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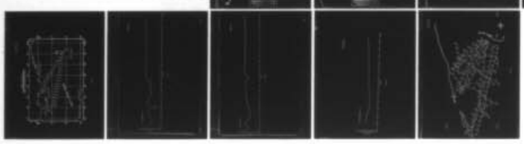

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NAVAL UNDERWATER SYSTEMS CENTER
NEWPORT, RHODE ISLAND 02840

BATHYMETRY OF BLOCK ISLAND SOUND

by

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and

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Technical Memorandum No. TA131-136-71

29 April 1971

ADMINISTRATIVE INFORMATION

This memorandum was prepared under NUSC Project Title: Bottom Environmental Acoustic Characteristics, J. Gallagher, Principal Investigator. The sponsoring activity was Naval Ship Systems Command, Code OOV1K, B. K. Couper, Program Manager.

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ILLUSTRATIONS

INTRODUCTION

The general bathymetry of Block Island Sound is quite well known. However, insufficient knowledge of the detailed distribution of small scale features, the time varying features, and the influence of navigational inaccuracies precludes a completely accurate description of the Sound's bathymetry.

The area of study comprises two physiographic provinces, i.e., the Embayed Section of the Coastal Plain and the Upland Section of the New England Province (1). The bathymetry of Block Island Sound is due, largely, to a history of uplift and erosion during the Tertiary Period, continental glacial erosion and deposition processes during the Pleistocene epoch, and subsequent submergence.

The geographical description of Block Island Sound as described by Williams (2) will be briefly summarized here. Block Island Sound is a partially closed body of water with an area of about 525 square miles. Block Island Sound separates Fisher's Island, N.Y.; Montauk Point, N.Y.; and Block Island, R.I. The adjacent water bodies are Long Island Sound to the west, Rhode Island Sound to the east, Fisher's Island Sound to the north, and the Atlantic Ocean to the south.

This description of the bathymetry of Block Island Sound, particularly the BIFI Shallow Water Acoustic Propagation Ranges, is the first in a series of planned memoranda describing the geology of the Sound. Subsequent memoranda will discuss distribution of physical and acoustic properties of the unconsolidated sediments, mineralogical distribution, sediment thickness and basement rock topography.

This effort was undertaken to support the Laboratory's shallow water acoustic propagation programs by defining the characteristics of the bottom boundary along the acoustic transmission corridors.

HISTORY OF FORMATION

The basins of Block Island Sound and Long Island Sound, were probably formed by erosion during the Tertiary period; between 2 million and 60 million years ago.[3]

During the Eocene and Oligocene epochs southern Connecticut experienced cycles of gradual uplift, erosion, and inundation by the sea. Following each uplift drainage was southeasterly from the eastern Connecticut land mass as evidenced by the pattern across the exposed sea floors.[4] Block Channel appeared to be the trunk of this dendritic drainage system, draining most of southern New England.[5]

Apparently, uplift continued from late Miocene - early Pliocene time to the end of this Tertiary period. During this longer erosional time span the valleys were widened and deepened by the cutting away of softer material. From sub-bottom profiler records, the depths of these river channels imply that the land elevation was much greater than at present. In Block Island and Long Island Sounds the inshore edge of the Tertiary fluvial deposits formed lowlands, and a cuesta out of the existing sediments.[7,8]

Distribution of Tertiary deposits on land in southern Rhode Island, southern Connecticut and Long Island is extremely limited. Where present, these deposits are usually less than 15 meters thick, and show many outcroppings of older rocks.[6] These deposits are chiefly nonmarine and contain little organic content.

The close of the Tertiary period was characterized by a marked land uplift, and renewed erosion. This activity preceded the early glacial activity, which marked the beginning of the Quaternary period.

During the Pleistocene epoch southern New England was invaded several times by southward advancing continental ice sheets. During each glacial stage the bottom of the Sound was exposed above sea level. Each advance was followed by a warmer interglacial period, during which the glaciers receded northward and the sea level rose. The fluvial deposits of the Tertiary period in Block Island and Long Island Sounds were modified by glacial erosion and deposition. The Connecticut River's pre-glacial outlet at New Haven was diverted eastward to its present location at Old Saybrook.

The maximum southerly advance of each glacial movement is usually marked by the deposition of a terminal moraine. Two such moraines are significant in this geographic area. The earlier deposit is referred to as the Ronkonkoma-Nantucket moraine, and is partially evident today as Montauk Point, L.I., Block Island, Martha's Vineyard, and Nantucket Island. The later moraine, called the Harbor Hill-Buzzards Bay moraine, or, the Charlestown moraine, is partially evident as Orient Point, L.I., Fisher's Island, and the south shore of Rhode Island, through Watch Hill, R.I.

