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Marine Geology and Geophysics Laboratory
Atlantic Oceanographic and Meteorological Laboratories
Miami, Florida

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ABSTRACT

A hydrographic survey of the New York Bight Apex was undertaken by the New York District of the Corps of Engineers under contract to NOAA as part of the MESA Program. A bathymetric map was prepared and a comparison was made between the 1973 data and hydrographic data from the most recent previous survey of the area, H-6190, done in 1936 by the U.S. Coast and Geodetic Survey. A resulting contoured net bathymetric change map shows that the most significant change has occurred in the dredge-spoil dumpsite, where there has been up to 10 m of shoaling. Calculations of volumes of eroded and deposited sediment indicate that the area has generally eroded and that, except at the dredge-spoil dumpsite and the now abandoned dumpsites near Ambrose and Sandy Hook Channels, dumping is not causing significant changes in water depths.

1. INTRODUCTION

The disposal of solid wastes from the New York-New Jersey metropolitan area causes considerable environmental concern, as large volumes of these wastes are dumped in waters outside of the harbor mouth (Table 1 gives the source of Bight wastes). Dredge spoil and sewage sludge constitute 89% by weight of the solids dumped; their disposition is an important part of related environmental studies.

The U.S. Coast and Geodetic Survey (now the National Ocean Survey [NOS], NOAA) has made hydrographic surveys in the New York Bight since 1845. The last C.&G.S. survey to cover the Bight Apex, which is the area immediately adjacent to the harbor mouth where dumping is most intense, was in 1936 (survey H-6190). In 1973 the NOAA Marine EcoSystems Analysis (MESA) Program initiated research to determine recent effects of dumping in the New York Bight. A new hydrographic survey of the Bight Apex was conducted to determine what changes had occurred in bottom topography since 1936. The contract for the survey was let by NOAA to the U.S. Army Corps of Engineers, New York District. In turn, the New York District subcontracted the area south of 40°26'N latitude to the Philadelphia District to use the high-speed, 65-ft, survey catamaran *Shuman* because of the longer distances to the nearest port at Atlantic Highlands, New Jersey. Work north of 40°26'N was done with the New York District's 58-ft survey vessel *Hatton*. Changes in water depths reported in this study were calculated from the 1936 and 1973 surveys. Original data and calculations of net changes have been converted from English to metric units. Comparison between the 1845 and 1936 surveys (Williams and Duane, 1974) revealed the development of several knolls due to early dumping.

2. THE 1973 SURVEY

Location. The area covered by the survey was the Bight Apex from 40°18'N latitude northward to as close to the Long Island shoreline as was practical (generally from the 5 to 7 m isobath) and from 73°40'W longitude westward to equivalent New Jersey isobaths. This area included all of the Apex dumpsites, the upper part of the Hudson

Shelf Valley and its northward terminus (the Christiaensen Basin), the western part of Cholera Bank, and the entrance to New York Harbor between Rockaway Beach and Sandy Hook (see Fig. 1). The Christiaensen Basin was defined on the basis of topography as the area between 26 and 37 m depths north of 40°24'N. The Hudson Shelf Valley area lies north of 40°19.22'N at depths greater than 37 m.

Survey Lines. Survey lines were laid out approximately perpendicular to the average shoreline in three sub-areas (Fig. 2). Line spacing was established at 305 m (1000 ft) as a compromise between the desire for close line spacing and the time and cost involved. Soundings were taken on all lines. On alternate lines, at 610 m (2000 ft) spacing, other geophysical data (side-scan sonar and 3.5 kHz seismic reflection profiling) were taken. Lines with the added geophysical data were run first in each sub-area, with NOAA personnel and geophysical equipment on board. Then the survey vessels ran soundings-only lines without NOAA assistance. Field work was accomplished from June 19 to September 1, 1973.

Navigation. Navigation for the entire area was provided by the New York District using a Cubic Autotape DM40A system, accurate to ± 0.5 m at 5 km range and ± 1.0 m at maximum range of 50 km. Shore stations were set up at an old lighthouse at Highlands, New Jersey, and atop a 17-story apartment house at Far Rockaway Beach, New York, for most of the southern area. The Highlands station was moved to an abandoned lighthouse on Sandy Hook for middle and northeastern lines. For northwestern lines, stations were established at Ft. Tilden on Rockaway Beach, and at the Sandy Hook lighthouse.

Both survey vessels were equipped with fathometer, timer, and readout of the two navigation ranges. Data from all three were recorded on magnetic tape every 10 sec and printed on paper tape every minute.

Positions were plotted every minute on boat sheets (1:20,000 scale) provided by the New York District. The fathometer on the *Hatton* printed a paper record in addition to the magnetic tape recordings. Bar checks for fathometer accuracy were made at the beginning and end of each day's work.

