WESTINGHOUSE OCEAN RESEARCH LABORATORY

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SEDIMENT RESPONSE TO INNER SHELF
HYDRAULIC REGIMES

Progress Report

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ABSTRACT

The current regime of the inner continental shelf and its effect on the shallow nearshore sea floor is poorly known, yet a knowledge of sediment transport in this area is crucial to proper design of coastal and offshore facilities. This program includes an array of current and wave sensors to monitor bottom currents in a linear shoal field off Assateague Island, Maryland. Prototype devices scheduled for installation at this site include an acoustic sediment transport probe and a pore-water pressure sensor to monitor "stability" of sand at the site. All data are sent via telemetry from a buoy to the shore-side station containing a data logger and transmitter. Transmissions are for 30 minutes every 4 hours.

To date, data are restricted to fairweather (low wave) conditions. Net current flow appears to parallel to, or obliquely away from, the shore. Sediment textural analyses from this area support the theory of net offshore transport. Wave refraction programs and spectral analyses of wave records provide a measure of energy expended along this coastal segment.

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1. INTRODUCTION

One of the significant but unanswered questions in the study of nearshore marine processes is that of the rate and magnitude of sediment transport on the inner continental shelf. Past attempts to measure the flow regime of bottom waters near coasts have been partially successful in that data of limited duration have been recovered from specific sites. However, the requisite data essential to an understanding of transport processes which lead to prediction of sediment transport rates and directions remain unrecorded. The key to resolving these questions, and the information which will permit formulation of the correct and most direct approach to further measurements, lies in the collection and analysis of time-series data. The Westinghouse Ocean Research Laboratory (WORL) is currently under contract (E (11-1)-2553) to perform such a study. This brief Progress Report is intended to complement the proposal for Phase II (Continuation) studies which has been forwarded to the Energy Research and Development Administration for consideration in extending this study for another 12-month period.

2. SCOPE OF PRESENT INVESTIGATIONS

2.1 Field Operations

At the present time, WORL is maintaining a sea floor array of instruments off Assateague Island, Maryland (Fig.1). The array consists of three wave gauges (Bass Engineering type) and a tri-axial current meter (Marsh-McBirney type). Both types of instruments are mounted on supports

Figure 1. Bathymetry of the Inner Shelf Off Assateague Island. Black Circle is Location of Ocean City, Md. Arrow Points to Ridge Under Study. Contours in Fathoms.

Figure 2. Array diagram. Channels 2, 3 and 4 are wave gauge stations; current meter and other electronics are located at point z .

Figure 3. Spar buoy deployed off Assateague Island, Maryland. Rectangular object near top of cylindrical spar is radar reflector. Buoy is equipped with flashing light and is painted orange and white. Antenna for transmission of data and reception of shore signals projects above the circular end-plate.

Figure 4. Diver is shown during attachment of armored transmission cable to base of spar buoy (upper right). Water clarity at this site is generally from two to four feet.

buoy some 2.5 miles offshore. Seismometers to record north-south east-west and vertical components of motion will permit monitoring of micro-earthquake frequencies affected by surf at this site. A microbarometer complements this system, and the short-period fluctuations in atmospheric pressure will be correlated with both the seismometer data and the offshore information. Wind speed and direction at the site are recorded by State Park personnel every three hours. We have initiated and maintained contact with the National Ocean Survey regarding tide data from their Ocean City gauge (mounted at the end of the City pier). Tidal data are to be correlated with all other data.

2.2 Laboratory Operations

Data recovered from the offshore array are being categorized as either wave or current data. For wave data, we are calculating:

1. Energy density spectra
2. Coherence spectra
3. Direction of wave travel
4. Tidal motion

For the current data, we are calculating

1. Kinetic energy density spectra
2. Progressive current vector diagrams
3. Threshold velocity for sediment transport
4. Non-wave-induced currents

One wave gauge record and corresponding energy density spectrum for

early August is shown in Figure 5.