It is estimated that a maximum sea level lowering of about 120 meters occurred during the last glacial stage, about 18,000 years ago. It is believed by some authors that Long Island, Block Island and Rhode Island Sounds were fresh water lakes during the last glacial stage.[9,10] The last glacial retreat appears to have occurred about 12,000 years ago. It had little effect on Block Island Sound because the meltwater of the receding glacier was trapped in Lake Worden, an ancient glacial lake which formed behind the Charlestown moraine and drained westward via the Pawcatuck River into what is now known as Little Narragansett Bay.[3]

Today, the sea is still encroaching upon the land. Radio carbon-dated samples show that the Connecticut coast has submerged about 3 meters in the last 3,500 years and about 8.4 meters in the last 8,000 years.[11] Erosion of a shoreline is dependent upon the resistance of the shoreline rock. Since a considerable part of the Connecticut and Rhode Island shorelines are formed by unconsolidated glacial deposits, they are changing quite rapidly.[12] Profiles of the eastern Connecticut shoreline show highly dissected terrances and cliffs that represent ancient uplifted coastlines which were eroded by rising sea levels and accompanying wave action. The eroded material contributes to the formation of barrier beaches and bars generally running east-west, normal to the predominant north-south axes of tributaries and embayments. The stretch of ocean beaches extending from Watch Hill to Point Judith constitute barrier beaches which were built in part from erosion of terminal moraines and other glacial materials, blocking off estuaries to form lagoons that are locally called salt ponds. It should be noted that the rate of erosion above sea level (sub-aerial) is usually more rapid than that below. Thus, prior to rising sea levels the bottoms of these sounds were subjected to sub-aerial erosion. As submergence progressed waves and currents worked and sorted surface sediments until sea level rose sufficiently to place the sediments beyond the influence of the waves. Since that time subsurface currents have been the dominant influence in forming the present sediment distribution. Throughout much of the post-glacial history Block Island Sound remained a relatively closed basin, protected from the destructive forces of storm waves. This condition and the very small river discharge into the sound since the Pleistocene have allowed the bottom to retain many of its glacial and postglacial characteristics. Today, the bulk of the surface deposits in the sounds are chronologically classified as Pleistocene.

TOPOGRAPHY OF BLOCK ISLAND SOUND

The characteristics of the larger topographic features in the Sound can be inferred from similar features on adjacent land masses. The eastern Connecticut rock outcrops tend to be aligned along a North-North-East to South-South-West direction, and dip West-North-West at about a 10° angle from the horizontal. The precipitous cliffs and the steep escarpments of hills generally face East to Southeast, sloping more gradually to the West-North-West. Basement rocks in Block Island Sound have been observed from sub-bottom profiling records to strike East-Northeast and dip South-Southeast.[8]

The bathymetry of Block Island Sound is shown in Figure 1, the track chart for this data is shown in Appendix I. This data was collected aboard the USNS SANDS (T-AGOR-6) in 1967, using a hull mounted UQN-1 12 kHz echo sounder and a Gifft model GDR-IC-19T recorder; the data is not corrected for tide height or transducer depth (13). A portion of the Sound south of Fishers Island and Watch Hill was not surveyed at the time because this zone was restricted. Another available detailed bathymetric map which includes this zone is shown in Figure 2. This chart was extracted from a larger U.S. Coast and Geodetic Survey Chart, number H.O. Misc. 15359-5A. The type of sounding equipment used to collect the C & GS data in 1939 is not known.

A natural division of the topography of the Sound appears to exist. The eastern half of the Sound is characterized by a flat to gradual southeastward sloping surface, with relatively low relief. The western half also slopes southeastward but is dissected by many holes, submerged valleys and ridges.

EASTERN SECTOR - A broad flat, rather smooth plain covers most of the east central portion of the Sound at a mean depth of about 33.5 meters. This plain is believed to be a delta type deposit formed at a time of lower sea level.[14] Water flow rate is impeded in this zone by an elongated topographic high trending Northwest-Southeast, north of Block Island. It grades out to the north into deeper water, and is truncated on the southern end, just north of Block Island, by a North-Northeast-South-Southeast trending valley.

WESTERN SECTOR - South of Fishers Island two well defined submerged valleys trend Northwest-Southeast. The northermost valley diverges eastward and then converges to the South-Southeast. The floors of both of these valleys reveal a mean depth of about 51.5 meters indicating that both are a part of the same drainage system.[3] Each valley has limited depressions in the floor about 4.6 meters deep. At about 41°10' North latitude these valleys tend to form the head of Block Channel. This channel trends Southeast cutting through the submerged terminal moraine between Montauk Point and Block Island, feeding Block Canyon.

