

CHAPTER 25

SHELL DREDGING AS A FACTOR IN ESTUARINE SEDIMENTATION

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ABSTRACT

During the past few decades, industrial demands for buried shell have been rapidly increasing. Highway construction, the petrochemical industries, and cement manufacturers are among the major users of shell. Semi-fossil oyster shell is found in tidal embayments in deposits of varying thickness and is dredged from depths varying from two or three feet up to forty feet by suction type hydraulic dredges which often discharge wash waters immediately into the surrounding embayment.

Because shell deposits are often covered with several feet of overburden, large quantities of silt and clay are pumped on board the dredge with the shell. On the dredge the shell is washed, screened, and loaded onto barges. Unwanted shell fragments and sediments are then pumped overboard with the wash water.

Considerable quantities of estuarine sediments are placed into motion by continuous dredging operations and uncontrolled dredging can lead to serious depositional problems. Exposed shellfish producing reefs can be damaged, small craft channels can be filled, and vital shore protection can be removed in instances where shell dredging is uncontrolled.

INTRODUCTION

During the past several decades industrial demands for buried oyster shell have been increasing at a very rapid rate. Commercially shell has a multitude of uses with perhaps one of the most important being its use in the construction of road bases in coastal areas. Shell is also used as a surfacing material, as an aggregate in concrete, as a pad for drilling operations, and it is used in the manufacture of chemicals, lime, cement, glass, plastics, and even in poultry feeds. Along with oil, natural gas, and commercial fisheries, semi-fossil oyster shell necessarily must be considered as one of the important and vital natural resources found in tidal embayments. Unlike commercial fisheries, buried shell is a non-replenishable resource. Shell deposits have semi-fossil characteristics and several hundred years are required to

build deposits of sufficient thickness to be economically dredged.

LITERATURE REVIEW

Dredging for buried shell has been carried on for more than fifty years in many of the tidal waters of the Gulf Coast states. Most major shell dredging operations involve more than one dredge and are capable of producing millions of cubic yards of shell annually. Permits granted to shell dredgers generally contain clauses authorizing state conservation agencies to control dredging operations and to insure that no damage is done to other natural resources. While shell dredging has had a long and successful history, relatively few systematic investigations have been carried out to determine the effects of shell dredging on other natural resources.

Mackin (1961) has traced the history of dredging and its relation to oyster reefs back to the work of Cary in Louisiana in 1906. For the results and conclusions of these early studies the reader is referred to the work of Mackin and the extensive bibliography included with his paper.

More recently, in a Master's thesis, Wilson (1950) reported on a study of the effects of shell dredging on oysters in Copano Bay, Texas. Based on his data, Wilson reported that turbidities of 4,000 parts per million could be found close to the outlet of a dredge, and that these turbidities were harmful to oysters. Wilson further summarized four factors which determined the movement and deposition of suspended material in Copano Bay to be: (1) The composition of the material; (2) The flocculation of silt and clay in sea water; (3) Wind action; and, (4) Bottom topography. Wilson further summarized that the movement of suspended material and resulting sedimentation was significant up to distances approximately 300 yards from the dredge and that bottom basket traps within 300 yards of the dredge were always covered with sediment if they were set at a location that was at the same depth as the surrounding bottom. When the traps were set above the bottom they were not silted unless spoil was deposited directly on them. Wilson further summarized that controlled dredging may be beneficial to oyster production and that the excavations made by the dredge furnished a better supply of water for the oysters.

R. Ingle (1952) studied dredging in some Florida bays. Among the principal conclusions of R. Ingle's study were that the flow of water determines the direction of transport of suspended material and, in general, the distance suspended material is carried depends on the size of the particles within the suspensoid and the speed of the current with which the particles are transported. Ingle also reported that water

moving at a given level may be deflected upward as it passes over a ridge causing the suspension of finer particles and enhancing transport ability. Ingle reported it was logical to assume that for any dredging situation there exists a point beyond which heavier particles will not be deposited in any appreciable amount. Beyond this point Ingle reports that only fine materials would be in suspension and could be expected to continue to be transported indefinitely. Furthermore, since these fine sediments would probably not remain on oyster reefs for any length of time they would not have any effect on oyster mortality. Ingle further recommends that "controlled" dredging be used based on local variations in sediment, tides, depths, etc.

Mackin's study (1961) was of channel dredging and silting in Louisiana and of the effects of dredging on oysters in some shallow bays of Louisiana. The study consisted of three case histories of dredging; first, that of a hydraulic dredge, secondly, that of a clam dredge operating in a channel, and thirdly, that of a hydraulic dredge releasing sediment in a half circle. Mackin concluded that silt was carried a maximum distance of 1,300 feet from a working dredge with rapid dispersal by dilution and sedimentation. A maximum of one percent of the sediment drifted away from the site of dredging operation, and turbidities beyond a few hundred feet did not exceed the natural level of 20 to 200 parts per million. Experiments showed no harmful effects on oysters for turbidities up to 700 parts per million.

