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Geological and benthic evaluation of sand resources in the lower Chesapeake Bay, Report 2, Tail of the Horseshoe : Final Report v.1

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GEOLOGICAL AND BENTHIC EVALUATION OF SAND RESOURCES IN THE LOWER CHESAPEAKE BAY

REPORT 2: TAIL OF THE HORSESHOE

Final Report

to the
Council on the Environment
Virginia Coastal Resources Management Program

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INTRODUCTION

This is the second of two reports concerning the resources of sand in the lower portions of Chesapeake Bay. The first, Geotechnical and Benthic Evaluation of Sand Resources in the Lower Chesapeake Bay (Kimball and others, 1989), presents a study of the resources in Thimble Shoal. The present work is a study of the area known as Tail of the Horseshoe which is just east of Thimble Shoal (Figure 1). The deposits of sand described in this report will be of most interest to the communities of Norfolk and Virginia Beach.

In the late 1970's, the General Assembly of the Commonwealth of Virginia created the Coastal Erosion Abatement Commission which, in its 1979 report, stated, "there is a need to locate sources of sand supplies for rebuilding public beaches." In response to the Commission's recommendations the General Assembly provided funds for a general inventory of sand resources in the lower portion of Chesapeake Bay. This inventory (Hobbs and others, 1982b) is the starting point for the present works.

The need for sand with characteristics suitable for beach nourishment is persistent. Additionally, there is a general concern in some quarters that the area's terrestrial reserves of construction aggregate might become prohibitively expensive within a decade or so. Thus there likely will be an increasing interest in offshore reserves of sand and gravel.

The present study was performed to update and expand the 1982 work. It reports the results of an exploration program to describe the deposits of beach-quality sand in the study area that would be available to the cities of Norfolk and Virginia Beach. Because the areas of the deposits are large and the volumes great, this study is not a "final," or "dredging design" document. Rather it presents the information that should be able to guide a very detailed, site specific engineering study. This report follows the general form of the Thimble Shoal report (Kimball and others, 1989) in providing both geotechnical and benthic resource evaluations of the area. Additionally there are a brief study of the changes in wave energy across the area that could follow dredging of large quantities of sand and a listing of much of the data that went into the study.

The project has been performed for the Commonwealth of Virginia, Council on the Environment, Virginia Coastal Resources Management Program, Contract NA88AA-D-CZ091.

The work could not have been accomplished without the assistance of L. D. Ward and S. H. George, Captain and crew of the R/V Bay Eagle. R. A. Gammisch, C. S. Hardaway, P. V. Gapcynski, C. T. Fischler, J. K. Dame, and S. L. Leyland provided great assistance in various capacities. L. T. Marshall and C. D. Gaskins prepared the manuscript for publication. R. J. Byrne and L. D. Wright reviewed a draft of the report. The work benefited from the assistance of S. M. Kimball. We thank each and all of them.

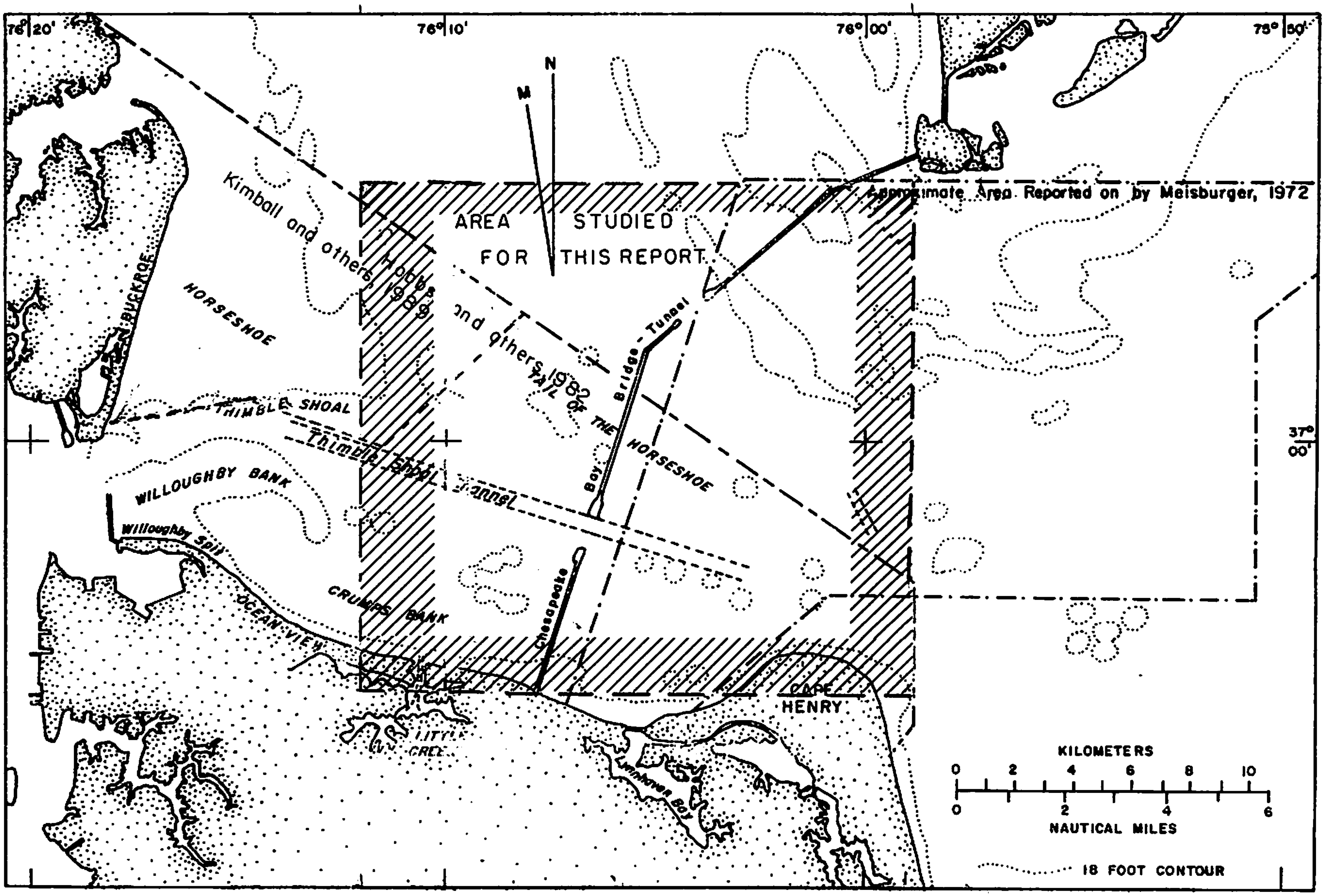


Figure 1: General location map of the lower Chesapeake Bay, Tail of the Horseshoe study area.

PART I: GEOTECHNICAL INVESTIGATION OF SAND RESOURCES

SEDIMENT STUDIES

Introduction

The Cities of Virginia Beach and Norfolk have a need for quantities of beach-quality sand to rebuild, maintain, and enhance their public beaches. As long as the cities place utilization and development of the beaches and waterfront as priorities, and the economics of the tourism and recreation industries suggest that maintenance of the waterfront will remain a high priority, this need will continue.

Although sand sometimes is available from state and federal projects to dredge or otherwise maintain the area's navigation channels, the geotechnical properties of the sediments, the timing, and the logistics of the projects do not always mate with the site and time specific needs of the cities. Therefore it is necessary to develop additional sources of beach-quality material that could be available when and as needed. Additionally, should a private or commercial demand for marine sand for construction aggregate unfold, it would be beneficial to the localities to have previously identified sources of specific deposits.

The area of this study (Figure 1) is the the 353 square kilometer (103 square nautical mile) region bounded on the south and north by 36°55′ and 37°05′ north latitude and on the east and west by 75°59′ and 76°12′ west longitude. The Chesapeake Bay Bridge and Tunnel crosses the area from northeast to southwest. The bay's two deep access channels, Thimble Shoal Channel and Chesapeake Channel, which is the outermost portion of the York Spit Channel, traverse the area.

The objectives of the geotechnical phase of the project include

1. Identification and description of offshore areas that might serve as sources of beach-quality sand,

2. Description of the sediments within those areas,

3. Comparison of the sediments with the sediments already on the beach, and

4. Estimation of the vertical and areal extent of the possible reserves.

The integration of this material with the evaluation of the area's benthic resources, Part II of the report, will allow recommendations as to which areas are most or least appropriate for use as sources of sediment. The technical information presented herein will form the basis on which a specific proposal and plan for dredging sand for beach nourishment might be prepared.

Previous Work

Discounting bathymetric surveys, whether for existing conditions or for pre-dredging studies, the earliest geological work in the bay mouth region that is applicable to the project at hand is the coring that was done for the Chesapeake Bay Bridge and Tunnel (Moran, Proctor, Mueser & Rutledge, 1960). A map depicting the locations of these cores is included in the Appendices. Their data and cross section, especially as redrawn by Berquist (1986) (Figure 2), provide a good summary of the general geology of the region.

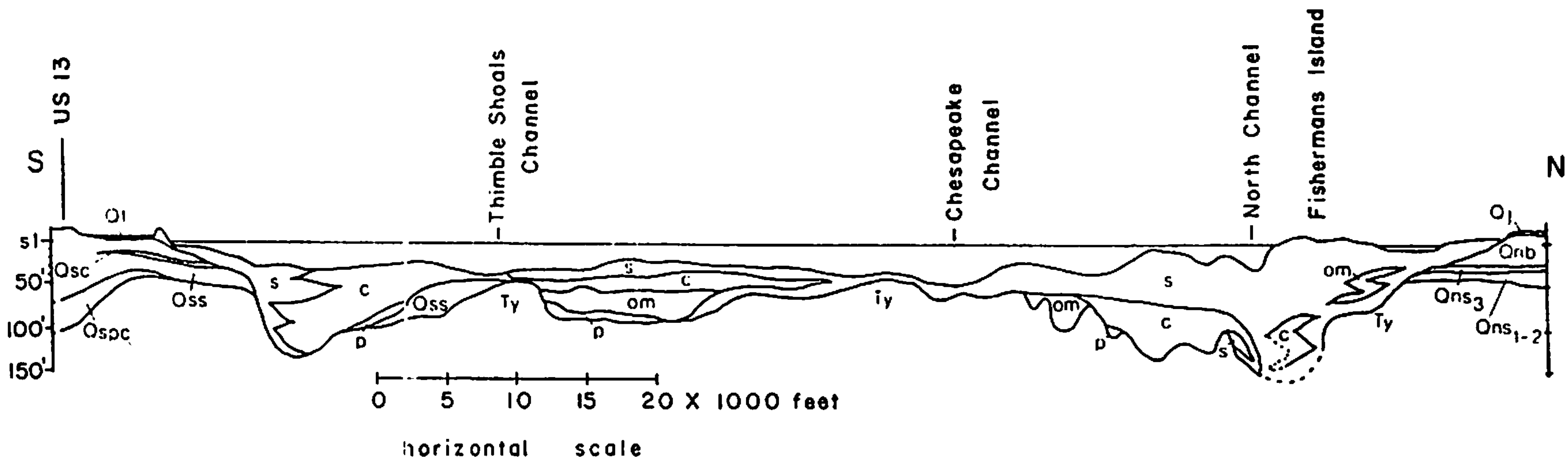
A significant quantity of relevant data also can be found in various unpublished and published documents and project reports. Meisburger (1972), as part of the U.S. Army Corps of Engineers, Coastal Engineering Research Center's Inner Continental Shelf Sediment and Structure (ICONS) Study, presented a study of the outer portion of the entrance to Chesapeake Bay (see Figure 1). In this report, Meisburger described a deposit of "economically recoverable material" at the seaward end of the Thimble Shoal Channel. Hobbs and others (1982b) provided additional information on this same deposit. A figure showing the location of the cores used by Meisburger, tables summarizing data on the sediments, and descriptive logs of the cores are in the Appendices.

Ludwick (1970, 1975, 1981; Granat and Ludwick, 1980; Perillo and Ludwick, 1984) have presented several studies on the interactions of the surficial sediments and the currents in the lower bay.

The Virginia Department of Transportation (VDOT) and its predecessor, the Virginia Department of Highways and Transportation, have been responsible for the acquisition of several sets of data from the vicinity of the present study area. These works were concerned with locating deposits of sediment with engineering characteristics suitable for use either as overburden or as base material for man made islands associated with the construction of bridges and tunnels in Hampton Roads. The locations, descriptive logs, and sediment analyses for a series of the Department's cores are included in the Appendices.