The greatest depth recorded in the Sound is a closed basin about 98.5 meters deep, located about four miles south of East Point, Fisher's Island. It is located at the head of the northern valley. Two other closed basins at depths of 57.9 meters and 73.2 meters lie approximately two miles to the north, in a general East-West trending depression which extends into Rhode Island Sound. On either side of the sill that extends across The Race from Valiant Rock to the western terminus of Fisher's Island lie deep depressions. The eastern depression reaches a depth of 86.9 meters while the western depression is as much as 97 meters deep.

An extensive shoal area trending Northwest-Southeast restricts the free exchange of water between Block Island and Long Island Sounds. Endeavor and Cerebus shoals north-westward to Valiant Rock constitute this circulation boundary at depths of from 3.0 meters to 9 meters.

TOPOGRAPHY OF THE BIFI ACOUSTIC RANGES

Geographic perspective for the axes of both ranges is provided in Figure 3.

a) Block Island - Fishers Island Range

The axis of this acoustic range lies approximately on a 279° T bearing from the entrance to Great Salt Pond, Block Island. The range transects both the smooth, shallow basin in the eastern sector and the highly varied relief in the western sector of the Sound. A cross-section profile along this bearing was constructed from the bathymetric chart shown as Figure 1, and is presented in Figure 4.

A cross-section profile of the bottom along a track approximately 9 kilometers south of the 279° T range line is shown in Figure 5. This trace was recorded aboard the University of Connecticut vessel R/V UConn, using a towed 12 kHz echo sounder. The depression between the 20 and 22 Kilometer distances from the submerged acoustic source, off Block Island, represents the outer portion of the northern drainage valley converging toward the southern valley to form the head of Block Channel. The relief in the western sector is significantly less, than that at about 9 Kilometers to the north although that in the eastern sector is not modified significantly.

It should be noted that small errors in navigation in the western sector of the range can result in significantly different bathymetric profiles. The problem is further aggravated by the strong surface currents in the sector, which tend to divert a prescribed course. Bathymetric differences between Figure 1 and Figure 2 could be due primarily to navigation errors. The 1967 USNS SANDS survey used ship's radar and Loran-A for navigation. The navigational technique used during the 1939 C & GS survey is not known.

b) Block Island - Watch Hill Range

The axis of this range lies approximately on a 299° T bearing from the entrance to Great Salt Pond, Block Island. A cross-section profile of the bathymetry along this bearing is shown in Figure 6.

The eastern portion of this transect is also represented by the smooth plain. There is much less relief in this western sector than that in the Block Island-Fisher's Island range. At about 13 Kilometers from the acoustic source the transect diagonally intersects an East-West trending depression. At about 19 Kilometers from the source the transect encounters a relatively steep rise which characterizes the transition zone between the Sound basin and the adjacent land masses.

WATER CIRCULATION

Topography influences water circulation, particularly sub-surface circulation, by channeling or obstructing flow. Conversely, water circulation influences topography by controlling erosion and deposition processes. The topographic control of flow is evident throughout Block Island Sound, particularly in its influence of tidal current flow.

The present distribution of sediments in the Sound is due primarily to tidal currents, which tend to mask the non-tidal circulation. The flood tidal current enters Block Island Sound from two directions: a northwestward set through Block Channel and a southwestward set from Rhode Island Sound. The surface component of the North-Westward setting current also enters Long Island Sound but the sub-surface component of this North-Westward flow veers eastward in Block Island Sound.[15] During the ebb period it flows both eastward along the Rhode Island coast and southward along the western edge of Block Channel. The Southwestward setting flood current from Rhode Island Sound turns southward toward the western shore of Block Island and appears to exit through Block Channel during the ebb flow.

The ebb tidal current from Long Island Sound sets southeastward through The Race and Plum Gut. After passing through the Race the current diverges to form a Southeastward set toward Block Channel and an eastward set toward Rhode Island Sound. While there is an appreciable volume exchange of water through the Race and Plum Gut the strong currents through these passages probably preclude deposition of fine-grain sediments from the Thames and Connecticut Rivers in Block Island Sound. In all probability the bulk of the suspended load of fine material entering Block Island Sound is transported through Block Channel and deposited on the Continental shelf. In the western part of the Sound the topographic depressions act as sediment traps for the coarser sediment transported along the bottom by traction.

A net sub-surface drift westward from Rhode Island Sound through Block Island Sound and into Long Island Sound at speeds of 1.8-3.7 Kilometers per day was observed.[16] The east-central plain area probably received the bulk of its siltysand material from this westward flow.[14]

SUMMARY

(Block Island - Fisher Island

This description of the bathymetry of the (BIFI) shallow water acoustic propagation ranges is the first in a series of planned memoranda describing the geology of Block Island Sound. Subsequent memoranda will discuss distribution of physical and acoustic properties of the unconsolidated sediments, mineral distribution, sediment thickness, structure of the sediment column and basement rock topography. This effort supports the Laboratory's shallow water acoustic propagation programs by describing the characteristics of the bottom boundary along the acoustic corridors.