Although some rather detailed studies have been carried out on the effects of shell dredging, there is little unanimity in the conclusions that have been reached. It is interesting to note in the literature that many of the studies have been carried on with little concern for the basic concepts of estuarine sedimentation. Many authors have used some measure of turbidity as an indication of sediment movement and deposition. Turbidity, however, is not always dependable because suspensions having the same concentrations of sediment may give entirely different readings of turbidity, as determined for example by the Jackson Candle, simply because of color, mineral composition, or the presence of suspended organic material.

Only little mention has been made of the possibilities of mud flows or density currents of very high concentrations of sediment. Many of the studies on shell dredging have used surface water samples as an indicator of sediment deposition, and little has been said of the flocculation process so important to all estuarine sedimentation processes. For example, R. Ingle's conclusion that the direction of flow of water current determines the direction of transport of suspended material can be quite misleading. This author's experience has been that many times water currents near the bottom of the bay do not follow the same direction as surface currents, and only rarely do ebb currents follow the same

paths as flood currents in wide shallow embayments. In the event that sediments discharged by dredges flocculate into a density current, gravity can become equally important or perhaps more important than currents, and the direction that the sediments move may be totally different than indicated by the surface currents.

There has been a great deal written and said about the effects of shell dredging on shell and fin fish resources and there are numerous unpublished reports, papers, and newspaper articles available to the interested reader. However, many of the conclusions set forth are inconsistent with one another and are based only on very meager field data.

SHELL DEPOSITS

Shell deposits vary both in size and in depth. Surface areas range from a few acres up to several square miles and depths vary from a few feet up to at least forty feet. The depths to which some deposits extend is not accurately known, however, forty feet is about the maximum depth from which dredges can effectively take shell. Shell deposits may be completely buried beneath the floor of an embayment or they may be exposed and in some cases actually rise above the bottom. When the deposits are exposed they provide potential oyster growing areas and in numerous instances may be covered by live oysters. Shell deposits also occur in layers separated by a few feet of fine sands, silts, and clays. It is not uncommon to find layered deposits in which there may be a thin layer of exposed shell followed by two or three feet of sediments and then twenty to thirty feet of buried shell deposit. Because of the oyster growth on these thin layers of shell, valuable deposits are often locked up and not available for commercial use.

The general pattern of stratigraphy in the area of exposed reefs is often that of a fairly homogeneous sequence of fine-grained detrital materials including sands, silts, and clays. This sequence, especially along the flanks of oyster reefs, is occasionally inter-mixed with fine to coarse shell fragments. Lack of distinct bedding can be attributed to the activities of numerous marine burrowing organisms. With constant burrowing, tunneling, and mixing of the sediments by these organisms, little of any original stratification of the sediments is preserved.

In addition to the homogeneous sequence of materials normally found, there are generally numerous occurrences of fine to coarse shell fragments found within cores taken near or on the flanks of present day reefs. These fragments are shell debris from the reefs and are derived from the reef by wave action or by oyster harvesting breaking up shell and scattering the debris along the flanks of the reefs.

Figure 1 is a triangle diagram showing sand, silt, and clay content of the active sediments in core samples taken from the vicinity of reefs in Central and East Central Texas Gulf Coast bays. Typically these sediments are found in the silty-clay class with lesser amounts in the sand-silt-clay, the clay-sand, and sand classes. A close relationship is noted between the results in Figure 1 and those reported by Shepard and Moore (1960).

The sediments found in overburden vary from sands and fine sands down to clays. The change in sediment composition can generally be explained by the energy environment of the sample and the partial source of the sediments. Typically, in shallow water near bay shores, wave action effectively sorts out the finer clays and silt size fraction leaving behind sand particles. As water depths increase away from the shore, the waves become less effective in sorting out the finer particles and the quieter deep water is conducive to the accumulation of silt and clay particles.

The size distribution of the particles in the overburden sediments is important in evaluating the potential deposition from dredging activities. In taking shell, dredges return all sediments to the embayment waters. If the overburden material is composed primarily of sands, rapid deposition will take place and the sediments will not move appreciable distances away from the dredges. On the other hand when sediments are composed mostly of clays and silts, flocculation of the sediments occurs in salt water. Density currents of "fluid mud" may form and movement for appreciable distances may occur.

SHELL DREDGES

Shell dredges all operate in essentially the same manner. Basically the shell is dredged from buried deposits by a cutter head attached to a ladder at the bow of the dredge. The buried shell, along with water and sediments, is taken up by a suction pipe located immediately behind the cutter blade. Shell and sediments are then pumped on board the dredge where they are washed and passed through a series of screens. In some instances the size of the smallest screen is prescribed by the state conservation agency charged with managing shell dredging operations. By controlling the size of the screens, shell of various sizes is separated and then either temporarily stored on board the dredge or loaded directly onto barges by conveyers located on either side of the dredge.

While in the process of digging for shell, a dredge moves ahead by swinging about one of two spuds located at the stern of the dredge and by pulling itself with anchors moved and set with booms located on either side of the bow of the dredge.

