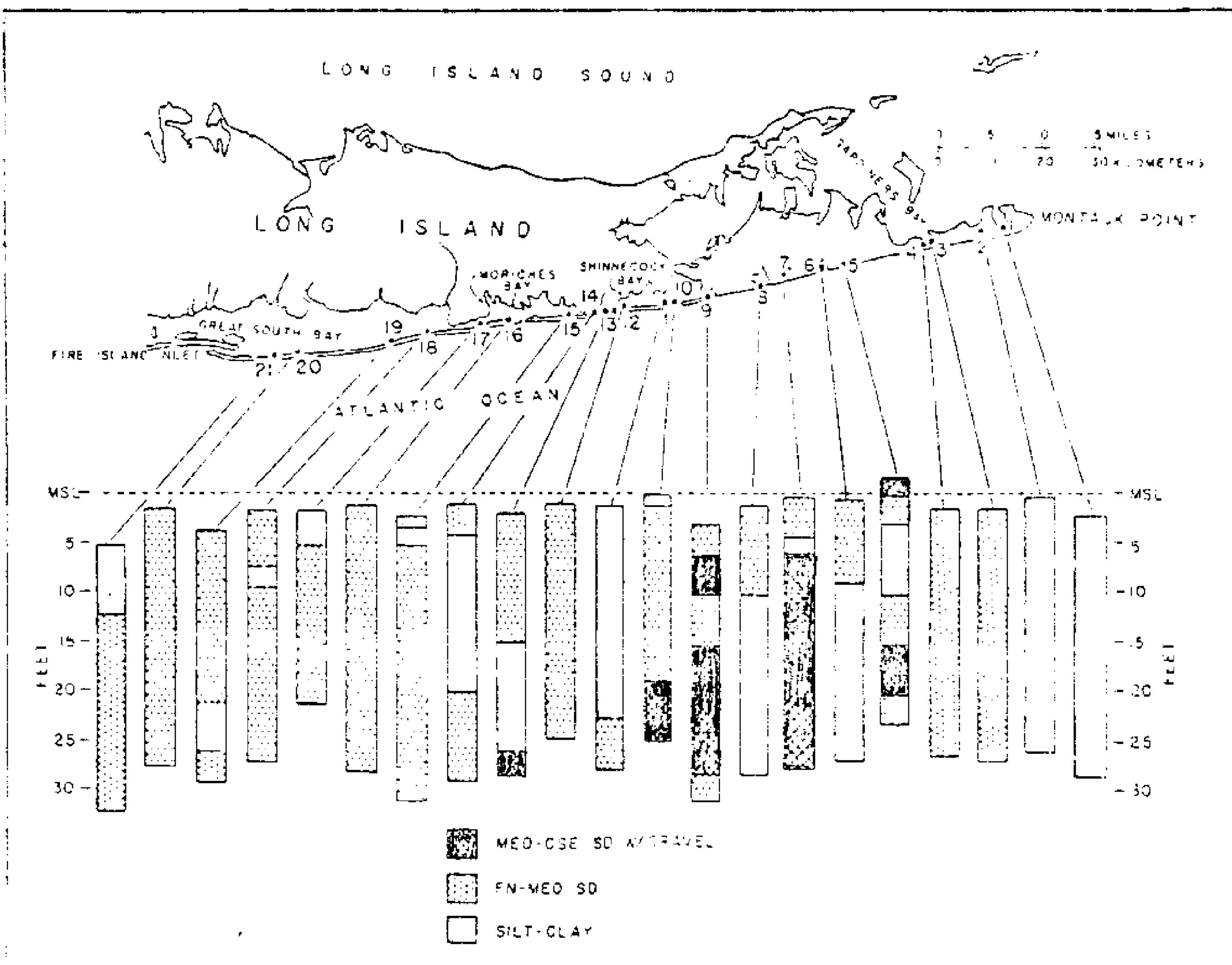
The map shows the extent of seismic and core data coverage (shaded area) and the major submarine physiographic features.

Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure, and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., TP-76-2, March 1976, p. 11.

In Figure 7, typical stratigraphic sequences of sands, silt, and/or clay are reproduced from 21 borings taken from along the South Shore of Long Island [63, 64]. The preponderance of fine-to-medium sand (.125-.5 mm) interspersed with organic silt and/or clay is immediately apparent from this visual display. Little medium-to-coarse sand with gravel occurs (.25-1.00 mm) other than in heterogeneous mixtures with fine-to-medium sediment and silt.

Figure 7

Visual Display of Cores Taken from South Shore Long Island
Showing Stratigraphic Sequences of Sand and Mud



Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA., TP-76-2, March 1976, p. 40.

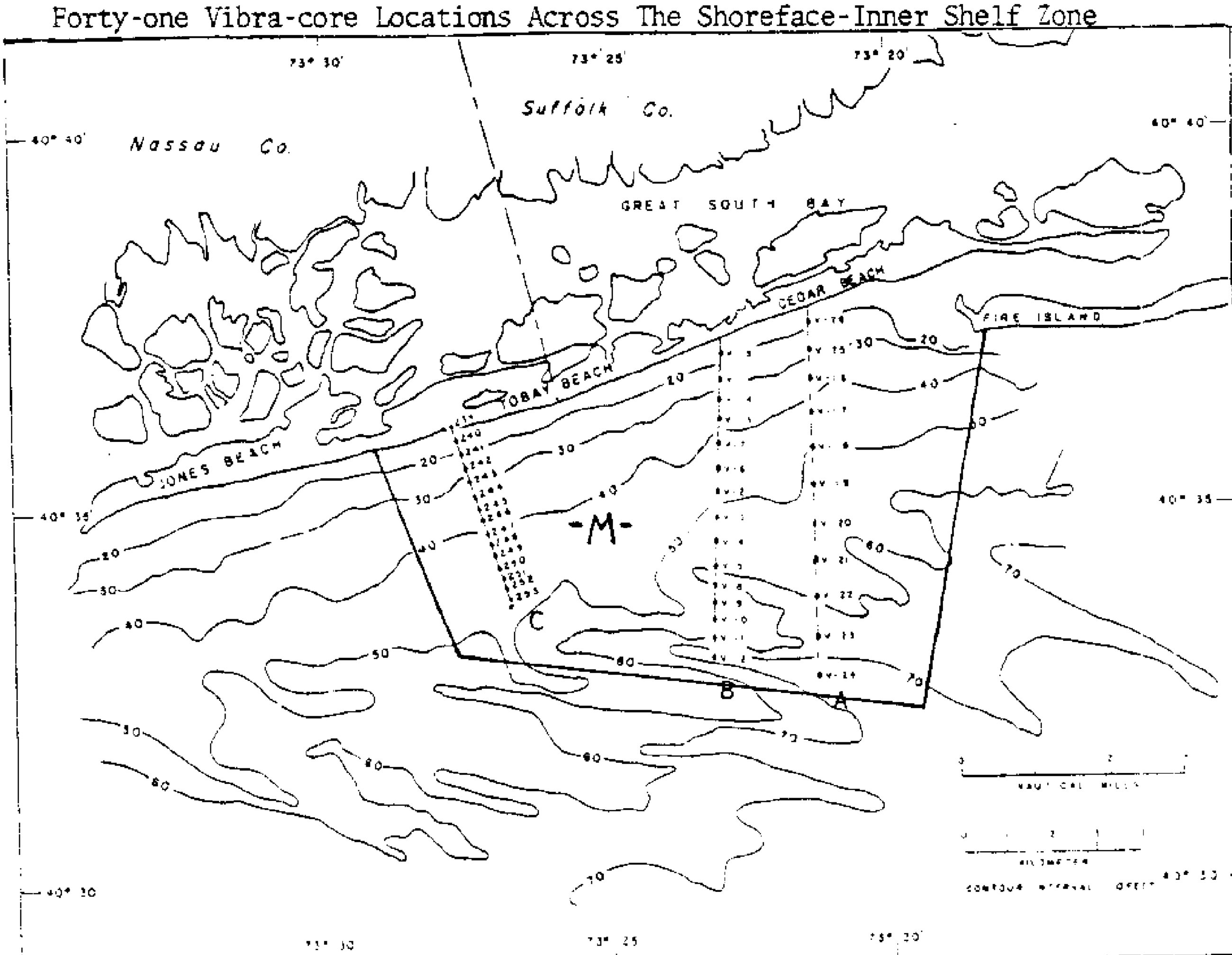
From this analysis, it appears that south shore sediment is very similar to that typically found in Long Island Sound. A few homogeneous (clean) areas of sand are apparent, separated by the "typical" sediments consisting of fine-to-medium sand mixed with sand and/or clay.