Block Island Sound is naturally divided into two dissimilar bathymetric sections: the flat, gradual sloping eastern sector and the high relief western sector. The acoustic ranges transect both sectors. The western sector of the Block Island-Watch Hill acoustic range however reveals a somewhat lower relief than that of the Block Island-Fishers Island acoustic range. In the eastern sector there is no significant difference in the bathymetry of either range.

Lateral variability of bathymetry in the western sector of the Sound imposes a severe demand on high resolution, high accuracy navigation in determining depth at a particular geographic site. Strong currents add to the problem in this application as well as in station keeping, implantment, grid-pattern measurements, etc.

The smooth eastern sector of the acoustic ranges may provide a convenient area for the field study of small scale roughness effects on the distortion of low grazing angle acoustic signals at short lateral ranges in the 1-5 kHz frequency range, or higher.

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Marine Science Institute

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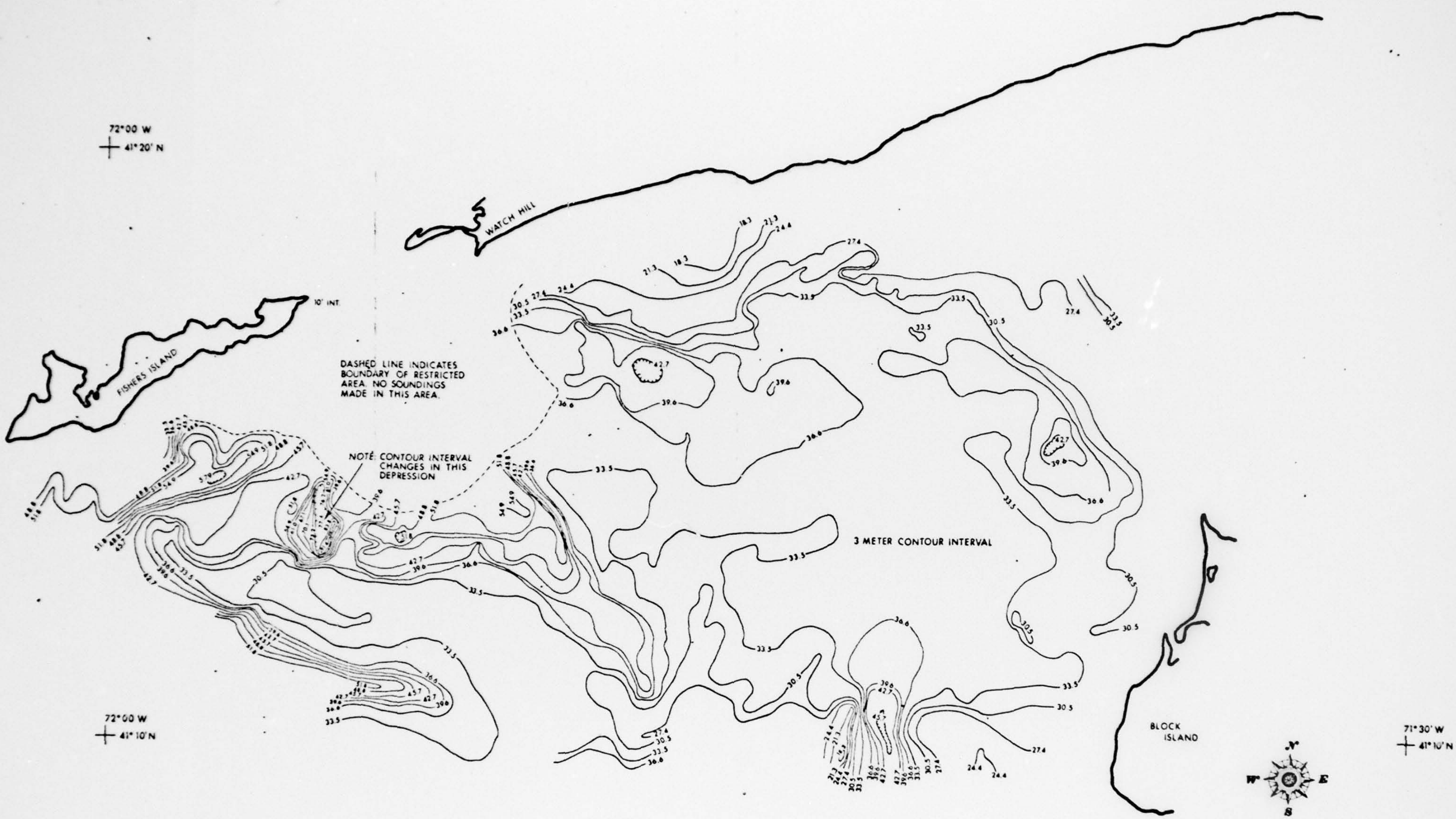
72°00 W
41°20' N
72°00 W
41°10' N
71°30' W
41°10' N
FISHERS ISLAND
WATCH HILL
BLOCK ISLAND
10' INT.
DASHED LINE INDICATES BOUNDARY OF RESTRICTED AREA. NO SOUNDINGS MADE IN THIS AREA.
NOTE: CONTOUR INTERVAL CHANGES IN THIS DEPRESSION
3 METER CONTOUR INTERVAL
N
E
S
W

