CECW-EH-D Engineer Regulation 1110-2-1457	Department of the Army U.S. Army Corps of Engineers Washington, DC 20314-1000	ER 1110-2-1457 24 June 1985
	Engineering and Design HYDRAULIC DESIGN OF SMALL BOAT NAVIGATION PROJECTS	
	Distribution Restriction Statement Approved for public release; distribution is unlimited.	

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
DAEN-CWH-D Washington, D. C. 20314-1000

Engineer Regulation
No. 1110-2-1457

24 June 1985

Engineering and Design
HYDRAULIC DESIGN OF SMALL BOAT NAVIGATION PROJECTS

1. Purpose. This regulation prescribes the design procedure and rationale for development of small boat navigation projects. Detailed design guidance is contained in the references listed in paragraph 3.

2. Application. This regulation applies to all HQ/USACE elements and field operating activities having civil works design responsibilities.

3. References.

a. ER 1105-2-40

b. ER 1110-2-1403

c. EM 1110-2-1612

d. EM 1110-2-1615

e. EM 1110-2-2904

f. EM 1110-2-5025

4. Design Rationale. The hydraulic design of a small boat navigation project must result in a safe, efficient, reliable, and cost effective project with appropriate consideration of environmental and social aspects. A satisfactory design must cover portions and/or extensions of the following elements to the degree appropriate as the design progresses through the various stages of project development.

a. Safety - potential hazards to humans and property, creation of a false sense of security, and consequences of storm intensities exceeding the design conditions.

b. Efficiency - channel dimensions and alignment and breakwater configuration selected to optimize degree of protection, operation and maintenance.

c. Reliability - ability to achieve project purposes throughout the project economic life and the proper functioning of features such as channel, turning basins, breakwaters, and wave absorbers.

d. Cost effectiveness - initial, operational, maintenance, and replacement costs optimized on an annual cost basis.

e. Environmental aspects - provide for continuation of favorable aspects, provide initial beautification efforts, and mitigate significant adverse impacts.

f. Social aspects - provide recreational opportunities, maintain community cohesion, and improve aesthetics.

5. Project Design Process.

a. The initial step in the hydraulic design process is to develop a study plan in support of the design effort. This plan will indicate the time, manpower, cost, and scheduled completion of the various design studies to be performed as the design progresses through the various stages of project development. Careful consideration of the type and complexity of the hydraulic design studies, data acquisition, and phasing of this effort with other on-going project development efforts is necessary (See Appendix A). Coordination with other disciplines to assure the timely availability, format, and adequacy of the hydraulic design technical information inputs to and outputs from the hydraulic design studies is essential. Physical and mathematical model studies (ER 1110-2-1403) should be provided for early in the study plan, when they are needed. The hydraulic design study plan must be flexible and able to adjust to changes in the project development and other circumstances.

b. Alternative designs are to be studied and presented in sufficient detail to provide a valid basis for plan comparison and plan selection. Cost and benefit estimates should be appropriate to the stage of project development.

c. Environmental studies are needed early in the design process so adverse impacts can be avoided or minimized.

6. Hydraulic Design Presentation.

a. General. The hydraulic design presentation portion of all reports forwarded for approval or information will contain sufficient detail to allow an independent assessment as to the soundness of the report conclusions and recommendation. The accuracy of hydraulic design studies (computations, physical and mathematical modeling, etc.) is dependent on the accuracy of input data and the degree to which the analytical procedure is representative of the hydraulic phenomena. The effects of uncertainty should be demonstrated by sensitivity analysis procedures when significant design elements are involved. Typical elements of a small boat navigation project are listed in Appendix B. The hydraulic design presentation will normally discuss the following subjects:

b. Water Levels. Water level parameters needed are: range, frequency, duration, and short term fluctuation amplitude. Water levels can be affected by storm surges, seiches, river discharges, natural lake fluctuations, reservoir storage limits, and ocean tides. High water levels are used for prediction of wave penetration and breakwater heights. Low water levels are used to determine channel and moorage area water depth and breakwater toe design. (EM 1110-2-1615).