Williams presents extensive data to supplement these "visual cores," consisting of seismic profiles, vibra-core descriptions, granulometric data silting, and geologic history. It is beyond the scope of this report tc analyze such data in detail. Instead, the data are summarized and reported based upon 14 sub-areas outlined by Williams. (See Map 6 and Appendix C)

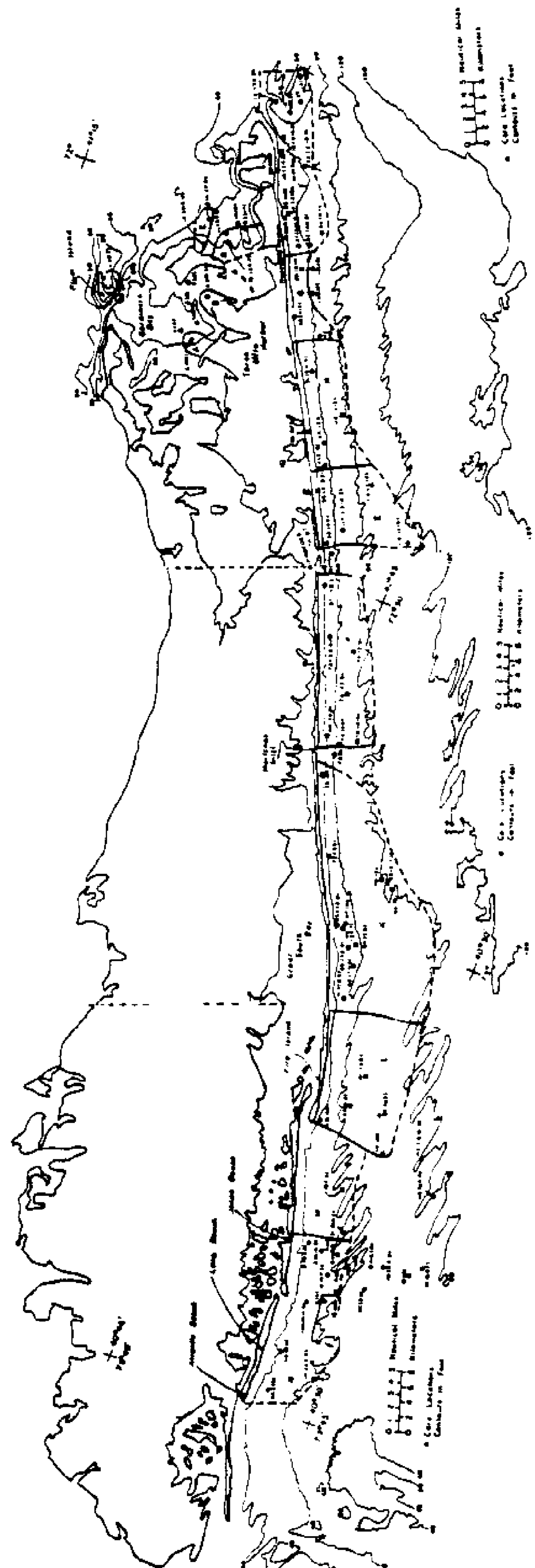
Area M is unique, including the largest number of cores of any area (a total of 41 cores are located and described in Figures 8 and 9).

Figure 8

Forty-one Vibra-core Locations Across The Shoreface-Inner Shelf Zone



Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir,



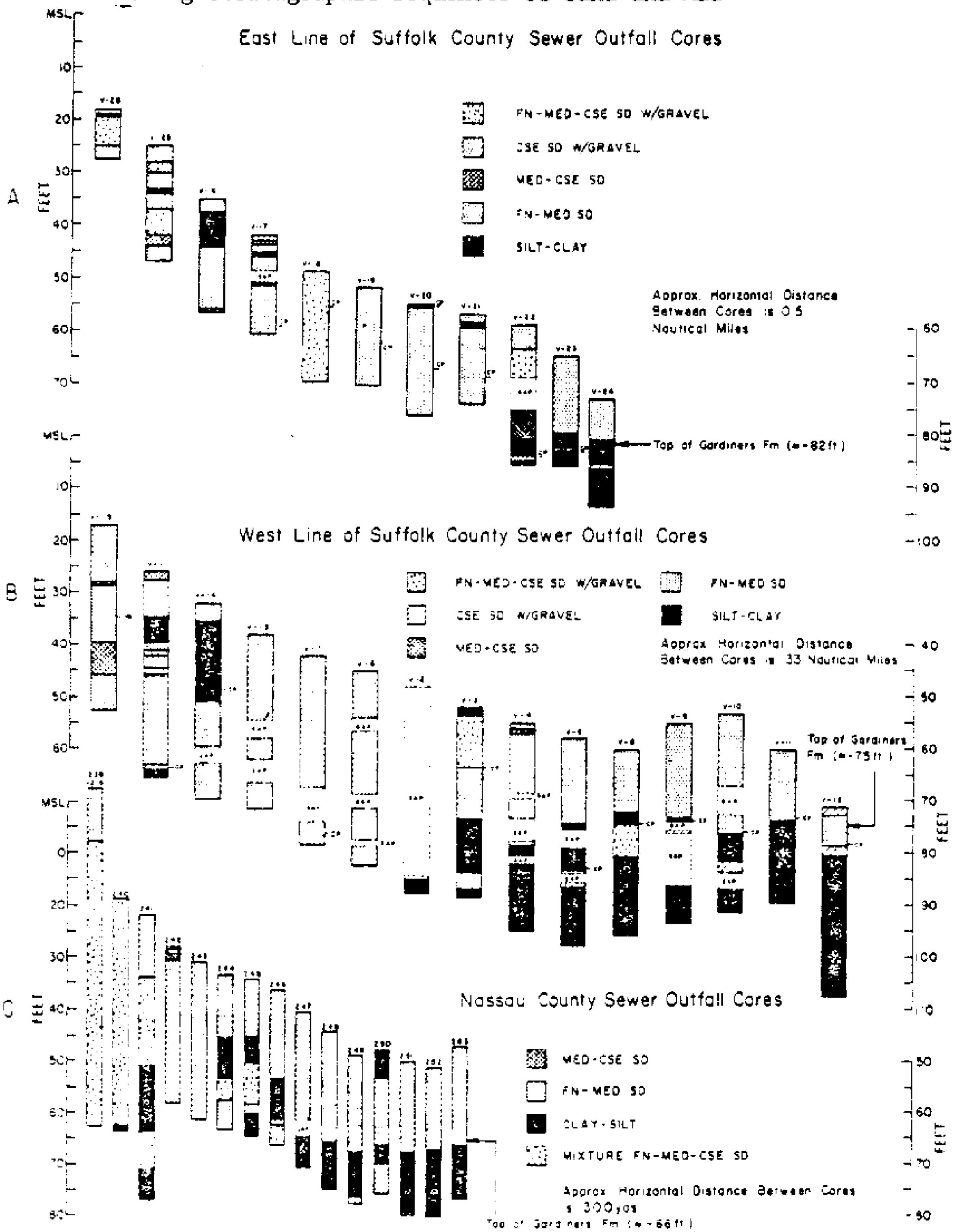
Map 6

Study Area of Williams

Source Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure, and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., TP 76-2, March 1976, p. 68-73.

Figure 9

Visual Display of Cores Taken From Shoreface-Inner Shelf Zone (Area M) Showing Stratigraphic Sequences of Sand and Mud



Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure and Sediments of the Atlantic Inner Continental Shelf Off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., TP 76-2, March 1976, p. 32.

The Nassau County sewer outfall cores show that the upper 12-30 feet of shelf sediment in this region are composed of fine-to-medium sand with lesser amounts of coarse and fine sand, silt, and clay. A continuous clay/silt surface is present at the -50 foot MSL (mean surface level) inshore (Core #24) and seems to slope offshore and then level off at approximately -66 foot MSL (Cores #247, #253).

