

V. COASTAL SEDIMENTATION

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A. Introduction

In this section several important coastal sedimentation problems are identified where application of existing or anticipated remote sensing technology might provide valuable information.

B. Coastal Fine Particle Sediment Systems

Particles are added to the coastal marine environment by rivers, the atmosphere, shore erosion, biological activity, and by municipal and industrial discharges. The particles are both organic, living and dead; and inorganic, naturally occurring and anthropogenic. Man has clearly modified the flow of natural particles into coastal systems by land-use practices--deforestation, agriculture, urbanization--and by water-use practices--construction of dams and reservoirs, diversion of rivers and streams, construction of shore protection devices, etc. His activities have also introduced significant quantities of anthropogenic particulate matter.

Because particulate matter can strongly affect the quality of the coastal environment in a variety of ways, the ability to predict its behavior is of the greatest scientific and practical importance. This is particularly true of the fine-grained fraction which poses the greatest problems: economic, aesthetic, and environmental.

The ultimate objective is to understand how fine-grained sediment systems of coastal waters operate. Among the most important questions are:

- (1) What are the sources of sediment, their locations and strengths?
- (2) What is the character of the material introduced, its size distribution, composition, and associated contaminants?
- (3) What are the routes and rates of sediment transport?
- (4) What are the sites of accumulation, the transient repositories, and the final resting places?
- (5) What are the rates of accumulation in these repositories and how much material is lost to the ocean?

There is not a single coastal system for which all of these questions can be answered satisfactorily for scientific or management purposes. Coastal systems are heterogeneous (patchy) in many of their characteristic properties and sediment sources vary markedly temporally. Adequate characterization with conventional shipboard techniques would require many samples collected nearly synoptically, and observations over long periods of time. With present sampling techniques, such sampling programs are not practical. Remote sensing from

satellites, and particularly from aircraft, may provide valuable tools for studying coastal sediment systems, but before they can be usefully employed, certain questions must be answered. Some of the most important questions are listed below.

- (1) Can remote sensing techniques distinguish suspended organic particles from inorganic particles?
- (2) Can remote sensing techniques be used to estimate the concentration of total suspended solids? Over what range in concentrations?
- (3) Can remote sensing techniques integrate over the water column to estimate the total suspended load? To what depth and over what range of concentrations?
- (4) Can remote sensing techniques be used to estimate the partitioning, by sedimentation, of suspended solids among different segments of an estuary or other coastal embayment?
- (5) What sea-truth measurements are required for calibration of remote sensing observations?

Concentrations of total suspended matter in coastal areas range from less than 1 mg/l to many thousands of mg/l, and even into the hundreds of thousands of mg/l off the mouths of some large rivers such as the Yellow and Yangtze. Over the length of an estuary the total concentration may drop by one to two orders of magnitude between the head and the mouth and the partitioning of mass between the inorganic and organic fractions may change from >99:1 at the head to <1:99 at the mouth. The size distribution may also change significantly over the length of an estuary. And large variations are not confined to changes over relatively large distances in the horizontal; large changes may occur over relatively small distances in the vertical. For example, in the upper reaches of the Chesapeake Bay estuary the concentration of total suspended matter may increase by at least a factor of 20 over a depth of <5 m between the surface and near the bottom.

Temporal variations in the concentration of total suspended matter can also be very large. Seasonal variations of the concentration of total suspended matter of one to two orders of magnitude are relatively common in temperate estuaries, and episodes can increase concentrations substantially above normally high values. Variations of higher frequency are also common. Near-bottom concentrations may vary by several orders of magnitude over periods of hours as bottom sediments are resuspended by wind waves or tidal scour. In the Chesapeake Bay, Schubel (1971) found variations in the concentration of total suspended solids of semitidal period of >20X with concomitant changes in the mean diameter of the suspended particles of from about 2 μm near times of slack water when concentrations were low to more than 20 μm near times of maximum ebb and flood tidal currents when concentrations were high.

C. Events and Coastal Sediment Systems

Recent studies have shown that events such as floods and hurricanes can dominate the sedimentation of coastal systems (Chesapeake Research Consortium, 1976). Schubel (1974) showed that during Tropical Storm Agnes (June 1972), the Susquehanna River - the principal source of fluvial sediment to the Chesapeake Bay - discharged more suspended sediment in 1 week than it does during 25 years of average runoff. Hirschberg and Schubel (in press) showed that two floods, Agnes in 1972 and the Great Flood of 1936, accounted for more than one-half of all sediment deposited in the upper Chesapeake Bay since 1900. Other investigators have shown that inlets cut during hurricanes can completely alter the circulation and sedimentation of bar-built estuaries and lagoons. It is clear that while they have a low frequency of occurrence, episodic events can dominate the natural evolution of coastal water bodies.

Synoptic observations are desirable during events because water properties frequently change rapidly in time and space during and immediately following events. Shipboard observations during this period are, at best, difficult to make because of weather and sea conditions and synoptic observations over relatively large areas are virtually impossible. While cloud cover may frequently rule out satellite observation during episodic weather events, low flying aircraft might be useful. Because of their very nature, episodic events frequently cannot be predicted very far in advance, if at all. The key to effective studies is rapid response. Aircraft that could be deployed quickly with remote sensing packages could provide very valuable data for science and management.

Among the more important geological questions relating to episodes are:

- (1) During floods how much sediment is discharged to the coastal zone?
- (2) Where are the principal sources of this material - upland areas, bank erosion, purging of reservoirs, etc.?
- (3) What is the ultimate fate of the material? How is it partitioned among different segments of an estuary or other coastal embayment?
- (4) How rapidly does the system recover to normal levels of total suspended solids?
- (5) What changes in shoreline configuration are produced - erosion, deposition, formation of new islands, cutting of new inlets, etc.? Does the system recover, and over what time scales?
- (6) How much sediment is discharged to the ocean and what is its fate?
- (7) What is the importance of episodes, relative to average conditions, in determining the natural geological evolution of coastal systems?