FIGURE 1

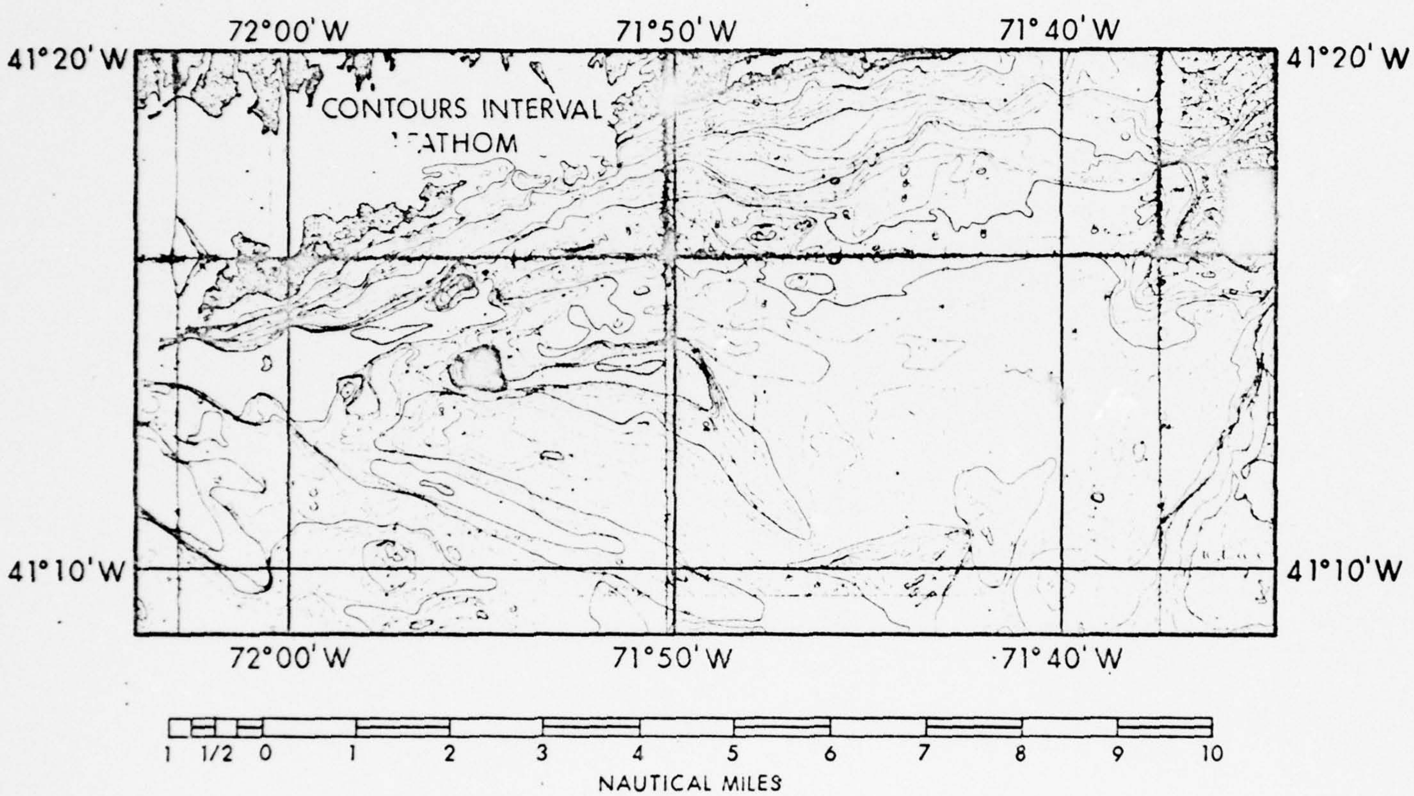
72°00'W
71°50'W
71°40'W
41°20'W
41°20'W
CONTOURS INTERVAL
41°10'W
41°10'W
72°00'W
71°50'W
71°40'W
1 1/2 0 1 2 3 4 5 6 7 8 9 10
NAUTICAL MILES