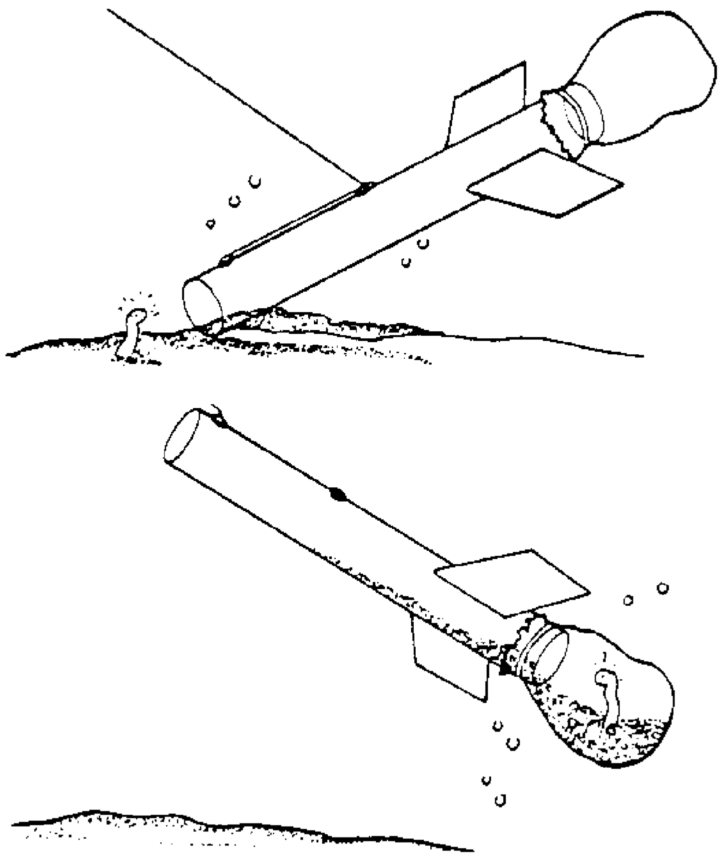
In the Suffolk County Sewer Outfall Study, most cores shoreward of the 50-foot bathymetric contour contained varied stratigraphic sequences of fine-to-medium-to-coarse sand above and below layers of silt-clay (except Cores #13, #7 and #6, which contain continuous sand sequences). All of the cores seaward of the 50-foot depth contour show 10-23 feet of sand overlying a flat, featureless, silt-clay substructure at the -73 foot MSL. Because of the stratification with silt and clay in this area, its suitability for construction-grade aggregate is questionable.

Friedman and McKinney [24] analyzed surface sediments off southern Long Island with a Phipps Underway Grab Sampler (see Figure 10). The study area (see Map 7) roughly conforms to Williams' areas K and L, extending seaward in a southeasterly direction to the 100-fathom depth level (600 feet). (This report and its mother thesis [36] are technical by nature). Only surface sediment was collected and analyzed, with no substantiated conclusions as to sediments existing below the surface. Since the study area extends to the 600-foot depth contour, many deposits are beyond current feasible dredging depths. For the purpose of this study, sediment analysis cut to the 20-fathom (120 feet) depth is relevant (see Figures 11 and 12).

Friedman and McKinney's analysis very closely conforms to Williams' study of the surficial sediment in areas K and L. The material consists of clean, fine-to-medium sand with little coarse sand and gravel.

Figure 10

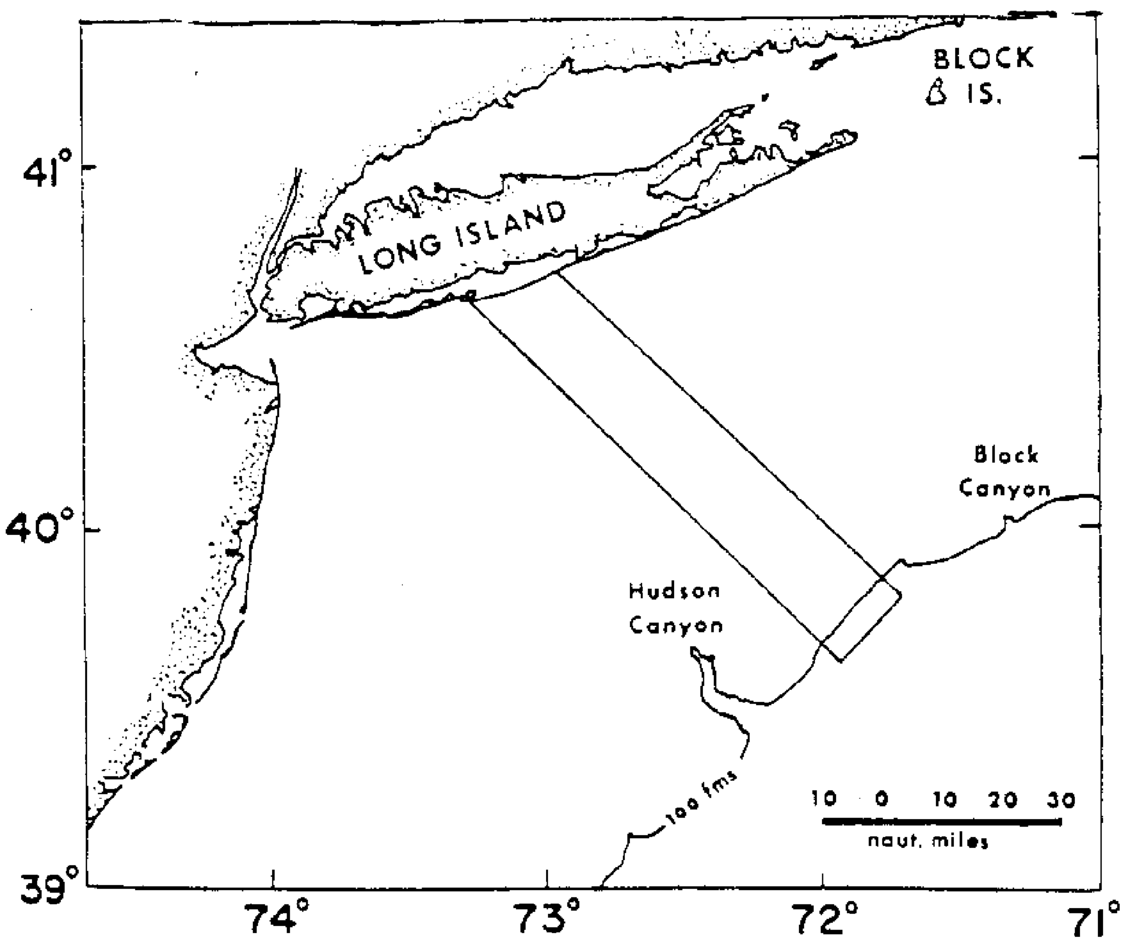
Operation of the Phipps Underway Grab Sampler



Source: Friedman, G.M. and T.F. McKinney, "Continental Shelf Sediments of Long Island, New York," Journal of Sedimentary Petrology, Vol. 40, No. 1, p. 213-248, March 1970.

Map 7

Study Area of Friedman and McKinney



Source: Friedman, G.M. and T.F. McKinney, "Continental Shelf Sediments of Long Island, New York," Journal of Sedimentary Petrology, Vol. 40, No. 1, p. 213-248, March 1970.

Figure 11

Sample Locations, Bottom Topography, and Mean Sediment Grain Sizes for Friedman-McKinney Study Area (contour interval is five fathoms)

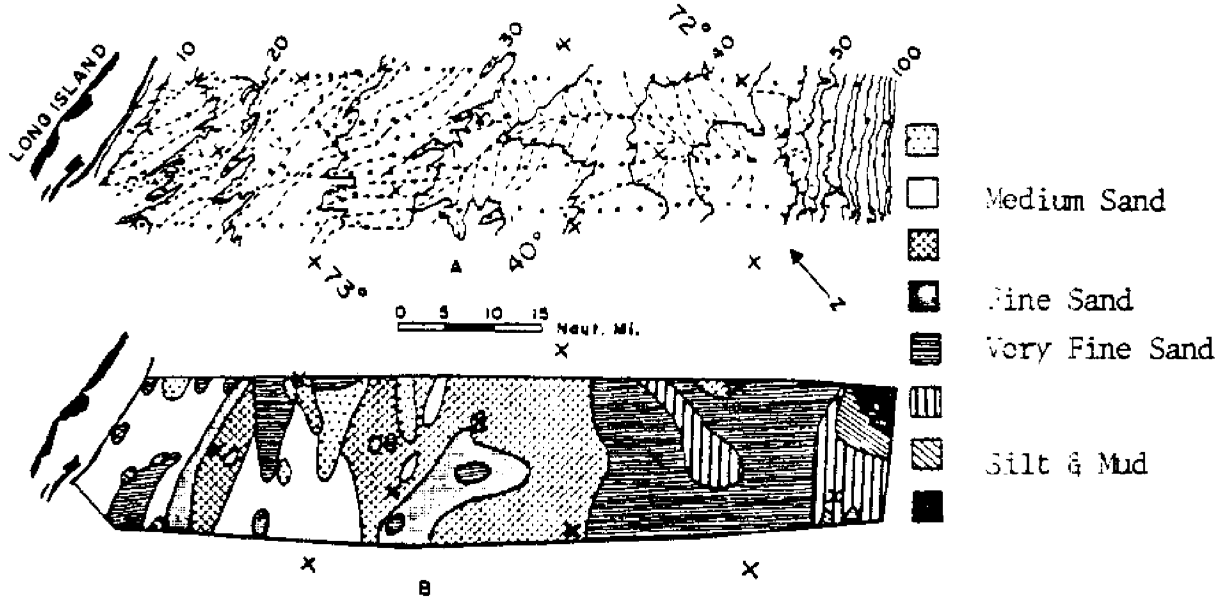
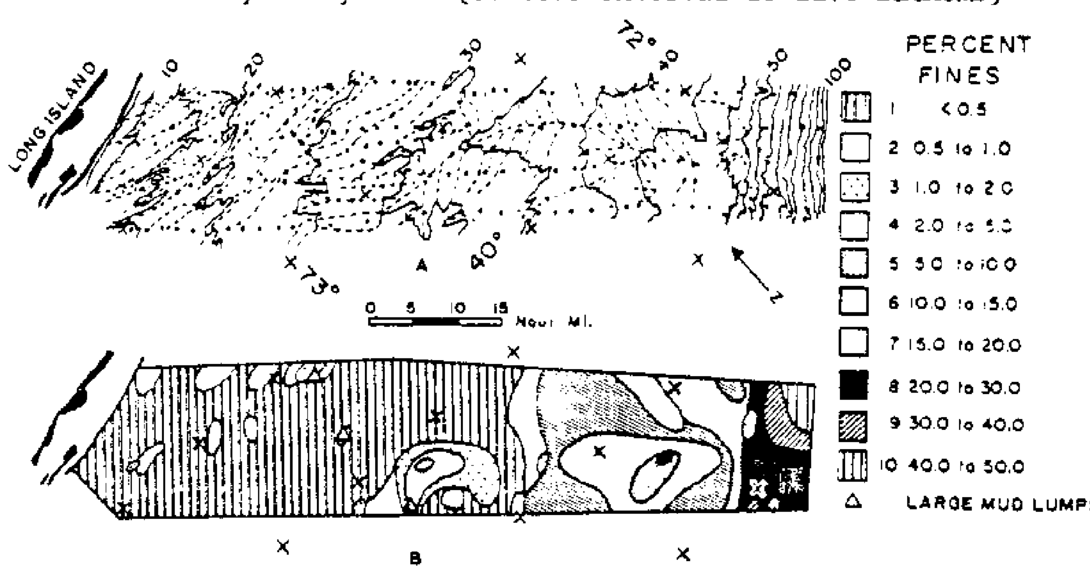