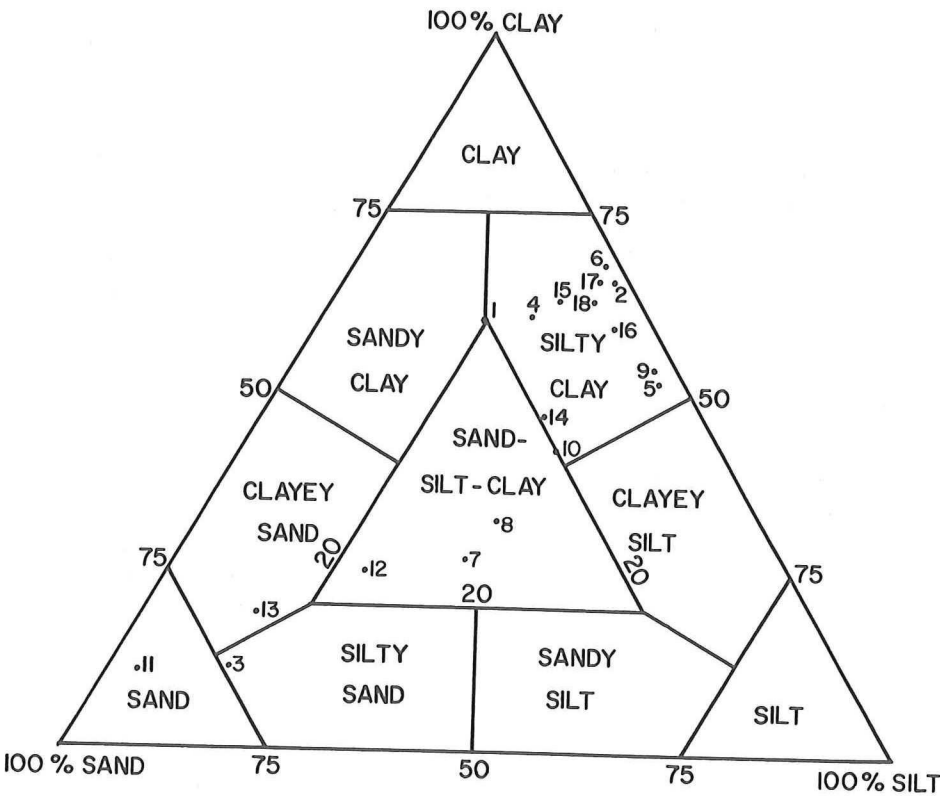


Figure 1. Triangle Diagram Showing Sand-Silt-Clay Content of Active Sediment in Core Samples

The main differences in shell dredges lie in their size and in the manner in which they release wash waters. Some of the largest shell dredges are over 300 feet long and displace over 3,000 tons. These large dredges are capable of digging from depths up to 45 feet with a length of cut over 300 feet. Depending on the capacity and number of pumps, large shell dredges discharge wash water at the rate of over 40,000 gallons per minute, and under continuous operation produce upwards of 300,000 cubic yards of shell per month.

As a general rule, shell dredges discharge along with the wash waters all sediments and shell particles finer than the smallest screen immediately back to the waters of the embayment. Some dredges release all or a portion of the wash water directly through an open discharge pipe. Other dredges return wash waters to the embayment through velocity reduction boxes. Velocity reduction boxes are probably quite effective in promoting the rapid deposition of sands and shell particles. However, the reduction in velocity probably has little effect on the sediment particles in the silt and clay range. Regardless of the type of discharge used, there is generally a great deal of turbulence in the waters immediately surrounding the dredge, so that the finer sediments are kept suspended where they are free to be moved away from the dredge by existing currents.

The amount of sediment any given dredge discharges while digging shell depends primarily on the overburden and the amount of sediment mixed in with the shell deposit. Table 1 shows the range of suspended fixed sediment concentration that could be expected from two different dredges working under different conditions.

Table 1. Suspended Sediment Concentration in Dredge Wash Water.

Dredge	Date	Suspended Fixed Solids mg/l	Remarks
A	12-23-64	7,000	Deep clean shell
A	12-29-64	29,000	Heavy overburden
B	12-23-64	14,000	Layered shell
B	6-25-65	3,000	Deep clean shell

The reported sediment concentrations in Table 1 are for fixed sediments and do not include the volatile solids which may add another three to six

percent to the total suspended solids since the sediments are taken from the bottom.

Dredge size has little to do with the concentration of the suspended solids discharge. The main difference in dredge size results from the time of operation and rate of wash water discharge. Generally the larger dredges operate with fewer interruptions and discharge wash waters at higher rates. Hence, the dredge which operates the maximum amount of time with the highest discharge will introduce or re-suspend in the embayment waters the greatest amount of sediments which eventually must be deposited.

INSTRUMENTATION AND OBSERVATIONS ON SEDIMENT MOVEMENT FROM SHELL DREDGES

A number of different types of devices have been used to observe sediment movement and deposition in the area of shell dredging activities. Among the most common sampling devices are funnel traps, mud boards, core tubes, silt baskets, and water samplers. Funnel traps have been described by Wilson (1950) and Galtsoff (1964). An effective funnel trap used by this author consisted of a 225 ml polyethylene bottle fitted with a cork and a 2-1/4 inch plastic funnel as shown in Figure 2. The funnel trap was attached to a heavy metal screen suspended from a 2 inch x 2 inch stake driven into the shallow bay bottom. Other traps could also be located at various depths by simply attaching other containers to the supporting rope and inserting the traps into the containers. In general the procedure for locating funnel trap stations involves first a visual observation of the movement of sediment from the dredge. After some data is collected and analyzed, the pattern of sediment movement can be determined and additional stations can be established to better define the sediment movement. It should be emphasized that the readings from funnel traps are not measures of the amount of sediment that would deposit in a given area. Actually, the traps catch and hold sediment which would normally pass through the area and perhaps be washed away by tidal currents. The traps are useful mainly to define the extent of sediment movement and to get an indication of the relative intensity of the movement throughout the area affected by a given dredge. For this reason, it is desirable to leave traps out approximately 24 hours so that the sediment movement throughout a tidal cycle can be determined.

