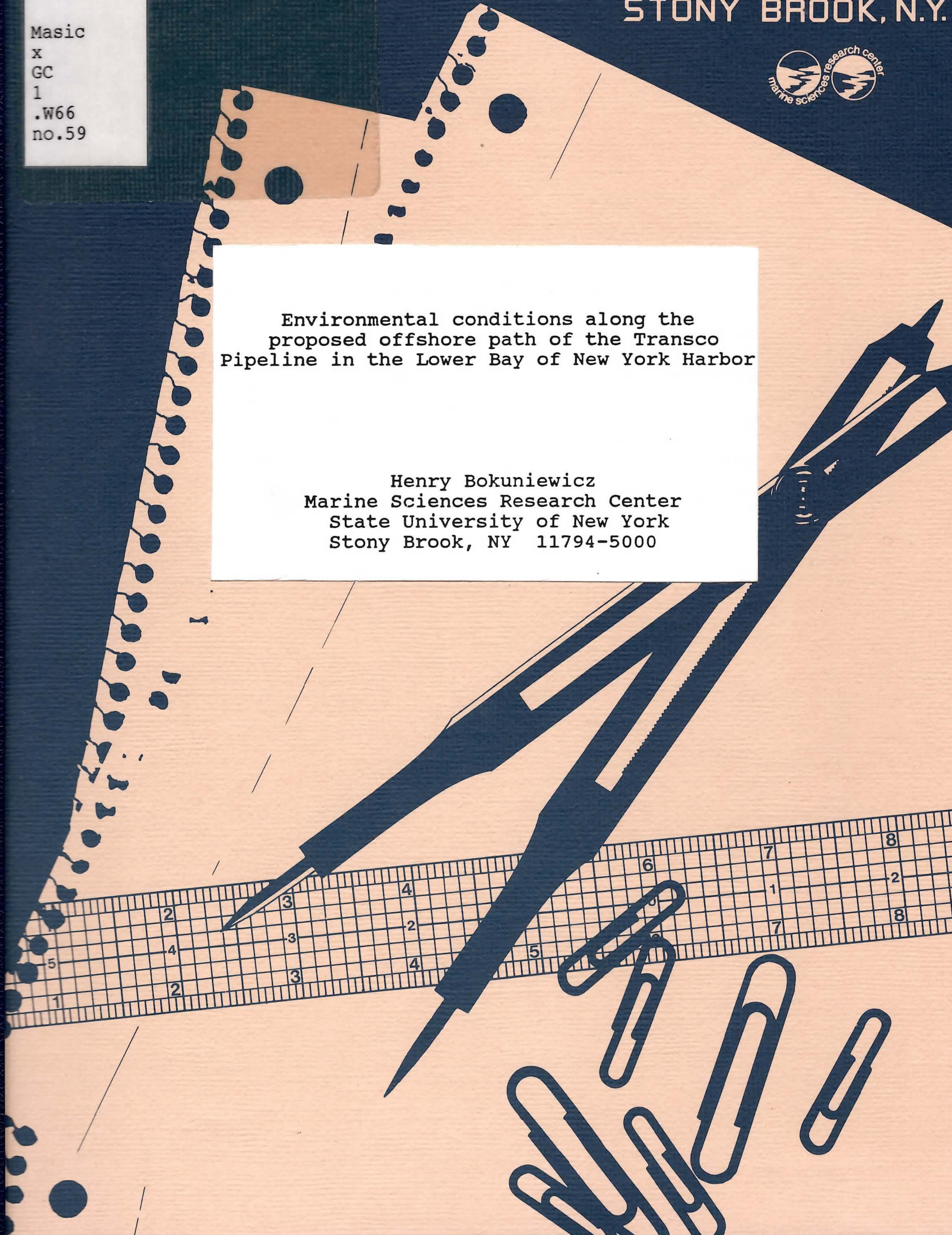
MARINE SCIENCES RESEARCH CENTER
STATE UNIVERSITY of NEW YORK
STONY BROOK, N.Y.



Environmental conditions along the proposed offshore path of the Transco Pipeline in the Lower Bay of New York Harbor

Henry Bokuniewicz
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000

MARINE SCIENCES RESEARCH CENTER

STATE UNIVERSITY OF NEW YORK

STONY BROOK, NEW YORK 11794-5000

Environmental conditions along the proposed offshore path of the Transco Pipeline in the Lower Bay of New York Harbor

Henry Bokuniewicz
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000

Approved for Distribution

J R Schubel

J. R. Schubel, Director

Working Paper #59
Reference #92-05

INTRODUCTION

A buried gas pipeline is proposed to run from the southern tip of Staten Island westward across Raritan Bay thence across the Ambrose Channel to Kennedy International Airport (Figure 1). The purpose of this report is to review the geological and environmental conditions along this route.

BEDROCK AND SEISMICITY

Crystalline bedrock outcrops in northwestern Staten Island and generally dips to the southeast under the Lower Bay. Borings that have reached bedrock in both New Jersey and on Long Island can be used to define the regional trend and to interpolate the altitude of the buried bedrock surface beneath the bay (Spangler and Peterson, 1950; deLaguna and Brashears, 1948). Bedrock should lie at a depth of about 250 feet under the southern tip of Staten Island, increase to a depth of about 800 feet at the northern tip of Sandy Hook (Figure 2) and lie about 1000 feet beneath the surface at the eastern terminus of the proposed route at Kennedy Airport. These are Paleozoic and Precambrian rocks. Precambrian soapstone was encountered at a depth of 95 m near Great Kills, Staten Island, and granites under New Jersey's Raritan Bay coast and Rockaway Beach (Hutchinson and Grow, 1985). These rocks are bounded to the east and west by Jurassic-Triassic rocks and related fault system, particularly the New York Bight Fault about 30 km off the New Jersey shoreline in the east (Hutchinson and Grow, 1985) and the Ramapo Fault about 40 km to the west.

Specific faults in the rock underlying the route are unknown and earthquake activity in this area has not been ascribed to specific faults although it appears to be due to reactivation of previously fractured surfaces (Sbar and Sykes, 1977). The region is one of moderate, low-level seismic activity (Sbar and Sykes, 1977). Since 1737 at least 10 earthquakes with intensities between V and VII (or approximately between magnitudes 4.4 and 5.7) occurred with epicenters in the vicinity of the Lower Bay (Weems and Perry, 1989). Between 1975 and 1981 five earthquakes occurred here with magnitudes (by the Nuttli formula) of 1.8 (1982, off Sandy Hook), 3.5 (1979, Cheesequake, NJ), 2.0 (1978, offshore NJ), and 2.8 and 1.9 (1976 offshore NJ; Hutchinson and Grow, 1985). On 9 January, 1992 a earthquake with magnitude 3.2 occurred at Old Bridge, NJ (about 10 miles south of Perth Amboy, NY Times, 10 Jan. 1992, p. B5). Based on the data between 1730 and 1980, Mitronovas (1982) observed the following recurrence intervals for earthquakes in this region:

Intensity (modified Mercalli)	Approximate Magnitude (Nuttli formula)	Recurrence Time (years)
IV	3.7	4
V	4.7	10
VI	5.0	40
VII	5.7	125

SEDIMENT DESCRIPTIONS

At the western end of the proposed route, there is a good set of 14 borings taken across the Arthur Kill in 1971 (Lovegreen, undated; Figure 3). North of the Kill, bedrock (the Palisades diabase) is encountered at a depth of about 50 feet below sea level. South of the Kill, the rock surface under

Staten Island drops to depths greater than 100 feet below sea level. It is overlain by Cretaceous sediment whose surface lies at a depth of between 30 and 50 feet below sea level and generally covered with Pleistocene strata of sand, sand and gravel, and clay. On either side of the proposed route about where it crosses Route 440, Cretaceous sediments extend to depths of at least 190 feet below sea level on the west and 120 feet on the east. The upper 50 to 100 feet of the Cretaceous is fine-grained and the lower layers sand. The Pleistocene cover has a base of sand and gravel between 8 feet thick (in the west) and 14 feet thick (in the east). These may be the northern edge of the Cape May Formation overlain by undifferentiated clay and sand layers that are not well-mapped and vary in thickness between 1 and 26 feet thick. South of Route 440, the southern tip of Staten Island is covered by the Harbor Hill terminal moraine; the surface sediment is poorly sorted till in which large boulders will be encountered.

South of Staten Island a good set of borings were available between Sequine Point, Staten Island and Conaskonk, NJ, about a mile east of the proposed pipeline route. These had been taken in 1930 and 1931 for a bridge and discussed by MacClintock and Richards (1936). The deepest boring reaches -180 feet through 155 feet of sediment (Figure 4). The Cretaceous Raritan Formation is penetrated at a depth of about 60 feet below sea level.

In Raritan Bay below water depths of between 5 and 10 feet, the bay floor is composed of marine mud. The borings described by MacClintock and Richards (1936) show this mud to be infilling a channel cut into the underlying sands with a thalweg at a little over 150 feet. This feature is not resolved in other places; appropriately placed deep borings do not exist. However, the buried channel is postulated to extend eastward under the muddy sediment of Raritan and Sandy Hook Bay to Sandy Hook (and beyond to the Highland Channel) (Bokuniewicz and Fray, 1979). The muds are generally 10 to 15 feet thick over the bottom of the bay outside of the channel's axis.

Near the submerged route of the proposed pipeline, there are only five relatively short cores and one deeper boring. Several seismic reflection surveys cross the area but the structure is obscured in Raritan Bay both because of the generally opaque character of the mud and the shallowness of the water. East of Sandy Hook, the sediment's acoustic structure shallower than 100 feet is complicated by various dipping and discontinuous acoustic horizons probably due to the alluvial, cut-and-fill deposits, but there seems to be a strong, horizontal reflector at a depth of about 100 feet. This is probably an outwash sand layer above the Gardiners clay which should be at a depth of 150 feet and may be resolved on seismic tracks reported by Williams and Duane (1974). Since there have been no extensive clay layers described above the Gardiners, coarse-grained sediments most likely persist to this depth and the boring taken near Sandy Hook (Williams and Duane, 1974) might be characteristic of the upper 100 feet of the sediment here. That boring was composed of:

Interval (feet)	Description
0-5	Dark grey, fine to medium sand with organic silt and shells
5-18	Dark grey, fine to medium sand with shells
18-26	Greyish brown, fine to medium sand with traces of gravel
26-36	Grey, fine to medium sand
34-39	Yellowish brown fine to medium sand

These data are summarized in the cross section along the submerged path shown in Figure 5. The proposed pipeline route has two possible paths leaving Staten Island (Figure 1). The westernmost path is represented on Figure 5. It would begin to transverse a sandy bay floor (the Wards Point sand) until the Channel is reached. This sand is estimated to be about 13 feet thick. If we assume that the stratigraphy here is represented by the boring between Sequine Point and Conaskonk, then these sand would be underlain by a thin layer of consolidated marine mud resting on a gravelly red sand of the Cape May Formation which extends to a depth of about 40 feet. Below this the grey sand of the upper Raritan Formation would be encountered superimposed on a clay layer at a depth of about 140 feet. (The eastern path would first cross a muddy bay floor. The stratigraphy here is unknown but these muds are likely to be a thin blanket recently deposited over the Wards Point Sand with an underlying stratigraphy like that just described.)

Both of these routes would cross the mud-filled valley of the ancestral Raritan River at about the position of the Channel. Based on the borings south of Sequine Point, this valley would have a thalweg at about 150 feet cutting through the Cape May Formation and the upper sand layer of the Raritan and be infilled by fine-grained sediments. Crossing this valley, the eastern path would cross the exposed Wards Point Sand but both would traverse a muddy bay floor until they turn 90° to the east (B on Figures 1 and 5).

At this point (B, Figures 1 and 5) the mud layer would extend to a depth of about 30 feet as sampled by two short cores along the eastward route (2 and B7, Bokuniewicz and Fray, 1979). This mud overlies the Cape May Formation which is encountered here as a clayey gravel. The surface of the Raritan dips downward along this track from an elevation of -60 feet where the route turns eastward (B) to a depth of about 140 feet at the location (C on Figure 1 and 5) where the alternate route joins the main route. The proposed path crosses the West Raritan Bay Muds and then the Keansburg Sands, between Raritan and Sandy Hook Bays, for a distance of about 1.5 n. miles. These sands are found interlayered with mud and may be about 14 feet thick (Bokuniewicz and Fray, 1979).

Further to the east under Sandy Hook Bay, the Magothy Formation should begin to be encountered above the Raritan, but no borings in the bay have definitely encountered the Magothy. The two are similar in composition; the Magothy is generally described as alternating beds of clay and light sand containing abundant lignite. Acoustic records north of Sandy Hook show a horizontal reflector at a depth of about 100 feet. This may be an erosional surface that truncates the Magothy further to the west (as shown in Figure 2). Above this horizon the deposits are undifferentiated alluvial sands and gravels.

Before the route angles northeastwardly past Sandy Hook (D on Figure 1) the mud-filled valley of the ancestral Raritan should be crossed again. There are no borings or seismic records that confirm its presence. Its route has been inferred from (a) the borings south of Sequine Point, (b) the presence of mud lines under Sandy Hook and the location of the Highland Channel on the shelf which was assumed to have been its path across the shelf (Bokuniewicz and Fray, 1979). (There are a series of borings that were taken along the U.S. Navy Pier at Earle (Figure 6). Although the section detailed by these borings does not extend far enough north to intersect the proposed route of the pipeline, which passes north of the channel here, borings near the channel show estuarine mud to a depth of at least 47 feet.)

The deep boring (B1), referred to above, is not located along the track and its water depth is uncertain but the log of this boring is given on Figure 4 since the layering is probably characteristic of the region. After the route turns to pass Sandy Hook, the top of the Magothy should lie below 150 feet. The character of the unit directly above the Magothy between 100 and 150 feet deep is unknown. It has been referred to as the " -layer"; it is assumed to be coarse grained; and it is bounded by a horizontal seismic horizon at a depth of about 100 feet (Bokuniewicz and Fray, 1979). Between that horizon and a depth of about 65 feet, layered sands with occasional gravel, are found. This has been referred to the " -layer" and may be the Cape May Formation.

Little is known about the stratigraphy of the inner shelf between the location where the route passes north of Sandy Hook until it turns northward to reach Rockaway Beach (location "6" on Figures 1 and 4). The surficial sand bodies were described by Bokuniewicz and Fray (1979); these are shown on Figure 7 and the areas crossed by the proposed route west of the Ambrose Channel have the following descriptions.

Deposit (Figure 7)	Description	Estimated thickness (Bokuniewicz and Fray, 1979)
XXb	fine sand	160 feet
XlX	medium sand	52 feet
XXl	medium to very coarse sand	8 feet

East of the Ambrose Channel, vibrocores in the surficial 8 to 12 feet of sediment show layers of medium to coarse sand, medium sand, fine sand, fine to medium sand, medium sand with pebbles and a shell hash. Maps show that the surficial sediment is sandy gravel (10 to 50% sand) on the south bank of the Ambrose Channel but 90% sand along the rest of the route (Freeland, 1981).

Where the track turns northward ("6" on Figure 1), seismic records slightly to the east show cross-bedded structures above -100 feet presumably alluvial sands and gravels. Another horizontal reflector at a depth of about 150 feet (Williams and Duane, 1974) may be the top of the Gardiner's Clay which lies at about this depth under the Rockaway shoreline (Figure 2). The identification is uncertain, however, and if the horizon at -150 feet is the Gardiner's surface, the composition of the overlying layer is uncertain.

Heading north towards Kennedy Airport, the route trends updip over the formation underlying Long Island. These are shown on Figure 2 as interpolated from deep borings. In ascending order, these are (Perlmutter and Arnow, 1953)

a. the basement (granitic) rocks.

b. the Llyod sand member of the Raritan Formation. This is a medium to coarse sand and fine to medium gravel which contain beds of fine sandy clay, clayey sand and thin layers of clay.

c. the Raritan clay (laminated silt and clay with sandy lenses).

d. the Magothy Formation of fine clayey sand, fine sand, silt and clay layers. Occasionally coarse sand and gravel layers are encountered.

e. the coarse sand and gravel beds of the Jameco Gravel which has been reported to contain "some cobbles, boulders and scattered layers of silt and clay".

f. the Gardiner's Clay which is described as a "silt and solid clay" but may also contain layers of fine to coarse sand.

g. undifferentiated outwash and alluvial deposits ranging in size from clay to gravel.

WATER LEVELS AND WAVE CLIMATE

There are no site specific wave measurements for the region of the mouth of the Lower Bay of New York Harbor, but wave statistics have been hindcasted from weather conditions over a 20-year period by the U.S. Army Corps of Engineers (Jensen, 1983). At a station 1.5 nautical miles south of Rockaway Point for a water depth of 10 m, the hindcasted wave distribution is shown in Figure 8. The average significant wave height is 0.47 m while the largest is 3.71 m. Over the year the average wave height ranges from 0.66 m in March to 0.38 in August while the maximum wave heights range from 3.71 m in March to 2.24 m in June. The monthly hindcasts are given in Table 1.

Storm surges, excluding tropical storms, have been calculated by Ebersole (1982) using the NOS tide gage records at Sandy Hook which has been in operation since 1933 (Figure 9). A preliminary calculation has also been done by the Waterways Experiment Station including tides, hurricanes and nor'easters and shown as a dashed line on Figure 9. An extreme water level with a 100-year recurrence interval is forecast to reach 11.5 feet above mean sea level.

CONTAMINATION

Recently deposited fine-grained sediments in this general region contain elevated levels of contaminants. The sediments in the Arthur Kill and the submerged muds around Kennedy Airport should be expected to be contaminated but the greatest extent of contaminated sediments along proposed route are the muds of Raritan and Sandy Hook Bays. Zinc concentrations in Raritan Bay range from 200 to 400 ppm; copper, from 200 to 410 ppm; lead, from 100 to 240 ppm; PCB, from 0.04 to 1.4 ppm; and petroleum hydrocarbon have concentrations as high as 892 ppm (Olsen, et al., 1984). The concentrations tend to be higher in the western part of the Bay. In the Raritan Bay Channel, contamination may extend through a surficial layer about 30 cm thick but on the

Table 1 (page 1 of 4)

STATION 53 MONTH 1 FOR ALL DIRECTIONS
SHORELINE ANGLE = 19.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS)													TOTAL
	0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-LONGER	
0. - 0.19	.	18	234	271	271	329	606	458	358	23	18	.	.	2586
0.20 - 0.39	.	.	189	376	239	166	239	629	453	68	5	.	.	2364
0.40 - 0.59	.	.	.	361	284	131	94	392	202	26	10	84	7	1591
0.60 - 0.79	.	.	.	39	313	129	39	226	258	7	2	173	.	1186
0.80 - 0.99	.	.	.	.	150	173	39	155	118	5	42	31	13	726
1.00 - 1.19	.	.	.	.	18	123	55	92	100	5	94	.	28	515
1.20 - 1.49	.	.	.	.	.	63	102	102	65	5	21	.	57	415
1.50 - 1.99	.	.	.	.	.	.	52	139	81	23	26	.	36	357
2.00 - 2.49	.	.	.	.	.	.	13	79	31	7	2	13	26	171
2.50 - 2.99	.	.	.	.	.	.	.	2	15	.	.	18	.	35
3.00 - 3.49	.	.	.	.	.	.	.	.	.	2	.	7	.	9
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	18	423	1047	1275	1114	1239	2274	1681	171	220	326	167	

AVE HS(M) = 0.55 LARGEST HS(M) = 3.41 TOTAL CASES = 3794.