Figure 12

Sample Locations, Bottom Topography, and Percentage of Fine Sediments, Friedman-McKinney Study Area (contour interval is five fathoms)



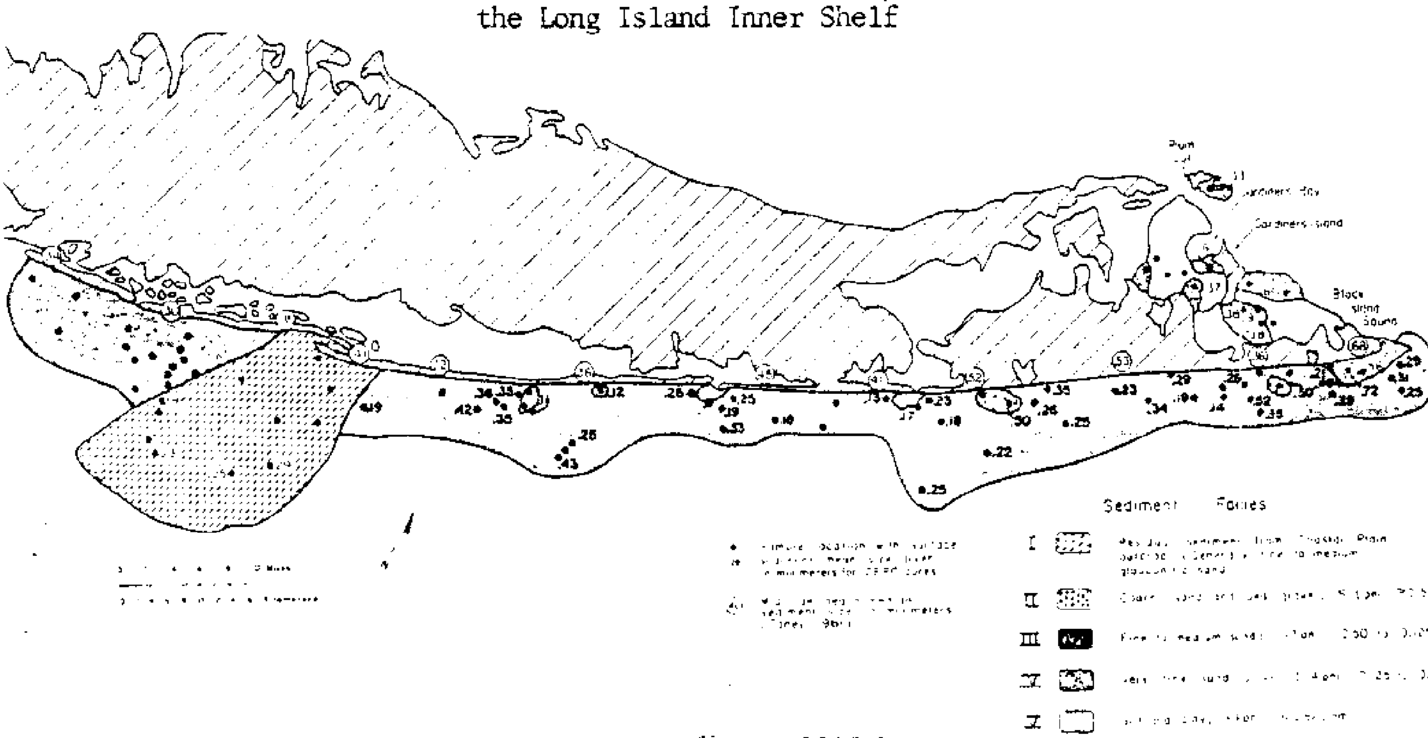
Source: Friedman, G.M., and T.F. McKinney, "Continental Shelf Sediments of Long Island, New York," Journal of Sedimentary Petrology, Vol. 40, No. 1, p. 213-248, March 1970.

South Shore Conclusions

The surface sediment distribution of the South Shore study area is shown in Map 8. Data for this map is based on core sediment analyses and on extrapolation between cores by seismic profiles.

Map 8

Surface Sediment Distribution for Five Primary Sediment Facies on the Long Island Inner Shelf



Source: Williams, S.J., "Geomorphology, Shallow Sub-bottom Structure and Sediments of the Atlantic Inner Continental Shelf off Long Island, New York," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., March 1976, p. 51.

In general, the entire area contains vast amounts of clean (without silt and/or clay), continuous (non-stratified with dissimiliar sediments), fine-to-medium sand. The average sand thickness lies between nine and 15 feet, which is critical to the economical mining of underwater sediments. Certain areas of gravel and coarse sediment exist about areas IV and I but these are non-continuo and mixed with layers of fine sand, mud, organic peat, and silt and/or clay.

It is evident that the geologic assets of this area are its deposits of continuous sand. These are suitable for beach replenishment, fill, and "fine" sediment available for construction activity. This "fine" sediment would require extensive processing to be made suitable for construction activities. Such processing would wash out the very fine sand, silt, and/or clay, and supplement the remaining sediment with coarse material greater than 1 mm mean grain-size diameter.

Offshore New Jersey

A most comprehensive work, in a survey format, on the sediments off New Jersey was done by John Schlee [55]. This section, in its entirety, is taken from "Sand and Gravel" [56], with slight alterations made to make it more readable to a non-technical audience.

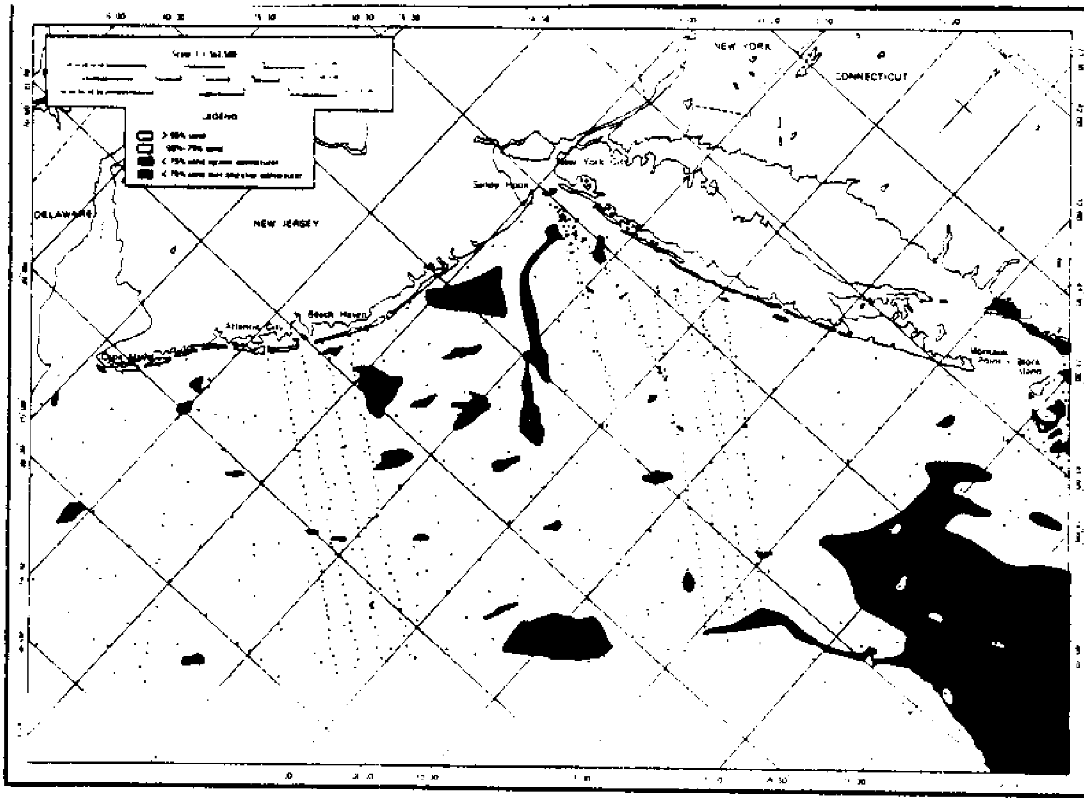
Data presented in Maps 9, 10 and 11 show concentrations of sand, gravel, silt, and clay. These data are a compilation from Cohie [8], the USGS-WHOI Project [31], Friedman and students [24,25], Cornell University [12], and data provided by R.L. McMaster [37]. A sediment map prepared by Williams and Duane [69] was used to refine the contours in the vicinity of the New York Bight harbor.

