CHAPTER 41

ISOPACHOUS MAPPING OF THE LOWER PATUXENT ESTUARY SEDIMENTS BY CONTINUOUS SEISMIC PROFILING TECHNIQUES

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ABSTRACT

The thickness and extent of the sediment cover in the Patuxent Estuary has been determined using a high-frequency, high-spatial resolution, shallow penetration, continuous seismic profiling system. From these data, an isopachous map was prepared The isopachous map provides the subbottom information required to determine optimum locations for placing test equipment on the river bottom

Mud filled depressions, acoustically transparent to 12-kHz sound pulses, occur mainly to the north of Half Pone Point, and east of the present channel Based on the identification of first subbottom reflectors, these depressions are as much as 16 feet thick The dominance of the thicker deposits east of the channel and evidence of a submerged terrace indicates that either the channel has migrated to the west, or that the channel of the Patuxent River at this location was larger in the past and has subsequently filled in much of the material in the eastern edge Maximum penetration at the scarp of the submerged terrace was 36 feet beneath the water-sediment interface This study demonstrates the use of seismic profiling techniques for collecting and presenting data required for coastal engineering applications

INTRODUCTION

The Maryland State Road Commission is considering plans to build a bridge across the Patuxent River near Solomons Island, Maryland (Figure 1) The proximity of the bridge to the existing naval test range located between Point Patience and Hooper Neck may require relocation of the test range A knowledge of the strength characteristics of the river bottom are critical for effective use of the test range Instrument packages may sink into soft muddy sediments and become impossible to locate or retrieve, other instruments could be damaged because of impact with hard sandy materials In order to delineate these two sediment materials, a seismic investigation was conducted from Town Point northward to Broomes Island (Figure 2)

This paper deals with the use of the isopachous map to present continuous seismic reflection data of the sediment cover in the Lower Patuxent Estuary An isopachous map shows the varying thickness of a designated stratigraphic unit by lines of equal thickness (isopachous lines) The stratigraphic unit used in this study is the acoustically transparent sediment cover, which is composed of fine-grained silt- and clay-size sediments

