CHAPTER 3

ENVIRONMENTAL CONSIDERATIONS IN DESIGN

3-1. Circulation and Water Quality.

a. Estuary Hydrodynamics. Many deep-draft navigation channels are located in estuaries. Estuaries are transition areas between the ocean and the freshwater inflow from rivers. Mobile Bay, shown in Figure 3-1, and Chesapeake Bay are examples of estuaries. Circulation in these areas is complex and is mainly dependent on the relative magnitudes of tidal variations in water levels and currents, freshwater inflow, density currents caused by density differences between the ocean and fresh water, and, to a lesser extent, the Coriolis acceleration. Wind and waves also become important for short durations. The mixing regime and resultant salinity distribution depend on the relative magnitudes of these forces.

(1) Mixing regimes. Three types of salinity distributions are possible: highly stratified, partially stratified, and well mixed. Figures 3-2 and 3-3 show conditions typical of stratified and partially mixed estuaries. In a highly stratified estuary, the interface between saltwater and fresh water is reasonably well defined (Figure 3-2), but in a well-mixed estuary there is a gradual transition from saltwater to fresh water and salinity differences from surface to bottom are slight.

(2) Effect of tidal variability. The tide imposes a cyclic upstream and downstream movement of salinity. In some estuaries, a strong correlation between salinity stratification and the neap-spring tide cycle exists. During spring tides, more energy is available for vertical mixing. This phenomenon has been observed in Chesapeake Bay.

(3) Effects of freshwater discharge. Another measure used to classify the degree of stratification is the ratio of the volume of fresh water discharged into an estuary over a tidal cycle to the tidal prism volume. If this ratio is greater than one, the estuary is likely to be highly stratified. As this ratio decreases, the stratification also decreases. Therefore, for a given set of tidal conditions, increasing tributary freshwater input tends to stratify the estuary, while decreasing inflows allow greater mixing.

(4) Residual circulation. Circulation in estuaries can be described as the superimposition of the back-and-forth tidal flow on a net, steady circulation. This net, steady circulation is often referred to as the "residual circulation." The residual circulation can be obtained at any point in the estuary by integrating the observed velocity at that point over the tidal cycle. Residual circulation is always present in an estuary to some degree.

(a) Tidal pumping. Tidal pumping is a term that refers to a tidal body of water in which the ebb flow path differs from the flood flow path in a consistent manner, causing a net steady circulation or "pumping" effect. One form of this circulation often occurs just inside many inlets, where the flood flow enters as a confined jet, while the ebb flow comes from all around the mouth in a much different flow pattern from the flood jet (Figure 3-4a). Another example of tidal pumping occurs in braided channels in which the

