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	Engineering and Design ENVIRONMENTAL ENGINEERING FOR SMALL BOAT BASINS	
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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

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Manual
No. 1110-2-1206

31 October 1993

Engineering and Design
ENVIRONMENTAL ENGINEERING FOR SMALL BOAT BASINS

- 1. Purpose.** The purpose of this manual is to incorporate environmental considerations into the planning, engineering, design, construction, operation, and maintenance of small boat basins. Much of this guidance is general in nature with many references to appropriate Corps manuals and other design guides. However, specific design guidance is provided for areas involving basin design and operation.
- 2. Applicability.** This manual applies to all HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities having Civil Works responsibilities.
- 3. General.** Small boat basins, which are located on coastlines, estuaries, lakes, and riverbanks, provide direct access to each boat, parking, technical services, shops, and other amenities. The increasing prosperity of the world population has resulted in an increased popularity of and need for small boat basins. The development of small boat basins is a concern to environmental groups and local residents because of the potential effects of these basins on the quality of rivers, lakes, estuaries, and ocean shorelines. The goal of this manual is to provide general environmental considerations guidance during the planning and design stage.

FOR THE COMMANDER:



WILLIAM D. BROWN
Colonel, Corps of Engineers
Chief of Staff

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
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Chapter 1 Introduction

1-1. Purpose

Small boats are classified as recreational craft, fishing boats, or other small commercial craft with lengths less than 100 ft (31 m). A small boat basin is a place to obtain essential supplies such as food, fuel, and drinking water. Small boat basins provide direct access to each boat, adequate depth of water, parking, toilet facilities, technical services, shops, and other amenities. Small boat basins are found on coastlines, estuaries, lakes, and riverbanks. The increasing prosperity of the world population has resulted in an increased popularity of and need for small boat basins. The development of small boat basins is a concern to environmental groups and local residents because of the potential effects of these basins on the quality of rivers, lakes, estuaries, and ocean shorelines. This manual provides general guidance for incorporating environmental considerations into the planning, engineering, design, construction, operation, and maintenance of small boat basins. When these facilities are poorly planned and/or managed, they may pose a threat to the health of aquatic systems and may pose other environmental hazards.

1-2. Applicability

This manual applies to all HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities having Civil Works responsibilities.

1-3. References

Required and related publications are listed in Appendix A.

1-4. General Study Authority

The U.S. Army Corps of Engineers (USACE) has the general authority to investigate the need for navigation improvements under Section 107 of the River and Harbor Act of 1960, as amended (U.S. Army Corps of Engineers 1989). The investigations are limited to determining means to satisfy immediate and future needs for small craft refuge. Desirable sites and facility alternatives are formulated and evaluated, and the best plan is selected based on sound engineering design, economics, and environmental and cultural acceptability. The evaluation criteria used are based on principles and guidelines established by the U.S. Water Resources Council.

1-5. Permit Processing

Because of the possible environmental impact of developing small boat basins, the activities must be consistent with national environmental policies. These policies can be complex and confusing when dealing with the variety of Federal, state, and local regulations concerning small boat marina development in coastal areas and inland waters. Appendix B lists several Federal statutes, executive orders, and USACE regulations that often require studies of existing and future environmental conditions.

a. Federal agencies. The USACE is the Federal agency with direct permitting authority for coastal marinas. Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act give USACE permitting authority for these facilities. Section 10, in conjunction with other environmental laws, provides USACE authority to control, through its permit program, construction and excavation or deposition of any material in navigable waters. The Section 404 program is designed to protect water quality, aquatic resources, and wetlands. It provides USACE with authority to issue permits for the discharge of dredged or fill material into waters of the United States. Guidelines developed by the U.S. Environmental Protection Agency (USEPA) state that no discharge will be permitted if it will result in significant adverse impacts on municipal water supplies, recreation, and economic and aesthetic values. The USEPA does not typically exercise direct permitting control over marina development whenever disposal of dredged and fill material is an issue. However, Section 404 gives the USEPA authority to veto dredged and fill permits proposed by USACE.

(1) The overall process followed by USACE in reviewing permit applications is shown in Figure 1-1. This diagram generally illustrates overall USACE responsibilities and decision points. Typically, when a USACE application form is used, only one form is submitted for both Sections 10 and 404 approval. Once USACE receives the permit, a preliminary assessment is conducted to determine the type of environmental review required. Based upon the potential extent of adverse impacts on the natural and man-made environment, this environmental review may range from a categorical exclusion to a full Environmental Impact Statement. The next step in the permit process is a public notice, which goes out to all interested parties and agencies. The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) are interested in the impact to fish and wildlife resulting from potential water resource

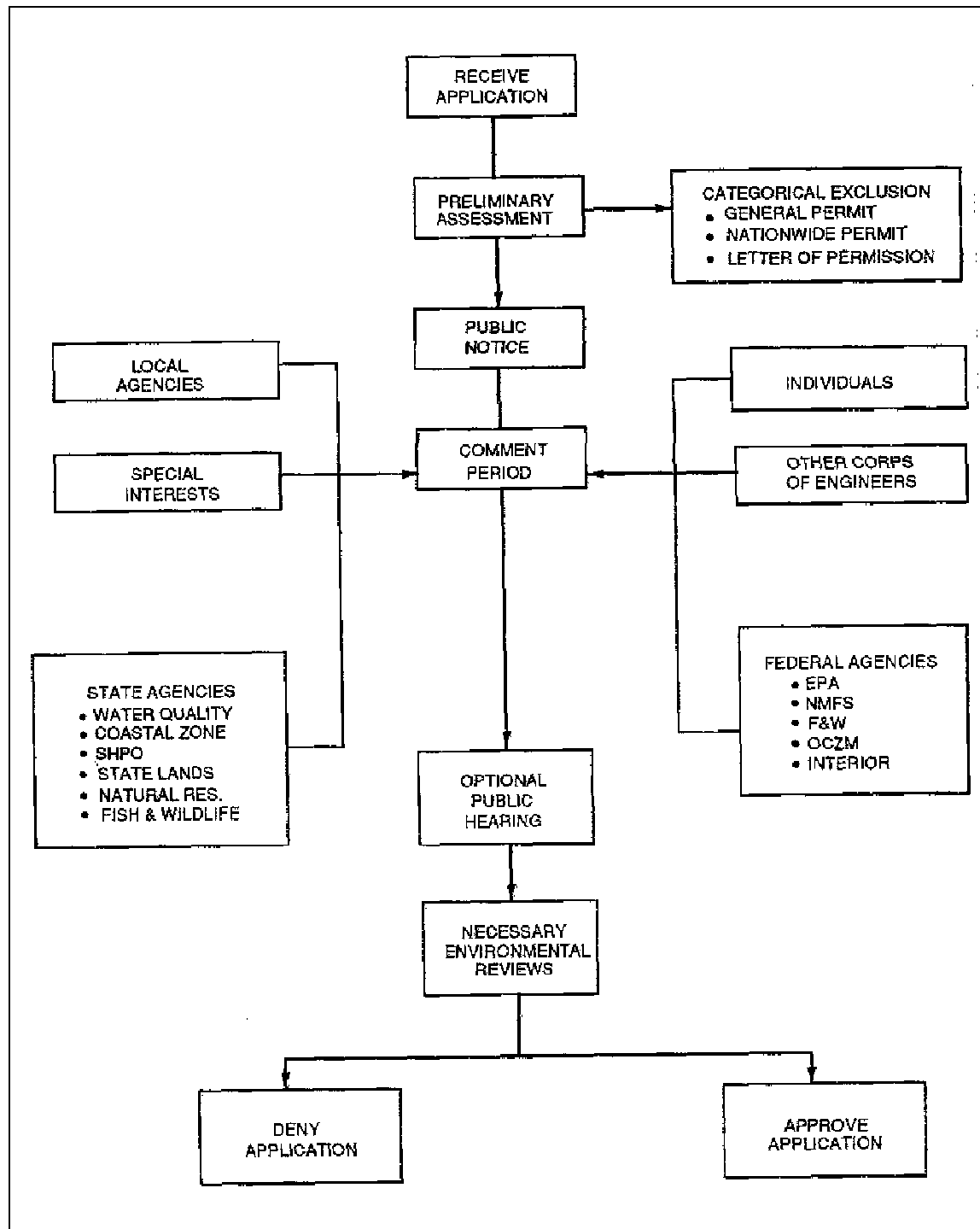


Figure 1-1. U.S. Army Corps of Engineers permitting process

development activities. When permits are reviewed, the USFWS considers whether alternative, non-wetland sites are available and whether construction can be accomplished without adverse impact to fish and wildlife in aquatic, terrestrial, or wetland habitats. The NMFS reviews applications for potential impacts to aquatic and wetland resources as they affect commercial fisheries. Both agencies' comments are quite important in the decisionmaking process; they are, therefore, reviewed extensively. Another agency interested in the permitting process is the U.S. Coast Guard, which regulates marine sanitation devices (MSD). The Clean Water Act prohibits discharges from MSD into freshwater lakes and rivers except those bodies that support interstate navigation. For vessels operating in saltwater estuaries and territorial seas, new vessels operating after January 1980 must have no discharge or have an MSD capable of limiting fecal coliform bacteria to 200 most probable number (MPN) per 100 ml and suspended solids to 150 mg/l. Older boats are still allowed to operate MSDs with lower levels of coliform and solids removal but are not permitted to use pump-through devices. The Coast Guard also reviews applications with respect to boating safety and navigation. If it is determined necessary by comments received from the public notice, the next step is a public hearing. The permit application is then evaluated and the necessary environmental review, as determined in the preliminary assessment, is conducted. The final step in the permit process is to either issue or deny the permit based on the completion of the environmental review.

b. State agencies. States play a major role in the permitting of marina developments. There is broad variation from state to state in the type of approval required and the way in which regulatory programs are administered.

(1) The minimum level of state involvement is review and comment on Section 10 permit applications. When Section 404 permits are required, the states must provide a certification to the Corps that the proposed activity will not violate the state's water quality standards throughout construction and subsequent operation of the facility. The state must also indicate that any other required state licenses, permits, or approvals can be secured. The

USACE will not approve the 404 permit without this assurance.

(2) Another level of state involvement is a consistency review of the USACE permit action under the state Coastal Zone Management Program (CZMP) (if applicable). In states where a CZMP has been approved by the Secretary of Commerce, an applicant for a Federal license or permit to conduct any activity affecting a coastal zone must furnish a certification that the activity will be consistent with the goals of the state's CZMP. Some states are zoning land areas adjacent to water with restrictions favoring commercial fishing, sport fishing, water recreation, water conservation, and commercial development. The USACE will deny the 404 permit unless the state is in agreement.

(3) The highest level of state involvement is where a state has developed a separate regulatory program controlling marina development. Different states have taken different approaches to direct regulation of marina activities. Some states have developed a wetland or coastal area permit, while other states have developed separate wetland or marshland permitting programs. Some states have developed dredge and fill permit programs. Some states claim ownership of submerged lands.

c. Local agencies. Local agencies exercising control over marina development may include regional authorities, counties, and cities. Generally, these agencies are not involved in the comprehensive evaluation of the suitability of a marina based on environmental water quality issues. The local agencies are generally intended to complement the state and Federal regulations applicable to a given area. Local regulations usually take into account special characteristics of the local environment that may require special restrictions on construction or development. Examples of such local concerns include land use controls, building codes, subdivision ordinances, and provision and operation of public facilities. Additional local regulations may also be implemented to reduce damage from hurricanes, tornadoes, earthquakes, and extreme weather conditions.

Chapter 2 Water Body Designations

2-1. Salt Water

a. Saltwater harbors supporting deep-sea fishing are generally located within 15 miles (24 km) of open water. A 5-ft (1.5-m) minimum channel depth is usually maintained. Navigation to and from the marina should be relatively easy, with numerous aids to navigation. There are usually no restrictions on speed or wake, except within the immediate vicinity of the marina. Estuarine harbors are typically located within 5 miles of suitable fishing waters. A 4-ft (1.2-m) minimum channel depth is usually maintained. Navigation is normally easy, with readily identifiable landmarks and numerous guides to navigation (Chamberlain 1983).

b. It is desirable to locate coastal marinas or small boat basins in protected waters such as tidal rivers, bays, estuaries, lagoons, inlets, and coves. However, unprotected coastal environments may also be suitable if breakwaters or artificial harbors are constructed to protect the marina against waves and currents. Facilities constructed in such high energy environments require a more detailed design and are more costly to construct, as compared to a marina in a more protected environment.

c. Small boat basins are designed to provide safe and secure vessel mooring with quick, convenient access to navigable waters. The design should be appropriate for local weather conditions, i.e., wind, precipitation, ice, fog, etc. A deep-water site with maximum natural protection will minimize alterations of the site and adverse impacts of construction. Dredging and maintenance of the facility will be minimized by locating the harbor in an area with these natural physical features. In the past, marshes and mangroves were often selected for marina sites, as they possess environmental requirements desirable for a small boat basin (that is, protection from waves and strong currents). These wetland environments should be avoided because of their high biological value and the "no net loss" policy related to wetlands.

d. Small boat basins usually occupy several tidal zones extending from terrestrial through the subtidal zone in order to accommodate land facilities, automobile parking, boat dry storage, launching ramps or lifts, boat docks, fueling docks, bulkheads, breakwaters, and jetties or groins (see Figure 2-1). Due to concerns over construction in wetlands, intertidal, and nearshore zones, and the lack of suitable sites, some small boat basins have been

excavated in upland areas with connecting channels to navigable waters (U.S. Fish and Wildlife Service 1980). Such sites have their own unique environmental problems that should be thoroughly investigated prior to selecting a site for a small boat basin.