Vessel speeds were about 9 km/hr (5 kn) during the running of geophysical tracklines. Soundings-only tracklines were run at about 22 km/hr (12 kn) on the *Shuman* and 11 km/hr (6 kn) on the *Hatton*.

Data Processing. A total of 2438 km (1317 nmi) of soundings trackline were run, including three tie lines, of which 1043 km (563 nmi) were run to take the added geophysical data. Soundings and navigation data taken by the *Shuman* were computer processed by the Philadelphia District using tidal corrections from the Sandy Hook tide gage station. The final products were computer-printed boat sheets at 1:20,000 scale with soundings to the nearest 0.03 m (0.1 ft) printed at 101-m (333-ft) intervals along tracklines.

Paper fathometer records from the *Hatton* were processed by drawing an average depth line through wave tracings on the record and plotting the tidal corrections from the Sandy Hook station. Corrected depths were then hand plotted at the same accuracy and spacing as the *Shuman* data on boat sheets (1:20,000 scale),which were checked for positional accuracy against the original plotting sheets.

Six boat sheets, which summarized the data for the entire survey, were delivered to NOAA. Copies of each sheet were contoured at 1-m and 1/2-fathom intervals, reduced to a scale of 1:40,000 and then spliced to assemble the complete map. Maps were further reduced to page-size for publication.

3. NET BATHYMETRIC CHANGE

The primary objective of the 1973 survey was to calculate the changes in bottom topography in the Bight Apex for geological studies of the nature of sediment transport.

Map Construction and Contouring. Examination of the boat sheets from survey H-6190 (1936) revealed trackline spacing of approximately 900 m (3038 ft) compared with 305 m (1000 ft) spacing for the 1973 survey; trackline directions between the two also diverged. In order to compare surveys, boat sheets from both surveys were contoured by NOAA at 0.9 m (3 ft) intervals at a common scale of 1:20,000. Boat sheets and contour maps were then sent to the Marine Sciences Institute, University of Connecticut, where net change values were calculated. Hydrographic profiles of the 1936 data were constructed for lines that coincided with tracklines of the 1973 survey. Depths along these profiles were determined by linear interpolation at every fourth 1973 posted depth (every 305 m [1000 ft]). The 1936 interpolated depth was then subtracted from the 1973 depth. The differences (net change values) were checked for sign and magnitude consistency by plotting them as profiles and were then plotted on a map at a scale of 1:40,000. After correction for a sea level rise of 0.189 m (0.62 ft) calculated from NOS mean monthly sea levels at Sandy Hook, New Jersey, values were then contoured at 0.6-m (2-ft) intervals from 0 to 1.83 m (6 ft) and at 1.52-m (5-ft) intervals for values higher than 3.05 m (10 ft) for both deposition and erosion. However, isopleths of 1.83 m for deposition and 0.6 m for erosion were used for the maps reduced to page size.

Determination of Areas of Deposition and Erosion. Five sub-areas were defined on the basis of anthropogenic net bottom change and natural topography (Table 2): 1) the Ambrose and Sandy Hook Channels area to the northwest of a zero deposition contour enclosing the peninsula-shaped area of mapped data (Fig. 3). Up to 14 m (45 ft) of bottom sediment "erosion" is due to dredging of navigation channels and for construction sand; lesser amounts of deposition are from spoil dumping; 2) the dredge-spoil dumpsite (also referred to as the mud dump), within a surrounding zero-deposition contour but excluding the cellar-dirt dumpsite and a contiguous area of 0-1.8 m deposition to the northeast. Up to 10 m (34 ft) of deposition was mapped; 3) the cellar-dirt dumpsite, within a zero-deposition contour to the southeast of the dredge-spoil dumpsite; 4) the Christiaensen Basin; and 5) the Hudson Shelf Valley.

Volume Calculations. Volumes of erosion and deposition were calculated by repetitive measuring of the areas within all contours by planimeter and multiplying the mean by the appropriate contour interval. Volumes for sediment in the slope between contours were calculated and added.

The net change map (Fig. 3) consists of enclosed contours for deposition greater than 0 m net change, and for erosion greater than 0.6 m. The volume of material eroded between the 0 and 0.6-m erosion isopleths was calculated by adding the areas inside the 0 deposition contours to the areas inside the over-0.6-m erosion contours, then subtracting that sum from the total area considered. This was done for each of the five sub-areas mentioned above and for the remainder of the

Apex outside the sub-areas. The data thus obtained were multiplied by 0.204 m (0.67 ft) (the average depth of erosion after sea-level correction) between the 0- and 0.6-m erosional contours to obtain the volume of sediment eroded in this interval. This figure was then added to data from erosion contours greater than 0.6 m to obtain total volume of erosion for each area.

Areas, volumes of erosion and deposition, and net changes for Bight Apex features are listed in Table 2.