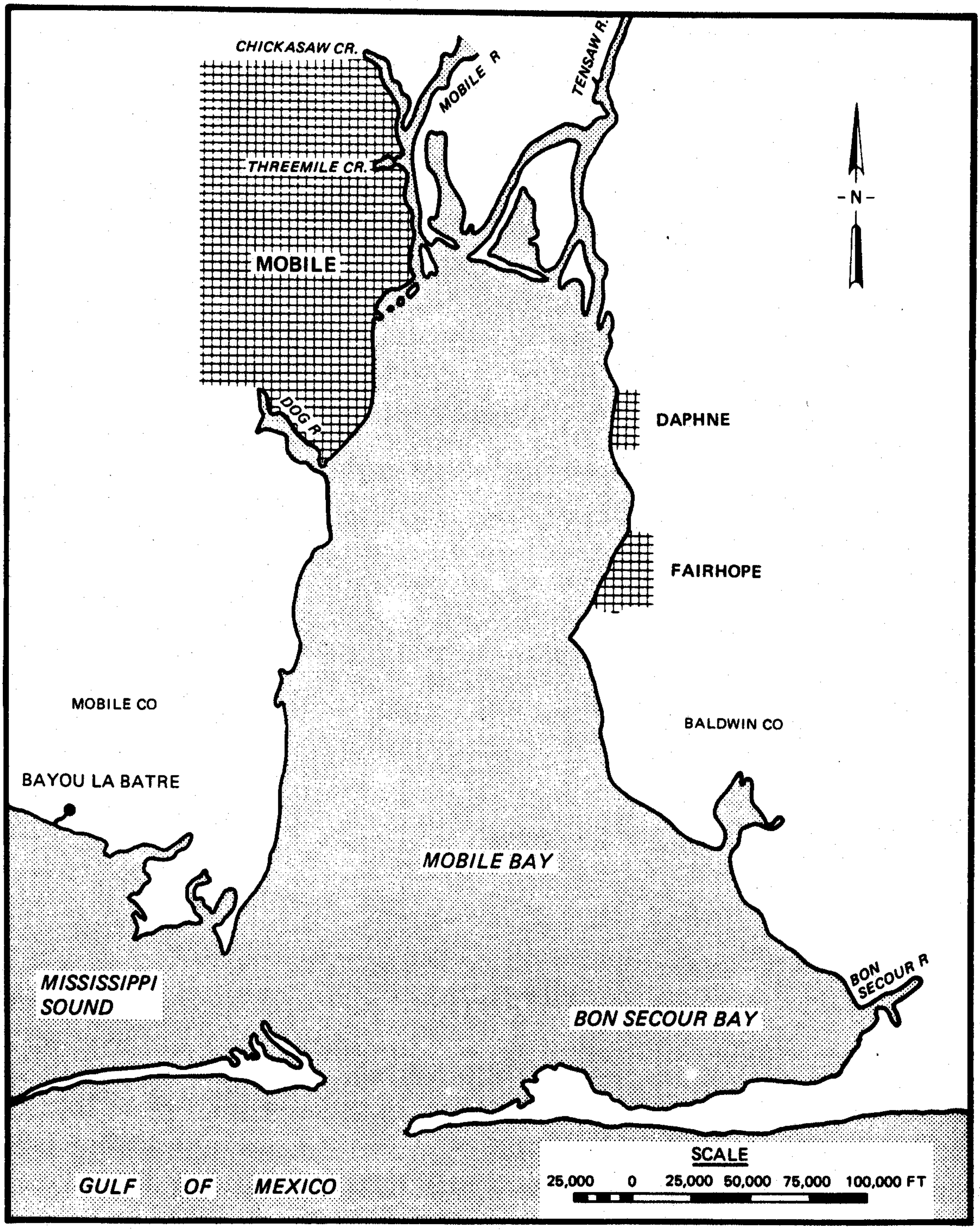


Figure 3-1. Mobile Bay estuary

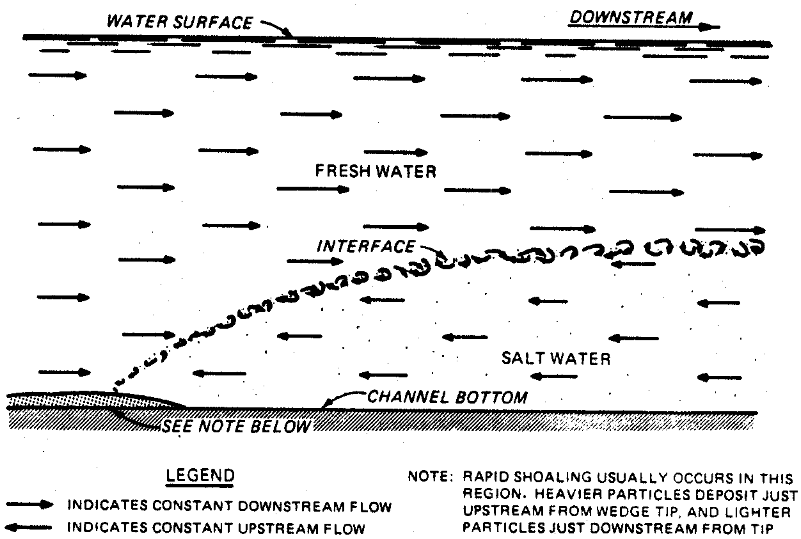


Figure 3-2. Conditions typical of highly stratified estuary

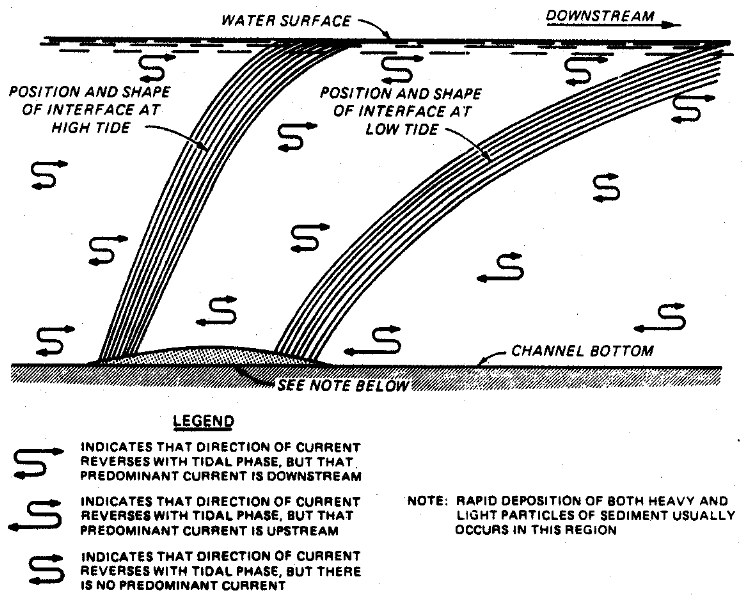
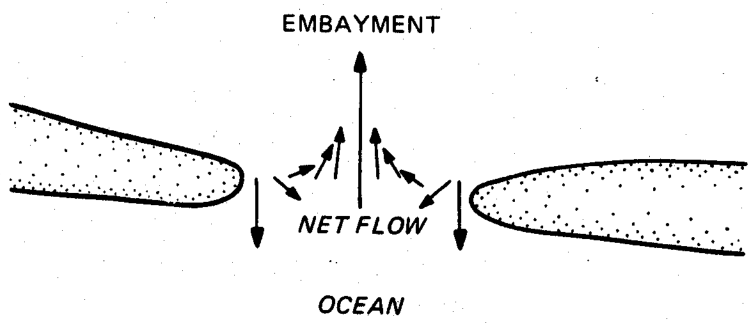
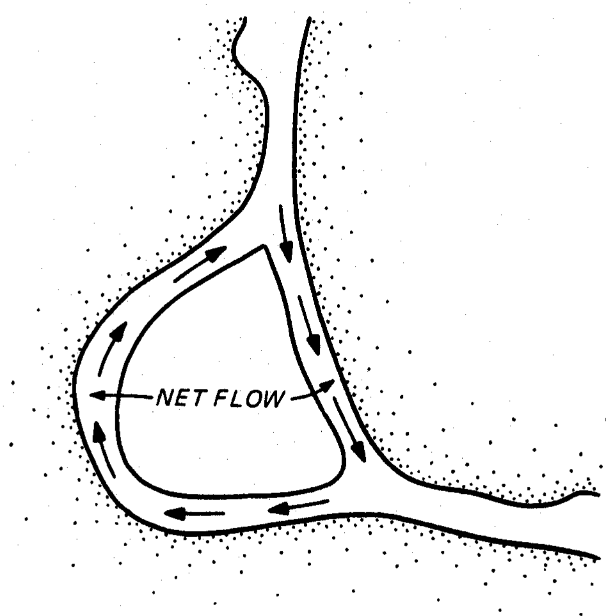


Figure 3-3. Conditions typical of partially mixed estuary



a. Residual flow pattern at an inlet



b. Residual flow pattern at River Cutoff

Figure 3-4. Examples of residual circulation caused by tidal "pumping"

distribution of flood flow is different from the distribution of ebb flow, resulting in a net, steady circulation (Figure 3-4b).

(b) Freshwater inflow. Tributary inflow causes residual circulation due to the density difference between the river and ocean water (gravitational circulation) and to the distribution of river flow within a wide estuary. Density currents are generated due to longitudinal and vertical salinity gradients. Tidal velocities greatly exceed the density currents in magnitude, but even weak currents due to salinity gradients greatly enhance the inland transport process. Whenever an estuary is highly stratified or partially mixed, density currents are generated which result in residual flow landward along the bottom and seaward along the surface in the region of the estuary below the limit of saltwater intrusion (Figure 3-5). Above the limit of saltwater intrusion, salinity gradients and resultant density currents do not exist, and the residual circulation caused by river flow is downstream both

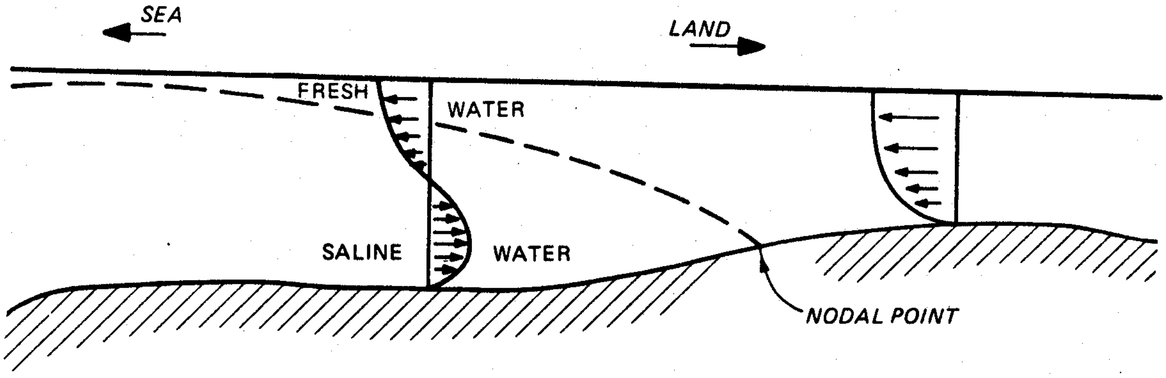


Figure 3-5. Distribution of velocity over depth in typical stratified estuary

along the surface and the bottom. Thus, a nodal point exists along the bottom at a point or points where the net transport over a tidal cycle is zero. For a highly stratified estuary, this point is near the limit of salinity intrusion; for a partially mixed estuary, it would be seaward of this limit. The nodal point represents a "trapping zone" in the lower water column which must be considered when water quality is studied.

(c) Coriolis acceleration. In large estuaries, one cause of residual circulation is the earth's rotation, which deflects currents to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. To an observer facing seaward in the Northern Hemisphere, flood tide currents are deflected toward the left shoreline and ebb tide currents to the right shoreline, resulting in a net counterclockwise circulation. This inertial-induced residual circulation is also referred to as Coriolis circulation and explains why in Chesapeake Bay the salinity is, on the average, higher on the eastern shore (on the left looking seaward) than on the western shore.

(d) Wind stresses. Another type of residual current is that generated by wind stresses on the water surface. If the estuary is of sufficient size, wind stresses can generate residual circulation of considerable magnitude.

b. Changes in Hydrodynamics Due to Deep-Draft Projects. Deepening or realignment of navigation channels alters the volume of an estuary. The changes in volume are usually very small compared with total estuarine volume. Small changes in volume result in insignificant changes in tidal flow. However, channel deepening or realignment can have a major impact on residual circulation. Altered circulation can affect water quality not only along the channel but in areas of the estuary far removed from the dredged channel. In general, the effect of deepening is to increase the landward extent of salinity intrusion, and vertical salinity stratification becomes more pronounced. There is also likely to be a net increase in the vertically averaged salinity as well. Refer to Appendixes B and C for more information on the use of mathematical and physical models in deep-draft environmental studies.

(1) Deep-draft project construction usually has only indirect effects on tidal pumping and insignificant impact on Coriolis- and wind-induced

circulation. However, channel deepening directly impacts the gravitational circulation in that the nodal point and the resulting trapping zone are allowed to intrude further up the estuary. In addition, channel deepening tends to enhance or strengthen the gravitational circulation and intensify stratification. These changes can in turn produce changes in water quality parameters other than salinity.

(2) Excavation of a deep-draft channel in a wide or braided estuary can cause significant redistribution of freshwater inflow, producing unexpected results. In wide estuaries, channel deepening can result in portions of the estuary becoming fresher, even though the overall salt content of the estuary is increased. This phenomenon has been observed in physical model investigations of channel deepening in Mobile Bay, Alabama, and is discussed in WES TR H-75-13. A similar phenomenon, unexpected freshening of a portion of the estuary, was also noted in physical model investigations of channel deepening for Grays Harbor, Washington, which is described in WES TR H-72-2. Grays Harbor is not a wide estuary but does have multiple channels, thus allowing for the redistribution of freshwater flow as one channel is deepened.

(3) Since the salinity regime will be affected by a deep-draft channel, it is important to consider the effect it could have on water-supply intakes. During low freshwater discharge, the potential for the intake of saltwater increases. Channel deepening and resultant saltwater intrusion could result in saltwater encroachment into aquifers as well as in effluents from point discharges being carried upstream.

c. Prediction of Circulation and Water Quality Changes. A project-specific study of the impact of a deep-draft navigation channel on circulation is required to establish the exact nature of changes in water quality that would be associated with channel construction. The results of such a study can sometimes be used in evaluation of the project's beneficial or adverse effects on ecological resources.

(1) Systematic procedure. Characterization and prediction of the deviation of all water quality parameters from baseline conditions due to project construction would require excessive time and money. Therefore, the following systematic procedure should be used:

(a) Hydrodynamic modeling techniques can be used to simulate the velocity under baseline conditions and following proposed modifications. Mathematical hydrodynamic modeling and physical modeling are discussed in Appendixes C and D, respectively.

(b) Dye tracers, salinity, or DO can be used to estimate changes in dilution, detention times, and stratification.

