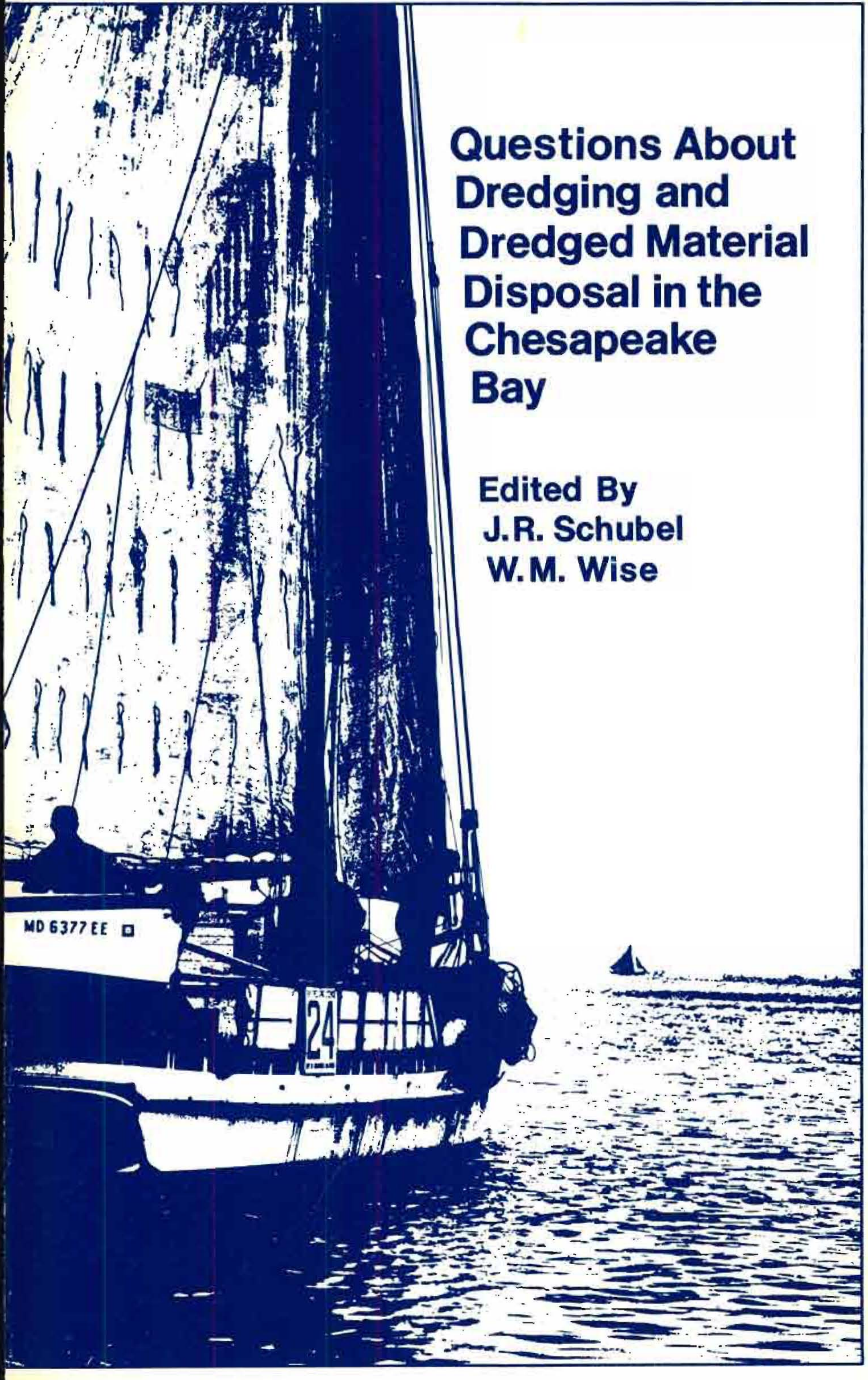
Questions About Dredging and Dredged Material Disposal in the Chesapeake Bay

Edited By
J.R. Schubel
W.M. Wise



QUESTIONS ABOUT

DREDGING AND DREDGED MATERIAL DISPOSAL

IN THE CHESAPEAKE BAY

Edited by:

J. R. Schubel

W. M. Wise

Prepared by:

S. Bayley
H. J. Bokuniewicz
O. P. Bricker
B. H. Brinkhuis
M. M. Bundy
K. N. Chytalo
L. E. Cronin
W. B. Cronin
M. G. Gross
F. L. Hamons, Jr.
D. J. Hirschberg
D. W. Pritchard
W. H. Queen
J. R. Schubel
W. R. Taylor
O. W. Terry
P. K. Weyl
W. M. Wise

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J.R. Schubel

J. R. Schubel, Director

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1. INTRODUCTION

Oystermen in Chester River.

1.1 WHAT IS DREDGING AND WHY IS IT NECESSARY?

Dredging is the removal of submerged materials by hydraulic or mechanical means. Dredging is most commonly used to create or maintain waterways or to gather materials (often sand and gravel) for fill, construction aggregate, or other commercial purposes.

Dredging is necessary to maintain the depth of many shipping channels and that of the water adjacent to many docking facilities, including those used for recreational boating and commercial fishing. Estuaries, including the Chesapeake Bay, are areas of rapid sedimentation. If there were no more dredging, harbors would gradually fill and marine transportation would be severely limited. Recreational boating, commercial and recreational fishing and naval operations would be hampered by reduced access to shore facilities.

1.2 WHAT WAS THIS BOOKLET DESIGNED TO DO?

This booklet was designed to provide, when read from start to finish, an over-view of the history of dredging and dredged material disposal in the Maryland portion of the Chesapeake Bay, an assessment of how these activities have affected the Bay and its biota, an examination of alternative modes of disposal, and a general discussion of research priorities. It was also designed to provide answers to specific questions you may have about these topics without having to read the entire volume.

The questions were compiled at a series of workshops in which scientists, environmental decision makers, and lay people participated.

1.3 HOW SHOULD YOU USE THIS BOOKLET?

This booklet can be read in conventional fashion and/or be used as a reference document to answer specific questions. To find answers to specific questions, identify the subject area in the Table of Contents and proceed to the indicated page.

1.4 WHAT UNITS ARE USED?

Units are reported in British engineering units to conform with standard dredging terminology. Metric equivalents are usually presented. The Table below gives factors for converting British engineering units to metric units.

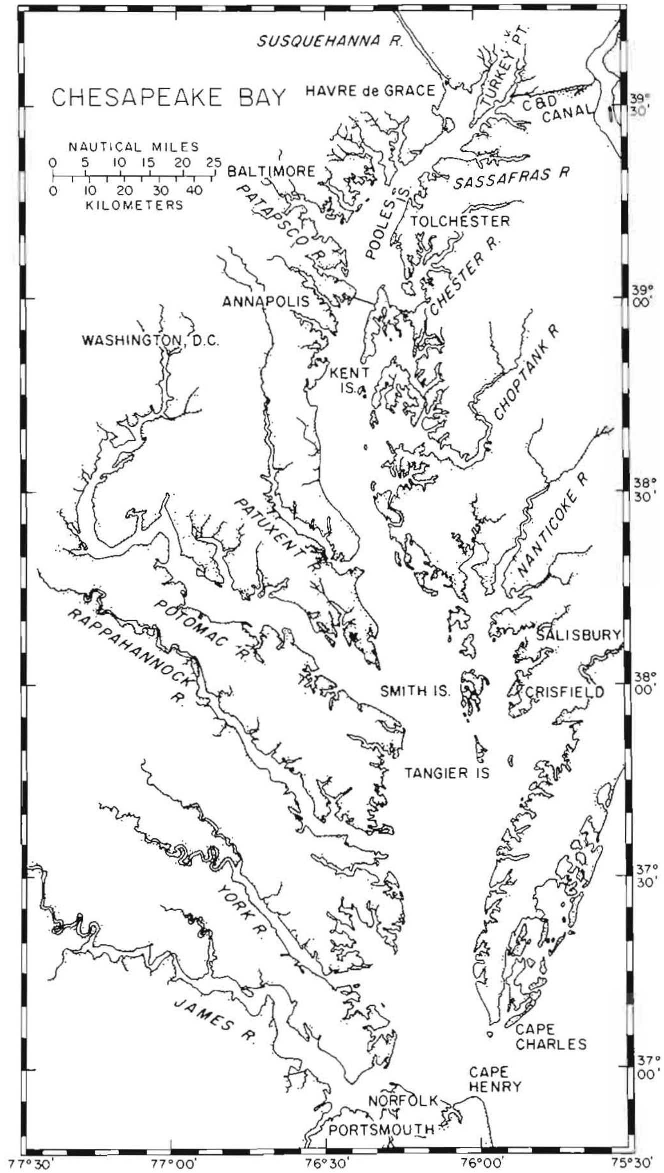
Table 1.4

Conversions from British Engineering to Metric Units.

To Convert From	To	Divide By
inches (in)	centimeters (cm)	0.3937
feet (ft)	meters (m)	3.2808
nautical miles (NM)	kilometers (km)	0.5396
sq. statute miles (mi^2)	sq. kilometers (km^2)	0.3861
acres	sq. kilometers (km^2)	247.1054
cubic feet (ft^3)	cubic meters (m^3)	35.3147
cubic yards (yd^3)	cubic meters (m^3)	1.3080
feet/sec (ft/s)	centimeters/sec (cm/s)	0.3208
knots	meters/sec (m/s)	1.9425
short tons	metric tons	1.1023

2. THE CHESAPEAKE BAY: A GEOLOGICAL PERSPECTIVE

The Susquehanna River at Conowingo (MD) during Agnes, June 1972.



Map of Chesapeake Bay.

2.1 WHAT IS THE CHESAPEAKE BAY?

The Chesapeake Bay is an estuary--a semi-enclosed, coastal body of water having free access to the ocean and within which seawater is measurably diluted by freshwater from land drainage. Freshwater from numerous rivers and streams is mixed within the semi-enclosed Chesapeake Bay basin with seawater that enters through the Virginia capes. The mixing, primarily by tides, produces density gradients that drive the characteristic two-layered circulation pattern that eventually leads to the discharge of the freshwater into the Atlantic Ocean.

The Chesapeake Bay is actually a complex estuarine *system* made up of the Bay proper and its tributary estuaries.

Pritchard, D. W. 1967. What is an estuary: physical viewpoint. Pages 3-5 *in* G. H. Lauff, ed. Estuaries. Amer. Assoc. Adv. Sci., Wash., D.C.

2.2 HOW AND WHEN WAS THE CHESAPEAKE BAY FORMED?

The Chesapeake Bay and all other present day estuaries were formed by the most recent rise in sea level which began approximately 15,000 to 18,000 years ago. During the last glacial stage (the Wisconsin), the level of the sea was about 410 ft (125 m) below its present level and most of the continental shelves of the world were exposed to the atmosphere. With the melting and retreat of the great ice sheets, sea level rose rapidly from about 15,000 years ago until about 9,000 years ago when it reached a position approximately 66 ft (20 m) below its present level. By 3,000 years ago the level of the sea was within 10 ft (3 m) of its present position; since then the sea has risen more slowly.

As the sea rose, it advanced across the previously exposed continental shelf. It invaded numerous coastal embayments and produced estuaries in those that received enough freshwater to measurably dilute the encroaching seawater. The advancing sea reached the present mouth of the Chesapeake Bay basin less than 10,000 years ago. The sea penetrated into the Bay basin, drowning the ancestral river valley system which was carved during the previous lowstand of sea level, transforming the riverine system into an estuarine system.

The Chesapeake Bay is a classic example of a drowned river valley estuary. The age of the *estuary* decreases from mouth to head; the northern Chesapeake Bay estuary is, then, very young geologically.

Schubel, J. R. 1972. The physical and chemical conditions of the Chesapeake Bay. J. Wash. Acad. Sci. 62(2):56-87.

2.3 WHAT ARE THE NATURAL GEOLOGICAL PROCESSES AFFECTING THE CHESAPEAKE BAY? HOW DO THEY AFFECT IT?

Like other estuaries, the Chesapeake Bay is an ephemeral feature on a geologic time scale. It is being rapidly filled with sediments; sediments from rivers, from shore erosion, from the remains of organisms, and from the sea. As the Bay contracts in volume, depth, and eventually in area, the intruding sea will be displaced progressively seaward, transforming the estuary back into a river valley system. Typically, estuaries fill from their heads and their margins. An estuarine delta usually forms in the upper reaches of the estuary--near the new river mouth. The estuarine delta grows progressively seaward, extending the realm of the river and thereby expelling the intruding sea from the semi-enclosed coastal basin. Lateral accretion by marshes may also play a major role. As a result of these processes, the estuarine basin is converted back into a river valley. Finally, the river reaches the sea through a depositional plain and the transformation is complete. This is the general sedimentation pattern observed in Chesapeake Bay. Sedimentation rates in the upper reaches of the Bay are more than ten times higher than farther seaward.

If relative sea level remains nearly constant, this process will take, at most, a few tens of thousands of years to complete. If relative sea level falls, the Chesapeake Bay estuary's lifetime will be shortened. If relative sea level rises, the life of the estuary will be prolonged.

Schubel, J.R. 1972. The physical and chemical conditions of the Chesapeake Bay. J. Wash. Acad. Sci. 62(2):56-87.

2.4 WHAT ARE THE SOURCES OF MOST OF THE SEDIMENT DREDGED IN THE CHESAPEAKE BAY?

Estuarine sediments come from three principal sources: river inputs, shore erosion, and the skeletons of organisms that live in the water (plankton) and on the bottom (benthos). Near the mouths of some estuaries, including the Chesapeake Bay, the ocean may also be an important source of sediment; sands are moved into the estuary from the adjacent continental shelf. The sources of sediment are thus external, marginal, and internal to the estuary. The relative importance of each source varies with time and space. In regions far from river mouths and from shore, the remains of planktonic organisms account for a larger percentage of the sediments than in regions closer to shore or nearer river mouths.

Rivers tributary to the Bay are not necessarily sediment sources to the main body of the Bay. Most of the tributary rivers (e.g., the Potomac, Patuxent, James, Rappahannock, etc.) discharge into estuaries of their own far upstream from their junctures with the Bay proper. Each of these estuaries traps most of the river-borne sediment discharged into it, and little of this material reaches the main body of the Bay. The only river that discharges directly into the Bay is the Susquehanna, which enters at its head.

The Susquehanna is the dominant source of river-borne (fluvial) sediment to the Bay proper and most of its sediment load is deposited in the upper reaches of the Bay--north of the mouth of the Patapsco estuary. In this segment of the northern Bay, the Susquehanna is the principal source of sediment; shore erosion contributes less than 20-25% of the total sediment input; biological productivity less than 5-10%. Thus, most of the sediment

Coastline near Grove Point in Upper Chesapeake Bay.

that must be dredged from the main body of the northern Bay is fluvial in origin, but the coupling between "source" and "sink" is not so direct. More than 70% of the annual discharge of sediment from the Susquehanna occurs within a few weeks during the spring freshet. This sediment is deposited over the upper Chesapeake Bay in a layer that decreases in thickness seaward from the head of the Bay at Turkey Point. The sedimentation rates in dredged channels are much greater than can be accounted for by the river input, or indeed by inputs from all sources. Sediments are continually being resuspended and redistributed by wind waves, and particularly by tidal currents. Dredged channels are effective traps for these moving sediments and, as a result, their sedimentation rates are much higher than in contiguous shallower areas.

The major sediment source to Baltimore Harbor is probably the suspended sediment of the main body of the adjacent Bay. Direct river input of sediment to the Harbor by the Patapsco River is small and embayments like Baltimore Harbor are often very effective sediment traps. The sediments of Baltimore Harbor are similar in their physical properties to the sediments accumulating in the main body of the Bay. They are, however, more contaminated because of local sources of industrial pollutants and the strong affinity many contaminants have for fine particulate matter.

Farther seaward in the Bay, south of the mouth of the Patapsco estuary, shore erosion and primary production become increasingly important as sources of sediment; the strengths of these sources increase relative to the fluvial input. In the middle and lower reaches of the Bay, sediments from shore erosion and primary productivity combined may exceed the input from rivers.

Schubel, J.R. and H.H. Carter. 1977. Suspended sediment budget for Chesapeake Bay. Pages 48-81 *in* M. Wiley, ed. Estuarine Processes, Vol. II. John Wiley and Son, New York.

2.5 WHAT ARE THE IMPACTS OF MAN'S ACTIVITIES ON SEDIMENTATION RATES IN CHESAPEAKE BAY?

Agriculture, urbanization and other disturbances of the soil increase the rate of soil erosion and add sediments to streams. These sediments are carried downstream to the estuary thus increasing the need for dredging. Ever since the first European settlers landed, man has affected the amount of sediment in streams draining North America. The influence of man on sedimentation is especially well documented in the Chesapeake Bay region, where clearing of forests and wasteful farming practices (especially those used in raising tobacco) contributed enormous loads of sediment to the rivers. Clear streams became muddy and once relatively deep harbors at the heads of a number of the tributaries were filled with sediment. Sediment yields were increased 10 to 100 times over precolonial levels. Even today, streams that drain farmlands in many mid-Atlantic states carry about 10 times as much sediment as those that drain equivalent areas of forested land.

Urbanization is the most recent of man's activities to contribute large amounts of sediment to streams. Sediment loads derived from land being cleared or filled for the building of houses, roads, and other facilities are best documented in the area between Washington, D.C. and Baltimore, Md. During construction of housing developments, shopping centers, and highways the soil is disturbed and left exposed to wind and rain. The concentration of sediment in storm runoff from construction sites is 100 to 1,000 times what it would be if the soil had been left in its natural vegetated state. Even though the soil is left exposed to erosion of this intensity for only a short time--a few years at most--the amount of land cleared

Bay has acted to decrease the input of fluvial sediment to the Chesapeake Bay estuarine system. Whether reservoirs are built for hydroelectric power, flood control, water supply, or recreation, they share a common feature--the ability to trap sediment. Even a small reservoir can trap a significant proportion of a river's sediment load. A reservoir that can hold only 1% of the annual inflow of water is capable of trapping nearly half the river's total sediment load. A reservoir whose capacity is 10% of the annual water inflow can trap up to 85% of the incoming sediment load.

The net effect of man's activities has no doubt been to increase the sediment input to the Chesapeake Bay system, but we cannot say by how much. Although reservoirs have reduced the sediment discharge of the Susquehanna and several other rivers that discharge into the Chesapeake Bay, they have only partly offset the influences that caused the increased loads in the first place. Furthermore, sediment takes decades to move through a river system. Much of the sediment released by past mistakes--such as poor soil conservation practices associated with agriculture and urbanization/suburbanization--is still in temporary storage in the river valleys in transit between its sources and the Chesapeake Bay estuarine system. Even if the active supply of sediments to the Bay's tributary rivers were completely checked today, many decades would pass before the sediment loads would drop to their natural, pre-colonial levels.

Schubel, J.R. and R.H. Meade. 1977. Man's impact on estuarine sedimentation. Pages 193-209 *in* Estuarine Pollution Control and Assessment. Proceedings of a Conference, Vol. I. U.S. Environmental Protection Agency, Office of Water Planning and Standards, Wash., D.C.

for new housing and ancillary uses in the Washington-Baltimore area has been so great in recent years that the contribution of sediment is significantly large. The U.S. Geological Survey has estimated that the Potomac River receives about a million tons of sediment per year from streams that drain the metropolitan Washington area. This is about the same amount of sediment that the Potomac River brings into the Washington area from all its other upland sources.

Another of man's activities that increases the sedimentation rates of estuaries is the disposal of dissolved phosphorus, nitrogen, and other plant nutrients into rivers and estuaries. Municipal sewage effluents, including effluents that have received secondary treatment--the highest degree of conventional treatment--contain high concentrations of nutrients. In some areas, agricultural runoff from fertilized croplands and animal feedlots also contributes nutrients to rivers and estuaries. These nutrients promote the growth of diatoms and other microscopic plants (phytoplankton) in the rivers and in their estuaries. The mineral structures formed by many of these organisms persist after the organisms die and become part of the sediment loads of the rivers and the sedimentary deposits of the estuaries.