Remote sensing techniques, particularly from low flying aircraft, should be very useful in answering a number of these questions. Sea-truth data will certainly be required, not only for calibration of the remote sensing data but to extend the observations to greater depth. Concentrations of total suspended solids may be so high (>1000 mg/l) that penetration of optical signals will be limited to a thin near-surface layer.

A series of approximately daily over-flights would be desirable throughout the recovery period.

D. Routes and Rates of Sediment Transport on Continental Shelves

Relatively little is known about the routes and rates of sediment transport on the continental shelves of the world. This is particularly true of the fine-grained fraction, the silt and clay-sized particles. Aside from the obvious scientific reasons for wanting to understand the dispersal of sediments on continental shelves, there are important practical reasons. With the increasing potential for use of our continental shelves for energy-related activities - for oil exploitation and siting of floating nuclear power plants - and with increasing exploitation of sand and gravel resources, it will become increasingly important to be able to predict the routes and rates of sediment transport. Fine particles are the principal pathway for carrying particle-associated contaminants (e.g., oil, radionuclides, and metals) in continental shelf waters back to the continents and therefore to man. The mobility of the bottom must be considered in the siting of facilities, laying of pipelines, etc.

With present shipboard techniques, it is impossible to obtain a synoptic view of a relatively large segment of the continental shelf. This information is particularly important for studies of fine-particle systems. An assessment of the mobility of the bottom - movement of bedforms - with present shipboard techniques is equally intractable. Remote-sensing from satellites and aircraft may provide useful data for answering both of these sets of questions.

Some of the more important questions include:

- (1) What are the distributions of total suspended matter in time and space?
- (2) What are the sources of sediment to continental shelves?
- (3) What are the routes and rates of transport of fine-grained sediments?
Do fine-grained particles constitute an effective mechanism for returning particle-associated contaminants back to land and to man?
Are fine-grained materials bypassing the shelf? If so, where are they being deposited and at what rates?
- (4) What are the routes and rates of transport of coarse-grained (bottom) sediments? What are the characteristic bedforms, how stable are they in time and space?

E. Dredging and Dredged Material Disposal

Since most of the nation's seaports are located on estuaries and since most estuaries are characterized by relatively rapid sedimentation rates, dredging has been a persistent activity of coastal areas since colonial days. The dredging has been a combination of new work and maintenance dredging. The development of facilities to support recreational boating and fishing and commercial fishing has also increased dredging activities. Throughout the U.S. more than 400×10^6 yd³ of material are dredged annually by the U.S. Army Corps of Engineers and over the past decade, an additional 75×10^6 yd³ have been dredged each year by nonfederally financed projects (Boyd et al., 1972).

Most dredged materials are composed of natural sediments eroded from upland areas and carried into coastal waters by rivers and streams. Other sources include shore erosion, primary productivity, and municipal and industrial discharges. The relative strengths of these sources vary with location and with time at any given location. The shoaling of channels is frequently dominated by a proximate source of sediment - the resuspension of bottom sediments by tidal scour and wind waves and the transfer of these materials into the channels where they are trapped. Since most of the materials that are dredged are natural soils and organic matter, one would expect that their disposal need not create any serious environmental problems. In general this is true. But pollutants are added to rivers and directly to estuaries and other coastal embayments by municipal and industrial discharges, and by accidental releases.

The sources of most pollutants are concentrated near cities and ports. Since many contaminants are relatively insoluble and have a high affinity for fine-grained particles, they are rapidly scavenged by fine suspended particulate matter and end up on the bottoms of estuaries and other coastal embayments where fine-grained sediments are accumulating. The disposal of these materials in open waters - the most common mode of disposal - has created a number of environmental problems, real and perceived. Several important questions related to the physics of disposal are listed below.

- (1) How extensive and persistent are plumes of suspended solids produced during open water disposal operations? What are the excess concentrations of suspended solids?
- (2) How stable are open-water deposits of fine-grained dredged materials? Are they confined to the disposal sites or are they resuspended by waves and currents and dispersed? If they are dispersed, what are the areas affected?
- (3) How can suitable potential open-water disposal sites be identified? Both "confinement" sites - natural sites from which materials will not be dispersed - and dispersal sites may be desirable.

While the first question is tractable with shipboard measurements, observations from aircraft could be useful, particularly during periods of rough seas, and to provide graphical synoptic coverage. The other two questions may be amenable to remote sensing. Determination of the stability of dredged material deposits is difficult with conventional shipboard sampling. It is frequently difficult to sample during periods of rough seas when dispersal is most likely to occur and areal coverage is frequently not adequate for management purposes. In relatively clear and shallow waters, remote sensing may be valuable in delineating changes in the areal extent of deposits of dredged materials if these materials are substantially different from the natural substrate.

There is a need to identify suitable open-water disposal sites for relatively uncontaminated fine-grained dredged materials, sediments that pass the present bioassay tests. Both confinement and dispersal sites are needed. Open-water confinement sites are those from which, because of natural processes, disposed materials will not be dispersed. Dispersal sites, on the other hand, are characterized by vigorous reworking by waves and currents and from which sediments will be broadly disseminated. In relatively clear and shallow coastal waters, remote sensing may be useful in identifying potential disposal sites. Changes in bathymetry, bed form movement, and near-bottom turbidity are indications of bottom stability.

F. References

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