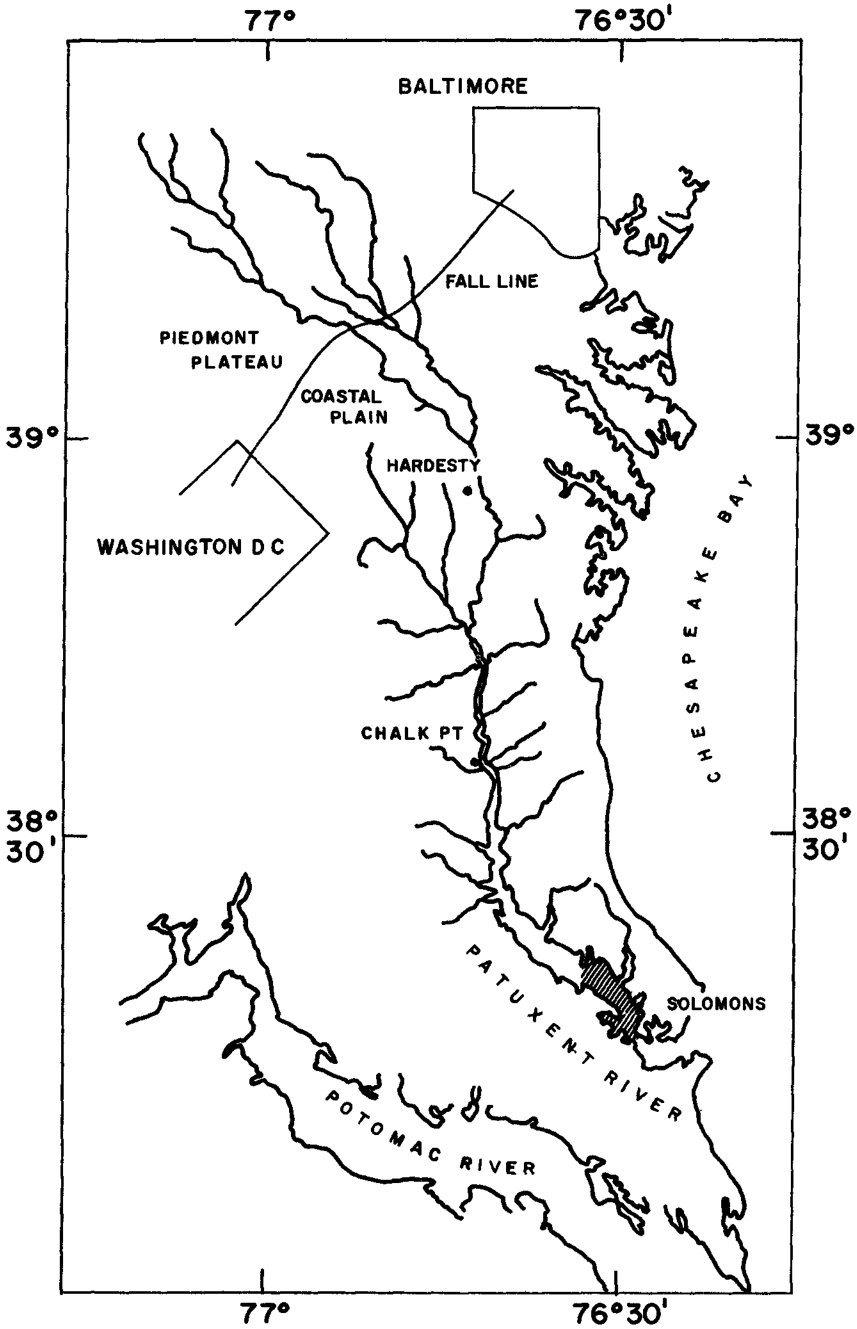

FIGURE 1 INDEX MAP SHOWING AREA OF STUDY

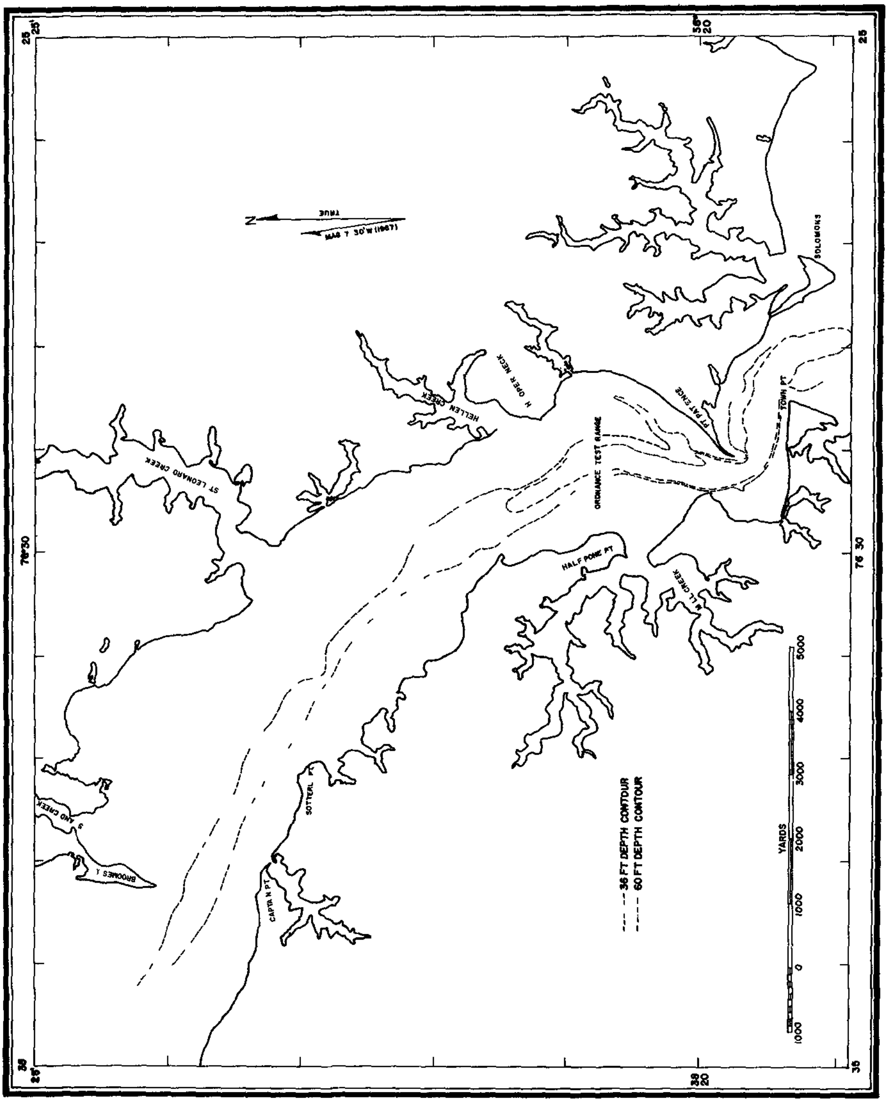

FIGURE 2 BATHYMETRIC CHART OF LOWER PATUXENT ESTUARY

The Patuxent River drainage basin lies entirely within the state of Maryland and occupies 930 square miles (Crooks, O'Bryan and others, 1967) The mouth of the Patuxent Estuary is located where the river enters Chesapeake Bay The upper limit of the sea salt water ranges from 27 miles (Chalk Point) to 56 miles (Hardesty) above the mouth The portion of the waterway between the upper limit of tidal influence and the limit of sea salt intrusion is designated the tidal river (Pritchard, 1967, and Owen, 1969) Between the upper limit of the sea salt intrusion and the mouth of the river is the estuary The Patuxent has been termed moderately stratified by Pritchard (1967), and Owen states "The Patuxent Estuary has a normal two-layered flow associated with an intermittent three-layered flow " Chesapeake Bay itself is a moderately mixed estuary

Owing to the abundance of readily accessible erodible material in the Coastal Plain the sediment yield of the drainage basin is fairly high, 235 tons per square mile at Hardesty near the estuary head (Johns Hopkins University, 1966) Figure 3 shows the change in the lower estuary channel from 1859 to 1944 Although the location of this cross section is not shown, depth and width values correspond with the segment of the estuary between Helen Creek and Broomes Island (Figure 2)

PROCEDURE

Continuous seismic profiles of the Patuxent River between Town Point and Broomes Island were recorded during the period 7 to 10 May 1968 Work was performed on a 45-foot utility boat provided by the U S Naval Ordnance Laboratory Test Facility The transducer was rigidly mounted on the side of the boat three feet beneath the water surface A total of 19 tracks were run over a distance of 30 nautical miles (Figure 4) Boat speeds of about three to four knots were maintained for all traverses Positioning was determined from the two triangulation towers located at Point Patience

The seismic profiler, nicknamed a "Mud Penetrator" (Yules and Edgerton, 1964), consists of three main components (1) an acoustic transceiver and recorder (EG&G, Model 254 Seismic Recorder), (2) a transmitter/receiver transducer (EG&G, Model 228A Pinger Probe), and (3) a gasoline powered electric generator The system operates at an acoustic frequency of 12-kHz which is sufficiently high so that only fine-grained sediments can be effectively penetrated