A wave-refraction program adopted from a previous study has been applied to this area, and sample wave orthogonal plots for the area are presented in Figures 6-8. For waves of periods less than 6 seconds, we may introduce the orthogonals as parallel lines, essentially deep-water wave conditions, at the outer margin of the area. For waves with periods in excess of 6 seconds, we must approximate the azimuth of orthogonals which have experienced refraction prior to their arrival at the boundaries of the area. These values must be interpolated from diagrams presented in the literature. Although this provides only an approximation of orthogonal trajectory, it is superior to a projection of parallel orthogonals at the margins. It is most interesting to examine the approach of orthogonals resulting from a "northeaster" (azimuth 045° , see Figure 8). Severe refraction occurs due to the parallel alignment of the shoals, implying a significant loss of energy to the sea floor during the passage of such wave trains. We shall investigate this coincidence with the hope of clarifying the role of topographic features in forcing flow in the water column to conform to the preferred grain which exists on the inner shelf in this region.

Sediment samples from 74 stations in the area of interest have been analysed for textural parameters, and these data are presented in map form in Figures 9-11. At the next battery change, we will install a series of marked stakes which will permit periodic measurement of sand erosion or accretion at the sea floor array site. We have also recovered local samples in the area each time divers service the site. An analysis

Figure 5. Wave record and spectra for one fairweather interval, August, 1975.

Figure 6. Wave Refraction Diagram for 6 Sec. Wave from Southeast.

Figure 7. Wave Refraction Diagram for 6 Sec. Wave from East.

Figure 8. Wave refraction Diagram for 6 Sec. Wave from Northeast.

Figure 10. Sorting (standard deviation - Folk and Ward parameters). Contours in feet.

Figure 11. Mean grain size (Folk and Ward parameters). Contours in feet.

of the change (if any) in textural parameters will be included as part of the geological monitoring.

3. SIGNIFICANT RESULTS

On the basis of limited field data which, at the date of this writing can only include "fairweather" information, we may acknowledge several aspects of the current study which we feel are of significance to an understanding of sediment transport processes on the inner shelf.

Current meter data from previous deployments has shown a net southerly and offshore vector to bottom currents. Our most recent records indicate that transport parallel to shore occurred during a period of relative quiet conditions. This supports the contention that onshore flow of bottom water, if it occurs, must be manifest under conditions which we have not yet experienced. Winter season data will reveal the nature of currents and sediment transport under the most rigorous conditions, and a more complete description of the annual regime will be possible by summer, 1976.

Sediment distribution in this area implies a net offshore flow of bottom waters. This distribution was noted on similar features to the south of our test area during a recent cruise with NOAA, and a descriptive model of annual flow which would account for this distribution is now being formulated.

Spectral analyses of selected wave data obtained under the fair-weather seasonal regime have revealed a bi-directional aspect to wave

train approach. As shown in Figure 5, two periods dominate the wave regime observed during this period. The interaction of waves with periods of around 12-seconds, from the southeast with those having periods around 8-seconds from the east produce a beat period of about 80 seconds. This situation is to be expected, since the summer swell from the southern quadrant will reflect arrivals from southern hemisphere winter storms. Previous work by others has been limited to single-day visual measurements from aircraft, and we believe that the data presented in Fig. 5 represents the first measured observation of multinodal spectra, with directional determination, to be achieved off this coast. Continued monitoring will permit refinement of the range and magnitude of this coupling.

Sediment data processed from the 74 stations occupied prior to this contract have shown distributional patterns which imply a net offshore transport of sediment. This assumption is supported by previous current meter records from the site, as shown in Figure 12. Recently completed detailed field studies with AOML (NOAA) scientists reveal similar sediment distributions to the south of this area. Although this research is continuing exclusive of the current contract with ERDA, the two programs are complementary and serve to support one another. The preliminary findings represent significant new insights into inner shelf sediment transport - that is, a net offshore displacement of sediment. Our tentative conclusions have been submitted in abstract form to two forthcoming meetings (see Appendix listing papers and presentations which have included descriptions of work under this contract).