The effects of nutrient loading from municipal wastes on primary productivity are readily observable in the Potomac estuary, in Baltimore Harbor and in the Back River estuary. Stimulation of plant growth by nutrient-enriched runoff from agricultural areas is apparent in the upper reaches of Chesapeake Bay--the estuary of the Susquehanna River.

Man's activities can also decrease the inputs of sediment to estuaries. The construction of reservoirs on the Susquehanna and other rivers tributary to the Chesapeake

2.6 WHAT ARE THE ESTIMATED SHOALING RATES IN THE MAIN BODY OF UPPER CHESAPEAKE BAY AND ITS CHANNELS?

The shoaling rates in the Bay have been estimated in two different ways. The first was by estimating the inputs of sediment from rivers, shore erosion, and biological production; the loss of sediment to more seaward segments of the Bay; and assuming that the difference between these two numbers represents the mass of sediment deposited on the floor of the upper Bay. This is the "mass balance" or "sediment budget" approach. The second method by which the sedimentation rate has been estimated is by using radioactive elements which occur naturally in all sediments to "date" sediment cores.

The Maryland portion of the main body of the Bay can be roughly sub-divided, on the basis of shoaling rate, into two segments. One segment extends from the head of the Bay at Turkey Point south to about Tolchester; the second extends from Tolchester south to the Maryland-Virginia line. Each of these segments can be further subdivided into near-shore sandy areas, dredged channels, and the remainder of the Bay floor.

During the years of normal riverflow--years without large flood events--the average rate of infilling of the upper Bay, Tolchester to Turkey Point, outside of dredged channels and away from near-shore areas is about 0.2-0.3 in/yr (0.5-0.8 cm/yr). The rate is somewhat greater than this in the northern part of this segment. The sedimentation rates estimated for this segment of the Bay by the two methods described above agree very well.

The actual long-term average rate of shoaling of the upper Bay is controlled by the frequency and magnitude of large flood events in the drainage basin of the

Susquehanna River. Recent studies have shown that two large storm events, one in 1972 (Tropical Storm Agnes) and one in 1936 have contributed at least half of all the sediment deposited north of Tolchester since 1900. Historical records show that before 1900 at least three other large floods occurred. These have been identified tentatively in the sedimentary record of the upper Bay as well. The true rate of infilling of the upper Bay, averaged over at least the past 80 years, is about 0.4-1.2 in/yr (1-3 cm/yr).

Sedimentation rates in channels are greater than the rates in shallower areas to either side of the channel. The shoaling rate of the Approach Channel to the Chesapeake and Delaware Canal can be estimated by dividing the average volume of material that would have to be removed to maintain the Channel at its project depth by the area of the Channel and by the period of time between successive dredgings. The Approach Channel is approximately 28.5 NM (52.8 km) in length with an average width of 450 ft (137 m), so it has an area of approximately 7.5 million yd^2 (5.7 million m^2). Maintenance dredging in this channel averages 1.2 million yd^3/yr. The average rate of sediment accumulation in the channel is then about 1.2 million $yd^3 \div 7.5$ million yd^2 $= 0.16$ yd/yr = 6 in/yr = 15 cm/yr.

Deposition in the Channel is also dominated by episodic events. Following the flooding of the Susquehanna associated with the passage of Tropical Storm Agnes in June, 1972, sections of the Chesapeake and Delaware Canal Approach Channel shoaled by as much as 3 ft (1 m) in three days.

Farther seaward in the Bay, the sedimentation rate decreases substantially, but the actual value is not well known. In the main body of the Bay between Swan Point and the Maryland-Virginia line, the average sedimentation rate away from the littoral (near-shore) zone and outside of dredged channels is probably between 0.04-0.20 in/yr (0.1-0.5 cm/yr) with the higher rate being representative of the northern reaches of this segment.

The annual shoaling rate for the Approach Channel to Baltimore Harbor can be estimated by dividing the amount of material that must be dredged annually to maintain the Craighill and Brewerton Extension Channels ($\approx$2 million yd^3) by the area of these channels (8 million yd^2). This method yields a shoaling rate of about 9 in/yr (23 cm/yr).

Schubel, J. R. 1976. Suspended sediment in Chesapeake Bay. Pages 245-264 *in* Ocean Engineering III, Specialty Conference of Amer. Soc. Civil Eng., June 9-11, 1975, Vol. I. University of Delaware.

Schubel, J. R. and D. J. Hirschberg. 1977. Pb^{210} determined sedimentation rate and accumulation of metals in sediments at a station in Chesapeake Bay. Chesapeake Science 18:379-382.

3. THE CHESAPEAKE BAY: HUMAN USES REQUIRING DREDGING IN MARYLAND.

Baltimore Harbor Ore Pier

3.1 WHAT IS THE IMPORTANCE OF THE PORT OF BALTIMORE TO THE ECONOMY OF MARYLAND?

According to a 1973 study of the economic impact of the Port of Baltimore on Maryland, carried out by the University of Maryland, the Port of Baltimore is the most important economic component of the State of Maryland, having a total value of about $2.5 billion each year. The total *direct* impact is greater than $470 million each year while the total *indirect* impact is approximately $1.8 billion. Direct impacts are those that arise directly from the traffic handled by the Port and include: vessel disbursements, crew expenditures, surface transportation, insurance and banking, and port services. Indirect impacts are those which are dependent on the Port but not directly related to the traffic handled by it. These include such categories as port-related primary metals processing, other port-dependent processing, shipbuilding, repair and dismantling, and government expenditures. The study showed that of the direct impacts, the most significant contribution came from the inland surface movement of cargoes which approached $370 million. Primary metals processing, whose total contribution exceeded $900 million, was the most significant of indirect impacts.

The report points out that in 1973 the Port directly employed 65,000 people and that port-related employment added another 104,000 jobs. This total indicates that about 10% of all jobs in Maryland are ultimately dependent on the Port.

In 1973, Maryland had a Gross State Product (GSP) of $25.1 billion. Of this total, the Port was responsible for $317.3 million in tax contributions to the State, county, and local governments of Maryland. Baltimore City

3.2 WHAT TYPES AND LEVELS OF WATER-BORNE COMMERCE TAKE PLACE IN THE PORT OF BALTIMORE?

In 1974, a total of 160 million short tons of cargo was shipped on the Chesapeake Bay. Nearly 40% of this freight (60 million s.t.) passed through the Port of Baltimore, making it the 6th largest international port in the United States. To handle such a large volume of commerce, Baltimore is served by four railroads, over 150 trucking firms, 120 steamship lines and 44 freight forwarders. Complete commercial handling services are provided by nine major international marine cargo terminals.

Water-borne commerce passing through Baltimore is dominated by the transport of bulk commodities, as shown in Fig. 3.2A. Bulk oil, coal, iron ore, and grain account for 77% of the total tonnage passing through the Port. Miscellaneous bulk commodities account for another 7% of the total commerce. Baltimore is basically an import port, Fig. 3.2B. Combined foreign imports and domestic receipts account for 75% of the total traffic in the Port. Petroleum, petroleum products, iron ore, and iron ore concentrates dominate the import commerce in Baltimore. The main export products are grain and coal. Baltimore also ranks first among the nation's ports in the importation of automobiles and automobile equipment and is second in iron ore concentrates and containerized cargo.

For the past several years an average of over 4,000 ships have passed through the Port of Baltimore each year. Approximately 30% of this traffic travels through the Chesapeake and Delaware Canal. Recent projections indicate that the volume of bulk oil and iron ore concentrates entering the Port will double by the year 2020, as will the tonnage of containerized general cargo. Traffic in other commodities is expected to increase at a rate proportional

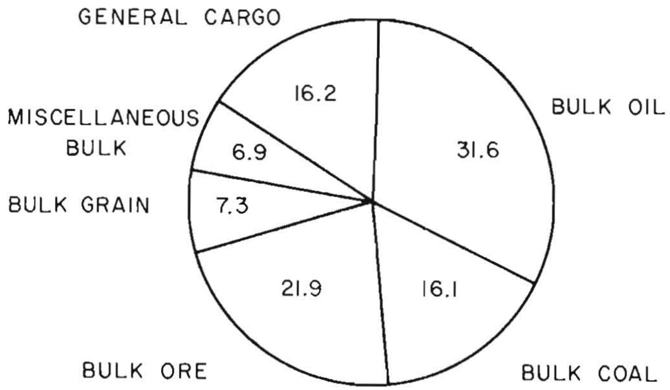


FIG. 3.2A · COMMODITY DISTRIBUTION OF TOTAL WATERBORNE TRAFFIC THROUGH BALTIMORE HARBOR, 1972 (%)

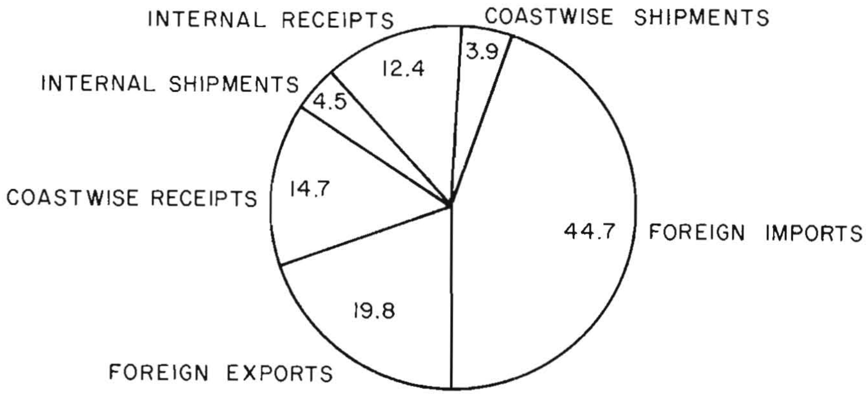


FIG. 3.2B . DISTRIBUTION OF MAJOR TRAFFIC FLOWS THROUGH BALTIMORE HARBOR IN 1972(%)

to the increase in population in various market areas.

U.S. Army Corps of Engineers, Baltimore District. 1977. Chesapeake Bay Future Conditions Report. Vol. 8. Navigation, Flood Control, Shore-line Erosion. 299 pp.

3.3 WHAT IS THE EXTENT OF THE COMMERCIAL FISHERY IN THE MARYLAND WATERS OF THE CHESAPEAKE BAY?

Chesapeake Bay is one of the oldest and most productive estuarine fishing grounds in the United States. Most of the important species in the finfish catch are migratory, entering the Bay in late spring and summer and departing in late fall. Maryland commercial landings from the Bay and its tributaries (including the Potomac River) in 1977 are presented in the Table below. The importance of shellfish to the total landings is apparent, accounting for over 95% of the landed value of the total catch from Maryland waters of the Bay. The oyster *(Crassostrea virginica)* is the dominant species in the catch, in terms of landed value, followed by blue crab *(Callinectes sapidus)* and soft clam *(Mya arenaria)*. The most important finfish in the Bay, in landed value, is striped bass *(Morone saxatilis)*, accounting for nearly 62% of the total landed value of all finfish.

Table 3.3

Commercial Fishery Landings from Maryland Portion of Chesapeake Bay (1977).

Finfish	lb.	$
Alewife	43,514	2,273
Bluefish	140,680	7,113
Carp	56,194	1,193
Catfish/Bullhead	199,050	24,014
Crappie	3,453	336
Croaker	22,493	3,479
Drum	292	23
Eel, Common	77,469	31,247

Table, 3.3 Cont'd

Finfish	lb.	$
Flounder, Fluke	3,495	1,444
Gizzard shad	6,747	67
Hickory shad	313	98
Menhaden	5,314,981	184,470
Mullet	241	36
Sea Trout, grey	14,925	3,057
Shad	50,664	18,502
Spot	4,400	1,004
Striped Bass	1,065,130	627,539
Suckers	651	59
Sunfish	6,959	697
White Perch	566,701	104,813
Yellow Perch	17,062	3,419
TOTAL FINFISH	7,595,414	1,014,883
Shellfish	lb.	$
Crabs, blue		
hard	14,865,179	3,478,452
soft/peeler	1,004,862	1,205,835
Clam, soft, meats	1,594,704	2,574,564
Oyster meats	12,819,759	13,360,731
Terrapin	356	224
Turtle, snapping	22,046	5,453
TOTAL SHELLFISH	30,306,906	20,625,259
GRAND TOTAL	37,902,320	21,640,142

In 1970, over 11,000 boats were engaged in commercial fishing activities on the entire Chesapeake Bay, off-loading at more than 450 wholesale and processing establishments. Many of these port areas require periodic maintenance dredging to preserve water depth in docking basins, turning basins, and access channels to naturally deep water.

National Marine Fisheries Service and Maryland Department of Natural Resources. 1977. Maryland Landing, December 1977. Current Fisheries Statistics No. 7459.

3.4 HOW MUCH RECREATIONAL BOATING ACTIVITY IS SUPPORTED BY THE MARYLAND WATERS OF THE CHESAPEAKE BAY AND WHERE IS IT CONCENTRATED?

As in most coastal areas in the United States, recreational boating activity on the Chesapeake Bay has increased in the past decade. The number of pleasure boats registered in the State of Maryland rose from 62,000 in 1968 to over 113,000 in 1974, an increase of over 80%. This figure is a conservative estimate, because Maryland registration procedures prior to 1974 exempted (1) boats propelled by engines of less than 7.5 hp. and (2) unpowered sailboats under 25' in length, which remain unregistered even under the more inclusive registration procedures currently in effect. Table 3.4 A summarizes the distribution of boating activity in Maryland waters.

Table 3.4 A

Boating Activity Distribution in Maryland

Body of Water		% of All Activity
Patuxent River		1.8
Chesapeake Bay		59.8
from Pooles Island north	13.0	
Pooles Island south to Bay Bridge	19.3	
Bay Bridge south to Patuxent River	20.4	
Patuxent River south to Virginia line	7.1	
Chincoteague Bay		1.3
Atlantic Ocean		0.5
Potomac River		12.2
Inland waters		24.4
		100.0%

In the Bay, areas of heaviest recreational boat traffic north of the Bay Bridge include the mouths of the Magothy, Middle, Back, Susquehanna, and Sassafras Rivers, in the Rhode and West Rivers, and in Kent Island Narrows and Knapp's Narrows.

Table 3.4 B shows the temporal distribution of recreational boats in the upper Chesapeake Bay during the boating season. This table indicates that on a random Sunday or holiday at 3:00 pm, over 12,000 recreational boats were operating on the upper Bay, more than 7 times the number found on an average weekday.

Table 3.4 B

Temporal Distribution of Seasonal Boating Activity

	Peak Number of Boats	Ratio of Weekday Number	Number Days in Season
Sundays/Holidays	12,214	7.1	25
Saturday	8,878	5.2	22
Weekdays	1,714	1.0	106

The activities most frequently engaged in by recreational boaters on the upper Bay include fishing (39.7%), water-skiing (20.3%), pleasure cruising (8.9%) and speed boating (20.2%). Other activities occupied 10.9% of the total boat-hours.

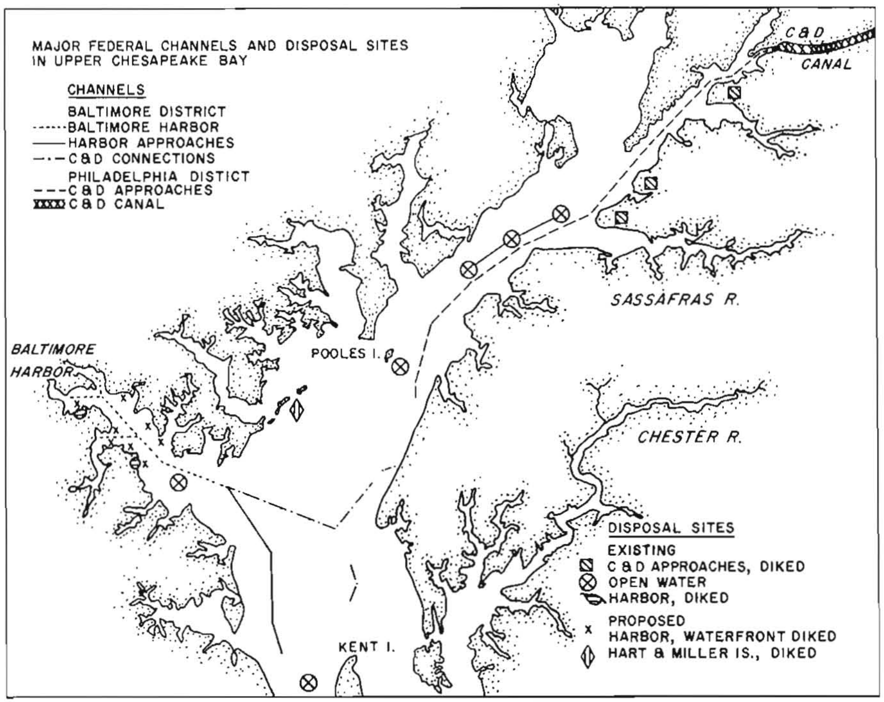
Roy Mann Associates. 1976. Recreational Boating on the Tidal Waters of Maryland. A Management Planning Study. Report prepared for Energy and Coastal Zone Administration, Dept. Natural Resources, State of Maryland. 172 pp.

4. THE CHESAPEAKE BAY: DREDGING AND DISPOSAL ACTIVITIES IN MARYLAND.

Open-water pipeline dredging operation in Upper Chesapeake Bay.

4.1 WHERE ARE THE MAJOR FEDERAL NAVIGATION CHANNELS AND DISPOSAL SITES IN THE MARYLAND PORTION OF THE MAIN BODY OF THE BAY?

The major Federal navigation channels and disposal sites in the Maryland portion of the main body of the Bay and in Baltimore Harbor are shown in the figure below.



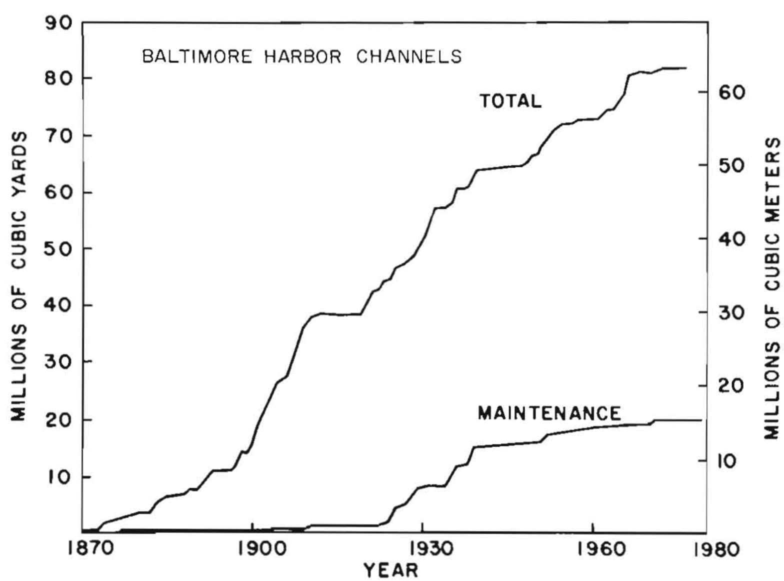
82 million yd^3 (62.7 million m^3) of material has been removed, 25% of this total, 20 million yd^3 (15.3 million m^3), has been maintenance work.

U.S. Army Corps of Engineers. Reports of the Chief of Engineers, 1860-1976.

4.2 HOW MUCH MATERIAL HAS BEEN DREDGED FROM BALTIMORE HARBOR CHANNELS OVER THE PAST 100 YEARS AND WHERE HAS IT BEEN PLACED?