The technique for continuous seismic profiling of subsurface acoustic horizons uses a repetitive sound source which propagates acoustic wave fronts through the water and subsurface materials As these wave fronts encounter materials of contrasting acoustic impedance--normally manifestations of geologic stratification or boundaries--echoes are returned to the surface, sensed by the transducer, and then synthesized by the recorder to produce a real-time, continuous profile of the water column,

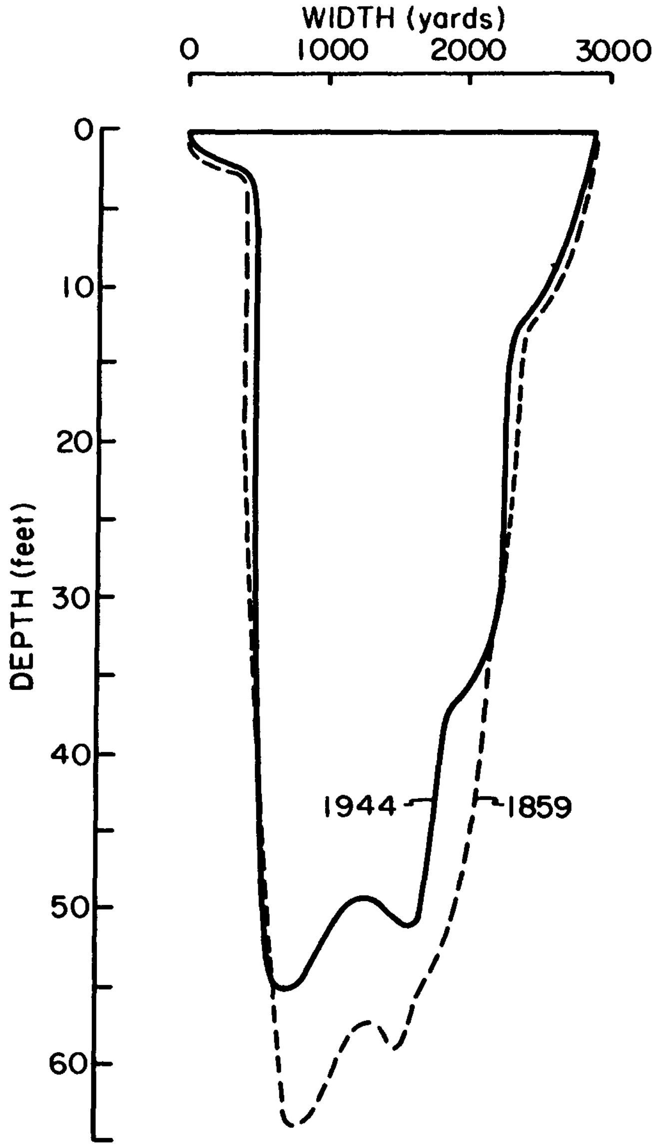

FIGURE 3. SEDIMENTATION IN THE PATUXENT ESTUARY. (AFTER JOHNS HOPKINS UNIVERSITY, 1966)