The Norfolk District of the U.S. Army Corps of Engineers has a long history of work in the southern portion of Chesapeake Bay. Much of this work has been in conjunction with studies for channel dredging (U.S. Army Corps of Engineers, Norfolk District, 1972, 1985; Bowen and Swean, 1985) and beach nourishment or hurricane protection projects (U.S. Army Corps of Engineers, Norfolk District, 1980, 1982). Additionally, the Corps has sponsored other work (Williams, 1987) that has provided valuable information about the area. The nature of the Corps's work is such that it is unending and it continues to provide new data on the sediments of the lower bay.

Following the Commonwealth of Virginia's stated interest in the sand resources of the lower bay (Coastal Erosion Abatement Commission, 1979, Hobbs and others, 1982b), the U.S. Fish and Wildlife Service



EXPLANATION

c	Holocene clays
s	Holocene sands
om	Holocene organic mud
p	Holocene peat
Ql	Lynnhaven Formation: sandy mud
Qs	Sedgefield Formation: Qsc- silty clay; Qss- sand; Qspc- peat and organic clay
Qj	Joynes Neck Formation: sand and mud
Qnb	Nassawadox Fm., Butler's Bluff Mbr.: sands
Qns	Nassawadox Formation, Stumptown Member: Qns_1- coarse sand; Qns_2- peat and sand; Qns_3- clayey silt
Ty	Yorktown Formation: shelly muddy fine sand; may include Chowan River and Eastover formations

Figure 2: Cross-section along the Chesapeake Bay Bridge and Tunnel (from Berquist, 1986).

(Mayne and others, 1982) offered a review of the factors impacting the benthic resources of the area should there be a substantial dredging effort and made several recommendations concerning possible actions to minimize the adverse consequences. Important among their conclusions are recommendations that final design studies "should evaluate the impacts of removal of sand on the hydrodynamics and sedimentation and erosion patterns of the shoals and nearby shorelines. These studies should also compare different methods of constructing borrow areas to determine which method would have the least effect from both biological and physical processes." They also recommended that long-term monitoring projects are necessary to evaluate the consequences of dredging on the area's fisheries.

The Virginia Institute of Marine Science has performed several studies in the lower bay. Of direct bearing to this study is a baywide study of surficial sediments (Byrne and others, 1982; Hobbs and others, 1982a). Figure 3, which depicts the weight percent sand of the present study area's surface sediments, was prepared with data from Byrne and others (1982). Although their work demonstrated that there is considerably more sand in Chesapeake Bay than earlier had been thought, much of the sand is too fine grained to be of use for beach nourishment. Hobbs and others (1982b) and Kimball and others (1989) have directly addressed the sand resources. Although covering an area larger than that of the present study, Hobbs and others (1982b) concluded that the area at the eastern end of the Thimble Shoal Channel contained approximately 18 million cubic yards (14 million cubic meters) of suitable sand. As noted above, this was a confirmation of Meisburger's (1972) work. Two other areas, Crumps Bank near shore adjacent to the landing of the Chesapeake Bay Bridge and Tunnel and a zone just offshore of Cape Henry, contained quantities of usable sand but were not suitable for dredging. Kimball and others (1989), studying an area immediately west of the area of the present study, confirmed the work of Hobbs and others (1982b) that portions of the Thimble Shoal area contain substantial quantities of usable sand.

Berquist's (1986) study, Calliari and others (in press), and Ozalpasan (1989) provide further information on the pathways of sediment movement in the area. Hobbs and others (1986), Colman and Hobbs (1987), Colman and others (1988), and Hobbs and others (in press) address the geological history of the bay mouth region. These studies tend to document a net transport of sediment into the bay from the inner shelf. Calliari and others (in press) suggest that there is some seaward transport of sediment, especially along the southern shore of the bay mouth.

Methods

We performed a joint sub-bottom profile and side-scan sonar survey within the study area (Figure 4). The sub-bottom profiles were obtained with a Datasonics SBP 5000 system which operates at 12 kilowatts producing a 3.5, 5.0 or 7.0 kHz acoustic signal. (The use of brand names is for descriptive purposes and does not imply endorsement

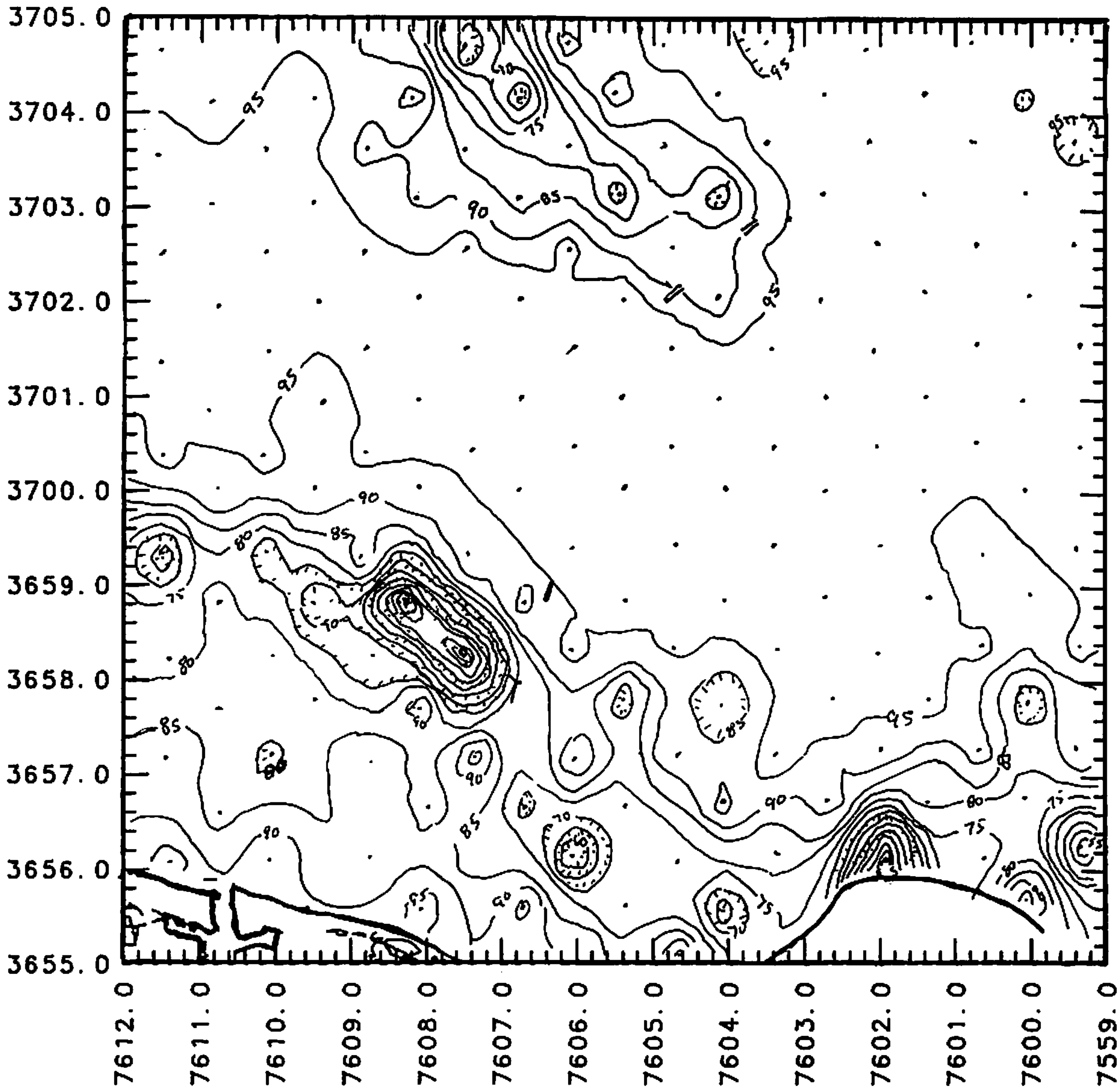


Figure 3: Weight percent sand of the surface sediments. (Data from Byrne and others, 1982)

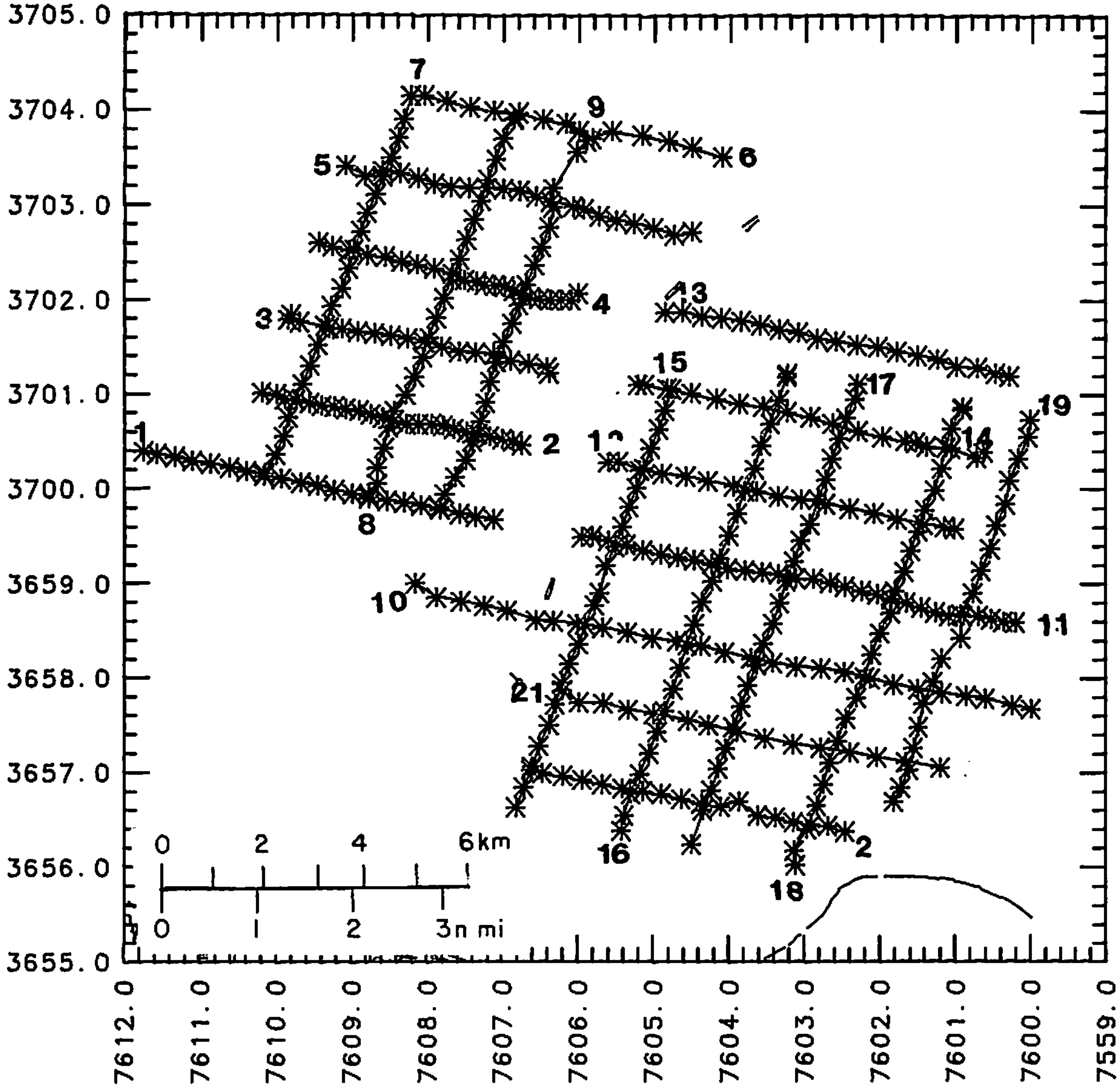


Figure 4: Map depicting the locations of the sub-bottom profiles obtained during the course of this work.

of the product.) This downward-directed signal penetrates the bottom but is partially reflected by various sections of the sub-bottom sediment. The reflected signals are received by the instrument and presented on an EPC graphics plotter. The plots give a very good indication of the continuity and interrelationships of the various sediment layers, strata, immediately beneath the bottom. Unfortunately these data present no information about the nature of the sediments within the layers or about lateral changes within an individual layer.