(c) Minor changes in the velocity field can be used to postulate minor water quality impacts. This postulate may be invalid if a preliminary water quality reconnaissance indicates potential toxicant effects on biotic populations.

(d) Significant changes in dilution, detention times, or stratification indicate a need for more detailed water quality analysis.

(2) Detailed analysis. Detailed analysis should be limited to selected water quality constituents and should be based on a knowledge of the system hydrodynamics. Detailed evaluation should be conducted for those constituents that:

(a) Exist in concentrations approaching or exceeding numerical standards or criteria.

(b) Can be used to define habitat suitability for selected biological populations.

(c) Are of sociopolitical concern.

(d) Must be included because they interact with constituents of concern.

(3) Overall water quality analysis. Evaluation of potential water quality changes due to altered circulation should provide input to an overall evaluation of project effects on water quality. As discussed in paragraph 2-3, water quality impacts of deep-draft projects can be addressed in three categories: (a) dredging and disposal during construction and maintenance; (b) increased pollutant loadings due to facility construction, vessel discharges, and accidental spills; and (c) altered circulation due to changes in geometry. Categories (a) and (b) primarily describe the introduction and mobilization of water quality constituents and can be mathematically modeled through source and sink terms.

3-2. Prevention and Control of Salinity Intrusion.

a. Approach. In order to reduce salinity intrusion, several approaches can be considered:

(1) Blockage of the saltwater path.

(2) Increased mixing.

(3) Constriction of the estuary cross section.

(4) River flow regulation.

b. Blockage of Saltwater Path. Complete blockage of the saltwater path can be accomplished by placement of a barrier extending from the channel bottom up through the saline layer, which for a highly stratified estuary might be just a portion of the channel depth, but for a well-mixed estuary might extend through the entire water column (Figure 3-6). This type of barrier might be a curtain or inflatable barrier that could be opened to allow navigational traffic or a dam-type barrier accompanied with a lock structure if navigation is desired past the barrier. The Calcasieu River saltwater barrier, Louisiana, is an example of this method of salinity control (US Army Corps of Engineers 1971). Some additional methods might be needed to block saltwater that intrudes through the lock or past the mobile barriers. Methods that have been used for salinity control include: complete exchange of salt/freshwater while lock gates were closed, air screens, water screens, locking by pumping instead

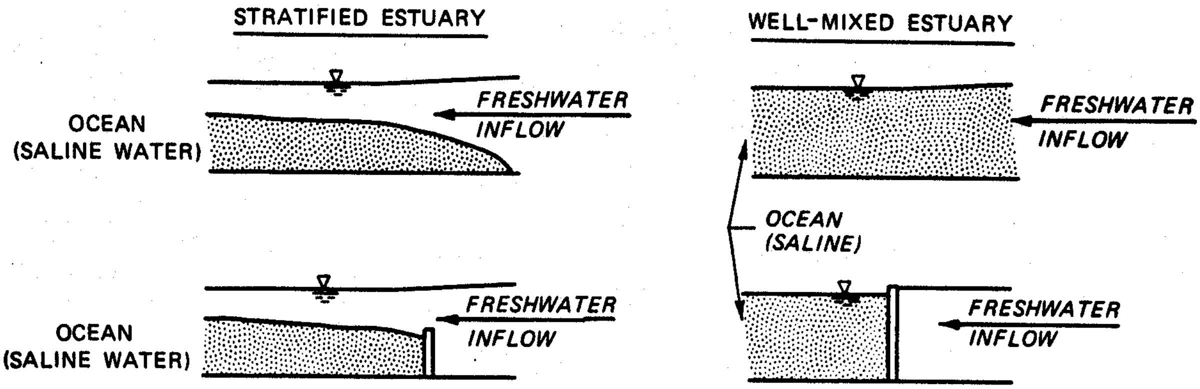


Figure 3-6. Schematic of blockage of saltwater path

of gravity, selective withdrawal during intrusion, and selective withdrawal after intrusion has taken place.

c. Increased Mixing. If a region of the estuary is stratified, the length of salinity intrusion can be reduced by creating greater mixing of the fresh and saline waters (Figure 3-7). In effect, this is making greater use of the river flow. Pneumatic barriers (air screens) or hydraulic barriers (water screens) could theoretically be used to increase mixing; however, these methods have not been attempted in a prototype application. Barriers that constrict flow also induce mixing. However, this method has rarely been used for general estuarine salinity intrusion, and the use of pneumatic barriers has been confined to intrusion through navigation locks.

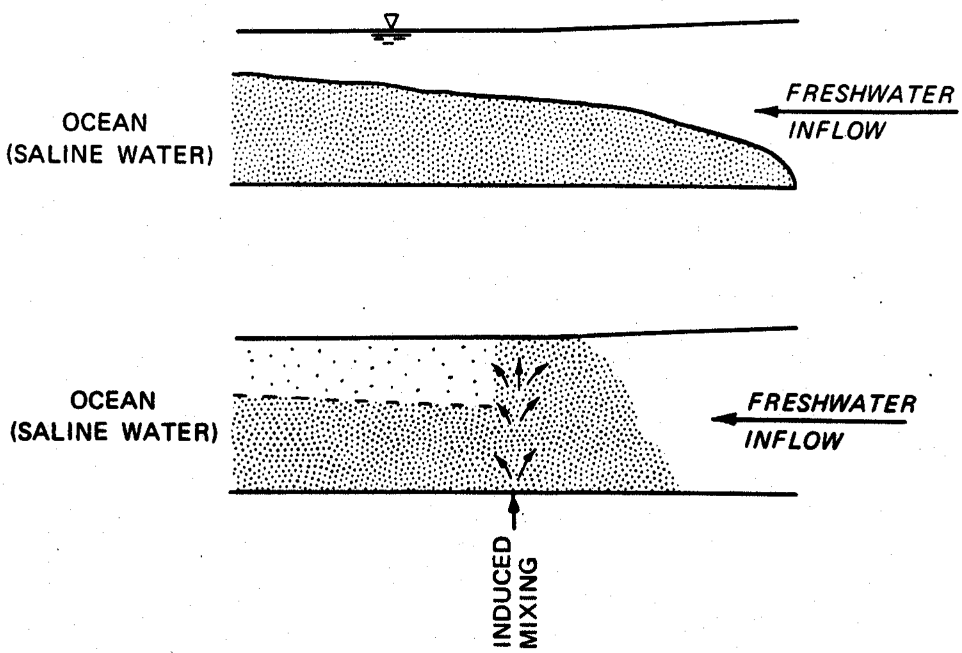


Figure 3-7. Schematic of mixing using pneumatic barrier

d. Constriction of Estuary Cross Section. Constriction of the estuary cross section could reduce tidal fluctuations above the constriction and would not reduce the freshwater flow through the estuary. This method would be of benefit primarily if intrusion were a problem only during a portion of tidal cycle (Figure 3-8). It would be of less value in an estuary with a very low

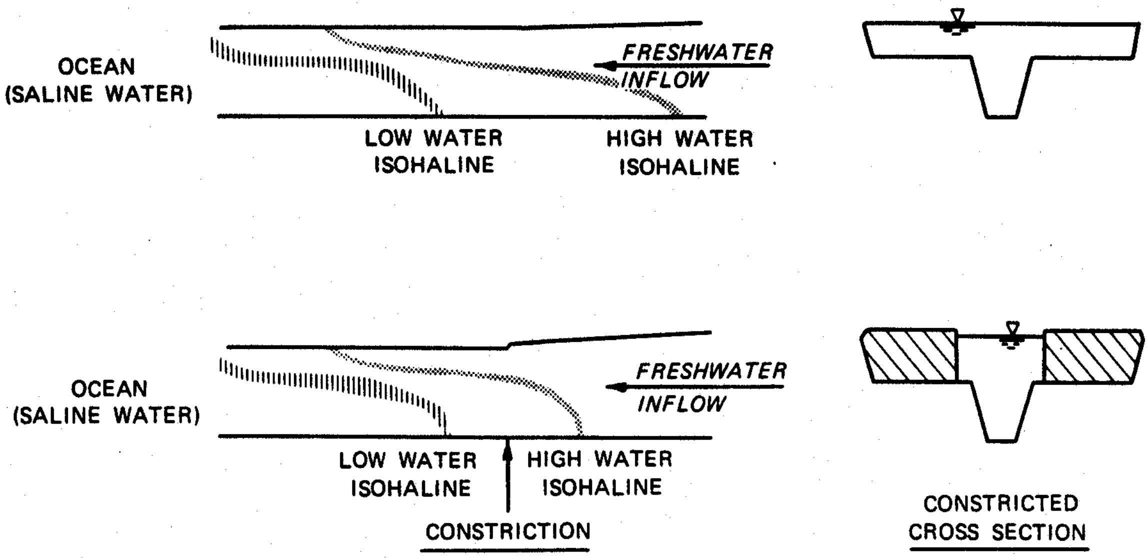


Figure 3-8. Schematic of estuary constriction

tidal range, where the length of salinity intrusion might not vary greatly during the tidal cycle. If, for instance, the length of salinity intrusion increased considerably from low water to high water slacks due to a large tidal range, constriction could be an effective measure. The constriction might consist of dikes across the shallow to reduce the cross section and force freshwater flow to the channel. Barriers in the navigation channel would again have to be mobile or deep enough not to interfere with navigation.