FIGURE 2

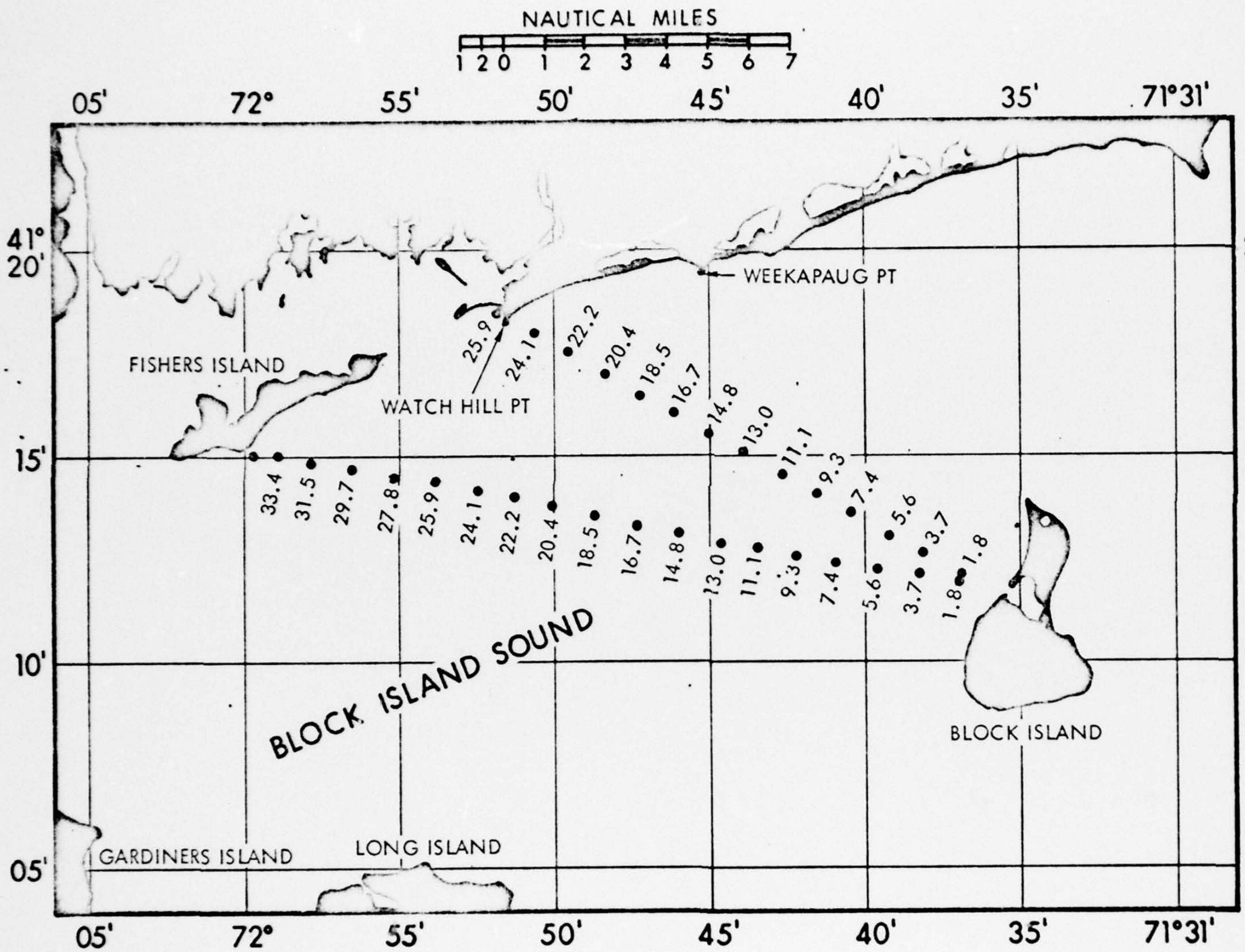
NAUTICAL MILES
1 2 0 1 2 3 4 5 6 7
05'
72°
55'
50'
45'
40'
35'
71°31'
41° 20'
15'
10'
05'
WEEKAPAUG PT
FISHERS ISLAND
WATCH HILL PT
BLOCK ISLAND SOUND
BLOCK ISLAND
GARDINERS ISLAND
LONG ISLAND
25.9
24.1
22.2
20.4
18.5
16.7
14.8
13.0
11.1
9.3
7.4
5.6
3.7
1.8
33.4
31.5
29.7
27.8
25.9
24.1
22.2
20.4
18.5
16.7
14.8
13.0
11.1
9.3
7.4
5.6
3.7
1.8