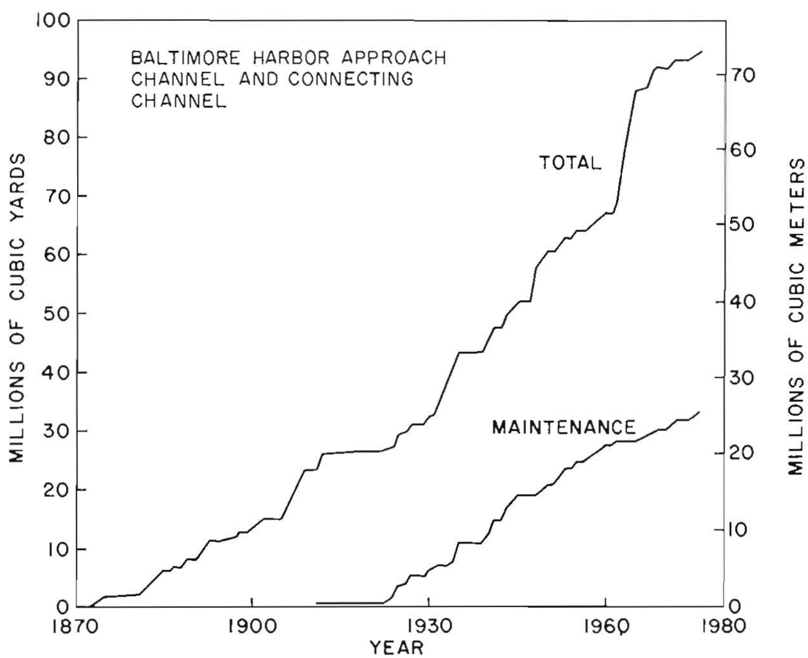
Baltimore Harbor Channels have been defined as all channels in the Patapsco River west of a line from North Point to Rock Point. Prior to 1920, virtually all material dredged from these channels was used as fill in connection with industrial shoreline development. During the middle part of this century, material was disposed of at a variety of open-water sites in the Bay. In 1968, the Commission on Submerged Lands recommended using the Pooles Island Deep in the upper Bay for disposal of material from Baltimore Harbor. This site was used from December 1968 thru December 1971. No maintenance or improvement dredging occurred in Baltimore Harbor between December 1971 and February 1975. In 1975, it was made illegal to dispose of Baltimore Harbor sediments in the open waters of Chesapeake Bay because these materials were *defined* to be contaminated.

Cumulative dredging volumes from Baltimore Harbor channels are presented below. Since 1870, a total of nearly



4.3 HOW MUCH MATERIAL HAS BEEN DREDGED FROM THE BALTIMORE HARBOR APPROACH CHANNEL AND CONNECTING CHANNEL OVER THE PAST 100 YEARS AND WHERE HAS IT BEEN PLACED?

The Baltimore Harbor Approach Channel is composed of the entire length of the Craighill Channel and the Brewerton Cut-off Angle. The Connecting Channel between Baltimore Harbor and the Western Approach Channel to the Chesapeake and Delaware Canal includes the Brewerton Extension Channel and the Tolchester and Swan Point Channel sections in Chesapeake Bay. Cumulative dredging volumes over the past century are presented in the figure below. Approximately 95 million yd^3 (72.6 million m^3) have been removed during this period, 35% of this volume, 33 million yd^3 (25.2 million m^3): was maintenance work.

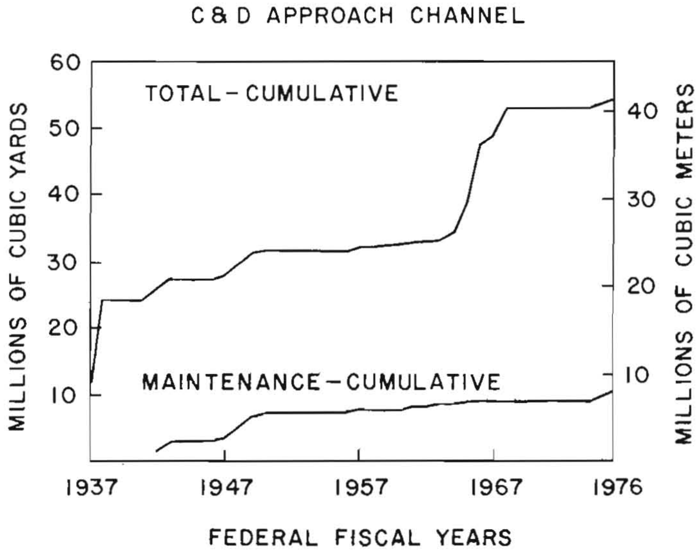


Examination of U.S. Army Corps of Engineers records indicates that essentially all the material dredged from the Baltimore Harbor Approach Channel and Connecting Channel has been disposed of overboard in areas paralleling the channels or on the Kent Island dumping ground.

U.S. Army Corps of Engineers. Reports of the Chief of Engineers, 1860-1976.

4.4 HOW MUCH MATERIAL HAS BEEN DREDGED FROM THE APPROACH CHANNEL TO THE CHESAPEAKE AND DELAWARE CANAL OVER THE PAST 100 YEARS AND WHERE HAS IT BEEN PLACED?

The cumulative volume of material dredged from the Approach Channel to the Chesapeake and Delaware Canal between 1937 when the first dredging was conducted, and 1976, is summarized in the figure below. The figure shows the accumulated total volume of material dredged and the volume removed for maintenance.

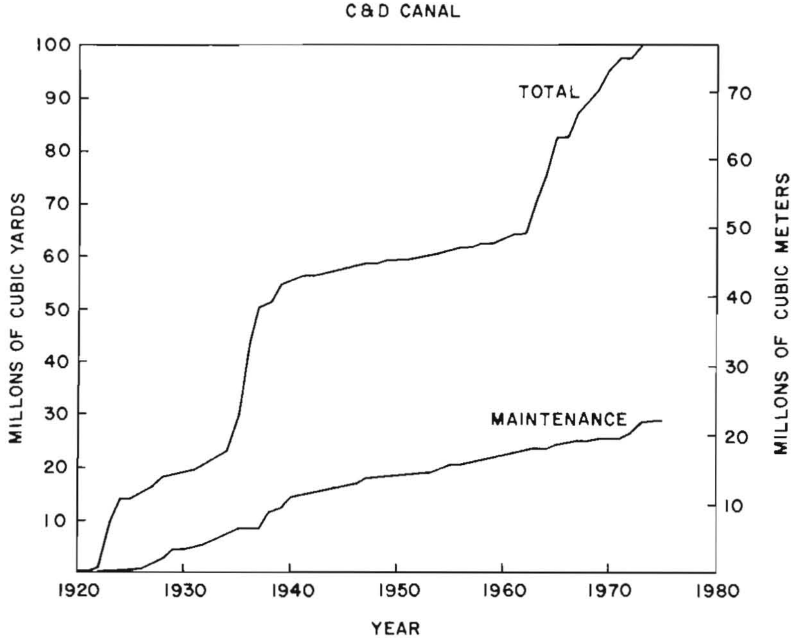


The figure does not include material dredged from the Canal itself. The total volume of material dredged over this 40-year period is nearly 55 million yd^3 (42 million m^3) of which only about 10 million yd^3 (8 million m^3) were for maintenance. The records of disposal areas are incomplete, but certainly more than 10 million yd^3 (8 million m^3) and perhaps as much as 20 million yd^3 (15 million m^3) were disposed of overboard. The remainder was placed on fastlands bordering the Bay.

Schubel, J.R. and A.D. Williams. 1976. Dredging and its impact on Upper Chesapeake Bay: some observations. Pages 70-115 *in* Time-Stressed Coastal Environments: Assessment and Future Action. Proceedings of the Second Annual Conference of the Coastal Society, 17-20 Nov. 1976.

4.5 HOW MUCH MATERIAL HAS BEEN DREDGED FROM C&D CANAL OVER THE PAST CENTURY AND WHERE WAS THIS MATERIAL PLACED?

Dredging records for the Chesapeake and Delaware Canal are available from 1920 to the present and are shown in the figure below. During this time, approximately 100 million yd^3 (76.4 million m^3) of material have been dredged; maintenance dredging accounted for 29% of this work [29 million yd^3 (22.2 million m^3)].



Virtually all of the material dredged from the Canal has been placed on fastlands bordering the Canal or behind diked disposal areas.

Schubel, J.R., A.D. Williams and W.M. Wise. 1977. Suspended Sediment in the Chesapeake and Delaware Canal. Special Report 11, Ref. 77-7 of the Marine Sciences Research Center, SUNY, Stony Brook. 72 pp.

4.6 WHAT SIZE PROJECTS ACCOUNT FOR MOST OF THE DREDGING (BY VOLUME AND BY NUMBER) IN THE ENTIRE CHESAPEAKE BAY?

An analysis of U.S. Army Corps of Engineers permits was made for Chesapeake Bay dredging projects between January 1973 and March 1976. Since permits are not required for U.S. Army Corps of Engineers projects, these were not included in the analysis. The data, summarized below, indicate that most (more than 61%) of the projects were relatively small, involving volumes less than 1,000 yd^3 each. The cumulative total volume of these projects accounted for only about 1% of the total *volume* of material dredged, however. More than 80% of the total *volume* of material dredged in the Chesapeake Bay came from less than 5% of the total number of projects. If the U.S. Army Corps projects had been included in these statistics, the relative importance of large projects to the total volume of material dredged would be even greater because USACE projects typically involve dredging of 100,000 to 1,000,000 yd^3 each.

Table 4.6

Chesapeake Bay Dredging Projects[1]
January, 1973 - March, 1976

Permits			Volume	
Category yd^3*	Number	Percentage of Total**	yd^3	Percentage of Total
<1,000	249	61	77,000	1
1,000-10,000	93	23	380,000	3
10,001-100,000	48	12	1,600,000	15
>100,000	19	5	8,800,000	81
Totals	409	100	10,857,000	100

* To convert from cubic yards to cubic metric, divide by 1.308

** Does not add due to rounding.

[1] Data collected by Wetland Edges Program of Chesapeake Research Consortium.

4.7 HOW MUCH MATERIAL MUST BE DREDGED EACH YEAR TO MAINTAIN THE PRINCIPAL NAVIGATIONAL CHANNELS IN THE MARYLAND PORTION OF THE CHESAPEAKE BAY?

Table 4.7

Annual maintenance requirements of principal navigational channels in the Maryland portion of the Chesapeake Bay

Channel*	Millions of yds^3	Millions of m^3
Chesapeake and Delaware Canal (to MD boundary)	0.2	0.15
Western Approach Channel to C&D Canal	1.2	0.9
Baltimore Harbor Approaches and Connecting Channel	0.8	0.6
Baltimore Harbor	0.3	0.2
TOTAL	2.5	1.8

*See 2.1 for locations of channels.

Chesapeake Research Consortium, Inc. 1977. Proceedings of the Bi-State Conference on the Chesapeake Bay, April 27-29, 1977. CRC Pub. 61, Chesapeake Research Consortium, Inc., Annapolis, Md. 302 pp.

4.8 WHAT NEW DREDGING PROJECTS HAVE BEEN PROPOSED FOR ENLARGEMENT OF THE PRINCIPAL NAVIGATION CHANNELS IN THE MARYLAND PORTION OF THE CHESAPEAKE BAY?

Table 4.8

Navigation Channels

Proposed new channel dredging for the enlargement of navigation channels in the Maryland portion of the Chesapeake Bay

Channel	Millions of yd^3	Millions of m^3
Western Approach Channel to C&D Canal Deepening to 35 ft (10.7 m)	10.0	7.6
Baltimore Harbor Approach Channel Deepening to 50 ft (15.2 m)	23.3	17.8
Connecting Channel to C&D Approach Channel Deepening to 35 ft (10.7 m)	7.4	5.7
Baltimore Harbor Channels Deepening to 50 ft (15.2 m)	23.4	18.0
Crisfield Harbor	0.2	0.15
TOTAL	64.1	49.1

Chesapeake Research Consortium, Inc. 1977. Proceedings of the Bi-State Conference on the Chesapeake Bay, April 27-29, 1977. CRC Pub. 61, Chesapeake Research Consortium, Inc., Annapolis, Md. 302pp.

4.9 WHAT ARE THE MAXIMUM DREDGING PROJECTIONS FOR THE MARYLAND PORTION OF THE CHESAPEAKE BAY FOR THE 20 YEAR PERIOD, 1976-1995?

Table 4.9

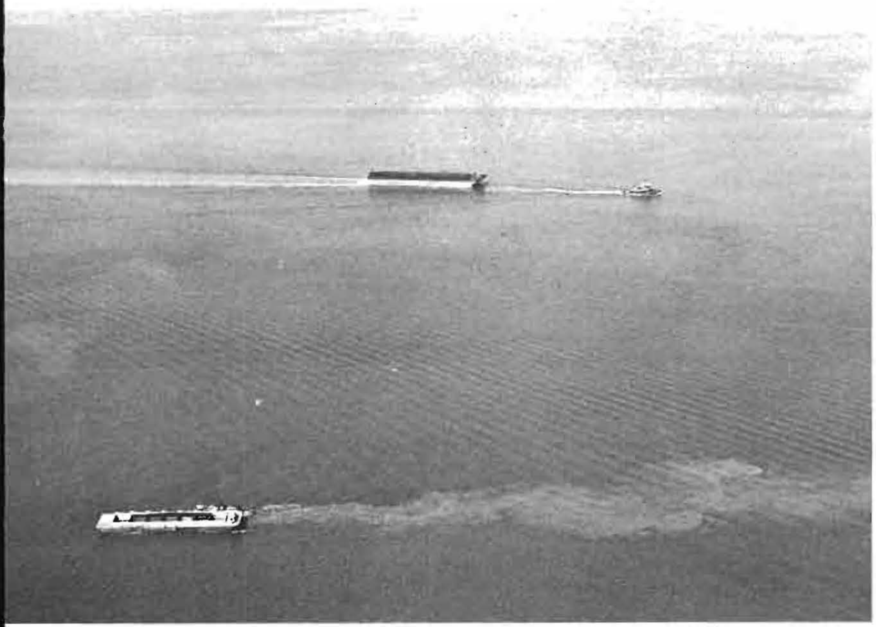
Estimated 20 year (1976-1995) maximum dredging requirements for Maryland portion of Chesapeake Bay.

FEDERAL PROJECTS	Millions of yd^3	Millions of m^3
Authorized Deepening:		
Baltimore Harbor	23.4	18.0
Harbor Approaches	23.3	17.8
C&D Connections	7.4	5.7
Other Projects	10.0	7.6
Sub-total New Work	64.1	49.1
Maintenance:		
Baltimore Harbor	6.0	4.6
Harbor Approaches & C&D Connections	16.0	12.2
C&D Approaches	23.5	18.0
C&D Approaches (existing backlog to 35 ft)	9.2	7.0
C&D Canal (to Maryland State line)	4.0	3.1
Sub-total Maintenance	58.7	44.9
Total Federal Projects	122.8	94.0
STATE PROJECTS		
Maryland Port Administration Maintenance	4.0	3.1
Maryland Port Administration New Projects	10.0	7.6
State Highway Administration	3.8	2.9
Total State Projects	17.8	13.6
PRIVATE SECTOR		
Baltimore Harbor Maintenance	2.0	1.5
Baltimore Harbor 50 ft Access Channels	2.6	2.0
Other Baltimore Harbor New Projects	10.0	7.6
Other Projects in Maryland Waters (includes State and Local Projects)	5.0	3.8
Total Private Sector	19.6	14.9

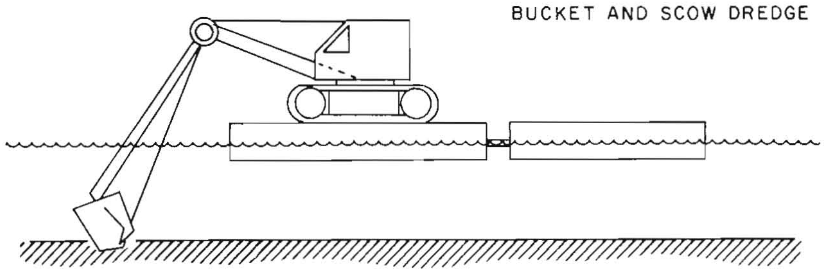
TOTALS	Millions of yd^3	Millions of m^3
Baltimore Harbor	61.8	47.4
Harbor Approaches & Brewerton Extension	46.7	35.2
C&D Canal, Approaches	36.7	28.1
Other	15.0	11.5
Grand Total All Dredging	160.2	122.7

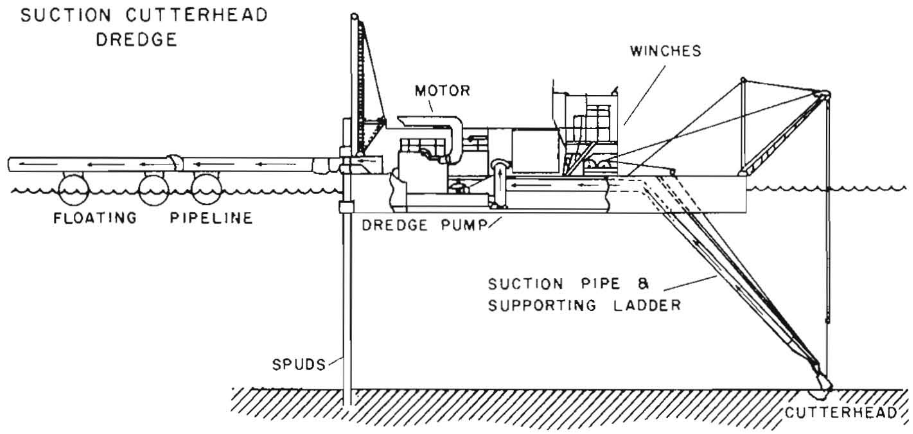
Chesapeake Research Consortium, Inc. 1977. Proceedings of the Bi-State Conference on the Chesapeake Bay, April 27-29, 1977. CRC Pub. 61, Chesapeake Research Consortium, Inc., Annapolis, Md. 102 pp.

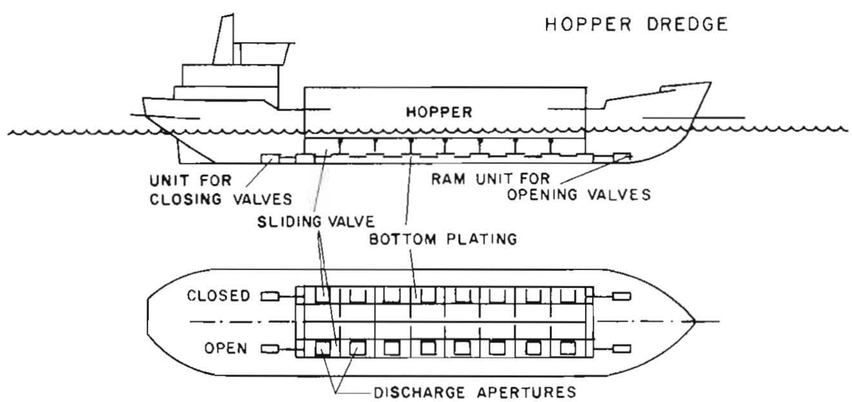
5. DREDGING AND DISPOSAL METHODS COMMONLY USED IN THE MARYLAND PORTION OF THE CHESAPEAKE BAY AND THEIR ENVIRONMENTAL EFFECTS.



Bottom-dumping barge in Baltimore Harbor.


BUCKET AND SCOW DREDGE


SUCTION CUTTERHEAD DREDGE
WINCHES
MOTOR
FLOATING PIPELINE
DREDGE PUMP
SUCTION PIPE & SUPPORTING LADDER
SPUDS
CUTTERHEAD


HOPPER DREDGE
HOPPER
UNIT FOR CLOSING VALVES
RAM UNIT FOR OPENING VALVES
SLIDING VALVE
BOTTOM PLATING
CLOSED
OPEN
DISCHARGE APERTURES

5.1 WHAT METHODS OF DREDGING ARE COMMONLY USED IN CHESAPEAKE BAY?

Three common kinds of dredges used in Chesapeake Bay are (1) suction-cutterhead, (2) hopper, and (3) crane and bucket. They are described below and in Table 5.1.