Sources of Error. Accuracy of the net change map is dependent upon the accuracy of the two surveys, the net change calculations, the contouring of these values, and the area and volume calculations. Of these, the accuracy of the 1936 survey is probably the greatest source of error. On relatively even bottoms or in critical depths less than 20 m (66 ft), soundings were accurate to 0.15 m (0.5 ft), and to within 1% of greater depths (Adams, 1942). In rapidly changing depths and over irregular bottoms, errors could be twice the above limits. The Corps of Engineers estimated that the accuracy of the 1973 soundings was 0.03 m (0.1 ft). The soundings picked for each survey for net change calculations were estimated to have an accuracy of 0.06 m (0.2 ft). If the errors are assumed to be random, and the total error $E = \sqrt{e_1^2 + e_2^2 + e_3^2 + e_4^2}$, where e_1, e_2, e_3, and e_4 are the mapped-soundings and net-change-soundings errors mentioned above, the net change error is $\pm$ 0.18 m (0.58 ft).

4. DISCUSSION

4.1 Anthropogenic Sediments

Sediments are introduced into the Bight Apex almost entirely in the form of fine-grained sand (0.25-0.0625 mm) and mud-sized (less than

0.0625 mm) particles. Dredge spoil is the greatest source of solids brought in by man (see Table 1). Estimates of the total amount of dredgings from 1936 to 1973 using Corps of Engineers data (records are questionable for years prior to 1954) indicate that about 142×10^6 m^3 (186×10^6 yd^3) of material was dumped. Our calculations of net bottom change indicate that 124×10^6 m^3 (162×10^6 yd^3) has accumulated on the bottom at the dredge-spoil dumpsite and at the dumping areas near Ambrose and Sandy Hook Channels (Table 2). This indicates that approximately 87% of the dredge spoil dumped is still in place on the bottom. Detailed mapping of the dredge-spoil dumpsite shows that shoaling of up to 10.4 m (34 ft) has occurred over an area of 36 km^2 (10.4 nmi^2) south of a knoll which was formed by earlier dumping (see Figs. 4-6).

Sewage sludge, on the other hand, is a much smaller source of Bight sediment by weight: it contains an average of 2.6% solids, has a mean bulk density of 1.0090 (less than that of sea water, 1.019-1.025; Callaway et al., 1976) and contains 80% to 100% organic matter (Hatcher, 1977). Mean particle sizes vary from 0.025 mm to 0.065 mm, but due to flocculation and low particle densities (a mean of 1.50 g/cc dry), settling velocities vary from 0.5 cm/s (equivalent to 0.074 mm, very fine sand) to less than 0.001 cm/s (equivalent to clay particles less than 0.004 mm; Callaway et al., 1976). Larger particles settle to the bottom (24 m at the dumpsite) in about 5 min, but many particles often remain in the water column after 4 h (Proni et al., 1976). Spreading the entire annual volume of sludge (3.3×10^6 m^3; see Table 1) over the area of the Christiaensen Basin and the upper Hudson Shelf Valley (106 km^2) would result in a layer 3 cm thick (sediment was assumed to have compacted to a bulk density of 1.052 at which water content would be 600% and dry grain density 1.50; from Bennett et al., 1971). If the total volume of sludge dumped since 1924 (approx. 107×10^6 m^3; Mueller et al., 1976) accumulated in these areas, the layer would be 1 m thick. Since currents carry some of the suspended matter out of the Christiaensen Basin and Hudson Shelf Valley areas, and since storms resuspend, mix, and disperse natural and anthropogenic particles already on the bottom, it is not surprising that sludge cannot be found on the bottom as a discrete layer. At present it is possible to distinguish sludge-derived material from natural organic mud only by the interpretation of a number of complex organic chemical analyses now ongoing (Harvey, 1977). While sludge is being mixed with natural muds in the topographically low areas, there is a close balance of deposition versus erosion during the 37 years prior to 1973 (see below).

Cellar dirt, the third anthropogenic sediment, consists of construction rubble from demolition, foundation rock and dirt, and slag. Brick, metamorphic rocks, and red sandstone are commonly recovered in grab samples. Cellar dirt, although making a recognizable spoil mound, is not considered an important input because of its comparatively low volume.

4.2 Natural Sediments

Natural sediment input from land sources comes mainly from stream runoff (mostly from the Hudson River drainage basin) and urban runoff (mostly from the New York metropolitan area; Table 1). These sources are relatively easy to measure compared with sediment transported from other areas of the shelf. Various estimates of sediment transport indicate that, for the continental margin of the eastern U.S., three conclusions can be reached: 1) 90% of the sediment from land sources is deposited in estuaries and wetlands; 2) net suspended fine sediment transport on the shelf is probably landward, with possibly much of the material finally settling in estuaries; and 3) recycling (resuspension and settling) of sediment on the shelf may transport amounts of sediment that are greater by orders of magnitude than either enter or leave the shelf (Meade et al., 1975; Milliman et al., 1972).