The side-scan sonar survey used a 105 kHz EG&G SMS-960 system which produces an image, or sonograph, depicting the character of the bottom surface along a track 200 meters wide, 100 meters each side of the centerline. The information obtainable from the sonograph includes the position of artifacts such as ship wrecks or debris and the size and orientation of surficial sedimentary features such as sand waves. The intensity of the image provides an indication of the general type of sediment, hard or soft, in the area covered by the sonograph. As the tracklines run for the survey were more than 200 meters apart, the side-scan survey did not provide total coverage of the bottom.

The side-scan sonar and sub-bottom profiler were operated simultaneously. Loran-C was used for navigational control during the course of the surveys.

Figure 5 is a map depicting the locations of the many cores that have been taken within the study area. The appendices to this report contain detailed information including specific locations, logs, and sample analyses on individual cores by project.

Sediment samples collected for the project were sieved to remove the gravel and wet sieved to remove the silt and clay portions of the sample. The gravels, if any, were weighed. The silts and clays were analyzed by conventional pipette methods to determine the weights of the silt and the clay. The sands were subjected to grain-size analysis in a Rapid Sediment Analyzer (settling tube). This technique, which is based on the hydraulic equivalent size of the particles, is preferable to mechanical sieving as it is more representative of the transport characteristics of the material.

Using the methods discussed in Kimball and others (1989), it was determined that the characteristics of the sands sought in this project would be a mean grain size of 0.25 to 0.35 mm (1.5 to 2.0 phi), poor sorting (sorting coefficient between 1 and 2 phi, that is a mix of sediment sizes), and not over 5 percent fines. Sediments with this set of characteristics would serve well because they have acceptable overfill ratios if used to nourish the beaches of Virginia Beach and Norfolk.

The overfill ratio is one measure of the suitability of a particular sediment type for use as beach nourishment on a specific beach. The overfill factor, developed by James (1975), enjoys wide use by the U.S. Army Corps of Engineers. The assumption behind the

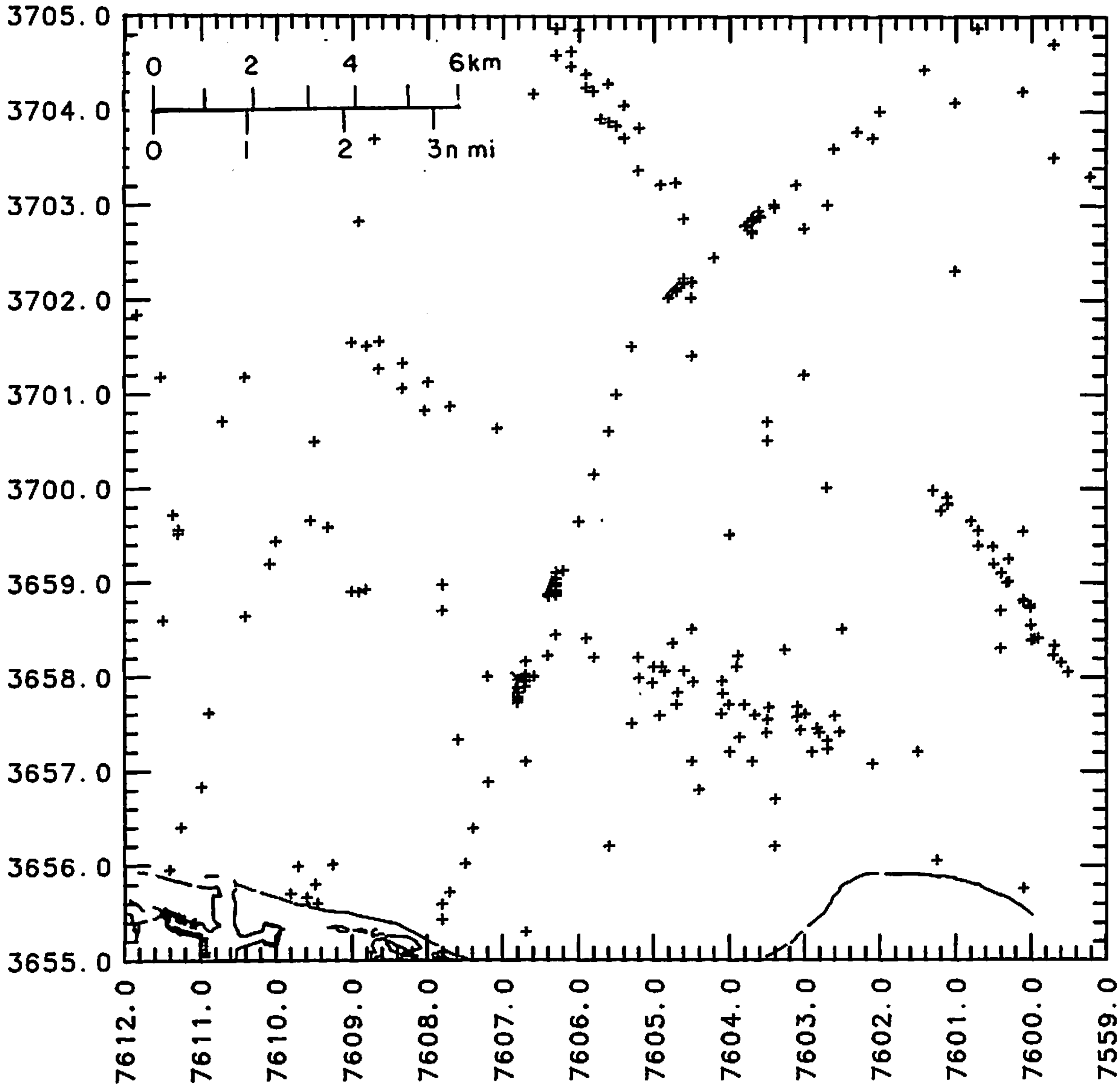


Figure 5: Map depicting the locations of cores from various projects within the study area.

overfill factor is that the distribuion of grain sizes on a stable beach is representative of a dynamic equilbrium between the supply of material to the beach and the rate of transport that removes it (U.S. Army Corps of Engineers, 1984). Thus, sediments that have grain size characteristics similar to those of the native material would be the most suitable for use in nourishment projects. The overfill ratio provides an indication of how much of the nourishment material should be lost initially to the transport processes and thus how much sediment should be placed in order to obtain the desired results after the nourished system has had time to adjust to the ambient energy regime.

Results

The side-scan sonography (Figure 6) generally is unremarkable. There are two areas that display what might be drag marks from anchors or commercial fishing gear and several areas of sand waves. There are no indications of ship wrecks; nor is there any suggestion from the sonographs that the bottom is being used in a manner that would preclude sand mining. The largest sand waves, as expected, are associated with the flanks of the channels. The original side-scan sonographs are on file at the Division of Geological and Benthic Oceanography, Virginia Institute of Marine Science, College of William and Mary.

The sub-bottom profiles (Figures 7, 8, 9, and 10) generally indicate a surficial layer that is 1 to 4 meters (3 to 12 feet) thick. It is this layer, especially in the region surrounding the outer portions of the Thimble Shoal Channel, that offers the greatest promise as source. The original seismic-profiles are filed with the sonographs as above.

Lines 10 and 16 (Figures 9 and 10) pass near the sites of several cores. The location of these cores and a brief description of the sediments are presented along with the seismic interpretations in the figures. Although there often is very good correlation between the acoustic profiles and the lithologies as seen in the cores, it, nevertheless, is difficult to trace specific strata. The local "acoustic basement," probably the Pliocene Yorktown Formation (Colman and Hobbs, 1987), appears to be a fine grained sediment, silt or clay, that often contains shelly material. The Quaternary, Pleistocene and Holocene or recent, units are more varied. Many of these strata contain "fining upward sequences" (Peebles, 1984), that is, the grain sizes decrease from coarse to fine as one goes upward. Since the Pleistocene units may have been eroded during low stands of sea level, and as there are lateral changes in sediment texture, facies changes, it is reasonable to expect significant changes in sediment type within an acoustic unit.

Figures 11 and 12 depict the thickness of the usable sand and the thickness of the overburden as seen in the cores. Usable sand is that sediment meeting the mean grain size and sorting characteristics described above except that, in some instances, a slightly coarser

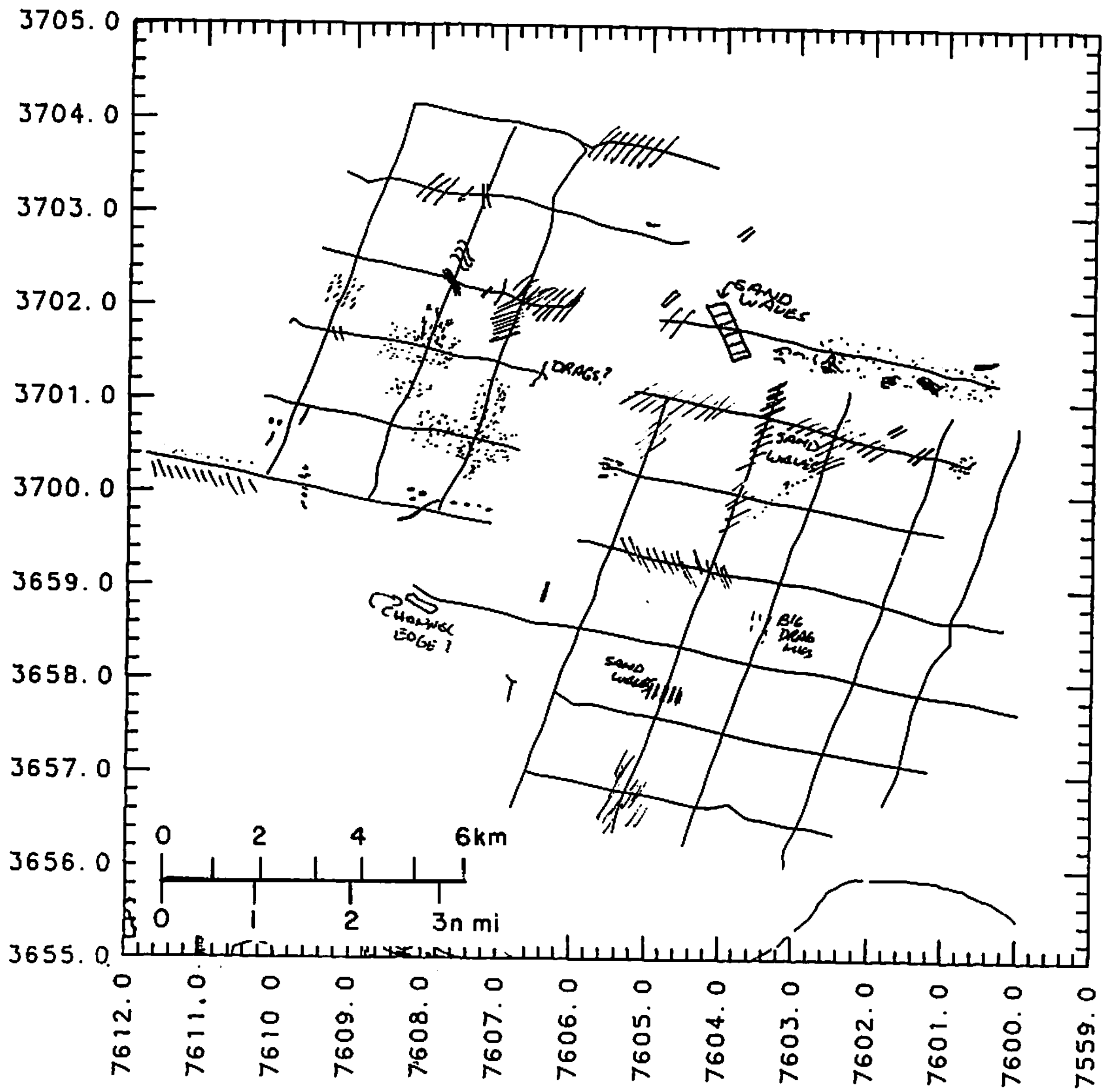


Figure 6: Interpretative sketch of the side-scan sonography.