A typical mud board for measuring the accumulation of sediment is shown in Figure 3. Such a board is useful for measuring the actual accumulation of sediment in a given area. However, the board does need to be set nearly flush with the bottom of the embayment; and since it cannot be lifted without disturbing the accumulated sediments, observations can be obtained only by a diver.

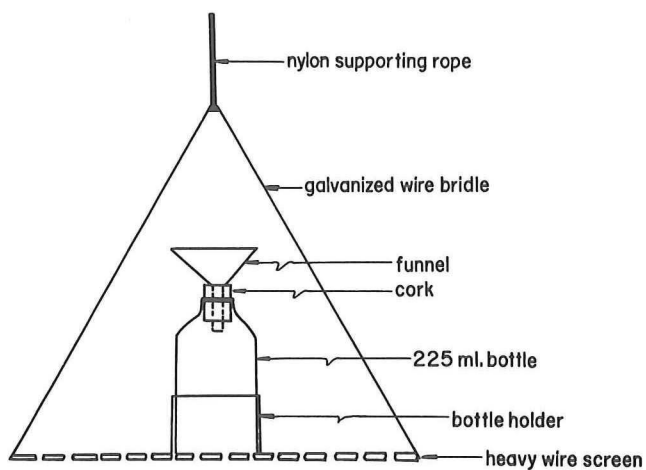


Figure 2. Funnel Trap

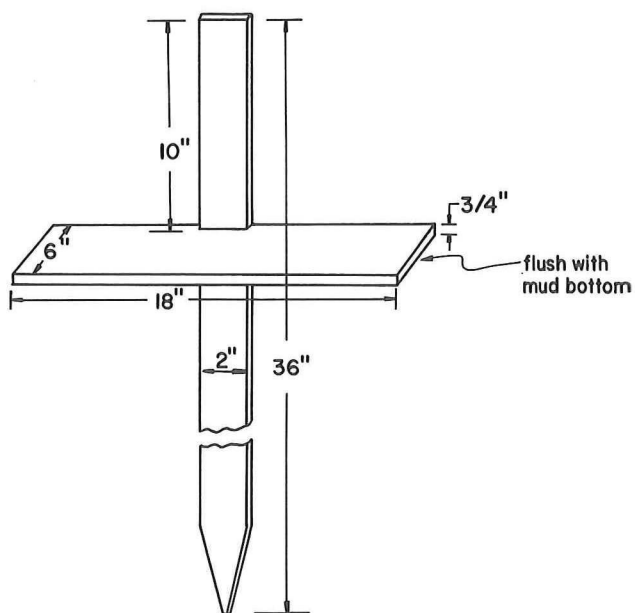


Figure 3. Mud Board (after Galtsoff, 1964)

A simple and effective coring tube has been developed by Mackin (1961) to determine recent deposition in shallow embayments with soft bottoms. This coring tube shown in Figure 4 consists of a plastic tube about 2 inches in diameter and approximately 4 feet in length. The tube is attached to a handle which can be made either of wood or 1/2 inch galvanized pipe. Also mounted on the handle is a guide for directing a stopper into the upper end of the tube. The bottom end of the tube may be fitted with a sharpened steel edge to facilitate forcing the tube into the bottom muds. As the tube is inserted into the bottom, water passes up through the valve at the top of the tube. When the core tube is withdrawn from the bottom the stopper seats in the top of the tube allowing some of the bottom muds and the column of water above these muds to be withdrawn. The principal disadvantage in the use of this coring tube is that some of the bottom sediments often fall out from the bottom of the tube, and disturb the water column collected above the sediment sample.

A fourth very simple method that can be used to determine the relative intensity of deposition are silt baskets. The baskets are made up of a 1 inch mesh chicken wire folded to form a basket about 2 feet square. The basket is filled with clean oyster shell and is attached by a nylon rope to a 2 inch x 2 inch stake driven in the bay bottom. In order to obtain an indication of the relative intensity of sediment activity observed on the baskets, it is recommended that numbers be assigned for different silt basket readings, such as defined by Murray (1965), Table 2,

Table 2. Scale for Sediment Basket Readings.

Scale	Description
0	Clean
1	Trace
2	Coating
3	Layer
4	Heavy Layer
5	Buried

Figure 5 is a photograph of a silt basket with a scale reading of 2. The scale is obviously subject to personal interpretation. However, it does provide some standardization and gives a very quick indication of relative sediment activity.