From our net change map (Fig. 3), volumes of natural sediment deposited and eroded in the Bight Apex over the 37 year period between surveys have been calculated (Table 2). After the anthropogenic material in the Ambrose-Sandy Hook Channels area and the dredge spoil and cellar dirt dumpsites are subtracted, the volume of material eroded exceeds deposition by 79 x 10^6 m^3 (103 x 10^6 yd^3), equivalent to a layer 13.5 cm (5.3 in) thick over the non-anthropogenic areas. This is an average of 3.6 mm (0.14 in) per year. It is also less than the calculated error estimate of $\pm$ 18 cm for the net change map, representing 106 x 10^6 m^3 (138 x 10^6 yd^3) over the non-anthropogenic areas. Therefore, within the error estimate, the net change could be from 185 x 10^6 m^3 (242 x 10^6 yd^3) of erosion (31 cm or 12 in) over the non-anthropogenic areas to 27 x 10^6 m^3 (35 x 10^6 yd^3) of deposition (4.5 cm or 1.8 in) over the non-anthropogenic areas for the 37 years. Thus the system appears to be nearly in balance, requiring periodic removal of bottom sediment. From other ongoing studies, this erosion apparently occurs primarily during storms that occur most frequently in winter months.

5. ACKNOWLEDGMENTS

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TABLE 2

Volumes of Erosion and Deposition in the New York Bight Apex Between 1936 and 1973

	Area (km^2)	Volume (10^6 m^3) Erosion(E)	Deposition(D)	Net Change
1. Entire Apex	718	161	162	1 D
2. Dredge Spoil Dumpsite	36		93	93 D
3. Cellar Dirt Dumpsite	9		5	5 D
4. Ambrose and Sandy Hook Channel Areas	86	49	31	18 E
5. Total Anthropogenic (2-4)	131	49	129	80 D
6. Christiaensen Basin[1]	83	13	6	7 E
7. Hudson Shelf Valley[2]	23	10	2	8 E
8. Other Non-Anthropogenic	397	89		64 E (bracketed, both lines)
	84		25	
9. Total Non-Anthropogenic(6-8)	587			79 E[3]
Total Erosion	477	112		
Total Deposition	110		33	

[1]Area between 26 and 37 m depths north of 40°24'N.

[2]Area deeper than 37 m north of 40°19.22'N.

[3]Equal to a layer 13.5 cm thick (3.6 mm/yr).

TABLE 1

Source of Solids Transported Annually into Marine Waters of the New York Bight

SOURCE	VOLUME		WEIGHT		
	10^6 m^3	% of barged	10^6 metric tons	% of barged	% of total input
Dredge spoil	8.8	53	4.7	85.3	53.4
Sewage sludge	4.3	26	0.165	3	1.9
Cellar dirt	0.5	3	0.6	10.9	6.8
Acid waste	2.5	15	0.04	0.73	0.5
Chemical waste	0.5	3	0.003	0.05	0.03
Total barged	16.6	100	5.51	100.00	62.6
Atmospheric fallout			0.427		4.8
Wastewater* Municipal			0.35		4.0
Industrial			0.02		0.2
Runoff* Gaged			1.4		15.9
Urban			1.1		12.5
Total input			8.81		100.00

From Mueller et al. (1976)

*98% of these coastal zone inputs come through the Rockaway-Sandy Hook transect. Figures do not include shelf-derived sediment from outside the Bight.