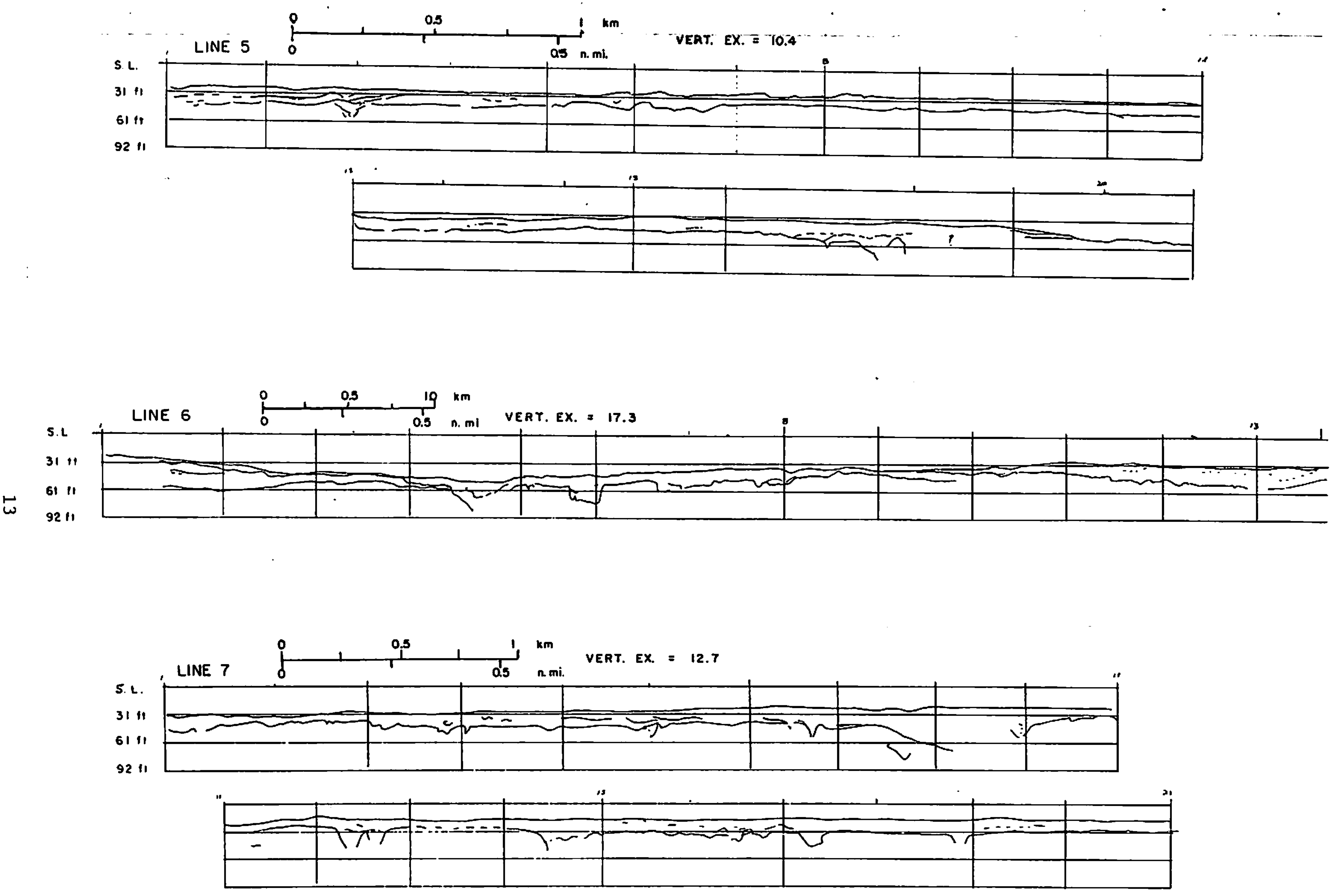


Figure 7: Interpretations of sub-bottom profile lines 5, 6, and 7.

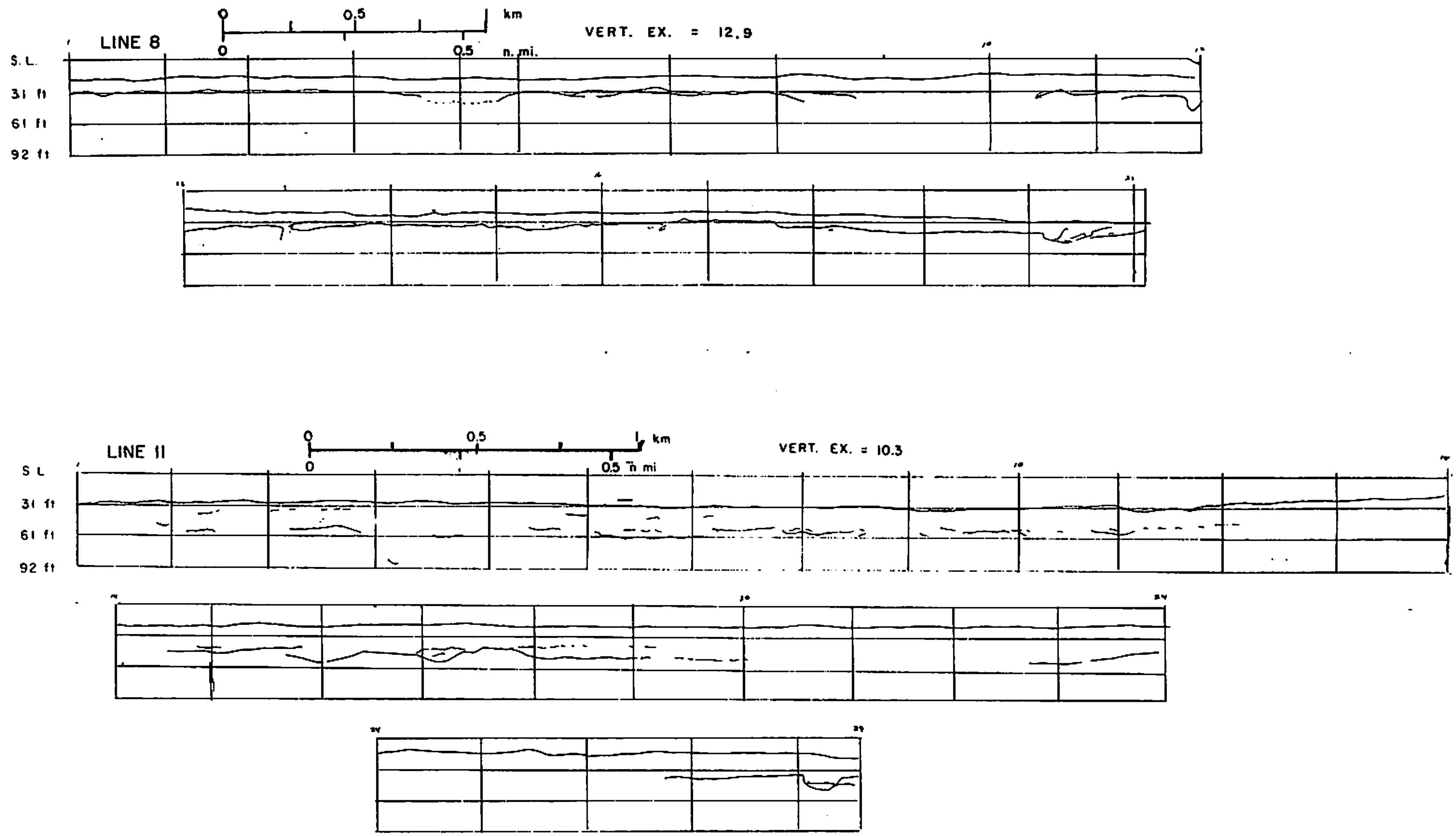


Figure 8: Interpretations of sub-bottom profile lines 8 and 11.

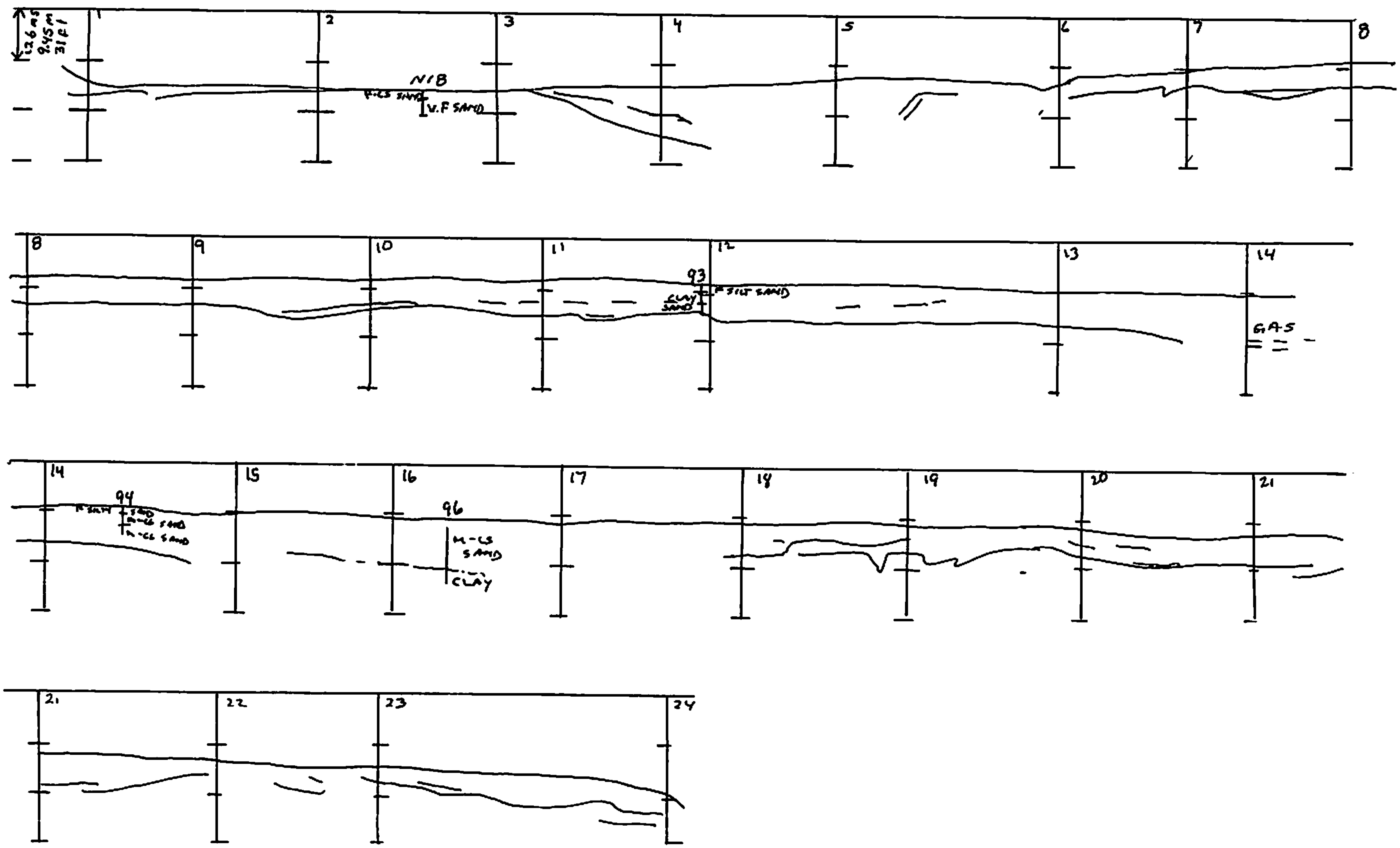


Figure 9: Interpretation of sub-bottom profile line 10 including locations and descriptions of associated cores.