One of the most effective methods for collecting water samples was

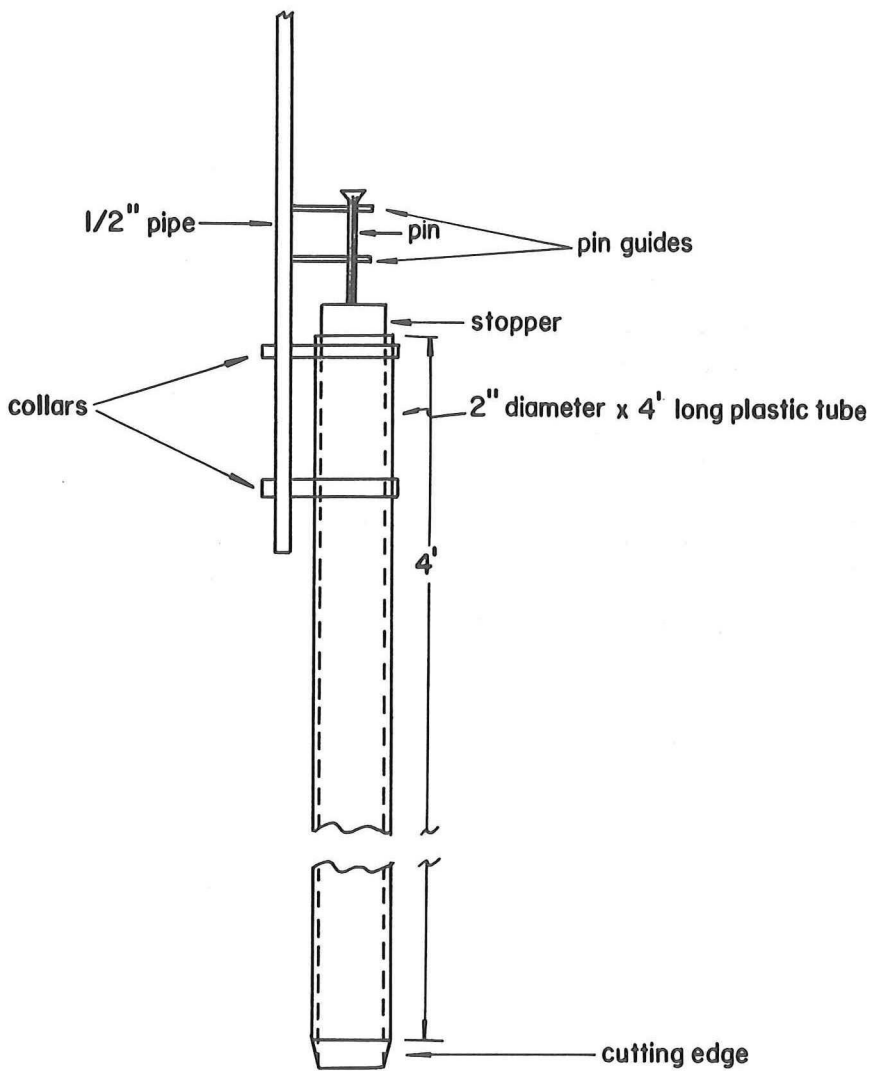


Figure 4. Coring Tube (after Mackin, 1961)

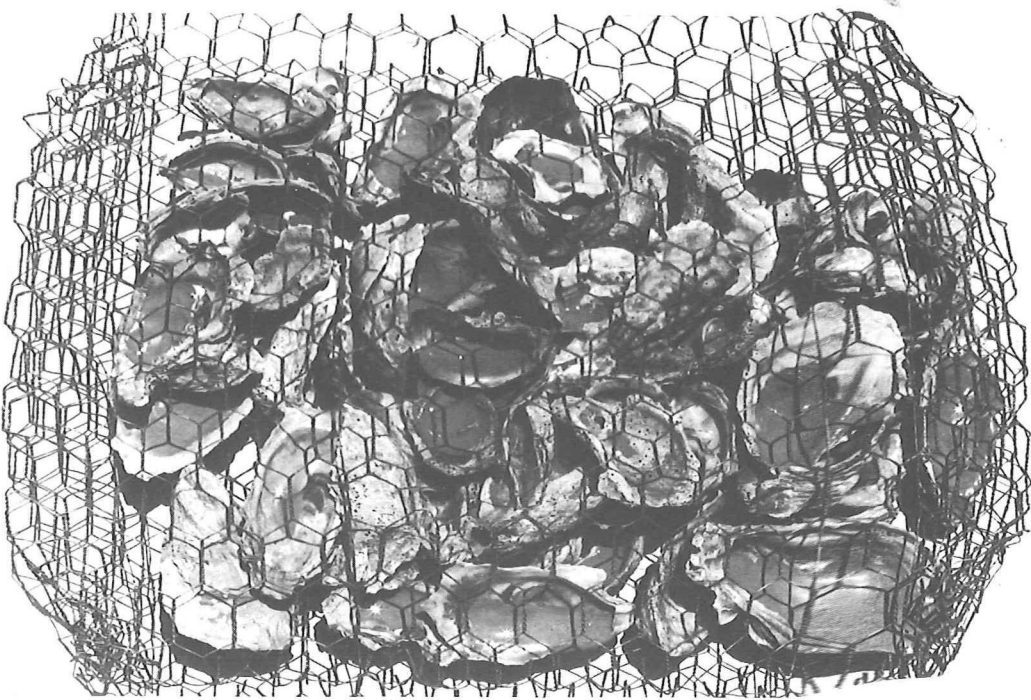


Figure 5. Silt Basket - Scale 2. (photograph)