STATION 53 MONTH 2 FOR ALL DIRECTIONS
SHORELINE ANGLE = 19.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS)													TOTAL
	0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-LONGER	
0. - 0.19	.	36	163	115	181	178	286	362	236	52	57	2	.	1668
0.20 - 0.39	.	.	134	249	168	149	165	518	265	63	68	549	5	2333
0.40 - 0.59	.	.	2	265	278	131	57	310	336	163	70	397	26	2035
0.60 - 0.79	.	.	.	26	273	149	31	268	310	181	89	57	.	1384
0.80 - 0.99	.	.	.	.	165	134	31	184	105	126	128	63	.	936
1.00 - 1.19	.	.	.	.	42	152	39	105	89	21	31	21	.	500
1.20 - 1.49	.	.	.	.	.	123	84	134	55	2	15	44	.	457
1.50 - 1.99	.	.	.	.	.	7	105	136	73	10	26	55	.	412
2.00 - 2.49	.	.	.	.	.	.	28	102	47	10	5	.	.	192
2.50 - 2.99	.	.	.	.	.	.	.	15	23	5	.	.	.	43
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	2	.	.	.	2
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	36	299	655	1107	1023	826	2134	1539	635	489	1188	31	

AVE HS(M) = 0.62 LARGEST HS(M) = 3.55 TOTAL CASES = 3803.

STATION 53 MONTH 3 FOR ALL DIRECTIONS
SHORELINE ANGLE = 19.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS)													TOTAL
	0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-LONGER	
0. - 0.19	.	22	128	192	116	121	245	433	318	4	48	133	32	1792
0.20 - 0.39	.	.	149	316	178	82	105	571	371	98	25	135	9	2039
0.40 - 0.59	.	.	.	314	222	80	43	449	268	61	73	94	.	1604
0.60 - 0.79	.	.	.	52	314	89	38	272	240	71	71	204	.	1351
0.80 - 0.99	.	.	.	.	247	133	61	160	167	41	91	112	112	1124
1.00 - 1.19	.	.	.	.	45	165	50	121	84	22	45	38	61	631
1.20 - 1.49	.	.	.	.	4	119	133	146	91	25	57	16	123	714
1.50 - 1.99	.	.	.	.	.	6	91	181	105	20	6	6	77	492
2.00 - 2.49	.	.	.	.	.	.	20	57	45	13	9	6	6	156
2.50 - 2.99	.	.	.	.	.	.	.	11	20	4	.	2	.	37
3.00 - 3.49	.	.	.	.	.	.	.	.	.	6	2	.	.	8
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	2	.	.	2
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	22	277	874	1126	795	786	2401	1709	365	429	746	420	

AVE HS(M) = 0.66 LARGEST HS(M) = 3.71 TOTAL CASES = 4359.

Table 1 continued (page 2 of 4)

```
                          STATION  53   MONTH  4    FOR ALL DIRECTIONS
                   SHORELINE ANGLE =   19.0  DEGREES AZIMUTH
                   WATER DEPTH = 10.00  METRES
                   PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS
HEIGHT(METRES)                            PERIOD(SECONDS)                                       TOTAL

                 0.0-  1.0-  2.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0- 12.0-
                  0.9   1.9   2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  11.9 LONGER

0.   - 0.19          .    22   173   162    90    76   250   663   324   112    13    31     .    1916
0.20 - 0.39          .     .   162   349   164   106   356   663   424    13    40    88     .    2365
0.40 - 0.59          .     .     .   412   252   101    85   415   300     2   162   133    97    1959
0.60 - 0.79          .     .     .   101   318   112    27   234   182     .   221    78   153    1426
0.80 - 0.99          .     .     .     6   248   194    45   164   130     2    27     4   103     923
1.00 - 1.19          .     .     .     .    42   182    49    94    67     4     .     2    20     460
1.20 - 1.49          .     .     .     .     6    97    92   180    90     9     4     .    11     489
1.50 - 1.99          .     .     .     .     .    13    99   146    60     2     2     .     2     324
2.00 - 2.49          .     .     .     .     .     .     9    47    33     4     .     .     .      93
2.50 - 2.99          .     .     .     .     .     .     .     .     .     6     .     .     .       6
3.00 - 3.49          .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.50 - 3.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.00 - 4.49          .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.50 - 4.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
5.00 - GREATER       .     .     .     .     .     .     .     .     .     .     .     .     .       0
   TOTAL             0    22   335  1030  1120   881  1012  2606  1610   154   469   336   386
  AVE HS(M) = 0.57    LARGEST HS(M) = 2.76    TOTAL CASES =  4431.
```

```
                          STATION  53   MONTH  5    FOR ALL DIRECTIONS
                   SHORELINE ANGLE =   19.0  DEGREES AZIMUTH
                   WATER DEPTH = 10.00  METRES
                   PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS
HEIGHT(METRES)                            PERIOD(SECONDS)                                       TOTAL

                 0.0-  1.0-  2.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0- 12.0-
                  0.9   1.9   2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  11.9 LONGER

0.   - 0.19          .    37   251   171    64    62   720   443   134     2    43     .     .    1927
0.20 - 0.39          .     .   203   508   261    87   330  1210   466    20     2     .     .    3087
0.40 - 0.59          .     .     .   544   381   125    75   944   280     2     .     .     .    2351
0.60 - 0.79          .     .     .   117   483   138    27   406    69     4     .     .     .    1244
0.80 - 0.99          .     .     .     .   284   123    35   148    60     2     .     .     .     652
1.00 - 1.19          .     .     .     .    41   146    39    94    18     2     .     .     .     340
1.20 - 1.49          .     .     .     .     2    56    50    58    39     4     .     .     .     209
1.50 - 1.99          .     .     .     .     .     2    35    54    37     .     .     .     .     128
2.00 - 2.49          .     .     .     .     .     .     .    10    20     2     .     .     .      32
2.50 - 2.99          .     .     .     .     .     .     .     .     2     .     .     .     .       2
3.00 - 3.49          .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.50 - 3.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.00 - 4.49          .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.50 - 4.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
5.00 - GREATER       .     .     .     .     .     .     .     .     .     .     .     .     .       0
   TOTAL             0    37   454  1340  1516   739  1311  3367  1125    38    45     0     0
  AVE HS(M) = 0.47    LARGEST HS(M) = 2.65    TOTAL CASES =  4776.
```

```
                          STATION  53   MONTH  6    FOR ALL DIRECTIONS
                   SHORELINE ANGLE =   19.0  DEGREES AZIMUTH
                   WATER DEPTH = 10.00  METRES
                   PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS
HEIGHT(METRES)                            PERIOD(SECONDS)                                       TOTAL

                 0.0-  1.0-  2.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0- 12.0-
                  0.9   1.9   2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  11.9 LONGER

0.   - 0.19          .     6   115   111    65    46   553   481   119     .    12     .     .    1508
0.20 - 0.39          .     .   279   502   149    65   473  1643   332     .     .     .     .    3443
0.40 - 0.59          .     .     4   502   385   115    86  1142   464     .     .     .     .    2698
0.60 - 0.79          .     .     .    73   450   134     8   319   271     .     .     .     .    1255
0.80 - 0.99          .     .     .     4   199   143    21   115   103     .     .     .     .     585
1.00 - 1.19          .     .     .     .    27    65    12    52    37     .     4     .     .     197
1.20 - 1.49          .     .     .     .     .    25    18    54    33     .    48     .     .     178
1.50 - 1.99          .     .     .     .     .    10    10    46     4     4    25     .     .      99
2.00 - 2.49          .     .     .     .     .     .     2     6     4     .     .     .     .      12
2.50 - 2.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.00 - 3.49          .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.50 - 3.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.00 - 4.49          .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.50 - 4.99          .     .     .     .     .     .     .     .     .     .     .     .     .       0
5.00 - GREATER       .     .     .     .     .     .     .     .     .     .     .     .     .       0
   TOTAL             0     6   398  1192  1275   603  1183  3858  1367     4    89     0     0
  AVE HS(M) = 0.46    LARGEST HS(M) = 2.24    TOTAL CASES =  4753.
```

Table 1 continued (page 3 of 4)

```
                    STATION  53   MONTH  7    FOR ALL DIRECTIONS
            SHORELINE ANGLE =  19.0  DEGREES AZIMUTH
            WATER DEPTH = 10.00  METRES
            PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)                          PERIOD(SECONDS)                                  TOTAL

                    0.0-  1.0-  2.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0- 12.0-
                     0.9   1.9   2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  11.9 LONGER

0.   - 0.19            .     4   122    97    52    28   433   501   238     .     .     .     .    1475
0.20 - 0.39            .     .   220   429   162    55   448  1829   768     2     .     .     .    3913
0.40 - 0.59            .     .     .   592   383    93    89  1151   802     2     .     .     .    3112
0.60 - 0.79            .     .     .    71   350    89    26   207   209     4     .     .     .     956
0.80 - 0.99            .     .     .     .   114    55    20    36    55     .     .     .     .     280
1.00 - 1.19            .     .     .     .    14    36    16    18    26     .     .     .     .     110
1.20 - 1.49            .     .     .     .     .    32    20    32    18     .     .     .     .     102
1.50 - 1.99            .     .     .     .     .     .    10     4     4     8     .     .     .      26
2.00 - 2.49            .     .     .     .     .     .     .     4     .     .     .     .     .       4
2.50 - 2.99            .     .     .     .     .     .     .     2     .     .     .     .     .       2
3.00 - 3.49            .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.50 - 3.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.00 - 4.49            .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.50 - 4.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
5.00 - GREATER         .     .     .     .     .     .     .     .     .     .     .     .     .       0
   TOTAL               0     4   342  1189  1075   388  1062  3784  2120    16     0     0     0

AVE HS(M) = 0.41    LARGEST HS(M) = 2.83    TOTAL CASES =  4908.
```

```
                    STATION  53   MONTH  8    FOR ALL DIRECTIONS
            SHORELINE ANGLE =  19.0  DEGREES AZIMUTH
            WATER DEPTH = 10.00  METRES
            PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)                          PERIOD(SECONDS)                                  TOTAL

                    0.0-  1.0-  2.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0- 12.0-
                     0.9   1.9   2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  11.9 LONGER

0.   - 0.19            .    33   224   177    82    33   297   782   449     .    16     .     .    2093
0.20 - 0.39            .     .   276   565   237    76   315  1859  1106     6     .     .     .    4440
0.40 - 0.59            .     .     2   614   340   121    30   670   330     .     .     .     .    2107
0.60 - 0.79            .     .     .    55   253    90    16   198   163     .     .     .     .     775
0.80 - 0.99            .     .     .     .   117    76    12    76    86     .     .     .     .     367
1.00 - 1.19            .     .     .     .     4    41     4    30    18     .     .     .     .      97
1.20 - 1.49            .     .     .     .     .    18    18    28     4     .     .     .     .      68
1.50 - 1.99            .     .     .     .     .     .    10     8     2     2     .     .     .      22
2.00 - 2.49            .     .     .     .     .     .     2     .     2     6     .     .     .      10
2.50 - 2.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.00 - 3.49            .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.50 - 3.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.00 - 4.49            .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.50 - 4.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
5.00 - GREATER         .     .     .     .     .     .     .     .     .     .     .     .     .       0
   TOTAL               0    33   502  1411  1033   455   704  3651  2160    14    16     0     0

AVE HS(M) = 0.38    LARGEST HS(M) = 2.46    TOTAL CASES =  4846.
```

```
                    STATION  53   MONTH  9    FOR ALL DIRECTIONS
            SHORELINE ANGLE =  19.0  DEGREES AZIMUTH
            WATER DEPTH = 10.00  METRES
            PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)                          PERIOD(SECONDS)                                  TOTAL

                    0.0-  1.0-  2.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0- 12.0-
                     0.9   1.9   2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  11.9 LONGER

0.   - 0.19            .    91   375   279   163   145   563   532   717     .     4     .     .    2869
0.20 - 0.39            .     .   339   755   266   100   216   851   286   194     .     .     .    3007
0.40 - 0.59            .     .     .   529   310   100   122   427   158    64     .     .     .    1710
0.60 - 0.79            .     .     .    84   310    87    26   194   239    20     .     .     .     960
0.80 - 0.99            .     .     .     2   187    93    24   192   102     .     .     .     .     600
1.00 - 1.19            .     .     .     .    33    73    42   125    35     .     .     .     .     308
1.20 - 1.49            .     .     .     .     .    46    15   105   111     .     .     .     .     277
1.50 - 1.99            .     .     .     .     .     6    31    87    58     4     2     .     .     188
2.00 - 2.49            .     .     .     .     .     .     4    20    17     .     2     .     .      43
2.50 - 2.99            .     .     .     .     .     .     .     .     2     2     2     .     .       6
3.00 - 3.49            .     .     .     .     .     .     .     .     .     .     .     .     .       0
3.50 - 3.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.00 - 4.49            .     .     .     .     .     .     .     .     .     .     .     .     .       0
4.50 - 4.99            .     .     .     .     .     .     .     .     .     .     .     .     .       0
5.00 - GREATER         .     .     .     .     .     .     .     .     .     .     .     .     .       0
   TOTAL               0    91   714  1649  1269   650  1043  2533  1725   284    10     0     0

AVE HS(M) = 0.44    LARGEST HS(M) = 2.72    TOTAL CASES =  4472.
```

Table 1 continued (page 4 of 4)

STATION 53 MONTH 10 FOR ALL DIRECTIONS
SHORELINE ANGLE = 19.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS) 0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-LONGER	TOTAL
0. - 0.19	.	76	239	246	214	178	375	357	151	233	11	15	.	2095
0.20 - 0.39	.	.	350	463	158	126	183	545	289	194	6	9	.	2323
0.40 - 0.59	.	.	.	371	203	115	76	547	420	214	133	.	.	2079
0.60 - 0.79	.	.	.	63	343	106	52	303	190	140	126	.	.	1323
0.80 - 0.99	.	.	.	2	190	106	36	156	171	4	101	95	.	861
1.00 - 1.19	.	.	.	.	31	149	31	104	90	40	31	24	.	500
1.20 - 1.49	.	.	.	.	15	90	36	110	79	15	.	18	.	353
1.50 - 1.99	.	.	.	.	.	15	40	104	81	4	2	.	.	246
2.00 - 2.49	.	.	.	.	.	.	6	61	83	.	.	.	.	150
2.50 - 2.99	.	.	.	.	.	.	.	.	24	.	.	.	.	24
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	76	589	1145	1154	885	835	2287	1578	844	410	161	0	

AVE HS(M) = 0.55 LARGEST HS(M) = 3.00 TOTAL CASES = 4420.

STATION 53 MONTH 11 FOR ALL DIRECTIONS
SHORELINE ANGLE = 19.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS) 0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-LONGER	TOTAL
0. - 0.19	.	71	247	175	155	225	290	268	211	83	7	50	.	1782
0.20 - 0.39	.	.	131	388	151	105	227	352	239	386	254	11	103	2347
0.40 - 0.59	.	.	.	359	280	163	105	350	299	215	309	2	153	2235
0.60 - 0.79	.	.	.	62	374	153	76	278	194	105	38	16	83	1379
0.80 - 0.99	.	.	.	.	218	208	47	191	151	21	14	14	2	866
1.00 - 1.19	.	.	.	.	38	163	62	110	107	9	2	4	7	502
1.20 - 1.49	.	.	.	.	4	117	117	88	83	4	.	2	.	415
1.50 - 1.99	.	.	.	.	.	7	62	110	67	9	2	2	.	259
2.00 - 2.49	.	.	.	.	.	.	9	62	67	7	2	.	.	147
2.50 - 2.99	.	.	.	.	.	.	.	7	16	.	.	.	.	23
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	71	378	984	1220	1141	995	1816	1434	839	628	101	348	

AVE HS(M) = 0.57 LARGEST HS(M) = 2.90 TOTAL CASES = 4167.

STATION 53 MONTH 12 FOR ALL DIRECTIONS
SHORELINE ANGLE = 19.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS) 0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-LONGER	TOTAL
0. - 0.19	.	42	252	242	224	282	304	519	351	24	9	117	82	2448
0.20 - 0.39	.	.	172	499	274	197	189	693	466	22	134	7	19	2672
0.40 - 0.59	.	.	.	359	287	179	99	322	147	34	77	2	7	1513
0.60 - 0.79	.	.	.	47	369	119	57	197	99	29	39	.	2	958
0.80 - 0.99	.	.	.	.	167	182	34	132	107	19	32	.	.	673
1.00 - 1.19	.	.	.	.	29	142	84	104	124	9	12	.	.	504
1.20 - 1.49	.	.	.	.	7	72	89	117	157	12	9	.	.	463
1.50 - 1.99	.	.	.	.	.	32	74	204	102	17	12	.	.	441
2.00 - 2.49	.	.	.	.	.	.	12	107	49	9	.	.	.	177
2.50 - 2.99	.	.	.	.	.	.	.	14	42	22	2	.	.	80
3.00 - 3.49	.	.	.	.	.	.	.	.	2	17	4	2	.	25
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	42	424	1147	1357	1205	942	2409	1646	214	330	128	110	

AVE HS(M) = 0.57 LARGEST HS(M) = 3.25 TOTAL CASES = 4006.

undredged muddy shoals it is probably confined to the upper 10 cm or less. Underlying muds and sands would be essentially uncontaminated. If these layers were to be disturbed by dredging, the resuspension and elevated turbidity levels would be expected to be local, temporary and probably small compared to the ongoing natural resuspension.

There have been extensive studies of turbidity generated around dredges and a review has been done by Herbick and Brahme (1983). In general elevated turbidity levels are limited to within a few hundred meters of the dredge and high levels are associated with silt and clay. The Lower Bay and Raritan Bay have been subject to dredging on a regular schedule so that this type of disturbance has been routine. Brinkhuis (1980) had applied a model of a continuous dredging operation to a site on the East Bank near Ambrose Channel. The predicted plumes under worse-case conditions (Brinkhuis, 1980), including maximum tidal currents, are of relatively small extent, long and narrow, with high concentrations only within a few hundred meters of the source. Brinkhuis (1980) also review the biological impacts of such plumes on 40 invertebrate species and 16 fish species. In particular, estuarine fish species are often subjected to elevated levels of suspended sediments by natural processes and do not appear to be strongly affected by temporary excess turbidity (Brinkhuis, 1980). They also avoid areas with high levels of suspended sediment (Stickney, 1973). As a result, it seems extremely unlikely that a plume generated by the proposed operation will cause an unacceptable impact on the fish populations.