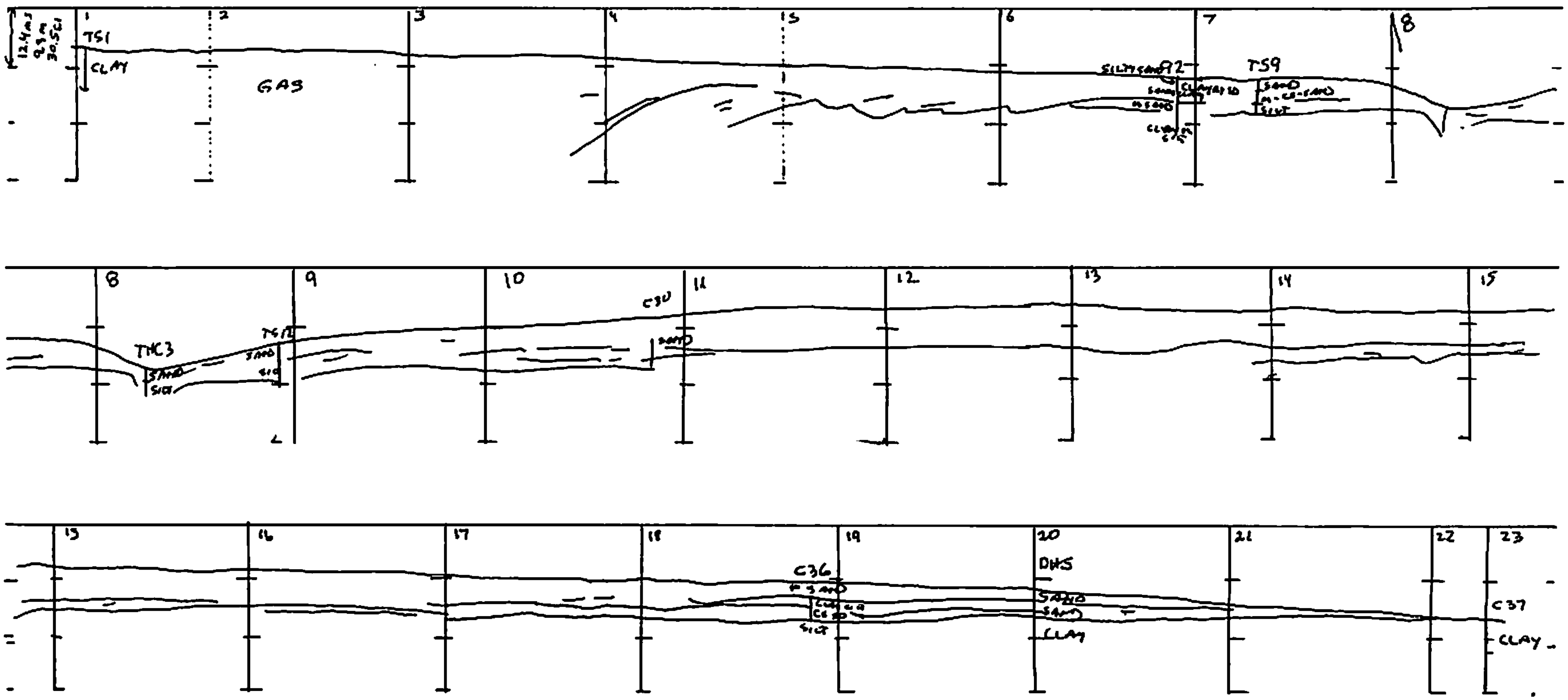


Figure 10: Interpretation of sub-bottom profile line 16 including locations and descriptions of associated cores.

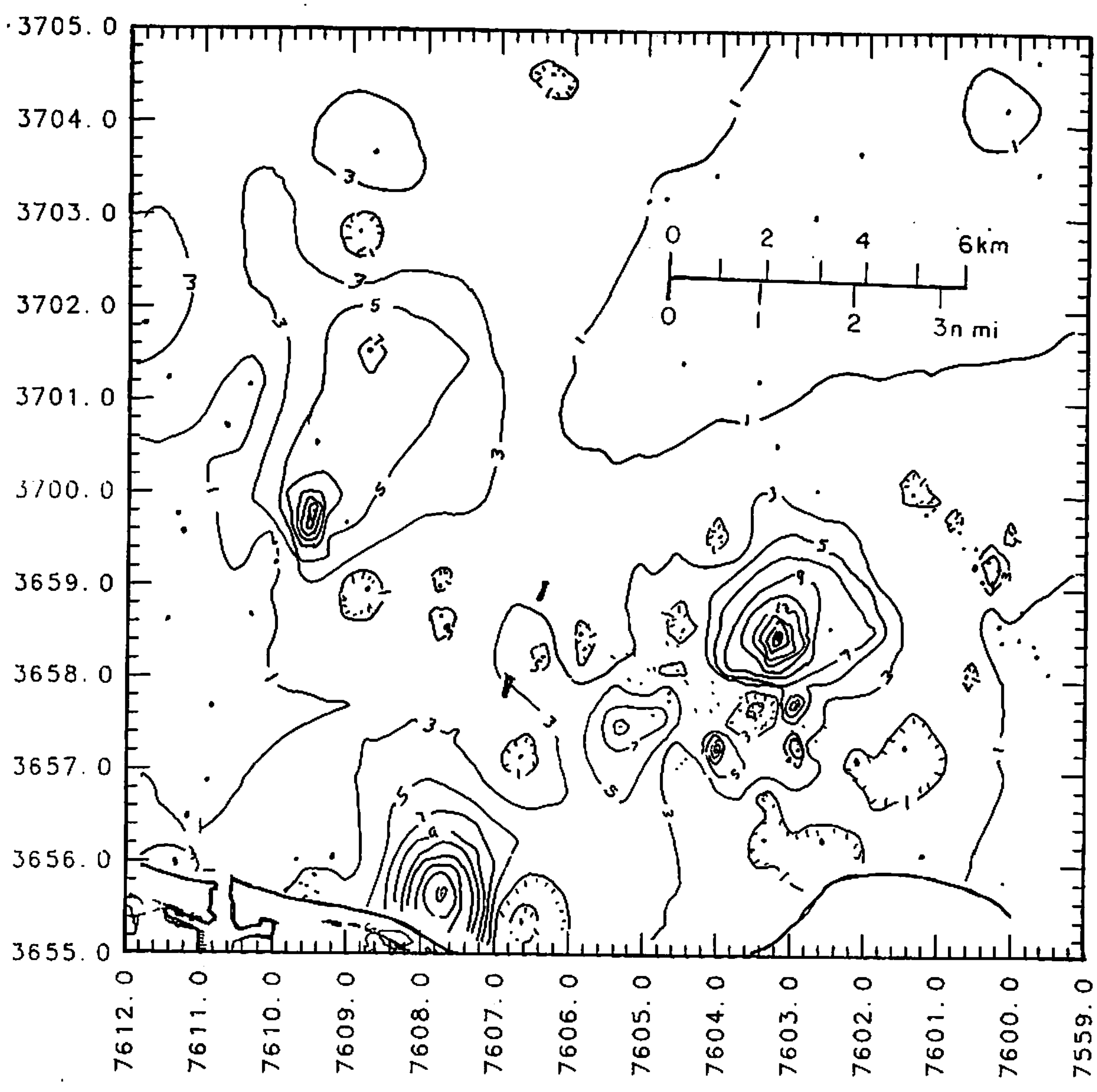


Figure 11: Isopach map of thickness (in feet) of usable sand.

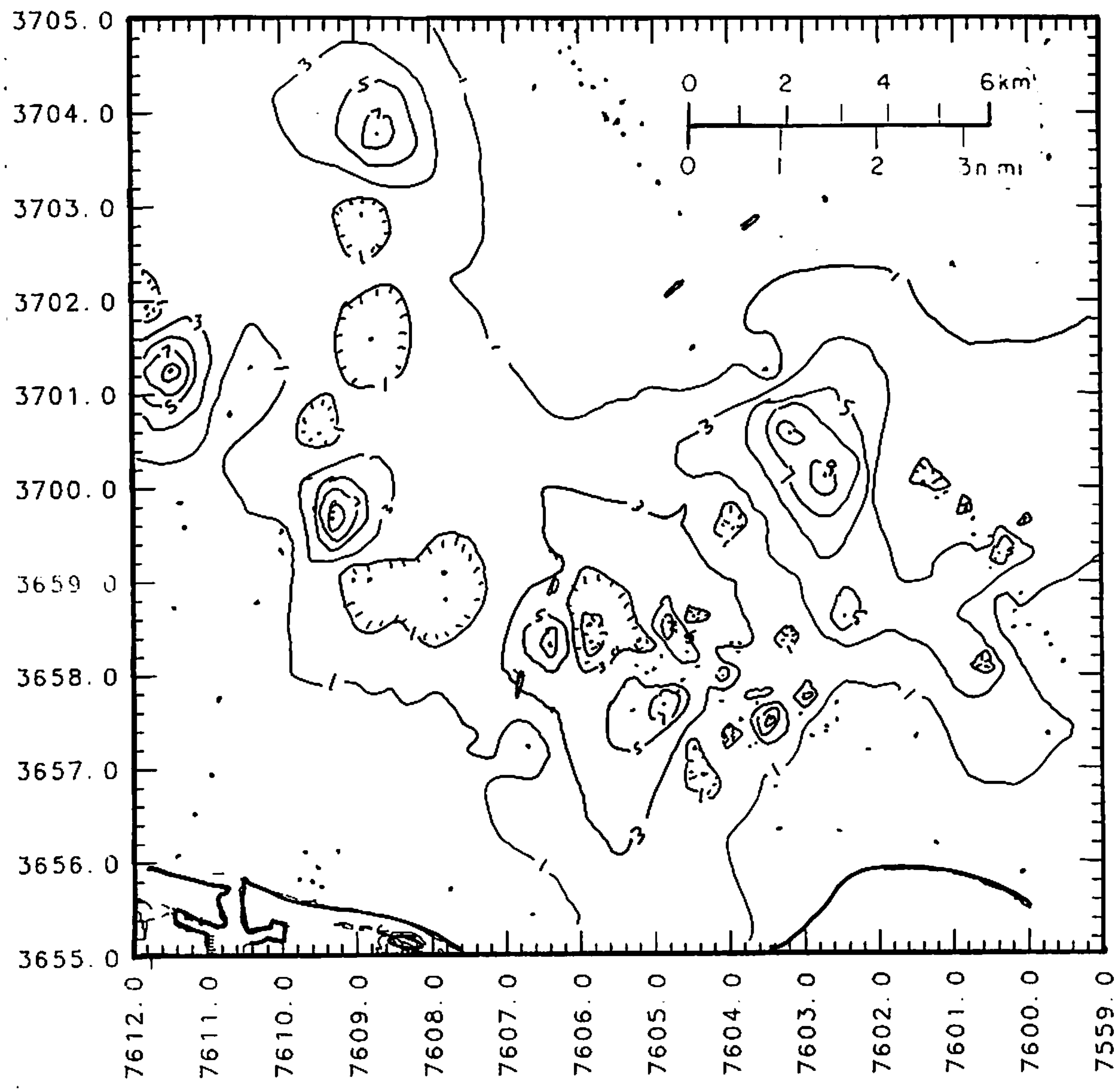


Figure 12: Isopach map of the thickness (in feet) of the overburden on top of the usable sand.

layer associated with other layers meeting the criteria were considered acceptable, as were slightly less well sorted sediments. The overfill ratios usually were under 2.25 and often approached unity.

The usable sand is the coarser material that occurs either in areas of modern, coarse grained deposition or in the lower portions of a fining upward sequence. The latter are most accessible when the sequence has been truncated either by nondeposition or erosion.

The data again indicate, as did Meisburger (1972) and Hobbs and others (1982b), that the most accessible and desirable of the sands with appropriate characteristics occur adjacent to the Thimble Shoal Channel slightly seaward of the Chesapeake Bay Bridge and Tunnel. Other areas of suitable sand are associated with the Cape Henry Channel (see Bowen and Swean, 1985), and, to a lesser extent, along the York Spit Channel immediately northwest of the Bridge and Tunnel. The area within the present study area, west of the Bridge and Tunnel, and between the Thimble and York Spit Channels, contains a limited quantity of suitable sand and probably is not suitable for exploitation.

WAVE STUDIES

As part of the geotechnical studies of the sand resources in the Lower Chesapeake Bay study area, we conducted an analysis of the changes in wave patterns that might result from the modification of the bathymetry that accompanies dredging. Although a previous study of the area (Hobbs and others, 1982b) contained wave refraction studies, we performed the new analyses on the basis of a revised computer model and selected input wave criteria from recently obtained empirical data.

The new computer wave-refraction program is a locally modified (Wright and others, 1987) version of the U.S. Army Corps of Engineers RCPWAVE model (Ebersole and others, 1986). Differences between the 1982 and present refraction studies include revised considerations of bottom friction, modifications to compensate for the circumstance that the input waves are shallow water, not deep water, waves, and inclusion of locally generated wind-waves.