2-2. Fresh Water

Freshwater recreational fishing is supported by marinas, harbors, and access facilities on natural lakes, reservoirs, and inland waterways. Facilities for lake and reservoir fishing are often on the shoreline. Waterway harbors are located within 5 miles of fishing waters. Minimum depth for channels is 4 ft, with easy navigation resulting from readily identifiable landmarks and numerous guides to navigation (Chamberlain 1983).

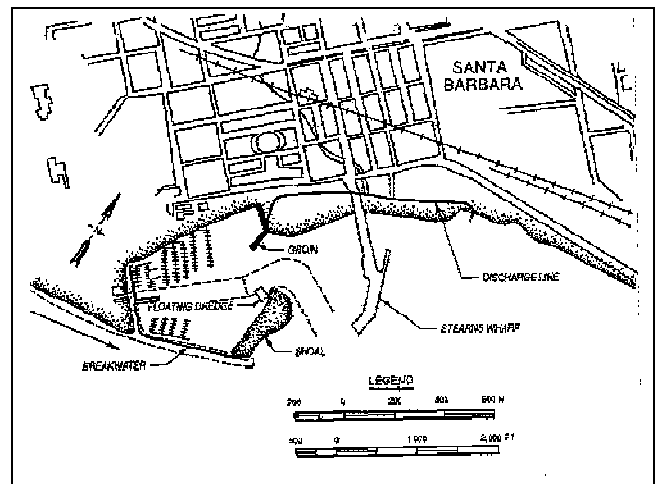


Figure 2-1. Breakwater protecting recreational harbor, Santa Barbara, CA

2-3. Great Lakes

a. An appropriate site for a small boat basin along the Great Lakes, as well as other locations, must have convenient access to water supply, electric power, and suitable transportation to nearby business or residential centers. However, physical attributes of the proposed site must be considered if the boat basin is to function in its intended manner. High water and dangerous currents from nearby rivers can be hazardous to navigation and mooring facilities. Strong winds could cause water damage and could be hazardous to the facility and moored boats.

b. Longshore currents driven by wind-generated waves carry large volumes of sand (usually from the northeast toward the southwest) along much of the shoreline of the Great Lakes (Wood and Davis 1978). In order to

maintain a natural balance between destructive and constructive wave forces, this movement of sand should not be interrupted. However, when a barrier is placed across the active transport zone, an imbalance occurs that can result in sedimentation on the updrift side and severe erosion on the downdrift side. A breakwater placed to protect the entrance to a small harbor can disrupt this natural flow of sediments along the shoreline. Negative effects can be reduced if a proposed boat basin is located

in a natural harbor. However, dredging on the updrift side and beach nourishment on the downdrift side may be the only suitable solutions to this problem. Maintenance-free boat basins are an unreasonable goal along the Great Lakes. However, facilities can be located where damage from wind and high water is unlikely. If a natural breakwater or cove is unavailable, the small boat marina facility will have to be constructed.

Chapter 3

Basin Design and Operation Criteria

3-1. Basin Design Criteria

a. Harbor function. The function that a harbor is to provide will determine its design requirements. Sembler et al. (1969) categorize harbors according to the following functions: harbors of refuge, commercial, fishing boat moorage, convenience harbor, recreational center, and yacht club.

(1) Harbor of refuge. When a remote harbor is provided specifically to accommodate transient small boats rather than as a home port for the local boats of the immediate area, it is designated as a harbor of refuge. Such harbors need not have all the refinements of a home port, but must have an entrance that is navigable in adverse weather, access to emergency aid, and appropriate facilities to accommodate the transient boater. Depending on the class of boat and characteristics of the region, the safe cruising distance for small boats is usually between 20 and 40 miles, or two hours cruising time. In remote areas, harbors of refuge meeting just the needs of the transient boaters often are subsidized. In these instances, the harbor of refuge may possibly be made self-sustaining by berthing a small number of home-based boats in addition to meeting the periodic needs of transient boats; it may not survive economically on either type of boat alone.

(2) Commercial. Small boat harbors are designed for various commercial fishing fleets, barges, and small boat transportation terminals, including berths for excursion craft of various kinds. Small boat facilities are often within or adjacent to harbors built primarily for deep-draft cargo or passenger vessels. In such cases, large ships and small craft will move through the same waters. Planning criteria must be adopted to reduce the collision hazard to a minimum without curtailing the activities of either class more than is essential for navigational safety (Dunham and Finn 1974).

(3) Commercial fishing boat moorage. Harbors for commercial fishing boats may be considered a special type of installation. This is due largely to the type of usage, the characteristics and habits of commercial fishery, and equipment requirements. Because a fishing boat is a work boat and the operator's work in port is essentially preparation for the next trip, utility usually supercedes appearance.

(4) Convenience harbor. The convenience harbor is generally designed as an enroute stopover point and provides a minimum of services. Such harbors may serve for overnight stays, temporary tie-ups for repairs and obtaining supplies, and similar usages. Facilities of this type should generally be located at or near population centers for availability of food, fuel, and amusement. Some degree of harbor protection is necessary, but moorage facilities can be minimal and services limited. Because of the lack of direct revenue from a harbor of this type, it is anticipated that it would be installed at community expense with few, if any, charges, its benefit to the community coming from other business generated.

(5) Recreational. Small boat harbors are designed for various recreational craft, including: sailboats, rowboats, pedal craft, and air-cushion vehicles. Other exotic craft are not specifically covered, although the basin and entrance design techniques described will be found satisfactory for all classes of small boat. The development of a recreational harbor will require not only the best weather protection, but also waterside and landside facilities that are best suited for its function. Boaters may patronize a deluxe restaurant, a pleasant bar, and various concessions. They may support boat sales, boat repair facilities, a marine supply store, clothing shops, and other similar establishments. They may use facilities for dancing, skating, bathing, skin diving, and water-skiing, if available. However, they usually demand the most in conveniences, utilities, and services, and a well-managed, clean, and attractive marina.

(6) Yacht clubs. In many areas, boating enthusiasts group together into yacht clubs. These are usually, by their nature, private installations accessible to members only. Yacht clubs may be somewhat meager in their facilities and appointments or may be quite lavish. Of prime importance will be a clubhouse at the water's edge with a good dining room and bar, and an assembly place for races and regattas. These races and regattas constitute one of the major interests in boating of a large segment of small boat owners. These are classed as amateur sports and can be sponsored only by a recognized yacht club. On this basis, the yacht club performs a desirable function and one or more of these should be considered in the planning and design of any recreational type of small boat harbor.

b. Site selection.

(1) Site selection for a small boat basin is probably the single most important aspect of developing a marina in an

environmentally sound manner. A site selected to complement the marina concept and to permit maximum use of the natural attributes can facilitate the entire development process from permit application through completion of construction. For example, wetlands and island refuges may be developed through the construction process.

(2) Selection of a site that has favorable hydrographic characteristics and requires the least amount of modification can reduce potential impacts. Any future modification or expansion should be considered in the design phase. One method is to set a basin perimeter when the basin is constructed. Thereafter, modifications that occur within that perimeter (such as dock reconfiguration) are considered not significant. Another method is to set a limit, such as a 25-percent increase in the number of slips or a set number of slips (such as an increase of more than five slips). The final method is a combination of the above methods.

(3) Small boat basins should not be located in or immediately adjacent to wetlands. In addition, development of small boat basins should not disrupt unique areas such as mouths of streams, isolated aquatic plant beds, or small areas with valuable rock/rubble substrate. These areas should be avoided, or at least small boat basin design and subsequent operation should be implemented to minimize disruption to these habitats. Suitable habitat evaluation techniques are available for wetlands (Adamus et al. 1988).

(4) Site selection considerations for recreational harbors are intended to ensure that a site provides usable land and water resources for marina operation. Chamberlain (1983) recommends that at a minimum, the land area should be at least 10 acres and above the local floodplain. The usable water area should be approximately equal to available land area. The site should offer protection from wave action in the adjacent body of water and at least some protection from wind. The water depth should not be less than 8 ft (2.4 m) at mean low water and not over 20 ft (6.1 m) at mean high water. Figure 3-1 illustrates desirable and undesirable site locations for boat basins.

(5) A major requirement in designing a small boat basin is that it be located and sized to accommodate present and future user needs and related harbor facilities. It must be located in adequate depths for safe vessel operation and be accessible to a nearby navigation channel. Alternative measures and sites for developing a small boat basin must be evaluated and compared for impacts on the

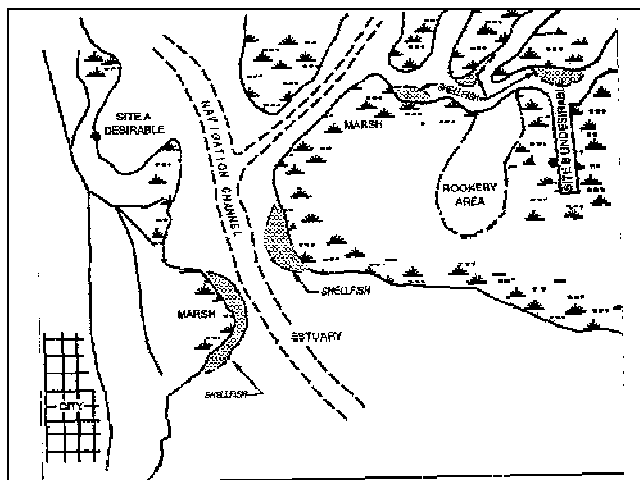


Figure 3-1. Desirable and undesirable site characteristics

natural environment, as mandated by the National Environmental Policy Act and other environmental Policy Act and other environmental statutes and guidelines.

(6) Physical factors that must be considered in locating a small boat basin are circulation and current patterns, bottom conditions, wave action, tides, sedimentation and shoaling, and prevailing winds (Brockwell 1987). If conditions are not suitable, major environmental problems may result. Hazardous conditions for small craft operating out of the basin because of waves, currents, and shoaling may be created. Water quality may be degraded if tides and currents are not adequate to flush the basins. The potential for flushing of marina waters should be the prime consideration in selecting a site. Sites on open

water or at the mouth of creeks and tributaries generally have higher flushing rates than those in coves and toward the head of creeks and tributaries that have lower flushing rates.

(7) Dredging and maintenance can also be minimized by selecting deep sites with low sediment transport potential. The land topography at inland sites should be suitable to provide protection to the boat basin from winds, tides, and river flow.

(8) A small boat basin should have the following site characteristics:

- (a) Easy access to open water.
- (b) Accessibility from roads and waterways.

- (c) Location in protected waters.
- (d) Location near navigable water.
- (e) Access to areas suitable for dredged material disposal.
- (f) High tides and flushing rates.
- (g) Compatibility with existing land and water uses.
- (h) Good water quality.
- (i) Absence of commercial shellfish beds.
- (j) Low value as a fish and wildlife habitat.
- (k) Absence of rare, threatened, or endangered species.

c. *Site conditions.* The natural elements of a site for constructing a small boat basin, such as local weather conditions, ice conditions, tides, currents, waves, and shoaling factors all have to be investigated.

(1) Weather factors. Weather factors such as precipitation, wind, and fog must be considered when evaluating a site.

(a) Precipitation. Maximum rainfall or snowfall present no serious problems for small boat basin operations, although all surface drainage measures have to be considered in marina planning. Drainage facilities have to be designed to be capable of draining or diverting a maximum amount of rainfall. In regions where snowfall is heavy, land-based structures must be designed to withstand these snow loads.

(b) Wind. The prevailing wind is a wind blowing from one general direction for a major portion of the year. Prevailing winds are not the strongest winds. Winds of greater intensity, which occur less frequently, come from other directions. A wind rose may be used to graphically represent the direction, frequency, and intensity of winds at a particular location over a period of time. Heavy wind may affect water levels in the marina basin, raising or lowering the water level. Land-based structures must be designed to withstand the unusually heavy forces. Heavy wind may generate waves or move sand located in dune areas which may shoal the basin or the entrance to the marina. Breakwaters are constructed to protect the entrance to the basin. Planting grass or construction of sand fences may be used to stabilize sand movement.

(c) Fog. Fog may be a serious navigational problem if it reduces visibility. Many marinas have occasional foggy conditions, and for this reason, channels in a small boat basin should be as straight as possible. In regions where fog is a problem, marker buoys and other channel-marking devices have to be installed.

(2) Ice.

(a) In northern climates ice is a serious problem in the operation of small boat basins. In areas with moving ice sheets, marinas must be located in protected areas, because these ice sheets may crush not only boats but also marine structures. Protection is provided by locating the entrance to the marina oriented away from the direction of the prevailing wind or current. This will encourage ice floes to move out of the marina during breakup. The marina should be located as close as possible to an industrial complex so that any available waste heat may be utilized. Although thin ice formation cannot damage boats, they are usually removed from the water during the winter, even in protected marinas. In protected marinas, thick, unbroken ice sheets forming around piles which support marina piers may lift these piles when the water rises, and thus bring the whole structure out of alignment. Repeated freezing and thawing may eventually jack piles completely out of the ground. In large natural basins, wind-driven ice floes may crash onto marine structures as the ice melts in spring, causing considerable damage to these structures.