The impact of the dredging on the concentration of dissolved nutrients, metals and dissolved oxygen in the water column will be negligible. Many field and laboratory studies have tried and failed to detect significant releases of trace metals to solution during the resuspension of dredged sediment. These negative results are in agreement with current geochemical theory about the mechanisms of sediment-metal interactions which predict the general immobility of trace metals in reducing sediment. Metals become bound to fine-grained sediment particles by three mechanisms. They may become bound to organic matter associated with the particles. They may co-precipitate with those common sedimentary metals (manganese and iron) that are insoluble under oxidizing conditions or they may precipitate as insoluble sulfide compounds under reducing conditions. It appears that the extremely low dissolved metal concentrations in nearshore waters are the results of these effects (Turekian, 1977).

Both field and experimental evidence confirms that the mechanisms for binding metals to sediment particles are numerous and operate under a wide range of chemical conditions (e.g., Gambrell et al., 1980; Jenne, 1977; Patrick et al., 1977). Observations of metals and nutrients around a dredging operation in the Thames River (CT) showed that the water column disturbance was local and small-scale and that it did not represent a significant source of dissolved material to the estuary under typical conditions (Tramontano and Bohlen, 1984). In addition, no significant release of metals has ever been observed during the aquatic disposal of dredged material in the United States

(Wright et al., 1978). This indicates that the resuspension of this material does not significantly alter the chemical conditions of the particles probably because of the rapidity of descent.

Persistent ecological effects from nutrient releases are also unlikely to occur. Detailed monitoring of dredging and disposal operations around the country (Wright et al., 1978) has failed to detect significant elevations of nutrient levels in receiving waters even from very large operations. Dilution is rapid and effective, and any elevated nutrient concentrations transitory. Observations at the New London Disposal Site in Long Island Sound, for example, showed that dissolved oxygen, total suspended solids, pH, eH, turbidity, and dissolved organic carbon all returned to background, predisposal levels within two hours of a scow discharge (National Marine Fisheries Service, 1977). Similar results were obtained in the Chesapeake Bay during dredging and pipeline disposals (Flemer, 1970) and at an open-water disposal operation offshore of Pearl Harbor, Hawaii (Chave and Miller, 1983).

SAND BUDGET

In the Lower Bay the natural sand floor appears to be stable. A study of bathymetric surveys that were conducted over a period in excess of 100 years shows minor shifts of the depth contours but no major changes in the bathymetry outside of dredged areas (Fray, 1969). Only small ripples have been observed on the East and West Banks of the Lower Bay (Bokuniewicz, et al., 1986). The major shoal structure at the mouth of the Bay, however, is in a dynamic equilibrium with major sources of sand being supplied to the Bay primarily from the littoral drift along both the New York and New Jersey shorelines and a principal sink in Ambrose Channel.

Along the south shore of Long Island, the littoral transport of sand from the east carries about 450,000 cubic yards per year; similarly littoral sand moves northward and up the coast of New Jersey at a rate of about 493,000 cubic yards per year (Kastens, et al., 1978). A small amount of sand may be provided by any existing erosion of the shoreline around the Lower Bay itself but this sediment is redistributed locally along the Staten Island shore and it is very unlikely that it participates substantially in the sediment budget around the bay mouth. More sand may be supplied directly to the Lower Bay from the Atlantic shelf. An onshore supply of sand has been postulated along Long Island's south shore to account for increases in the magnitude of the longshore drift of sand along Long Island (McCormick and Toscano, 1980: Research Planning Institute, Inc., 1985; Niedoroda et al., 1985; and Williams and Meisburger, 1987). Where any offshore sand supply reaches the beach along either the Long Island or New Jersey shore, it is incorporated into the longshore littoral transport and included in the above figure. Some of the onshore supply from the shelf, however may enter the Harbor directly. Underwater sand waves have been found on the floor of Ambrose Channel indicating a transport of sand landwardly along the channel (Coch and Bokuniewicz, 1985). The strength of this source is unknown, but the amount is probably small. Although detailed information on sand waves in the channel is not available, in other estuarine locations, sand waves represent a transport of sand at rates between 0.08 and 0.50 cubic meters of sand per meter of wave crest per day:

Location	Transport Rate m^3/m/day	Citation
St. Andrews Bay, FL	0.01	Salsman, et al., 1966
Warts Bank, Isle of Man	0.50	Jones, et al., 1965
North Sea	0.17	Terwindt, 1971
Chesapeake Bay	0.25	Ludwick, 1972
Long Island Sound	0.08	Bokuniewicz, et al., 1977

Such rates in Ambrose Channel would correspond to a total transport of between 22,000 and 129,000 cubic yards of sand per year. The total supply from all sources, therefore, could be as high as 1,072,000 cubic yards per year. Once in the channel the sand supplied is effectively removed from the littoral system. An average of 834,000 cubic yards of sand is dredged annually from Ambrose Channel (Schubel and Summers, 1985); in other words, with allowance for uncertainties in the estimates, all the sand that enters the channel presently is trapped there and removed by dredges.

In the immediate vicinity of the proposed pipeline crossing, Malcolm Pirnie, Inc. (1983) estimated that 8,300 cubic yards of sand enter the channel from the south annually while 20,700 cubic yards enter from the north. The rates and routes of sand transport near the mouth of the harbor are complicated, however, (Gadd, et al., 1978) and they have not been studied. Along the

Bight’s coast, intense sand transport by waves is limited to water less than 21.5 feet deep although it can occur in water depths up to 82 feet (Hallenmeier, 1981). Where a trench for a pipeline was cut in sand in less than 21.5 feet of water, it would be reasonable to expect refilling and regrading of the sea floor by waves in a relative short time (1 yr). In deeper water, sand transport by a combination of waves and tides should be expected but the rate of transport would be more episodic and the ability of these agents to refill a trench and regrade the sea floor considerably less. In the muddy sediments of Raritan and Sandy Hook Bays, the deposition rate is probably less than a millimeter per year and resuspension is limited to the upper few millimeters of the sediment surface. Fine-grained sediment with a high water content would be expected to accumulate in a dredged trench rapidly (about 10 cm/yr) but sidecasted, dredged sediment would probably not regrade naturally. There are no reports of documented areas of natural scour, but the Swash Channel might be candidate.

OTHER ACTIVITY

Over 9,000 vessels transit the Ambrose Channel each year and the Channel is dredged more-or-less continuously. In the past few years, the company dredging the Channel in New Jersey waters has been recovering the sand for fill and construction aggregate and is requesting permission to deepen the Channel to -67 feet (except over the existing pipeline crossing). New York State is considering similar mining activity on the East Bank and a depth limit of -90 feet is being considered. Plans for creating a deeper water port in New York for coal trans-shipment, naval use, or increased cargo capacity had called for a 100 foot controlling depth for the channel. Although these plans are no longer being actively pursued, they could be revived with changing circumstances.

The Corps of Engineers also removes sand occasionally for beach renourishment and a large project is expected at Coney Island. With the exception of the mining operation in Ambrose Channel, these other activities are not planned along the pipeline route. Because of the weather conditions, sand dredging in the channel is usually done near the proposed route south of the existing pipeline crossing in the winter and farther offshore in the summer.

Fishing activity is summarized in Figures 10 to 12 (Figley, 1984). The proposed path will not cross the fishing grounds for sea bass, tautog, porgy, spot, winter flounder, crab, eel; in the Bay, however, will transverse recreational fishing grounds for striped bass, summer flounder, bluefish, and weakfish, and the commercial fishing areas for blue crab, and some areas historically used for pound netting. On the shelf, the route will cross a small part of the extensive coastal sport fishery for striped bass, whiting and red hake, black sea bass, weakfish, bluefish, taugog, fluke and the commercial fishery for bluefish and weakfish, fluke, whiting and red hake, menhaden, and clams (Figures 13-24).

Porgy, sea bass and summer flounder are probably the most important species. Although catches vary from year-to-year, porgy catches tend to remain important year-round; sea bass in mid-summer and summer flounder in mid-to-late summer. Bluefish catches are usually high in the late summer and early fall while, striped bass tends to be a fall fishery. Although it is unlikely that damaging turbidity would be generated during the placement of the pipeline, if this was possible, or if the operation would interfere with free navigation, care must be taken, of course, to insure that these fisheries would not be impacted.

Some Recommendations

1. Additional cores and borings along the route would be helpful to (a) locate the postulated, buried valley of the ancestral Raritan River and (b) identify layers bounded by acoustic horizons on the shelf.
2. Side scan records along the route would be helpful in describing the nature of sediment transport although a determination of the rates and routes of transport would require a substantially more extensive effort.
3. In Raritan and Sandy Hook Bays, a dredged trench will probably have to be backfilled artificially and it is unlikely that the sea floor will regrade itself naturally there. The extent to which the operation changes the texture of the bay floor may change benthic habitats and should be discussed with agencies responsible for living marine resources.
4. The impact of excess turbidity on shellfish beds in Raritan and Sandy Hook Bays may deserve more attention. Although any significant impacts on the fisheries seems unlikely, care must, of course, be taken to avoid conflicts with the fishing interests.

REFERENCES

Bokuniewicz, H.J.. R. Cerrato, and D. Hirschberg. 1986. Studies in the Lower Bay of New York Harbor associated with the burial of dredged sediment in subaqueous borrow pits. State University of New York, Marine Sciences Research Center, Special Report 74: 67 p.

Bokuniewicz, H.J. and C. Fray. 1979. Volume of sand and gravel resources in the Lower Bay of New York Harbor. Marine Sciences Research Center, Special Report 32, Ref. No. 79-16, State University of New York, Stony Brook, New York. 34 pp.

Brinkhuis, B.H. 1980. Biological effects of sand and gravel mining in the Lower Bay of New York Harbor. An assessment from the literature. Marine Sciences Research Center, Special Report 34, State University of New York, Stony Brook, New York. 193 p.

Chave, K.E. and J.N. Miller. 1983. Pearl Harbor dredged material disposal. Pp 91-98 in: Kester et al., eds. Dredged Material Disposal in the Ocean, Vol. II, Wastes in the Ocean. John Wiley and Sons, NY.

Coch, N.K. and H.J. Bokuniewicz. 1986. Oceanographic and geologic framework of the Hudson system. Northeastern Geology 8: 96-108.

deLaguna, W. and M.L. Brashears. 1948. The configuration of the rock floor in western Long Island, NY. New York Water Power and Control Commission Bulletin GW-17.

Ebersole, B.A. 1982. Atlantic coast water-level climate. U.S. Army Corps of Engineers, Waterways Experiment Station. Wave Information Studies Report 7: 34 p. + appendicies.

Figley, W. 1984. Commercial and recreational fishing grounds of Raritan/Sandy Hook and Delaware Bays. Unpublished report, N.J. State Department of Environmental Protection, N.J. Division of Fish, Game and Wildlife, Bureau of Marine Fisheries, Trenton, NJ. Project No. 3-34000: 33 p. + figures.

Flemer, D.A. 1970. Project B, phytoplankton. Pp. 16-25 in: Gross physical and biological effects of overboard spoil disposal in Upper Chesapeake Bay. Nat. Res. Inst. Spec. Rpt. 3. Chesapeake Biological Laboratory, Univ. of MD.

Fray, C.T. 1969. Final Report Raritan Estuary sedimentation study. Unpublished report prepared for the Federal Water Pollution Control Administration, Dept. of the Interior. Alpine Geophysical Associates, Inc., Norwood, NJ.

Freeland, G.L. 1981. Surficial sediment of the New York Bight Apex Area, National Ocean Survey, 4 sheets.

Gadd, P.E., J.W. Lavelle, and D.J.P. Swift. 1978. Estimates of sand transport on the New York Shelf using near bottom current observations. Journal of Sedimentary Petrology 48: 239-252.

Gambrell, R.P., R.A. Khalid and W.H. Patrick. 1980. Chemical availability of Hg, Pb, and Zn in Mobile Bay sediment suspension as affected by pH and oxidation-reduction conditions. Environ. Sci. and Tech. 14: 431-436.

Hallermeier, R.J. 1981. Seaward limit of significant sand transport by waves: An annual zonation for seasonal profiles. U.S. Army Corps of Engineers. Coastal Engineering Technical Aid 81-2: 23 p.

Herbich, J.B. and S.B. Brahme. 1983. Literature review and technical evaluation of sediment resuspension during dredging. Ocean and Hydraulic Engineering Group. Civil Engineering Dept. Texas A&M University Report No. COE-266: 141 p. plus appendices

Hutchinson, D.R. and J.A. Grow. 1985. New York Bight Fault, Geological Society of America. Bulletin 96: 975-989.

Jenne, E.A. 1977. Trace element sorbtion by sediments and soils - sites and processes. Chapt. 5 in Chappel and Peterson, eds. Symposium on Molybdenum in the Environment. M. Decker, Inc., N.Y.

Jensen, R.E. 1983. Atlantic coast hindcasts, shallow-water significant wave height information. Wave Information Study Report 9. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, MS.

Kastens, K.A., C.T. Fray and J.R. Schubel. 1978. Environmental effects of sand mining in the Lower Bay of New York Harbor, Phase 1. State University of New York, Marine Sciences Research Center, Special Report 15: 139 p.

Long, D. and W. Figley, 1981. New Jersey's recreational and commercial ocean fishing grounds. N.J. Department of Environmental Protection and Marine Fisheries Administration Technical Series 81-1: 86 p.

Lovegreen, J.R. Undated. Paleodrainage history of the Hudson Estuary, M.A. thesis, Columbia University, 129 p.

MacClintock, P. and H.G. Richards. 1936. Correlation of Late Pleistocene marine and glacial deposits of New Jersey and New York. Bulletin of the Geological Society of America 47: 289-338.

Malcolm Pirnie, Inc. 1983. New York Harbor Navigation Study, unpublished report to the NY District, U.S. Army Corps of Engineers.

McCormick, C.L. and M.A. Toscano. 1980. Origin of the barrier island system of Long Island, New York. Geological Society of America Abstract with Program. Northeastern and Southeastern Combined Sections Meeting. Vol. 14, Nos. 1 and 2.

Mitronovas, W. 1982. Earthquake statistics in New York State, Earthquake Note 53: 5-22.

National Marine Fisheries Service. 1977. Physical, chemical and biological effects of dredging in the Thames River (CT). Final report to the U.S. Navy and Interagency Scientific Advisory Subcommittee.

Niedoroda, A.W., D.J.P. Swift, A.G. Figueiredo, Jr., and G.L. Freeland. 1985. Barrier island evolution, middle Atlantic shelf, U.S.A. Part II: Evidence from the shelf floor. In: G.F. Oertel and S.P. Leatherman (Editors). Marine Geology. Vol. No. 63. pp. 363-396.

Olsen, C.R., I.L. Larsen, R.H. Brewster, N.H. Catshall, R.F. Bopp, and H.J. Simpson. 1984. A geochemical assessment of sedimentation and contaminant distributions in the Hudson Raritan Estuary. NOAA Tech. Rpt. NOS OM 52: 101p.

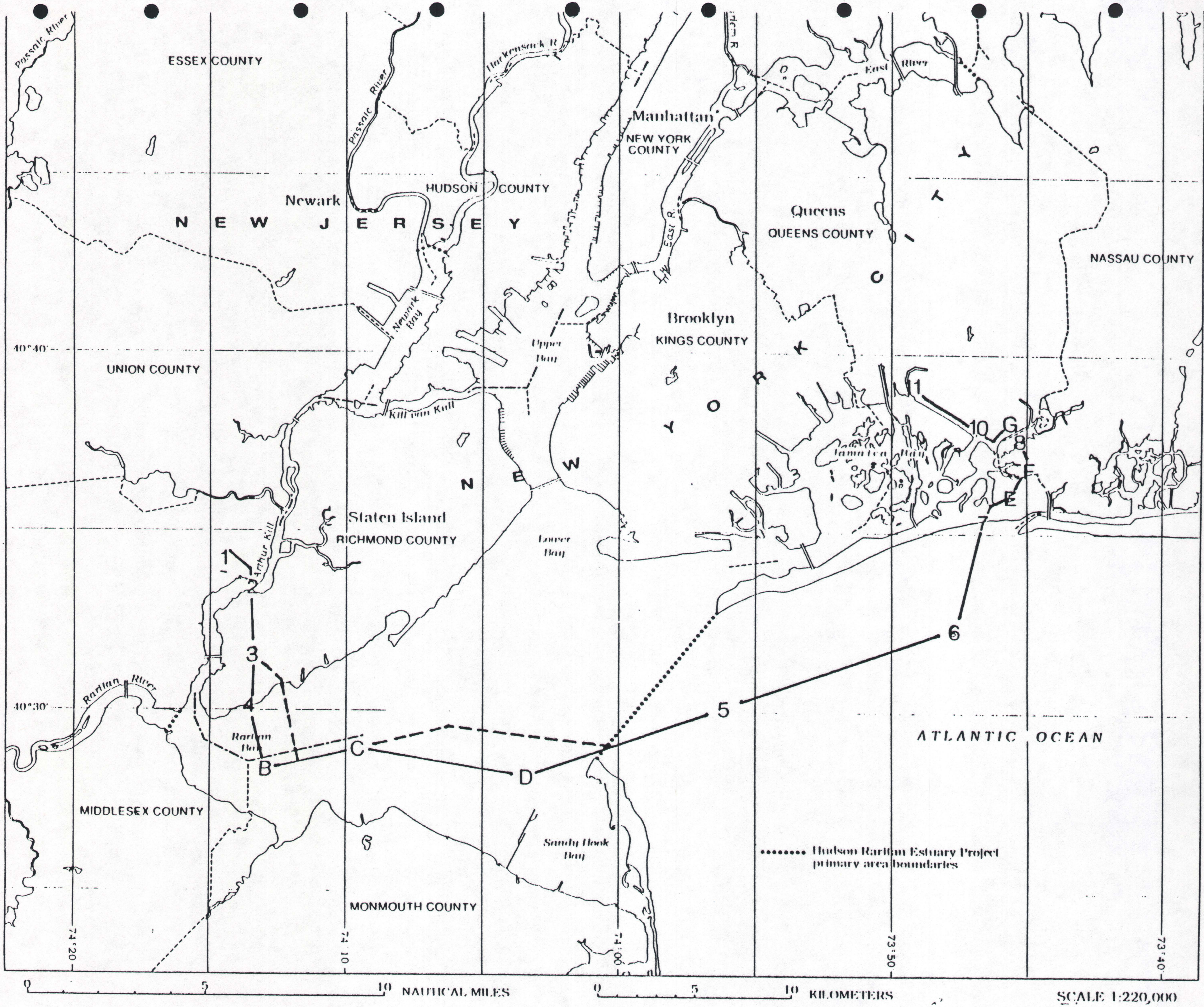
Patrick, W.H., R.P. Gambrell and R.A. Khalid. 1977. Physiochemical factors regulating solubility and bio-vailability of toxic heavy metals in contaminated dredged sediment. Environ. Sci. Health 9: 475-492.