<u>Suction-Cutterhead Dredge</u>

A suction-cutterhead dredge has a rotating cutter at the end of a dredge ladder which physically excavates the materials and dilutes them with water so they can be pumped. Dredged materials are usually discharged through pipelines to open-water or enclosed disposal areas. Cutterhead dredges are the basic tool of the private dredging industry in the U.S.

<u>Hopper Dredge</u>

A hopper dredge is a self-propelled vessel equipped with centrifugal pumps, drag arms extending down to the bottom, and hopper bins to receive the dredged material and transport it to the disposal site. Dredged materials are usually discharged through doors in the bottom of the hoppers.

Soft bottom materials are pumped aboard through the drag arms and discharged initially in the hoppers. If no overflow is permitted, the hoppers must then be discharged. Under "economic load" conditions, overflow of water and low density, fine-grained material is permitted until the maximum load of material is retained in the hopper before disposal operations begin.

<u>Bucket and Scow</u>

A bucket and scow dredge, frequently termed a clamshell dredge, is simply a "steamshovel" placed on a floating barge. The bucket of the power shovel is modified to allow excess water to drain, making the dredge more efficient.

The dredged material is loaded into bottom-dumping scows which are towed to the disposal area where the dredged material is discharged. Bucket and scow operations are restricted to relatively shallow water.

Gren, G.G. 1976. Hydraulic dredges, including booster. Pages 115-124 *in* P.A. Krenkal, J. Harrison, and J.D. Burdick III, eds. Proceedings of the Specialty Conference on Dredging and its Environmental Effects. Amer. Soc. Civil Eng. 1037 pp.

Table 5.1 SOME DREDGING TECHNIQUES APPROPRIATE FOR USE IN NORTHERN CHESAPEAKE BAY.

	DREDGE TYPE		
	Hopper Dredge	Cutterhead (hydraulic) Dredge	Clam Shell (Orange Peel Bucket) Dredge
Dredging Principle	Sediment is removed and picked up together with dilution water by drag-head sliding over bottom (or stationary) and flows through suction piping, pump, and discharge piping into hoppers of vessel.	Sediment is removed with a rotary cutter (or plain suction inlet in light material), picked up with dilution water by the suction pipe, and transported through the pump and the discharge line.	Removes sediment by forcing opposing bucket edges into it while dredge is stationary. Lifts bucket and deposits dredged material in a conveyance or on a bank.
Material Transport	After material is in hoppers, transport is over any suitable waterway. Material can be bottom dumped or pumped out (if so equipped). Pump-out is similar to pipeline dredge operation.	Dredged material moved by pipeline. Length of discharge line depends on available power, but can be extended with booster pump units to a total length of several miles.	Transport occurs in barges, trucks, or cars; dredge does not transport material. Material disposal occurs in many ways.
Density of Mixture of Dredged Material and Water	Diluted to an average of 1200 g/ℓ.	Diluted to an average of 1200 g/ℓ.	Approaches in-place density in mud and silt. Approaches dry density in coarser material.
Comments	Suitable for all but very hard materials. Production depends on travel time to dump and mode of discharge.	Suitable for all but very hard materials. High production for size of plant.	This machine can be assembled by placing a crane on a barge. Suitable for all but the hardest materials. Low production for its size.

After Mohr, A.W. 1974. Development and future of dredging. J. Waterways Harbors and Coastal Engineering Division, Amer. Soc. Civ. Eng. 100(WW2):69-84.

5.2 WHAT ARE THE FACTORS THAT DETERMINE WHAT METHOD OF DREDGING AND DISPOSAL WILL BE USED ON A PARTICULAR PROJECT?

The primary factors that determine what method of dredging and disposal will be used when improving or maintaining Federal navigation channels in the upper Bay are the nature and location of the disposal area, and economics--the low bid. An upland site available in close proximity to the dredging site is currently viewed by many regulatory offices as the most attractive alternative. In such a case, the dredging/disposal method used would most probably be hydraulic pipeline. In fact, there are relatively few upland sites available in close proximity to important navigation channels in the upper Bay, particularly in Baltimore Harbor.

If the only practical alternative is open-water disposal, the proximity of the identified spoil disposal site to the dredging site and the water depth at the disposal site are the primary criteria that govern the choice of dredging/disposal methods. The presence of an important shellfish bar would also be considered in making the selection. If the open-water disposal site is within 3 mi (4 km) of the dredging site, hydraulic pipeline would be the method most frequently used. If the disposal area is farther than this distance and the water at the disposal site is relatively shallow, a bucket and scow operation would probably be used. Hopper dredging and disposal is most frequently employed when a long run to the disposal area is involved and the water depth at the disposal site is greater than 30 ft (9 m).

Most of the Federally-financed dredging operations in the upper Bay are done by private dredging concerns who bid competitively for a particular job. Hydraulic pipeline operations are generally cheaper than hopper dredging, and bucket and scow operations are the cheapest of the three methods.

5.3 WHAT IS OVERBOARD DISPOSAL?

Overboard disposal is the term usually used to describe the discharge of dredged materials in unconfined (open-water) disposal sites in rivers, lakes, estuaries and other water bodies. The sites are usually relatively close to the area being dredged. The terms "overboard disposal" and "open-water disposal" are frequently used interchangeably.

5.4 WHAT IS THE HISTORY OF ENVIRONMENTAL CONCERN REGARDING DREDGING AND DREDGED MATERIAL DISPOSAL IN MARYLAND WATERS OF CHESAPEAKE BAY?

Controversy has been associated with dredging and disposal of dredged materials in Maryland's waterways since colonial days. Most early controversy centered around conflicting user interests, rather than the quality of the environment *per se*, which at that time was not an issue.

Conflict of user interests and an awareness of the importance of water navigation to the development of Maryland's economy are both evident in an act of the General Assembly of the Colony of Maryland passed in 1753 "to prevent injuring the navigations to Baltimore Town and to the inspecting house at Elk Ridge Landing on Patapsco River." This Act stipulated that those digging iron stone from the banks of the Patapsco River must refrain, under penalty of law, from throwing earth, sand, or dirt into the River; and that no earth, sand, or dirt could be placed on the beach or shore of the River below common high water mark unless contained so that it could not wash into the River. The careless disposal into the water of debris from the digging of iron stone was shoaling channels and restricting passage of larger vessels.

Conflicts between the commercial shippers and commercial fishermen developed during the 1870's. Oystermen were upset when the Craighill Channel was dredged through existing oyster beds at the mouth of the Patapsco River. Their persistence in dredging for oysters in and around the newly-developed channel, in violation of a State statute, prompted Baltimore

District Engineer Colonel Craighill in 1876 to advise the State to strictly enforce the statute to prevent damage to the channel.

Potentially adverse impacts to commercial fisheries from the disposal of dredged material in open water were officially recognized in 1902 when District Engineer Colonel Peter C. Haines determined that spoil indiscriminately disposed of could be swept across oyster beds and destroy them. He proposed construction of an artificial island with the dredged material. Opposition by watermen to the open-water disposal of sediment has persisted from the turn of the century to the present day.

State of Maryland Water Resources Administration. 1977. Management Alternatives for Dredging and Disposal Activities in Maryland Waters. Maryland Department of Natural Resources, Annapolis, Md. 91 pp.

5.5 WHAT ENVIRONMENTAL CONCERNS HAVE BEEN EXPRESSED REGARDING CHANNEL DREDGING IN THE MAIN BODY OF THE UPPER BAY?

The objections raised to channel dredging include:

(1) Removal of benthic organisms and destruction of habitat.

(2) Possible release of oxygen-consuming substances that could lead to lowered levels of dissolved oxygen in overlying waters.

(3) Possible release of nutrients (especially ammonia) that could lead to increased levels of phytoplankton production.

(4) Possible release of metals and other toxic substances that could adversely affect the biota.

(5) Creation of a turbid plume of fine-grained suspended matter around the dredge, particularly when a bucket and scow dredge is used.

These potential effects are assessed later in this section.

5.6 WHAT ENVIRONMENTAL CONCERNS HAVE BEEN EXPRESSED REGARDING OVERBOARD DISPOSAL IN CHESAPEAKE BAY?

Objections to overboard disposal include:

(1) Shellfish beds may be smothered.

(2) Dredged material may move up onto the beaches.

(3) Benthic organisms will be buried and destroyed; benthic community structure will be disrupted.

(4) There may be undesirable aesthetic effects--increased turbidity, trash from the dredge, the presence of the dredge itself.

(5) Mounds of dredged material hang-up fishermen's drift nets and tear them.

(6) Crabs in pots may be smothered.

(7) Crab pots may be fouled and not fish (work effectively).

(8) The increased turbidity may adversely affect the biota: finfish, shellfish, zooplankton, phytoplankton, and submerged aquatic vegetation.

(9) Discharge of the dredged material into the water may depress the levels of dissolved oxygen and kill organisms.

(10) The dredge and discharge line and the plume of suspended sediment may interfere with the migration of finfish.

(11) Anchors left by dredges may catch and tear nets.

(12) Exposure of organisms to low levels of contaminants released by dredging and disposal may have an adverse effect.

Most of these concerns are assessed elsewhere in this section.

5.7 WHAT ENVIRONMENTAL CONCERNS HAVE BEEN EXPRESSED REGARDING SPECIFIC DISPOSAL SITES IN THE CHESAPEAKE BAY AND WHAT SCIENTIFIC INFORMATION IS AVAILABLE DOCUMENTING THE ENVIRONMENTAL EFFECTS OF DISPOSAL AT THESE SITES?

Patapsco River Disposal Area Off Rock Point.

It has been suggested that material dumped into this area moves back into the channel and into the area off the cooling-water intake of the Baltimore Gas and Electric generating station at Brandon Shores. The Chesapeake Bay Institute monitored sediment disposal during recent (1976-1977) dumping operations in this area and found no evidence that the disposed materials spread into either of these areas. In both studies, however, observations extended over a period of only a few months.

Cronin, W.B., M.G. Gross, R.C. Whaley, W.C. Boicourt, J.R. Schubel and W.R. Taylor. 1977. Investigation of Dredging Operations: Craighill Angle--Patapsco River Mouth, 9 March-25 May 1977. Open File Report No. 12, Chesapeake Bay Institute, The Johns Hopkins University.

Cronin, W.B., M.G. Gross, W.R. Taylor, W.C. Boicourt and J.R. Schubel. 1976. Investigation of Dredging Operations: Brewerton Channel Cut-Off. Patapsco River Mouth Disposal Site. 10 April-26 May 1976. Open File Report No. 10, Chesapeake Bay Institute, The Johns Hopkins University.

Kent Island Dumping Ground.

It has been asserted that material disposed at this site:

(a) moves up onto the beaches of Kent Island

(b) moves onto adjacent shellfish bars smothering the organisms.

(c) kills crabs and other benthic organisms.

(d) will fill the deep trough and destroy important over-wintering areas for finfish.

During disposal operations in February-March 1975, material was dumped from the U.S. Army Corps of Engineers hopper dredge ESSAYONS. The effects of these operations on the environment and the biota were investigated by a consortium of scientists from the Chesapeake Bay Institute, the Westinghouse Ocean Research Laboratory, the Center for Estuarine and Environmental Studies, the Maryland Department of Health and Mental Hygiene, and the Maryland Department of Natural Resources. The following conclusions have been extracted from their report.

Dispersal of Material

(1) During a dump excess turbidity, produced by suspended dredged material, extended from the water surface to the bottom and increased with depth.

(2) Within 30 minutes after a dump, turbidity in the disposal area had returned to background (pre-dump) levels except very near the bottom.

(3) The dumped material descended rapidly to the bottom.

(4) No accumulation of material was detected on the adjacent Broad Creek oyster bar east of the dump site.

(5) Post-operational surveys showed "no compelling evidence for removal (by normal tidal action) of dredged material from the disposal site."

Biological Effects

Clams and Oysters

(1) Clams and oysters suspended at normal growth depths near the disposal site where maximum turbidities

were expected to occur did not exhibit any increase in metals that could "... be attributed to the disposal operations."

(2) "There was no detectable mortality or change in health status in oysters, soft shell clams or other benthic organisms or commercially important shellfish beds that could be related to spoil disposal operations."

Other Benthic Organisms

(1) "Changes in the benthic community at the dump-site were transitory and the spoil was recolonized by benthic forms within thirty to sixty days."

It is important to point out that the hopper dredge ESSAYONS discharged the material at a depth of about 30 ft (9 m) and that the approved discharge area was carefully monitored. This combination of factors increases the probability of emplacement of the material within the designated disposal area. With other modes of disposal and less attention to the point of discharge, the dispersal of material out of the disposal area might be greater.

State of Maryland Water Resources Administration. 1976. Monitoring of Open Water Dredged Material Disposal Operations at Kent Island Disposal Site and Survey of Associated Environmental Impacts. A report prepared for the Maryland Port Administration and the Maryland Department of Natural Resources. 119 pp.

Pooles Island Deep

The following concerns have been expressed:

(1) The Pooles Island Deep is a naturally deep area that "is there for a reason." Material placed in the Pooles Island Deep will not remain there but will be removed by tidal scour and redistributed throughout the upper Bay.

(2) The Deep is an important over-wintering area for finfish.

The Pooles Island Deep is, because of its relatively warm temperatures, allegedly an important over-wintering area for a number of species of commercially and recreationally important finfishes, particularly striped bass, white perch, and hogchoker. The winter temperatures in the Deep are not higher, however, than those in more extensive nearby areas of similar depth.

A recent study by the U.S. Army Corps of Engineers produced evidence that, to some degree, supports the contention that material placed in the Pooles Island Deep will be resuspended by tidal currents and moved out of the Deep. Fine-grained particles tagged with radioactive gold and placed in the Deep were observed to be moved out and distributed both upstream and downstream. There is other evidence, however, that the Deep has been an area of net sediment accumulation over at least the past 130 years.

Through the use of hydrographic survey sheets, it was estimated that in the 125 year period from 1846 to 1971, the average depth of the Deep decreased approximately 16 ft (5 m). Calculating the approximate area of the Pooles Island Deep disposal site, this shoaling corresponds to a total sediment accumulation of about 11 million yd^3 (8 million m^3). Natural sedimentation during this period can account for only approximately 10% of this, assuming uniform sedimentation throughout the area. This leaves more than 9 million yd^3 (7 million m^3) of material to account for, a not unreasonable estimate of the amount of dredged material that might have been placed there. Unfortunately, detailed disposal records for the Deep are unavailable.

Toll, A.R. 1976. Chesapeake Bay Radioactive Tracer Study, prepared for office, Chief of Engineers, U.S. Army Corps of Engineers, Wash. D.C.

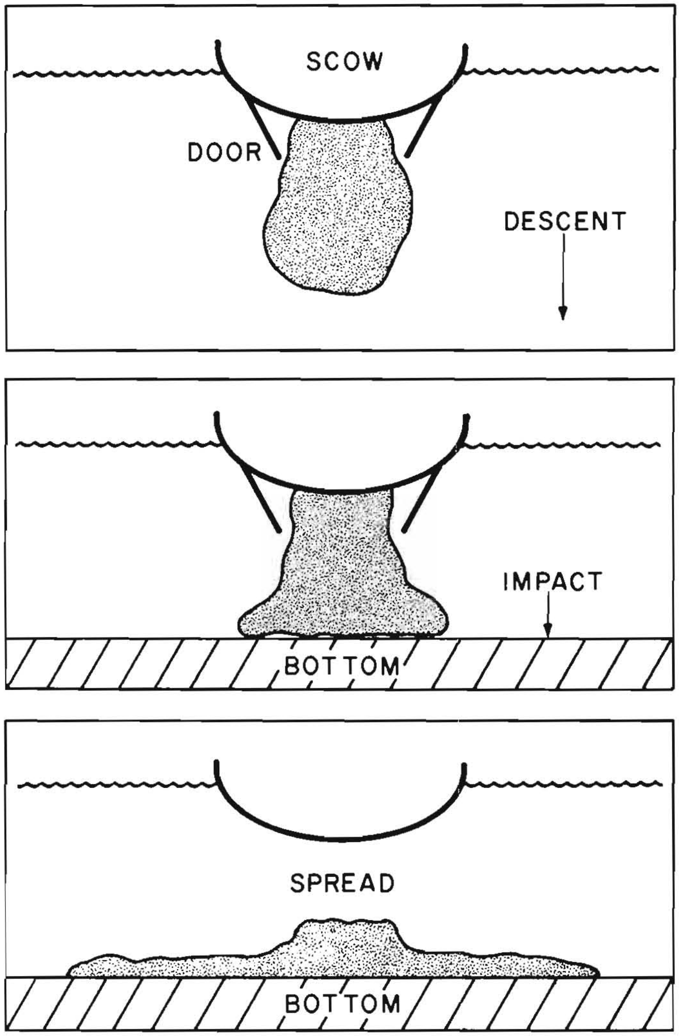
Stroup, E.D. and R.J. Lynn. 1963. Atlas of Salinity and Temperature Distributions in Chesapeake Bay 1952-1961 and Seasonal Averages 1949-1961. Geographical Summary Report 2, Ref. 63-1, Chesapeake Bay Institute, The Johns Hopkins University. 410 pp.

5.8 WHEN DREDGED MATERIAL IS RELEASED FROM A SCOW OR HOPPER DREDGE, WHAT HAPPENS TO IT?

Material released from a scow or hopper dredge is deposited on the sea floor in three steps. Upon release, the dredged material descends rapidly through the water column as a well-developed jet of high density which may contain some solid blocks. This jet has been observed to fall at speeds in excess of 2 knots (100 cm/sec). Ambient water is entrained during descent and the total volume of the descending jet may be increased about a hundred-fold before it reaches the sea floor in depths of about 65 ft (20 m).

After sinking through the water column, the material hits the bottom. Some of the released material spreads radially outward from the impact point as a toroidal density surge only a few yards thick. The bottom surge slows and thins as it travels outward and has been observed to run a few hundred yards, at most, from the point of impact. Initially, the surge moves swiftly and carries material away from the impact point until the surge velocity is reduced sufficiently to permit deposition.

These three steps--descent of the jet, impact on the bottom, and spread of the bottom surge--have been observed to occur under a wide range of hydrographic conditions, dredged material characteristics, and dredging and disposal equipment. The limiting conditions under which these steps will occur have not been determined but they have been documented in water depths of up to 220 ft (67 m) and currents of up to 4 knots (200 cm/sec).



Behavior of dredged material released from a scow.

A small fraction of the released material will be found in the water column above the bottom surge. This is material that has spilled over the top of the hopper before discharge, has been washed out of the hopper or scow after the discharge, or is left behind by the descending jet and the spreading surge. This diffuse cloud of residual material drifts with the currents and settles slowly. While the cloud of turbid water may be very noticeable around the dredge or scow, this drifting material accounts for only about 1-5% of the total mass of material released.

Bokuniewicz, H.J., J.A. Gebert, R.B. Gordon, J.L. Higgins, P. Kaminsky, C.C. Pilbeam, M.W. Reed and C. Tuttle. 1978. Field Study of the Mechanics of the Placement of Dredged Material at Open-Water Disposal Sites. Final Report. Tech. Rept. D-78-F. Vol. I. U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab, Vicksburg, Miss. 94 pp. and appd.

Gordon, R.B. 1974. Dispersion of dredge spoil dumped in near-shore waters. Estuarine Coastal Marine Science 2:349-358.