FIGURE 3

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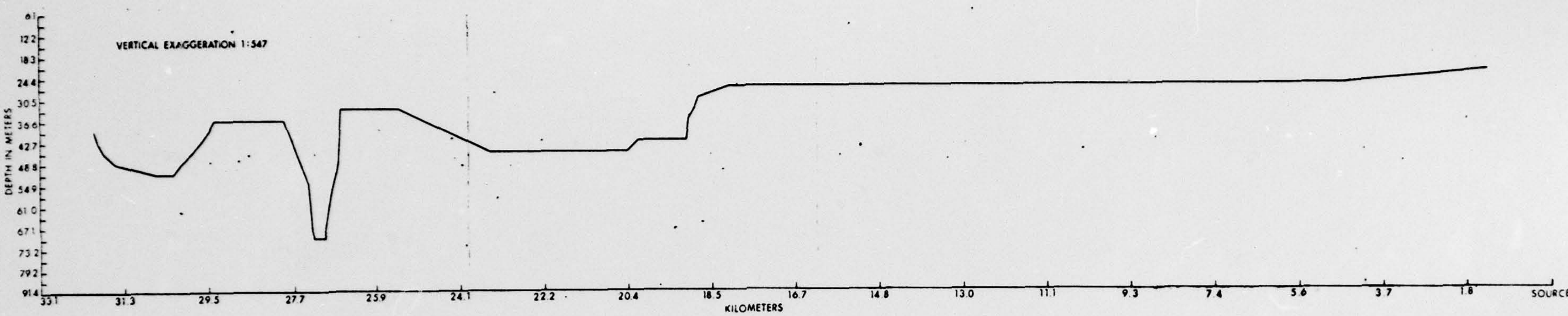
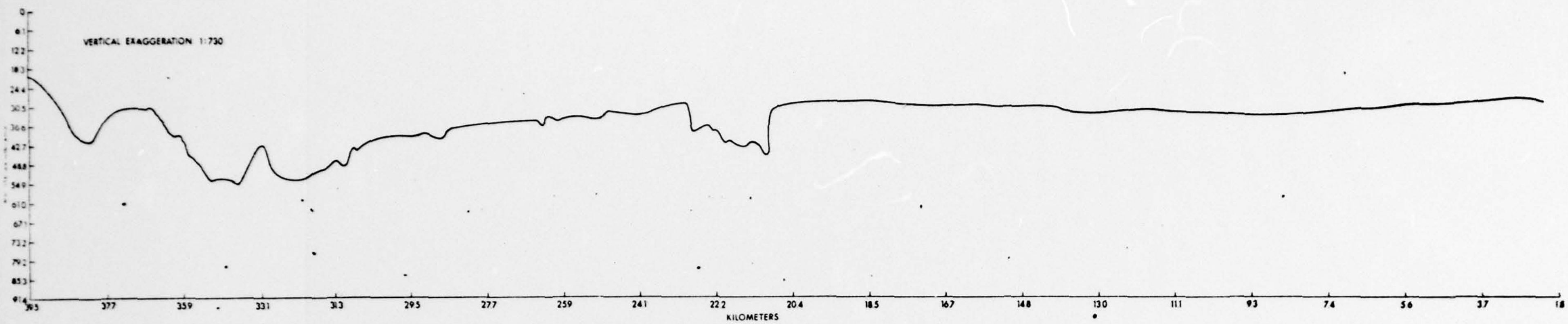


FIGURE 4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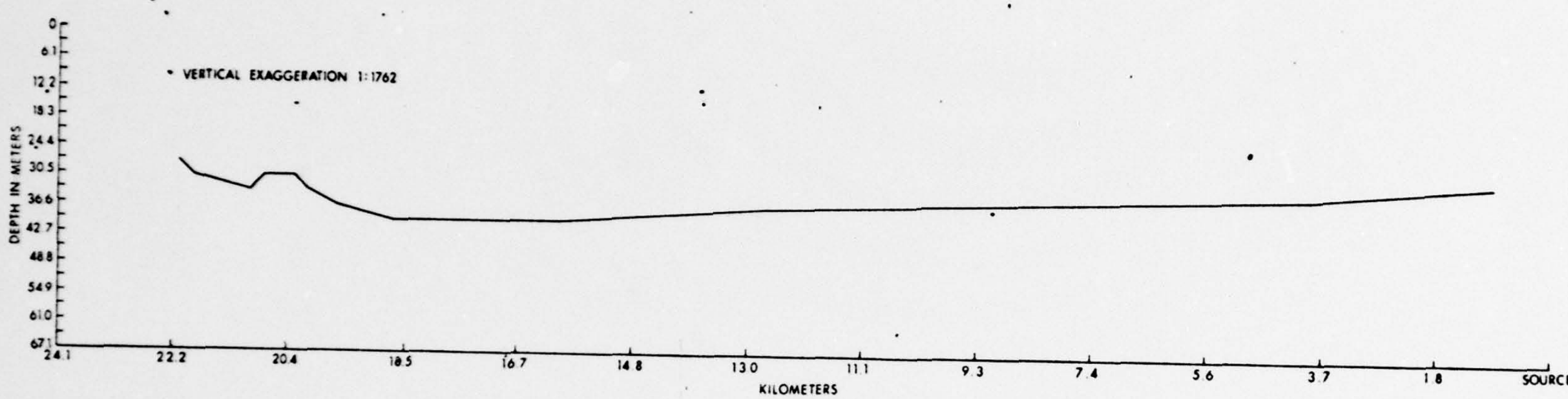
0
61
122
183
244
305
366
427
488
549
610
671
732
792
853
914
395
377
359
331
313
295
277
259
241
222
204
185
167
148
130
111
93
74
56
37
18
KILOMETERS