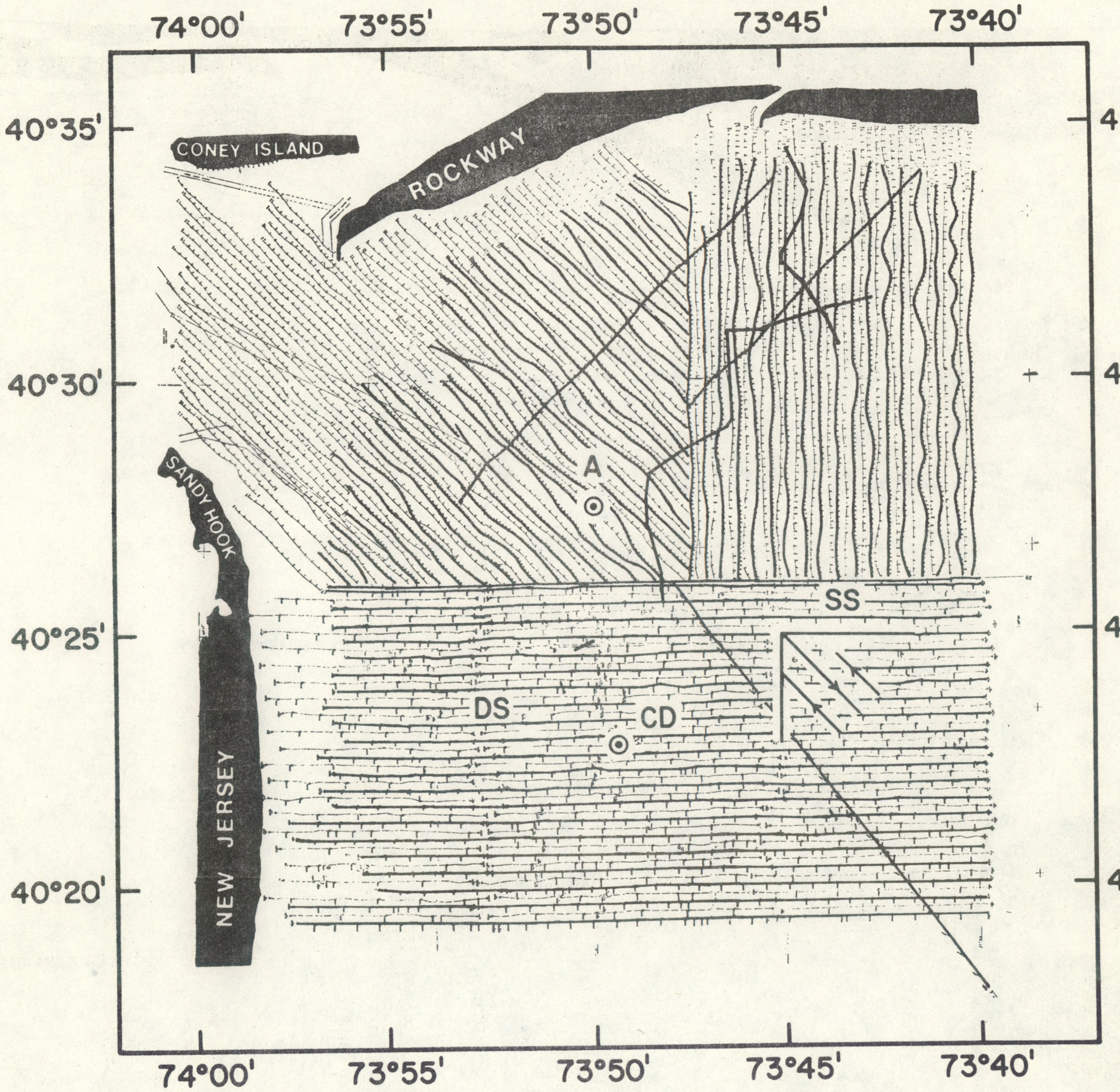

Figure 2. Tracklines of the 1973 bathymetric survey. Light lines show tracklines for bathymetry only. On heavy lines both bathymetric and geophysical data were collected. A: Ambrose Light Tower; SS: Sewage-sludge dumpsite; DS: Dredge-spoil dumpsite; CD: Cellar-dirt dumpsite.

Figure 1. 1973 bathymetric map of the New York Bight Apex, from the NOAA-Corps of Engineers survey. Contour intervals are 1 m.