e. River Flow Regulation. If salinity intrusion were only a seasonal problem occurring during drought periods, regulation of freshwater inflow with reservoirs might be sufficient to keep the saline water seaward by moderating seasonal flow variation. Provision of storage for this purpose must usually be done in the planning stage to avoid conflicts among competing water uses. Low-flow augmentation might also significantly alter mixing (and thus circulation) characteristics during the low-flow periods. Careful monitoring and complex riverflow regulation have been used in the San Francisco Bay and Delta system to moderate salinity intrusion.

f. Investigation. The process of salinity intrusion is quite complex as a result of several interrelated phenomena. This has made the design of salinity intrusion mitigation measures correspondingly complex. Therefore, a study of salinity intrusion mitigation measures generally requires an extensive project-specific investigation of siting, operation, and usefulness of control measures. This could involve a numerical or physical model, laboratory testing, field data efforts, or some combination of these techniques.

3-3. Sedimentation Effects.

a. Sedimentation Processes. Sedimentation processes in inland or coastal deep-draft navigation projects may be classified according to the physical characteristics of the sediment as either cohesive or noncohesive. Inland riverine sedimentation is composed primarily of noncohesive sands and silts, whereas coastal shoaling usually covers a wide range of sediment sizes, from coarse sand and shell fragments to cohesive clay particles. A good review of estuarine sedimentation processes may be found in Ariathurai (1982). Dyer (1979) provides much of the information necessary for data collection and estimation of parameters.

(1) Noncohesive sedimentation. Noncohesive sediment particles are transported as individuals. A grain on the bed begins to move when the lift and drag exerted on it by the flow overcome the restraining forces of grain weight and friction. The particles may roll or be entrained in the flow for a period. There is a continuous interchange of grains between the bed and the sediment in transport. When the capacity of the flow to transport sediment is equal to the sediment supplied, the deposition and erosion are in balance and a stable bed results. If the supply and the flow capacity to transport are not equal, the bed will either aggrade or degrade. Many formulas to estimate the discharge of bed sediment under conditions of uniform steady flow have been developed. These transport functions are primarily dependent on the grain-size distribution and flow conditions. Measurement of these parameters and necessary procedures and methodologies may be acquired from several publications (Thomas 1976; US Geological Survey 1972; Schmid and Schmid 1979).

(2) Cohesive sedimentation. The behavior of cohesive sediments differs from that of noncohesive sediments due to the essence of interparticle bonds. These bonds are manifested in the flocculation (sticking together) of particles to increase settling velocity, and entrainment occurs only when the interparticle bonds are broken. The erosion rate of the cohesive beds is linearly dependent on the hydraulic shear stress at the bed above some critical value. Cohesive sedimentation results when shear stress on the bed is insufficient to prevent contact of suspended particles and the bed or to resuspend particles that reach the bed. The rate of deposition also varies linearly with bed shear stress.

b. Project Effects on Shoaling Rates. The construction of deep-draft navigation channels often leads to increased shoaling rates, and rates are usually directly related to project dimensions. Shoaling in a riverine environment is usually dominated by the peak flow periods when the sediment supply is very large. Increased channel dimensions result in lower transport capacity, and when the sediment supply is large, the increase in shoaling can be substantial.

(1) Shift of nodal point. Estuarine shoaling is complex, with the driving mechanisms originating from the tide, wind-generated waves, freshwater inflow, density gradients, and interaction of shallow and deep regions. As described in paragraph 3-1 above, the density difference between fresh water and saltwater produces density currents that create a trap near the nodal point or points along the channel bottom where the net transport is zero over a tidal period. Residual circulation patterns also result in sluggish net flow.

Sediment is transported to these trapping, or null, zones both from the landward and seaward directions, and these zones usually experience high suspended sediment concentrations and high shoaling rates. An example is shown in Figure 3-9. This shows the location of the null zone for 1953-1954 shoaling in Savannah Harbor for particular channel conditions. Also shown are the shoaling conditions along the channel, with the highest shoaling occurring near the null zone. Navigation channel construction results in landward movement of the null zone, which in turn causes the high shoaling rate region to also shift upstream. Experience in changed shoaling distribution due to several factors is summarized by Simmons (1965).

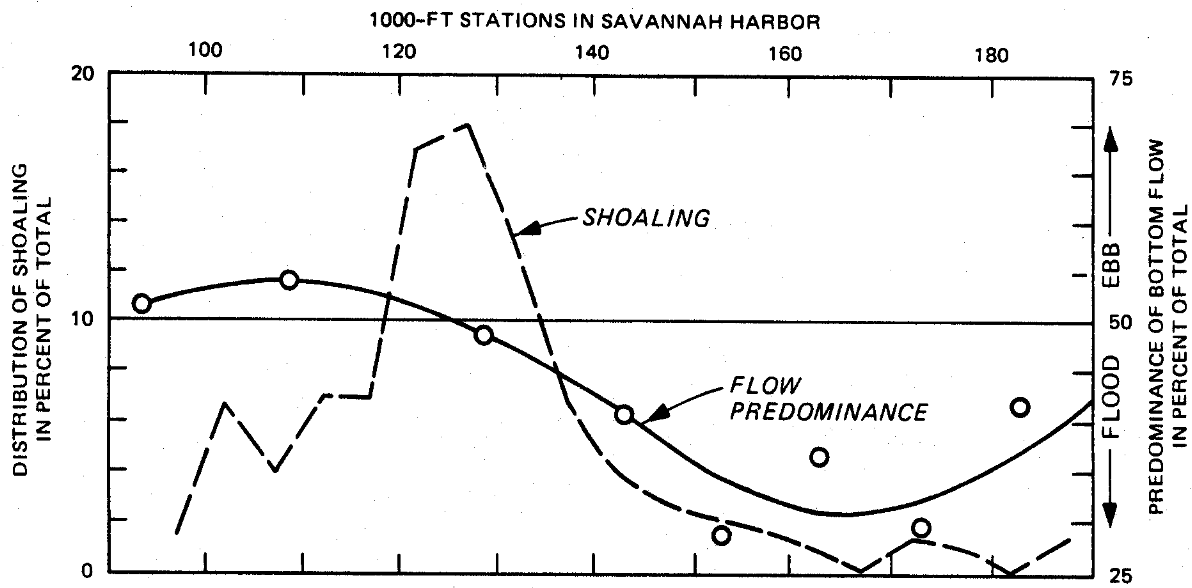


Figure 3-9. Relation of shoaling and null zone location

(2) Exceptions. While it is common for channel construction or enlargement to result in increased maintenance requirements, this is not always the case. For example, the change in shoaling rate with channel enlargement, as indicated by the amount of accumulated new work, for Galveston Channel and Houston Ship (Bay) Channel in Texas are shown in Figures 3-10 and 3-11, respectively. The amount of shoaling increased with channel enlargement early in the projects' histories, but since then the shoaling rate has shown no increase. In fact, there is a slight downward trend. Estuarine channels, unlike riverine systems, have flow rates in which the tidal portion is determined by the dimensions of the channel and estuary. So an enlarged channel will have a greater volume of cyclic flow passing along it and may not show a velocity decrease after channel enlargement.

c. Sediment Control and Management. It is difficult to reduce shoaling rates in estuarine channels since they are efficient sediment traps. Reduction of shoaling rates may be accomplished either by reduction of the sediment supply or by enhancement of the transport capacity of the channels. Generally, the reduction of sedimentation rates in estuaries has been accomplished by increasing transport capacity. Methods include training works that concentrate flow in the channel, modification of the channel geometry by smoothing expansions and contractions, and channel realignment. Sediment management includes