(b) In Finland, small boat basins have been built with considerable success having piers and quays with a width of 1.5-3.0 m supported by wooden batter piles (Kivekas and Sarela 1985). Batter piles provide better stability in the foundation soil. When water fluctuates steadily, the ice attached to the shore (to a wall of a solid type construction or to a dense row of piles) will break easily at that location when the water changes level. However, in tidal zones, ice could easily build up on vertical surfaces of structures that are fixed on the bottom, thus creating a destabilizing buoyancy force or an additional load on the foundation.

(3) Waves.

(a) Natural phenomena such as waves may be caused by winds, tides, earthquakes, or by disturbances caused by moving vessels. A designer should be interested in waves produced by wind and moving vessels, since they have the most influence on site selection and basin design. Passing ships may generate waves which are sometimes

of greater length than wind waves. Small boat basins on rivers experience the passing of ships or barges that may generate damaging waves. The effect of waves will depend on the height of the wave generated and the distance between the ship and the project site. As a rule of thumb, it can be assumed that the wave height is equal to twice the amount of vessel squat. The wave height at the riverbank is then computed using refraction and diffraction techniques. The wave length is equal to approximately one third of the vessel length (EM 1110-2-1615). If ship-generated waves are considered to be the design wave, model tests or prototype measurements are needed to verify or adjust the predictions. Additional information on the possible impact of vessel wakes may be obtained from Camfield, Ray, and Eckert (1980).

(b) Marina sites need to be protected from adverse wave effects. Some sites may be protected by one or more islands which shield the entrance from waves. If the site does not have natural protection against wave action, breakwaters or other wave-dissipating devices are used at the entrance or inside the marina.

(4) Tides. Tides and tide-like effects (e.g., water level change in inland lakes and rivers due to spring and fall flood) often play an important role in water quality control. The current-producing exchange of water by water fluctuation action may be essential to the marine ecology and the prevention of stagnation conditions. Water circulation is an important component in marina design and can be accomplished by the effective use of the tidal prism of the water. In inland lakes and rivers, water fluctuates in a slower cycle, and although it occurs too slowly to produce substantial water exchange effects, these effects have to be taken into account for the design.

(5) Currents.

(a) Currents are essentially horizontal movement of the water. At coastal locations, currents or flow of tides or freshets moving at only a few tenths of a knot generally cause no serious problems to marina operations. However, in swiftly moving rivers (with a speed of several knots) where seasonal floods are expected, or in large open bodies of water, where wind-generated current may be damaging to the marina, marinas should be in protected locations, e.g., secluded inlets, bays or lagoons, or breakwaters must be installed. Apart from the possibility of direct interference with marina operation, currents may also present other adverse functional effects such as scouring, deposition of sediments, and increased erosion rates.

(b) Currents may cause changes in wave effects, and in the impact of ice and flotsam (floating debris), as well as hampering construction operations. In tidal estuaries, the current can be expected to reverse. The value of tidal current velocity for many locations around the world may be obtained from tables that are published annually by the National Oceanic and Atmospheric Administration (NOAA). Depending on location as well as importance and cost, current velocity measurements may be considered for the project (Coastal and Ocean Engineering 1990).

(6) Shoaling.

(a) A principal cause of shoaling at entrances to marina basins is littoral drift, which is mainly the result of wave and/or current action. Any structure that interferes with wave or current action would cause abnormalities in the wave or current pattern and could substantially affect the shoaling process. Dunham and Finn (1974) suggested the following example. If the unprotected approach channel is dredged through a beach into an inner basin, the wave impinging on either side at the mouth will be refracted in such a way as to cause changes in the wave pattern approaching the lips of the channel. If the approach of the prevailing waves is normal to the shore, the initial effect will be a movement of the littoral material from the lips inward along each flank of the channel, thus eroding the lips and shoaling the inner channel fed by material from the beach on either side of the entrance. Unless tidal currents are strong enough to maintain an opening against the forces tending to shoal the entrance, the channel will soon be blocked. Where the prevailing wave approach is oblique to the shoreline, sediments being transported along the shore by littoral currents will be interrupted at the channel opening near the updrift lip, and that lip will soon begin to accrete. As the wave-induced longshore current again begins to "feel" the shore downdrift of the channel mouth, it attempts to reacquire its sediment load. As a result, at the same rate as the updrift lip accretes, the channel mouth will migrate in the downdrift direction. In each of these cases, the forces of nature are attempting to re-establish the littoral balance that was present before the channel was excavated. The above example is an oversimplified version of an extremely complex process, and excludes consideration of the effects of sandbar formation, eddy currents, and tidal channel meandering (Coastal and Ocean Engineering 1990).

(b) The customary solution to entrance shoaling is the construction of jetties along each flank of the channel

from the lips of the mouth seaward beyond the breaking zone. The structural features of the jetties must be such that the materials will not be washed through or over the structure into the channel. A typical section of a sand-tight, rubble-mound jetty is shown in Figure 3-2. If the littoral transport from one direction predominates and the entrance is stabilized by jetties, accretion will occur along the updrift shore and erosion along the downdrift shore.

(c) The entrance to off-river marinas is often subject to shoaling because of sediment deposition in the quiet water area and to eddy currents that might be created by the entrance configuration and the flowing water in the river. Although shoaling cannot be prevented, it is often reduced by proper entrance design. For example, a flat area on the downstream lip of the entrance could be provided from which a dragline can excavate deposits from the bottom of the entrance channel and cast them into the river downstream of the entrance (Figure 3-3). The entrance must be kept as narrow as practical to permit such an operation, and a training dike at the upstream lip is helpful in reducing the deposits (Coastal and Ocean Engineering 1990).

d. Marina design.

(1) General. Design considerations for a marina may include boat slips, water supply, sanitation, structural integrity, and esthetics of structural/environmental compatibility.

(a) Boat slips. Slip sizes are determined by the size the boats intended to use them. Table 3-1 shows the recommended widths and lengths for fixed and floating slips. The water acreage required for slip use is shown as the maximum number of boats per acre in Table 3-2. Alignment of the slips should be parallel to the current. Configuration of boat slips efficiency is achieved by use of single or double-wide slips with access from walkways attached to the shore. Walkways between rows of slips should be oriented perpendicular to the shoreline. Slips generally should be perpendicular to the main walkway. Designs that use curved walkways or curved slips are not efficient in use of water area, promote damage to boats, and are more expensive to build and maintain. If slips of different widths are off the same walkway, the slips should be arranged symmetrically by width on either side of the walkway to ensure symmetrical transmission of stresses to the walkway. Smaller slips should be placed closer to the shore. Double-wide slips can be used, saving money and water space and allowing more flexibility, but increasing the possibility of damage to boats by boat operators or wave action. Figure 3-4 shows a generalized layout of boat slips (Chamberlain 1983).

(b) Walkways. Walkways should be designed to be above the water level at all times and should be structurally sound and safe, kept free of mud, ice, snow, and grease. Walkways should be constructed perpendicular to the shoreline. Walkways less than 200 ft (61 m) long should be straight, while those greater than 200 ft (61 m) can jog or angle at the halfway point. This change

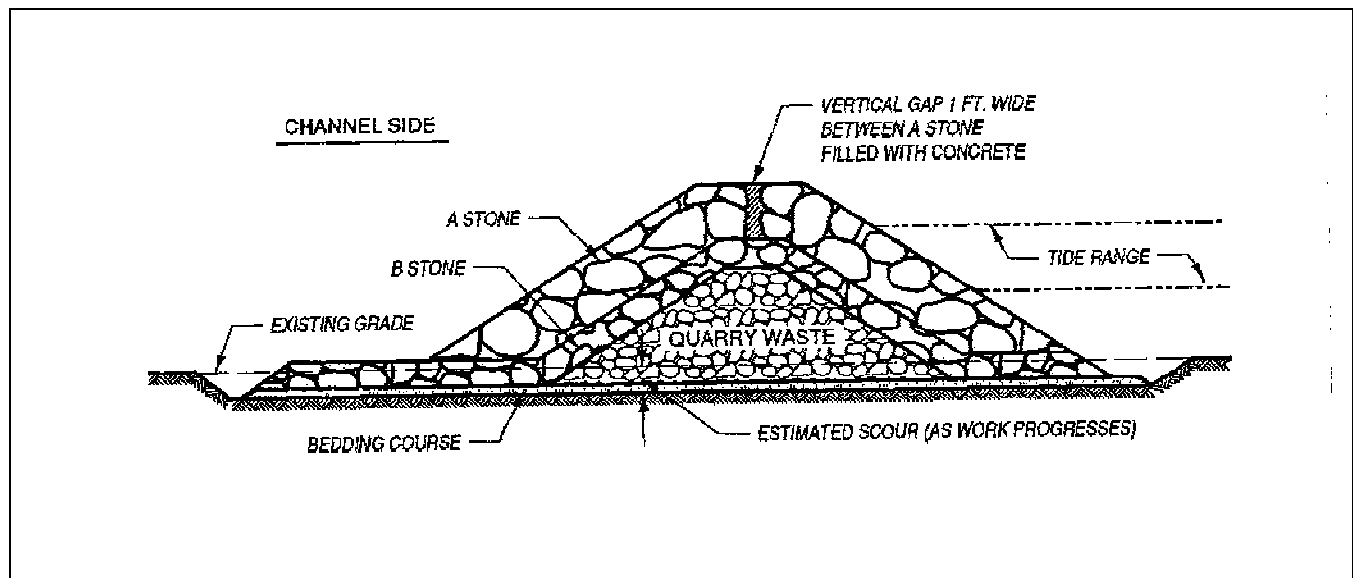


Figure 3-2. Typical cross section of a rubble-mound jetty

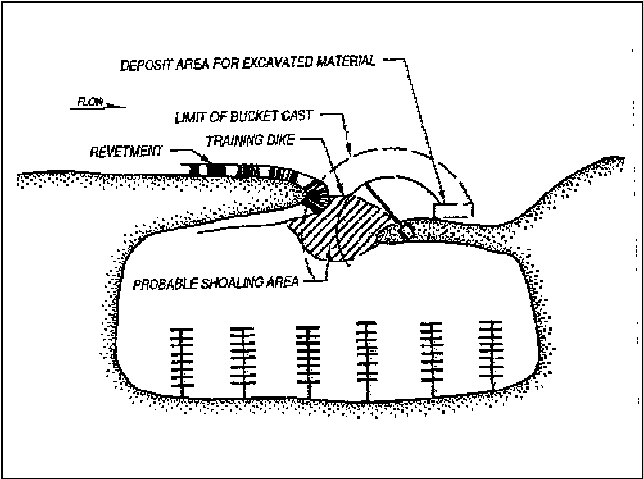


Figure 3-3. Maintenance of entrance to off-river marina basin with land-based equipment

	Slip Length									
	25	30	35	40	45	50	55	60	65	
Width, floating slips	10	11	12	14	15	17	18	18	19	
Width, fixed slips	11	12	14	16	18	19	19	20	22	

Table 3-2
Maximum Number of Boats Per Acre

Fairway Width Boat Length (L)	Floating Slips 1.25 X L	Floating Slips 1.5 X L	Fixed Slips 1.5 X L
25	90	87	93
30	69	66	72
35	50	47	52
40	38	37	41
45	32	31	32
50	26	25	27
55	21	21	25
60	20	19	22
65+	17	16	18

improves lateral stability and modifies the impression of a long pier. Curved or star arrangements for walkways are wasteful of water space, conducive to boat damage, and are expensive to build and maintain. For floating walkways, the finger walkways should extend the full boat length. The finger walkways should not be less than 3 ft wide. A "T" should be placed at the end of a walkway for lateral stability of the pier, and should be at least as long as the slips on either side of the main walkway.

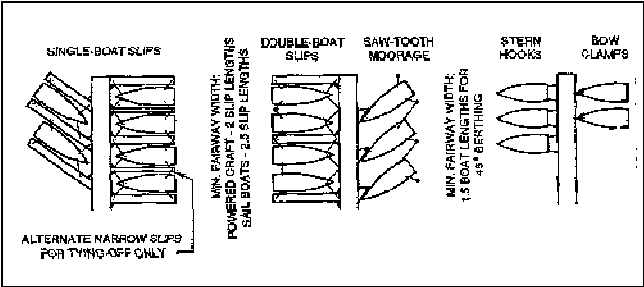


Figure 3-4. Small-craft berthing system (Sembler et al 1969)

Main walkway widths should be a minimum of 4 ft wide. If vehicles such as golf carts are anticipated, a minimum width of 8 ft (2.4 m) should be allowed for turning. Additionally, if significant pedestrian traffic is expected, the width should be at least 8 ft (2.4 m). Finger walkways may need widths greater than 3 ft (0.9 m) for stability (floating) or for strength and rigidity. Finger walkways do not have to extend the length of the slip (Chamberlain 1983, National Water Safety Congress 1988).

(c) Moorings. Mooring piles at the outmost end of the slip allow stern-to-bow mooring (Figure 3-5). For slips longer than about 25 ft (7.6 m), an additional mooring pile should be placed about halfway down the length of the slip. This additional pile, called a spring pile, helps restrain the fore and aft motion and provides protection between boats of adjacent slips. Additionally, a spring pile can be substituted for every other finger walkway (Chamberlain 1983).

(d) Fairway. The width of the area between adjacent rows of slips, i.e., the fairway, should be 1.5 times the length of the longest slip. If the current parallel to the long dimension of the slip exceeds 2 to 3 knots, even temporarily, the fairway should be widened to 1.75 to 2.00 times the length of the longest slip to allow for maneuvering in the down current (Chamberlain 1983).