The maps give a two-dimensional view of sediment in the area of the New York Bight. Because of differences in the density of sampling, the view is spotty and intended to be a regional prespective. Also, differences in the sampling methods presented some difficulty in contouring the data. For example, Friedman and McKinney [24] found almost no fine detritus (sediment transported by currents) in the transects across the continental shelf along Long Island, and no fine aggregate out to the shelf edge off New Jersey. Other investigations found as much as 18 percent silt and clay in this same area off New Jersey. Friedman's Phipps Underway Sampler may not have penetrated the bottom as deeply as did comparable apparatus used by the other investigators.

Sand is the predominant shelf sediment and is distributed over the entire shelf but concentrated along the sand-wave-dominated inner shelf south of Long Island and the entire shelf off southern New Jersey (see Map 9). Mixtures of gravel in the G.N.Y.M.A. study area occur mainly on the inner shelf off New Jersey. Gravel and gravelly sand are distributed in patches off northern New Jersey (see Map 9), but these deposits are not as continuous as indicated by

Map 9

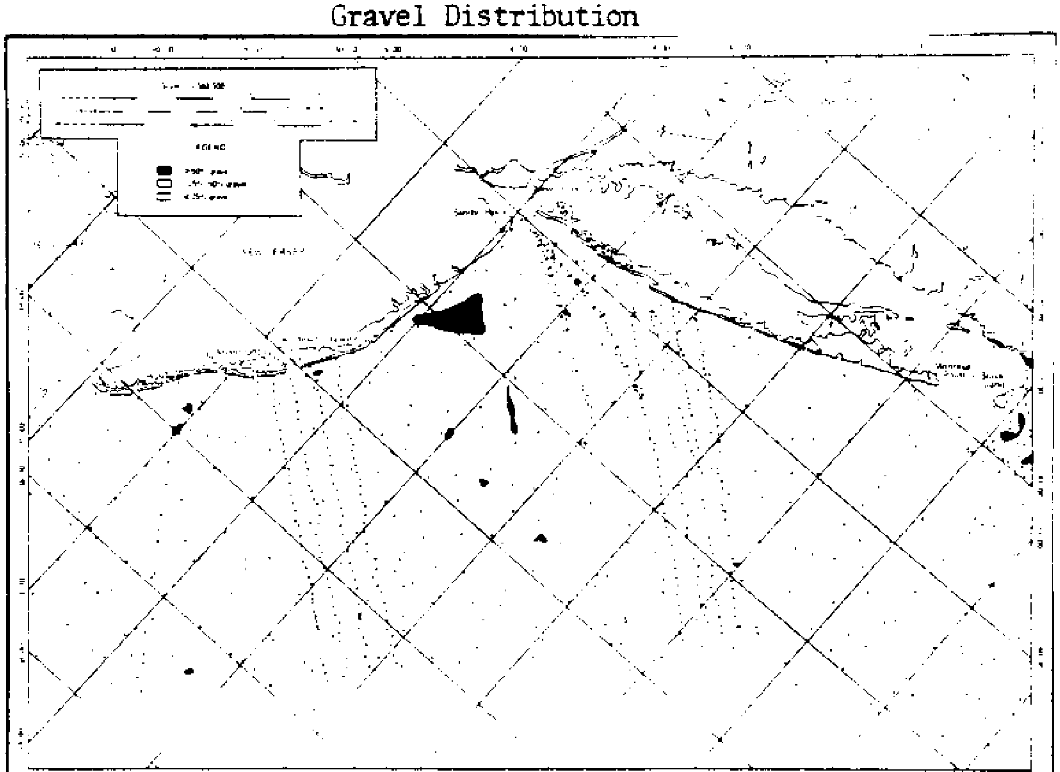
Sand Distribution



Source: Schlee, J. and Sanko, P., "Sand and Gravel," New York Sea Grant Institute, MESA New York Bight Atlas Monograph 21, July 1975, p. 13.

Map 10

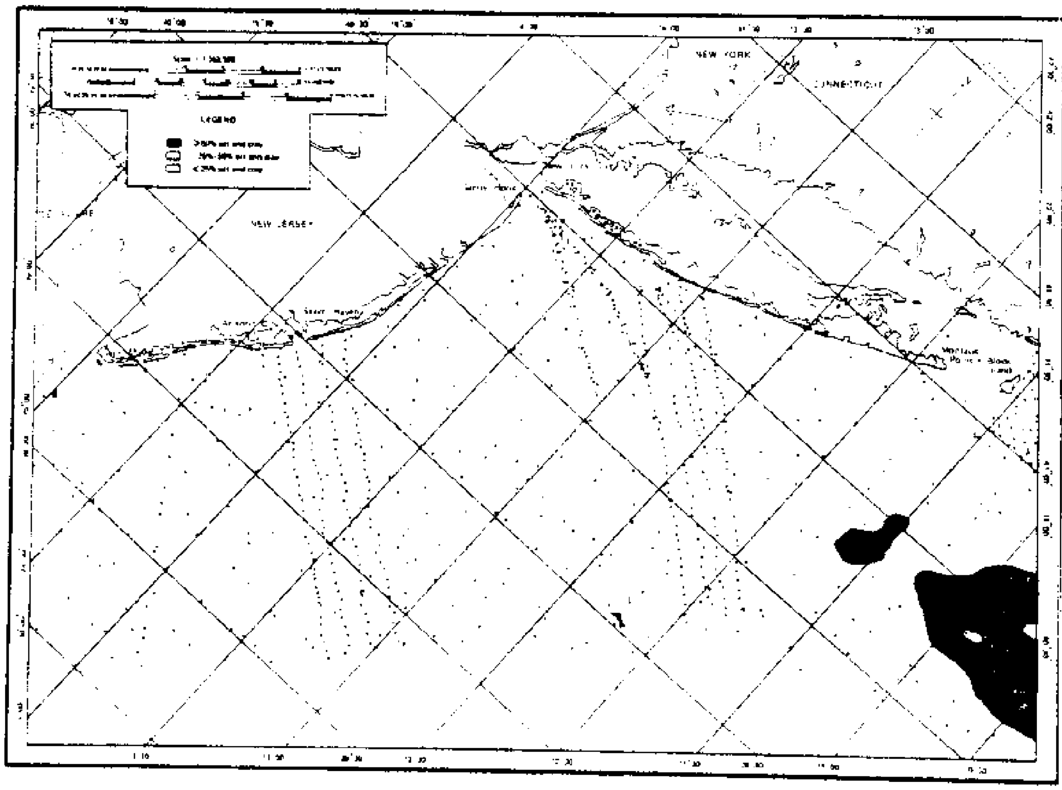
Gravel Distribution



Source: Schlee, J. and P. Sanko, "Sand and Gravel," New York Sea Grant Institute, MESA New York Bight Atlas Monograph 21, July 1975, p. 14.

Map 11

Silt and Clay Distribution



Source Schlee, J. and P. Sanko, "Sand and Gravel," New York Sea Grant Institute, MESA New York Bight Atlas Monograph 21, July 1975, p. 15.

Schlee [56]. They exist mostly between the 82-and 164-foot depth contours off northern New Jersey as far south as Atlantic City. The gravel is predominantly in troughs between low, broad sand ridges. Gravel mixed with sand occurs in a few areas seaward of Cape May, and small patches of gravel are located north of the Hudson River Channel, bracketing the 82-foot depth contours.

This gravel in the Bight consists mainly of rounded quartzose rock types. Sedimentary rock is also present, fragments being sandstone, claystone, and silt stone. The feldspar content of associated sands is lower in the gravelly areas off northern New Jersey than it is in the channel ways. Fine, current-deposited sediment has accumulated in a few closed depressions, the largest being the Hudson River Channel.