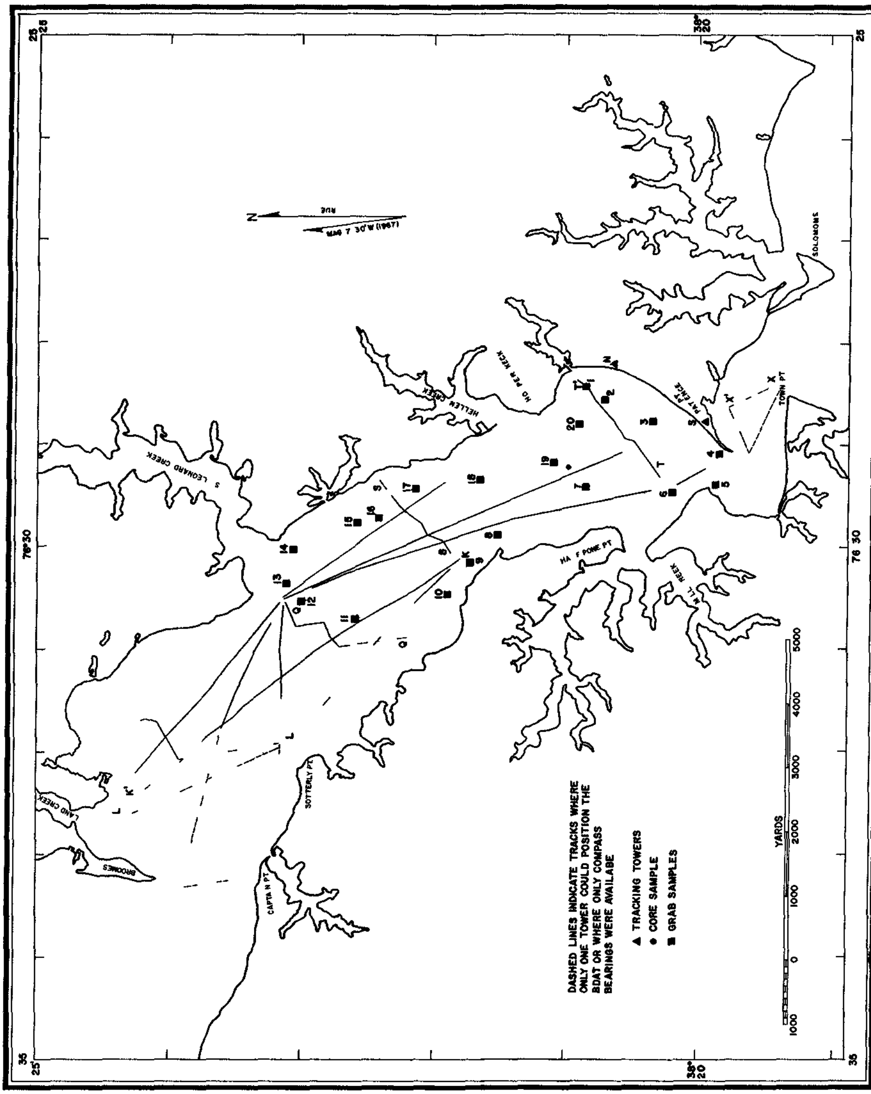

FIGURE 4 LOCATION OF BOAT TRACKS AND SEDIMENT SAMPLES

bottom, and subbottom The vertical scale is in time (milliseconds) and the horizontal scale is a function of recorder-paper speed and ship speed The time values shown on the seismic records are total travel times (two-way times) and must be halved for computing thickness Conversion of the time scale to thickness is accomplished by multiplying one-half the total travel time by a sound speed factor All depths in this report are based on a sound speed of 1500 meters per second in both the water and sediment. This value corresponds closely with measured values on two core samples obtained near the mouth of the Patuxent Estuary (Stiles and Wiesnet, 1970).

Analysis of the seismic profiles in this investigation is based on the following premise. Observed subsurface geologic features on the seismic record are acceptable as proof of existence of subbottom structure However, the converse of this statement is not necessarily true The absence of subbottom structure on the seismic record does not always mean that a subbottom reflector does not exist The absence may indicate masking by a cover of sand, gravel, or other coarse-grained material For a given frequency, mud is normally much less attenuating than sand or coarser grain sediments In most cases where a mud cover overlies a coarser grain sediment mass, the impedance contrast will be sufficient to record the thickness of the mud Exceptions may exist where the thickness of the surface cover is too great for the acoustic energy of the particular seismic system to penetrate and return to the sensor

Development of an isopachous map from seismic profile records requires identification of a particular reflecting horizon which corresponds to a designated stratigraphic unit, transferring the thickness values (e g , in this paper, the distance between the first subbottom layer and the water-sediment interface) on to a track chart, and contouring these values

DISCUSSION OF RESULTS

Results of this investigation are presented in the form of annotated seismic profiles and an isopachous map Interpretation of the seismic records was based in part on previous work with this system Earlier studies by Breslau and Edgerton (1968) in the Gulf of La Spezia, and by Stiles and others (1969) in four Vietnamese rivers have shown that the acoustic energy of this system is not capable of penetrating coarse-grained sediments, such as sands or gravels, whereas, fine-grained materials, such as silts and clays, are transparent to the 12-kHz sounds of the system After completion of the isopachous map, 20 sediment samples were collected Comparison between the sediment properties from these bottom samples which were collected simultaneously with seismic profiles corroborates the interpretation of seismic profiles in this investigation (Figure 5 and Table I)

The stratigraphic unit used in this study is the acoustically transparent sediment cover. This sediment cover is composed mainly of fine-grained silt- and clay-size sediments,

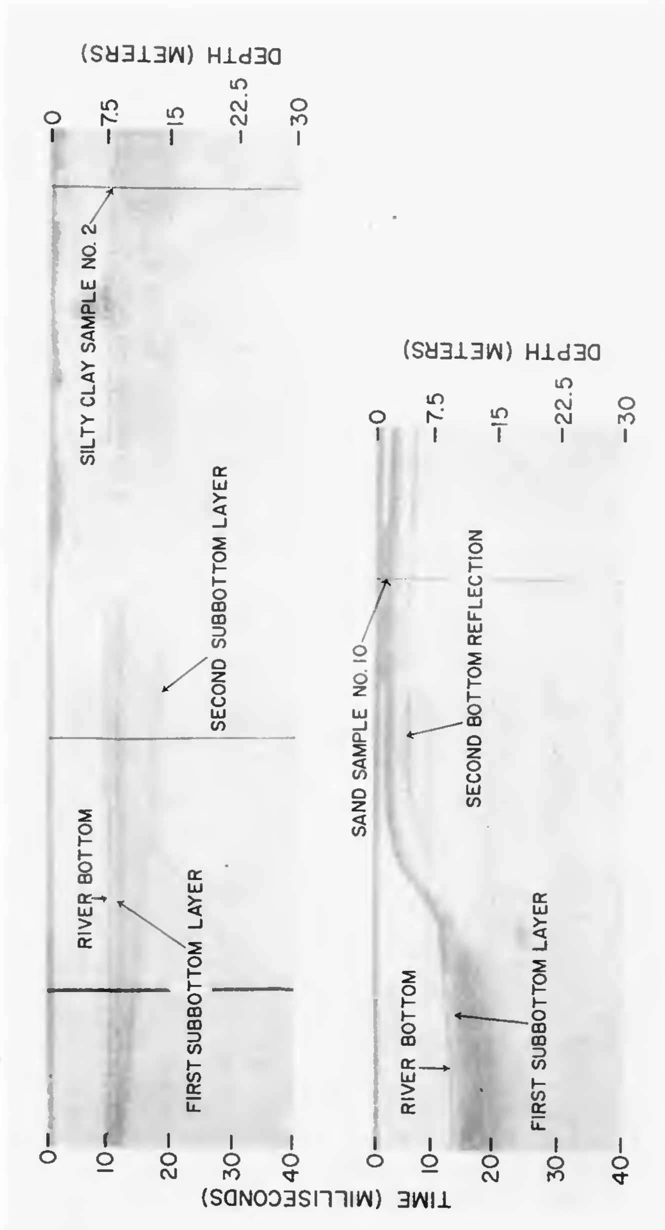

FIGURE 5. COMPARISON BETWEEN SEDIMENT TYPE AND ACOUSTIC PENETRATION.