c. Waves. The naturally occurring waves and vessel generated waves require analysis and prediction. Wave height period, direction, and duration are needed to design suitable breakwater and revetment protection. Wave conditions are needed in the channels and moorage area to develop suitable designs for these elements. Reduction of channel dimensions are accomplished when wave effects on vessel maneuverability are diminished. (EM 1110-2-1615)

d. Currents. Currents can be tidal, river, or seiche induced. The currents can have a beneficial effect by promoting harbor flushing. However, if the currents are too strong, they can adversely affect vessel maneuverability in the channels and turning basin and cause problems with moored or anchored vessels. Prediction of current strength and duration is needed for selection of the design conditions. Prototype current measurements may be needed before the final design is completed. (EM 1110-2-1615)

e. Shoreline Changes. The natural growth or recession of the shoreline and offshore hydrography is needed to predict project impacts. If the project creates adverse impacts such as accretion or erosion, suitable mitigation measures are needed. Some of these measures can be sand bypassing or beach protection structures. (EM 1110-2-1615)

f. Sediment Budget and Channel Shoaling. A sediment budget and channel shoaling estimate are needed to develop maintenance dredging volumes and costs. The sediment budget will also indicate potential erosion/accretion areas for shores adjacent to the entrance channel. The coastal budget will identify sediment volumes moved, reversals, sources, and sinks (shoaling areas). A river sediment budget is similar to the coastal budget, except the transport mechanism is river current. The river budget will identify sediment sources, volumes moved, and sinks. These river or coastal sediment budgets will indicate approximate volumes of shoaling in channels and mooring areas. Movable bed hydraulic models and/or mathematical models may be needed to refine shoaling estimates. (EM 1110-2-1615)

g. Design Vessel or Vessels. The design vessel or vessels are selected from comprehensive studies of the fleet expected to use the project during its design life. The design vessel (and smaller vessels) will provide the economic optimum project; however larger vessels may use the project under special conditions such as infrequent one way transit. There may be different design vessels for the design of different project features. For example, sail boats may have the deepest draft for channel depth design and fishing boats may have the widest beam for channel width design. The design vessel or vessels are identified by their dimensions and manuverability. (EM 1110-2-1615)

h. Channel Width. A rational design is needed to allow safe and efficient transit of the vessels expected to use the project. Factors to be considered are:

(1) Vessel size.

(2) Vessel maneuverability.

(3) Traffic congestion.

(4) Effects of wind, waves, and currents.

Increased width is necessary for: adverse wind, wave, and current conditions; vessels with poor maneuverability such as sail boats; and high traffic volumes involving passing and reversing maneuvers during peak periods. Interior channels generally need less width than the entrance channels because of reduced wind, waves, and currents. Widening on bends is needed to allow safe turns. Physical hydraulic models or mathematical ship simulator studies can be used to determine the optimum safe channel width. (EM 1110-2-1615)

i. Channel Depth. The channel depth must be adequate for the design vessel draft, trim, squat, sinkage due to fresh water conditions, water level changes (tides, river stages, etc.), and appropriate under keel safety clearance. Minimum under keel safety clearance is two feet for soft channel bottoms and three feet for hard channel. Additional channel depth may be provided by advanced maintenance dredging based on the economics of dredging intervals and the need to assure appropriate under keel clearance between dredging periods. An additional 1 to 3 feet below the selected channel depth is generally provided as a dredging pay item because of the inability to dredge a uniform depth from a fluctuating water surface. This allowance is called "dredging tolerance." Access channels are usually not as deep as the entrance channel because the wave action adjustment is normally less. Channel depths are referred to a low water datum plane. (EM 1110-2-1615)