Most of the sediment samples were collected using techniques which only scrape deposits on top of the seafloor. These analyses are two dimensional and not reflective of depth. However, some gravity cores, vibra-cores, and borings have been taken which indicate the depth of the resources. These show that the surficial sediment is only a veneer.* The records of foundation borings for U.S. Coast Guard 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 [69] show that the sea-floor off the approaches to New York Harbor is covered by a few meters of fine-to-medium-grained sand (coarse-gravelly in some areas); this surficial sand sheet covers another layer of sand ranging in thickness from 33-148 feet.

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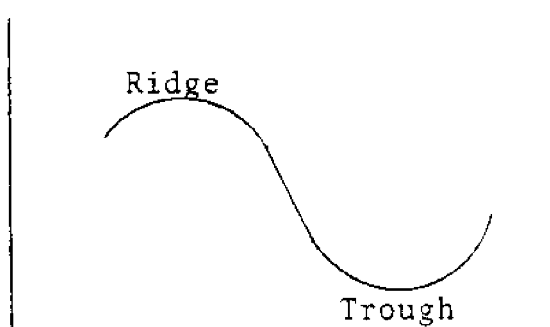
*Much of the deeper borehole data is summarized by Emery and Uchapi [23].

Cores taken in Navy-sponsored research done by Cornell University [12] indicated that grain size generally increased with core depth. This was substantiated by Schlee [57], who examined 99 analyses of surficial sediments taken from the Cornell cores. He found that grain size increased with core depth in 53 percent of the cores, decreased with depth in 15 percent, and was stable in 32 percent of the cores. Usually grain size increased irregularly from sand to slightly pebbly sand at depth. Donahue [15] collected 18 cores off central New Jersey which showed that thin sand covered clay, peat, or shells existing 6-24 inches below the seafloor. Stahl et al. [63] and Stubblefield et al. [62] reached similiar conclusions for the inner shelf off Beach Haven, N.J., and farther offshore for the same area. Stahl's work was done on an underwater sand ridge which was 1.1 miles long and had sand resource depths of 11.8 feet; the ridge was built over clays. Seaward of this area, Stubblefield took four vibra-cores off a trough-ridge complex. (See Figure 13.)

Figure 13

Trough-Ridge Complex



NOTE:

Ridge relief equals 44.3'

Source: Stahl, L., J. Koczan, and D.J. Swift, "Anatomy of a Shoreface-Connected Sand Ridge on the New Jersey Shelf: Implications for the Genesis of the Shelf Surficial Sand Sheet," Geology 2(3): 117-120, 1974.

Approximately eight inches of sand covered silty clays in the troughs, and 7.9 feet of sand on the upper flank of the trough and ridge.

Only general estimates of sand plus gravel can be made for sectors of the Continental Shelf because of the lack of thorough surveys (involving closely spaced shallow core data tied to high resolution seismic reflection.) These estimates are presented in Table 6. The area was delineated into four sections using shelf valleys or their inferred extensions as boundaries between sections (see Map 2). The inner-shelf boundary was set at a distance of six miles from the coastline, while an outer boundary was chosen at that distance where the depth of water was 164 feet. Schlee's choice of the inner boundary was influenced by British leasing policy of dredging well away from shore, staying out of the most active sediment transport regions of the inner shelf, and being just visible from shore. Although the outer boundary is beyond current American dredging technology, Schlee felt that dredging at that depth would become feasible in the future.

Table 6

Estimates of Sand Plus Gravel On The Inner Shelf Of the Bight

Source	Area		Short Tons (in millions)
	mi^2	km^2	
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 is 1 m (3 ft) below the seafloor; dry weight 1.75 short tons/m^3 (assuming a 40 percent porosity).

Source: Schlee, J., "Sand & Gravel on the Continental Shelf of N.E., USA. U.S. Geological Survey Circular 602, p. 5-6, 1968.

Dredging beyond state jurisdictional three-mile boundaries has not been attempted in the United States. Certain factors are involved which have not been previously assessed. These include royalty policy. The federal government has no royalty structure; New York State royalty increases the cost of aggregate in New York's waters by $.25 per cubic yard. Travel time to resource site is another factor. The distance to the resource and weather conditions have significant effects on travel time and, therefore, resultant mining costs.

Schlee comments that the estimates given in Table 6 are probably optimistic as far as construction-quality sand and gravel are concerned. A closer estimate for this use would be gained from considering only the gravelly areas seaward of New Jersey's northern and central coast. This area covers approximately 502 square miles and may contain 2.2 billion short tons of construction-quality sand and gravel.

Offshore New Jersey Conclusions

Although Schlee considers an area larger than offshore New Jersey, his survey results west of Long Island are the most pertinent for our purposes. Most of the samples from this area are grab samples, which reveal only the surficial structure of the study area. Several small-scale studies involving seismic profiles and vibra-cores reveal that this surficial sediment is only a veneer overlying coarse sand, silt, and/or clay. Furthermore, the area can be characterized as a non-uniform ridge-trough system. One cannot predict sand layer thickness or material profiles with accuracy due to the complex nature of such systems.

Potentially, the most valuable resource in the study area is fine-to-coarse sand, with the "possibility" of significant deposits of construction-quality gravel. Unfortunately, exploration has been sparse to make conclusions as to the specific locations and distributions, with depth, of these gravel deposits. Typical uses for the "sand" material found in offshore New Jersey might be as fill, beach replenishment, and supplemental of sand for construction-grade aggregate.

New York Harbor

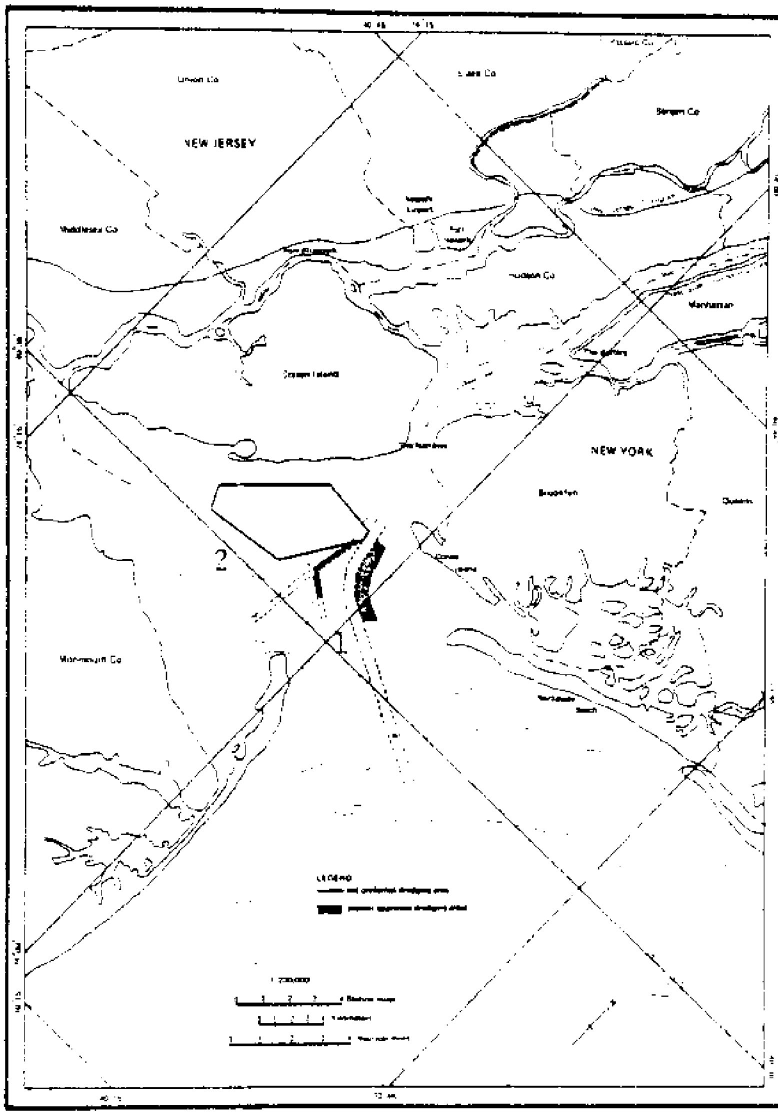
The lower bay of New York Harbor (see Map 12) has been the largest single source of commercial sand for the G.N.Y.M.A. since 1963 (4.5-5.5 M yds^3. per year). The East Bank of Ambrose Channel is preferred for dredging because of heavy littoral drift of sand into this area, replenishing it by 1.5 million cubic yards per year [56]. This area is the present approved dredging site by the New York State Office of General Services.