The wave climate in the region of the Tail of the Horseshoe is dominated by northerly winds in the fall and winter and by southwesterly winds in the spring and summer. Data from wave gages deployed by VIMS indicate a modal wave height of 0.7 meters and a period of 6.0 seconds. Also, there are storm waves which approach 1.5 meters in height with a period of 6.0 seconds. These conditions, applied to waves approaching from the northeast and from the north northwest, were the input criteria for the computer model.

The computer model was run for two conditions of bottom topography: the first being the bathymetry as shown on modern surveys, the second with the bathymetry modified by creating a 3 meter deep depression across an area 2,200 meters long and 1,400 meters wide along the southwestern side of the York Spit Channel just inshore of the

Chesapeake Bay Bridge and Tunnel (Figure 13). The volume of this model excavation is approximately 9.24 million cubic meters (12.2 million cubic yards).

Under the northeasterly approach conditions, neither the 0.7 meter nor the 1.5 meter waves show significant changes when comparing the natural to the modelled, "post dredging" bottom conditions. With the north northwesterly approach, both the 0.7 meter and the 1.5 meter waves are noticeably altered. The 1.5 meter, 6.0 second waves turn rapidly across the depression and combine on the south side with a wave height of approximately 1.7 meters (Figure 13). The resulting wave orthogonals then appear to concentrate and move southward toward the area adjacent to the southern terminus of the Chesapeake Bay Bridge and Tunnel, Chesapeake Beach. Although the computed waves were not projected all the way into the shore, this suggests that the dredging might cause an increase in the wave energy reaching some sections of the shore. It is not possible, however, to project what, if any, specific impact this might have on the shore.

Because this analysis indicates the potential for changes in wave energy reaching the shore, it reinforces Mayne and other's (1982) recommendation that site and project specific wave refraction studies be performed in conjunction with any definite proposal for sand mining.

The specific results, the computer print-outs of the present study, are available at the Division of Geological and Benthic Oceanography, Virginia Institute of Marine Science, College of William and Mary.

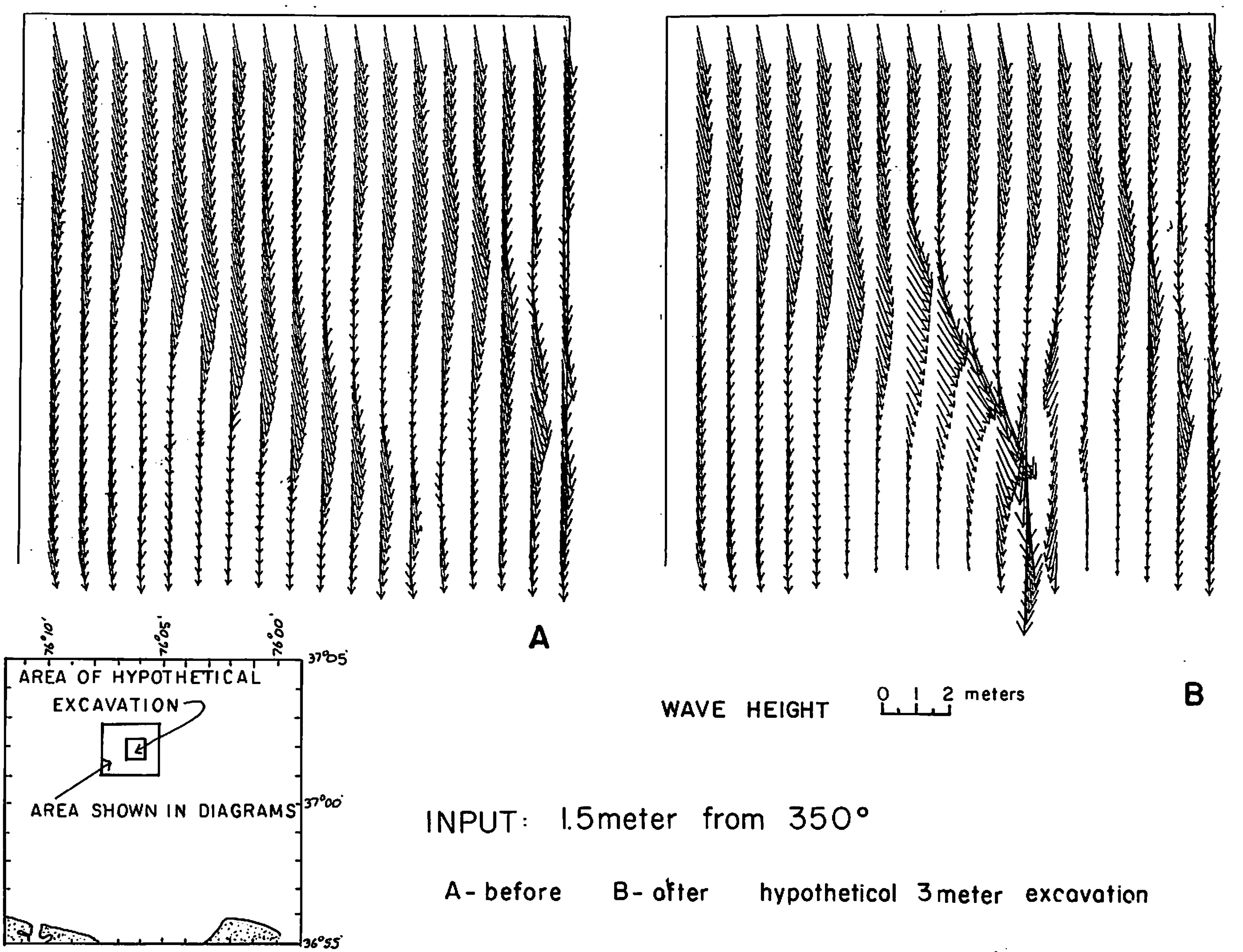


Figure 13: Diagrams depicting wave height and direction before and after hypothetical modification of the bottom.

PART II: EVALUATION OF BENTHIC RESOURCES

Introduction

Benthic invertebrates are a large and diverse group of organisms that encompasses many different life styles. These organisms are important components of the estuarine system. They serve as a major link in the estuarine food web, passing energy from lower trophic levels to top carnivores such as crabs and fishes. Many commercially important species utilize benthic invertebrates as a food source during some portion of their life history. Some species, such as the blue crab *Callinectes sapidus*, under natural conditions feed almost exclusively on benthic organisms. Thus, much of the fisheries harvest from the bay is dependent on the production of invertebrates living in bottom sediments.

Activities which disrupt bottom sediments in Chesapeake Bay have the potential to alter the value of benthic resources by 1) altering the availability of bottom-dwelling invertebrates to predatory fishes and crabs and 2) disrupting populations of commercially important species such as the blue crab *Callinectes sapidus*.

Previous investigations of bottom-dwelling invertebrates, including the hard clam *Mercenaria*, in areas considered for sand mining activities in the lower bay produced preliminary estimates of relative resource values for some of the areas considered in this study (Hobbs and others, 1982). That investigation did not evaluate availability and utilization of living benthic resources by demersal fish or habitat utilization by the blue crab. Thus, the objectives of this study were

1. to evaluate the importance of proposed sand mining areas as habitat for the blue crab,

2. to determine prey abundance and availability and utilization of invertebrate prey by demersal fish predators,

3. to relate apparent resource value of the bottom to other areas of the lower Bay.

Sampling Design and Methods

Evaluation of blue crab utilization of the proposed lower bay sand mining area was conducted during January 1989. Dredge sampling was conducted within five areas (designated Areas I to V, Figure 14) to provide information on overwintering blue crab densities. Dredging was accomplished aboard the *R/V Bay Eagle* using a 4 foot wide crab dredge as described by Schaffner and Diaz (1988). Tows were placed randomly within the five study areas. The number of tows collected for each area was determined *a priori* based on the approximate surface area of each study area as determined from bathymetric charts (Table 1). All tows were 5 minutes duration.

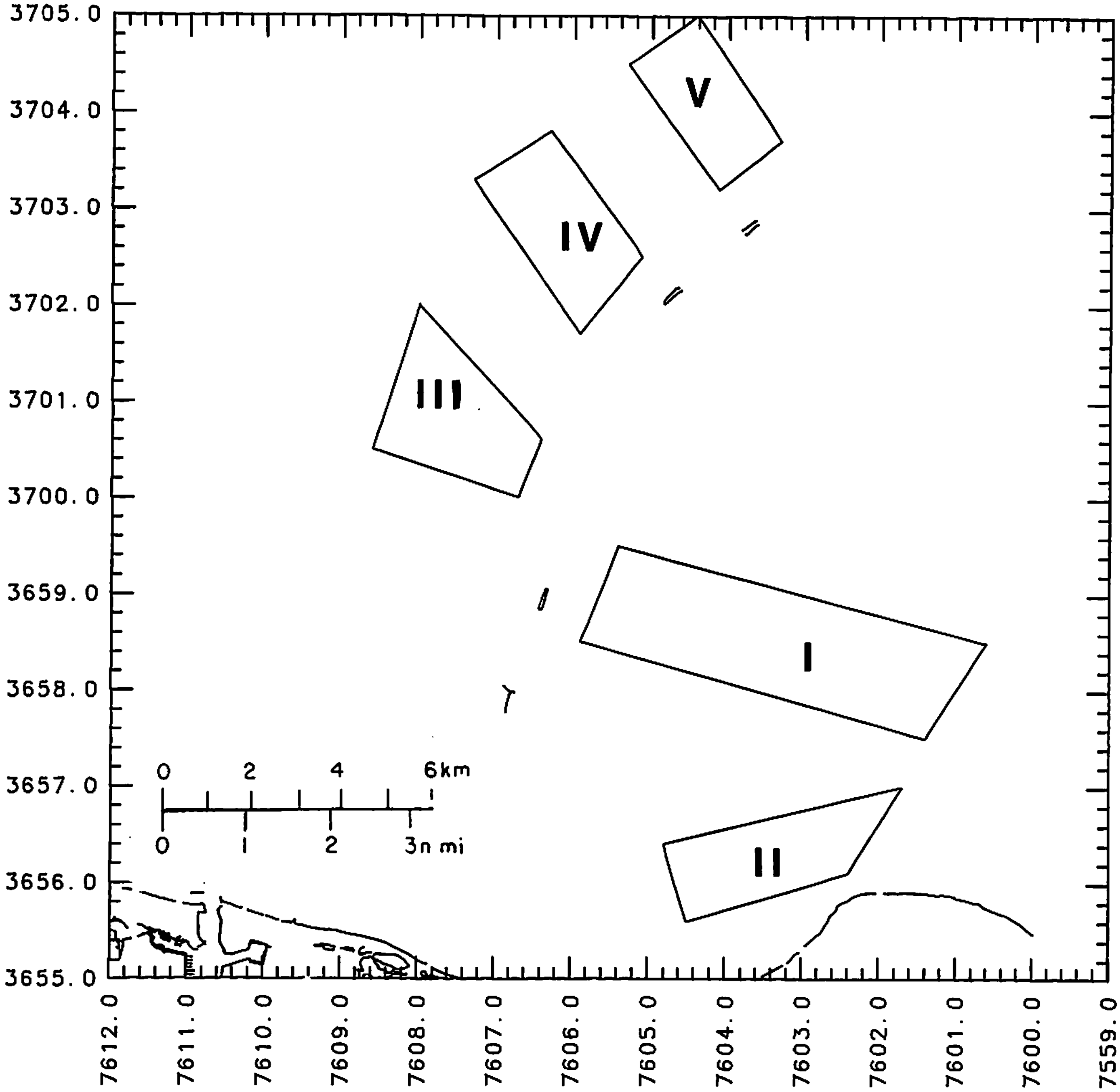


Figure 14: Map depicting location of benthic evaluation study areas.

Table 1. Sampling effort allocation for each study area within the bay mouth region.

Area	Dredging (winter) Number of Tows	Box Core Collections	Trawling (Summer) Number of Tows	SPI Deployment Surface	Profile
I	7	7	4	70	21
II	5	-	-	-	-
III	3	3	3	30	9
IV	5	4	4	40	12
V	4	4	4	40	12
Total	24	18	15	180	54

Benthic invertebrate prey abundance and potential availability to demersal predators was determined during June of 1988 using a direct core sampling technique. Quantitative box core samples were collected from each of the study areas except area II which was excluded based on results of the winter crab survey. The number of stations within an area was determined based on the approximate surface area of that study area (Table 1).