with the sampler shown in Figure 6. This sampler consisted of an 8 inch long x 2 inch diameter Lucite tube with a small rubber valve attached to the bottom of the tube. The upper end of the cylinder was closed with a rubber stopper which was fitted with Saran tubing and an aquarium valve. Water samples were collected by first closing the empty plastic tube with the stopper, thereby building up pressure within the tube. The closed tube was adjusted on a metal pipe so that the bottom of the sampler was at the depth from which a water sample was desired. The aquarium valve was then opened, the inside pressure was relieved, and water flowed into the tube through the ball valve. These samplers were tested in aquariums containing soft clay bottoms to determine whether sediments were sucked from the bottom. These tests showed that in general no sediments were sucked from the bottom by the sampler even though the sampler was within less than an inch from the bottom. These samplers had the added advantage that several of them could be attached to a single 1/2 inch pipe so that it was possible to take point water samples over the entire depth simultaneously.

DISCUSSION AND CONCLUSIONS

Two factors seem to be particularly pertinent to the movement of sediments from shell dredging operations. First, for appreciable sedimentation to occur on exposed reef areas, the reef must be covered by a layer of sediment several inches in thickness. This layer must be composed of fine sediment concentrations greater than about 10 grams per liter so that the settling within the layer is hindered. Figure 7 shows a suspended sediment concentration profile for a dredge working in Galveston Bay, Texas. This profile was taken in 10 feet of water and at a distance of 600 feet from the dredge. The profile was obtained using the water sampler of Figure 6. The thickness of the mud layer was about 10 inches and concentrations within the layer were in excess of 100,000 mg/l at 6 inches above the bottom, and more than 160,000 mg/l at 3 inches above the bottom. The concentrations of sediment found within the density current are over the 10 grams per liter required for hindered settling. It is primarily due to this hindered settling and the interference of particles or flocs with one another that prevents the complete settlement and allows the sediments to flow as density currents for relatively long periods of time.

Such mud layers generally form only when dredges operate in shell covered by relatively large overburden or in layered shell deposits separated by two or three feet of mud. Furthermore, it appears that for the layer to form, the overburden, or mud layers, must consist of more than about 80 percent by weight of particles smaller than .0625 mm, of which about 50 percent by weight or more should be in the clay range or less than .0039 mm. When dredges operate in areas in which sediments contain large quantities of sand, deposition of the sands occurs very