Except for an ongoing study by J. Schubel and C. Fray at the State University of New York at Stony Brook, very limited sampling has been done in the harbor. Most of the sample data used in our research project were from wash borings, dating from the latter part of the nineteenth century to the early 1900's, and from grab samples. Isolated areas have been documented with sewer outfall cores, which lie close to shore and beyond the "environmental" limits of practical dredging. It has been found that mining too close to shore fosters citizen fear of beach depletion.

The New York District Office of the Army Corps of Engineers, reports that channel areas contain aggregate which is generally composed of 90 percent sand (fine) and 10 percent silt, clay, or mud existing in stratification. Sanko [56] reports that the East Bank of Ambrose Channel and the Chapel Hill North Channel contain fine-grained sand (80 percent is less than .297 mm mean grain-size diameter) with almost no silt. Similiar sediment exists off Rockaway beach, but with more coarse-grained sediment. Throughout the harbor areas, particularly to the southeast, surficial silt and sludge may exist in patches. If the current dredging depth restriction of -45 feet can be overcome, minimum amount sand available in New York Harbor is 500 million cubic yards.

Map 12

Sand Mining in Lower New York Bay



Source: Schlee, J. and P. Sanko, "Sand and Gravel," New York Sea Grant Institute, MESA New York Bight Atlas Monograph 21, July 1975, p. 25.

(1) : Ambrose Channel

(2) : Chapel Hill North Channel

Summary and Conclusions

Construction aggregate is necessary to almost all highway and building construction. Even if we assume only nominal growth of the G.N.Y.M.A. by the year 2000 AD., regional shortages of mineral aggregate will occur. Because of high transportation costs for moving existing on-shore supply aggregate to demand sites, consumers and producers of sand and gravel will be forced to look offshore for these construction materials.

Review of existing surveys indicates that large quantities of clean sand exist in the offshore reaches of the G.N.Y.M.A., deposited through glaciation and mechanical transport (i.e., river currents). A summary of offshore resources is given in Appendix D.

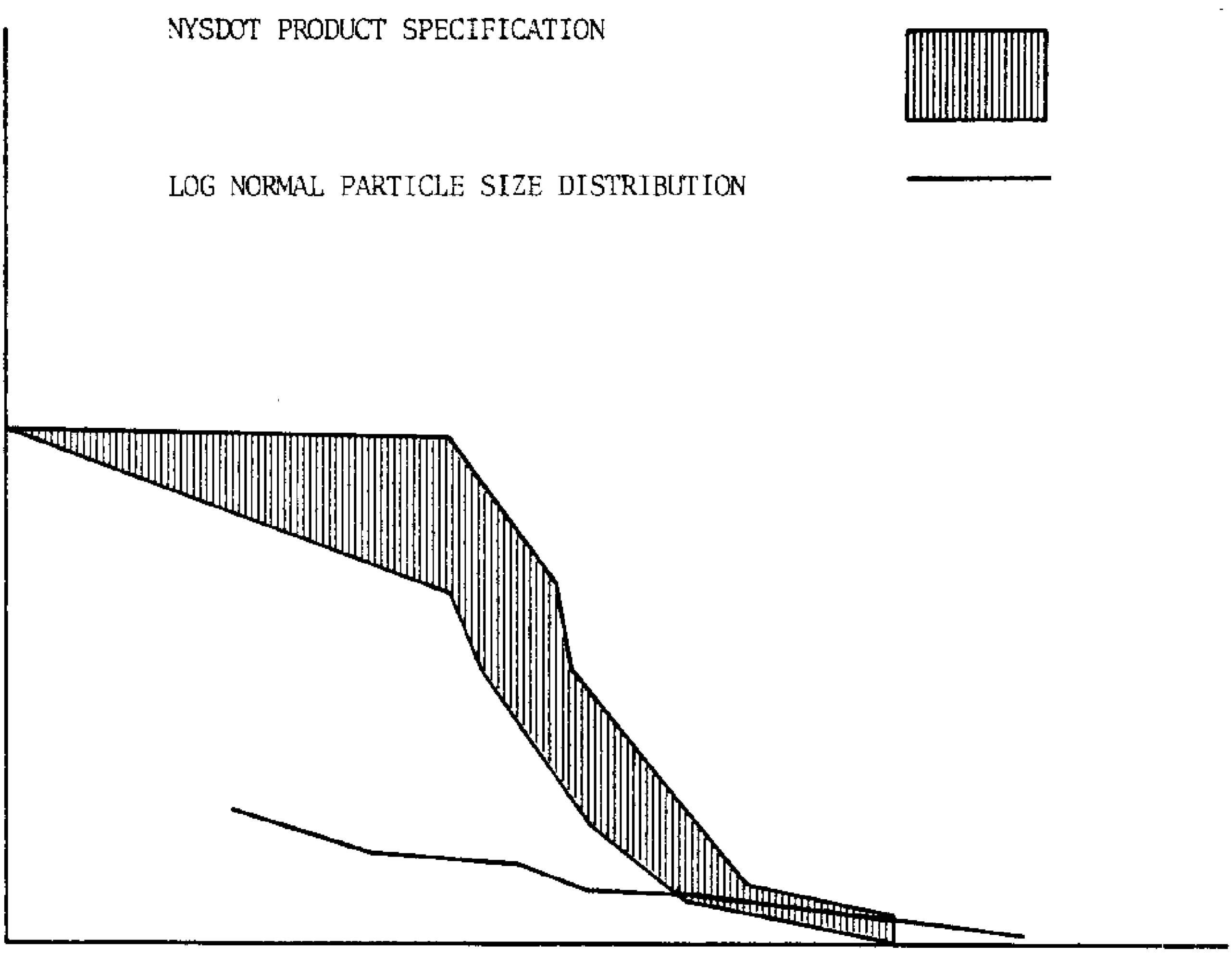
The available offshore resource is fine-to-coarse sand with minimal local deposits of gravel. This resource is typically found near shore and at shallow depths (100 feet). Suitable uses for this material are fill, beach replenishment, and supplemental fine sand for construction uses. Since it is "supplemental sand," processing must occur to bring the material up to certain product specifications.

Figure 14 visually demonstrates the lack of compatibility of the available resource with typical product specifications.

NYSDOT specifications for "Bituminous Stablized Coarse," which is a typical construction product, is graphed as an area because of the latitude within the specifications. A typical core slice particle size distribution from Long Island Sound is represented by the heavy black line. Wherever there occurs an intersection between the two graphs, compatibility of resource occurs (26 percent of particle size distribution by weight); whenever the NYSDOT graph is above the core line, onshore processing must occur, supplementing the material with coarse aggregate. When the percent of of particle size by weight exceeds the specifications (6 percent in the example), onboard processing must occur to wash out superfluous fine material. Although this figure is a simplified representation, it does portray the non-conformity between the available resource and product specifications.

Figure 14

NYSDOT Specifications for Bituminous Stabilized Coarse Graphed With a Representative Vibra-core Section from Long Island Sound



The exploratory research in this area has been macroscopic in nature, serving only to identify general areas of resource potential (see Table 10). These areas must be surveyed in detail, by extensive core sampling prior to any large-scale mining which involves extensive capital resources.

Several problems will emerge whenever mining for construction-quality aggregate occurs in the G.N.Y.M.A. Since the resource is located near shore, in shallow water, conflicts will exist with local shellfishing interests. These conflicts may have either primary impact (i.e., the direct disturbance of shellfish beds by dredging apparatus) or indirect impact; (i.e., the dumping of silt effluent, a byproduct of onboard processing of sediment. This effluent can cover and contaminate shellfish areas.)

As previously noted, "state of the art" dredges can provide for the yearly construction aggregate needs of the entire G.N.Y.M.A. in 12 weeks or less. Storage might either be in barges or at onshore sites located near demand areas. Since it is not economical to buy "state of the art" equipment for less than full utilization, thought must be given either to serving an area larger than the G.N.Y.M.A. or to processing both fill and construction aggregate by a single dredge or dredging system.

APPENDIX A

Summary Results For Donohue And Tucker's Exploratory Cores

Legend: + Positive Economic Potential,
- Negative Economic Potential, and
? Questionable Economic Potential.*

Core #	Water depth in feet	Average amount of sand & gravel percent	Economic potential	Remarks
1	58	21	-	Mostly silt and or clay (70-90 percent), little gravel and sand; no clean sediment throughout core.
2	18	88	?	Mostly sand with areas of up to 50 percent silt and/or clay; less than 10 percent gravel.
3	66	77	-	Same as above, with areas of heavy concentration of clay and/or silt.
4	26	83	?	Same as above.
5	140	82	-	Too deep to mine economically with present American technology.
6	26	62	-	Same as Core #2.
7	128	80	-	Too deep to mine economically.
8	29	58	-	Same as Core #2.
9	NO SAMPLE OBTAINED			
10	98	75	?	Composition of gravelly sand with little (10 percent) silt and/or clay; too deep for economical mining.
11	52	75	-	Stratified sediment occurs from heavy silt to gravelly sand.
12	90	79	?	Gravelly sand with patches of heavy silt and/or clay concentration.
13	36	60	-	Same as core #12 with even more silt and/or clay.
14	29	59	-	Same as core #13.