j. Channel Alignment. Entrance channels will usually follow the shortest route to deep water. This alignment usually requires the least initial construction dredging. Alignment is affected by the direction of wind and waves and their effects on navigation. A channel crossing a shoal or bar, often aggrades rapidly and should be avoided. Access channels are generally adjacent to the breakwater or jetty. A moorage plan (docks, boat ramp, anchorage areas, etc.) is needed before the access channel alignment is selected. Movable bed hydraulic models and/or mathmetical models will estimate shoaling rates for various entrance and access channel alignments. Fixed bed hydraulic models with radio controlled vessels or ship simulator studies will assess the transit safety of alternative alignments. (EM 1110-2-1615)

k. Turning Basin. A turning basin is generally provided to allow vessels to change direction. Depths should be adequate for the allowances presented in paragraph 6i. However, the safety clearance can be reduced to a minimum of one foot. (EM 1110-2-1615)

l. Anchorage and Moorage Areas. Anchorage and moorage areas need sufficient space for safe movement of anchored and moored vessels. Depths will contain allowances for draft, trim, squat, wave action, one foot or more safety clearance, and tide allowances using the lowest tide or water surface fluctation expected during the navigation season. (EM 1110-2-1615)

m. Boat Launch Ramp. Channels which provide access to boat ramps need sufficient space near the ramp for boat maneuvering and adequate channel width for safe boat transits. Channel depth should be adequate for the depth allowances presented in paragraph 6i. However, the safety clearance can be decreased if channels with similar wave, tide and underkeel safety clearance are shown to be safe and reliable.

n. Basin Layout. A basin layout can include the following features: breakwaters, jetties, piers, turning basins, interior channels, boat ramps anchorage areas, wave absorbers, and other marine structures. A basin layout showing project features is needed to illustrate how the anticipated fleet is accommodated. Breakwaters and/or jetties, if needed, must provide adequate protection to entrance and access channels, moorage areas, and other basin features. Allowable wave heights may be different in the various basin features. Wave penetration studies are needed to show acceptable wave heights in all channels and moorage areas. Hydraulic model studies (physical and mathematical) will determine wave heights inside the basin. The basin layout will be evaluated for potential harmonic oscillations. (EM 1110-2-1615)

o. Breakwater and Jetty Design. Breakwaters must be stable for all imposed design loads including waves, ice, and impact from debris or vessels. For bottom connected breakwaters, an acceptable layout is developed and the height of the optimum breakwater is selected. Several heights, including no overtopping, are analysed and annual cost developed by adding amortized first cost and replacement cost, annual maintenance, and average annual damages to vessels and structures from overtopping waves. The minimum annual project cost is the optimum economic design. Consider other factors, such as fishing or pedestrian access on the breakwaters, in the height selection. Floating breakwaters will be analysed the same way except the waves that penetrate the basin will usually be transmitted under, around, and over the breakwater. Jetty design considerations are the same as for bottom connected breakwaters. The use of published breakwater stability coefficients are acceptable for preliminary design; however, final design will require hydraulic model testing to verify breakwater and jetty stability and performance. (EM 1110-2-1615 and EM 1110-2-2904)

p. Ice Control Measure. Ice control measures to minimize damage to vessels and marine structures are considered for boat basins in cold regions. Some of these measures are: ice booms, bottom connected ice deflectors, and air bubbles to suppress ice growth. (EM 1110-2-1612 and EM 1110-2-1615)

q. Dredging and Disposal. When dredging is required, a study is needed to identify the dredging and disposal method and short- and long-term disposal effects. Beneficial uses of dredge material need to be evaluated. The type of dredge equipment is to be assessed to assure it is capable of operating in the shallow project dimensions usually selected for small boat projects. (EM 1110-2-1615 and EM 1110-2-5025)