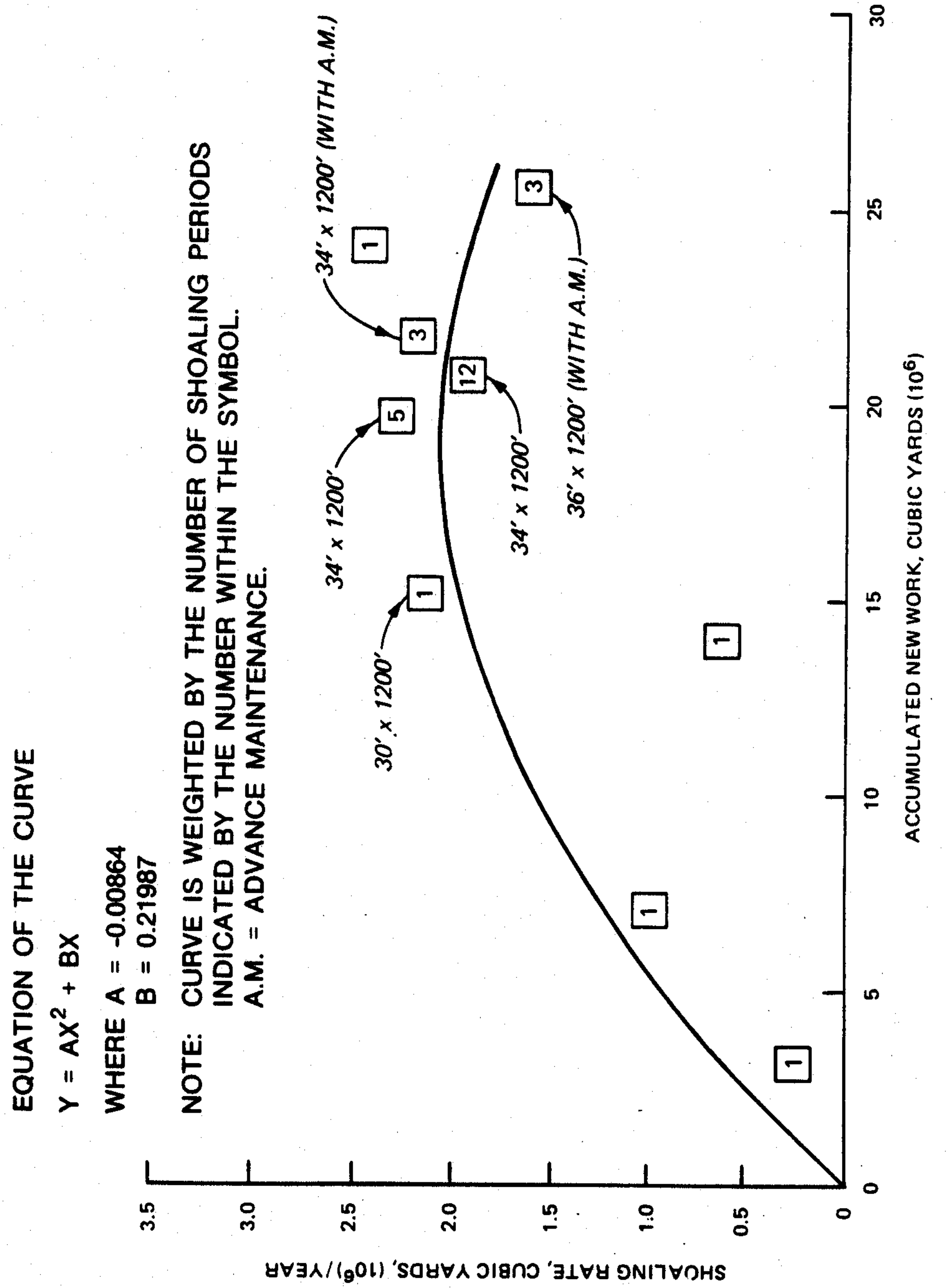


Figure 3-10. Change in shoaling rate, Galveston Channel

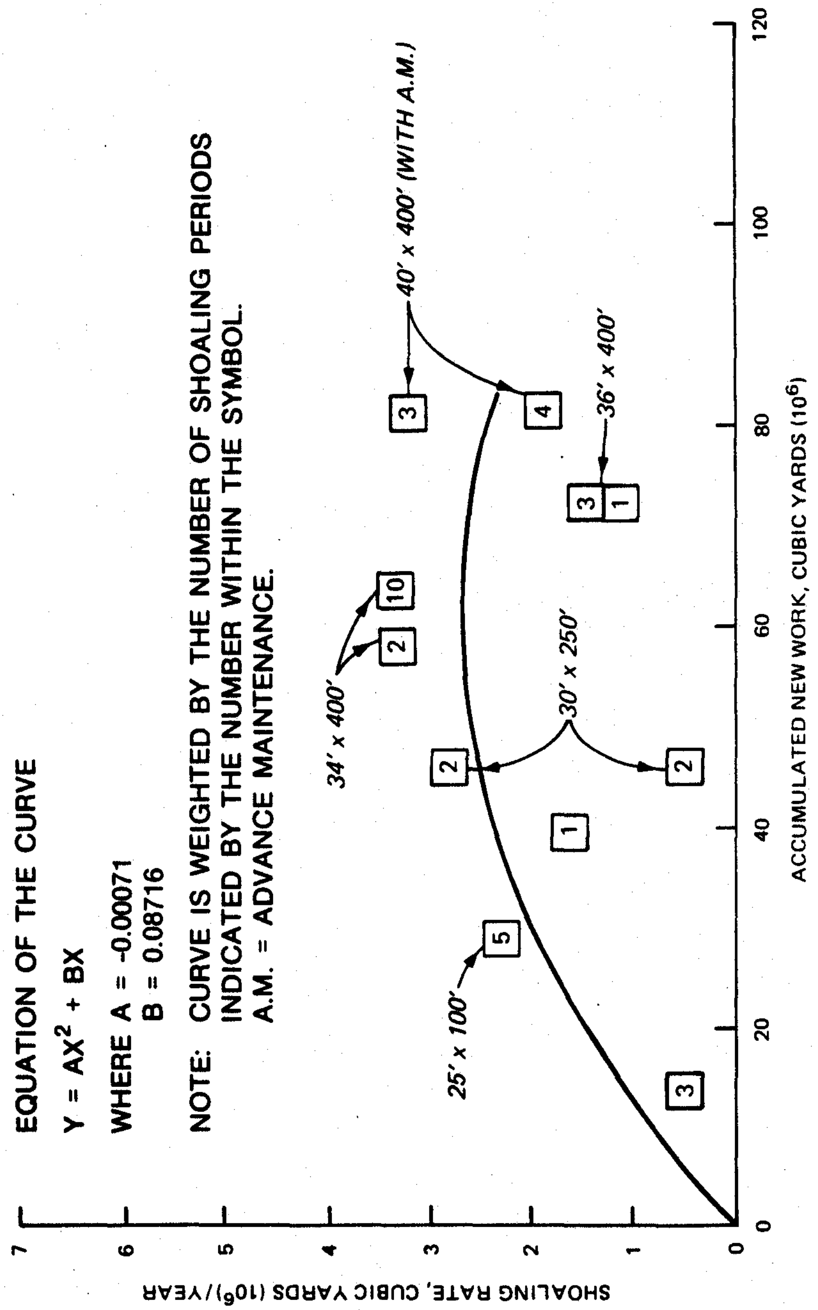


Figure 3-11. Change in shoaling rate, Houston Ship Channel

special dredging techniques such as overdepth or overwidth dredging, advance maintenance, and use of sediment traps.

(1) Training works. Training works have frequently been used to increase transport potential and to reduce shoaling. These have consisted of jetties, pile dikes, jacks, and rock-filled pile dikes. Additionally, the presence of the channel and associated navigation may necessitate bank protection. Various types of revetments, rock windrows, pervious fences, and groins, as well as training structures, are described in "Sedimentation Engineering" (Vanoni 1975). Training works (except for jetties) are much more common in shallow-draft waterways than deep-draft. A more detailed discussion of environmental considerations in the design of training work is given in US Department of the Army, Office, Chief of Engineers (1984).

(2) Dredging tolerance. Dredging tolerance is the additional depth below project depth in which the contractor is allowed to remove material for pay to ensure that minimum project dimensions are provided. This tolerance is allowed because the contractor cannot precisely control the position of the dredge suction. Minimizing dredging tolerance will in turn minimize the total volume of maintenance dredging.

(3) Advance maintenance. Advance maintenance is the technique whereby the channel is enlarged beyond project dimensions to provide additional time before the project needs redredging. Additional information on the use of advance maintenance is given in Trawle (1981).

(a) Estuarine projects that do not experience increased shoaling rates after channel deepening are good candidates for advance maintenance. Costs associated with mobilization and demobilization for dredging operations can be reduced if the additional depth provided by advance maintenance provides a reduced dredging frequency.

(b) It is doubtful that advance maintenance, generally applied, would be particularly satisfactory in riverine conditions, as the amount of maintenance dredging would increase and the dredging frequency, if determined by the peak flow event, would not be reduced. However, it may prove useful to apply in a few short reaches that experience high shoaling during nonpeak flows and have to be redredged before the bulk of the project needs redredging. These critical regions may be deepened beyond project dimensions to allow the elimination of an intermediate dredging operation.

d. Ecological Significance. Sedimentation processes are important modifiers of habitat quality; the bottom sediment (substrate) characteristics such as percent organic carbon, grain-size distribution, sediment depth, and shear strength are major factors influencing the distribution of marine benthic organisms and have also been demonstrated to be important factors for estuarine organisms. Composition and stability of both unconsolidated and consolidated sediments affect the types of benthos found on any particular bottom. Substrates are vital for attachment and as a food source for associated benthos. Sessile epifaunal benthos require consolidated, firm substrates for attachment. Burrowing, suspension-feeding, and tube-building types of benthos modify the quality and may enhance the stability of unconsolidated sediments by binding inorganic and organic particles together as fecal pellets and pseudofeces, by the redistribution of sediments during feeding activities or tube building, and by the secretion of mucopolysaccharides. Benthic infauna may influence sediment stability and subsequent erodibility by reworking the near-surface sediment layers and increasing porosity due to subsurface burrowing activities. Kendall (1983) provides additional detail regarding the role of physical-chemical factors in structuring subtidal marine and estuarine benthos.