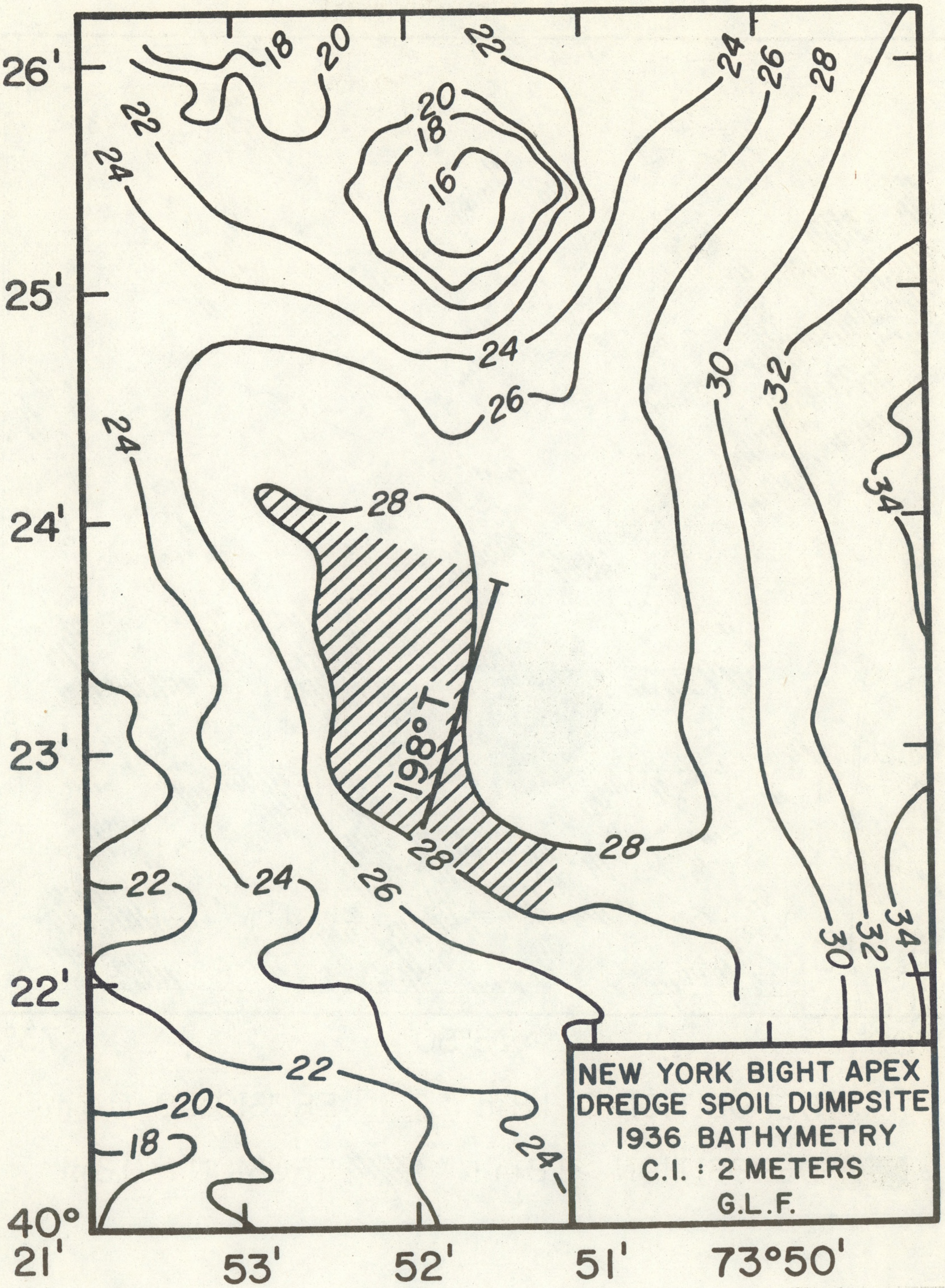

Figure 4. New York Bight dredge-spoil dumpsite. 1936 bathymetry. Line marked 198°T and hachured area show the dumpsite designated prior to 1977 based on 1936 soundings to lie within the 27.4-m (90-ft) isobath.