r. Environmental Studies. The project designers should strive to create an environmentally compatable project that eliminates or minimizes adverse impacts. This requires early determinations of potential impacts and close coordination between the designer and environmental specialists during assessment of alternative designs. Environmental impacts generally fall into three categories: (1) dredging and disposal, (2) water quality of project during normal operation, and (3) induced erosion or accreation. The principal water quality impacts of a small boat project are changes in the water circulation and basin flushing rate (water exchange). Water circulation and flushing rates can be predicted in physical, or mathematical or combined hydraulic model studies. Flushing and circulation can be enhanced by rounding the basin corners and sloping or stepping the basin downward toward the entrance channel. If adverse water quality is predicted, the biological impact on affected organisms is needed to justify the cost of mitigation measures. Both beneficial and adverse impacts require analysis and presentation. (EM 1110-2-1615)

s. Model Studies. Model studies are used to predict the project performance and optimize layout of project features (ER 1110-2-1403 and EM 1110-2-1615).

(1) Physical hydraulic models are used to evaluate the following:

(a) Basin circulation and flushing.

(b) Basin layout (wave penetration).

(c) Breakwater stability (bottom connected).

(d) Floating breakwater performance and mooring loads.

(e) Channel width and alignment using radio control vessels.

(f) Channel shoaling.

(g) Ice effects.

(2) Mathematical models are used to evaluate:

(a) Basin layout (wave penetration).

(b) Floating breakwaters performance and mooring loads.

(c) Channel width and alignment (Ship simulators).

t. Datum. Navigation project features will be referred to appropriate low water datum planes. The relationship of the low water datum to the National Geodetic Vertical Datum (NGVD) is required for vertical control of construction. (EM 1110-2-1615)

u. Aids to Navigation. Small boat navigation projects usually require marking lights and channel buoys. The US Coast Guard will provide information on type and location of suitable aids. Channel alignments will consider the cost and effectiveness of aids to navigation. (EM 1110-2-1615)

v. Baseline Surveys. Physical and environmental surveys are needed during preconstruction design phases. Hydrographic and hydraulic survey data are also to be used for model construction and verification (EM 1110-2-1615). The following surveys are usual for the design of small boat navigation projects:

(1) Hydrographic.

(2) Beach profile.

(3) Waves: heights, period, direction and duration.

(4) Current: velocity, direction, and duration.

(5) Sediment: suspended and bedload.

(6) Beach composition.

(7) Foundation conditions.

(8) Wind: speed, direction, and duration.

(9) Ice: frequency, duration, and thickness.

(10) Biological population: type, density, distribution, and migration.

(11) Water quality.

Dredge material water disposal sites will usually need (1), (4) (10), and (11) baseline surveys.

w. Period of Analysis and Degree of Protection. The period of analysis of most small boat navigation projects is 50 years. The degree of protection during the 50 year period must be selected by an optimization process which determines the frequency and extent of damages when various design conditions (waves, currents, etc.) are exceeded. These damages are included in the life cycle project cost for each design condition (EM 1110-2-1615). The project design conditions selected by this comparison of costs will maximize net benefits. The economic determinations must comply with the requirements of ER 1105-2-40. Life cycle costs include:

(1) Construction Cost.

(2) Operation and Maintenance Cost.

(3) Replacement Cost.

x. Operation and Maintenance Plan (O&M). A comprehensive plan of how the project will be operated and maintained is required. This plan is presented to support the operation and maintenance costs (EM 1110-2-1615). The following elements are normally included in the O&M plan:

(1) Predicted Project Costs and Physical Changes. Include the post construction predictions of physical changes and anticipated O&M intervals and annual costs.

(2) Surveillance Plan. Describe the types and frequency of surveys. These could be hydrographic, beach profile, tide and wave measurements, water quality, and jetty stability. The plan will cover minimum monitoring of project performance to verify safety and efficiency. Cost for conducting the surveillance plan is used for O&M budgetary purposes.

(3) Analysis of Survey Data. Comparative studies of the survey data are needed. Those comparative studies verify design information such as rates of erosion, shoaling, and jetty deterioration.