Figure 12a (top) Vector average diagrams for two crest records and one trough. Record at right connects to bottom of crest trace at left. Note consistency in directions between crest and trough (4/16-26) and predominance of SSE flow. Tick marks on traces are midnight (0000 hrs). Ordinate in meters. Figure 12b (bottom) Velocity summary for observations. Directional variance of 31° is due in part to lack of a second record for the trough. Inclination of ridge axis to shore (18°) is identical with the mean azimuth deviation for other shoals in this area.

We must include under this section the fact that significant improvements have been realized in the instrumentation, both sea floor array and shore-side equipment, which renders it more reliable and accurate. This undertaking represents a major new effort in oceanographic data collection and the deployment of sensors, and supporting electronic systems, has required new approaches and techniques in installation, calibration and operation. Difficult problems have been overcome, but at the cost of time which we had hoped to devote to data collection and analyses. A complete description of the technical solutions to field problems will appear in the final report.

Two major problem areas have been in electronic noise suppression, the noise having resulted from interference within the system, and in maintaining reliable telemetry between the shore station and the buoy. The former has been corrected, and most noise eliminated, by electronic filtering; telemetry has been improved by the addition of new antennas and elevation of the shore-side antenna. Data now on hand which we consider marginal due to noise are under study to assess the possibility of rectification.

4. COMPLIANCE WITH CONTRACT REQUIREMENTS

To date, we have complied with all conditions and restrictions implicit in the contract document E(11-1)-2553 commencing 1 February 1975. As indicated above, data collection has been intermittent, but recent maintenance has resolved those problems. Expenditure of funds as of 9 November, 1975 was \$89,325 of the contract award of \$135,857, or about 66% expenditure. A renewal proposal has been forwarded as required.

5. SCHEDULE

The Principal Investigator, Dr. Harold D. Palmer, has spent approximately 20% of his time in support of this program. During the final month of Phase I he will devote at least 50% to the completion of the final report. Mr. Donald G. Wilson, Project Manager for this contract, has devoted approximately 75% of his time to the program; Dr. John Guala, Senior Engineer, has spend approximately 85% of his time on this program. Technician time has been employed as needed for field operations and support.

APPENDIX

Papers and Presentations which include a Description of
ERDA Contract E (11-1)-2553
(no contract funds were expended in travel)

Presentations

D.G. Wilson	Assateague Shelf and Shore Workshop	April 1975
H.D. Palmer	Virginia Institute Marine Sciences	
H.D. Palmer	IXth International Sedimentological Congress, Nice, France	July 1975
D.G. Wilson	Estuarine Research Federation, Annual Meeting, Galveston	September 1975
H.D. Palmer	Annual Meeting, Amer. Soc. Civil Engineers, Denver	November 1975

Papers*

H.D. Palmer	<u>Sediment Transport Studies, Nearshore Continental Shelf off Maryland.</u>
D.G. Wilson	Submitted to: The Offshore Technology Conference, Houston, Texas. May, 1976.
J.O. Blanton	
J.R. Guala	
J.Nolder	<u>Contemporary Sedimentation in Linear Sand Shoals: Examples from the Inner Shelf, Middle Atlantic Bight.</u>
H.D. Palmer	Submitted to: The Geological Society of America, Northeast/Southeast Sectional Meeting, Arlington, Va. March, 1976.
D.J.P. Swift	
T. Merryman	

* abstracts attached

ABSTRACT FORM

See instruction sheet for deadlines and addresses.