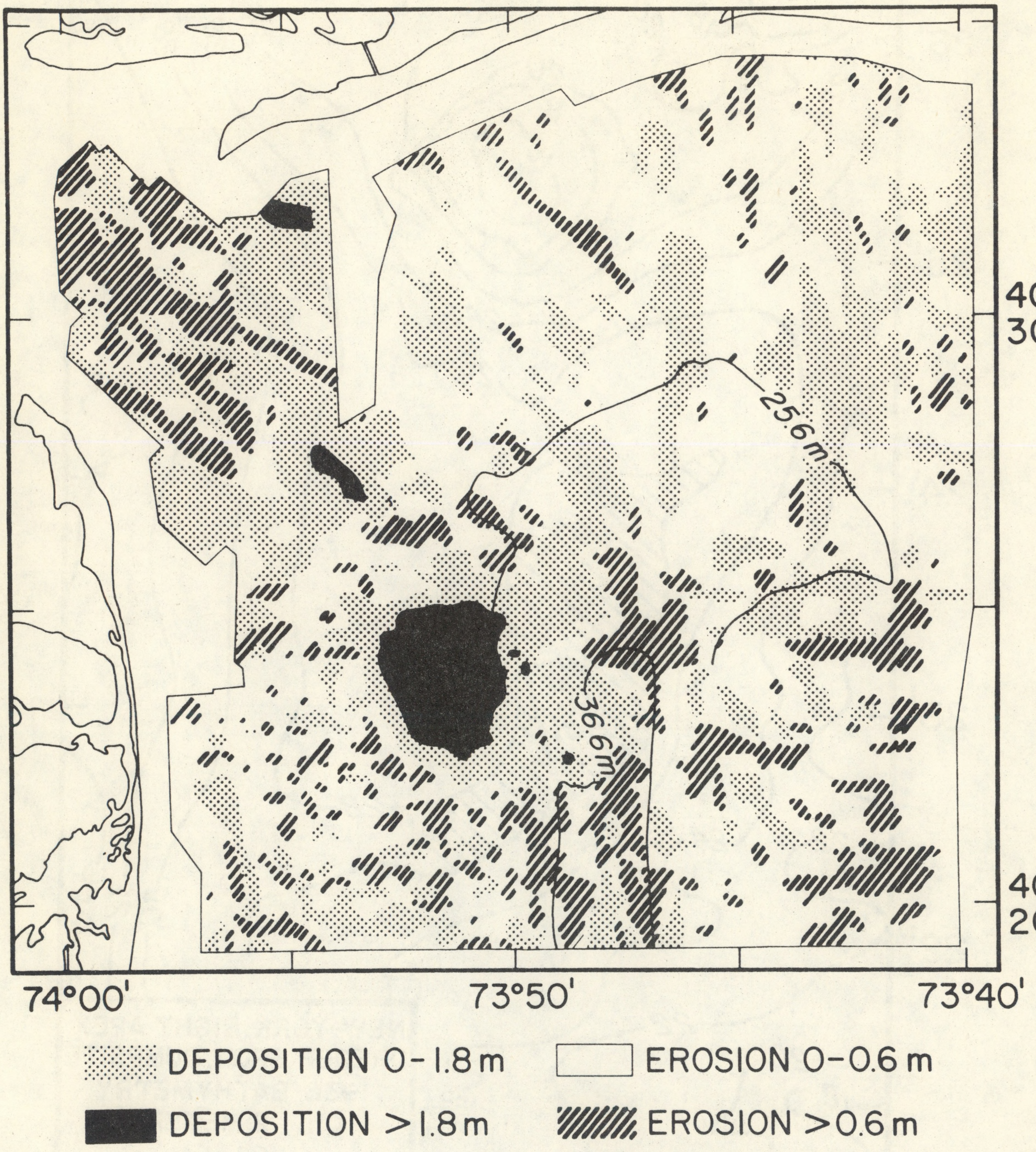

Figure 3. Net bathymetric change, New York Bight Apex, from 1936 to 1973.

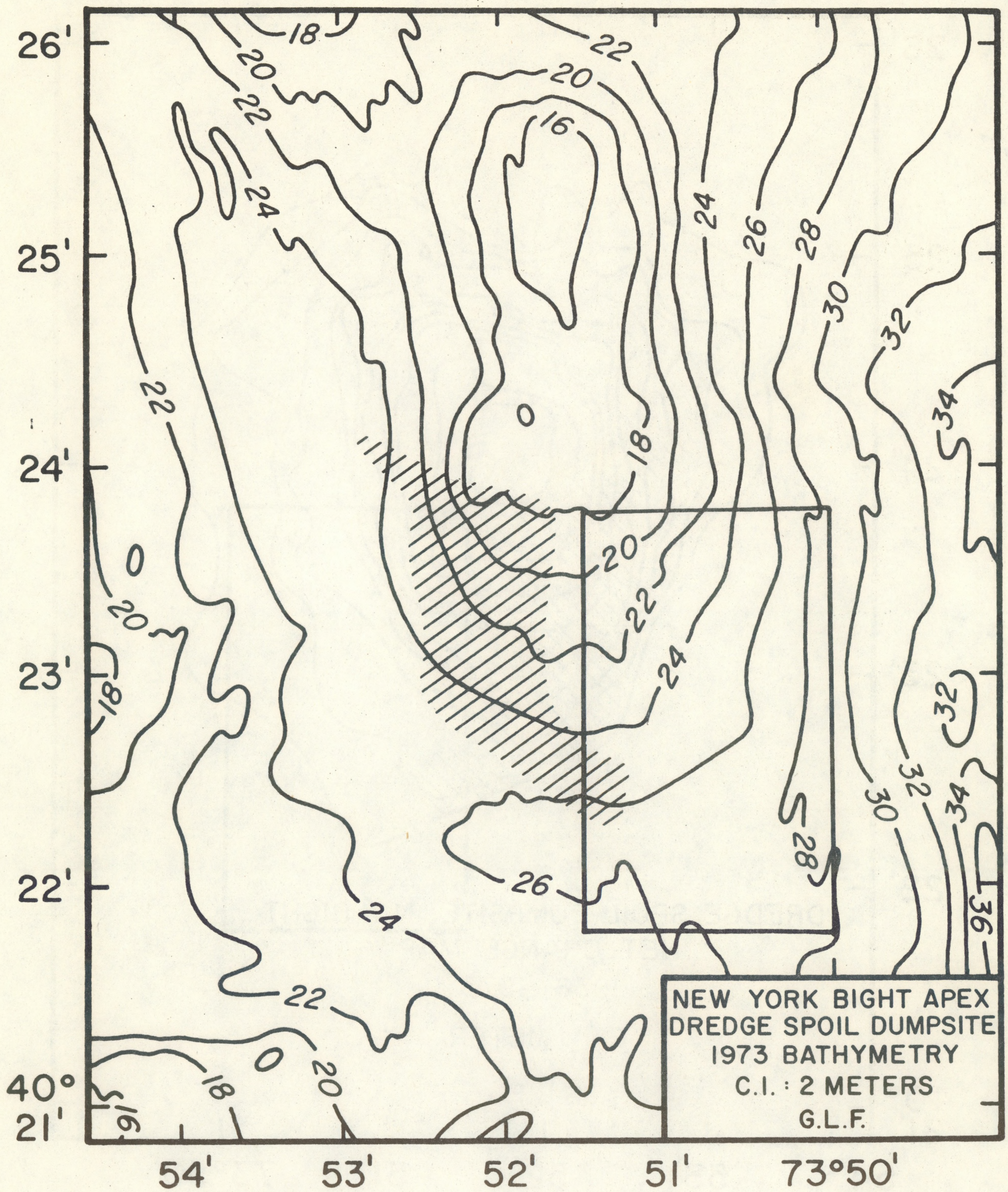

Figure 5. New York Bight dredge-spoil dumpsite, 1973 bathymetry. The rectangular area to the southeast of the mound is the dumpsite designated by the Environmental Protection Agency starting January 1977.