TABLE I

SEDIMENT PROPERTIES AND ACOUSTIC PENETRATION

SAMPLE NO	COARSE FRACTION >0 0625 mm %	FINE FRACTION <0 0625 mm %	MEAN DIAMETER mm	WET UNIT WEIGHT g/cm³	WATER CONTENT % dry wt	SEDIMENT TYPE	ACOUSTIC PENETRATION m
1	43	57	0 012	1 23	161	sand and clay	1
2	11	89	0 003	1 14	224	silty clay	2-7
3	12	88	0 004	1 25	172	silty clay	2
4	88	12	0 094	1 65	74	sand	0
5	– NO ANALYSIS –					shells	0
6	98	2	0 242	1 72	34	sand	0
7	70	30	0 914	1 19	194	clay and shells	3
8	10	90	0 003	1 15	231	silty clay	1
9	21	79	0 006	1 13	245	silty clay	1
10	99	1	0 236	1 59	33	sand	0
11	21	79	0 005		233	silty clay	1
12	– NO ANALYSIS –					shells	0
13	42	58	0 014	1 25	178	sand and clay	6
14	95	5	0 168	1 74	34	sand	0
15	90	10	0 119	1 61	45	sand	0
16	83	17	0 098	1 53	49	sand	0
17	51	49	0 109	1 16	216	clay and shells	4
18	– NO ANALYSIS –					shells	0
19	95	5	0 179	1 78	45	sand	0
20	24	76	0 006	1 19	200	silty clay	2

collectively referred to as mud The reflecting horizon used in all cases is the first subbottom layer Where penetration does not occur, the surface materials consist of coarse-grain sediments Both the opaque surface and subsurface reflectors are assumed to consist of similar sediments Selected longitudinal and transverse profiles are shown in Figures 6 through 9 Location of these seismic profiles are shown in Figure 4 The isopachous map is shown in Figure 10

Analysis of the seismic records shows numerous objects partially submerged on the river bottom The largest object is shown protruding from the bottom near the southern end of Profile L - L' (Figure 6), which is believed to be either a part of the mooring buoy plotted on U S Coast and Geodetic Survey Chart No 553 or a sunken barge (James Green, Naval Ordnance Laboratory Test Facility, Solomons, Maryland, oral communication) Green indicated that in addition to the barge there are many metallic objects scattered on the river bottom Some of these artifacts are probably the same objects observed on the seismic records (Figures 7 and 9) In addition to the objects lying on the river bottom, many reflections presumably caused by fish were recorded in the water column (Figure 9)

Subbottom layers are present in a majority of the seismic profiles north of Half Pone Point (Figure 10) Depressions filled with mud are as much as 16 feet thick One of the clearest records of subbottom structure is shown on Profile K - K' northwest of the "Black Hill" structure (Figure 7) We assume that the subbottom reflecting layer is mainly composed of quartz sands or oyster shells (Table I) The same reflecting horizon forms a terrace further northwest along Profile K - K' (Figure 7) Similar terrace-shaped structures are present on the northeastern margin of Profiles Q - Q' and S - S' (Figure 8) A terrace consists of two parts, the inclined portion is called the scarp and the flat lying part is called the tread In this paper, the term terrace is used even if only the scarp portion of the terrace is observed on the seismic record Indications of terraces are seen on these bottom profiles and clearly show that they are composed of highly reflecting materials (i e , sands or shells) with enough coherency to maintain slightly inclined slopes The vertical exaggeration between the profile record and the true slope angle should be realized The angle of the scarp shown in Profile Q - Q' is approximately 10 to 12 degrees A submerged terrace is visible on the northeastern edge of Profile T - T' (Figure 9) The stairlike terrace is traced on the record as a second subbottom layer, and is clearly an abandoned feature not related to the present river channel Maximum penetration at the deepest portion of the lower scarp is approximately 36 feet beneath the water-sediment interface It is assumed that the first subbottom layer has a higher concentration of fine-grained sediments than those reflecting horizons previously discussed, and thus is partially transparent to the acoustic energy of the system

The feature labeled on Profile K - K' as a "Black Hill" was viewed on several seismic records over this area The areal extent and shape

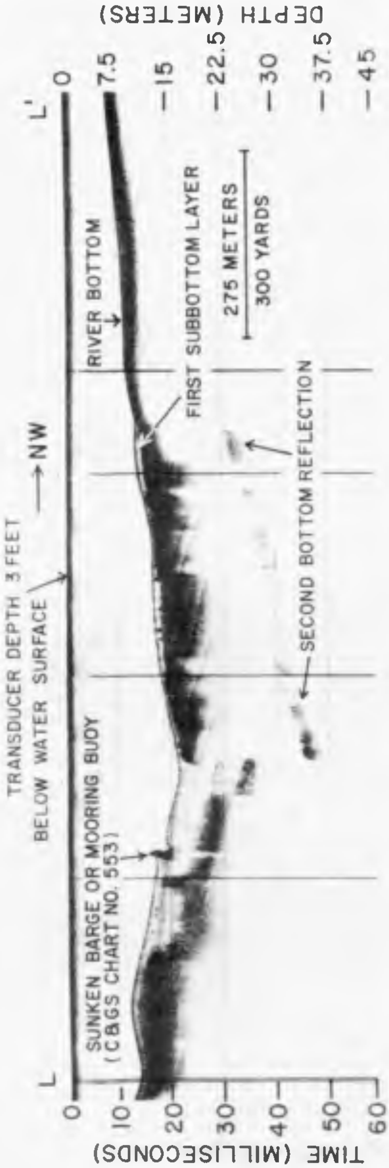

FIGURE 6. SEISMIC PROFILE OF LOWER PATUXENT ESTUARY (L - L').