Vertically partitioned core samples were analyzed for invertebrate distribution, abundance, and biomass using a modified version of the Benthic Resource Assessment Technique (BRAT) developed by Lunz and Kendall (1982). Core samples (0.03 m^2) were vertically partitioned into depth intervals 0-2, 2-5, 5-10 and 10-15 cm, sieved on 500 μm mesh screen and fixed in 10 percent formalin. In the laboratory, samples were examined for resident organisms under a research grade dissecting microscope. Organisms were first sorted to major taxa and wet weight biomassed for each depth interval for each core. Subsequently, all organisms were identified to the lowest possible taxonomic level.

Information on large or more sparsely distributed organisms dwelling on or just above the sediment surface was obtained using direct collection techniques (dredging and trawling) or a remotely deployed underwater camera system (SPI, Surface and Profile Imaging System developed at the Virginia Institute of Marine Science, Diaz and Schaffner, 1988). The system consists of a modified Benthos sediment profile camera and Camera Alive standard camera and flash. The standard camera is used to provide information on the sediment surface directly in front of the area profiled by the sediment profile camera.

A trawl survey was used to obtain fish for evaluation of feeding patterns and habitat use. Three or four 5 minute tows of a 30 foot otter trawl were used to obtain representative fish species from each study area. Fish obtained during the survey were identified to species and enumerated. Fish-stomach contents were evaluated to determine prey utilization.

Results

Crab Surveys

Crab densities, as determined by bottom dredging at 24 stations (Appendix I) during January 1989, varied among areas within the study region. As shown in Table 2, densities for the bay mouth region generally fall within the range observed for other lower Chesapeake Bay habitats. Mean densities observed in Areas I-III fall within the range observed for channel and basin habitats where much of the commercial fisheries catch is obtained (Schaffner, 1987; Schaffner and Diaz, 1988). Based on observed densities, catch per unit effort is likely to be high enough to sustain commercial fishery activities in Areas I-III and possibly also in Area IV. In general, the study region is considered to be an important winter dredging area for commercial

Table 2. A comparison of crab densities (number of crabs/5 minutes of towing/4 feet of dredge width) in the study region, January 1989, with densities in other Bay habitats.

Study Area	Number of Tows	Mean Density (SD)	Range
Bay Mouth Region			
Present study			
Area I	7	7.6 (6.0)	2-17
Area II	5	8.0 (4.3)	2-11
Area III	3	4.0 (2.6)	1-6
Area IV	5	6.4 (4.0)	2-12
Area V	4	0.5 (1.0)	0-2
Horseshoe Shoal[1] < 18 ft.	10	2.3 (1.9)	0-16
Lower Bay			
Channel[2]	15	5.7 (6.7)	0-26
Basin[2]	43	9.1 (7.5)	0-34
Shoal[2]	36	1.8 (3.4)	0-13

[1] From Kimball et al. (1989)

[2] From Schaffner and Diaz (1988)

fishermen (Milton Parks, Tangier Island waterman, personal communication; Linda C. Schaffner, personal observation). On the day this dredging study was conducted, a portion of the commercial crab dredging fleet (approximately 20 boats) was working at Station 24 within Area IV. Each of the proposed sand-mining areas also supports populations of the rock crab Cancer irroratus (Table 3). High densities of blue crabs and rock crabs were observed in Area II where very high densities of the blue mussel Mytilus edulis and seastar Asterias forbesi also were observed. For three of the five tows from this region the dredge was full on retrieval, suggesting that observed crab densities may be underestimates.

All of the proposed sand mining areas fall within the State's official "Crab Sanctuary," an area protected from crab-potting activities between June 1 and September 15 each year. During these summer months, this region apparently supports most ovigerous and spawning females of the Chesapeake Bay population (VanEngel, 1958).

Benthic Resource Value

Benthic core samples were collected from four of the proposed sand-mining areas (18 stations, Appendix I) on July 7, 1989. Area II was excluded from this sampling effort based on results of the winter dredging survey. Faunal density ($\pm$ standard deviation) was lowest in Area III (92 $\pm$ 22 indiv. per core) and highest in Area V (274 $\pm$ 204 indiv. per core). Biomass values were lowest for Area III (4.9 $\pm$ 1.2 grams per core) and highest for Area IV (16.8 $\pm$ 16.9 grams per core).

The major taxonomic characteristics and depth patterns of individuals and biomass at each site are shown in Figures 15 and 16. Bivalve molluscs and polychaete annelids were the numerically dominant taxonomic groups for all areas. Molluscs (shell weight included) were the dominant biomass contributors.

When converted to square meter areal units, data from this study can be compared with similarly collected data from other studies conducted in lower Chesapeake Bay (Table 4). Both mean densities and biomass levels observed for the bay mouth region during the present study are as high or higher than values previously observed for the lower bay. Much of the difference in biomass can be attributed to the abundance of molluscs and small crustaceans in the baymouth region. Annelid biomass values for Areas I-V range between values previously observed for sand and mixed sediment habitats. Relatively high densities in the bay mouth region can be attributed to high densities of bivalve molluscs, especially the razor clam Ensis directus and blue mussel Mytilus edulis (see Appendix II).

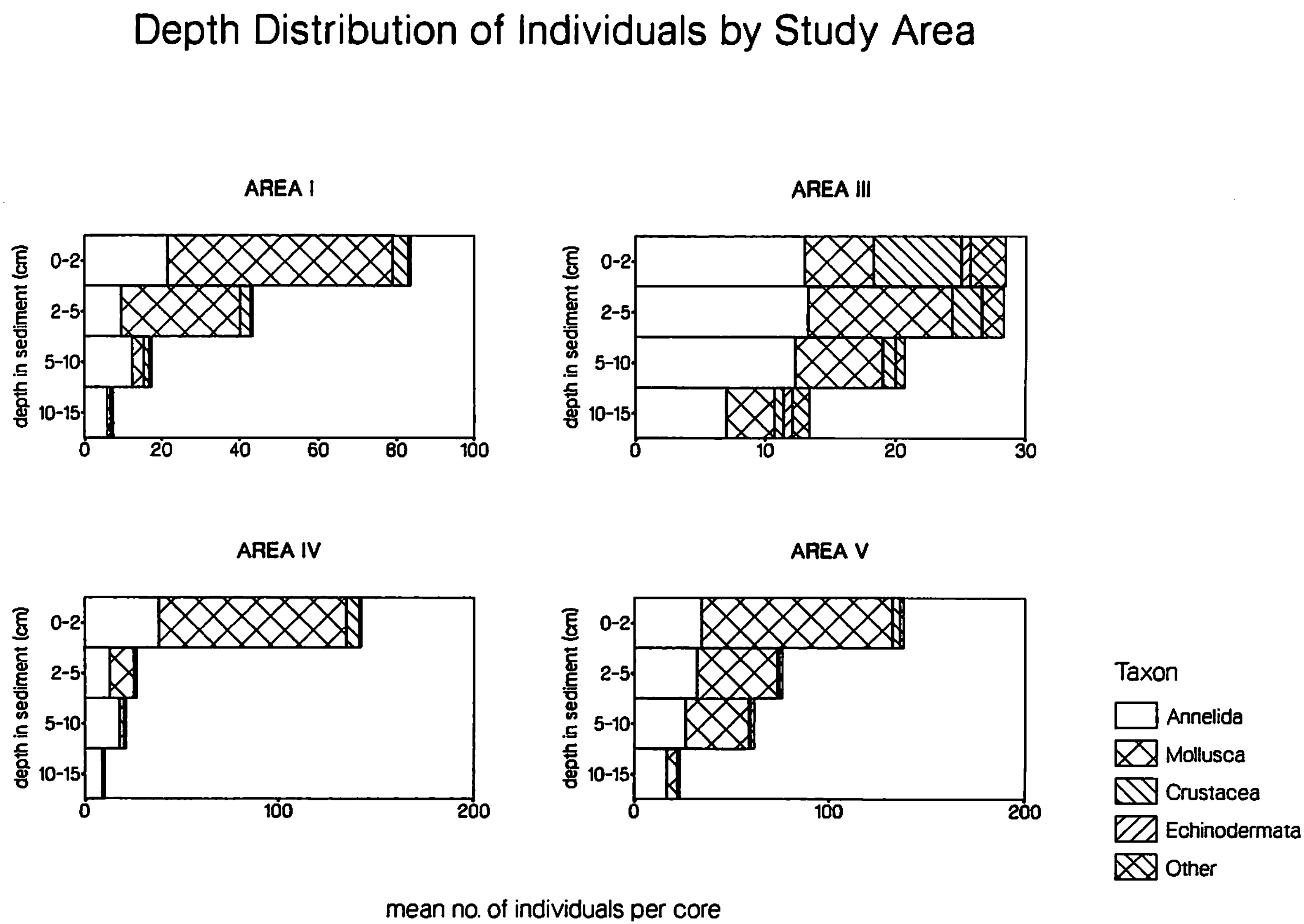


Figure 15: Depth distribution of individuals by study area.

Depth Distribution of Biomass by Study Area

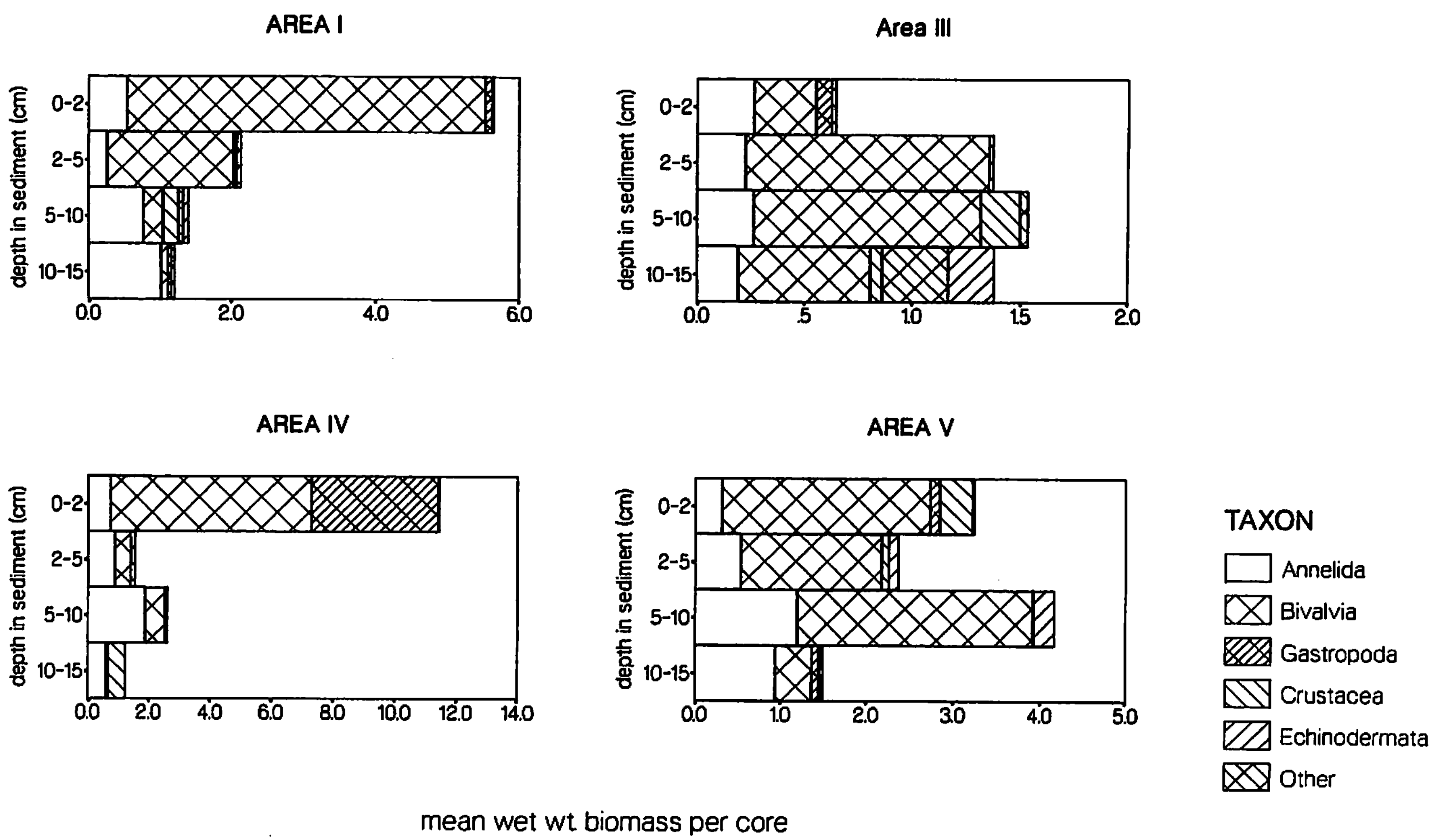


Figure 16: Depth distribution of biomass by study area.