Core #	Water depth in feet	Average amount of sand & gravel percent	Economic potential	Remarks
15	85	55	-	Same as core #12.
16	39	91	+	Concentrations of gravel exist here greater than 10 percent; little silt and/or clay.
17	24	86	+	Concentrations of gravel exist here greater than 13 percent, little silt and/or clay.
18	85	94	?	Higher concentrations of gravel occuring here, between 5-16 percent; heavy silt and/or clay on top layers.
19	50	89	+	Clean sand, stratified silt, and/or clay throughout but not in heavy concentrations.
20	29	97	+	Clean sand without significant silt and/or clay; very little gravel.
21	95	38	-	Consisting mostly (70-90 percent) of silt and/or clay with little sand and gravel.
22	46	82	?	Mixed sand with silt and/or clay on top covering clean sand.
23	20	94	+	Mixed sand with silt and/or clay in top layers covering clean sand; little gravel
24	96	44	+	Sediment consists mostly of silt and/or clay; little sand or gravel.
25	45	38	-	Sediment consists mostly of silt and/or clay; little sand or gravel.
26	20	58	-	Same as Core #25.
27	87	58	-	Same as Core #25.
28	36	54	-	Same as Core #25.
29	98	72	?	Clean sand with little silt and/or clay in top layer.
30	47	85	+	Clean sand with little silt and/or clay in top layers covering mixed silty sedime

Core #	Water depth in feet	Average amount of sand & gravel percent	Economic potential	Remarks
31	98	96	?	Thin layer of mixed silty sediment covering clean sand.
32	17	65	+	Thin layer of mixed silty sediment covering significant layer of clean sand.
33	110	98	?	Too deep to mine economically; consisting of all clean sand with little silt and/or clay.
34	18	57	-	Consisting entirely of mixed sediment with high (30-50 percent) concentrations of silt and/or clay.
35	158	95	?	Too deep to mine economically; sediment is all clean sand with concentration of gravel (3-10 percent).
36	17	93	+	Sediments consist of clean sand with little silt and/or clay; very little gravel.
37	128	81	?	Too deep to mine economically; sediment is clean sand with concentrations of gravel (7-27 percent).
38	24	68	?	Sediment consists of mixed sand with silt and or clay (30-50 percent); little gravel.
39	>215	81	-	Too deep to mine economically.
40	38	88	-	Stratified layers of clean sand with mixed sand and silt and/or clay.
41	49	56	?	Top layer consists of clean sand covering mixed sediment of sand and silt and/or clay.
42	32	40	-	Mixed sediment of sand with silt and/or clay.
43	45	67	-	Same as Core #42.
44	27	97	+	Consisting of clean sand with little silt and/or clay.
45	50	96	+	Same as Core #44.
46	20	97	+	Same as Core #44.

*Economic potential is a subjective judgment considering particle size distribution, mineral composition, and depth of resource.

APPENDIX C

Summary Results for S. Jeffress Williams' South Shore Long Island Area

Legend:
+ Positive Economic Potential
- Negative Economic Potential, and
? Questionable Economic Potential.*

Area	Composition	Resource depth	Volume millions yards^3	Economic potential*	Remarks
A	Clean, fine-to-medium sand without silt and/or clay (.125-.5mm diameter).	29'	24.30	+	Sea floor surface dips gently NE; beyond 30' depth, sediments are generally flat; muds cover resource at eastern boundary.
B	Clean, medium sand overlying coarse sand.	21'	min 10.41 max 32.35	+	This area seems to be an isolated pocket of sands surrounded by muds; core sediment obtained seems to be overlying coarser sediment.
C	Sand overlying silty sand, organic peat, and cohesive clay.	39'	min 14.32 max 21.48	?	Seismic records show that sand layer thickens towards Plum Island.
D	Clean, fine sand predominant, with limited medium-to-coarse sand. Mixtures with silt and fine shell fragments occurring at depth in northeastern region of this area.	23-' 37'	min 65.65 max 109.40	+	Seismic records show that sand appears to be flat-bedded and continuous with depth.
E	Western section contains clean, medium-to-coarse sand. Eastern section sediment is medium-to-coarse sand overlying 4.5 feet of organic mud, which in turn overlies clean, fine sand.	20-' 45'	min 38.64 max 48.21	+	Sand thickness is judged to be between 2 and 2.5 yards.
F	This area contains 14 cores, all exhibiting (except for core sample 23) clean, fine-to-coarse sand (.125-1mm), with rounded pebbles at few locations.	30' 75'	min 672. max 1,120.	+	Minimum sand thickness 9 feet; potential thickness 15 feet.

Area	Composition	Resource depth	Volume millions yards	Economic potential	Remarks
G	Clean, fine-to-medium sand with no silt and/or clay close to shore, seaward cores	36-' 68'	min 241. max 2591..	+ shoreward - seaward	Minimum sand thickness of 12'; potential thickness of 13'.
H	Clean, fine-to-medium sand with little silt.	19-' 81'	min 480. max 688	+	Minimum sand thickness of 9'; potential thickness of 13'.
I	Clean, fine-to-very coarse sand with some shells and silt is abundant in the northern section. Clean medium-to-very coarse sand with gravel in south-eastern section, fine-to-medium sand with some silt in southern seaward section of the zone.	30-105'	min 518 max 648	?	The western boudary for this area was testablished because the core seaward of Moriches Inlet contained very fine sand and silt overlying and mixed with medium sand and gravel; this area should be avoided as a borrow area until more detailed data are avilable.
J	This area contains evenly distributed sand (very fine to coarse).	37-73'	min 1512 max 1425	+	The minimum thickness of the sand deposit is 9 ft, with a potential thickness of 18 ft; the western boundary marks the transaction from clean sand to grey silt and clay.
K	This area consists of stratified deposits of clean, very fine sand to gravel overlying silt, organic peat, and cohesive clay in certain sections.	31-90'	min 960 max 1425	?	If this area were to be used as a borrow site, close attention to seismic studies would have to take place. Risk of clay and silt contamination exists, which may be outweighed by quanties of gravel existing in this area.
L	All cores exhibit clean, very fine-to-coarse sand, with the exception of Core #8 which is just south of the 60' depth contour, this core had 6 feet of silt and mud overlying clean, fine-to-medium sand.	25-' 68'	min 698 max 698	+	Minimum and maximum sand thickness of 9 feet.

Area	Composition	Resource depth	Volume millions yards	Economic potential	Remarks
N	This area contains eleven cores showing considerable stratigraphic variation in continuous sand content, which may be explained by the presence of three major buried river channels; the sediment ranges from clean, very fine sand, to gravel, to mud, silt and clay-separate and in mixtures.	25-' 105'	min 399.04 max 698.72	-	The stratified nature of this zone makes dredging a problem with risks of clay/silt/mud contamination.
M	See special section. (Figure 9).		min 960.30 max 960.30		See special section. (Figure 9).

*Economic potential is a subjective judgment based upon particle size distribution, mineral composition, depth of resource, and general consideration of the resource quality vis-á-vis proposed dredging.

APPENDIX D

Summary of Offshore Resources

Area	Volume of Resource	Composition	Comments/suitability
Long Island Sound			
Bridgeport Shoal	150M yd^3	Med-coarse sand, sparse gravel & shells.	Homogeneous patches of material exist for fill and supplement aggregate.
Norwalk Ridge	5.2M yd^3	Uniform med. grey sand	Fill & supplemental sand.
Norwalk	130M yd^3	Non-uniform sand, fine to coarse; local patches of silt.	Not ideal for large-scale commercial extraction.
South Shore Areas			
A-D	114-187M yd^3	Clean fill; medium sand with silt in area C.	Fill & supplemental sand; area D particularly good
E-H	1,431-2,115M yd^3	Clean, fine-medium sand throughout.	Good sand thickness between 6-15'; supplmental sand & fill.
I-K	2,990-3,490M yd^3	Clean, fine-coarse sand stratified with silt in area K.	More data need in Area I; silt & clay in K; area J good for fill & supplement sand.
L-N	2,057.3-2,356M yd^3	Clean, very fine-to-coarse sand in L; stratification of sand w/mud and silt in N; M is stratified also.	M has best core coverage of entire south shore area; best area for fill & supplemental sand is area L.
New Jersey			
Delaware	1,661 M yd^3	Fine-to-medium sand with gravel potential off Sandy Hook, N.J.	Areas in this sector were explored by grab samples which cannot give information on depth profiles, sediment may be surface veneer, with grain-size diameter increasing with depth.
New Jersey	17,631 M yd^3		
Block Island	463 M yd^3		
Long Island	4,628 M yd^3		
New York Harbor	500 M yd^3	90 percent sand, 10 percent silt and clay.	Patches of silt and sludge exist throughout.

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