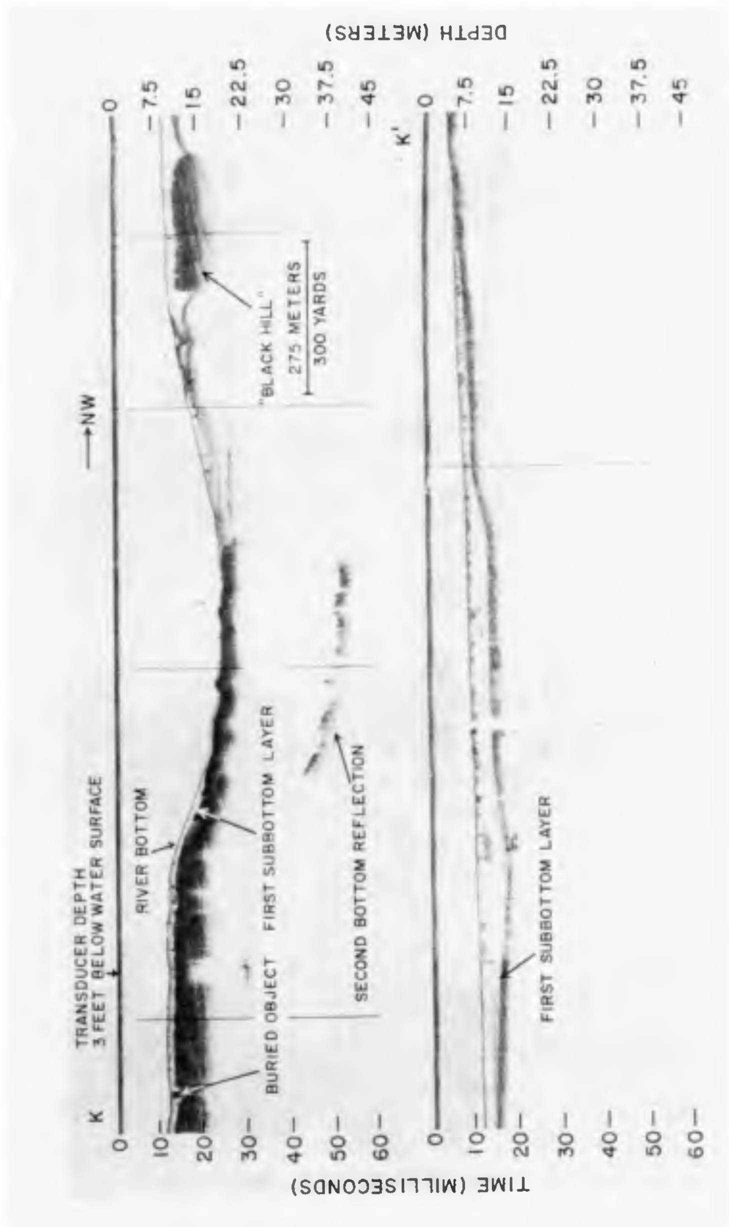

FIGURE 7. SEISMIC PROFILE OF LOWER PATUXENT ESTUARY (K - K').