Perlmutter, N.M. and T. Arnow. 1953. Ground water in Bronx, New York and Richmond Counties, with summary data on Kings and Queens Counties, New York City, New York. Water Power and Control Commission Bulletin GW-32.

Research Planning Institute, Inc. 1985. Sediment budget analysis summary, Fire Island Inlet to Montauk Point, NY, reformulation study. Final Report to the U.S. Army Corps of Engineers, New York District. 85 pp + appendices.

Sbar, M.L. and L.B. Sykes. 1977. Seismicity and lethiseric stress in New York and Adjacent Areas. Journal of Geophysical Research 82: 5771-5786.

Schubel, J.R. and R.M. Summers. 1985. Volume 1. Dredging and dredged material disposal in the Port of New York and New Jersey: A case study and an assessment of alternatives. State University of New York, Marine Sciences Research Center, Special Report 60: 125 p.



Compiled and drafted for the American Geographical Society by Lothar Roth. 1981.

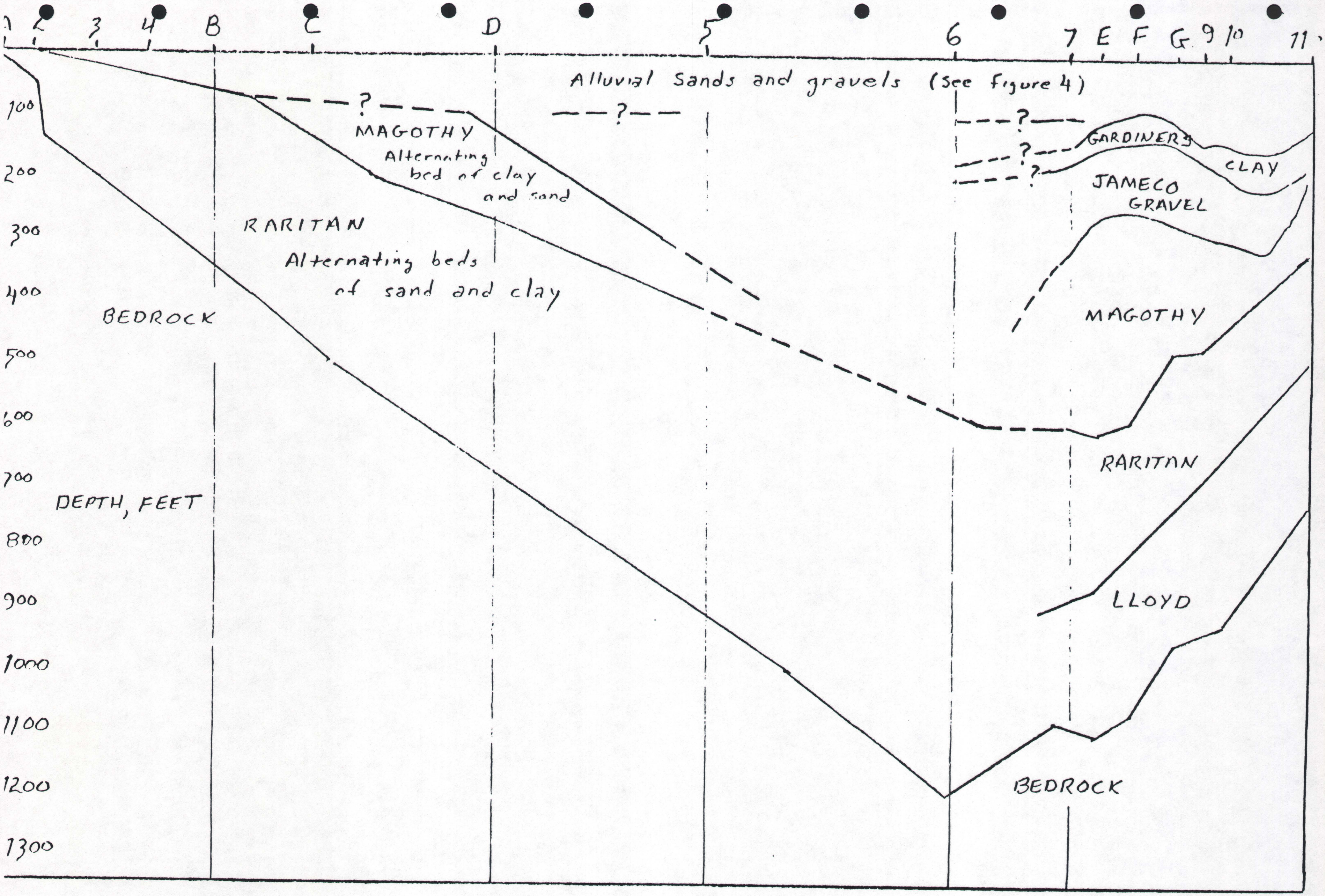
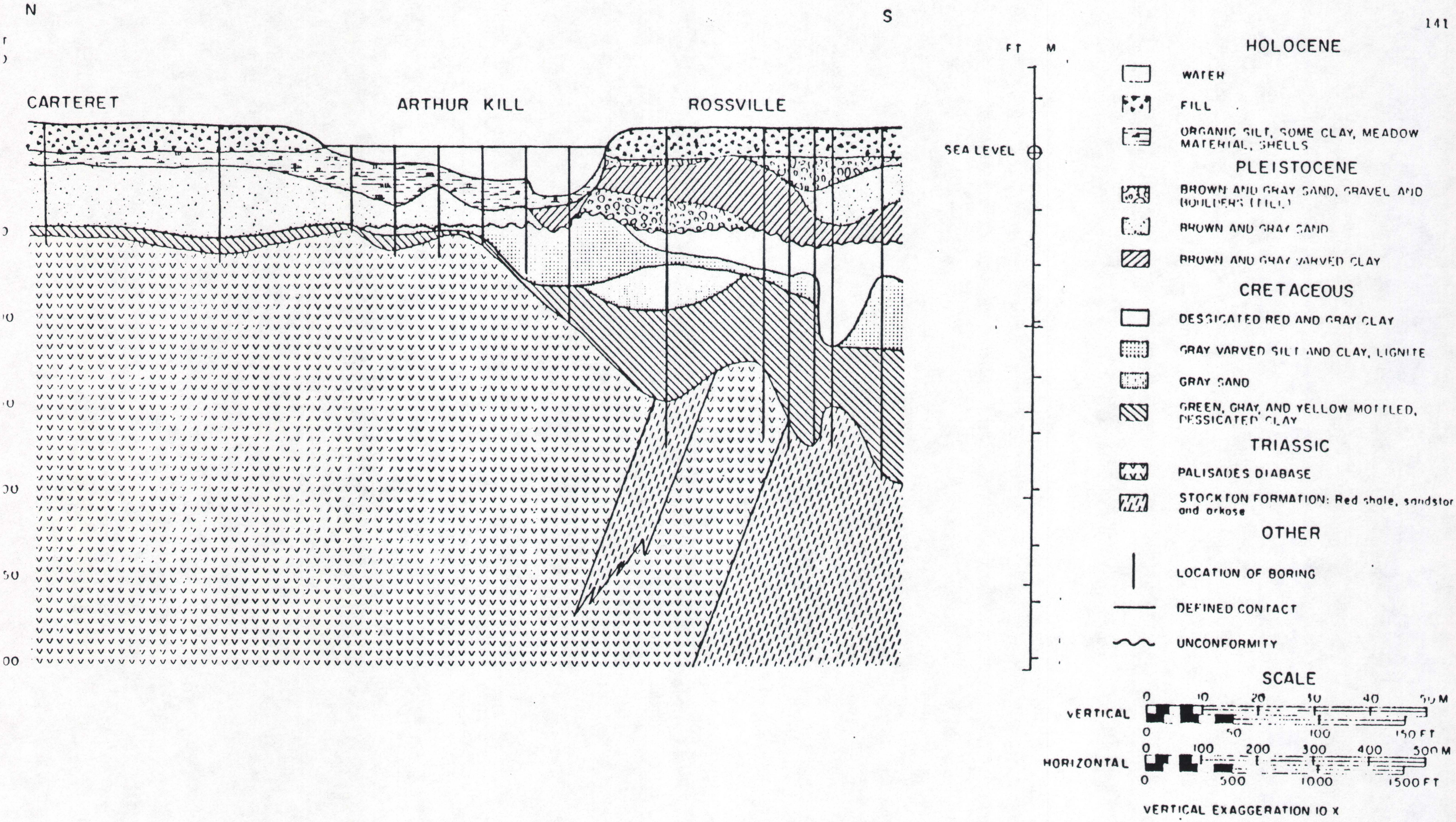

1
2
3
4
B
C
D
5
6
7
E
F
G
9
10
11
Alluvial sands and gravels (See figure 4)
?
?
?
?
?
MAGOTHY
Alternating bed of clay and sand
RARITAN
Alternating beds of sand and clay
BEDROCK
GARDINERS CLAY
JAMECO GRAVEL
MAGOTHY
RARITAN
LLOYD
BEDROCK
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
DEPTH, FEET

figure 2



SEE PLATE 7 FOR LOCATION

FIGURE 3

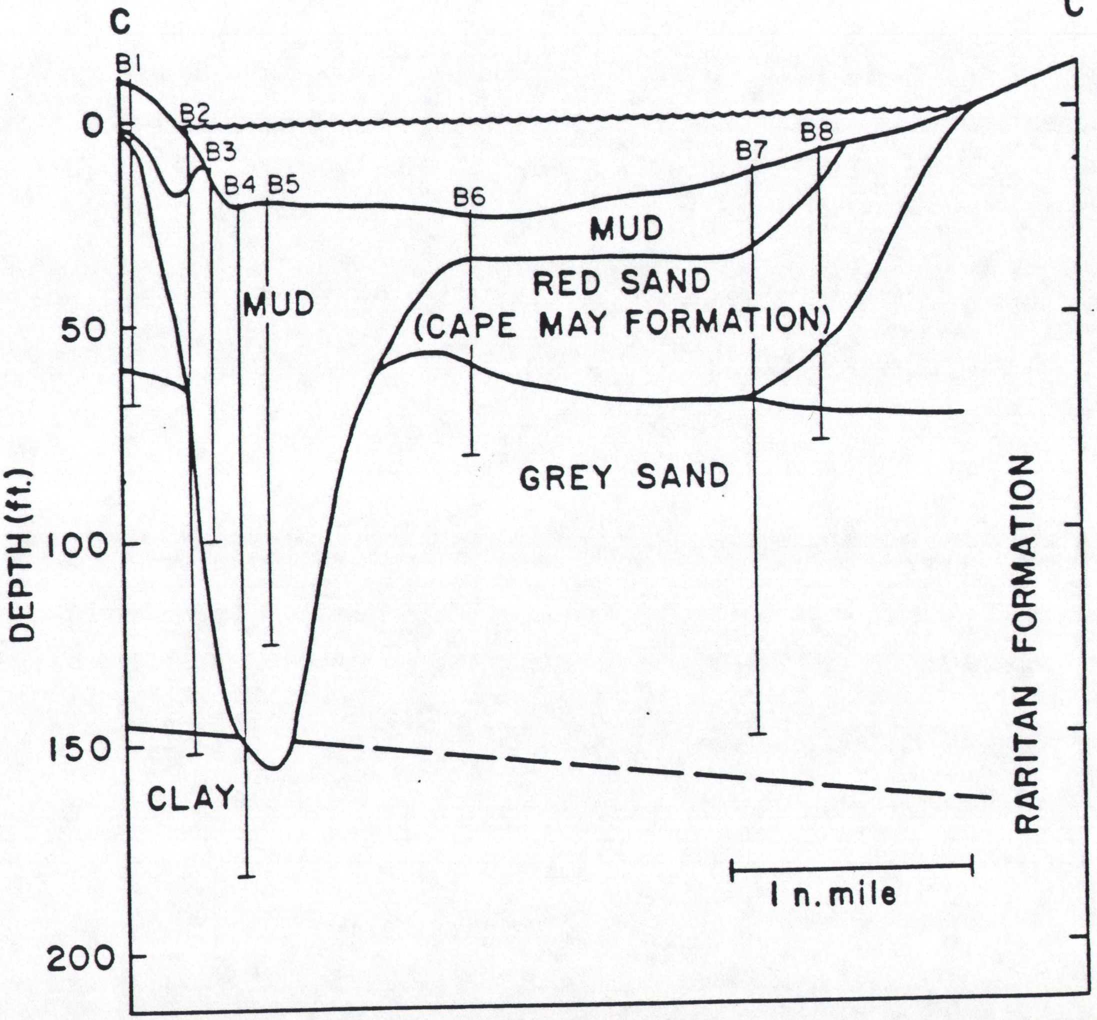

C
C'
B1
B2
B3
B4
B5
B6
B7
B8
0
50
100
150
200
DEPTH (ft.)
MUD
MUD
RED SAND
(CAPE MAY FORMATION)
GREY SAND
CLAY
RARITAN FORMATION
1 n. mile

Figure 4

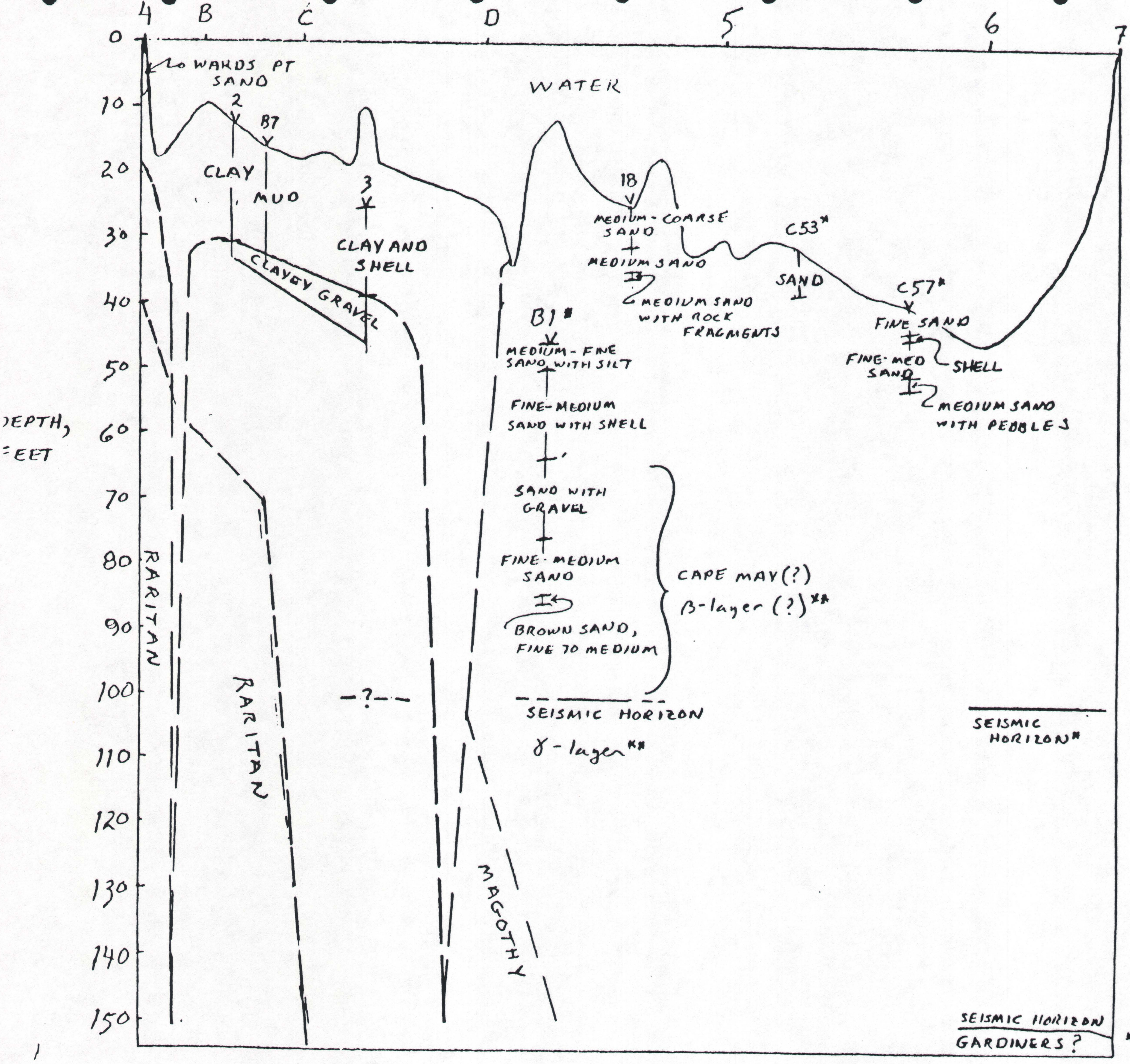
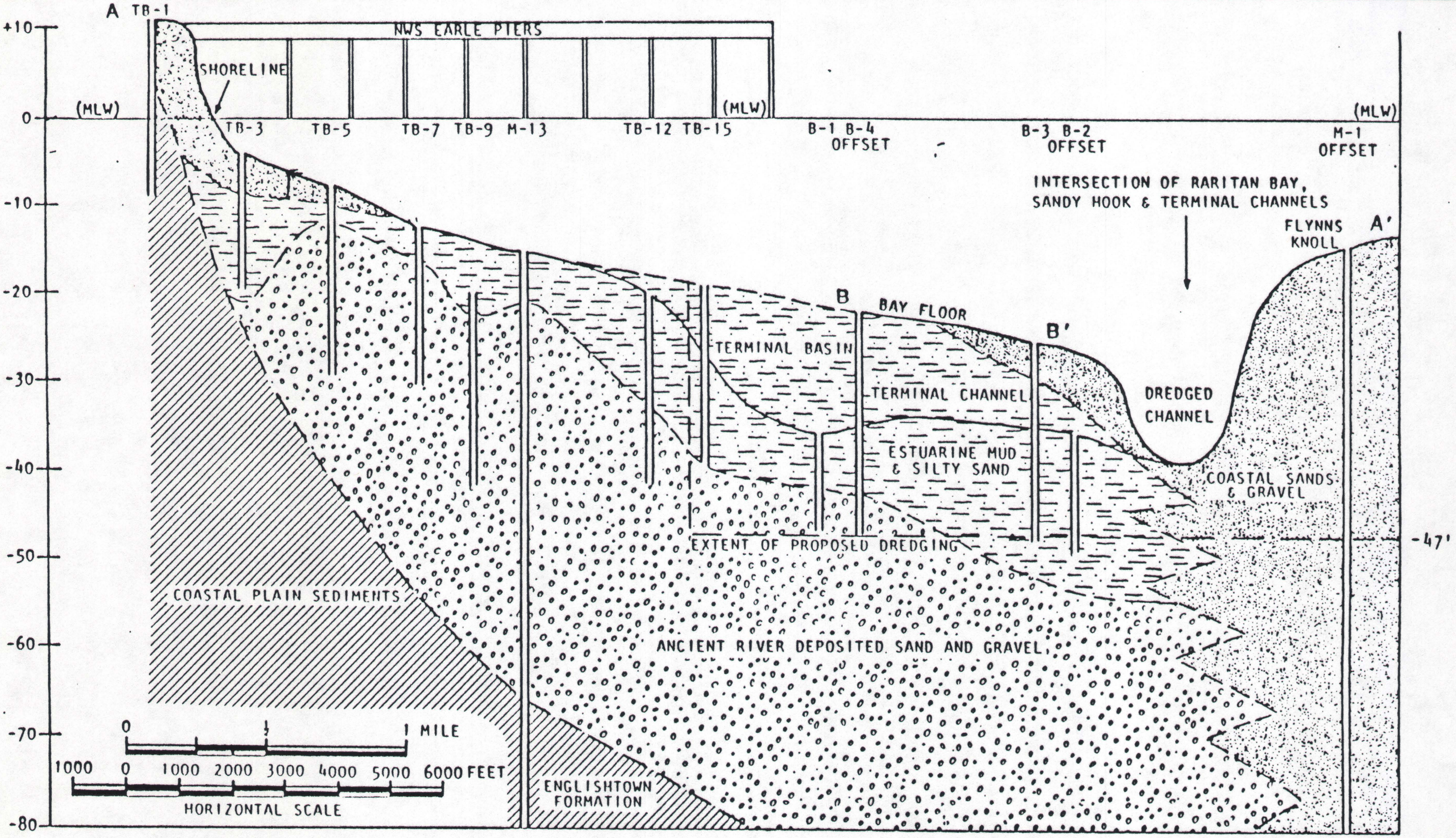


Figure 5

* WILLIAMS AND DUANE, 1974.