(4) Periodic Inspection and Project Performance Assessment. Present a tentative periodic inspection schedule. Inspections include a site assessment and comparison of survey data to establish project performance. Compare actual project O&M costs to predicted costs.

y. Repair and Rehabilitation. Repair (normal maintenance) of small boat harbor structures can be expected during the project economic life. These repairs may be necessary because of storms which exceed design conditions or by long term deterioration. Normal repair costs are to be included in the O&M budget. Rehabilitation of structures can be used to extend the project economic life in lieu of complete replacement or abandonment. Rehabilitation and replacement options are to be evaluated when normal maintenance becomes excessive or when the project stops functioning properly. Rehabilitation design will incorporate features that would be included in a modern project.

7. Summary. The design of small boat navigation projects requires an understanding of the problem, assembly and evaluation of all pertinent facts, and the development of a rational plan. The design engineer is responsible

for developing the design rationale and sufficient alternative plans so the economic optimum plan is evident and the recommended plan is substantiated. Applicable Corps of Engineers guidance is considered in the design. Pertinent textbooks, research reports or expertise from other agencies may be used as source information. The usual necessary steps leading to a sound plan are outlined below:

a. Review appropriate ER's, EM's, ETL's, etc.

b. Assemble and analyze pertinent factors and environmental data.

c. Conduct baseline studies.

d. Select rational set of design conditions.

e. Develop trial layouts with annual costs.

f. Model test

g. Select economic optimum plan.

h. Assess environmental and other impacts.

i. Develop recommended plan.

j. Develop operation and maintenance plan.

FOR THE COMMANDER:

Paul W. Taylor

PAUL W. TAYLOR
Colonel, Corps of Engineers
Chief of Staff

2 Appendixes
APP A - Principal Factors Affecting Hydraulic Design
APP B - Typical Deep - Draft Navigation Project Elements

APPENDIX A

Principal Factors Affecting Hydraulic Design

1. Climate-Weather

   a. Wind (Speed and direction)

   b. Waves (Height, period and direction)

   c. Visibility (rain, smog, fog, snow)

   d. Ice

   e. Temperature (Air-Water)

2. Site Characteristics

   a. Tides and/or river stage-discharge

   b. Currents (tidal and/or river)

   c. Sediment movement and/or longshore transport (budgets)

   d. Type of bottom (soft or hard)

   e. Water depth (Bathymetry)

   f. Obstructions (sunken vessels, abandoned structures others).

   h. Existing bridge crossing (location and clearance)

3. Fleet Characteristics

   a. Number of vessels

   b. Type of vessels

4. Vessel Characteristics

   a. Geometry (length, beam, draft).

   b. Maneuverability (speed, turning radius, reverse capability).

   c. Motions (pitch, yaw, squat, roll).

5. Environmental.

   a. Esthetics.

b. Culture.

c. Ecology.

d. Archeology.

6. Social.

a. Recreation.

b. Access.

c. Safety.

d. Displacement of homes or businesses.

APPENDIX B

Typical Small Boat Navigation Project Elements

a. Entrance Channel. Channel connecting the basin with deep water.

b. Breakwater. Bottom connected or floating strutures which reduces the incident wave heights to acceptable levels inside the basin.

c. Jetties. Structures normally parallel to the entrance channel to maintain channel alignment and depth. Jetties often function as breakwaters.

d. Access Channel. A channel which provides access from the entrance channel to anchorage areas, docks, berths, boat launching ramps, etc.

e. Turning Basin. Area provided for vessel to safely change directions. Usually located at or near the inner end of the access channel. One or more turning basins may be provided for long access channels.

f. Anchorage Areas. Areas provided for vessels to anchor unattended.

g. Moorage Areas. Areas provided for moorage docks, access walkways, etc.

h. Service Areas. Areas provided for service of sport and commercial vessels.

i. Special Features. Special features, as required, for site-specific problems will be included with the project design. The features could include provisions for wave absorbtion, ice control, water quality improvement, shoaling reduction, sand bypassing, and erosion control.