(e) Basin shape. Natural basins are often used for marina development, taking advantage of natural protection for boat slips. In some cases, it is necessary to construct a basin for protection from waves or high water levels. Surrounding the mooring area with a breakwater or other protection will provide the necessary protection. Marina basins should be rectangular in shape to utilize space and for design purposes, the shorter side should be a multiple of 200 to 250 ft (61 to 76.3 m). The use of vertical bulkhead walls should be minimized and interior

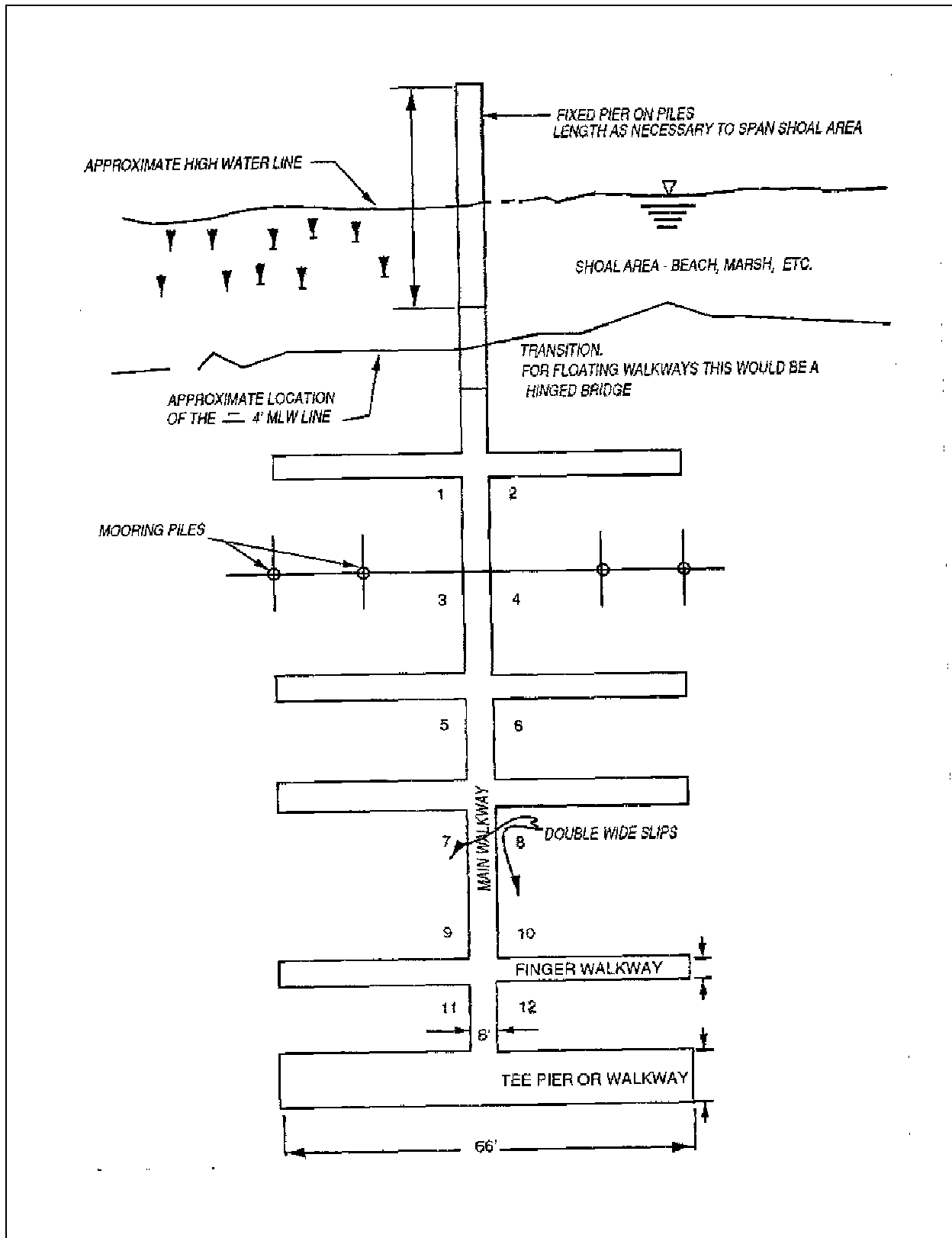


Figure 3-5. Basic layout for marina walkways (Chamberlain 1983)

corners should be gently rounded, preferably with constantly changing radii. Such designs result in the most efficient use of water area and promote water circulation. The basin bottom should be sloped toward the exit and the waterway outside the marina. In designing a basin, concern should be given to preserving or encouraging all natural flushing activities. If necessary, artificial flushing should be considered (Chamberlain 1983).

(f) Channels. Channel entrances and the channel leading to a marina should be as large as possible so as to provide safety and ease of passage in times of storm, fire, or other emergency, and to promote flushing. Where possible, the entrance should be located to avoid the direct entry of waves. Any bends that are necessary should be gradual (Dunham and Finn 1974). A breakwater can be constructed to protect channel entrances from the direct entry of waves (Chamberlain 1983).

(g) Harbor entrance channel. Harbor entrance channels should be at least 60 ft (18.3 m) wide or four times the beam of the widest boat berthed in the marina.

(h) Channel leading to the marina. A clear width of twice the entrance channel width, but not less than 60 ft (18.3 m), should be required.

(i) Channel turning. Required widths for turning are 2.25 times the length of the longest boat. For sites with frequent onshore winds or a large number of single screw power boats, the allowance for turning width should be increased from 2.5 to 2.75 times the longest boat.

e. Dead-end canal.

(1) General. Small boat dead-end canals are generally constructed for access to residences with docking facilities. Construction typically consists of excavation of an access channel through wetlands by widening an existing creek or excavating a totally new watercourse. The access channel provides easy access to the ocean, coastal waterway, river, reservoirs, or lake. Perimeter canals are often connected to the access canals to increase the density of home sites. Christensen and Snyder (1978) provide classification of existing canal systems; most canal systems in the classification terminated in dead ends.

(2) Environmental impact. The major environmental impact of early canal design was loss of wetlands. The dead-end configurations inhibited mixing and exchange of canal waters with the parent water body. As a

consequence, storm-water pollutants and domestic wastes accumulated in the canals, resulting in nuisance plant growth and depressed dissolved oxygen. Because of the resulting environmental degradation, most regulatory agencies prohibit the construction of new residential canals until it can be shown that such systems are compatible with the site, that the environment will not be degraded, and that all regulatory criteria are met. Several techniques have recently been developed for reestablishment of wetlands and sea grasses that can be used to mitigate for habitat losses and create new habitat. These techniques are discussed in EM 1110-2-1204 and EM 1110-2-5026.

(3) New canal design. New canal design recommendations that are less damaging to the environment have been suggested (USEPA 1975, Morris 1981, U.S. Army Corps of Engineers 1983):

(a) Canal developments should be restricted to non-wetland areas.

(b) Flow-through or indented boat slip designs are preferable to dead-end canals due to their superior circulation characteristics. To the extent possible, dead-end features should be eliminated from canal systems.

(c) Canal depths for shallow draft pleasure craft should be no more than 4-6 ft below mean low water. It has been observed that "deep" canals are not adequately flushed by tidal action and that lower layers act as a trap for sediments and organic material. It has also been observed that canals that are very shallow (under 4 ft) may have poor flushing characteristics, poor navigability, and increased turbidity due to boat traffic.

(d) The grade of the canal bottom should be such that no sills are created at any point in the system. When a canal is first dredged, before connection to the receiving water body, a plug is often left in place. Upon removal, a sill may remain which impedes the circulation of the bottom waters.

(e) Canals should be designed to maximize wind-induced mixing, i.e., maximum width, minimum length, and orientation with prevailing winds.

(f) Canal design should contain some shallows. Intertidal and littoral vegetation consume nutrients from the water; thus, the canal may improve the quality of the receiving waters by reducing nutrient content and possibly raising the level of dissolved oxygen.

(g) Surface drainage patterns should be designed with swales, contours, and shallow depressions for water retention, to minimize direct runoff into canal waterways.

(h) For residential sewage treatment, package plants or lagoon systems are recommended.

f. Launching ramps.

(1) General. If properly placed and designed, launching ramps should have a minimal impact on aquatic and terrestrial resources. Under some conditions there may be concern over the effects of wave wash on bank stability and vegetation. If adjacent areas are shallow, bottom-dwelling organisms and their habitat can be disrupted if boats run aground or scrape the substrate. Valuable habitats and their biota may be protected if well-marked routes to the launching ramp are established and recreational craft are kept away from sensitive areas. If ramps have to be located near valuable areas, breakwaters, bank protection devices, or speed warnings may be required.

(2) Ramp design. Direct access to water areas should be prevented by designing boat launching ramps that require a deliberate turn from any access roads. Boat ramp designs vary depending upon their usage (U.S. Fish and Wildlife Service 1980). Ramps are usually constructed adjacent to deep water for easy launching of boats on trailers. They may range in widths from 10 ft to over 50 ft (3-15 m). The length of a ramp may be over 60 ft (18 m). The slope should be between 12 and 16 percent above the waterline and 15 to 20 percent below the waterline (EM 1110-1-400, National Water Safety Congress 1988). It is recommended that a ramp be paved to about 5 ft (1.5 m) below the extreme low tide. There should also be a level, gravel shelf at the end of the ramp. The most common construction technique for a ramp is to use a gravel foundation covered by 3 to 6 in. of concrete. Piers should also be provided for boarding and holding a boat while launching. It is recommended that piers be provided on both sides of the ramp. The ramp should be placed in a well-protected area with minimal currents, but one that is well flushed to avoid the buildup of exhaust, petrochemicals, and other pollutants associated with boating operations. The ramp should have a washdown facility. Oil, grease, and other pollutants washed off a boat should be discharged into the sewer system rather than into the boat basin.

(a) Ramp safety designs. To provide adequate traction, the surfaces of the ramp should be scored or patterned. Deep grooves in the concrete should be perpendicular to the slope of the ramp to provide good

vehicular traction. Where drop-offs exist or could form, retaining curbs should be incorporated at the lower end of the ramp and on the outside edges or ramps. Consideration should be given to providing chock blocks, where feasible. Operation plans should include plans to keep ramps free of algae growth and siltation (National Water Safety Congress 1988).

(b) Ramp area design. For boat trailer parking, a general rule is 25 car and trailer parking spaces per lane, except where demand or site conditions require deviations. A minimum of one 75-ft- (23-m-) diam vehicular turn-around should be provided for each ramp. Courtesy loading docks should be provided to allow for safe loading and unloading of persons and gear (EM 1110-1-400, National Water Safety Congress 1988).

(c) Security lighting. Adequate security lighting should be provided. Appropriate signs should be placed to encourage safe boating practices. Overhead power lines crossing the water should be posted (National Water Safety Congress 1988).

(3) Environmental impacts.

(a) If not properly designed, the construction of a boat ramp and associated parking facilities can result in both immediate and long-term environmental effects. Construction of a ramp and parking facilities can cause increased erosion and associated turbidity as a result of altering the shoreline and intertidal habitats, smothering of benthic animals, and release of toxic substances used in the construction material. A possible solution is the planting of marsh grasses and sea grasses (EM 1110-2-1204 and EM 1110-2-5026). Ramp site selection should avoid, if possible, wetlands, and highly productive intertidal habitats (i.e., shellfish beds, sea grasses, nursery habitat, etc). The construction of a ramp will displace shoreline and aquatic habitats and in most cases replace it with less productive habitat, particularly if the ramp is heavily used. Construction can also result in increased noise and air pollution.

(b) Long-term impacts are associated with dredging and channel deepening to accommodate the ramp, protective structures that may be required, parking facilities that require clearing and grading the land, and increased human usage of the area. Increased operation of boats in association with the ramp will increase turbulence of the water, petrochemical pollution, and noise which may affect fish and wildlife resources and humans in the area. Generally, channel depths providing a clearance of 2-3 ft between the propeller of a vessel and the channel bottom

during low waters, will be sufficient to prevent increased turbidities (NOAA 1976). It is also possible that a greater number of boats and their wakes may increase shoreline erosion, requiring additional protective shoreline structures. If the ramp becomes a popular boat launching area, it may attract other commercial facilities that could further increase habitat alterations.

(4) Alternatives.

(a) An alternative that should be considered in place of a boat ramp is a hoist that can pick a boat up off a trailer and place it in the water. A hoist usually requires a pier or other structure to allow access to navigable waters. The hoist would be appropriate where the water is deep close to the shore. In areas where there is a narrow band of marsh or shallow water separating the shore from deep water, a dock or pier could be used to span these areas.

(b) A marine way (dolly) is another alternative to a boat ramp. This operation requires lifting the boat onto a rail and lowering the boat down the rail into the water. Its advantage is that boats can be launched in areas with a shallow slope at low tides.

3-2. Basin Operating Criteria

a. Periods of Operation.

(1) Under certain conditions, it is often possible to restrict dredging, construction, or related activities to appropriate times of the year so as not to negatively affect certain biota (LaSalle 1988, Sanders and Killgore 1989). Boat ramps are usually constructed during low water periods when banks are dry and construction will not be impeded by high water. There are probably fewer negative effects to aquatic biota during late summer and fall when aquatic plants have senesced, reproduction of fishes and macroinvertebrates has taken place, and many aquatic insects have emerged. Water clarity is usually highest during late summer and early fall, so the effects of sedimentation may appear great, although impacts to spawning or nursery areas will be minimal.