** See text.



COMPOSITE SUBSURFACE SECTION: SANDY HOOK BAY

LEGEND:

- ▨ TERTIARY AND CRETACEOUS COASTAL PLAIN SEDIMENTS
- ○ QUATERNARY ANCIENT RIVER DEPOSITS OF SAND AND GRAVEL
- ☰ QUATERNARY DEPOSITS OF MUD AND SILTY SAND
- ⁘ QUATERNARY COASTAL DEPOSITS OF SAND AND GRAVEL

‖ BORINGS AND CORES

TB-1 - TB-15-TEST BORINGS TAKEN FROM NAVFAC DRAWING NO. 2022289 EARLE, NEW JERSEY BY TAYLOR-WISEMAN & TAYLOR, 3/76

M-1, M-13-AUGER HOLES BY MINARD 1969

B-1 - B4-DAMES & MOORE BORINGS - SEE APPENDIX F FOR DETAILED BORING LOGS

NOTE: THE LOCATION OF BORINGS AND AUGER HOLES AND THE ALIGNMENT OF SECTIONS A-A' AND B-B' ARE SHOWN ON FIGURE II.C-19.

THYMETRIC PROFILES TAKEN FROM NOAA NAUTICAL
ART #12327, 1977 NEW YORK HARBOR

Figure 6

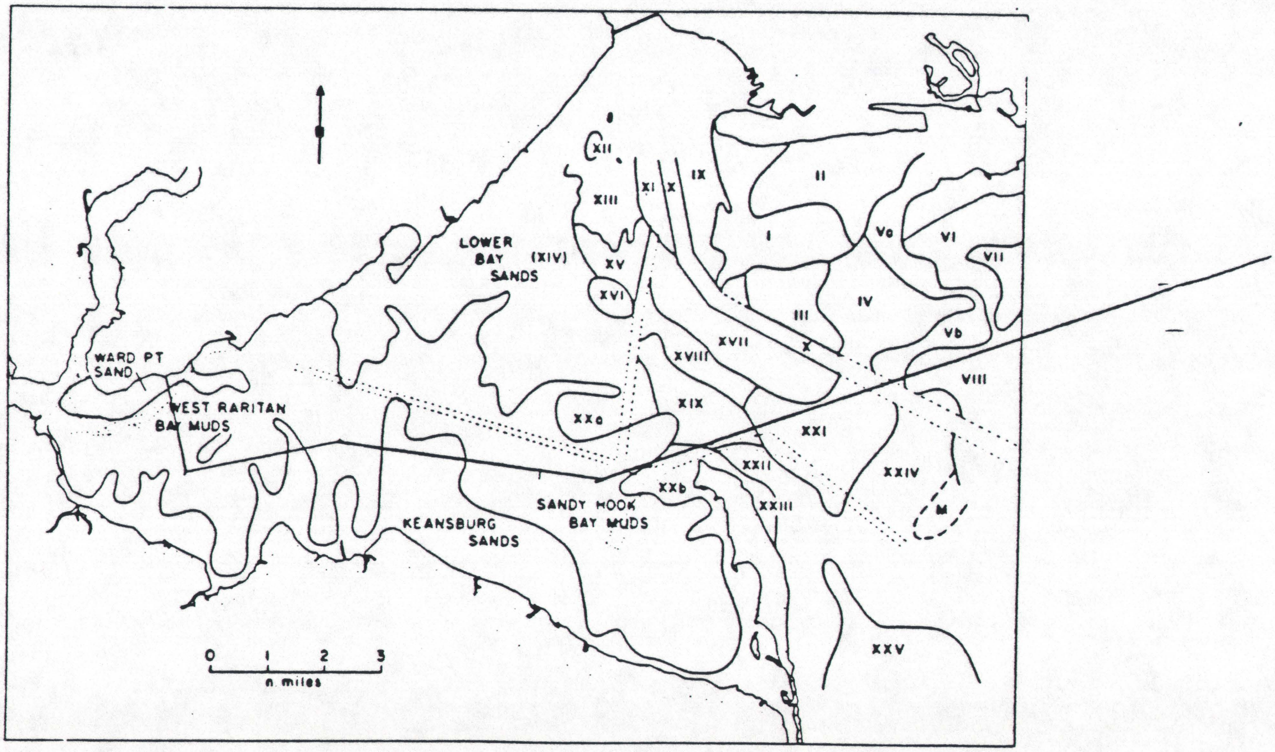

XII
XIII
XI
X
IX
II
I
Va
VI
VII
LOWER
BAY
SANDS
(XIV)
XV
XVI
III
IV
Vb
XVII
X
XVIII
VIII
WARD PT
SAND
WEST RARITAN
BAY MUDS
XXa
XIX
XXI
XXII
XXIV
XXb
XXIII
M
SANDY HOOK
BAY MUDS
KEANSBURG
SANDS
XXV
0
1
2
3
n. miles

Figure 7

```
                   STATION  53   20 YEARS    FOR ALL DIRECTIONS
              SHORELINE ANGLE =  19.0  DEGREES AZIMUTH
              WATER DEPTH = 10.00  METRES
              PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS
HEIGHT(METRES)                        PERIOD(SECONDS)                                   TOTAL

                    0.0-  3.0-  4.0-  5.0-  6.0-  7.0-  8.0-  9.0- 10.0- 11.0-
                     2.9   3.9   4.9   5.9   6.9   7.9   8.9   9.9  10.9  LONGER

0.   - 0.49          440   854   442   307   659  1648   874   148    88   125          5585
0.50 - 0.99            .   223   672   300    89   540   389    75   100   134          2522
1.00 - 1.49            .     .    29   182    98   155   112    13    26    33           648
1.50 - 1.99            .     .     .     7    52    92    47     7     7    13           225
2.00 - 2.49            .     .     .     .     7    46    28     4     1     3            89
2.50 - 2.99            .     .     .     .     .     5    12     2     .     1            20
3.00 - 3.49            .     .     .     .     .     .     .     2     .     .             2
3.50 - 3.99            .     .     .     .     .     .     .     .     .     .             0
4.00 - 4.49            .     .     .     .     .     .     .     .     .     .             0
4.50 - 4.99            .     .     .     .     .     .     .     .     .     .             0
5.00 - GREATER         .     .     .     .     .     .     .     .     .     .             0
   TOTAL             440  1077  1143   796   905  2486  1462   251   222   309

    AVE HS(M) = 0.47   LARGEST HS(M) = 3.71   TOTAL CASES =     58440
```

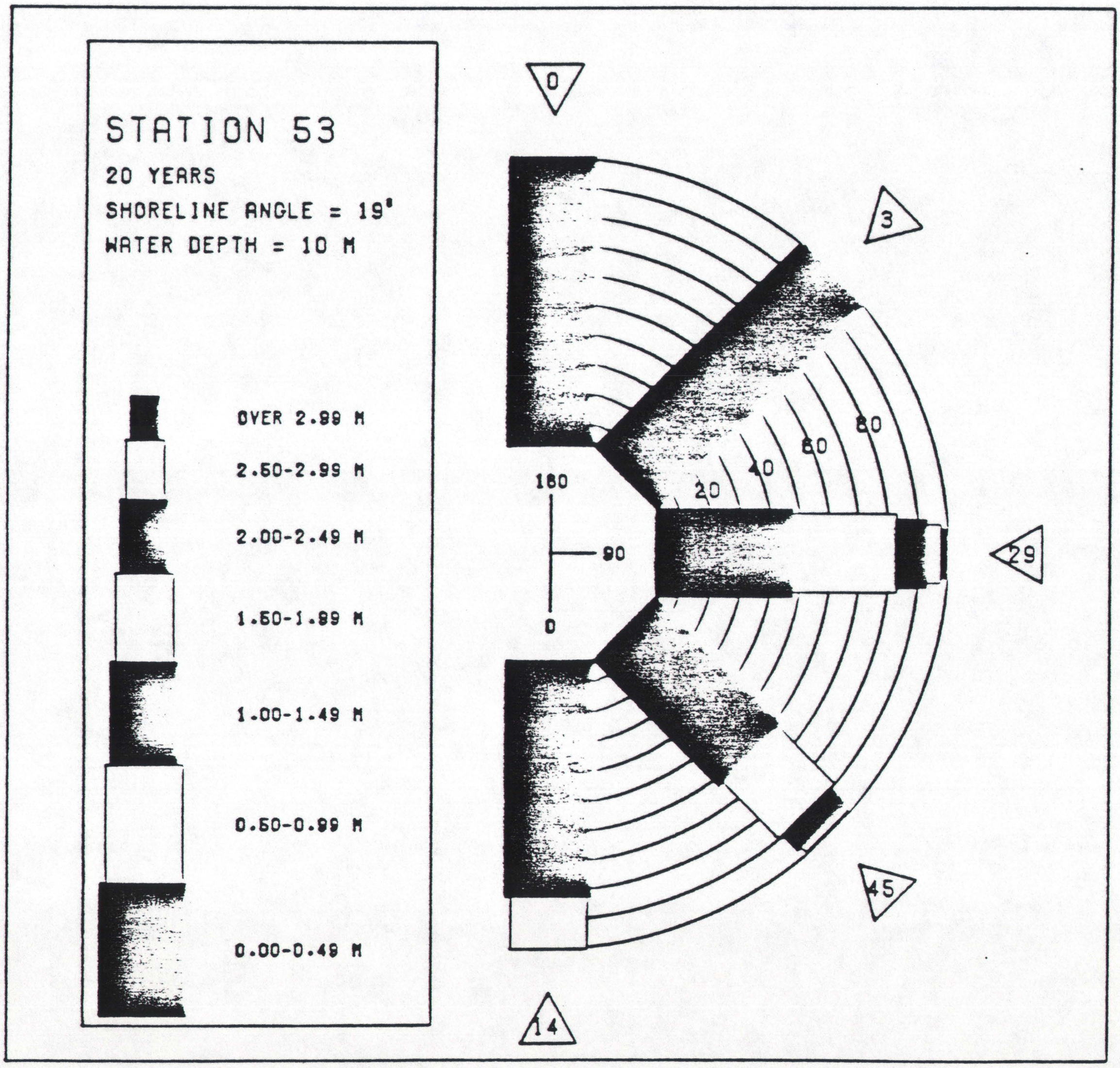


Figure 8

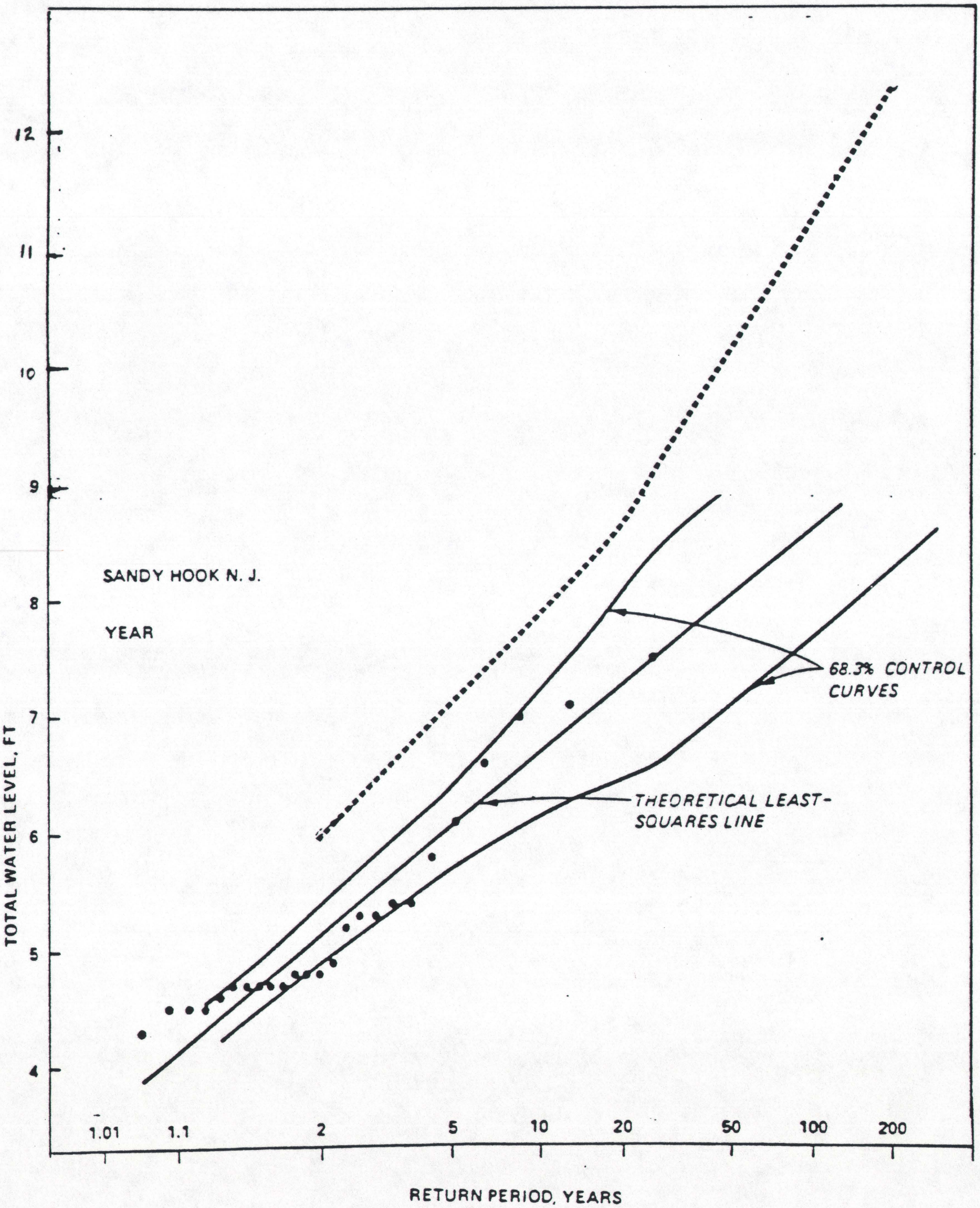
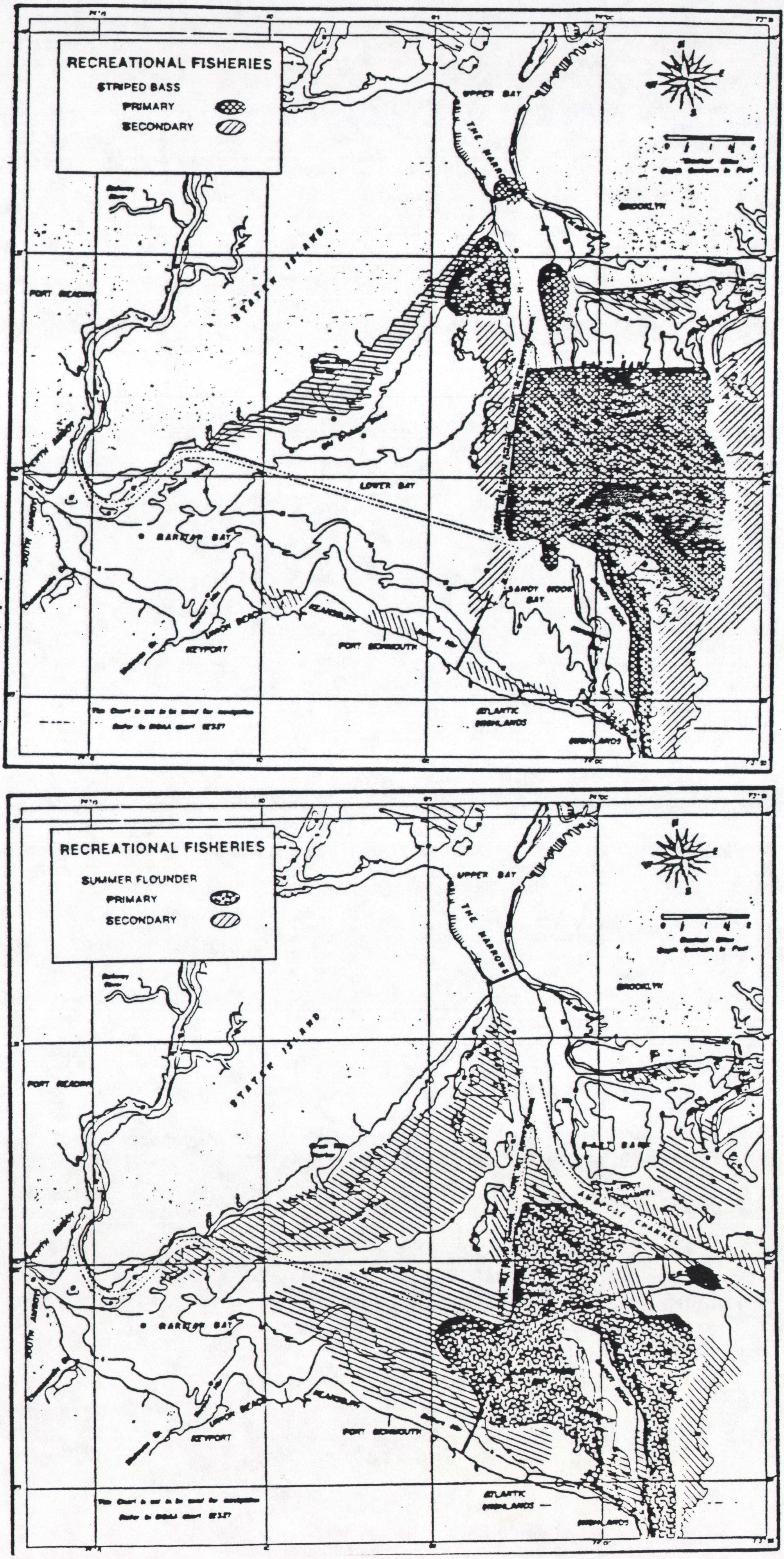