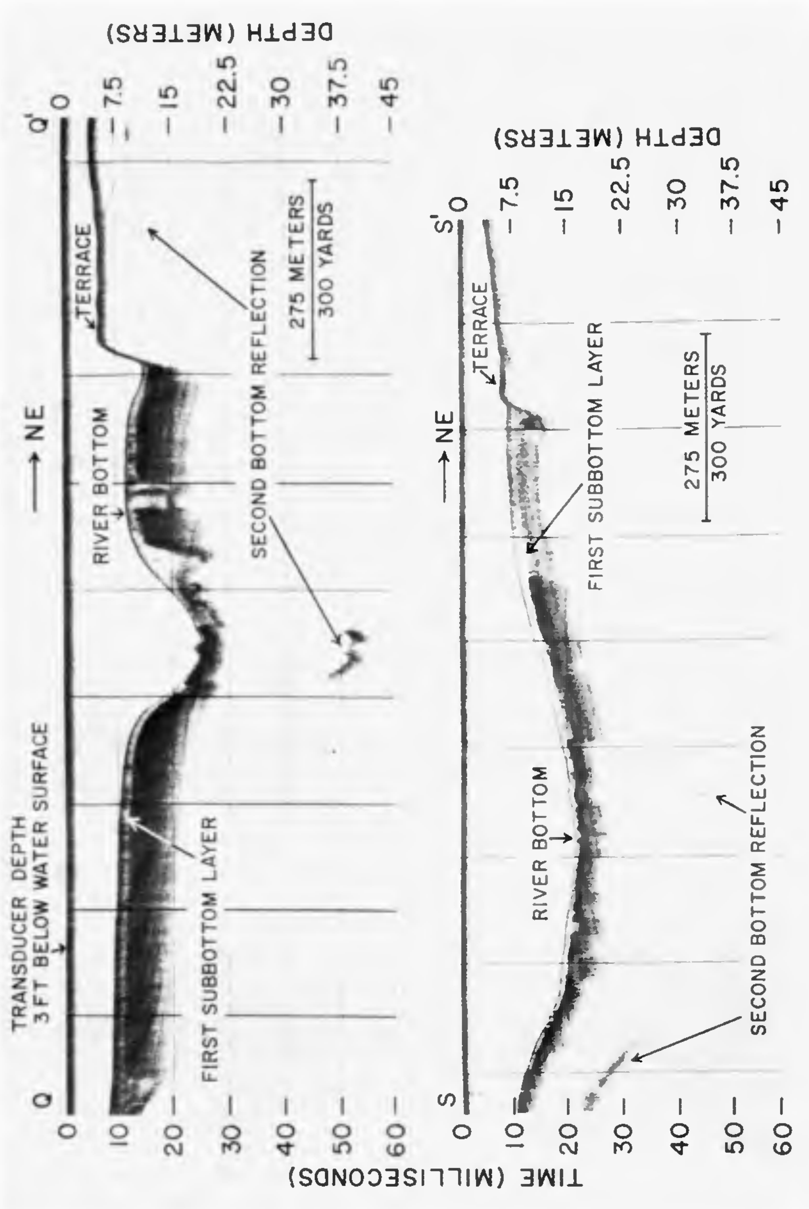

FIGURE 8. SEISMIC PROFILES OF LOWER PATUXENT ESTUARY (Q - Q' AND S - S').

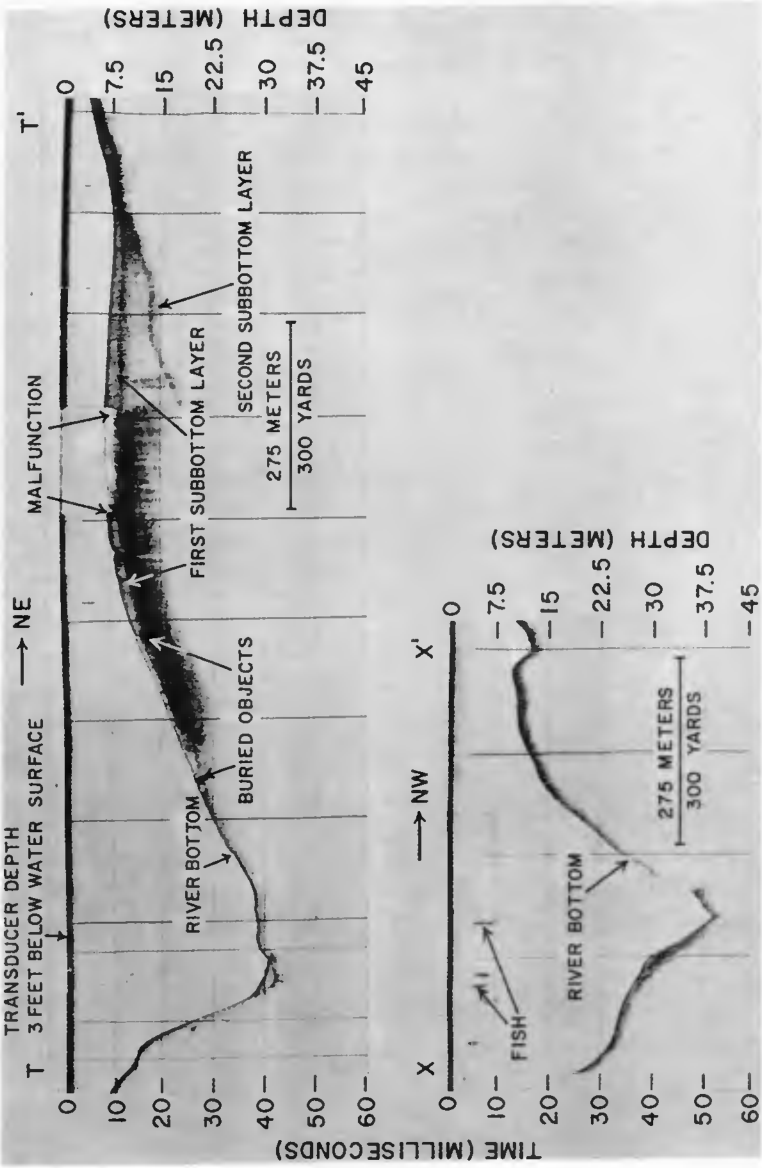

FIGURE 9. SEISMIC PROFILES OF LOWER PATUXENT ESTUARY (T - T' AND X - X').