(2) It may be virtually impossible to restrict access to boat ramps during selected times of the year. When fish spawning and plant growth are maximal (i.e., during the spring), recreation use is often at a peak. Rather than attempt to restrict access, boat ramps and facilities should be designed so that sensitive areas will not be damaged. The use of buoys and breakwaters, placing boat lanes so that they are straight and do not encroach on valuable

areas, and enforcement of reduced speed zones are all methods of protecting biota regardless of season. Seasonal restrictions on dredging and construction activities are based on perception or concern that such activities will have a negative impact on biological resources. The major concerns are related to impacts on migrating waterfowl, shore and wading birds, fish migration, and larval and juvenile fish and shellfish. Restrictions may be justified in cases where there are known occurrences of the animals in the vicinity of the construction site during specific seasons. Project activities should be scheduled to minimize interference with reproduction, rearing, and migration of these biological resources (Cardwell and Koons 1981). Careful planning and scheduling of dredging and construction can minimize these impacts.

b. Water quality impacts.

(1) Flushing. Water quality impacts of small boat basins can be attributed to excess input of pollutants and/or inhibited flushing. Flushing is a concept of how long a constituent remains in the water body. The term "flushing" is often misused in that a single number (e.g., 10 days) is sometimes used to describe the flushing time of a harbor. In actuality, the flushing rate ranges from 0 days at the boundary to several weeks depending on location within the marina water body. A decrease in flushing increases the time that a constituent exerts its influence on the water quality. Site selection, basin design, and operation procedures are the most effective ways to minimize possible water quality impacts. Objectives should include minimization of pollution sources and maximization of flushing. Evaluation of water quality impacts involves an assessment of the input of pollutants and flushing of the water body.

(2) Pollutant sources. The term pollutant refers to either naturally occurring or synthetic materials that may occur in sufficient quantity to adversely affect water quality. The major sources of pollution include storm water runoff, sanitary wastes, and wastes from boat operation and maintenance. In addition, pollutants may be introduced through dredging and dredged material disposal during either construction or maintenance.

(a) Rainfall creates runoff from roofs, parking lots, roads, fields, forests, lawns, etc. The runoff may carry a variety of pollutants that may degrade water quality. These pollutants include sediment, nutrients, pesticides, oil and grease, metals, and pathogens.

(b) Sanitary wastes cause an increase in the nutrient supply, an increase in biochemical oxygen demand, and

introduction of disease-causing viral and bacterial organisms. Pollutants from this source can enter small boat basins in wastewater directly discharged from boats or from improperly functioning or poorly located septic systems that allow sewage effluents to leach into the basin.

(c) Other wastes from boat operation and maintenance include pollutants such as gasoline, oil, and grease; solid waste; trash; lead; copper; and detergents.

(3) Predictive techniques. Application of predictive techniques to assess the water quality impacts (e.g., depressed dissolved oxygen (DO)) of these pollutants requires an estimate of pollutant loading. If actual values for various loadings are not available, the USEPA (1985) provides estimates of constituent concentrations for urban runoff and contribution from boats.

(4) Flushing and DO. The water quality in harbors is generally lower than the water quality of the parent water body. However, successful control of water quality is usually dependent upon periodic exchanges of harbor water with the parent water body. Dunham and Finn (1974) suggested that for single entrance marine harbors, an average daily exchange of water equivalent to about one-third of the harbor's mean tidal volume is usually sufficient to prevent water stagnation. Boozer (1979) stated that for marine harbors, turnover times of 2-4 days will generally prevent stagnation or the buildup of high pollution concentrations. By correlating hydraulic model estimates of flushing with water quality measurements in five Puget Sound Marinas, Cardwell, Nece, and Richey (1980) suggest that a mean exchange coefficient of 30 percent was necessary to prevent serious fluctuations in DO. The mean exchange coefficient is the percentage of water in a basin that is removed and replaced with ambient water during each tidal cycle. Although the three methods use different techniques, the results are nearly equivalent. Importantly, the three exchange estimates are for marinas for which tidal action is the dominant factor.

(a) Rivers and lakes. In flowing rivers, potential water quality problems are minimized because the river currents will induce circulatory flow. In lakes, small craft harbors are typically constructed in coves; the use of floating docks minimally affects the existing circulation and thus the exchange with the parent water body.

(b) Marinas. Marinas may be located near the ocean where solid breakwaters may be used for protection. The harbor construction may significantly affect the water exchange with the parent water body. Nece et al. (1979)

used physical models to study geometric effects of marina design and suggested design features for maximum flushing: the best design of a rectangular basin for optimal tidal flushing would have a length/breadth ratio between 0.5 and 2.0, rounded corners, and a centered entrance. However, asymmetric basins within the same length/breadth ratio and with rounded corners also exhibit adequate flushing characteristics. Little guidance was found on designs with multiple entrances; however, parent water body circulation could be used to enhance water exchange. Two openings at opposite ends of the marina could establish flow-through water currents. Other design considerations for enhancing flushing include (Boozer 1979): marinas should have wide and deep entrances with depth gradually decreasing toward the inner reaches of the marina; marinas should never be deeper than either the open water or channels to which they are connected and never deeper than their own access channels; and marinas should use floating breakwaters to dampen incoming waves yet allow less restricted water circulation. Most of the early designs of marina systems were based on a simple flushing analysis. The flushing analyses were a variant of the tidal prism method (Walton 1983). Such an approach for marinas is a reasonable "back-of-the-envelope" calculation to obtain an idea of the exchange of water between the marina and adjacent waterway. The procedure is described in Chapter 4 of the *Coastal Marinas Assessment Handbook* (USEPA 1985). In studying South Beach Marina in Oregon, Callaway (1981) used a simple flushing model to simulate mixing. His results showed excellent agreement with a physical model of the system, but showed that both the physical and flushing models overestimated the flushing time when compared to field data.

(c) Residential canals. Tidal prism analysis is not applicable to canal systems because the assumption of complete mixing is not valid. The use of the one-dimensional model DYNTRAN (Moore and Walton 1984) provides a relatively rapid, conservative, and inexpensive procedure for assessing flushing and DO. The procedure is conservative because the physical mixing processes due to wind, density-induced currents, and secondary currents are not included in the model. Several basin design features that promote flushing are basin depths that are not deeper than the open water, two openings at opposite ends of the marina to establish flow-through currents, minimal vertical walls, a rectangular basin with single entrances that are centered, and basin depths that gradually increase toward open water.

(5) DO analysis. The level of DO is used to characterize water quality because it serves as an integrated

measure of physical, chemical, and biological processes. DO is included in all state water quality standards. The procedure for DO analysis consists of two phases. The first phase consists of a flushing analysis for estimates of flushing rates or flows. The second phase consists of the use of the flushing rate estimates for the solution of mass balance equations relating DO to sources such as reaeration and sinks such as biochemical oxygen demand (BOD) decay. A procedure is outlined in the Coastal Marinas Assessment Handbook (USEPA 1985). Two- and three-dimensional numerical hydrodynamic and water quality models are available (Hall, Dortch, and Bird 1988) that can address the flushing and water quality of small boat basins. Although not justified in the past, due to the rapid decrease in computational costs and the capability to run some applications on microcomputers, the application of numerical models for analyses of small boat basins is now feasible.

(6) Water exchange. Water exchange does not always ensure good water quality. A significant factor in water quality control is the elimination of direct sources of pollution: storm-water runoff, sanitary wastes, and wastes from boat operation and maintenance.

c. Control of adjacent land and water use. Planning for adjacent land and water use should be documented in a master plan and in provisions of permits for marinas. The master plan should consider trash and garbage pickup, and provision of a boat maintenance area for washing boats. The need for maintenance dredging to minimize siltation and to ensure adequate channel depth and alignment should be evaluated. Maintenance dredging should be scheduled to minimize impacts on current paths and wave action and impacts to adjacent beaches and wetlands (Chamberlain 1983).

Chapter 4

Attendant Problems and Responsibilities

4-1. Boat Discharges

Due to the limited circulation in most small boat basins, the discharge of pollutants from boats can have adverse environmental impacts. Primary boat discharges include sanitary wastes and boat motor emissions.

a. Sanitary waste.

(1) Sanitary waste discharges from boats pose a health risk and can potentially violate state water quality standards, especially for boat basins located near bathing or shellfishing waters. Boat sewage can be visually repulsive (Chmura and Ross 1978) and may contribute to increased BOD in receiving waters (NOAA 1976). BOD is a measure of the DO required to stabilize the decomposable matter present in a water body by aerobic biochemical action. When BOD increases, DO available for aquatic organisms decreases. Anaerobic waters create a sump for pollutants and organics resulting in stagnant, sulfide-odorous, and slow-decaying (due to low DO) conditions.

(2) The most serious effect of discharging fresh fecal material is the potential for introducing disease-causing viruses and bacteria (pathogens). Problems may occur if boat sewage is released in the vicinity of shellfish (clam or oyster) beds or into enclosed waterways with limited flushing. Shellfish require clean water to be microbiologically safe for human consumption, regardless of whether they are eaten raw or partially cooked (USEPA 1985).

(3) Management of boat sanitary waste discharges includes the installation and proper use of equipment onboard the vessels and onshore equipment for collection and disposal. The onboard equipment is referred to as marine sanitation devices (MSD). Another means of managing boat sanitary waste discharges would be to educate boaters about the potential health risks associated with the discharge of sewage. Boat toilet use would be reduced if marinas discouraged "live-aboards" and provided well-maintained shoreside restroom facilities of sufficient quantity to accommodate above-average boating populations. Shoreside facilities must be convenient to the docks (Chmura and Ross 1978). USEPA does not require a National Pollutant Discharge Elimination System permit for: "Any discharge of sewage from vessels, effluent from properly functioning marine engines, laundry, shower, and galley sink wastes, or any other discharge

incidental to the normal operation of a vessel." However, this exclusion does not apply to permanently moored vessels.¹ Permanently moored vessels could be discouraged from marinas in order to avoid potential discharge of any sewage from all vessels into aquatic habitats by applying to the USEPA Administrator for issuance of a regulation prohibiting discharge into well-defined shellfish growing waters (USEPA 1985).

b. Boat motor emissions.

(1) Boat motor emissions include hydrocarbons and lead. Once exhausts are released from outboard motors, some of the hydrocarbons become suspended in the water column while others evaporate at the surface (Kuzminski, Jackivicz, and Bancroft 1973). Clark, Finely, and Gibson (1974) suggested that small amounts of hydrocarbons from outboard motor wastes may adversely affect mussels and oysters. They found that mussels were more sensitive to two-cycle outboard motor effluent than oysters, and that cumulative mortality in mussels after 10 days was 66 percent compared with 14 percent for oysters.

(2) The major source (approximately 88 percent) of lead that enters a basin through subsurface outboard motor exhaust was the combustion of leaded gasoline, which is no longer available (May and McKinney 1981). Lead is very toxic to most plants and is moderately toxic to mammals, where it acts as a cumulative poison (Bowen 1966). The aquatic organisms most sensitive to this metal are fish (Mathis and Kevern 1975). Boat motor emissions can be reduced through the increased use of unleaded fuels and by manufacturer research and development aimed at reducing the pollutants in emissions and increasing fuel efficiency. Public education directed toward the importance of well-tuned engines in reducing emissions and increasing efficiency is another mitigative measure to be considered (USEPA 1985).

4-2. Water Quality Monitoring and Maintenance

a. Sewage discharge from vessels moored in a boat basin is normally a minimal pollution problem. However, the development of recreation facilities will result in replacement of existing lands with impervious surfaces, increases in contaminants and surface runoff, and increased siltation.

¹ Letter from Roger O. Olmstead, Program Manager, Shellfish Sanitation, USFDA, Atlanta, GA to J. David Clem, Chief, Shellfish Sanitation Branch, 1 December 1982.

If small boat basin design results in a confined basin, there is the potential for stagnation and eventual accumulation of pollutants. This can result in decreases in dissolved oxygen levels below acceptable levels. The basin should be oriented so that flushing currents are introduced. Design components to encourage flushing include taking advantage of prevailing winds; elimination of corners or projections in basin design; and shaping and sloping of the bottom of the basin. In severe cases, flushing can be achieved by pumping water from an adjacent area or by aerating the basin.

b. Water quality monitoring can be expensive. The most economical alternative compared to field monitoring may be the use of a numerical model. All models require some field data for proper calibration. Tetra Tech (1988) determined that a better and more cost-effective approach would be a combination of both water quality monitoring and numerical modeling. These models may be used to predict flushing time and pollutant concentrations without site-specific data. Another advantage of numerical models over field monitoring is the ability to perform sensitivity analyses to establish a set of design criteria. Numerical models may be used to evaluate different alternative designs to determine the configuration that would provide for maximum flushing of pollutants. These models may also be used to perform sensitivity analysis on the selected optimum design.