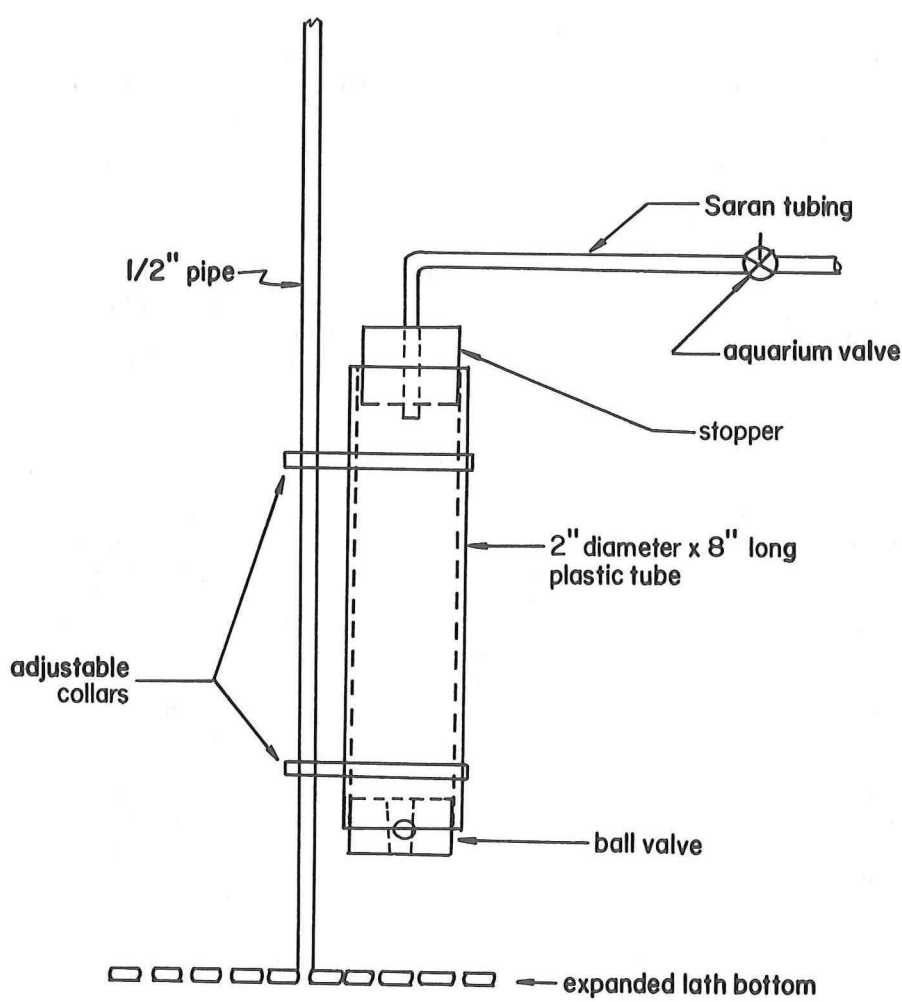


Figure 6. Point Water Sampler

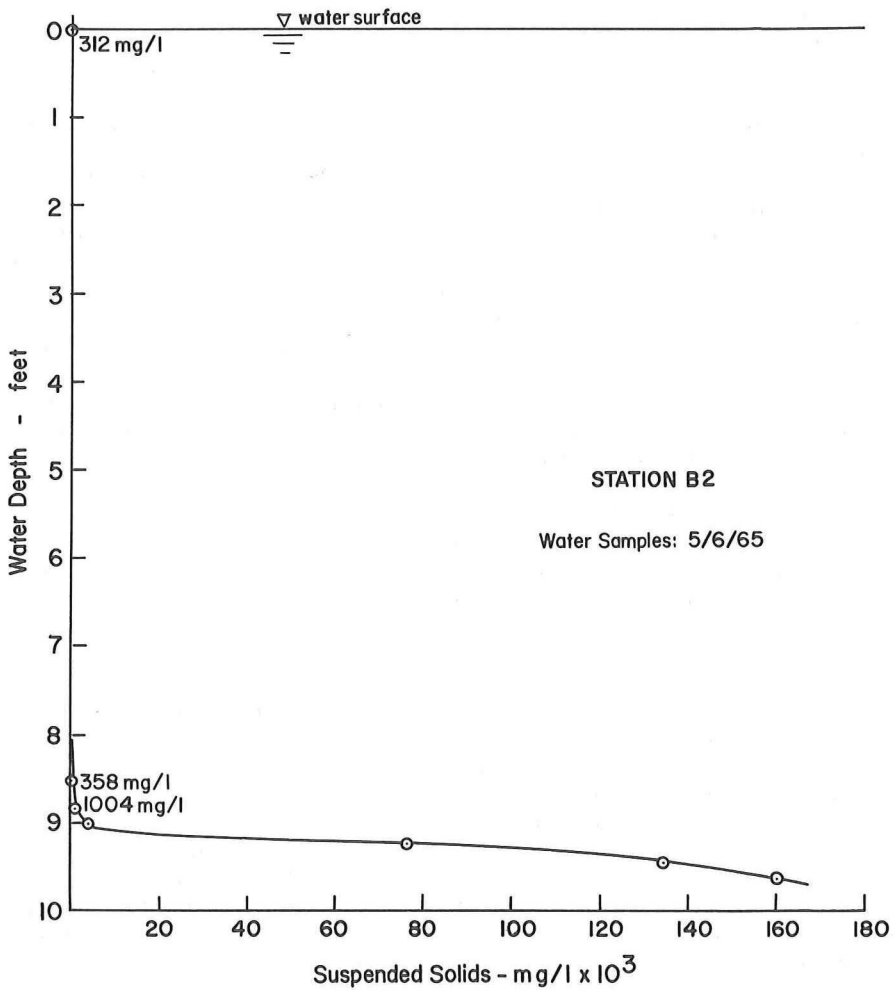


Figure 7. Suspended Sediment Concentration Profile

rapidly and settle out in the immediate area of the dredge unless water currents and turbulence in the area are of sufficient magnitude to keep the sand particles suspended where they can be moved by currents.

A second factor which appears to be of significance to reef deposition is reef topography. Shell reefs which contain a rise of a foot or more above the bay bottom seem to be less susceptible to deposition than those that do not rise above the bottom of the embayment. The reason for this can be related to the flow of the sediment as a density current. When density currents encounter a barrier such as would be provided by the rise in a reef, they are deflected in an upward direction, the height to which they rise being determined by the difference in density between the sediment layer and the surrounding waters. In the presence of a rise in the reef either one of two things appears to happen. If the rise of the density current is higher than the top elevation of the reef the sediment layer is swept over the top of the reef by the accelerated flow. Usually such an occurrence is accompanied by separation and turbulence so that the flocs are broken up and the sediment is re-suspended. This combination of turbulence and accelerated flow keeps the sediment from depositing on the reef. If the density current does not rise above the reef it piles up and then flows by gravity along the sides of the reef and even back in the direction from which it came. Figure 8 shows the concentration distribution of sediment from funnel traps along the edge of a reef containing a one foot rise. When reefs have no rise above the bottom of the bay, they are vulnerable to deposition from sediment density currents. Since the reefs provide no barrier the density current can flow over the reef covering areas of over 50 acres at a time with a mud layer 6 to 8 inches thick.

Sediments which move onto reefs in this manner can be washed off in some cases. However, such washing of sediments on and off of reefs is dangerous, and if allowed to go unchecked will generally result in actual deposition within a couple of days. Even though settling is hindered in the density current, consolidation of the flocculated particles takes place and the layer gains strength. Within a couple of days the layer usually has sufficient strength to resist the shear produced by low magnitude tidal currents and is no longer capable of being moved around by currents. Continued dredging in an area where such washing occurs can only aggravate the problem as more sediments are fed into the density layer.