5.9 WHAT EFFECT DOES OPEN-WATER PIPELINE DISPOSAL HAVE ON THE TURBIDITY OF LOCAL WATERS?

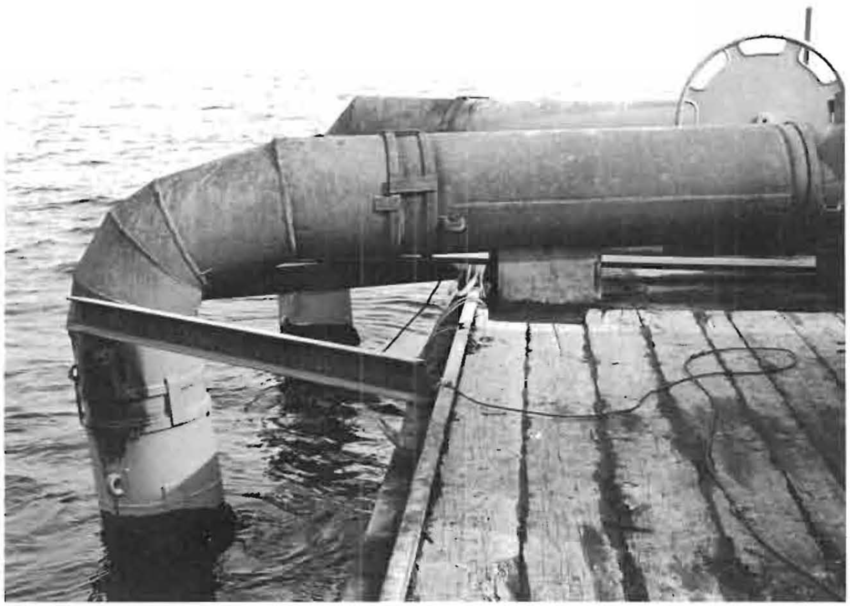
Less than 5% of the total amount of solid material discharged by open-water pipeline disposal is incorporated into the plume; more than 95% goes rapidly to the bottom very close to the source--within a few tens of yards--as a density flow. Studies in Gulf Coast estuaries showed that only about 1%-2% of the solid material discharged during open-water pipeline disposal operations was incorporated into the plume. While no such estimates have been made for Chesapeake Bay, they would be similar to those found for estuaries along the Texas, Louisiana, and Florida coasts since the sediments are of similar texture. In some environments, a fluid mud layer may form near the bottom and spread over relatively large areas.

An extensive investigation was made of the 1966-67 hydraulic dredging and pipeline disposal operation in upper Chesapeake Bay. The material was discharged overboard about 3 ft (1 m) below the water surface and was directed downward. There was little increase in turbidity near the surface except very close to the source. At a depth of 10 ft* (3 m), the maximum linear extent of the horizontal turbid plume that could be detected with transmissometers (instruments that measure the clarity of the water) was about 6,000 yd (5500 m), and it was usually between 2200-3300 yd (2200-3300 m). An increase in turbidity over background (natural) levels was never measured more than one tidal excursion from the source. The maximum width of the plume was

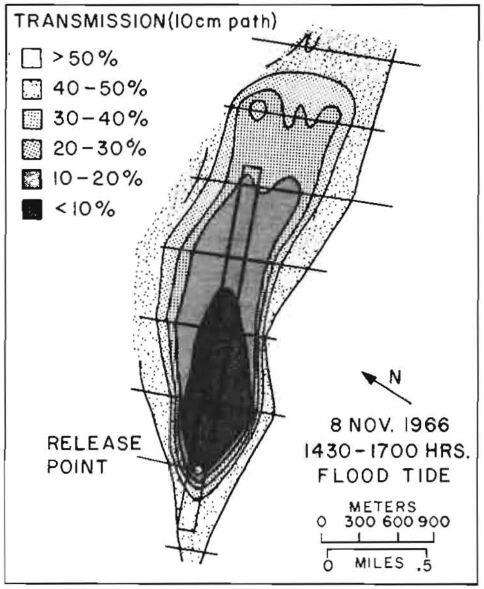
*The mean depth in the disposal area is about 13 ft (4 m).

less than 1100 yd (1000 m) and the maximum areal extent of the plume was about 1.6-2.0 mi^2 (4-5 km^2).

Shape and orientation of the plume were highly variable because of vigorous tidal currents, 0.1-2.0 knots (5-100 cm/sec). Whenever dredging was stopped, excess turbidities fell to background levels within 1-2 hours as a result of dispersion, dilution, and sedimentation. The plume was oriented in the direction of tidal flow and a new plume was generated on each reversal of the tidal current. An example of the discharge pipe configuration and of the extent of turbid plume at a depth of 10 ft (3 m) are shown. A transmission value of 50% corresponds to a concentration of total suspended sediment of roughly 30 mg/ℓ, and 25% to about 75 mg/ℓ. During the period of these observations natural background levels of total suspended sediment in the area averaged about 25-30 mg/ℓ.



Discharge structure used in Upper Chesapeake Bay in 1966-67.



Plume of turbidity generated by dredging in Upper Chesapeake Bay on 8 November 1968.

Biggs, R. 1970. Project A, Geology and Hydrography. Pages 7-15 *in* Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Natural Resources Institute Special Report No. 3, Chesapeake Biological Laboratory, University of Maryland. 66 pp.

Schubel, J.R., H.H. Carter, R.E. Wilson, W.M. Wise, M.G. Heaton, M.G. Gross. 1978. Field Investigations of the Nature, Degree and Extent of Turbidity Generated by Open-Water Pipeline Disposal Operations. Final Report. Technical Report D-78-30, U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab, Vicksburg, Miss. 257 pp.

5.10 HAS DISPOSAL OF DREDGED MATERIAL INTO THE WATERS OF CHESAPEAKE BAY RESULTED IN ANY PERSISTENT DEPRESSION IN THE LEVELS OF DISSOLVED OXYGEN?

Considerable quantities of reduced particulate material with a high potential oxygen demand are introduced into the water column during open-water pipeline disposal of dredged material and disposal from hopper dredges. Only a small fraction of this material however, is reactive on a time scale comparable to that associated with settling of the bulk of the mass of particulate matter. Between 95-99% of the material is deposited within a few tens to a few hundreds of seconds after discharge in shallow water. Thus, the "oxygen sag" resulting from open-water disposal of dredged material is smaller than would be predicted from either the organic carbon content or the total reducing capacity of the original in-place sediments.

The principal reduced species present in sediments capable of reacting with dissolved oxygen on a time scale of minutes to hours are present primarily in solution in the interstitial waters of the original sediment. The important species are reduced sulfur species (H_2S, HS^-, S^{--}), reduced iron (Fe^{++}), and reduced manganese (Mn^{++}). While organic matter and sulfide minerals can be expected to exert an oxygen demand, most organic matter decomposition is bacterially-mediated and oxidation of sulfide minerals is initially limited to particle surfaces. These factors increase time scales for oxygen demand of the particulate matter to the point where these reactions become important only after deposition of the material. Once dredged material is deposited, its rate of oxygen consumption from the overlying waters is initially dependent on the expulsion of interstitial water during compaction, and beyond this is diffusion-limited.

The Chesapeake Bay Institute conducted a study of the effects of clamshell dredging of the Approach Channel to Baltimore Harbor and disposal by a bottom-dumping barge in an open-water site in Baltimore Harbor. Their observations indicated that oxygen concentrations were reduced from about 7 mg/ℓ to 6 mg/ℓ in near-bottom waters about one hour after a disposal operation. The magnitude of the oxygen depression decreased with elevation above the bottom.

In a study of channel dredging in the Approach Channel to the C&D Canal, the Chesapeake Bay Institute documented reductions in the concentration of dissolved oxygen of only about 3% of ambient values in the dredging area.

The Chesapeake Biological Laboratory made continuous measurements of dissolved oxygen in the waters around the discharge of an open-water pipeline disposal operation in 1967. Their data showed that there was little or no oxygen sag except near the discharge where dissolved oxygen levels were decreased about 1 ppm (from 10 mg/ℓ to 9 mg/ℓ) within the first 2000 ft (600 m) down-current of the discharge. Data from open-water pipeline disposal operations in other estuaries have shown that depressions of more than about 1.0 mg/ℓ are restricted to the vicinity of the discharge and rarely exceed .04 mi^2 (0.1 km^2) in areal extent.

Biggs, R.B. 1970. Project A, Geology and Hydrography. Pages 7-15 *in* Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Natural Resources Institute Special Report No. 3, Chesapeake Biological Laboratory, University of Maryland. 66 pp.

Gross, M.G., W.R. Taylor, R.C. Whaley, E.O. Hartwig, and W.B. Cronin. 1976. Environmental Effects of Dredging and Dredged Material Disposal, Approaches to Chesapeake and Delaware Canal, Northern Chesapeake Bay. Chesapeake Bay Institute unpublished report to Maryland Dept. of Natural Resources. 86 pp.

Schubel, J.R., H.H. Carter, R.E. Wilson, W.M. Wise, M.G. Heaton, M.G. Gross. 1978. Field Investigations of the Nature, Degree and Extent of Turbidity Generated by Open-Water Disposal Operations. Technical Rept. D-78-30, Environmental Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, CE, Vicksburg, Miss. 257 pp.

5.11 ARE NUTRIENTS RELEASED DURING DREDGING AND OPEN-WATER PIPELINE DISPOSAL OPERATIONS AND, IF SO, WHAT EFFECTS DO THEY HAVE ON PHYTOPLANKTON?

An investigation was made of the gross biological effects of open-water pipeline disposal in the upper Chesapeake Bay between November 1965 and November 1968. Total phosphate and nitrogen were increased in the immediate vicinity of the dredge by factors of 50 and 1000 respectively, but limited field experiments did not show any detectable effects on photosynthesis by phytoplankton. The increases in the levels of nutrients were local and did not persist. Furthermore, any stimulation of phytoplankton that might have resulted from increased nutrients was more than offset by the increased levels of turbidity which reduced light penetration. The net effect was localized and transitory reductions in photosynthesis.

Flemer, D.A. 1970. Project B, Phytoplankton. Pages 16-25 *in* Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Natural Resources Institute Special Report No. 3, Chesapeake Biological Laboratory, University of Maryland. 66 pp.

5.12 WHEN MATERIAL HAS BEEN DISPOSED OF OVERBOARD IN THE UPPER BAY PARALLEL TO THE CHANNEL, HAS THE MATERIAL STAYED IN THE DISPOSAL AREA?

During the fall of 1966 and again in 1967, material was dredged from a 2 NM (3.7 km) section of channel in the upper Chesapeake Bay off the mouth of the Sassafras River, and deposited overboard in a shallow [13-20 ft (4-6 m)] area running parallel to the channel and about one mile (1.8 km) west of it. Bottom surveys made prior to the start of dredging, four days after the project ended, and again 150 days after completion of the project showed that there were 1.7 million yd^3 (1.3 million m^3) of dredged material on and adjacent to the disposal area at the end of the dredging period, and that only about 12% of this material had been lost from the area after 150 days. The total volume of material dredged was estimated to be about 1.9 million yd^3 (1.5 million m^3).

This surprisingly small loss of material from the disposal area deserves an explanation. Most of the material dredged from the channel in this operation was "new work" and was therefore older and more compact material than would be the case for sediment dredged in subsequent years to *maintain* the channel. Also, since the total period of dredging extended over more than one year, some of the more readily resuspendable material could already have been removed from the disposal area by the time disposal stopped and the first post-disposal survey was made.

Evidence from similar estuarine areas (e.g., upper Delaware Bay) clearly shows that material dredged for channel maintenance and discharged overboard in shallow areas adjacent to the channel does not remain in place. These materials tend to be very fluid in nature, and to spread outward from the area of discharge. Where the bottom slopes continuously from the disposal area to the channel, gravitational flow can result in the relatively rapid movement of dredged material back into the channel.

Tidal currents and wind wave-induced motions resuspend the natural bottom sediments in the shallow areas of the upper Chesapeake Bay. Some of this material ultimately ends up in the channel. The combination of the estuarine circulation pattern and the reduction in wind wave-induced turbulence with increased depth in the channel make it a natural trap for sediment. Thus, there is a net transport of sediment from the shallow areas to the deep channel. This conclusion is supported by the observation that the sedimentation rate in the dredged channels in the upper Bay is about 20 times higher than the rate in adjacent shallower areas.

Materials recently dredged for channel maintenance are more susceptible to resuspension and redistribution than materials dredged for new work and sediments naturally occurring in the disposal area. Maintenance material is less compacted than material dredged for new work. Maintenance material, dredged hydraulically, has a somewhat smaller mean particle size than naturally agglomerated bottom sediments because of shearing forces experienced during dredging and pumping. This means that the particles tend to remain in the water column longer and are at the mercy of the currents. Also, the material, though of a fluid nature and subject to gravitational spreading, would start as a mound on the natural bottom. Consequently, this material would be subjected to even greater resuspension and transport by tidal currents and wind wave-induced motions than the natural bottom sediments.

Cronin, L.E., R.B. Biggs, D.A. Flemer, G.T. Pfitzmeyer, F. Goodwyn, Jr., W.L. Dovel and D.E. Richie, Jr. 1970. Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Natural Resources Institute Special Report No. 3, Chesapeake Biological Laboratory, University of Maryland. 66 pp.

Schubel, J.R. 1968. The turbidity maximum of the Chesapeake Bay. Science 161:1013-1015.

5.13 HAVE MOUNDS OF DREDGED MATERIAL IN THE UPPER BAY INTERFERED WITH DRIFT NETS USED BY COMMERCIAL FISHERMEN?

Commercial fishermen have complained that mounds of dredged material produced by the 1966-1967 dredging and disposal operation between Turkey Point and Worton Point have interfered with their drift nets. It has been reported that the mounds sometimes catch the nets causing them to tear, and that in other cases they deflect the nets so that they are no longer perpendicular to the tidal flow and therefore fish less effectively. Since nets are drifted in series, when one net hangs-up there can be a domino effect.

Hang-up of nets can result from sudden changes in the natural bottom contours and from debris, as well as from mounds of dredged material. During periods of unusually high river flow, the Susquehanna River dumps into the upper Bay large amounts of debris, including tree branches, trunks, and even entire trees complete with root systems.

While the 1966-67 dredging and disposal operation may have produced irregular mounds in the disposal area because the material was new work and relatively well-consolidated, it is unlikely that maintenance material would remain in mounds very long. The material is so fluid that it will not support significant slopes. Post-dredging fathometer surveys could be done in the disposal area following future disposal projects. If a survey revealed any undesirable mounds, these could be smoothed out by a dragline operation at relatively little cost.

5.14 HOW LONG DOES IT TAKE AFTER A DUMPING OPERATION FOR REPOPULATION OF A DISPOSAL AREA? WHAT FACTORS CONTROL THE RATE OF REPOPULATION AND THE COMMUNITY STRUCTURE?

Most monitoring studies of disposal sites have documented drastic reductions in benthic abundance, total biomass, and species diversity immediately following deposition of dredged material. When the grain-size (texture) of the dredged material was similar to that of the natural sediments in the disposal area, and when the dredged material was not grossly contaminated, recolonization of the mound of dredged material was initiated within a few weeks after deposition. In most studies, recolonization was complete within 1 to 1-1/2 years; community structure and abundance could not be distinguished from pre-dredging conditions. These observations of disposal site benthic recovery have been documented at a number of sites throughout Chesapeake Bay and in other estuaries.

Recolonization usually begins with the appearance of "pioneering" organisms, primarily tube-dwelling polychaete worms, which can repopulate an area quickly, develop rapidly, and reproduce many times each year. These early colonizers generally feed from the water column or the sediment-water boundary. These organisms have a very high recruitment and immediate post-dump abundance may be very high. Following this initial peak abundance, these opportunistic species often experience high mortality and another group of species begins to appear on the spoil mound. These organisms are characterized by intermediate death and recruitment rates, and by lower peak abundance than the more opportunistic species. The least effective colonizers appear last, but have a lower mortality rate than the two previous groups. Members of this group of benthic colonizers also have fewer reproductions per year, tend to be large and mobile, and are primarily deposit feeders. They might be termed "equilibrium" species. This recolonization pattern featuring a succession of species types is characteristic of marine and estuarine systems. The specific factors which eliminate the early colonizers and allow the less opportunistic but more ecologically stable species to become dominant are not well-known but may include intra-specific competition for food or space.

The rate of repopulation and subsequent community structure are largely a function of initial substratum conditions. Stable substratum conditions will generally support a more diverse community than will an unstable substrate, although absolute abundance might be less on the stable substrate. Time of year also affects the rate of recolonization. Spoil deposited in the late fall will probably not repopulate to a great extent until the following spring when spawning of many organisms with planktonic larval stages occurs.

Pfitzenmeyer, G.T. 1970. Project C, Benthos. Pages 26-38 *in* Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. C. Benthos. Natural Resources Institute Special Report No. 3, Chesapeake Biological Laboratory, University of Maryland. 66 pp.

Harrison, W. 1967. Environmental effects of dredging and spoil deposition. Pages 535-539 *in* Proc. World Dredging Conference, Palos Verdes Estates, California.

McCall, P.L. 1977. Community patterns and adaptive strategies of infaunal benthos of Long Island Sound. J. Mar. Res. 35(2):221-266.

Rhoads, D.C. 1976. Containment spoiling in Central Long Island Sound: an example of short-term biological enhancement. Pages 56-69 *in* Time-Stressed Coastal Environments: Assessment and Future Action. Proceedings Second Annual Conference of The Coastal Society, 17-20 Nov. 1976.

5.15 HAVE ANY EFFECTS OF PAST DREDGING AND DISPOSAL OPERATIONS ON THE BAY AND ITS BIOTA BEEN DOCUMENTED?

Since the 1960's, scientists have been actively investigating dredging and disposal operations in the Chesapeake Bay. Scientific studies increased in the 1970's and since 1975 all dredging and disposal operations must be monitored. The emphasis of the monitoring and research programs has been on large projects in Federal navigation channels and on assessing short-term, acute effects of overboard disposal. Little attention has been devoted to assessing long-term chronic effects of these activities or to assessing the effects of shoreline modifications and marginal filling. Some of the most important findings of these monitoring and research programs are summarized below.

Hopper Dredging

In 1975 an investigation was made of the environmental effects of open-water hopper disposal operations at the Kent Island disposal site just north of the Lane Bridge. The only water quality parameter significantly changed was turbidity. Excess turbidity from the disposal operation was found throughout the water column within minutes after spoil disposal. This effect was most noticeable below 25 ft (8 m). Suspended sediment levels (turbidity) at the disposal site returned to background levels within 30 minutes after disposal except very close to the bottom. A plume of highly turbid water at depths greater than 25 ft (8 m) was recorded for approximately one hour after dumping. Rarely did the levels of suspended sediment produced by dumping exceed those observed in the same area following a period of high discharge of the Susquehanna River.

No changes in dissolved oxygen or heavy metal concentrations were detected in the disposal site water. No evidence was found indicating redistribution of material deposited at the disposal site.

Impacts on the benthic population of the dump site were similar to those observed in a study of hopper dredge disposal operations in the lower Chesapeake Bay. Immediately following disposal operations, benthic abundance and diversity levels decreased drastically. However, the spoil mound showed signs of recolonization after 30 days and within two months after disposal operations it supported a benthic assemblage identical to nearby, undisturbed bottom areas.

No impact was detected of disposal operations on oyster populations in areas near the disposal site. The disposal operation had no detected effect on the levels of fecal coliform, heavy metals, PCB's and other chlorinated hydrocarbons in shellfish from the surrounding areas.

Hydraulic Dredging and Open-water Pipeline Disposal

The most comprehensive field investigation of the acute (gross) effects of dredging and overboard pipeline disposal on the environment and biota of the upper Chesapeake Bay was conducted by scientists of the University of Maryland's Chesapeake Biological Laboratory between November 1965 and November 1968. The studies were done in conjunction with dredging of the C&D Canal Approach Channel. Most of the material was disposed of overboard through a submerged pipe with a right angle elbow and deflected off a plate parallel to the sea surface and located at a depth of about 6 ft (2 m). The disposal area was to the west of the channel.