4-3. Environmental Effects of Structures

Breakwaters and jetties associated with marinas, boat ramps, or harbors can benefit aquatic biota. Gravel and cobble provide substrate for small plants, crustaceans, and molluscs, which are food for fishes and waterfowl (Miller 1988, Payne 1989). In addition, rock structures create quiescent areas that are used by larval and juvenile fishes, as well as freshwater mussels and crustaceans. Jetties and other rock structures may be particularly beneficial if they are placed in lakes or estuaries where substrate consists mainly of fine-grained sands and silts. The negative effects of these structures probably originate from improper construction practices. Heavy equipment should be kept clear of shallow aquatic habitats, wetland vegetation, and unstable banks. Coarse rock and riprap are the best materials for construction of jetties and other rock structures. Although automobile bodies and rubble from construction can be used in place of riprap, this material is unsightly and can be dangerous for swimmers and may be a source of toxicants or nuisance flotsam.

a. *Marinas.*

(1) The impacts of small boat basins are dependent on the sensitivity of the site selected, the design of the marina, and the extent of the impacts on the environment. The nature of a small boat basin dictates the need for protected waters that are conducive to stagnation and associated water quality problems. Basins that contain dead-end canals and are inadequately flushed may create major water quality problems. Stagnation may result in higher temperatures and salinities in the basin than in unmodified areas. Poor circulation may also result in the buildup of debris, organic material in the water and sediments, phytoplankton blooms, depletion of oxygen in the water, and associated fish kills (de La Cruz 1983; McBee and Brehm 1979). There are a number of design features that can be considered to improve the environmental quality of a harbor. The shape of the basin is important. It should fit the flow patterns of the area if possible. This requires avoiding square-shaped basins and dead-end canals that create dead-water areas. Basins should be constructed so that they are not deeper than their access channel. The most desirable design would be a marina with a wide deep entrance channel with gradually decreasing depths toward the inner harbor (NOAA 1976). This design would provide improved flushing rates in the marina. With this design, larger vessels could be moored toward the mouth of the marina and shallower draft vessels in inner portions of the harbor. Flow-through designs would also be desirable. Open piles and floating breakwaters would be more conducive to water circulation in a basin. Where an open flow-through design is not feasible, breaches or culverts should be considered to enhance circulation and flushing of the basin. A small boat basin should not be located near sewage or industrial outfalls that may compound potential water quality problems.

(2) Water quality in the harbor may be further impacted by boating activities. Petroleum products may be released in the water from boat engines. Boating operations may also add to the turbidity of the water in the basin if it is shallow and may result in a reduction of photosynthesis and dissolved oxygen in the water. Generally, a water depth of 2-3 ft between the propeller of a vessel and the bottom during low water should prevent these problems (NOAA 1976). Other water quality problems may result from oil spills, sewage disposal, and land runoff into the basin. Contamination may also result from protective paints (copper) on boats.

(3) Noise and air pollution from construction and/or operation of a marina may also disturb aquatic and terrestrial animals and humans in the immediate area.

b. Jetties.

(1) Jetties associated with marinas are structures used to stabilize the position of the navigation channel, to shield vessels from wave forces, and to control the movement of sand along the adjacent beaches so as to minimize the movement of sand into the channel (EM 1110-2-1204). The sand transported into a channel will interfere with navigation depth. Because of the longshore transport reversals common at many sites, jetties are often required on both sides of a channel to achieve complete channel protection. It is the impoundment of sand at the updrift jetty that creates the major physical impact. When fully developed, the impounded sand extends well updrift on the beach and outward toward the tip of the jetty.

(2) Another major physical impact of a jetty is the erosion of the downdrift beach. Before the installation of a jetty, nature supplies sand by intermittently transporting it along shore. The reduction or cessation of this sand transport due to the presence of a jetty leaves the downdrift beach with an inadequate natural supply of sand to replace that carried away by littoral currents.

(3) To minimize the downdrift erosion, some projects provide for periodically dredging the sand impounded by the updrift jetty and pumping it through a pipeline to the downdrift eroding beach. This pumping provides nourishment of the downdrift beach and also reduces shoaling of the channel. If the sand impounded at the updrift jetty extends to the head or seaward end of the jetty, sand will move around the jetty and into the channel, causing a navigation hazard. Therefore, the purpose of sand bypassing is not only to reduce downdrift erosion, but also to help maintain a safe navigation channel.

(4) One design alternative for sand bypassing involves a low section or weir in the updrift jetty over which sand moves into a sheltered, predredged deposition basin. By dredging the basin periodically, channel shoaling is reduced or eliminated. The dredged material is periodically pumped across the navigation channel to provide nourishment for the downdrift shore.

c. Breakwaters.

(1) Breakwaters are wave energy barriers designed to protect any land form or water area behind them from the

direct assault of waves (EM 1110-2-1204). Because of the higher cost of these offshore structures, breakwaters have been mainly used for harbor protection and navigational purposes. In recent years, shore-parallel, detached, or segmented breakwaters have been used for shore protection structures.

(2) Breakwaters have both beneficial and detrimental effects on the shore. All breakwaters reduce or eliminate wave action in the lee (shadow). However, whether they are offshore, detached, or shore-connected structures, the reduction or elimination of wave action also reduces the longshore transport in the shadow of the breakwater. For offshore breakwaters, reducing the wave action leads to a sand accretion.

(3) Shore-connected breakwaters provide protection to harbors from wave action and have the advantage of a shore arm to facilitate construction and maintenance of the structure (Figure 4-1).

(4) At a harbor breakwater, the longshore movement of sand generally can be restored by pumping sand from the side where sand accumulates through a pipeline to the eroded downdrift beach.

(5) Offshore breakwaters have also been used in conjunction with navigation structures to control channel shoaling. If the offshore breakwater is placed immediately updrift from a navigation opening, the structure impounds sand in its lee, prevents it from entering the navigation channel, and affords shelter for a floating dredge plant to pump out the impounded material across the channel to the downdrift beach.

d. Physical considerations.

(1) Jetty, breakwater, and marina construction are invariably accompanied by localized changes in the hydrodynamic regime, creating new hydraulic and wave energy conditions. The initial disruption of the established dynamic equilibrium will be followed by a trend toward a new set of equilibrium conditions. Rapid dynamic alterations in the physical environment may occur in the short-term time scale as the shore processes respond to the influence of the new structures. Slower, more gradual, and perhaps more subtle changes may occur over the long term.

(2) In light of the dynamic character of shore processes, assessment of the effects of coastal engineering projects on shorelines is a difficult task. Shoreline changes

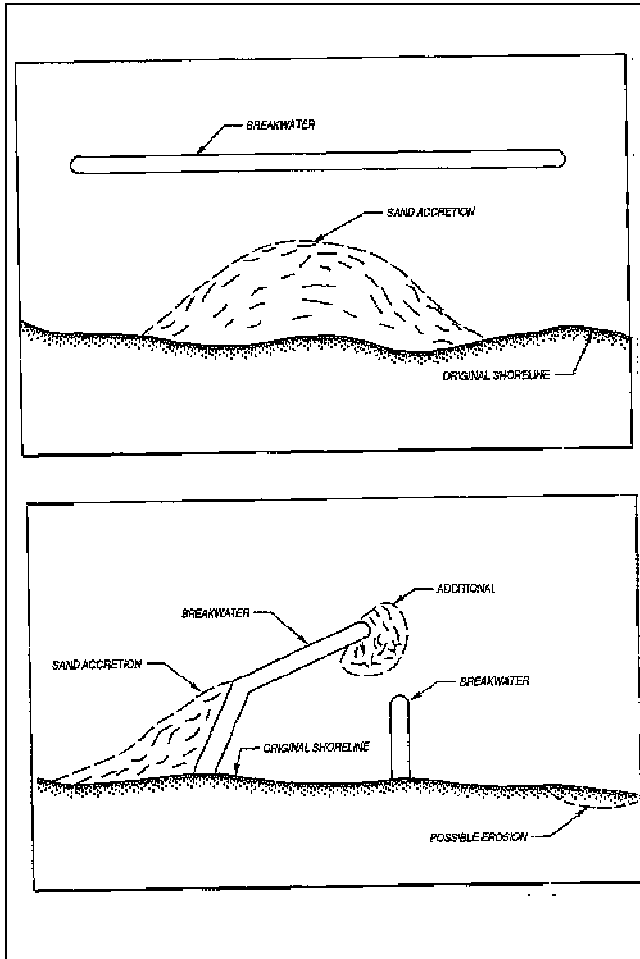


Figure 4-1. Erosion and accretion patterns in association with detached and attached breakwaters

induced by the presence of a structure may be masked by wide annual or seasonal fluctuations in natural physical processes. Several events, however, can be predicted in response to jetty, breakwater, and marina construction with reasonable certainty. For example, by creating wave-sheltered areas, construction will result in changes in the erosional and depositional patterns along adjacent beaches, both inshore and offshore. A jetty or shore-connected breakwater will form a barrier to longshore transport if the structure extends seaward beyond the surf zone. Spatial extent of the ensuing shoreline alteration will depend on the structure's effectiveness as a sediment trap, which is a function of its orientation to the prevailing wave climate. Updrift accretion of sediments will continue until the sink area is filled to capacity and the readjusted shoreline deflects longshore transport past the seaward terminus of the jetty. The volume of sediment trapped by the structure represents material removed from the natural sand bypassing process. Consequently,

the downdrift shoreline will be deprived of this sediment and become subject to erosion. In circumstances where waves are refracted around the structures in a proper manner, accretion can occur along the seaward side of a downdrift jetty. Reflection of waves from a jetty or breakwater may also cause erosion of adjacent shorelines. However, erosion further down the shoreline is not precluded. Planning for adequate sand bypassing is, in view of the above considerations, a critical requirement of coastal construction.

(3) Erosion related to jetties will not necessarily be limited to downdrift shorelines. Jetties confine flows through a channel such that current velocities are increased. An enhancement of ebb jet flows will result in displacement of sediments from between the jetties in a seaward direction to deeper waters.

(4) Shore-connected breakwaters of a small boat basin affect shorelines in much the same manner as jetties. Accretion occurs along the updrift junction of shore and structure and continues until longshore transport is deflected around the free end to the breakwater (Figure 4-1). Calm waters in the protected lee of the breakwater provide a depositional area that can rapidly shoal. Sediments trapped in the accretional area and terminal shoal are prevented from reaching downdrift beaches, and substantial erosion may result.

(5) Offshore breakwaters create depositional areas in their "shadows" by reflecting or dissipating wave energy (Figure 4-1). Reduction of wave energy impacting a shoreline in the lee of the structure retards the longshore transport of sediments out of the area and accretion ensues. The extent of accretion will depend on the existing balance of shore processes at a given project site. Generally, a cusped spit will develop between the shoreline and the structure as the system approaches a new equilibrium. However, if the breakwater is situated in the littoral zone such that it forms a very effective sediment trap, a complete connection will eventually form, merging the shoreline with the structure. A tombola associated with an offshore breakwater may present a severe obstruction to littoral transport and trap a significant volume of sediment. Extensive downdrift erosion may result.

(6) By modifying the cross-sectional area of a channel, jetty construction potentially can alter the tidal prism, or volume of water entering or exiting through a channel in one tidal cycle. Enlarging a channel can increase the tidal range within a harbor. In connection with channel deepening, seawater may intrude further into the harbor than occurred under pre-project conditions. Circulation

patterns within a basin may be altered as a consequence of modified floodwater current conditions. Thus, the area physically affected by jetty construction might be extended appreciable distances from the actual project site.

e. Water quality considerations.

(1) Suspended sediments. During the construction and dredging of a small boat basin, suspended sediment concentrations may be elevated in the water immediately adjacent to the operations (EM 1110-2-1204, U.S. Army Corps of Engineers 1989, NOAA 1976). In many instances, however, construction and dredging will be occurring in naturally turbid estuarine or coastal waters. Plants and animals residing in these environments are generally adapted to, and are very tolerant of, high suspended sediment concentrations. The current state of knowledge concerning suspended sediment effects indicates that anticipated levels (generally less than 1,000 mg/l) generated by construction and dredging do not pose a significant risk to most biological resources (U.S. Army Corps of Engineers 1989). The adaptability of the animals to high turbidities may minimize environmental impacts. However, turbidity control is always in the best interest of the environment during construction or dredging activities. Although estuaries and coastal waters are generally more turbid than coral reefs, they are not insensitive to potentially indiscriminate construction practices. High levels of suspended sediment concentrations remain a concern in construction projects. Limited spatial extent and temporal duration of turbidity fields associated with these construction activities reinforce this assessment. However, when construction and dredging are to occur in a clear-water environment, such as in the vicinity of coral reefs or sea grass beds, precautions should be taken to minimize the amounts of resuspended sediments. Organisms in these environments are generally less tolerant to increased siltation rates, reduced levels of available light, and other effects of elevated suspended sediment concentrations (U.S. Army Corps of Engineers 1983, EM 1110-2-1204). Potential negative impacts can be somewhat alleviated by erection of a floating silt curtain around the point of impact when current and wave conditions allow. However, high-energy conditions usually preclude the use of silt curtains (NOAA 1976, EM 1110-2-1202).

(2) Other water quality impacts. Indirect impacts on water quality may result from changes in the hydrodynamic regime. The most notable impact of this type is associated with breakwaters which form a semi-enclosed basin used for small boat harbors or marinas. If the

flushing rate of the basin is too slow to provide adequate removal of the contaminants, toxic concentrations may result (USEPA 1985, NOAA 1976, U.S. Fish and Wildlife Service 1980, EM 1110-2-1204). Also, fluctuations in parameters such as salinity, temperature, dissolved oxygen, and dissolved organics may be induced by construction or due to altered circulation patterns. Anticipated changes in these parameters should be evaluated with reference to the known ecological requirements of important biological resources in the project area.

f. Biological considerations.