3-4. Biological Considerations.

a. Disturbance Avoidance. The primary method to alleviate adverse biological effects associated with deep-draft navigation projects is to avoid disturbing and impacting environmentally sensitive areas. Project activities should be located in the least ecologically significant area available. For example, minor adjustments in channel alignment may prevent the destruction of an oyster reef or mussel bed. Structure designs should be carefully analyzed to determine the size, placement, and composition that are the least detrimental and the most beneficial. Use of materials with wide size gradations, such as quarry run stone, for structures results in aquatic habitat diversity due to the variety of sizes and shapes of crevices. This diversity allows utilization by different sizes and types of organisms.

b. Marsh Protection. Protective structures may be built to reduce impacts to valuable aquatic and terrestrial habitats in the shore zone. Figure 3-12 depicts concepts for several types of structures that may be used to protect natural or man-made marshes.

c. Fishery Management. A variety of fishery management techniques are available and may be feasible for increasing project benefits. Schnick et al. (1982) gives detailed information on these techniques.

(1) Structural and/or mechanical devices can be used to minimize the effects of dams and locks and intakes on fish populations.

(a) Fishways (fish ladders) have been used at a number of dams and locks to allow upstream movement of fishes. Fish negotiate fishways under their own power, whereas fish elevators or lifts transport fish (mechanically) upstream over a dam. Fishes whose upstream migration has been aided by fishways or fish lifts include salmon, steelhead, American shad, river herring, and striped bass.

(b) Fish screens and barriers aid in preventing the entrainment or impingement of fishes at industrial, irrigational, hydroelectric, and municipal water intakes.

(2) Placement of fish-spawning structures and fish attractors are additional fishery management techniques that can be used in waterways (Figure 3-13). Due to the extremely powerful forces exerted during storm and flood conditions, such devices need to be constructed of very dense materials (e.g., concrete blocks or vitrified clay pipe bundles) and placed in areas where less powerful current velocities occur.

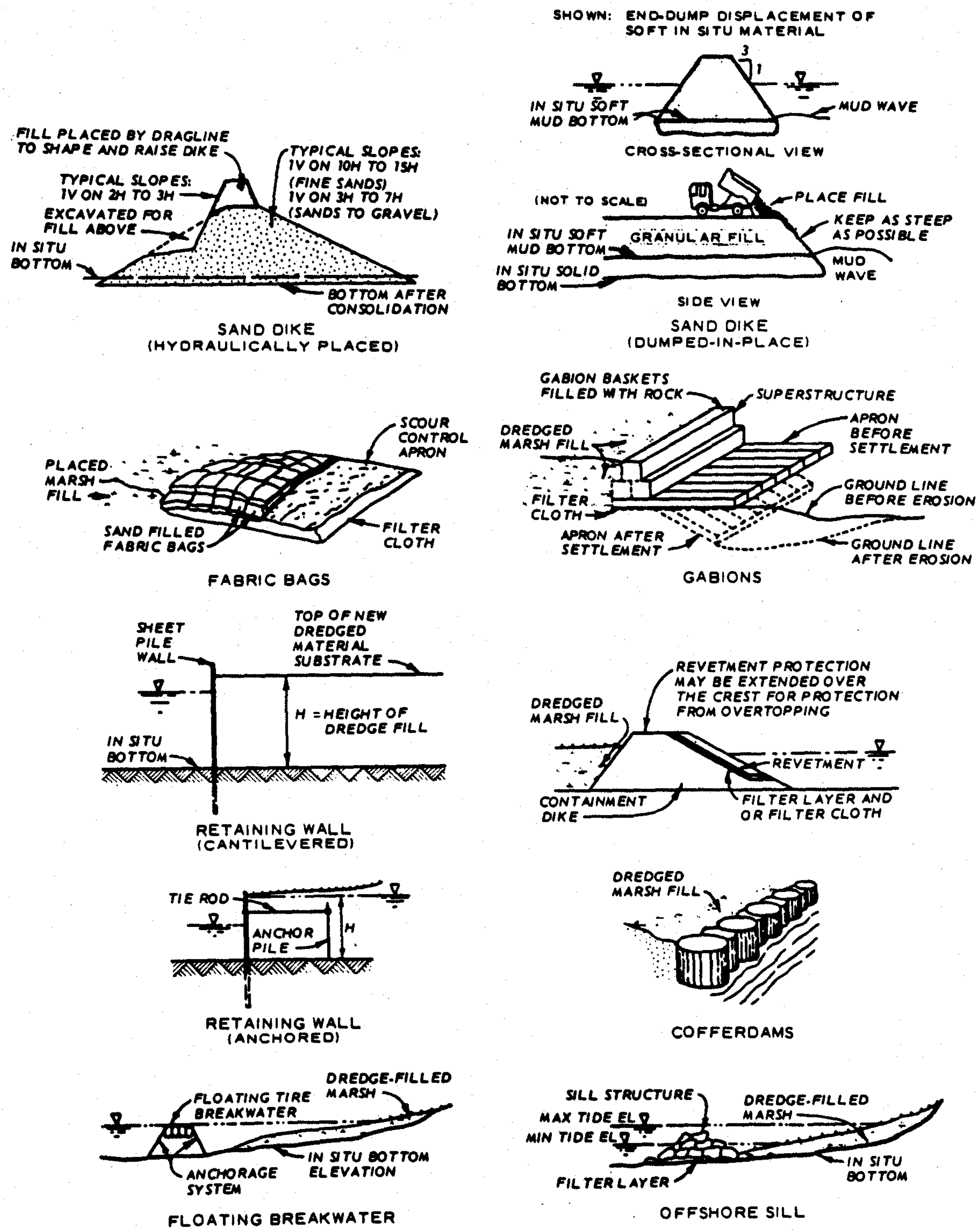


Figure 3-12. Marsh retention and protection structures

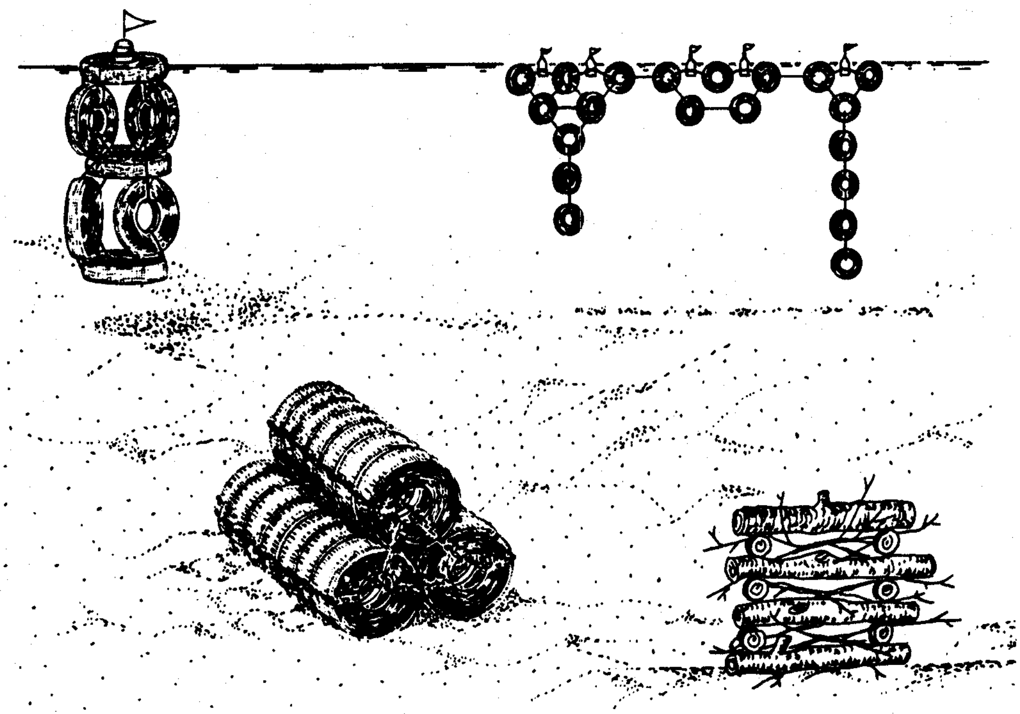


Figure 3-13. Fisheries habitat enhancement structures located adjacent to navigation channel

(3) The development of nursery ponds or coves is another technique for use along waterways. In these areas young fish of a single species are reared in a productive nursery area where they are isolated and are secure from predation. When fish reach a certain size and age, they are released into the aquatic system.