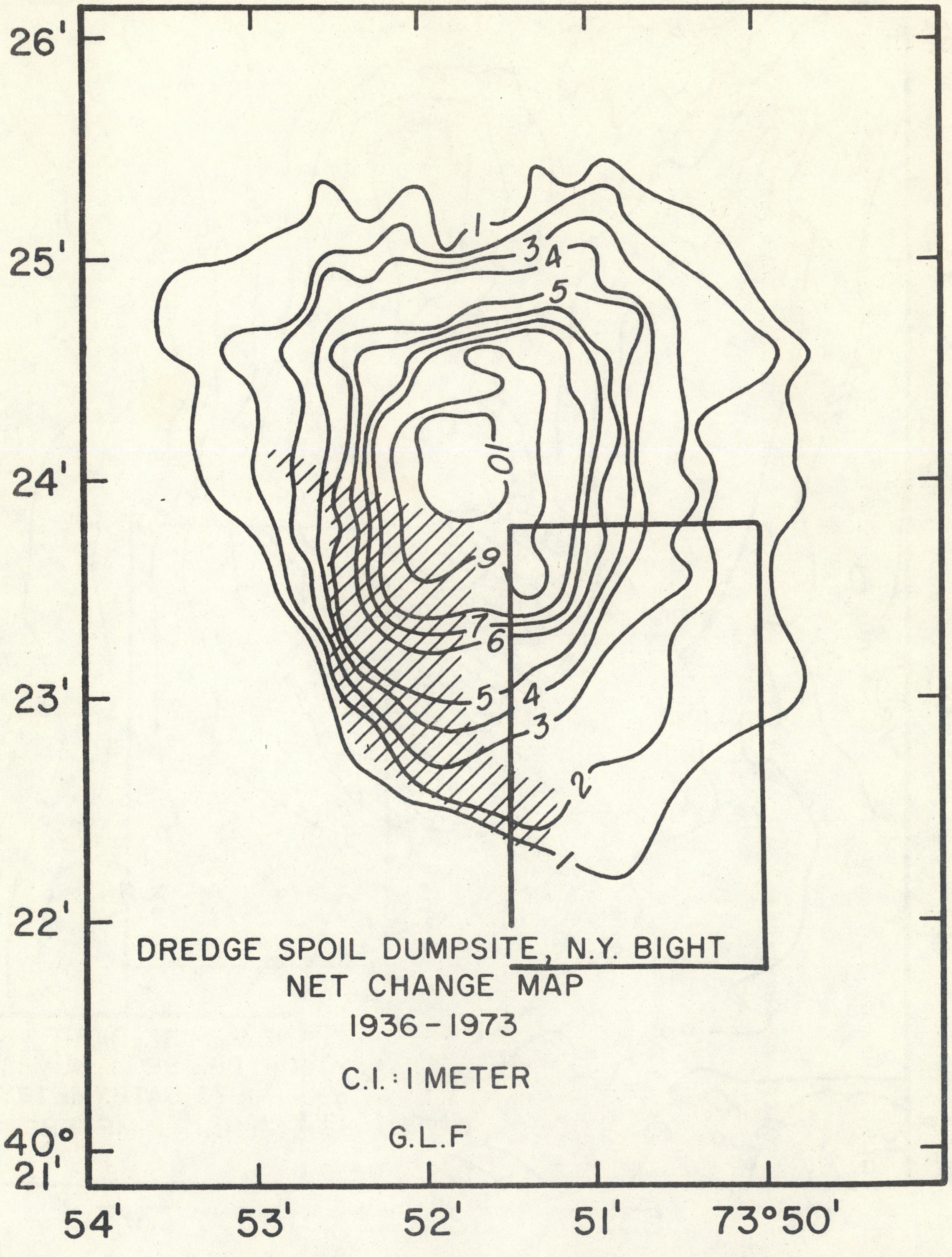

Figure 6. New York Bight dredge-spoil dumpsite. Net change in depth from 1936 to 1973. Note that the 14.3-m (47-ft) knoll in the 1936 map is essentially unchanged and that a large volume of material has been dumped north and east of the dumpsite designated from the 1936 map (hachured area). The rectangular area is the same as shown on Figure 5.