Dredging on either an incoming or outgoing tide has been proposed as a method to reduce reef deposition. However, for such methods to be effective sediments must be gotten rid of on the tide during which the dredge is in operation. In the event a density current forms and is not carried away from the area to be protected it may wash back onto flat reef areas during the reverse tide even though the dredge is not in operation.

It has also been reported that such factors as the direction of dredge

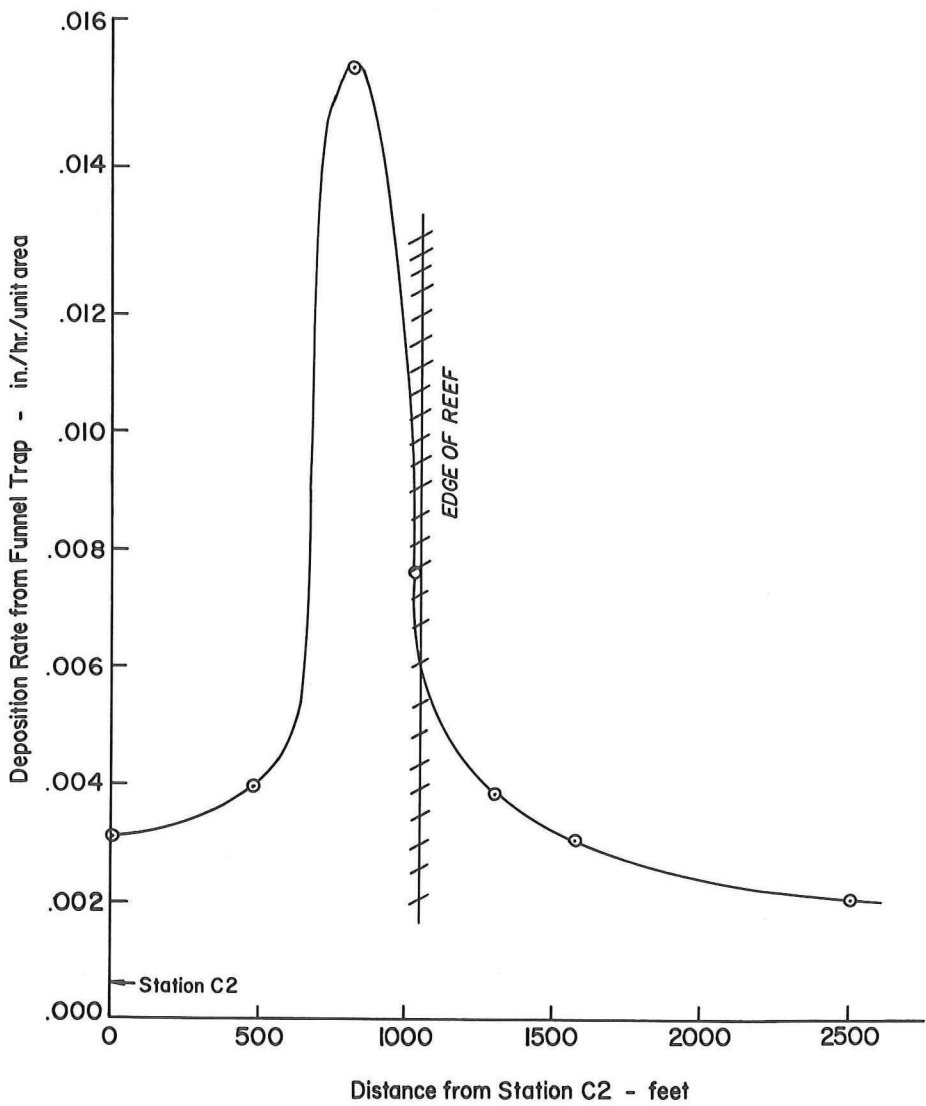


Figure 8. Distribution of Deposition Rate Across a Reef with a Rise

cut, the heading of the dredge, the type of waste discharge, among other things, are important to the understanding of sediment movement from dredges. It seems that most all examples of actual reef deposition can be explained in terms of the density current and the reef and surrounding topography. The main effect of dredge heading and direction and length of cut would be only in the location of the discharge point. Because of the size of many shell dredges, the point of wash water discharge can vary up to a couple hundred feet. Velocity reduction boxes would be useful only for speeding up the deposition of sand and shell particles, and unless deposited right on a reef so as to bury exposed shell, sand and shell particles are relatively unimportant to the movement of dredge sediments. Instead it is the fine silt and clay particles that are affected more by electro-chemical forces than by weight forces, that determine the extent of the movement of dredge sediments.

Finally, it should be noted that the deposition of some loose clay sediments is not necessarily damaging to an exposed reef from a physical point of view. However, from a biological basis other problems may arise during the deposition period which affect the entire ecology of the food chain and other natural biological processes and produce damage to live oysters. Physically, however, those sediments which may be several inches in thickness at the time of deposition consolidate and compact under natural hydro-static pressure to a fraction of their original thickness. Hence, in a short time even though the sediments do not wash off, they may compact to negligible thickness and produce no physical damage provided the dredging operation which produced the sediment was stopped and no more sediment re-suspended in the immediate area.

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