(4) The best overall fisheries management strategy is to manage the aquatic system so that a diversity of habitats is present, and spawning and nursery areas are available and preserved.

3-5. Dredging Effects Considerations.

a. General. Dredging is a major activity in developing deep-draft navigation projects. During the design phase of such projects, the environmental effects associated with dredging and dredged material disposal must be considered. Dredging for navigation projects requires consideration of both short- and long-term management objectives. The primary short-term objective of a deep-draft project is to construct a channel for navigation to authorized project dimensions. This should be accomplished using the most technically satisfactory, environmentally compatible, and economically feasible dredging and dredged material disposal procedures. Long-term dredging objectives concern the efficient management and operation of dredging and disposal activities required to continue operation and maintenance of the navigation project. The environmental considerations required to support the design of new-work dredging for deep-draft navigation projects are discussed below.

b. Basic Considerations. In order to consider the environmental aspects of dredging and dredged material disposal in the design phase of a project, the following activities are required:

Step	Information Source
(1) Analyze dredging location and quantities to be dredged	Hydrographic surveys, project maps
(2) Determine the physical and chemical characteristics of the sediments	WES TR DS-78-10 (Section 5-2)
(3) Determine whether or not there will be dredging of contaminated sediments	WES TR DS-78-6
(4) Evaluate disposal alternatives	EM 1110-2-5025
(5) Select the proper dredge plant for a given project	EM 1110-2-5025
(6) Determine the levels of suspended solids from dredging and disposal operations	WES TR DS-78-13
(7) Control the dredging operation to ensure environmental protection	WES TR DS-78-13
(8) Identify pertinent social, environmental, and institutional factors	Para 2-1
(9) Evaluate dredging and disposal impacts	WES TR DS-78-1 WES TR DS-78-5

Although dredging and related matters have traditionally been considered an operations and maintenance function, a well-coordinated approach in the planning and design stages can minimize problems in the operation and maintenance of the project. This is especially true regarding long-range planning for disposal of both new-work and maintenance dredged material.

c. Equipment Selection.

(1) Most Corps dredging is performed by private industry under contract, and the specifications should not be written such that competitive bidding is restricted. However, in certain situations, limitations may be placed on the equipment to be used to minimize the environmental impact of the dredging and disposal operation. For example, where the available upland containment areas are small, the size of the dredge should be restricted to minimize stress on the containment area dikes, to provide adequate retention time for

sedimentation, and to minimize excessive suspended solids in the weir effluent. Environmental protection is adequate justification for carefully controlling the selection and use of dredging equipment. Deep-draft navigation channels normally are constructed by either hydraulic pipeline cutterhead dredges (Figure 3-14) or mechanical bucket dredges (Figure 3-15) because they are ideal for the removal of the hard and compact materials often found in new-work dredging projects. Hopper dredges are also used for new-work as well as maintenance dredging where the materials to be removed are reasonably soft.

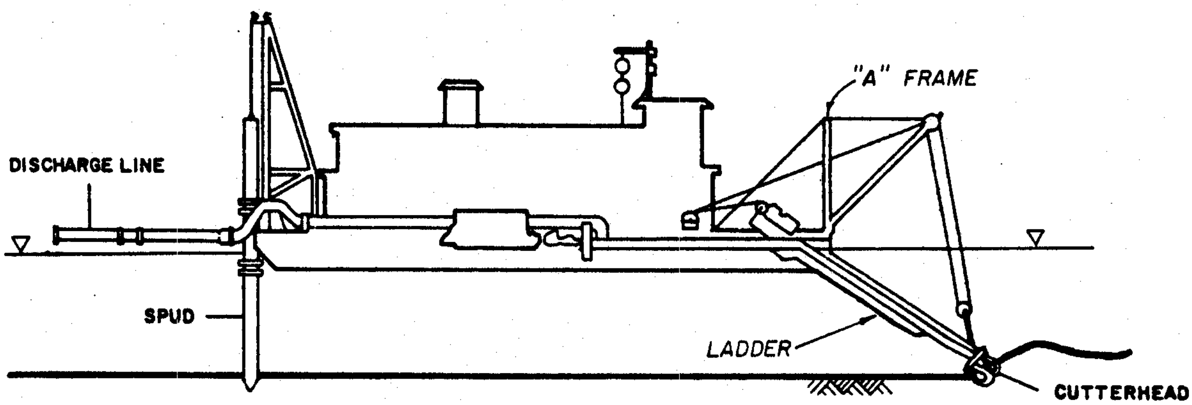


Figure 3-14. Hydraulic pipeline cutterhead dredge

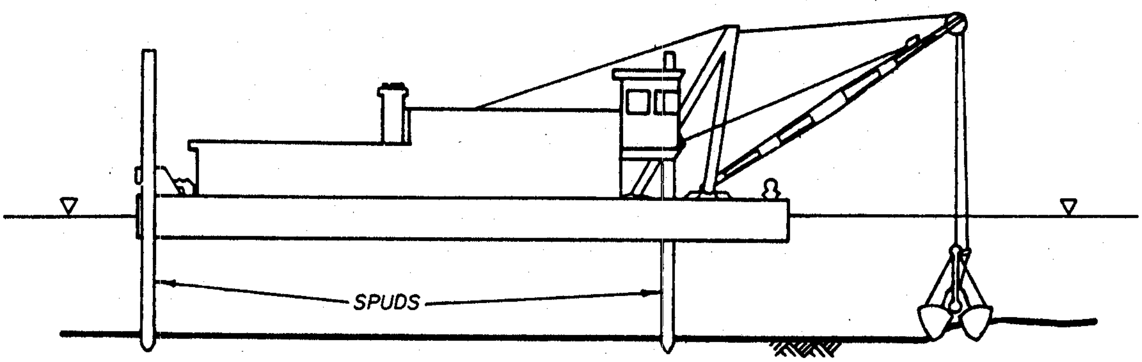


Figure 3-15. Mechanical bucket dredge

(2) The environmental effects commonly associated with dredging operations are increases in turbidity, resuspension of contaminated sediments, and decreases in DO levels. However, research results indicate that the traditional fears of water quality degradation resulting from the resuspension of dredged material during dredging and disposal operations are for the most part unfounded. More detailed information on the impacts of turbidity and the possible impact of depressed DO levels is given in paragraph 2-4 of this manual and EM 1110-2-5025.

(3) In some cases, the environmental impact associated with the dredging of uncontaminated sediment may be insignificant. However, the impact of fluid mud dispersal at open-water pipeline disposal operations appears to be significant, at least for short time periods (i.e. months). Regardless of the

type of dredging or disposal operations, there are certain environments (e.g., spawning grounds, breeding areas, oyster and clam reefs, areas with poor circulation) and organisms (e.g., coral, sea grasses, benthos) that may be extremely sensitive to high levels of turbidity and/or burial by dredged material. It is therefore necessary to evaluate the potential impact of each proposed operation on a site-specific basis, taking into consideration the character of the dredged material, the type and size of dredge and its mode of operation, the mode of dredged material disposal, and the nature of the dredging and disposal environment. The seasonal cycles of biological activity and the degree and extent of the potential short- and long-term impacts relative to background conditions in the areas to be dredged must also be evaluated. Although some of the impacts associated with existing dredging and disposal procedures are proving not to be as severe as previously alleged, techniques to minimize environmental impacts must be employed. These include implementing the guidelines given in this manual for evaluating the existing and resultant conditions, selecting dredges, improving operational techniques, properly using silt curtains, and selecting appropriate pipeline discharge configurations. Sources of guidance on dredging activities are listed below.

Activity	Information Source
Selecting dredge	EM 1110-2-5025
Improving operational techniques	EM 1110-2-5025 WES TR DS-78-13
Properly using silt curtains	WES TR DS-78-13
Selecting appropriate pipeline discharge configurations	WES TR DS-78-13

d. Disposal Alternatives.

(1) While selection of proper dredging equipment and techniques is essential for efficient dredging, the selection of a disposal alternative is of equal or greater importance in determining viability of the project, especially from the environmental standpoint. Three major disposal alternatives are available: open-water disposal, confined disposal, and habitat development.

(2) Each of the major disposal alternatives involves its own set of unique considerations, and selection of a disposal alternative should be made based on both economic and environmental considerations. A brief description of environmental considerations relating to each of the disposal alternatives is given in the following paragraphs. More detailed guidance is given in Section 4-1 and EM 1110-2-5025.

e. Beneficial Uses.