SANDY HOOK N. J.
YEAR
68.3% CONTROL CURVES
THEORETICAL LEAST-SQUARES LINE
TOTAL WATER LEVEL, FT
4
5
6
7
8
9
10
11
12
RETURN PERIOD, YEARS
1.01
1.1
2
5
10
20
50
100
200

Figure 9



6K

Figure 10 A,B

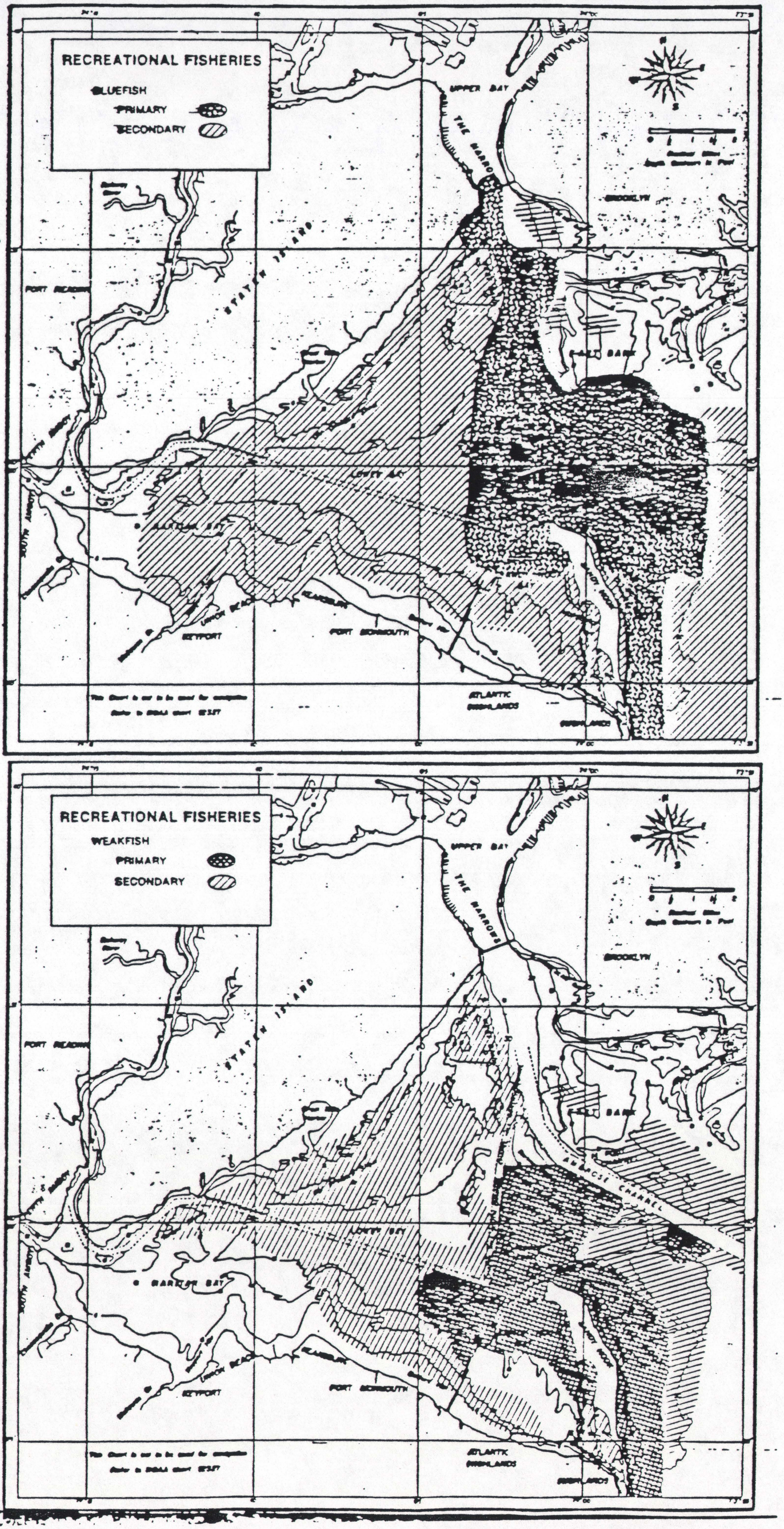

RECREATIONAL FISHERIES
BLUEFISH
PRIMARY
SECONDARY
UPPER BAY
THE NARROWS
BROOKLYN
STATEN ISLAND
PORT READING
LOWER BAY
RARITAN BAY
UNION BEACH
KEYPORT
PORT MONMOUTH
ATLANTIC HIGHLANDS
HIGHLANDS
RECREATIONAL FISHERIES
WEAKFISH
PRIMARY
SECONDARY
UPPER BAY
THE NARROWS
BROOKLYN
STATEN ISLAND
PORT READING
AMBROSE CHANNEL
LOWER BAY
RARITAN BAY
UNION BEACH
KEYPORT
PORT MONMOUTH
ATLANTIC HIGHLANDS
HIGHLANDS

Figure 11 A,B

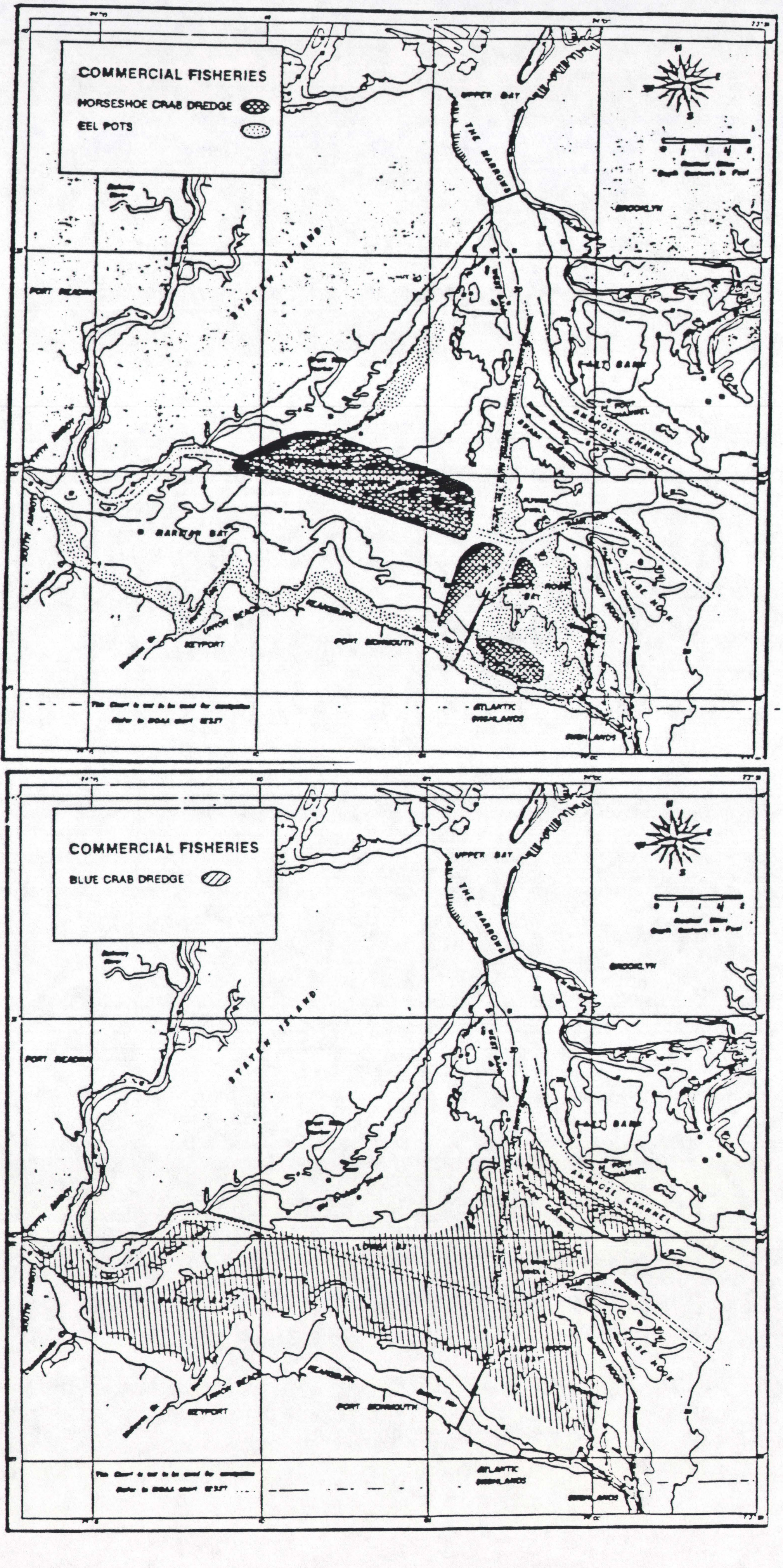
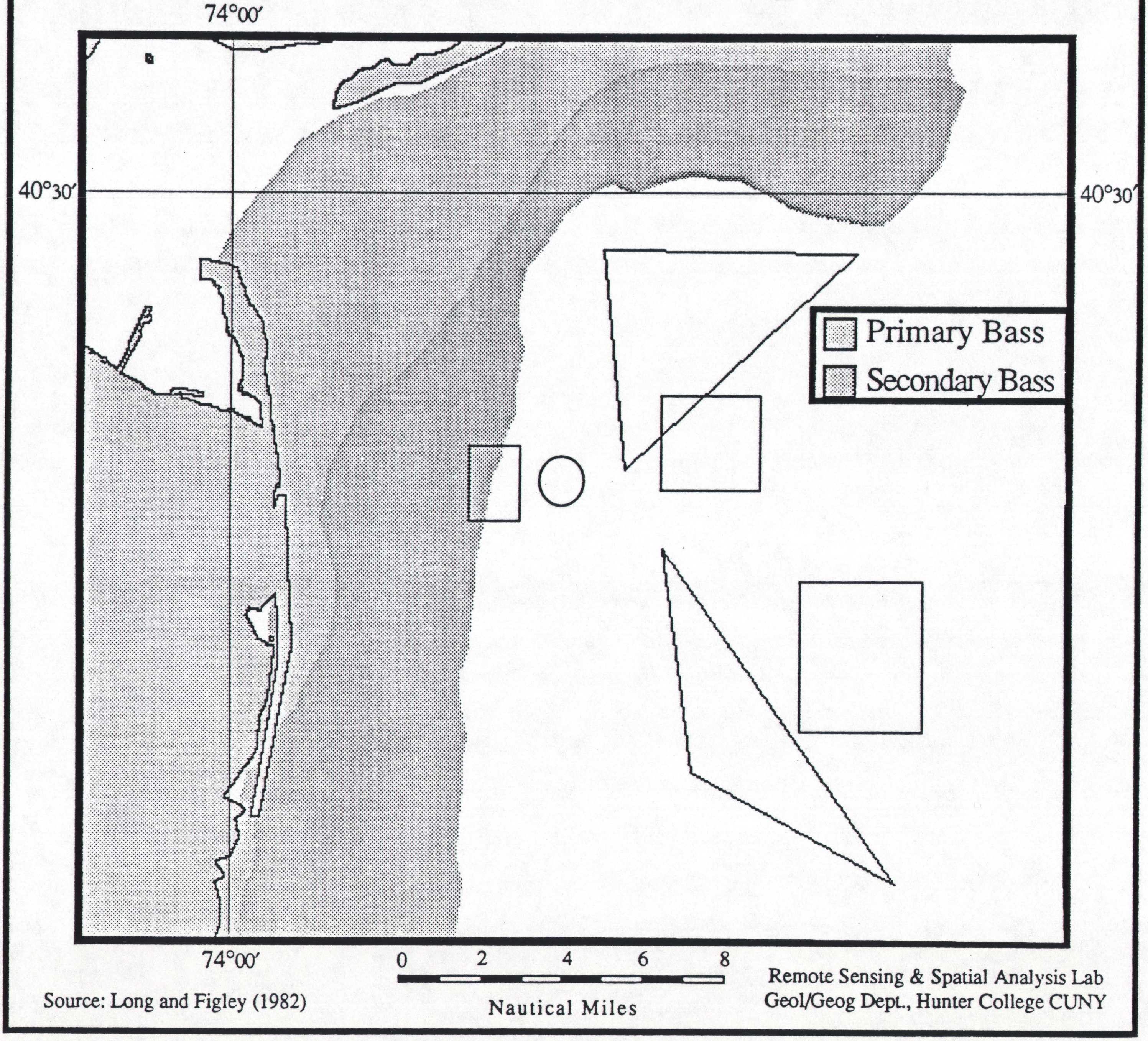

COMMERCIAL FISHERIES
HORSESHOE CRAB DREDGE
EEL POTS
COMMERCIAL FISHERIES
BLUE CRAB DREDGE
UPPER BAY
THE NARROWS
BROOKLYN
STATEN ISLAND
PORT READING
RARITAN BAY
AMBROSE CHANNEL
KEYPORT
PORT MONMOUTH
ATLANTIC HIGHLANDS
HIGHLANDS
FALSE HOOK

Figure 12 A,B

Sport Fisheries: Striped Bass

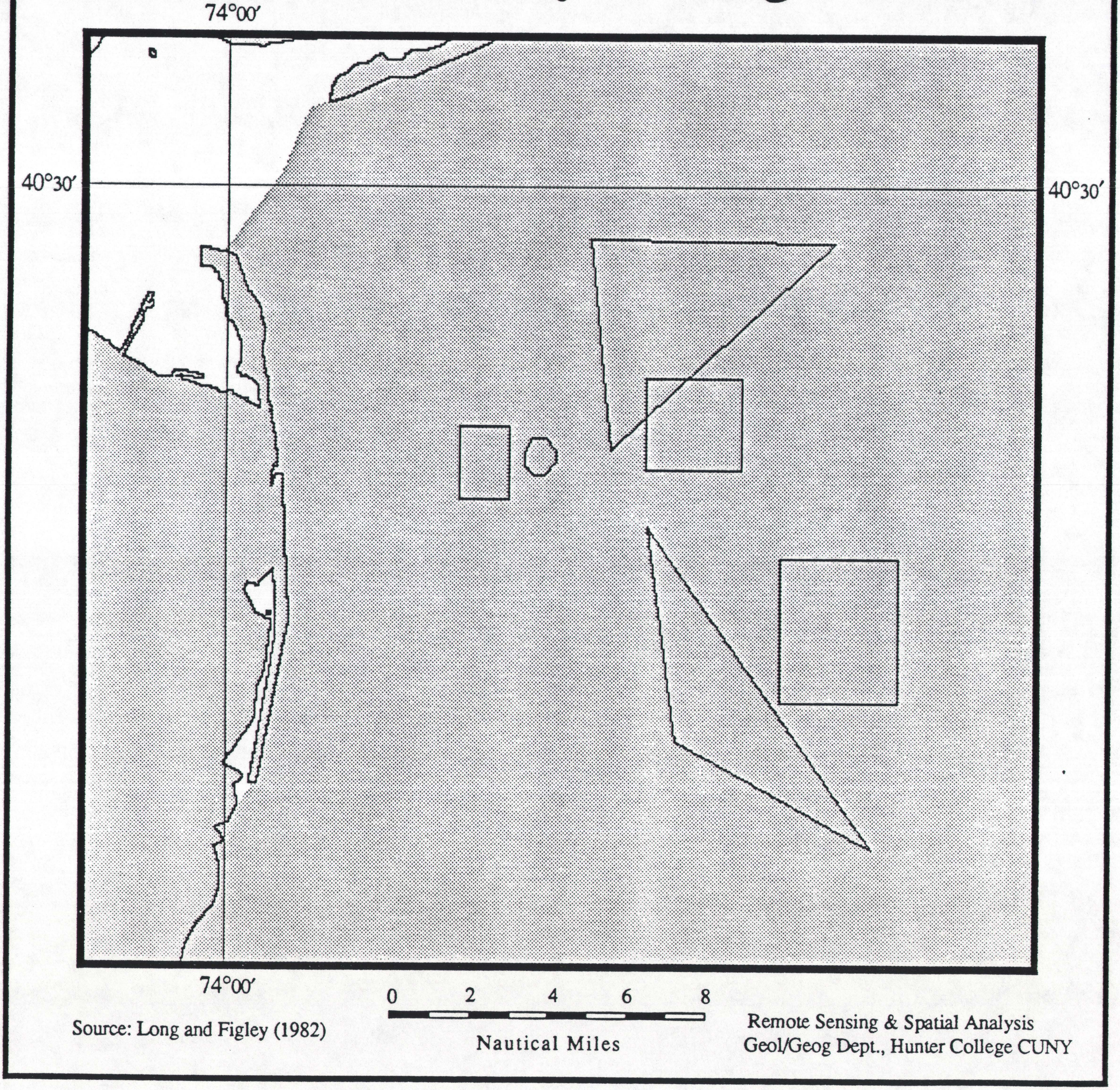


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 13

Sport Fisheries: Primary Whiting & Red Hake

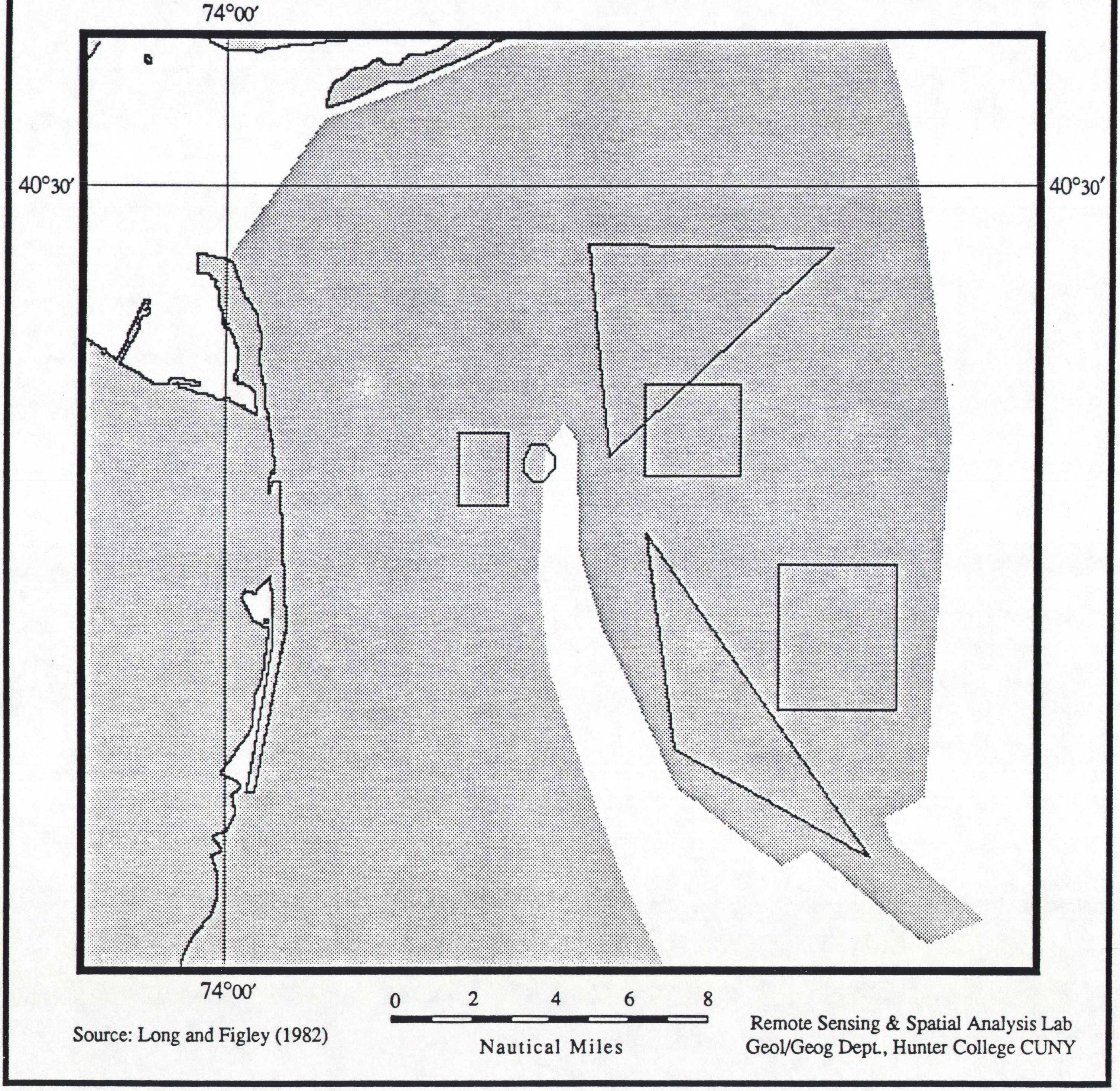


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis
Geol/Geog Dept., Hunter College CUNY