The studies were designed to determine gross effects which were defined to:

> "include those relatively large-scale effects which can be detected by the methods used in each project. These were designed to test for any massive mortalities, population reductions at the sites tested, or indications of direct and lethal damage to individual organisms."

These investigations showed that the effects of the discharge plume on water quality--suspended sediment (turbidity), dissolved oxygen, and nutrients--were local and did not persist after dredging was halted. The maximum linear extent of the turbid plume was about 17,000 ft (5200 m), and it usually did not exceed 9,000 ft (2700 m). An increase in turbidity over background levels was never measured more than one tidal excursion from the source, and the areal extent of the plume was less than 2.0 mi^2 (5.2 km^2). The total surface area of the segment of the main body of the upper Bay from Tolchester to Turkey Point is approximately 160 mi^2 (410 km^2). Shape and orientation of the plume were highly variable because of the vigorous tidal currents, 1-2 knots (50-100 cm/sec), and whenever dredging was stopped, the excess turbidities dissipated to background levels within one to two hours. The distribution of dissolved oxygen within the turbid plume and in surrounding waters showed that there was little or no oxygen sag except very near the discharge site.

The study of the acute effects of the turbid plume on phytoplankton showed no gross effects. Short-term effects of reduced light levels were observed but the effects were temporary. There were no gross effects of the dredging and disposal operations on zooplankton of the area.

Field and laboratory studies of the effects of increased suspended sediment levels produced by dredging and disposal on fish eggs and larvae failed to show any measurable effects on development and survival. Adult fish of four different species--hogchoker, white perch, striped bass, and channel catfish--were placed in cages in the disposal area to assess the effects of increased concentrations of suspended sediment on these fish. Gills of the exposed fish were examined microscopically to assess any damage to the epithelial cells of the gill filamental lamellae. From these and other associated investigations, it was concluded that there were "...no gross effects, either beneficial or detrimental, of the shallow water overboard disposal in the upper Chesapeake Bay on the species of fish available for study...."

As one would expect, the most significant and persistent effects of the dredging and disposal operation in the upper Bay were on the bottom dwelling organisms, the benthos. Shortly after disposal, there was a 70% reduction in the density (number per unit area) of benthic organisms in the disposal area and there was a "marked reduction" in the species diversity index. There was also a marked decrease in the species diversity index in the dredged area--the channel--after completion of the operation. The reported increase of 51% in the number of individuals in the dredged area a short time after dredging may be due to the recruitment of the worm, *Scolecolepides viridus*, or it may not be meaningful because the density of organisms was very low and highly variable. Recovery of benthic communities in the dredged and the disposal areas began soon after the project was completed and within one and one-half years the benthic communities of both areas were approximately at pre-dredging conditions.

In summary, the most comprehensive study of acute (short-term) effects of overboard spoil disposal in the upper Chesapeake Bay did not document any significant and persistent deleterious effects on water quality or on the biota.

State of Maryland, Water Resources Administration. 1976. Monitoring of Open Water Dredged Material Disposal Operations at Kent Island Disposal Site and Survey of Associated Environmental Impacts. A report prepared for the Maryland Port Administration and the Maryland Department of Natural Resources. 119 pp.

Cronin, L.E., R.B. Biggs, D.A. Flerrer, G.T. Pfitzenmeyer, F. Goodwyn, Jr., W.L. Dovel and D.E. Ritchie, Jr. 1970. Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Natural Resources Institute Special Report No. 3, Chesapeake Biological Laboratory, University of Maryland. 66 pp.

5.16 ARE DEEP HOLES IMPORTANT TO THE CHESAPEAKE BAY ECOSYSTEM?

There is no evidence whether or not isolated deep holes in the Bay have any significant ecological importance. However, the elongated deep trough that extends over much of the length of the Chesapeake Bay is certainly ecologically important. Croaker and other fish larvae are transported up the Bay in this deep trough from spawning areas on the continental shelf. The mid-Bay stretches of this trough serve as a relatively warm over-wintering area for a number of species of fish. A drift-net fishery for over-wintering striped bass exists in the channel reach from about the Lane Bridge at Annapolis south to Sharps Island. There are other smaller elongated depressions--troughs--in the Bay. The tongue-like trough that extends northeastward from the east side of Pooles Island reaches a maximum depth of over 70 ft (21 m) at a point about 1.5 NM (2.8 km) northeast of Pooles Island. The ecological importance of the so-called "Pooles Island Deep" has not been established. This needs to be investigated.

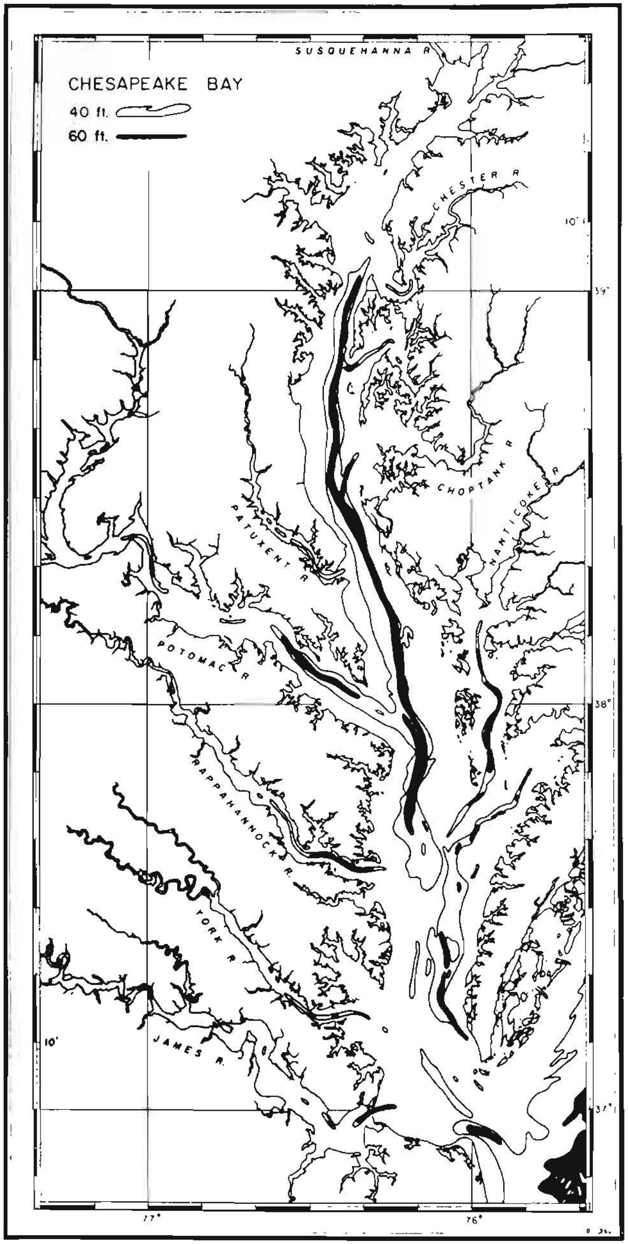
The question of what is "deep" must be considered in relation to both the general topography of the Bay and to local topographic features. The "sill depth" of a depression controls water properties such as temperature and salinity below that depth. The sill depth is the *maximum* depth at which there is a free horizontal exchange of water between a depression and the surrounding basin.

The controlling sill of the deep trough that extends over much of the length of the Bay is located in the lower Bay and is about 45 ft (14 m). Winter temperatures in the channel northward from the sill are determined primarily by conditions at the sill depth. In fact, winter temperatures are essentially constant below a depth of about 33 ft (10 m). The sill depth of the Pooles Island Deep is about 20 ft (6 m), and the controlling sill is located about 6 NM (11 km) south-southwest of Pooles Island.

5.17 IF THE DEEP TROUGH SOUTH OF THE BAY BRIDGE AT ANNAPOLIS WERE USED AS A DISPOSAL SITE, HOW MUCH MATERIAL COULD BE PLACED THERE BEFORE SIGNIFICANTLY AFFECTING THE CIRCULATION REGIME AND THE SALINITY AND TEMPERATURE DISTRIBUTIONS WITHIN THE TROUGH?

The deep trough south of the Lane Bridge at Annapolis extends for about 80 NM (150 km) to a point about 20 NM (37 km) south of the mouth of the Potomac. It has a mean depth of about 102 ft (31 m), a maximum depth of approximately 172 ft (52 m) off Bloody Point at the south end of Kent Island, and a minimum depth at several rises along the length of the trough of about 66 ft (20 m). The sill depth of the Bay--the maximum depth at which there is free horizontal communication between the Bay and the adjacent continental shelf--occurs in the lower Bay south of the end of the trough and is about 45 ft (14 m). With construction of the 50 ft (15 m) channel to Baltimore, the sill depth would increase to 50 ft.

Filling of this trough in the reach between the Chesapeake Bay Bridge and Sharps Island to a depth of 66 ft (20 m) would change the average cross-sectional area in the reach by 6%, while filling to 50 ft (15 m) would change the cross-sectional area by about 11%. The magnitude of the peak tidal currents and of the non-tidal velocities would be increased by about the same percent as the decrease in cross-sectional area. Note however, that sections already occur along this reach with maximum depths of about 66 ft (20 m). Also cross-sectional areas of sections along the reach vary by more than the projected changes which would result from filling of the



Map of Chesapeake Bay showing the deep trough.

trench. The tidal currents which would occur in this reach after filling of the trench would be within the range of currents found in other areas of the Bay.

Comparison of the flow patterns observed in reaches of the Chesapeake Bay having varying depths and cross-sectional areas within the range of the projected changes described above supports the conclusion that the filling of the trough to a depth of 66 ft (20 m) would have no significant effect on the circulation pattern or dispersion processes, or on the consequent salinity pattern. Even filling the trough all the way up to the projected sill depth of 50 ft (15 m) would produce only very small effects on the circulation pattern and on the salinity and temperature distributions. Above a depth of about 30 ft (9 m), the salinities would not be measurably altered; below 30 ft (9 m), the salinity would be slightly depressed by filling the trough to a uniform depth of 50 ft (15 m). The over-wintering temperature conditions in the trough at depths below about 30 ft (9 m) would not be significantly affected by filling the trough to either 66 ft (20 m) or 50 ft (15 m). The differences in effects that would be produced by filling the trough to 50 ft (15 m) or 66 ft (20 m) would increase with depth, but even with filling to 50 ft, the effects would be small compared to existing natural seasonal and year to year variations.

The volumes of the trough extending from the Lane Bridge at Annapolis (39°00'N) south to Sharps Island (38°35'N) are summarized in the Table 5.17.

Table 5.17

Volumes of Bay Within Different Depth Intervals from Lane Bridge at Annapolis to Sharps Island.

Depth Interval	Volume Millions of yd^3 (millions of m^3)
Surface to bottom	9630 (8806)
33 ft (10 m) to bottom	2000 (1829)
– – – – – – – – Sill Depth (45 ft) – – – – – – – –	
50 ft (15 m) to bottom	1071 (980)
66 ft (20 m) to bottom	577 (528)

The maximum total volume of dredged material projected for channel maintenance in the Maryland portion of the Bay for the next 20 years is about 65 million yd^3 (50 million m^3). The projected maximum total volume of new work for the same period is about 95 million yd^3 (73 million m^3). Both of these projections include material from the Chesapeake and Delaware Canal. The total of 160 million yd^3 (122 million m^3) represents less than 28% of the volume of the deep trough below a depth of 66 ft (20 m) in the stretch from the Lane Bridge at Annapolis to Sharps Island.

Since the total volume of this segment of the Bay is about 9630 million yd^3 (8806 million m^3), filling of the trough to a depth of 66 ft (20 m) would decrease the average cross-sectional area of this stretch by about 6%; filling to 50 ft (15 m) would decrease the average cross-sectional area by about 11%.

In summary, disposal of all the dredged material projected for the Maryland portion of the Bay for the next

20 years in the segment of the deep trough from the Bridge to Sharps Island would have no measurable effect on the circulation pattern, or on the distribution of salinity and temperature.

While for the purposes of clarity the above conclusions have been stated in a very positive manner, they are based on a somewhat limited data set. However, the degree to which the filling of the trough in mid-Bay to various levels might affect the non-tidal circulation and the salinity distribution in the Bay can be readily determined to a reasonably high degree of confidence by model tests, using either the U.S. Army Corps of Engineers hydraulic model at Matapeake, Md., or by using an appropriate three-dimensional mathematical model.

Stroup, E.D. and R.J. Lynn. 1963. Atlas of Salinity and Temperature Distributions in Chesapeake Bay 1952-1961, and Seasonal Averages 1949-1961. Graphical Summary Report 2, Ref. 63-1, Chesapeake Bay Institute, The Johns Hopkins University. 410 pp.

5.18 WHAT KINDS OF DREDGED MATERIAL ARE SUITABLE FOR SALT MARSH CONSTRUCTION? ARE CONTAMINANTS ASSOCIATED WITH DREDGED MATERIAL MOBILIZED BY SALT MARSH PLANTS?

It is possible to utilize almost any type of dredged material for the construction of new salt marsh areas. Initial growth of marsh grasses, following their introduction by seeding or transplanting, is roughly proportional to nutrient supply, especially that of nitrogen, *except* in fine-grained or highly organic material which can become anoxic. Because of this problem marsh establishment may often be more rapid on sandy substrates despite a lower nutrient supply. With time and surface stabilization almost any material can be successfully colonized, artificially or in many situations naturally, if it is placed at the correct inter-tidal elevation and has sufficient protection from erosion.

Normal zonation of salt marsh grasses and other plants is governed mainly by elevation relative to the pattern of local tide levels and successful marsh construction is possible only if the dredged material is stabilized at the correct elevation for the species introduced. Once established, long-term patterns of plant growth and sediment accretion depend mainly on the dissolved and suspended burden of the covering tides although the physical characteristics of the original dredged material, such as percolation, drainage, diffusion, and aeration are more important initially.

The capacity of salt marsh plants to mobilize metals associated with dredged material is dependent on the character of the sediment--particularly its texture and the levels and forms of the associated metals--and on the chemical conditions within the sediments, such as pH, oxidation-reduction potential, salinity, and sulfide concentrations.

There are conflicting reports as to whether *all* metals taken up by roots are actually translocated to above ground leaf material where they are more likely to be transferred to other organisms. Lee et al. (1976) found no significant translocation of any metals to leaf tops when roots were incubated in oxidizing nutrient solutions containing various metal and salt concentrations. In experiments conducted under natural sediment conditions, Gambrell et al. (1977) reported that mercury was more rapidly incorporated into leaves via roots under oxidizing sediment conditions and in weakly alkaline soils, than under reducing conditions and in acidic soils. Cadmium content in above-ground tissues was increased by exposing roots to oxidizing, acidic soils, while iron uptake and translocation to leaves was favored by acidic, reducing conditions in sediments. Gambrell et al. (1977) also stated that metal uptake under similar geochemical conditions is plant species dependent because some plant species may create their own local geochemical environment by modifying initial sediment chemical conditions. This appears to depend on the species' ability to transport oxygen or reducing substances to the plant root system.

In light of their findings, Gambrell et al. (1977) recommended that appropriate dredged material disposal strategies to minimize metal release depend on metal composition and chemical conditions of the sediments. For example, cadmium-containing reduced sediments should be maintained in a reduced state during and after disposal. Lead-contaminated sediments should be maintained at alkaline pH. The existence of several plant species which behave differently with regard to metal uptake in a given physico-chemical environment could be a valuable management tool in tailoring plant species to dredged material disposal/use alternatives.

Very little work has been conducted on mobilization of chlorinated hydrocarbons by salt marsh grasses from sediments. The Environmental Protection Agency is currently investigating chlorinated hydrocarbon uptake in salt marsh plants. However, other rooted plants, mainly cropland plants, do have the ability to transfer hydrocarbons from roots to leaves and it is reasonable to expect that rooted salt marsh plants have a similar capacity.

Backo, J.W., R.M. Smart, C.R. Lee, M.C. Landin, T.C. Sturgis, R.N. Gordon. 1977. Establishment and growth of selected freshwater and coastal marsh plants in relation to characteristics of dredged sediments. Final Report, Tech. Rept. D-77-2, U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 41 pp.

Falco, P.K. and F.J. Cali. 1977. Pregermination requirements and establishment techniques for salt marsh plants as affected by Eh, pH, and salinity. Final Report, Tech. Rept. D-77-40, U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 124 pp.

Gambrell, R.P., R.A. Khalid, M.G. Verloo and W.H. Patrick, Jr. 1977. Transformation of heavy metals and plant nutrients in dredged sediments as affected by oxidation reduction potential and pH. Final Report, Contract Report D-77-4, U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 336 pp.

Kadlec, J.A. and W.A. Wentz. 1974. State of the art survey and evaluation of marsh plant establishment techniques: induced and natural. Vol. I: Report of Research. Tech. Rept. D-74-9. U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 194 pp.

Lee, C.R., T.C. Sturgis and M.C. Landin. 1976. A hydroponic study of heavy metal uptake by selected marsh plant species. Final Report, Tech. Rept. D-76-5. U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 47 pp. + appendices.

5.19 BY WHAT MECHANISMS MAY CONTAMINANTS IN DREDGED MATERIALS BE MOBILIZED AND RELEASED?

Contaminants in dredged material deposits may be mobilized in a variety of ways:

(1) Contaminants may become dissolved in the interstitial waters of the dredged material and then transferred out of the deposit by:

   (a) diffusion into the overlying waters.

   (b) expulsion of interstitial waters as a result of compaction.

   (c) movement of interstitial waters as a result of groundwater flow.

   (d) alternate wetting and drying of the subaerial deposit.

   (e) pumping action of organisms.

(2) Contaminants may be taken up by plant roots and transferred to other parts of the plant and hence to other organisms.

(3) Contaminants may be ingested by burrowing organisms.

(4) Contaminants may be released by resuspension of subaqueous dredged materials by waves and currents.

(5) Contaminants may be released by gas bubbles that migrate up through deposits of dredged material gathering contaminants on their surfaces as they move.

5.20 HOW CAN MOBILIZATION OF CONTAMINANTS FROM DEPOSITS OF DREDGED MATERIAL BE REDUCED?

The mobilization of contaminants from dredged material deposits can be decreased:

(1) By decreasing the solubility of contaminants by maintaining the dredged material under appropriate physico-chemico conditions.

(2) By inhibiting diffusion from the pile of dredged material by covering it with clean material.

(3) By placing the dredged material in a location of minimum groundwater discharge.

(4) By keeping the dredged material covered with water to prevent drying and the development of desiccation cracks.

(5) By placing the dredged material in sufficiently deep water so that plants cannot grow on it due to a lack of light.

(6) By covering the deposit of dredged material with clean material of sufficient thickness so that burrowing organisms are confined to the layer of clean material.

(7) By placing the material in locations where there are no strong bottom currents and at a depth where waves generated by storms are sufficiently attenuated to prevent resuspension.

(8) By placing the dredged material at a depth sufficient to inhibit the formation of gas bubbles.

(9) By reducing the surface area of the deposit to reduce the rate of mobilization.

(10) By armoring the surface of the deposit with coarse-grained sediment that is not easily disturbed by currents.

5.21 HOW MAY VARIOUS MODES OF DREDGED MATERIAL DISPOSAL AFFECT THE MOBILIZATION OF CONTAMINANTS AND THEIR UPTAKE BY ORGANISMS?

MODE OF DISPOSAL	PATHWAYS OF CONTAMINANT RELEASE
Confinement upland	(1) Contaminants may be dissolved in the interstitial waters and enter the groundwater system. (2) Contaminants may be concentrated in the surface layer of sediment by alternate wetting and drying of the deposit and then leached into streams. (3) Contaminants may be taken up by plants.
Confinement underwater	(1) Contaminants may be dissolved in the interstitial waters and expelled during compaction and consolidation. (2) Contaminants may be mobilized by burrowing organisms. (3) In shallow areas, contaminants may be taken up by plants. (4) Contaminants may be scavenged by gas bubbles that form within the deposit and rise through it. (5) Contaminated particles may be physically dispersed by currents.