(1) General. The acquisition of suitable disposal acreage is probably the most common problem among Corps Districts related to deep-draft dredging. The problem exists because of the general perception of dredged material as a waste product and because of competition between dredged material disposal area development and other land uses. Often the materials dredged during

construction of deep-draft projects are ideal for beneficial uses such as marsh nourishment, upland habitat development, and as construction materials. Figure 3-16 shows a marsh and upland habitat developed using sand from a dredging project.

Figure 3-16. Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas

(2) Source documents. The following documents provide more detailed information on beneficial uses of dredged material.

Use	Information Source
Marsh nourishment	WES TR DS-78-16
Upland habitat development	WES TR DS-78-17
Land improvement using dredged material	WES TR DS-78-12 WES TR DS-78-21

(3) Example. Figure 3-17 illustrates potential marsh nourishment alternatives for bay and river sites using dredged material from an adjacent deep-draft navigation channel. This is an example of the beneficial use of dredged material in areas where the existing marsh is being destroyed by natural erosion and land subsidence.

f. Long-Range Planning. Dredging and disposal activities cannot be planned independently for each of several projects in a given area. While each project may require different specific solutions, the interrelationships among them must be determined. Thought must also be given to changing particular dredging techniques and disposal alternatives as conditions change. Long-range

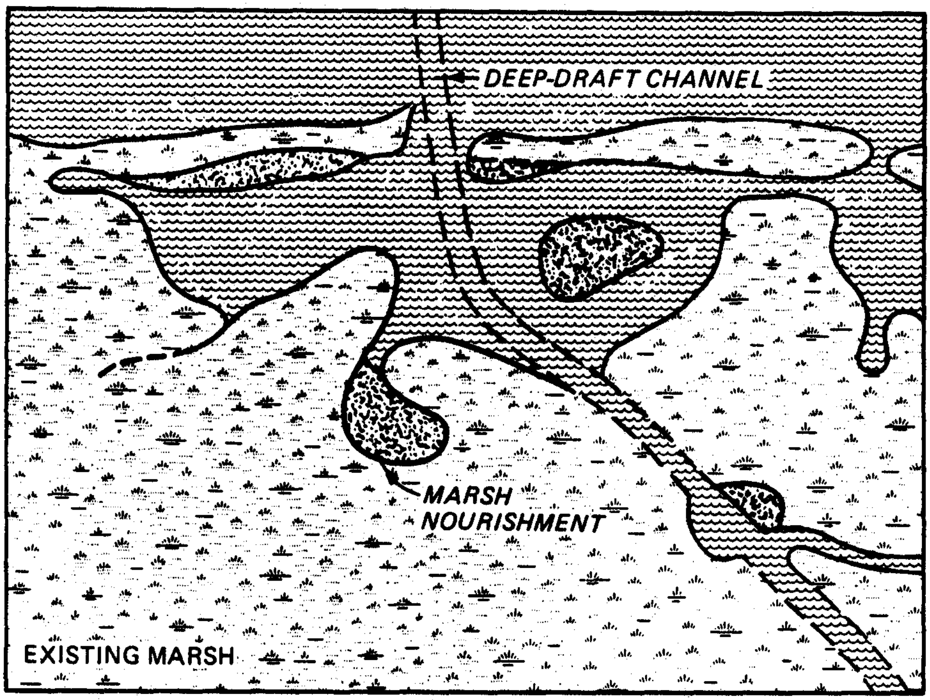


Figure 3-17. Marsh nourishment potential of dredged material at bay and river sites

regional dredging and disposal management plans not only offer greater opportunities for environmental protection and effective use of dredging equipment at reduced project cost, but they also meet with greater public acceptance once they are agreed upon. Long-range plans must reflect sound engineering design, consider and minimize any adverse environmental impacts, and be operationally implementable.

3-6. Associated Activities.

a. The enlargement and/or deepening of existing Federal channels or construction of new Federal channels will normally be associated with concurrent enlargement and development of non-Federal connecting channels and anchorages. Such non-Federal development should be considered in the overall evaluation of environmental effects resulting from changes in circulation patterns, velocities, salinities, etc., and from navigation traffic and spills.

b. Non-Federal channel enlargements will also result in additional volumes of new-work dredged material and perhaps increases in recurring maintenance volumes. Disposal areas used for Federal dredging activities are often used for non-Federal disposals as well. Therefore, requirements for disposal from associated activities should be considered in the selection of dredged material disposal alternatives and in the development of long-range disposal plans. Timing of non-Federal dredged material disposal activities should also be considered in long-range plan development. Since it is advantageous in many cases to dewater upland sites for long periods to promote drying and consolidation, ponding these sites for non-Federal as well as Federal work should be planned and scheduled.

c. Other associated activities may be intensified as a result of Federal and non-Federal channel development. Such activities include wharf and pier construction, fill construction, and associated industrial development (Figure 3-18). These activities may occur in stages and may be closely integrated with the major channel development. Opportunities for development of recreational facilities and fish and wildlife habitat (especially if staged construction is planned) should be considered in the planning and design stages.

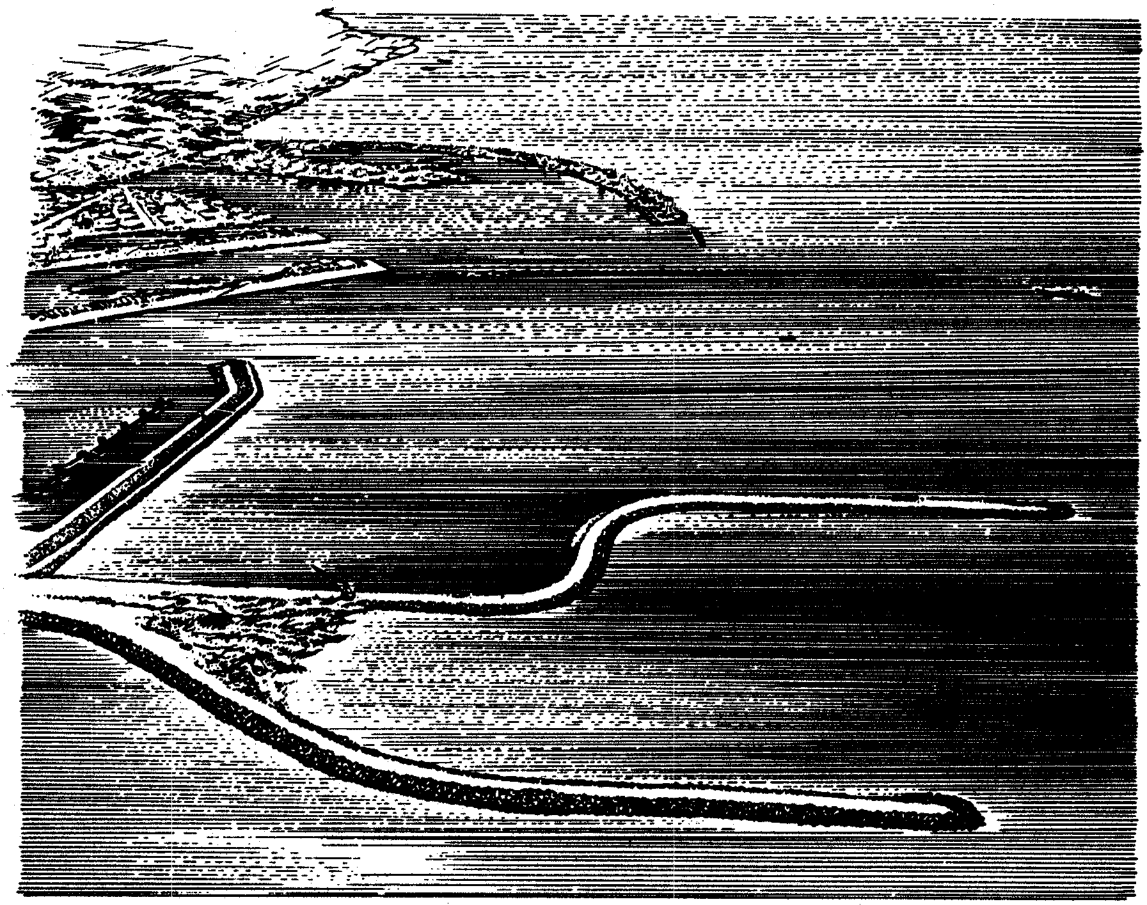


Figure 3-18. Expansion of harbor facilities as a result of deep-draft navigation channel

d. Figure 3-18 illustrates a potential non-Federal channel development activity associated with deep-draft navigation projects. This harbor was developed as close as possible to deep water for reception of larger container vessels. A number of impacts must be considered as a result of such development:

Impact	Information Source
The extension of harbor facilities into the ocean would have an impact on hydraulics. Current velocities would increase if the facilities constricted flow.	ER 1110-2-1404 EM 1110-2-1613
Some morphological changes may occur if unstable channel banks and shoreline exist in the area.	EM 1110-2-1613
Increased currents would likely cause impacts on navigation.	ER 1110-2-1404 EM 1110-2-1613