Figure 14

Sport Fisheries: Black Sea Bass

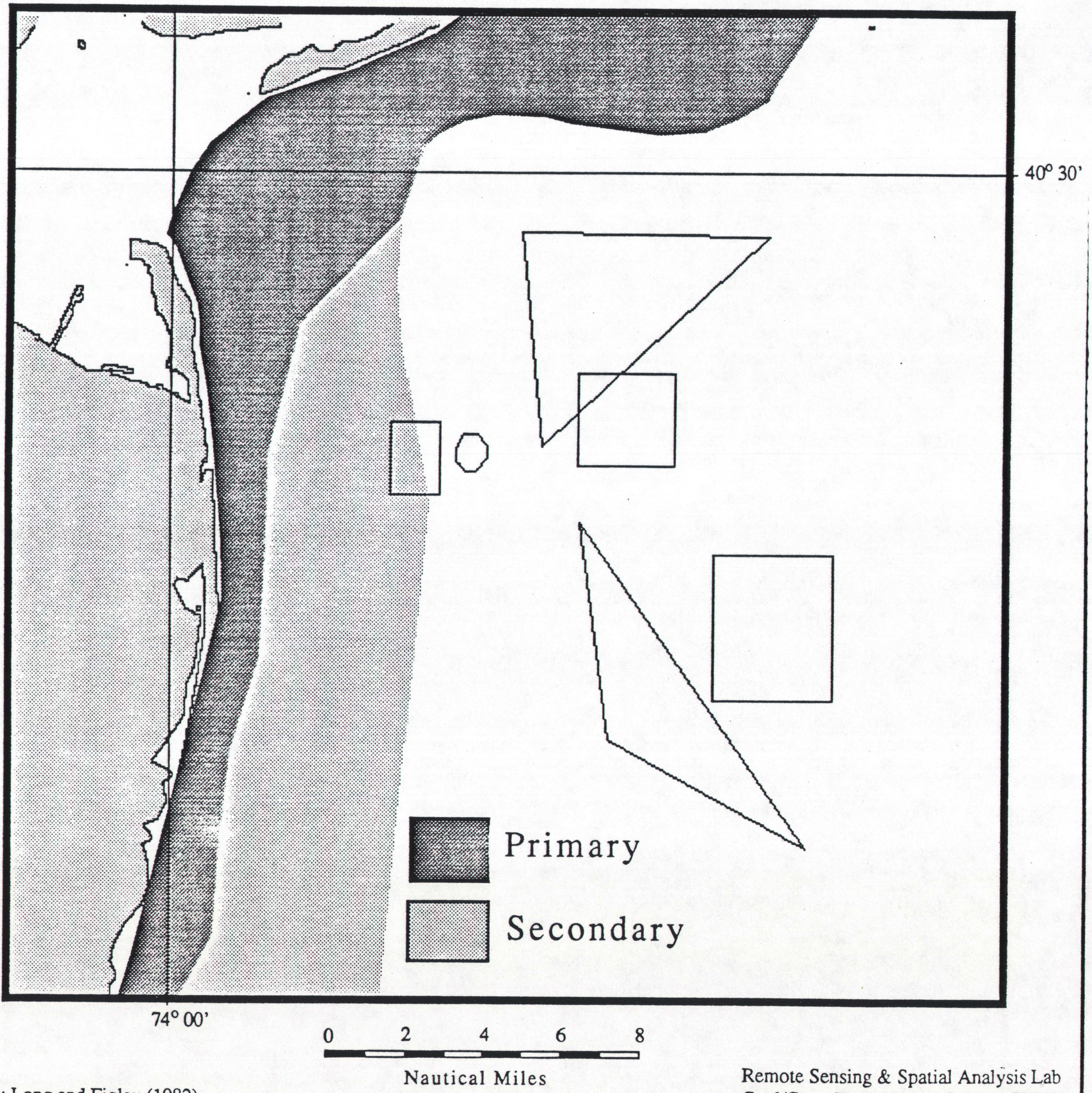


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 15

Sport Fisheries: Weakfish

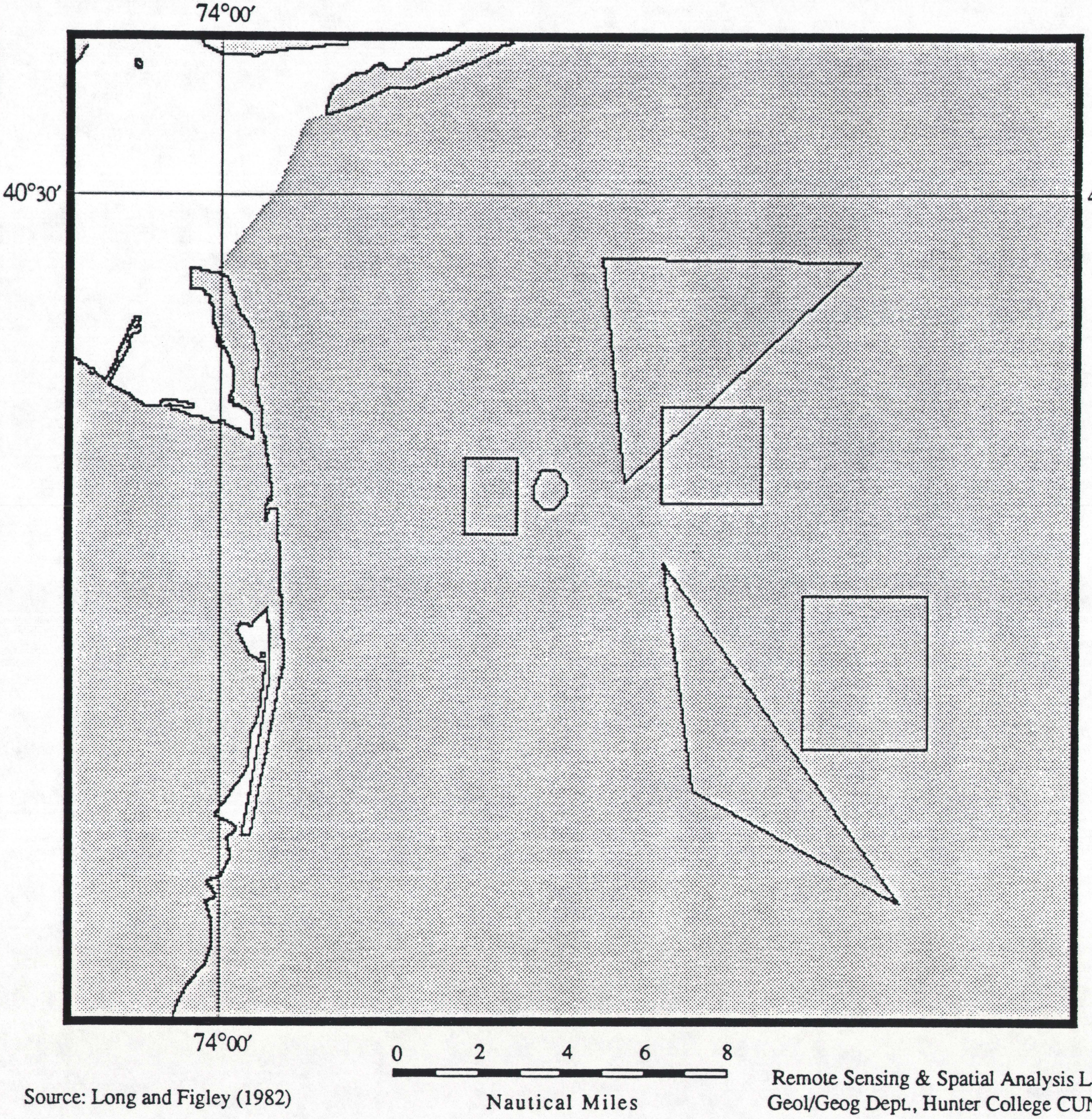


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept. Hunter College CUNY

Figure 16

Sport Fisheries: Bluefish

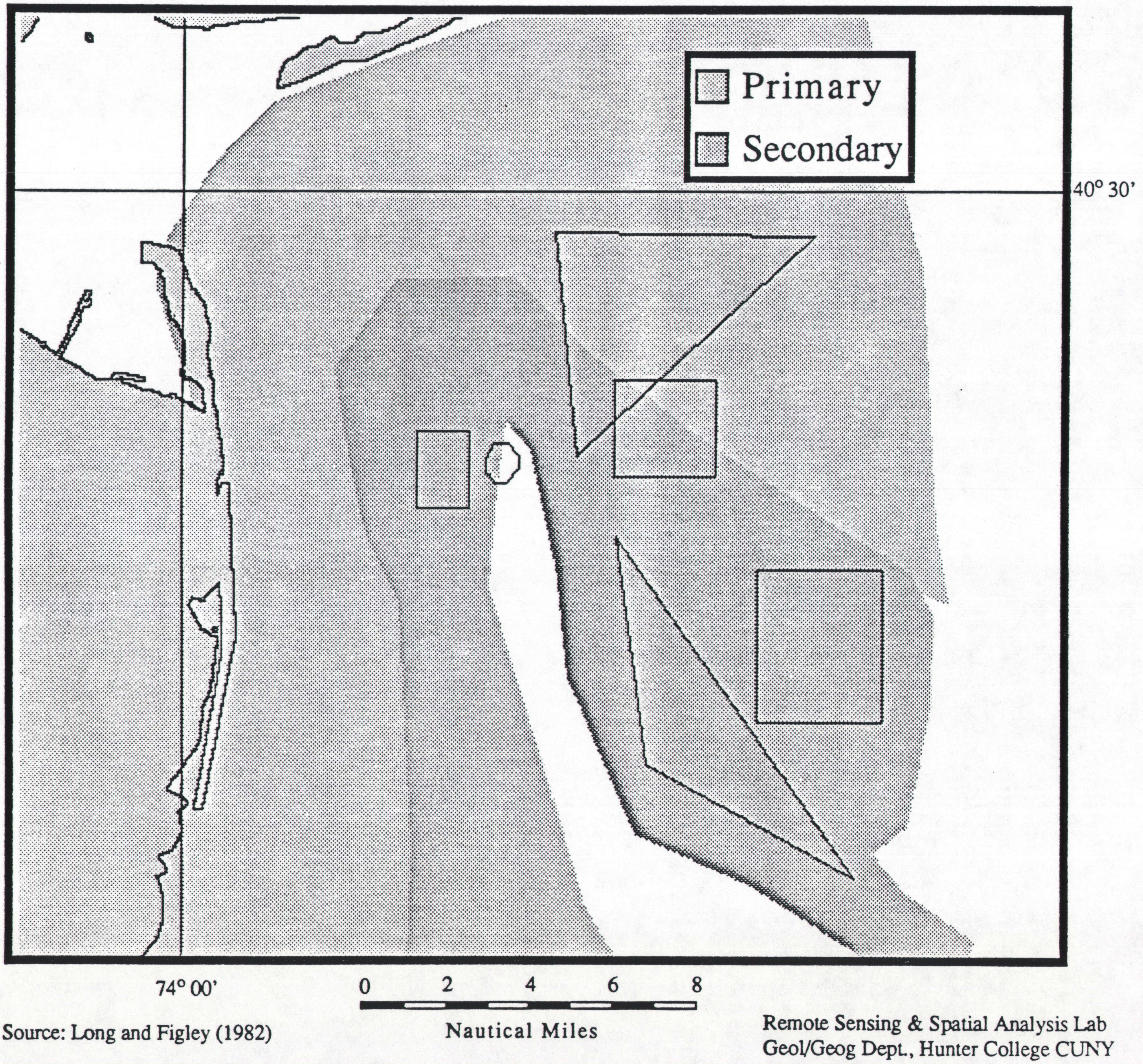


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 17

Sport Fisheries: Tautog

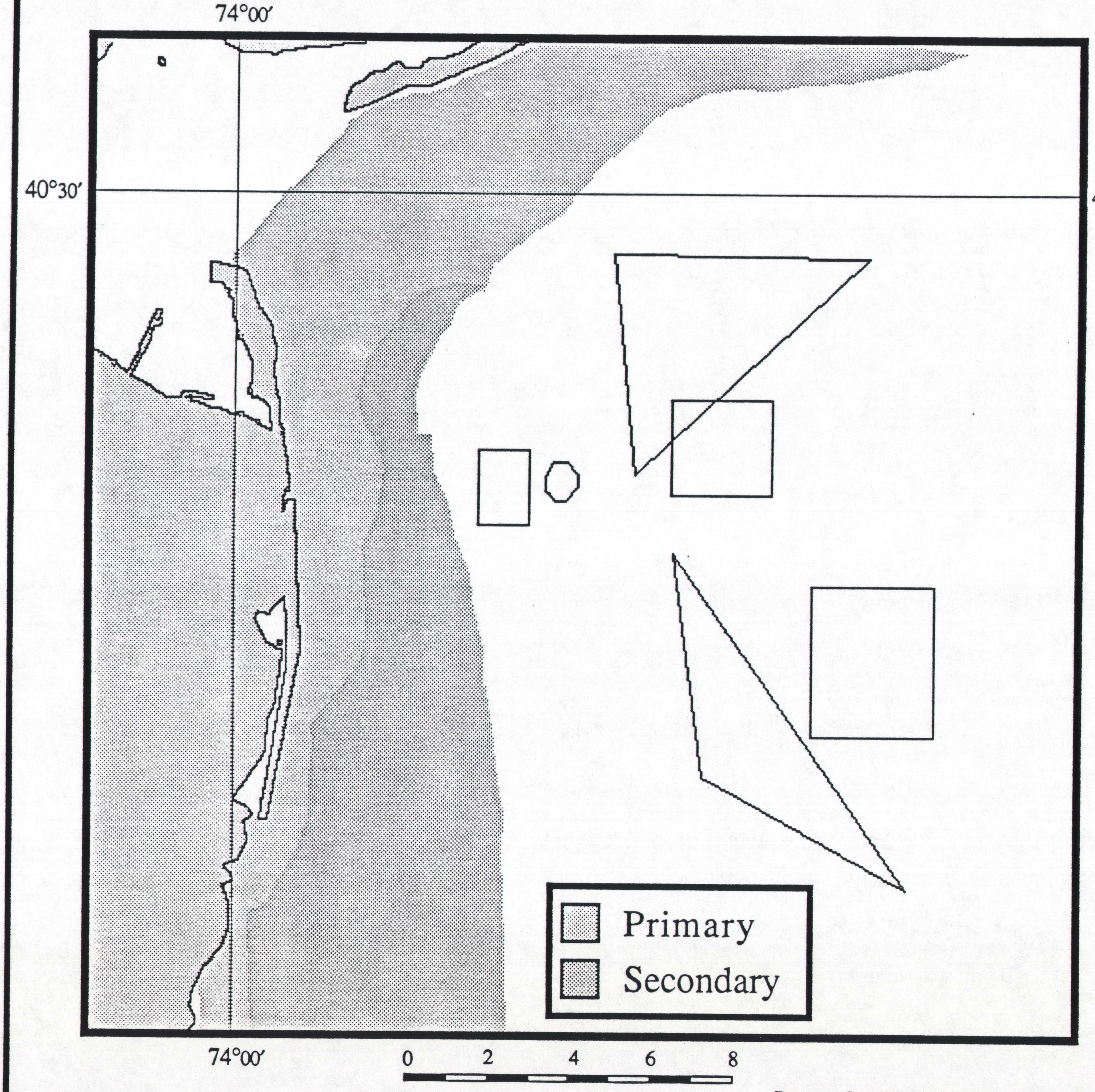


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 18

Sport Fisheries: Fluke

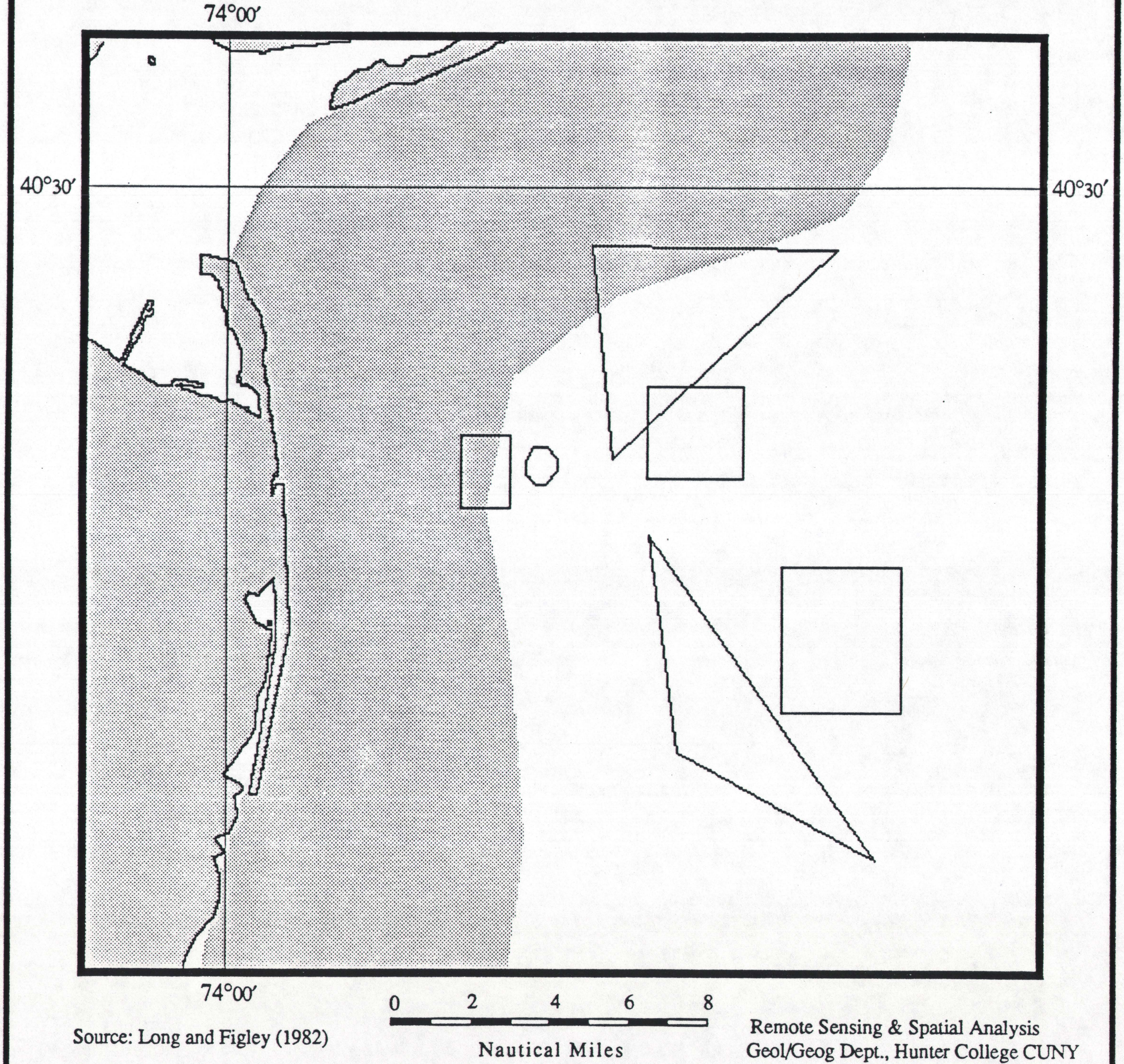


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 19

Commercial Fisheries: Bluefish & Weakfish