5.21 (Continued)

MODE OF DISPOSAL	PATHWAYS OF CONTAMINANT RELEASE
Confinement on Island; allowed to dry	(1) Contaminants may be concentrated in the surface layer of sediment by alternate wetting and drying of the deposit. (2) Contaminants may be returned to the water in dissolved and particle-associated forms by rain runoff. (3) Contaminants may be taken up by plants.
Confinement on Island; kept wet	(1) Contaminants may be returned to surrounding water by overflow of pond resulting from excess of precipitation over evaporation. (2) Contaminants may be taken up by plants. (3) Contaminants may be taken up by burrowing organisms. (4) Contaminants may be scavenged by gas bubbles that form within the deposit and rise through it.
Placed on wetlands	(1) Contaminants may be taken up by plants. (2) Contaminants may be taken up by burrowing organisms and other deposit feeders. (3) Contaminants may be concentrated in the surface sediment layer by alternate wetting and drying of the deposit and leach back into the water.

5.21 (Continued)

MODE OF DISPOSAL	PATHWAYS OF CONTAMINANT RELEASE
Overboard disposal	(1) Contaminants may be released to the water column in dissolved and particle-associated forms during the disposal operation. (2) In shallow areas, contaminants may be taken up by rooted plants. (3) Contaminants may be taken up by burrowing organisms and other deposit feeders. (4) Contaminants may be scavenged by gas bubbles that form within the deposit and rise through it. (5) Contaminants may be released by the periodic resuspension of the material by waves and currents.

5.22 WHAT ARE THE LEVELS OF CHLORINATED HYDROCARBONS IN BALTIMORE HARBOR SEDIMENTS? ARE THESE CONTAMINANTS MOBILIZED (RELEASED) DURING DREDGING AND DISPOSAL OPERATIONS?

The levels of chlorinated hydrocarbons (CHCs) in Baltimore Harbor bottom sediments are as high as 3.7 parts per million (ppm) by mass for polychlorinated biphenyls (PCBs), and 0.19 ppm for DDT and DDT residues, with lower concentrations of other pesticides such as chlordane. These concentrations are approximately the same as those found in similar aquatic environments in other highly industrialized areas. For example, the average concentration of PCBs in bottom sediments off Palos Verdes peninsula near Los Angeles County's Joint Water Pollution Control Plant Outfall System is 3.4 ppm. The average concentration of PCBs in fine-grained New York Harbor sediments is between 3 and 5 ppm.

Baltimore Harbor is a trap for fine-grain sediment in the upper Chesapeake Bay, and functions as a sink for CHCs from the suspended sediment reservoir of the Bay. The levels found in Baltimore Harbor sediments and in other industrialized areas are approximately ten times the levels found in sediments in open estuarine areas. In the upper Chesapeake Bay the concentration of PCBs averages about 0.28 ppm and total DDT averages about 0.05 ppm. In Long Island Sound, the average concentration of PCBs is about 0.30 ppm.

Chlorinated hydrocarbons are widely dispersed in the environment and occur in many species. PCBs, for example, are a family of one to two dozen mixtures that vary significantly in their properties. Most chlorinated hydrocarbons are relatively insoluble in water, but their solubilities range widely. The solubilities of PCB compounds differ by as much as a factor of 100. All CHCs are readily soluble in lipids and lipid-like materials (i.e., oils and greases).

CHCs are strongly adsorbed onto organo-clay complexes. Factors controlling the adsorptive capacity of estuarine/ marine sediments for chlorinated hydrocarbons include the size distribution, and the amounts of associated humic and fulvic acids. Fine sediments--silt and clay--have a greater adsorptive capacity than coarser materials, and this adsorptive capacity increases with the levels of fulvic, and particularly humic acids.

CHCs vary widely in the extent to which they are desorbed (released) from particles. Factors that will affect desorption for a particular compound are: solids-to-liquid ratio; CHC concentration in the sediment; particle size of the sediment, the concentration of organic matter, and oil and grease content.

The literature on the effects of dredging and disposal on the mobilization (release) of CHCs is contradictory. Some investigators have reported that virtually no CHCs are released during dredging and disposal. The results of other investigations indicate that CHCs may be released during these activities. Much of the discrepancy in results is probably due to variations in the behavior of the different species of chlorinated hydrocarbons. CHCs vary markedly in their partitioning between water and solids. It is not sufficient to talk about CHCs or even about PCBs; individual compounds must be considered on a site-by-site basis.

Organisms are able to accumulate CHCs from sediments. When exposed to sediments containing DDT, worms (*Tubifex tubifex, Capitella capitata, and Nephtys californiensis*) accumulated the pesticide, indicating that at least a portion of the sediment-adsorbed DDT is available to these deposit-feeding infauna. Oysters are believed to scrub PCBs from suspended sediment. Uptake of pesticides and PCBs by benthic organisms must come from ingestion of contaminated fine particulates. Suspended humic particulates (which tend to adsorb chlorinated hydrocarbons) may be important agents for transporting CHCs through the water column and for concentrating them in sediments and in detritus-feeding organisms.

The principal mechanism for PCB and pesticide uptake in fish is presently unresolved. Fish can accumulate CHCs directly through the food chain by ingesting contaminated phytoplankton, zooplankton, polychaetes, etc. They can also accumulate them directly from the sediments, suspended and deposited.

Chen, K.Y., S.K. Gupta, A.Z. Sycip, J.C.S. Lu, M. Knezevic, and W.W. Choi. 1976. Research Study on the Effect of Dispersion, Settling and Resedimentation on Migration of Chemical Constituents During Open-Water Disposal of Dredged Materials. Final Report. Tech. Rept. D-76-1, U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 243 pp.

Fulk, R., D. Gruber, and R. Wullschleger. 1975. Laboratory Study of the Release of Pesticide and PCB Materials to the Water Column During Dredging and Disposal Operations. Final Report. Tech. Rept. D-75-6. U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 88 pp. + appd.

Munson, T.O., D.D. Ela, and C. Rutledge, Jr., (eds). 1975. Upper Bay Survey. Final report to the Maryland Department of Natural Resources, Vol. II. Westinghouse Electric Corporation, Oceanic Division, Annapolis, Maryland.

Nathans, M.W., and T.J. Bechtel. 1977. Availability of Sediment-Adsorbed Selected Pesticides to Benthos with Particular Emphasis on Deposit-Feeding Infauna. Final Report. Tech. Rept. D-77-34. U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Effects Lab., Vicksburg, Miss. 83 pp.

5.23 WHAT ARE THE ADVANTAGES AND DISADVANTAGES OF USING SHALLOW NEARSHORE AREAS FOR DISPOSAL OF DREDGED MATERIALS?

Advantages

(1) Protection of shoreline against wave erosion.

(2) Possible creation of fastland for development.

(3) Possible creation of wetlands.

(4) Accelerate colonization by plants and animals.

(5) May facilitate access to deep water.

Disadvantages

(1) Loss of existing shoreline ecotone and benthic and shallow water biota already present.

(2) Contaminants may be mobilized and may damage the biota.

(3) Shoaling or erosion may be accelerated in areas adjacent to filled area.

(4) May impede access to water from present shoreline.

(5) May impede water navigation near shore.

(6) May increase turbidity in nearshore waters.

Woodhouse, W.W., Jr., E.D. Seneca and S.W. Broome. 1974. Propagation of *Spartina alterniflora* for Substrate Stabilization and Salt Marsh Development. Tech. Mem. No. Tm-46. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Va. 153 pp.

5.24 WHAT ARE THE POTENTIAL IMPACTS OF MODERATE TO SMALL-SCALE PROJECTS? HOW DO THEY DIFFER FROM POTENTIAL IMPACTS OF LARGE-SCALE PROJECTS? WHAT EVIDENCE EXISTS?

During the period January 1973 - March 1976 the Corps of Engineers granted 409 permits for dredging projects in Chesapeake Bay and its tributaries. The following Table shows that nineteen of these 409 projects (4% of the total) accounted for 81% of the material dredged. Projects of the Corps itself do not require permits and data on the number and scale of the Corps' projects are not included. If such data were added, the large-scale projects would be seen to account for an even larger percentage of the material dredged.

U.S. Army Corps of Engineers
Chesapeake Bay Dredging Projects;
January 1973 - March 1976

Category (cubic yards)	Number of Permits	Percentage of Total	Volume (cubic yards)	Percentage of Total Volume Dredged
<1,000	249	61	77,408	1
1,000 - 10,000	93	23	379,108	3
10,001-100,000	48	12	1,630,649	15
>100,000	19	4	8,792,875	81
Totals	409	100	10,880,040	100

Much of the public dialogue concerning the impact of dredging on Chesapeake Bay has been focused on the few large-scale projects. Little public concern has been voiced about moderate to small-scale dredging operations, i.e., those involving less than 100,000 cubic yards of material. A number of factors suggest that the effects of these smaller projects should be more carefully assessed. Several of these are discussed below.

1. Disturbance/Volume Relationships

All dredging projects disturb benthic communities. The areal extent of the disturbance, however, may differ substantially between large-scale projects and small-to-moderate-scale projects. The reason for this is that moderate-to-small-scale projects usually remove only several vertical feet of sediment. Five to ten vertical feet or more of sediment is often removed in each large-scale improvement operation. Hence, the areal extent of benthic community disturbance per cubic yard of material dredged is greater with the typical moderate-to-small-scale project, and the relative impact of moderate-to-small and large-scale projects on the Bay's benthic communities could be very different than that suggested by volume data.

2. Nature of Affected Area

Almost all large-scale dredging operations are carried out in shipping channels that are found in either: (1) relatively deep portions of the Bay, or (2) along very limited portions of the shoreline, such as Baltimore Harbor and Norfolk/Newport News, that have major port facilities. Two factors limit the ecological impact of dredging operations in deep-water areas: a) benthic communities of deep-water areas are less productive than those of shallow-water areas, and b) most of the deep-water channels were established years ago and are routinely subjected to maintenance dredging; hence, the large-scale dredging operations are not being conducted in "pristine" areas. Most of the large-scale projects that are undertaken in shallow-water areas occur either in Baltimore Harbor or along the Norfolk/Newport News shoreline. These areas, which are the sites of major port facilities, constitute only a very small portion of the Bay's shallow-water system; certainly less than 5% by area. For these reasons the ecological impact of the large-scale dredging operation itself in shallow-water areas can be considered to be limited. Obviously, large-scale dredging operations generate large amounts of dredged material. Whether this material will result in ecological damage depends on the manner and location of its disposal.

A very different situation exists with respect to moderate-to-small-scale projects. First, almost all moderate-to-small-scale operations are undertaken in near-shore, shallow-water areas, many of which have highly productive benthic communities. Second, a high percentage of the moderate-to-small-scale operations are for new projects, not maintenance operations. These projects are altering benthic communities that have not been previously modified by dredging operations.

3. Recovery Potential

Moderate-to-small-scale dredging operations generate only modest amounts of dredged material. Also, water quality changes resulting from these operations are limited in both areal extent and duration. For these reasons, moderate-to-small-scale projects are widely perceived as having a negligible impact on the ecological system of the Bay. The validity of this perception, however, depends on the recovery of benthic communities that are dredged. If the communities recover, the perception is probably valid; if they do not, the perception is open to serious challenge. Two factors suggest that the "pre-dredged" communities may not be reestablished following dredging; at least not to their "pre-dredged" level of productivity. First, moderate-to-small-scale projects frequently remove the Bay floor from the photic zone; hence, a different community will become established. Second, many of the moderate-to-small-scale projects create channels for small power boats. The high traffic load in many of these channels during the growing season could prevent the reestablishment of healthy benthic communities.

4. Catalytic Role

Water use is limited along shoreline segments of the Bay that are too shallow for small craft. Hence, it is reasonable to assume that the shorelines of these shallow reaches have fewer structural modifications (marinas, bulkheads, piers, piles, groins, etc.) and less upland development (houses, streets, parking lots, etc.) than those reaches with deeper water. If this assumption is valid, then dredging operations (moderate-to-small-scale) that create small boat channels will accelerate the construction of both physical structures along the shoreline and upland development. Both shoreline structures and upland development can adversely affect ecological systems of the Bay; e.g., bulkheads prevent marsh growth, groins may stimulate erosion as well as prevent it, and non-point source runoff from upland development may degrade water quality. Since these adverse effects would not occur, or would occur at a substantially reduced level, in the absence of the dredging operations that create small boat channels, then adverse effects can be attributed, to some extent, to the moderate-to-small-scale dredging projects.

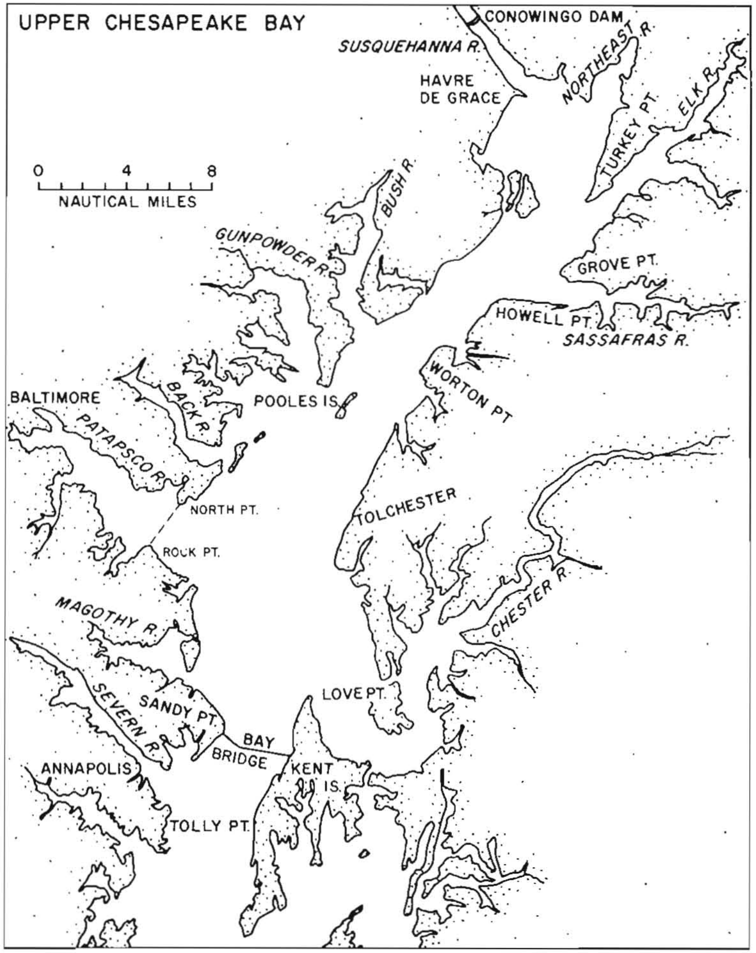
Obviously, the arguments presented above do *not* prove that moderate-to-small-scale dredging operations pose a serious problem for the ecological system of the Bay. They do, however, explain why regulatory agency personnel are concerned about the environmental impacts of moderate-to-small-scale dredging projects.

Sherk, J.A., Jr. and L.E. Cronin. 1970. The Effects of Suspended and Deposited Sediments on Estuarine Organisms. Chesapeake Biological Laboratory. Ref. #70-19.

Kaplan, E.H., J.R. Welker and M.G. Kraus. 1974. Some effects of dredging on populations of macrobenthic organisms. Fishery Bulletin 72(2):445-480.

6. DREDGED MATERIAL MANAGEMENT IN THE MARYLAND PORTION OF THE CHESAPEAKE BAY.

Gill net fishermen in Upper Chesapeake Bay.



Map of Upper Chesapeake Bay showing the outer limit of Baltimore Harbor.

6.1 HOW DOES MARYLAND DEFINE CONTAMINATED SEDIMENTS?

Sediments may be classified as "contaminated" on the basis of their physical-chemical characteristics or on the basis of their location.

In 1975, the Maryland General Assembly passed a law declaring that all sediments within Baltimore Harbor were considered to be contaminated and that it was illegal to dispose of these materials in the open waters of the Chesapeake Bay. The outer limit of the Harbor was defined by an arbitrary line across the mouth of the Patapsco estuary from Rock Point to North Point.

Any Federal standards or criteria for dredged material disposal that exist at the time of a project are, of course, enforced. Maryland's Department of Natural Resources has a policy that for open-water disposal contaminant levels in materials to be dredged should not exceed those in the sediments naturally accumulating in the proposed disposal area. The State analyzes sediments from both the dredging site and the proposed disposal site. If the quality of the material at the dredging site, as measured by the parameters listed below, is equal to or better than that of the material in the proposed disposal site, then the disposal site would not be rejected on the basis of potential degradation because of contaminant levels and/or changes in sediment texture.

The tests include:

<u>Chemical Tests</u>

Volatile Solids
Chemical Oxygen Demand
Hexane Extractables
Total Organic Carbon

Chemical Tests, cont.

Zinc

Mercury

Cadmium

Copper

Chromium

Lead

Total Keldjahl Nitrogen (TKN)

Total Phosphorus

Associated Chlorinated Hydrocarbons

Physical Tests

Particle Size Analysis

Other tests may be added if necessary, or appropriate.

The Maryland Water Resource Administration chairs a Disposal Criteria Committee which has responsibility for developing criteria for the disposal of dredged materials in Maryland waters. The committee has representatives from the following State and Federal agencies: Environmental Protection Agency; National Marine Fisheries Service; U.S. Fish and Wildlife Service; U.S. Army Corps of Engineers (Baltimore and Philadelphia Districts); Federal Food and Drug Administration; Maryland Department of Transportation/Port Administration; Maryland Environmental Health Administration; and Maryland Chesapeake Bay Administration.

State of Maryland Water Resources Administration. 1977. Management Alternatives for Dredging and Disposal Activities in Maryland Waters, Maryland Department of Natural Resources, Annapolis, Md. 91 pp.

6.2 WHAT PERMITS ARE REQUIRED BEFORE A DREDGING PROJECT CAN BEGIN IN THE MARYLAND PORTION OF THE BAY AND WHO ISSUES THESE PERMITS?

Any dredging project may require a number of permits--Federal, State, and local.

Federal

Under Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. S401 et. seq.) the U.S. Army Corps of Engineers is charged with the responsibility for evaluating requests to make physical alterations in the navigable waters of the United States. A dredging operation is such a physical alteration. The District office serves as a clearing house for other Federal, State, and local agencies concerning the environmental effects of a proposed action. The primary Federal agencies reviewing applications for physical alterations to areas under the aegis of the Baltimore District are the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service of the Department of the Interior, and the National Marine Fisheries Service of the Department of Commerce.

The decision whether or not to issue a permit will be based on an evaluation of the probable impact of the proposed activity on the public interest. That decision will reflect the national concern for both protection and utilization of important resources. The benefits which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. All factors which may be relevant to the proposal will be considered; among these are conservation, economics, aesthetics, general environmental concerns, historic values, flood damage prevention, land use classification, navigation, recreation, water supply, water quality, and in general, the needs and welfare of the people. No permit will be granted unless its issuance is found to be in the public interest.

State

Any dredging project, except a U.S. Army Corps project, must receive a State wetland license or a private wetland license.

State wetlands include "any land under the navigable waters of the State below mean high tide, affected in the regular rise and fall of the tide" [NR S9-101(M)]. Private wetlands are any wetlands not considered State wetlands bordering on, or lying beneath, tidal waters which are subject to regular or periodic tidal action and support aquatic growth.

In reviewing applications, the State must decide whether the proposal is: "in the best interest of the State, taking into account the varying ecological, economic, developmental, recreational and aesthetic values" of each application.

The Water Resources Administration of the Department of Natural Resources also issues a water quality certificate for any proposed dredging action. U.S. Army Corps of Engineers projects require only a water quality certificate. A grading and sediment control plan for spoil disposal sites must be obtained by an applicant from the local soil conservation district, or the Baltimore City Department of Public Works.

Local

Some local ordinances may require approval of the proposed dredging project by the city engineer's office or similar agency.