Table 3. Densities of selected macroinvertebrates, including the blue crab *Callinectes sapidus*, in the study region, January 1989.

Area	Tow	*Callinectes sapidus*	*Cancer irroratus*	*Busycon* spp.	*Mytilus edulis*	*Asterias forbesi*
I	1	15	3			
	2	7	4			
	3	4	2			
	4	17	5			
	5	5	4			
	6	2	10			
	7	3	4			
II	8	5	2		>1000	402
	9	11	52		>1000	540
	10	10	7	1		15
	11	12	29		>1000	198
	12	2	9			4
III	13	6	2			
	14	1				
	15	5	3	1		
IV	16	8	7	3		
	17	7	10	1		
	18	2	5	1		
	19	3	9			
	24	12	4	1		
V	20	2	5			11
	21	0	10			5
	22	0	7			3
	23	0	4			9

Table 4. Comparison of faunal abundance and biomass for present study areas with values for other habitats in the lower Chesapeake Bay (south of Wolf Trap Light). Number of samples is indicated for each area. Standard deviations in parentheses.

Number of Individuals / sq. meter

Taxon	Area I n=7	Area III n=3	Area IV n=4	Area V n=4	HSS n=27[2]	Mud n=120[1]	Mixed n=70[1]	Sand n=141[1]
Annelida	1637	1557	2610	3643	1688		3259	
Mollusca	6103	890	3693	5910	87		404	
Crustacea	187	357	283	183	357		311	
Other	87	257	67	223	487		199	
Total	8110 (3870)	3057 (733)	6650 (1437)	9123 (6797)	2620	1466 (2748)	4173 (7711)	3543 (4243)

Grams Wet Weight / sq. meter

Taxon	Area I n=7	Area III n=3	Area IV n=4	Area V n=4	HSS n=27[2]	Mud n=9[1]	Mixed n=30[1]	Sand n=15[1]
Annelida	85.8	31.3	136.3	98.0	13.6	10.8	140.6	31.9
Mollusca	240.3	103.9	392.4	244.2	2.5	3.3	15.3	31.8
Crustacea	7.9	8.9	26.1	15.5	2.5	0.3	2.0	1.6
Other	8.9	18.1	0.7	14.2	6.2	3.0	34.7	13.3
Total	342.8 (208.3)	161.7 (39.6)	555.1 (557.0)	372.1 (74.9)	25.1 (18.4)	17.4 (9.3)	192.6 (111.4)	78.7 (79.3)

[1] From Schaffner and others (1987) and Schaffner (1987)

[2] HSS= Horseshoe Shoal Region (sand shoal) from Kimball and others (1989)

Taxonomic Composition of Benthic Fauna

A full listing of taxa collected at each site is given in Appendix II. At least 76 species were obtained from the bay mouth region. Of these, 36 were polychaete annelids, 15 were crustaceans, 10 and 5 were bivalve and gastropod molluscs, respectively and 10 were miscellaneous taxa. A comparison of the mean number of species per taxon and mean total species number per core is given in Table 5. Study area species richness varies primarily as a function of annelid species richness.

Trawl Survey Results

A trawl survey for demersal fish and invertebrates was conducted on June 8, 1989. A total of 14 fish species were collected. Dominant species in the collection were the scup *Stenotomus chrysops*, the northern sea robin *Prionotus carolinus*, the spotted hake *Urophycis regius*, and smallmouth flounder *Etropus microstomus* (Table 6). Dominant macroinvertebrates collected in the trawl survey were the small shrimp *Crangon septemspinosa*, and the crabs *Ovalipes ocellatus* and *Callinectes sapidus*. For most of the fish species, crustaceans, especially *Crangon septemspinosa*, were an important food item (Table 7). Six species also fed on polychaete annelids, 5 on molluscs and 4 on other fish.

Camera Survey Results

Eighteen stations were occupied on July 7, 1989 for a camera survey of surface features (Appendix I). Rough weather conditions prevailing during the study period resulted in a considerable number of photographs that could not be interpreted due to high concentrations of suspended sediment in the water column (Appendix III). Results from analysis of interpretable photographs, presented in Table 8, show that surficial sediments in each of the study regions are primarily fine sands with bedforms. Most of the study areas showed evidence of the presence of the blue mussel *Mytilus edulis*. Other macroinvertebrates observed in Area I included the sand dollar *Mellita quinquisperforata*, unidentified hydrozoans, and the small hermit crab *Pagurus* sp.

Discussion and Recommendations

The areas under consideration for sand mining during this study constitute relatively large portions of Chesapeake Bay's bay mouth region. The major assumption made during this study is that abundance and taxonomic composition of the bottom community and predator feeding habits measured at a few points in time are representative of the relative value of the bottom. Ideally, a true measure of productivity should be used but obtaining this generally is cost prohibitive. Therefore, the potential impacts of sand mining are cast in terms of the relative value of one study area to another and between this bay mouth study region and other areas of lower Chesapeake Bay.

Table 5. A comparison of mean number of species (per 0.03 m^2) by major taxon and for the total assemblage for each study area in the baymouth region. Standard deviations given in parentheses.

Area	Total	Annelida	Mollusca	Crustacea	Others
I	21 (6)	13 (5)	4 (1)	3 (1)	2 (1)
III	19 (5)	9 (0)	5 (2)	2 (1)	3 (2)
IV	24 (7)	15 (3)	4 (2)	3 (1)	1 (1)
V	25 (7)	16 (5)	5 (2)	2 (2)	3 (1)

Table 6. Demersal fish and selected invertebrate species collected by trawl in the bay mouth region during June 1989. Total number of individuals collected in each area is given. Number of tows given in parentheses.

Species	Common Name	Area: I (4)	III (3)	IV (4)	V (4)
Pisces:					
Centropristus striatus	Black Sea Bass			9	1
Etropus microstomus	Smallmouth Flounder	21	6	28	22
Leiostomus xanthurus	Spot		4		
Merluccius bilinearis	Silver Hake	1			
Paralicthys dentatus	Summer Flounder		1		
Prionotus carolinus	Northern Searobin	23	37	20	39
Prionotus evolans	Spotted Searobin			1	
Raja eglantaria	Clearnose Skate			1	
Scopthalmus aquosus	Windowpane Flounder		1	1	1
Sphaeroides maculatus	Northern Puffer		1		
Stenotomus chrysops	Scup	7	17		148
Symphurus plagiusa	Blackcheek Tonguefish				1
Trinectes maculatus	Hogchoker	1			
Urophycis regius	Spotted Hake	40	2	48	2
Invertebrata:					
Busycon spp.	Whelk	1			
Callinectes sapidus	Blue Crab	7	17	1	2
Cancer irroratus	Rock Crab			2	2
Crangon septemspinosa	Sand Shrimp	21	4	3	43
Ovalipes ocellatus	Lady Crab	6	51	5	2
Mytilus edulis	Blue Mussel			P	
Mellita quinquisperforata	Sand Dollar		P		

P = present, not enumerated

Table 7. Prey items identified in stomachs of fish species collected during June 1989.

	Crustacea					Mollusca			Annelida	Pisces
	Copepoda	Ostracoda	Peracarida	*Crangon*	other Decapoda	*Ensis*	*Mytilus*	other Mollusca	Polychaeta	
Centropristus striatus			x	x					x	
Etropus microstomus	x	x	x	x	x	x		x		
Leiostomus xanthurus	x			x					x	
Merluccius bilinearis				x						
Paralicthys dentatus				x						x
Prionotus carolinus			x	x	x	x			x	
*Prionotus evolans**										
Raja eglantaria				x	x	x	x			x
Scopthalmus aquosus			x	x	x					
*Sphaeroides maculatus**										
Stenotomus chrysops	x		x	x		x			x	
*Symphurus plagiusa**										
*Trinectes maculatus**										
Urophycis regius			x	x	x		x	x	x	x

* no full stomachs obtained

Table 8. Summarized results of SPI camera survey. Number of photographs analyzed given for surface and profile cameras. For details see Appendix III.

Area	Station	n	Characteristics Sediment	Other
I	1	5,2	fs,b	_Mytilus_ present
	2	8,2	fs,b	_Mellita_ present
	3	7,3	fs,b	
	4	1,2	fs,b	Hydrozoa present
	5	0,3	fs,b	
	6	11,3	fs,ms	_Pagurus_, _Mytilus_, Hydrozoa present
	7	10,3	fs,sh,b	_Mellita_, _Pagurus_ present
III	13	10,2	fs,b	_Mytilus_ present
	14	4,2	fs,b	
	15	10,3	fs,b	
IV	16	10,2	fs,b	_Mytilus_ present
	17	2,2	fs	_Mytilus_ present
	18	0,2	fs	
	19	1,3	fs,b	
V	20	0,3	fs,b	_Mytilus_ present
	21	4,3	fs,sh,b	
	22	1,1	fs,b	
	23	0,3	fs,b	

Key as follows: fs=fine sand, ms=medium sand, sh=shell, b=bedforms

A relative ranking for comparison among areas, based on habitat utilization by overwintering blue crabs Callinectes sapidus and abundance of prey items preferred by demersal feeding fishes, is given in Table 9. This ranking suggests that, of the four areas considered, Area III had the lowest overall resource value. Nonetheless, the results of this study demonstrate that the bay mouth region is an area of high resource values relative to the range of habitats comprising lower Chesapeake Bay. With the exception of Area V, overwintering blue crabs generally were as dense or denser in the study region as they have been in other areas of the bay where commercial harvesting occurs. Crustaceans, an extremely important food item in the diets of demersal fish in the study region, exhibited abundances 1 to 2 orders of magnitude higher in this region than have been observed in other lower bay habitats. Given the apparently high resource value of these areas relative to other habitats in the lower Chesapeake Bay, it is not possible to strongly recommend any of these sites for sand mining.

Table 9. Relative desirability of sand mining sites for beach nourishment ranked from 1 (lowest resource value area) to 4 (highest resource value area) based on results of overwintering crab survey and macrobenthic invertebrate survey - fish feeding habits survey (both considered to be represented by abundance and biomass of primary taxonomic groups/food items, eg. Crustacea, Mollusca and Annelida). A= abundance, B= biomass.

	Crustacea		Mollusca		Annelida		Crab Survey	Sum	Combined Rank
Area	A	B	A	B	A	B			
I	1.5	1.5	4	2.5	2	2	3	16.5	2
III	4	1.5	1	1	1	1	1	10.5	1
IV	3	4	3	4	3	4	4	25	4
V	1.5	3	4	2.5	4	3	2	20	3

PART III: SUMMARY AND CONCLUSIONS

Although substantial quantities of beach and engineering quality sand are present within the Tail of the Horseshoe, lower bay study area, the value and character of the area's living resources strongly suggest that the area not be a primary sand-mining area. Sand mining, dredging, removes the benthic infauna leaving the area at least temporarily barren (Thompson, 1973; Tuberville and March, 1982). Sandy areas often recolonize rapidly (Courtney and others, 1974; Parr and others, 1978; and Cutler and Mahadevan, 1982). Thus, if the area were mined, specific care would have to paid to the timing of the work so as to have minimum impact on the biota that traverse the area and feed on the indwelling fauna.

Although only of the second lowest resource value, benthic evaluation Area I (Figure 14) is a more likely area for active sand mining than Area III which has the lowest resource value. Area I is substantially closer to shore and the end user than Area III, thus offering an appreciably lower access cost. This parallels and supports the suggestions and recommendations of Meisburger (1972) and Hobbs and others (1982b).

Sands could be harvested from on-going channel-dredging projects and be put to constructive use. All three of the area's maintained channels, Thimble Shoal, York Spit, and Cape Henry, have the potential to provide serviceable quantities of sand.

New projects designed primarily for the acquisition of sand probably should be directed toward the Thimble Shoal area of Kimball and others (1989) or, perhaps, offshore. Any specific proposal for sand mining should be the subject of a detailed, site specific evaluation.

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