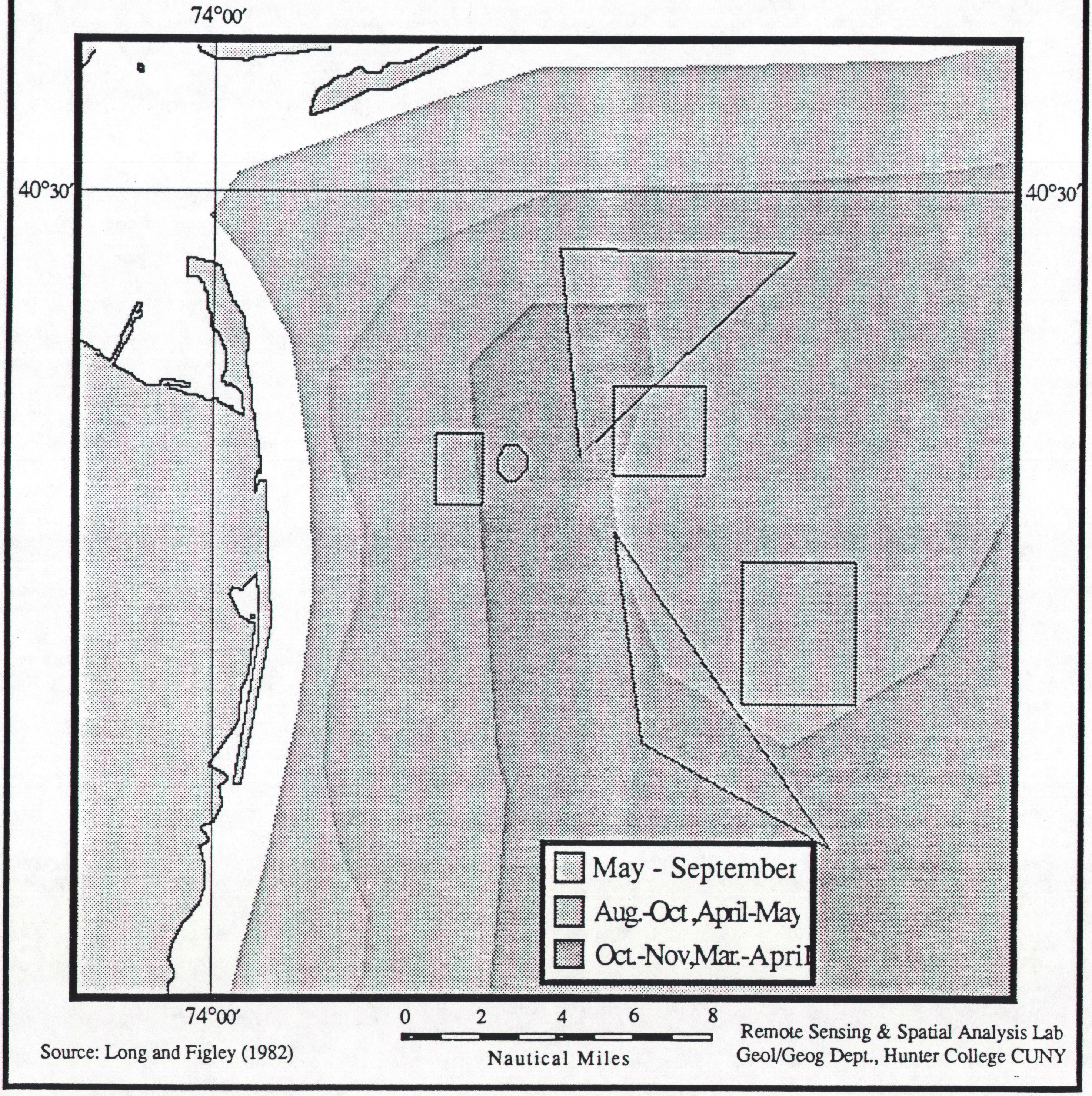


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis
Geol/Geog Dept., Hunter College CUNY

Figure 20

Commercial Fisheries: Fluke

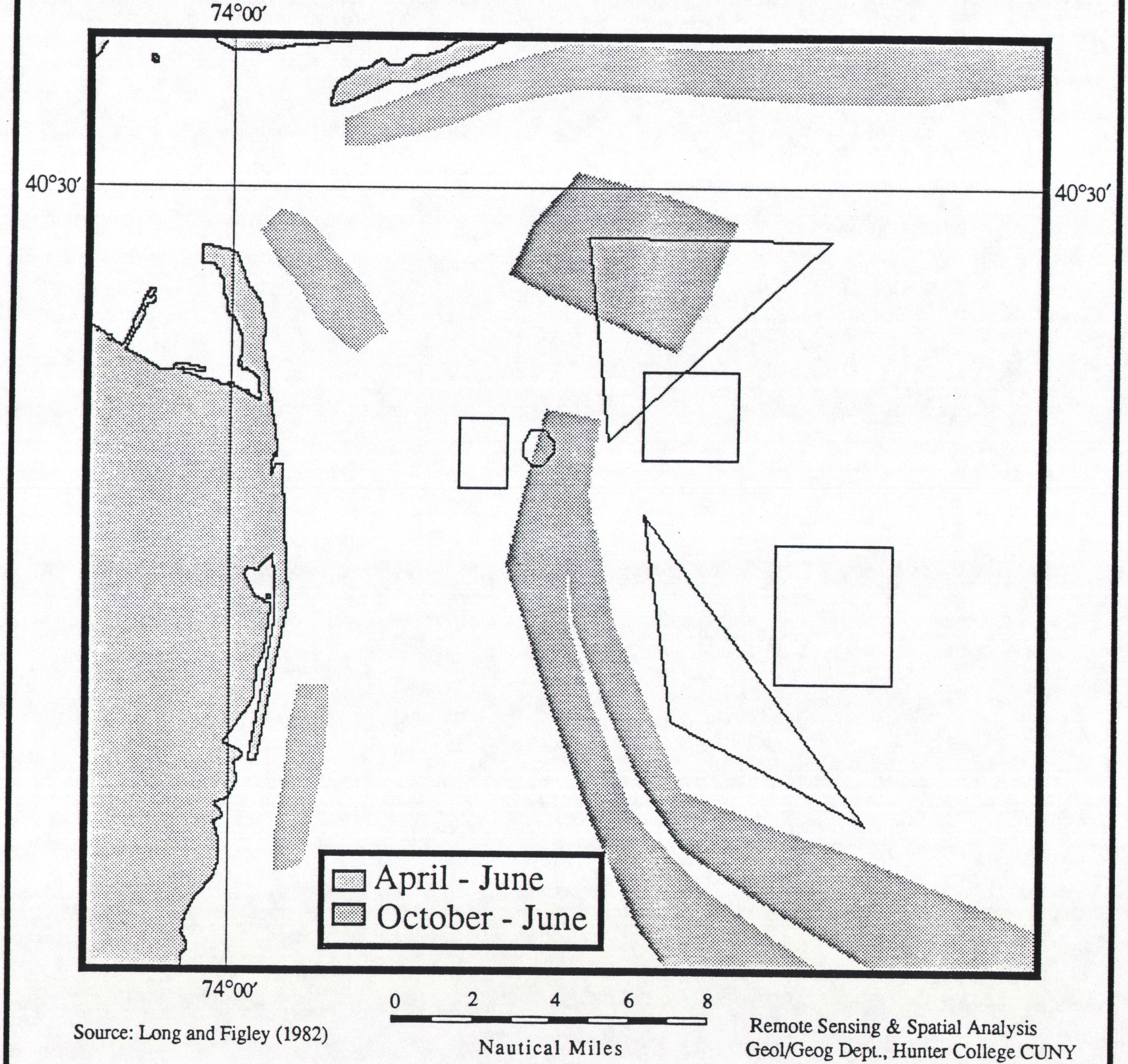


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 21

Commercial Fisheries: Whiting & Red Hake

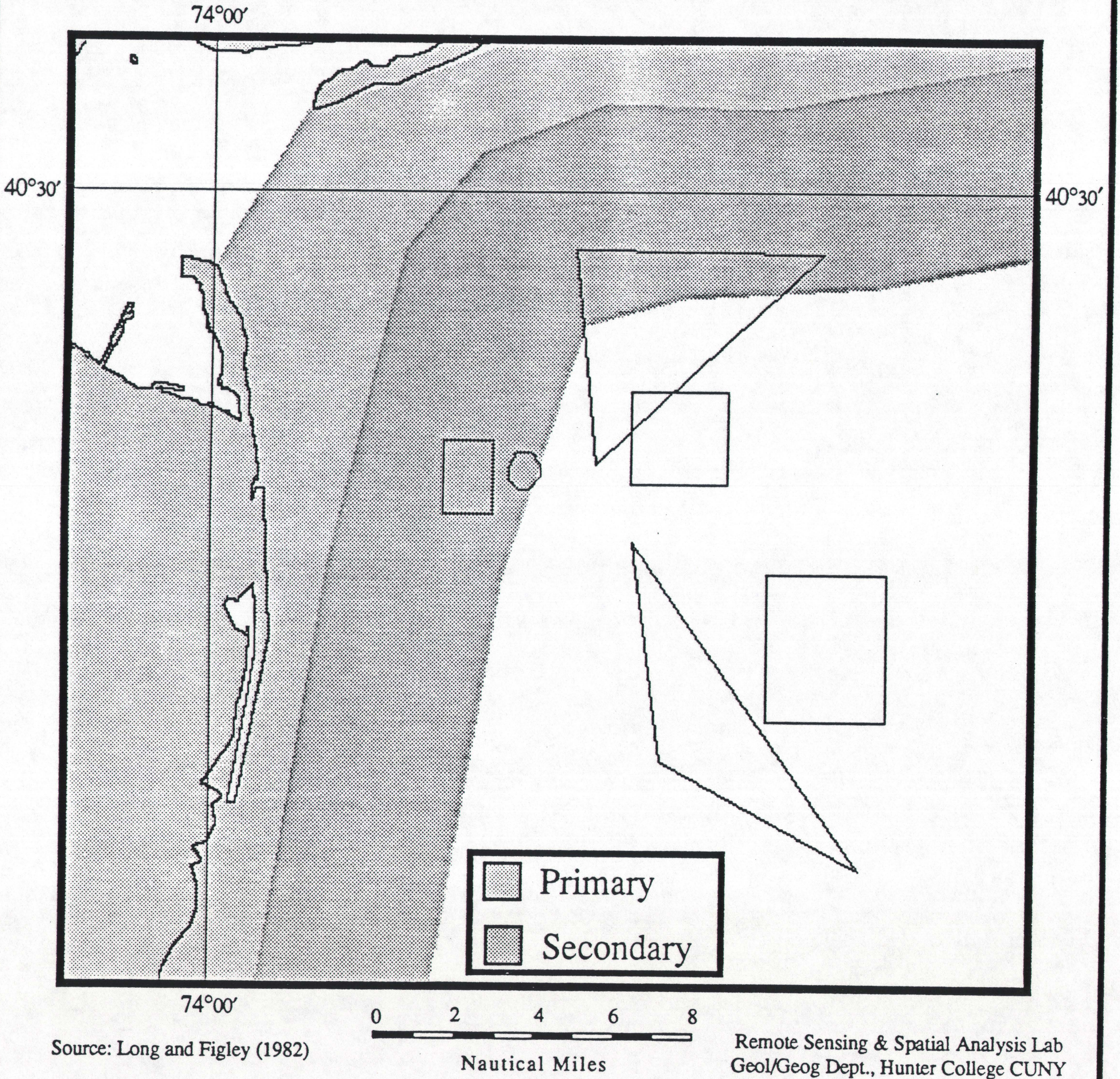


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis
Geol/Geog Dept., Hunter College CUNY

Figure 22

Commercial Fisheries: Menhaden

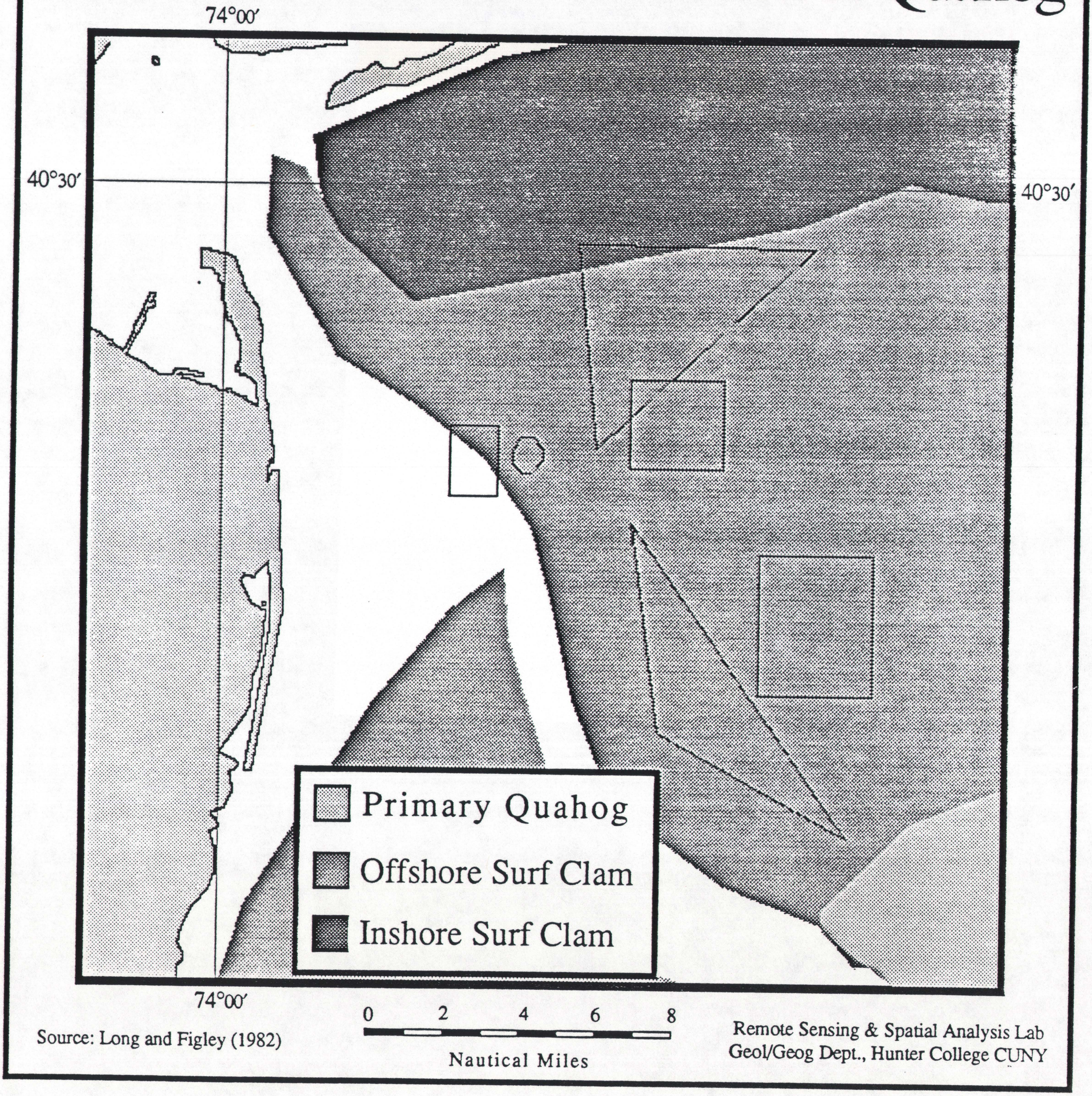


Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 23

Commercial Fisheries: Surf Clam & Quahog



Source: Long and Figley (1982)

Remote Sensing & Spatial Analysis Lab
Geol/Geog Dept., Hunter College CUNY

Figure 24