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CONTEMPORARY SEDIMENTATION IN LINEAR SAND SHOALS: EXAMPLES FROM THE INNER SHELF, MIDDLE ATLANTIC BIGHT

Nolder, Jeff L., Westinghouse Ocean Research Laboratory, P.O. Box 1488, Annapolis, Md. 21404; Palmer, Hal D., Westinghouse Ocean Research Laboratory, P.O. Box 1488, Annapolis, Md. 21404; Swift, Donald J.P., Marine Geology and Geophysics Laboratory, AOML/NOAA, Miami, FL 33149; Merryman, Tehana, Westinghouse Ocean Research Laboratory, P.O. Box 1488, Annapolis, Md. 21404.

The inner continental shelf off the middle Delmarva Peninsula is characterized by elongate shoals arrayed in sub-parallel sets forming northward-opening acute angles with the present shoreline. Detailed studies with a variety of acoustic, photographic and bottom sampling devices reveal a general pattern of sediment distribution indicative of long-term averages in local hydraulic regimes. Troughs between shoals are generally floored with fine sand or mud. Gravel and shell debris are often found at the shoreward base of these ridges. The bulk of a shoal consists of medium sand ($\pm$ shell) with the seaward slope characteristically finer and steeper than that facing shore, facts suggesting greater bottom shear stress and offshore sediment transport on shoreward flanks. Seismic reflection profiles reveal these ridges to be local accumulations in a veneer of sand atop extensive erosional surfaces.

Current meter data from a nearshore shoal show a net offshore flow of bottom water under fairweather conditions. Currents in excess of 21 cm/sec occurred 58% of the time at the crest; 26% in the trough. Flow vectors are parallel in both areas. The long axes of shoals are aligned with orthogonal of waves approaching from the northeast, the site of the most intense storms.

The combination of sediment textures, shoal geometry, prevailing currents and shoreline morphology reveal a net downcoast and offshore transport of bottom water and sediment. Continuity requires a surface flow toward shore, with the result that coastal downwelling supplies the most satisfactory model of an inshore hydraulic regime.

☐ Oral ☐ Discussion ☐ Poster ☒ Symposium Geology, Atlantic Continental Margin
(title of symposium)

Speaker Jeff Nolder

Indicate authors who are not GSA members Nolder, Merryman

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I will be available to serve as a cochairman for a technical session on or concerning Palmer -Marine, sedimentology

For correspondence purposes, list address of senior author if different from above - same

Phone numbers and dates where senior author can be contacted (301) 765-5298

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Abstract submitted to the Geological Society of America, October, 1975.

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

Paper Title: Sediment Transport Studies, Nearshore Continental Shelf Off Maryland

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DESCRIPTION OF THE WORK:

Linear sand shoals are a common feature of the continental shelf off the east coast of the United States. Their origin is unclear, and proposed mechanisms for their development and maintenance imply that currents having relatively high speeds are responsible for the present configuration of the shelf surface. The design of structures for exploration and production of petroleum reserves believed to be present in this area requires an understanding of the hydrodynamic regime in shoal areas, and a program to monitor currents on a nearshore linear shoal has been in progress since July of 1975. This paper summarizes the results of unique sediment transport studies at a test site off Assateague Island, Maryland.

APPLICATION:

Information derived from this investigation will be essential to the prediction of wave-induced sediment transport associated with seasonal aspects of wave spectra derived from bottom-mounted wave gauges and current meters. Such studies will provide information on scour potential and erosion/deposition regimes bearing upon the design of nearshore facilities which occupy or pass through the shallow regions off the coast.

RESULTS, CONCLUSIONS, AND GENERAL OBSERVATIONS:

Instrumentation on the seafloor has yielded fair-weather data which support the contention that a seaward drift of bottom waters prevails off the central U.S. east coast. Vector coverage diagrams show a net offshore displacement of water of 8.3 km/day on the crest of the shoal, while the shoreward trough revealed only 0.8 km/day in the same direction. Currents capable of transporting indigenous sand exceeded the threshold velocity 58% of the time on the crest, but only 26% of the time in the trough between the shoal and shore.

Please tear off and mail to OTC Headquarters

Abstract submitted to the Offshore Technology Conference, August, 1975