In general, the Army Corps of Engineers will not issue a permit for a project unless the applicant can document that he has already received the necessary State and local permits. The average processing time for a dredging application in the Baltimore District Office is usually between 2-4 months. If the proposed action becomes at all controversial, it may take much longer to go through the permitting process.

Chesapeake Research Consortium, Inc. 1974. Case Study of a Corps of Engineers Permit Application: NABOP-P (Watergate Village, Annapolis, Md.) 73-673. CRC Publication No. 1, 66 pp.

33 C.F.R. part 209 (38 Federal Register 12217).

6.3 WHY ARE DREDGING PERMITS REQUIRED FOR A SMALL PROJECT WHEN ITS ENVIRONMENTAL EFFECTS WOULD PROBABLY BE INSIGNIFICANT?

Though the effect of any one small dredging and disposal operation may be negligible, the cumulative effect of many operations could be significant. Just as the exhaust of any one automobile would not lead to air pollution, the operation of many cars can lead to poor air quality. Protection of the environment from the aggregate impact of many individually insignificant sources of pollution requires the regulation of all inputs.

6.4 WHO HAS THE RESPONSIBILITY AND THE AUTHORITY FOR DESIGNATING DISPOSAL SITES IN MARYLAND?

The State of Maryland has the legal responsibility for providing disposal sites for Federal maintenance projects and for improvement of Baltimore Harbor, its Approach Channels, and Connecting Channels to the C&D Approaches. The State is also responsible for dredging and choosing disposal sites for several inner Harbor channels, including the Spring Garden Channel and access channels to State-operated marine terminals. The State agency charged with these responsibilities is the Maryland Port Administration (MPA). Disposal sites for improvement and maintenance work in the Western Approaches to the C&D Canal and in the Canal itself are the responsibility of the Philadelphia District of the Army Corps of Engineers. Other Federal dredging in Maryland waters is usually coordinated by the Baltimore District of the Army Corps of Engineers with county or municipal governments. Most State and all private applicants for dredging and disposal operations are required to provide suitable disposal sites. These sites are usually upland sites and are subject to regulation by the Water Resources Administration of the State Department of Natural Resources (DNR), the Maryland Board of Public Works (BPW), and the U.S. Army Corps of Engineers.

Until recently, the Maryland Port Administration (MPA) has, through an unofficial "gentlemen's agreement", relied on DNR to develop disposal sites for Baltimore Harbor, Baltimore Harbor Approach Channels and for C&D Connecting Channels. In a September 1977 executive order, the Governor of Maryland assigned this responsibility to the MPA. The Department of Natural Resources is currently responsible for approval of sites and for environmental monitoring activities at Federal dredging and disposal sites and for issuing Water Quality Certifications to dredging applicants. Open-water sites suggested by the MPA require the approval of the Board of Public Works (BPW)--the only State agency which can legally sanction the use of State-owned submerged lands. The members of the BPW are the Governor, the Comptroller, and the State Treasurer.

State of Maryland Water Resources Administration. 1977. Management Alternatives for Dredging and Disposal Activities in Maryland Waters, Maryland Department of Natural Resources, Annapolis, Md. 91 pp.

6.5 WHY IS MONITORING OF DREDGING AND DISPOSAL OPERATIONS NECESSARY AND WHAT PARAMETERS ARE MEASURED?

Monitoring of dredging and disposal operations is required by State of Maryland law (Annotated Code of Md., Sec. 8-1413.1) to provide early warning if unexpected or unusual conditions arise that might necessitate modifying or stopping operations to avoid damaging resources or aesthetic values, and to provide information for decisions on future projects.

Factors that are frequently monitored include:

(1) Excess turbidity
(2) Dissolved oxygen
(3) Currents
(4) Suspended sediments for analysis of chlorinated hydrocarbons, petroleum hydrocarbons, and selected metals
(5) Benthic recovery
(6) Effects on planktonic and nektonic organisms
(7) Any other factors deemed appropriate.

6.6 COULD THE NEED FOR MAINTENANCE DREDGING BE ELIMINATED BY ENFORCEMENT OF STRICT SOIL CONSERVATION PRACTICES?

The ultimate method of controlling the sediment that rivers contribute to estuaries is to control erosion at the source. The possibility of complete control, however, is remote. Erosion is basically a natural phenomenon. All land, whether in its natural state or altered by man's activities, yields a certain amount of sediment. Because the natural processes of erosion are less subject to control than are man's influences on these processes, perhaps the best that one can hope for is to keep erosion down to its natural level. But even this is probably a vain hope. In spite of the marked reduction that conservation measures have caused in soil erosion since they began to be applied in earnest over 30 years ago, cultivated farmland in the eastern United States, for example, continues to yield sediment at about 10 times the rate of equivalent areas of forested land. In places where former croplands and grazing lands have been replanted in forests and grasses, sediment yields have been considerably reduced.

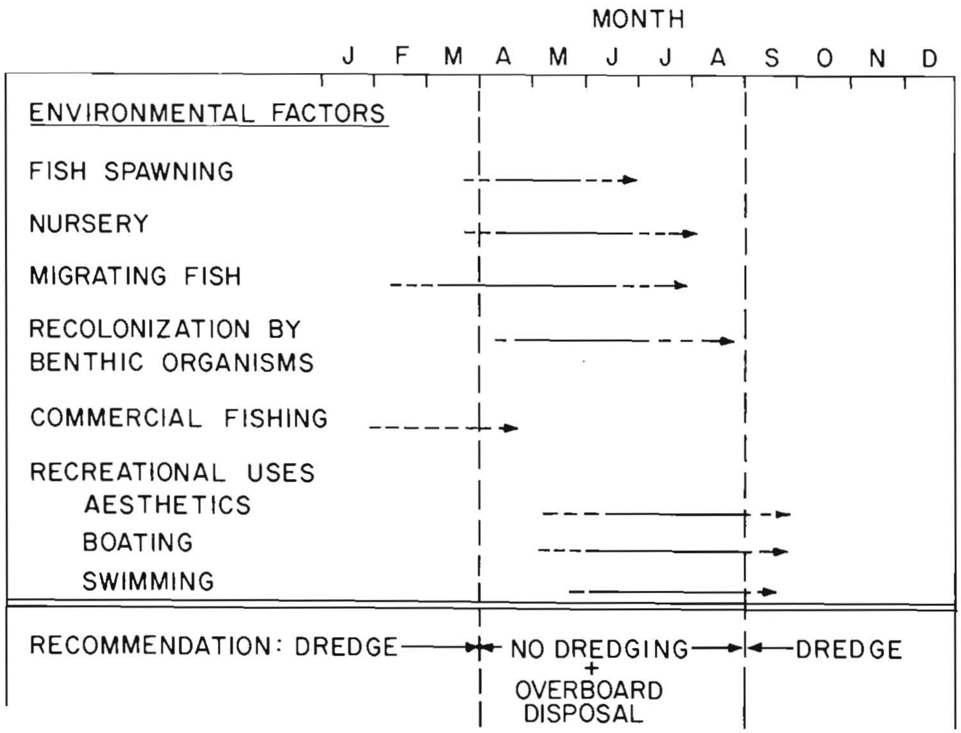
Although it is true that as long as men cultivate land, there seems to be little hope of reducing sediment yields to their natural rates--rates typical of heavily vegetated lands--much more effort should be directed at reducing sediment yields through appropriate soil conservation practices. If these controls are enforced not only for agriculture, but also for strip mining, urbanization, and highway construction, significant reductions in sediment inputs to estuaries will result. These reductions will, within a period of decades, be manifested in reductions in the dredging activity required to maintain many shipping channels; and may result in improvement in water quality of the estuarine zone, particularly if nutrient inputs are decreased. The need for dredging will, however, persist since new sediments will continue to be introduced and since sediments will continue to be transferred from shallow areas to dredged channels.

Meade, R.H. 1969. Errors in using modern stream-load data to estimate material rates of denudation. Geol. Soc. Amer. Bull. 80:1265-1274.

6.7 ARE THERE PREFERRED TIMES OF YEAR TO MINIMIZE THE PROBABILITY OF DAMAGE FROM DREDGING AND DISPOSAL OPERATIONS?

While none of the field and laboratory studies to date have indicated any persistent deleterious effects of dredging and disposal on the biota or aesthetic qualities of the Maryland portion of the Bay, one can minimize the probability of impact on any particular kind (group) of organisms or activities by restricting the times of year when dredging and disposal are permitted. It is clear, however, that no matter what period is specified, there is potential for impact on some kind (group) of organisms or conflict with some activities.

From the data presently available, September through March appears to be the most desirable time of year to schedule large dredging and open-water disposal operations to reduce the probability of adverse environmental impact on the greatest number of organisms and activities (see figure). From the operational standpoint of the dredges, late fall to early spring is not the best time to dredge; weather and sea conditions are less favorable and ice can be a problem. These factors are particularly important for open-water pipeline disposal operations. More frequent breakdowns mean greater costs and extended periods of dredging. As more data become available, the span of this "dredging window" should be adjusted to provide appropriate protection of the Bay's resources at acceptable economic costs.



Recommended dredging window for Maryland portion of Chesapeake Bay.

6.8 WHAT CREATIVE USES COULD BE MADE OF TYPICAL FINE-GRAINED CHESAPEAKE BAY SEDIMENT?

At present, only one creative use--formation of wetlands--appears to be economically attractive for fine-grained sediments typically dredged from the Chesapeake Bay's channels. If appropriate sites can be found, this material can be used as substrate for creation of new wetlands. An appropriate site for creation of a wetland is a shallow submerged area that is accessible, sufficiently protected from waves for marsh plants to grow and reproduce, and an area whose value would be enhanced by conversion to wetland. Where such an area can be identified, it can be diked and filled to a level just below mean high water. After settling and consolidation, marsh plants, seeds, or seedlings can be introduced.

Other economically attractive creative uses for fine-grained dredged material may be developed in the future.

Woodhouse, W.W., Jr., E.D. Seneca, S.W. Broome. 1974. Propagation of *Spartina alterniflora* for substrate stabilization and salt marsh development. U.S. Army Corps of Engineers, Coastal Engn. Res. Ctr. Tech. Mem. No. 46.

6.9 HOW CAN PRIVATE CITIZENS PARTICIPATE IN THE MANAGEMENT AND PLANNING OF DREDGING AND DREDGED MATERIAL DISPOSAL IN THE MARYLAND WATERS OF THE CHESAPEAKE BAY?

The most effective mechanism for incorporating public opinion and concern into dredging and disposal management in the upper Bay is the public hearing on a particular dredging project.

A public hearing is mandatory for all wetland's license/permit applications involving dredging. State wetlands are defined to include "any land under the navigable waters of the State below the mean high tide." [BR S9-101 (M)]. These hearings are held by a representative of the Maryland Board of Public Works in conjunction with the Department of Natural Resources. Private citizens may comment in writing or verbally on the proposed project at the hearing.

Personnel from the Maryland Department of Natural Resources provide the bulk of the expertise used in evaluating permit applications. However, the Board of Public Works does give weight to opinions of individuals and private interest groups when they are well-documented. The Department of Natural Resources and the Board of Public Works maintain a file on each permit application it receives, containing all the available information on that particular project. These files are open to public inspection by persons interested in obtaining more information on a proposed action.

All U.S. Army Corps of Engineers projects are subject to a public hearing or a more informal public information meeting. These activities are advertised well in advance in local newspapers. The Corps is required by law to take all well-substantiated opinions and comments into careful consideration when deciding on whether a given Federal action is in the public interest.

6.10 WHAT STATE AGENCIES SHOULD CITIZENS CONTACT FOR INFORMATION ABOUT A PARTICULAR DREDGING AND DISPOSAL PROJECT IN THE MARYLAND PORTION OF THE CHESAPEAKE BAY?

Department of Natural Resources
Tawes State Office Building
Annapolis, Maryland 21401

(301) 269-3348
(Technical Analysis Division)

(301) 269-3871
(Wetlands Permits)

Department of Transportation
Maryland Port Administration
World Trade Center Baltimore
Baltimore, Maryland 21203

(301) 383-5780

6.11 WHAT ELEMENTS SHOULD A DREDGING PLAN CONTAIN?

A dredging and dredged material management plan should:

(1) identify approved navigation channels and their characteristic dimensions.

(2) establish a policy for frequency of maintenance dredging of approved channels.

(3) establish a mechanism for acting on proposals for new dredging work.

(4) establish criteria for characterizing dredged material as to its suitability for different modes of disposal--overboard, upland, marginal filling, confinement on an island, etc.

(5) designate and rank different kinds of disposal sites for different "types"--quantities and qualities--of dredged material.

(6) assign designated disposal sites to projects that require maintenance dredging.

(7) recommend times of year for dredging.

(8) recommend methods of dredging and disposal for different projects.

(9) provide mechanisms for amending the plan to take account of changes in utilization of the Bay, improvements in dredging and disposal technology, or increased knowledge of environmental effects of different dredging and disposal strategies. A feedback mechanism to assess the effectiveness of the plan in a recurrent fashion is essential.

To be effective, a dredging and dredged material management plan must have built into it the authority to ensure that projects are carried out in accordance with the plan. This will occur only if the plan becomes a legal document.

APPENDIX

Hand tongers in Upper Chesapeake Bay.

APPENDIX

Names, Affiliations and Areas of Expertise of Participants.

Dr. S. Bayley
Director
Coastal Zone Management Program
Maryland Department of Natural Resources
coastal zone management; marine botany

Dr. H. J. Bokuniewicz
Assistant Professor of Geological Oceanography
Marine Sciences Research Center
State University of New York at Stony Brook
nearshore transport processes; coastal sedimentation; marine geophysics

Dr. O. P. Bricker
Geologist
Maryland Geological Survey
coastal sedimentation; sediment geochemistry

Dr. B. H. Brinkhuis
Assistant Research Professor of Biological Oceanography
Marine Sciences Research Center
State University of New York at Stony Brook
primary productivity of phytoplankton and seaweeds; biogeochemistry of trace metals in marine plants

Mr. M. M. Bundy
Biologist
Coastal Zone Management Program
Maryland Department of Natural Resources
fisheries and fishery resources of the Chesapeake Bay

Ms. K. N. Chytalo
Graduate Student
Marine Sciences Research Center
State University of New York at Stony Brook
bio-availability of chlorinated hydrocarbons

APPENDIX (continued)

Dr. L. E. Cronin
Director
Chesapeake Research Consortium
The Johns Hopkins University
marine ecology; coastal zone management

Mr. W. B. Cronin
Staff Oceanographer
Chesapeake Biological Institute
The Johns Hopkins University
biological oceanography

Dr. M. G. Gross
Principal Research Scientist
Chesapeake Biological Institute
The Johns Hopkins University
geological oceanography; coastal zone management; marine geochemistry

Mr. F. L. Hamons, Jr.
Chief of Technical Analysis Division
Water Resources Administration
Maryland Department of Natural Resources
coastal zone management; dredging and dredged material disposal

Mr. D. J. Hirschberg
Graduate Student
Marine Sciences Research Center
State University of New York at Stony Brook
coastal sedimentation dynamics; radioactive dating of coastal sediments

Dr. D. W. Pritchard
Associate Director for Research and Professor of Physical Oceanography
Marine Sciences Research Center
State University of New York at Stony Brook
estuarine and coastal dynamics; coastal zone management

Dr. W. H. Queen
Director
Institute for Coastal and Marine Resources
East Carolina University
coastal zone management; marine botany; shoreline use and development in the Chesapeake Bay

Dr. J. R. Schubel
Director and Professor of Oceanography
Marine Sciences Research Center
State University of New York at Stony Brook
coastal sedimentation; suspended sediment transport; coastal zone management; marine geophysics

Dr. W. R. Taylor
Acting Director
Chesapeake Biological Institute
The Johns Hopkins University
biological oceanography

Dr. O. W. Terry
Associate Research Professor of Biological Oceanography
Marine Sciences Research Center
State University of New York at Stony Brook
aquaculture; wetlands management

Dr. P. K. Weyl
Professor of Oceanography
Marine Sciences Research Center
State University of New York at Stony Brook
coastal zone planning; physical oceanography; paleoceanography

Mr. W. M. Wise
Technical Specialist
Marine Sciences Research Center
State University of New York at Stony Brook
environmental impacts of dredging and dredged material disposal; coastal zone management

Glossary of Terms

Agglomerate - a composite particle composed of two or more individual particles held together by relatively weak binding forces. Agglomerates are produced by physico-chemical processes and by organisms.

Benthos - marine organisms which live in or on the sea floor.

Biomass - the amount of living matter per unit area or volume expressed in units of mass/area or mass/volume.

Biota - the plant and animal life of a given region.

Continental Shelf - a zone adjacent to a continent or island and extending from the low water line to the depth at which there is a marked increase in the slope of the sea floor to great depths.

Delta - a deposit of sediment formed at the mouth of a river, stream or tidal inlet.

Density Flow - the flow of one water mass through, under or around another which retains its identity because of density differences from surrounding waters.

Deposit Feeder - an organism that feeds at or near the sediment-water boundary.

Depositional Plain - a low, flat area of sediment on either side of a river deposited during floods.

Detritus Feeder - an organism that feeds on the bacterially-decomposed remains of plants and animals, or on the bacteria themselves.

Drainage Basin - the land drained by a river or river system.

Fathometer - an instrument using sound impulses to measure water depth.

Fluid Mud Layer - a dense layer of fine-grained, unconsolidated sediment flowing along the sea floor, driven by gravity or by tidal currents.

Freshet - a flood or overflowing of a river, caused by heavy rain or melting snow.

Gradient - the rate of change of one quantity with respect to another; e.g., the rate of decrease of temperature with water depth.

Ground Water - that part of the subsurface water below the water table.

Heavy Metal - metallic elements with high molecular weights; some of these are toxic at low concentrations to plant and animal life.

Infauna - organisms permanently residing below the sediment-water boundary.

Interstitial Water - water contained in the pore spaces between the grains of rock or sediments.

Littoral Zone - the zone along the shore extending from the high tide line to some arbitrary shallow depth.

Nekton - swimming organisms that can direct their own movements against the action of marine currents.

Nutrient - any one of a number of compounds or elements used by photosynthetic organisms in the production of living material.

Otter Trawl - a large commercial fishing net using kite-like wooden boards at the corners of the mouth of the net, so angled that water pressure drives them apart, keeping the mouth of the net open as it is dragged through the water.

Oxidation - the process of chemical combination with oxygen or more generally, the removal of one or more electrons from an atom or molecule.

Percolation - process by which water passes through the pore space of rock or sediments.

pH - a chemical measure of the relative acidity of an aqueous solution.

Photic Zone - the layer of water which receives sufficient light for photosynthesis to occur; usually no deeper than 60m.

Photosynthesis - the production of organic compounds with the aid of radiant energy, principally light and carbon dioxide.

Plankton - plants (phyto) and animals (zoo) whose swimming powers are relatively weak. They usually float and drift passively in the water.

Polychaete - one of an order of marine worms, most of whom are segmented.

Primary Productivity - the amount of organic matter produced by plants from inorganic nutrients in a unit time per unit area or unit volume.

Recruitment - the increase in the size of a biologic population through the addition of new individuals.

Reduction - the process of chemically removing oxygen from a compound or, more generally, the addition of one or more electrons to an atom or molecule.

Spawning - the release of masses of eggs by fishes, mollusks, crustaceans, amphibians, etc.

Species Diversity - an index number based on the ratio between the number of different species in an area and either the total numbers of individuals belonging to those species or their biomass.

Tidal Excursion - the horizontal distance a water parcel travels during one-half a tidal cycle.

Topography - the surface configuration of an area, including its vertical relief.

Turbidity - reduced water clarity resulting from the presence of suspended material.

Zonation - the organization of an area into more or less separate and distinct areas with different plant and animal associations.

Zooplankton - animal components of the plankton, including various crustaceans, jellyfish, worms, mollusks and the eggs and larvae of a wide variety of other organisms.