(1) Habitat losses. Measurable amounts of bottom habitat are physically eradicated in the path of a fixed jetty or breakwater during construction of a small boat basin. If a rubble-mound structure with a toe-to-toe width of 164 ft (50 m) is used as an example, 0.6 mile (1 km) of structure removes approximately 12.5 acres (5 ha) of preexisting bottom habitat (EM 1110-2-1204). Once a structure is in place, water currents and turbulence along its base can produce a scouring action, which continually shifts the bed material. Scour holes may develop, particularly at the ends of structures. Scouring action may effectively prevent the colonization and utilization of that habitat area by sediment-dwelling organisms. Effects of scouring are largely confined to entrance channels and narrow strips of bottom habitat immediately adjacent to structures. Usually, only a portion of the perimeter of a structure will be subject to scouring, such as along the channel side of the downdrift jetty. Generally, the amount of soft bottom habitat lost at a given project site will be insignificant in comparison with the total amount of that habitat available. Exceptions to this statement may exist, such as where breakwater construction and dredging of the total enclosed harbor area will displace large acreages of intertidal habitat. Often such habitats function as nursery areas for estuarine-dependent juvenile stages of fishes and shellfish, and the availability of those habitats will be a determining factor in the population dynamics of these species. Most marina projects, however, require only a small amount of dredging. The impacts of these projects will be minor provided marshes, sea grasses, and other critical habitat are not disturbed. Dredged material should be placed on high ground within the marina area, if possible (NOAA 1976). Dredged material can be used to improve coastal ecosystems if it can be disposed in a manner to establish artificial marshes, sea grass beds, and shellfish beds (NOAA 1976, EM 1110-2-5026, Pullen and Thayer 1989). Additional habitat losses may occur when significant erosion of downdrift shorelines impacts spawning or nesting habitats of fishes, shorebirds, or other organisms and when the tidal range of a harbor is

modified by entrance channel modification, which in turn affects coastal habitat. Short-term impacts of this type may also occur during construction activities as heavy equipment gains access to the project site. Small boat basins in some coastal regions are constructed in areas of rocks or other hard bottoms and may require blasting to break up the rocks during construction. Fish kills may result from the blasting. The major damage is to fish with swim bladders. Tests have shown that a force of 40-50 psi from a high explosive charge is usually fatal to adult fish with swim bladders, whereas a charge as low as 2.7 psi will kill juveniles (U.S. Army Corps of Engineers 1989).

(2) Habitat gains.

(a) Losses of benthic (bottom) habitat and associated benthos (bottom-dwelling organisms) due to physical eradication or scouring will gradually be offset by the gain of new habitat represented by the structures themselves and the biological community, which becomes established thereon (NOAA 1976, EM 1110-2-1204). The trade-off made in replacing "soft" (mud or sand) bottom habitat with "hard" (rock, at least in rubble-mound structures) bottom habitat has generally been viewed as a beneficial impact associated with jetty and breakwater projects. Submerged portions of jetties and breakwaters, including intertidal segments of coastal structures, function as artificial reef habitats and are rapidly colonized by opportunistic aquatic organisms. Over the course of time, structures in marine, estuarine, and most freshwater environments develop diverse, productive, reeflike communities. Detailed descriptions of the biota colonizing rubble-mound structures have been made for project sites on the Pacific (Johnson and De Wit 1978), Atlantic (Van Dolah, Knott, and Calder 1984), Gulf of Mexico (Hastings 1979; Whitten, Rosene, and Hedgpeth 1950), and Great Lakes (Manny et al. 1985) coastlines. In some geographical areas, jetties and breakwaters provide the only nearshore source of hard-bottom habitat. Also, exposed portions of detached structures may be colonized by seabirds.

(b) The ultimate character of the biological community found on a jetty or breakwater of a small boat basin will depend on the quality of habitat afforded by the construction materials used. Physical complexity (i.e., rough surfaces with many interstitial spaces and a high surface area to volume ratio) is a desirable feature of rubble-mound structures in comparison with the relatively smooth, flat surface of steel sheet-pile, concrete bulkhead, caisson structures (EM 1110-2-1204, NOAA 1976, U.S. Fish and Wildlife Service 1980). The sloping sides

of rubble-mound structures also maximize the surface area of habitat created. Structures with sloping sides also provide more habitat within a given depth interval than structures with vertical elements. Where depths are sufficient, the biota on jetties and breakwaters exhibit vertical zonation, with different assemblages of organisms having discrete depth distributions. In general, then, structures built in deep waters will support a more diverse flora and fauna than those in shallow waters. This pattern will be influenced by such factors as latitude and tidal range.

(c) Just as changes in shoreline configuration and beach profile can entail habitat loss, they can also represent habitat gain. Accretional areas, such as exposed bars, and the above-water portion of structures may be used, for example, by wading and shorebirds for nesting, feeding, and resting sites.

(3) Migration of fishes and shellfishes.

(a) Eggs and larvae. Early life history stages, namely eggs and larvae, of many important commercial and sport fishes and shellfishes are almost entirely dependent on water currents for transportation between spawning grounds and nursery areas (EM 1110-2-1204). A concern which has sometimes been voiced by resource agencies in relation to jetty projects is that altered patterns of water flow may adversely affect the transport of eggs and larvae. Those eggs and larvae carried by longshore currents might be especially susceptible to entrapment or delay in eddies and slack areas formed adjacent to updrift jetties at various times in the tidal cycle. Even short delays in the passage of eggs and larvae may be significant because of critical relationships between the developmental stage when feeding begins and the availability of their food items. All aspects of this potential impact remain hypothetical. No conclusive evidence exists to support either the presence or absence of impacts on egg and larval transport. This fact is true even where jetties have been present for relatively long spans of time. The complexity of the physical and biological processes involved would render field assessments of this impact a long-term and expensive undertaking. The results of hydraulic modeling studies related to this question have been inconclusive (U.S. Army Corps of Engineers 1980). Future modeling studies combined with field verification studies may provide insight into resolving the validity of this concern.

(b) Juveniles and adults. Similar concern has been voiced regarding potential impacts of jetties and breakwaters on migration of juvenile and adult fishes and shellfishes. These stages generally have well-developed swimming capabilities, such that physical barriers imposed

by these structures are less of a concern than are behavioral barriers. This issue has been raised primarily in association with projects in the Pacific Northwest, and with anadromous fishes in particular (Faurot et al. 1989). Anadromous fishes, including many salmonids, spend much of their adult life in the ocean, then return to fresh water to spawn. Early life history stages spend various lengths of time in fresh water before moving downstream to estuaries where the transition to the juvenile stage is completed. Specific concerns are that juveniles or adults will not circumvent structures that extend for considerable distances offshore. Juveniles in particular are known to migrate in narrow corridors of shallow water along coastlines and may be reluctant, due to depth preferences, to move into deeper waters. The State of Washington has developed criteria whereby continuous structures that extend beyond mean low water are prohibited. Designs of coastal structures there are required to incorporate breaches or gaps to accommodate fish passage (EM 1110-2-1204).

(4) Increase predation pressure. Coastal rubble-mound structures provide substrate for the establishment of artificial reef communities. As such, jetties and breakwaters serve as a focal point for congregations of fishes and shellfishes which feed on sources of food or find shelter there. Many large predator species are among those attracted to the structures in numbers, as evidenced by the popularity of jetties and breakwaters as sites of intense sport fishing. Thus, there is concern, again largely associated with projects in the Pacific Northwest, that high densities of predators in the vicinity of jetties and breakwaters pose a threat to egg, larval, and juvenile stages of important species (Faurot et al. 1989). For example, fry and smelt stages of several species of salmon are known to congregate in small boat harbors prior to moving to the sea. The concern raised is that these young fishes are exposed to numerous predators during their residence near the structures. As is the case with the concern for impacts on migrating patterns, this concern remains a hypothetical one. Conclusive evidence demonstrating the presence or absence of a significant impact is unavailable and will be exceedingly difficult to obtain.

g. Environmental summary.

(1) Environmental design.

(a) Every small boat basin project scenario should incorporate engineering design, economic cost-benefit, and environmental impact evaluations from the inception of planning stages. All three elements are interrelated to such a degree that efficient project planning demands their

integration. Environmental considerations must not be an afterthought. Structural design criteria should seek to minimize negative environmental impacts and optimize yield of suitable habitat for biological resources. Minimizing impacts can best be achieved by critical comparisons of a range of project alternatives, including the alternative of no construction. From an environmental perspective, site selection is perhaps the single most important decision in the planning process. However, various engineering design features can be incorporated to optimize an alternative from an ecological viewpoint. For example, opting for a floating rather than fixed breakwater design might alleviate most concerns related to impacts on circulation, littoral transport, and the migration of fishes, because passage is allowed beneath the structure. Floating breakwaters are also excellent fish attractions and still provide substrate for attachment and shelter for many other organisms.

(b) In planning small boat harbors, configurations that minimize flushing problems should be examined. Rectangular basins that maximize the area available for docks and piers characteristically have poor water circulation, particularly in the angular corner areas. Designs with rounded corners and entrance channels located so that flood tidal jets provide adequate mixing throughout the basin are desirable. Selection of a less steep rubble-mound side-slope angle will maximize the availability of intertidal and subtidal habitat surface areas. The size class of stone used in armor layers of rubble-mound structures is another engineering design feature that has habitat value consequences. Selection of large-size material results in a heterogeneous array of interstitial spaces on the finished structure. Heterogeneity rather than uniformity enhances the quality of the structure in terms of refuge and shelter sites for diverse assemblages of fishes and shellfishes.

(2) Environmental assessment.

(a) Short-term impacts. Actual construction activities for small boat basins entail a number of potential impacts (Table 4-1). These impacts will vary in type and frequency from project to project. For example, temporary or permanent access roads may have to be built to allow transportation of heavy equipment and construction materials to the site. The access routes may cross marshes, creeks, and other water areas and have the potential for altering water circulation and displacing valuable wildlife habitat. Grading, excavating, backfilling, and dredging operations will generate short-term episodes of noise and air pollution and may locally disturb wildlife such as

Table 4-1
Marina Environmental Impact Matrix (NOAA 1976)

FACILITY COMPONENTS*	IMPACT CATEGORIES**	Alteration of Natural Areas***	Alteration of Water Circulation Patterns**	Turbidity	Release of Sewage	Oil Spills	Land Runoff	Erosion	Shoaling	Dissolved Oxygen Depletion	Air Pollution	Copper Pollution
Access Channels		•	•	•				•	•	•		
Boat Basins		•	•	•				•	•	•		
Piers and Docks		•	•	•								
Boat Moorings		•	•									
Launching Ramps		•					•	•				
Bulkheads		•	•	•				•	•			
Breakwaters		•	•	•				•	•			
Marine Sanitation Devices					•					•		
Pumpout Facilities		•			•					•		
Fuel Docks		•				•						
Boats				•		•		•	•		•	•
Access Roads		•	•				•	•				
Parking Lots and Cars		•					•	•			•	
Dry Storage Areas		•					•	•				
Club Houses		•					•					
Storm Sewer Outfalls				•	•	•	•			•		
Septic Tanks					•					•		
Dredging		•	•	•				•	•	•		
Dredged Material Disposal		•	•	•			•	•	•	•		
Boat Repair & Maintenance Areas		•				•	•					•

Notes:

* All facility components are not necessarily involved in each marina.

** All impact categories are not necessarily produced at each marina.

*** Impacts may be either positive or negative.

Dots indicate a potentially significant relationship between the facility component and impact category during either construction or operation. The component may be either a source or a cause for that impact.

nesting or feeding shorebirds. Project activities should be scheduled to minimize disturbances to waterfowl, spawning fishes and shellfishes, and other biological resources at the project site. Precautions should also be taken to reduce the possibility of accidental spills or leakages of chemicals, fuels, or toxic substances during construction and operation of a marina. Effort should be expended to minimize the production and release of high concentrations of suspended sediments, especially where and when sensitive biological resources such as corals or sea grasses could be exposed to turbidity plumes and increased siltation rates. Dredging of a channel and basin in conjunction with a small boat harbor project presents a need for additional consideration of impacts in relation to suspended sediments and dredged material disposal.

(b) Long-term impacts. Long-term impacts of small boat harbor construction are less definitive or predictable. Ultimate near-field effects on littoral sediment transport can be expected to become evident within several seasonal cycles. These effects will vary according to a given project's environmental setting and specific engineering design. For example, periodic maintenance dredging will be required for catch basins adjacent to weir jetties and in the harbors. The impact that constructing coastal structures will have on far-field shore processes is presently understood only qualitatively.

4-4. Non-Point Source Pollution (Commercial and Recreational Traffic Effects)

a. Passage of commercial or recreational craft can cause drawdown, turbulence, and waves. These disturbances can erode shorelines, resuspend alluvial sediments, and scour shallow areas. Physical effects of traffic are unique in that although they may last only a few minutes, they are often repeated many times during a 24-hr period. Concern has been expressed that the physical effects of movement of commercial vessels could negatively affect aquatic biota (Rasmussen 1983; Nielsen, Sheehan, and Orth 1986). Temporary periods of turbulence or elevated suspended sediments can stress or kill pelagic fish eggs and larvae, bottom-dwelling invertebrates such as mussels, aquatic insects, worms, and crustaceans. Characteristics of large rivers, which include size, shape, bed and bank material grain size, and ambient velocity and suspended sediment concentrations, influence the nature and magnitude of traffic effects. Shallow, narrow, sinuous waterways will be more susceptible to physical forces than large waterways. Sediment is more likely to be resuspended from alluvial substrates than from cobble or bedrock. Sediment resuspension due to commercial traffic is usually most noticeable during low flow since the vessels

are physically closer to the sediment. During higher flow, sediment resuspension due to traffic usually cannot be detected since the vessels are further away from the bottom and have less influence.

b. Chemical changes resulting in vessel passage are usually minor. Shifts in oxygen tension in the water column have been associated with tow-induced increases in suspended sediment (Lubinski et al. 1981). In a study by Environmental Science and Engineering (1981) it was concluded that the effects of tow passage on dissolved oxygen, specific conductance, pH, water temperature, and transmissivity adjacent to the navigation channel were nearly undetectable.