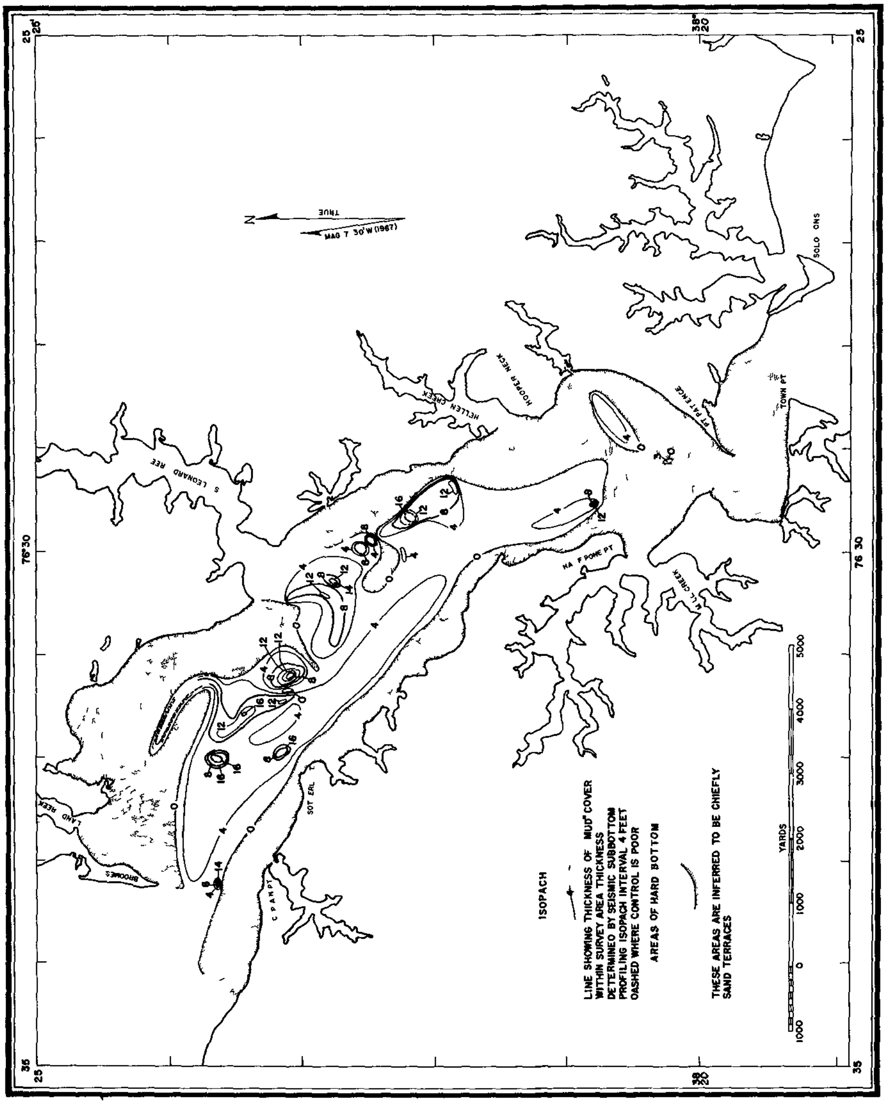

FIGURE 10 ISOPACHOUS MAP OF LOWER PATUXENT ESTUARY

of this structure is shown on the isopachous map (Figure 10) The structure is almost circular and lies directly northwest of the crescent-shaped mud hole at the mouth of St Leonard Creek The two almost circular 16-foot mud holes between Sotterly Point and Island Creek also closely resemble in profile and plan view this "Black Hill" structure Although the cause or nature of these structures is not known, it is believed that they may be oyster beds that have been covered during a period of prolonged sedimentation

CONCLUDING REMARKS

The work performed for this investigation demonstrates the stratigraphic variability of the surficial mud cover in the lower Patuxent River Estuary The thickness and extent of the mud cover is based on the occurrence of acoustic discontinuities seen on the seismic record These discontinuities occur only in areas where fine-grained materials, which are transparent to the 12-kHz sound, overlie coarse-grained sediments Where penetration does not occur, the surface materials are coarse grained Both the opaque surface and subsurface reflectors are assumed to consist of similar materials

Depressions filled with mud occur mainly to the north of Half Pone Point (Figure 10) The thickest mud layers lie to the east of the present channel These mud-filled depressions are as much as 16 feet thick The dominance of the deeper holes to the east plus the occurrence of a submerged terrace indicates that either the channel of the Patuxent River at this location was much larger in the past and has subsequently filled in much of the material on the eastern edge, or that the channel has migrated to the west

The presence of terraces on the edges of the channel was used as evidence for plotting the areas of hard bottom on the peripheral edges of the river (Figure 10) Although it was not possible to profile to the shoreline because the water was too shallow, it is safe to conclude that the materials which comprise the terraces extend also to the shoreline

The majority of the sediments below Half Pone Point allowed little acoustic penetration (Figure 10) The presence of coarse-grained sediments is supported in part by divers from the Naval Ordnance Laboratory Test Facility These divers have indicated that the eliptical mud hole north of Point Patience, as shown in Figure 10, extends northward and is a part of the large deposit of mud shown in the center of the river channel These divers also have indicated that small mud holes lie slightly north of Town Point

Recommendations for future study regarding the stratigraphic variability of the surficial mud cover are directed toward two potential problem areas More work is needed in defining the sediment properties responsible for acoustic reflections in the study area Secondly, little is known of the riverine and estuarine dynamics causing the distribution of sediments Owen (1969) states that "a distinguishing feature of the Patuxent Estuary is its intermittent transition from a two-layer flow system to a three-layer flow system, a transition which occurs most often in the month of April " On the basis of this concept of a two-layer flow system, i e , a net bayward (or seaward) flow of less saline (lighter) water at the surface and a net landward flow of more saline (heavier) water near the bottom, Meade (1969) has presented evidence that bottom sediments in Atlantic Coastal Plain estuaries are transported landward Some questions that remain to be answered are In the various flow layers is there some process going on differentiating sediment types? Of the materials brought down by the river, how much and what type of material is trapped in the estuary? What is the spatial distribution and temporal variation of this flow system which may control the distribution of sediments?

This study demonstrates the use of seismic profiling techniques for collecting and presenting data required for coastal engineering applications Other possible coastal engineering applications for this type of work are (1) determining the thickness of a particular stratum for estimating dredging or excavation costs as well as for obtaining construction materials, (2) foundation studies, (3) harbor mapping, (4) slope stability studies, (5) spoil location, and (6) location of tunnels and pipelines

ACKNOWLEDGEMENTS

We would like to express our special thanks to Dr Lloyd Breslau, former Head of the Coastal Oceanography Branch, U S Naval Oceanographic Office, now with the U S Coast Guard, whose guidance and valued advice during the field phase of this investigation are deeply appreciated His helpful comments and review of the manuscript are gratefully acknowledged

Appreciation is expressed to Dr Jerry Schubel of the Chesapeake Bay Institute, The Johns Hopkins University, Mr Leo Fisher of the U S Naval Oceanographic Office, and Mr Ralph Hightower and Mr Arne Yensen of the U S Naval Ordnance Laboratory for their suggestions and review of this manuscript

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