FIGURE 5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48.8
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61.0
67.1
VERTICAL EXAGGERATION 1:1762
24.1
22.2
20.4
18.5
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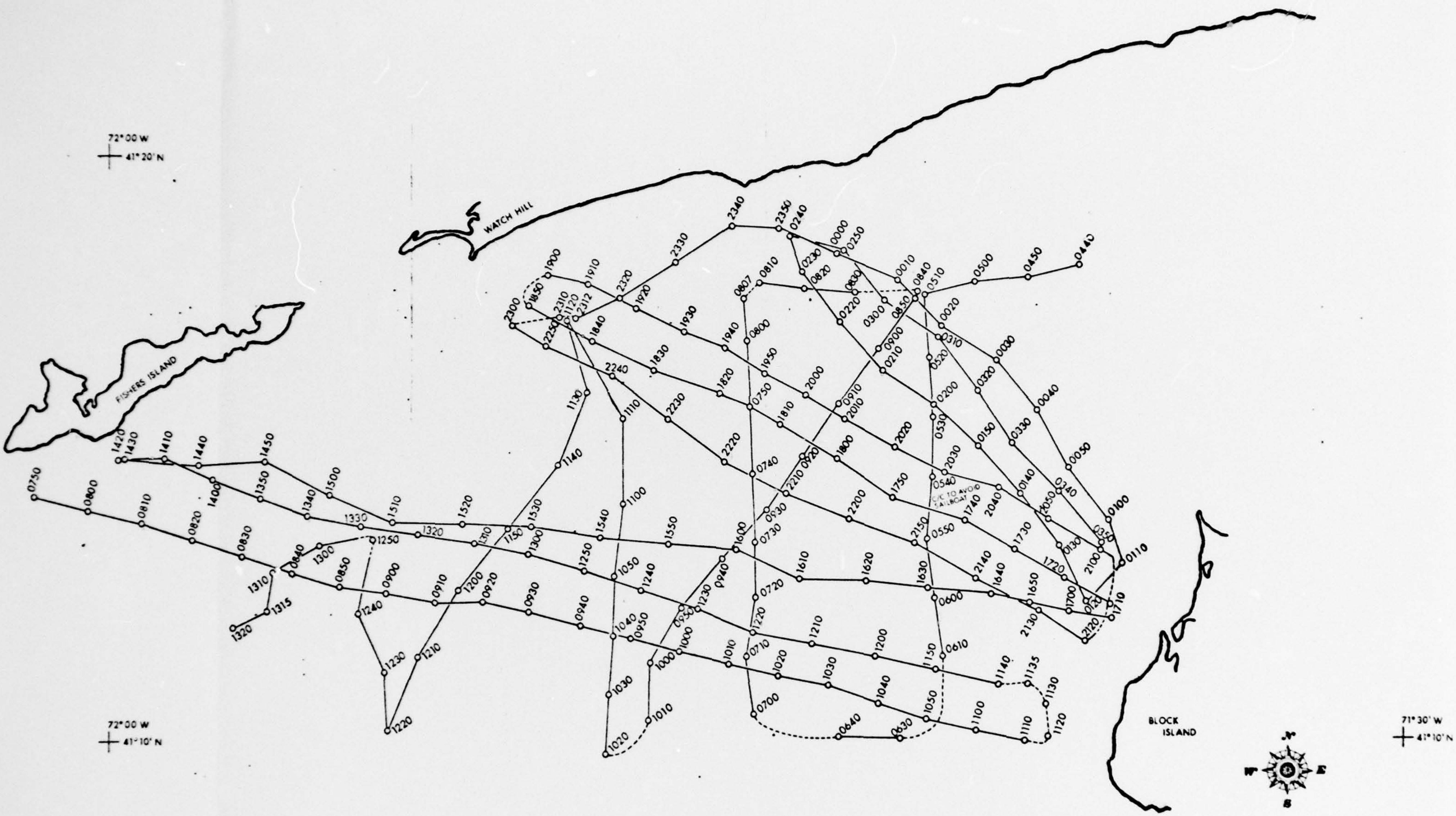
1.8
SOURCE
KILOMETERS

FIGURE 6


72°00 W
41°20' N
WATCH HILL
FISHERS ISLAND
BLOCK ISLAND
72°00 W
41°10' N
71°30' W
41°10' N
C/C TO AVOID SAILBOAT

APPENDIX