4-5. Point Source Pollution

a. *General.* Point sources of pollution in small boat basins can have an adverse effect on water quality in the basin and adjacent areas. These point sources of pollution may include dredging and disposal operations during harbor construction and maintenance. After construction is complete and the boat basin is in operation, point sources of pollution include storm and sanitary sewer utilities provided with the marina facilities, surface runoff, inadequate control of bilges, fueling facilities, and the dumping of garbage and trash in the harbor waters.

b. *Dredging and dredged material disposal considerations.* Nearly all harbor development projects will require some dredging operations. Factors influencing the amount of material that must be dredged are water depth, tidal range, size of vessels to be accommodated, distance to main navigation channels, and siltation rates. The environmental impacts associated with dredging are site-specific. Negative environmental impacts associated with dredge and disposal operations include short-term increases in turbidity, temporary reductions in oxygen content, burial of organisms, disruption of existing benthic communities, creation of stagnant water conditions, and resuspension of pollutants (Chmura and Ross 1978).

(1) During the design phase of the project, the environmental effects associated with dredging and dredged material disposal must be considered. Dredging and disposal should be accomplished using the most technically satisfactory, environmentally compatible, and economically feasible dredging and dredged material disposal procedures. The following activities are required to evaluate the environmental impacts of dredging and dredged material disposal in the design phase of the project.

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.	Palermo, Montgomery, and Poindexter (1978)
(3) Determine whether or not there will be dredging of contaminated sediments.	Brannon (1978)
(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.	Barnard (1978)
(7) Control the dredging operation to ensure environmental protection.	Barnard (1978)
(8) Identify pertinent social, environmental, and institutional factors.	EM 1110-2-1202
(9) Evaluate dredging and disposal impacts.	Wright (1978) Hirsch, DeSalvo, and Peddicord (1978)

(2) Limitations may be placed on dredging equipment to minimize the environmental impact of the dredging and disposal operation. If upland containment areas are small, the size of the dredge should be restricted to minimize stress on containment area dikes and provide adequate retention time for sedimentation to prevent excessive suspended solids in the weir effluent. Dredged material disposal may also be accomplished through open-water disposal and habitat development. The determination of a disposal alternative is very important in determining the environmental impact of dredging during marina construction and maintenance. Each disposal alternative involves its own set of unique considerations, and selection of a disposal alternative should be made based on both economic and environmental considerations. Detailed guidance for the selection of a disposal alternative is given in EM 1110-2-1202 and EM 1110-2-5025.

(3) The environmental effects commonly associated with dredging operations are increases in turbidity, resuspension of contaminated sediments, and decreases in DO levels. Research results indicate that the traditional fears of water quality degradation resulting from the resuspension of sediments during dredging are for the most part unfounded. More detailed information on the impacts of depressed DO levels is given in EM 1110-2-1202 and

EM 1110-2-5025. Regardless of the type of dredging used, 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 should also be considered. Techniques to minimize environmental impacts must be employed during dredging activities. 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 Barnard (1978)
Properly using silt curtains	Barnard (1978)
Selecting appropriate pipeline discharge configurations	Barnard (1978)

(4) Most of the negative aspects of dredging operations can be eliminated or minimized. Dredging can be used to enhance the environmental quality of a water body in some cases by increasing flushing rates. Harbor basin design features that promote flushing are basin depths that are not deeper than connecting waters and gradually increase toward open water, basins with few vertical walls and gently rounded corners, and even bottom contours with no pockets or depressions (*Coastal Marinas Assessment Handbook* (USEPA 1985)). Increased turbidity and burial of organisms by siltation can be minimized by the proper use of hydraulic cutter-head dredges, filters, and silt screens as opposed to unscreened mechanical dredging. The work should be seasonably timed so as to have the least impact on certain life stages of the surrounding biota such as fish larvae or oyster spat. The duration and areal extent of these impacts are a direct function of material particle size and the flushing rate (Burrage 1988). Dredged channels should follow the course of existing channels, and slips for boats with deep drafts should be built in naturally deep water. In all cases, the harbor should not alter tidal circulation patterns, salinity regimes, or change related nutrient, aquatic life, and vegetative distribution patterns (National Marine Fisheries Service 1983). Dredged material should be viewed as a potentially reusable resource, and should include provisions for access to such resources. Permanent, upland disposal sites should be sought in preference to wetland disposal. Areas containing submerged vegetation and regularly flood-emergent vegetation should not be used.

c. *Other point source discharges.*

(1) Other direct sources of pollution in a small boat basin may occur during marina construction where natural vegetative cover is usually replaced with impermeable surfaces such as parking lots and buildings. These areas reduce the area available for storm-water percolation and increased storm-water runoff and pollutants. These pollutants associated with storm-water runoff may include sediments, pesticides, oil and road dirt, heavy metals, and nutrients. An immediate effect of runoff may be a temporary reduction in DO in the water. Lower DO concentrations can be lethal for most marine species. Boat basins may have low DO concentrations because of reduced water exchange rates and therefore, may be more susceptible to deoxygenating pollutants. Although heavy metals such as zinc, mercury, lead, and cadmium in their pure state usually are not particularly hazardous to marine life, these metals become quite toxic when combined with organic pollutants.

(2) Pesticides and herbicides used at marinas and their associated developments may also be washed into marina waters by runoff. These pollutants are not only harmful to marine life, but may also be accumulated by fish and shellfish and then consumed by humans. Also, petroleum products resulting from fuel spills, parking lots, and bilge draining may be toxic to marine life. Other potentially harmful runoff products include sediments, detergents, and excessive nutrients. These pollutants can result in reduced DO levels, can stimulate algal blooms and the growth of nuisance plants, and can eventually change the texture of bottom substrates and produce a zone of reduced productivity.

(3) Sanitary pollutants can enter marina waters directly discharged as untreated or macerated fecal waste from marine sanitation devices (MSDs) aboard boats or from improperly functioning or poorly located septic systems that allow sewage effluents to leach into marina waters. The most serious effect of discharging sanitary waste may be the potential for introducing disease-causing viruses and bacteria. This problem may occur if boat sewage is released in the vicinity of shellfish (clam or oyster) beds.

(4) Expected pollutant concentrations in marina basins and adjacent waters can be estimated by evaluating the type and quantity of pollutant loadings expected and the dilution and transfer of such pollutants by various flushing mechanisms. Various methods to assess the water quality impacts of marina-derived pollutants on the environment are discussed in detail in the *Coastal Marinas Assessment Handbook* (USEPA 1985).

d. *Water quality mitigative measures.*

(1) Water exchange does not always ensure good quality, especially in the back basins of a multibasin harbor. Sanitary-sewer and industrial waste discharges into harbor waters can be and must be eliminated in harbor planning. The flushing of sanitary facilities and dumping of pollutants must be controlled by ordinance and by provision of pumping stations and garbage and trash collection services at convenient locations. The disposal services should be capable of handling heavy weekend or seasonal usage. Trash containers should be convenient and secure to prevent litter from falling or blowing into the water. Collection facilities for boat holding tank wastes should be conveniently available at existing fueling stations. The production of boat sanitary wastes can be reduced by providing convenient shoreside restroom facilities of adequate size with hot showers and wash basins. Well-maintained restrooms will reduce boat toilet use. Other

measures to prevent sanitary waste discharges into marina waters are to require all boats with MSDs to be connected to a sanitary waste collection system when moored, sealing boat discharge outlets when they enter the marina, and banning live-aboards or requiring that these boats be permanently connected to a shoreside sanitary waste collection system.

(2) A storm-water management plan that diverts storm water away from the harbor is required to maintain water quality within the marina. If local surface water cannot be diverted from the harbor, extra care should be taken to keep harbor streets, parking lots, and other marginal surfaces reasonably clean. Also, fertilized landscapes should be prevented from overflowing when watered.

(3) Careful attention to boat maintenance and repair activities is also essential to maintaining harbor water quality. Paint spraying, sandblasting, engine repairs, boat washing, and similar maintenance activities should not take place in the harbor or near ramps or railways. These activities should preferably be performed on shore, either indoors or behind canvas screens. Also, the use of non-phosphate detergents can greatly reduce the amount of nutrients entering marina waters.

4-6. Aquatic Plant Control

a. Submersed aquatic plants can interfere with recreation, water supply, and navigation in small boat basins.

Although moderate densities of vegetation improve habitat for fishes and waterfowl, nuisance levels usually have to be removed with an appropriate control measure. The following pertains to two methods of controlling submersed vegetation at small boat basins: mechanical harvesting and biological methods.

b. Mechanical harvesting of aquatic plants should be considered when areas are small, or when biological techniques are not appropriate. A mechanical harvester moves through the water, and cuts and processes the plants, which can be placed back in the water or loaded on a barge and shipped to shore for disposal. A computer model that simulates mechanical harvesting has been prepared that provides guidance on the effectiveness of various harvesting methods and the amount of time required for various harvesting strategies (Sabol 1983).

c. The white amur or grass carp (*Ctenopharyngodon idella*) has been used to control certain species of aquatic plants in lakes and ponds (Miller and Decell 1984, Miller and King 1984). Nonreproductive strains of the fish can be purchased and easily transported by truck. The fish do not compete with native fish for food or reproductive sites and are used successfully as control agents. These fish should only be used in small bodies of water where there are dense localized stands of submersed aquatic plants.

Appendix A References

A-1. Required Publications

Note: References used in this EM are available on interlibrary loan from the Research Library, ATTN: CEWES-IM-MI-R, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

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U.S. Environmental Protection Agency Guidelines for Specification of Disposal Sites for Dredged or Fill Material

40 CFR 220

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ER 200-2-2

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EM 1110-1-400

Recreation Planning and Design Criteria

EM 1110-2-1202

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Wild and Scenic Rivers Act, as amended

16 U.S.C. 1531, et seq.

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16 U.S.C. 4601-4601-11, et seq.

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33 U.S.C. 1401, et seq.

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33 U.S.C. 401, et seq.

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E.O. 11988

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ER 1110-2-400

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ER 1110-2-1404

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ER 1130-2-400

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ER 1165-2-28

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Appendix B Statutes and Regulations

B-1. Statutes and Regulations

Compliance with Federal statutes, executive guidelines, and Corps regulations often requires studies of existing environmental conditions and projections of conditions likely to occur in the future with and without various activities. Major environmental statutes and regulations that are currently applicable to Corps small boat harbors navigation projects are listed in Appendix A. Five statutes that have a major impact on the planning and operation of small boat harbors are: The National Environmental Policy Act; The Clean Water Act; The Marine Protection, Research, and Sanctuaries Act; The Coastal Zone Management Act and Estuary Protection Act; and The Marine Mammal Protection Act.

a. National Environmental Policy Act (NEPA). NEPA is the Federal statute that established national policy for the protection of the environment and set goals to be achieved along with the means to carry out these goals. The NEPA requires preparation of an environmental impact statement (EIS) for certain Federal actions affecting the quality of the human environment. The Corps normally prepares an EIS for legislation, feasibility reports, operations and maintenance activities, regulatory permits, and real estate management and disposal actions. Environmental assessments are prepared for all other Corps actions that may not have a significant impact on the environment except for certain minor actions that are categorically excluded from NEPA review. Emergency activities do not require the preparation of an EIS (refer to ER 200-2-2 for more detailed guidance).

b. Clean Water Act. Section 404 of the Clean Water Act governs the discharge of dredged or fill material into U.S. waters. The Corps regulates these activities by granting Federal permits, and is itself regulated by Section 404 through provisions for coordination with the states and the U.S. Environmental Protection Agency (EPA). Evaluation of the effects of dredged or fill material discharges must be done in accordance with EPA guidelines (40 CFR 230).

c. Marine Protection, Research and Sanctuaries Act - Section 103. Section 103 of the Marine Protection, Research, and Sanctuaries Act authorizes the Corps to issue permits for the transportation of dredged material for dumping in ocean waters. Evaluation must be done in accordance with EPA criteria found in 40 CFR 220. Note that in relation to Sections 404 and 103, Corps Regulation 209.145 also applies.

d. Coastal Zone Management Act and Estuary Protection Act. The Coastal Zone Management Act promotes coordination in the management, beneficial use, protection, and development of the coastal zone (16 USC 1451-1464; PL 92-583 as amended). Development, management, and protection are undertaken through long-term plans implemented by the states and local coastal zone management programs. The Estuary Protection Act is specifically for protection, conservation, and restoration of resources in estuaries (16 USC 1221-1226; PL 90-454). Information from state coastal management programs and local planning agencies can assist in determining what environmental resources exist in the project area and potential impacts of Repair, Evaluation, Maintenance, and Rehabilitation Research Program activities on the coastal zone and estuaries. Compliance with the Estuary Protection Act requires that studies funded by Congress, e.g., Corps planning or construction projects, consider the effect of the project on estuaries and their resources. The Secretary of the Interior, through the Fish and Wildlife Service (FWS), reviews plans and makes recommendations. This review is incorporated into authorization reports to Congress.

e. Marine Mammal Protection Act. The Marine Mammal Protection Act was enacted to protect diminishing populations of certain species of marine mammals (16 USC 1361-1407; PL 92-522 as amended). The Act establishes the Marine Mammal Commission to oversee protection activities. The FWS and NMFS administer the Act (16 USC 1379), but primary administrative responsibilities are delegated to states with marine mammal conservation and protection programs.