Chapter 2
General Considerations for Project Planning

2-1. General

This chapter provides an overview of the engineering, policy, and planning guidance applicable to developing a project plan for navigation improvements associated with the planning, design, construction, and major rehabilitation of navigation dams. Although there are a number of similarities among low-, medium-, and high-head lock and dam projects, care should be taken in use of this manual to ensure that guidance which applies only to low-head projects is not misconstrued as applicable to high-head projects. Because a navigation dam is usually planned concurrently with a companion navigation lock, the planning effort usually considers both types of navigational structures in the same studies. Therefore, the intent is for EM 1110-2-2602 to be used in conjunction with this manual as that manual covers many of the items mentioned below in more detail.

2-2. Project Team

The planning, engineering layout, and design of navigation dams as part of the overall development of a project plan for navigation projects comprise a complex, multidisciplinary planning and engineering effort. This effort involves the contributions from many public and private interests including local, state, and federal agencies; planners; design, operations, and construction engineers; architects; and natural habitat biologists. The team will either include or derive considerable input from budgetary, legal, and contracting specialists.

2-3. Project Formulation and Development Processes

The Corps of Engineers' involvement in these processes for navigation dams, i.e., civil works reconnaissance studies, feasibility reports, and preconstruction engineering and design (PED), is very similar to that for navigation locks, as covered in EM 1110-2-2602. Also, guidance for developing cost estimates discussed in that manual is applicable to the navigation dam. Since completion of the PED work is frequently scheduled to be at different times for the lock and the dam due to limited resources, it is important to carefully coordinate the details for these structural entities so that a quality end product is completed on time and within budget.

2-4. Legal Environment

Legal issues which must be considered in project development include, but are not limited to, method of funding, navigation servitude, environmental issues, historic properties, archeological concerns, and the National Historic Preservation Act. These issues will frequently be controlling factors in the overall project development process.

2-5. Project Components and General Feature Requirements

a. General layout. A navigation dam is similar to most other dams in that its intended purpose is to impound water. However, it is usually designed so that the water surface upstream of the dam is of such elevation that there will be sufficient depth for navigating a relatively long distance upstream from the dam without having to go through another lock or to dredge excessively. However, there are a number of factors--basically related to costs and impacts on existing developments and on the environment--which place limits on the upper pool which will be maintained by the dam. Except possibly in the case of impoundment for water supply, hydroelectric power, or flood control, the dam is designed to allow the same amount of flow through the waterway as existed prior to construction of the dam. The height, or lift, of a dam is the difference in elevations of the upstream pool formed by the dam and the minimum pool or natural stream surface below the dam. Passage of vessels between the upper and lower water levels is accomplished by a navigation lock.

b. Operational requirements. Because the primary purposes of a navigation dam are to impound water and to regulate stream flows so waterway traffic can lock through under almost all pool conditions, it is extremely important that the project structures be laid out to allow safe, timely, and efficient transit of the lock. The configuration of the upstream and downstream reaches of the stream and the currents and velocities of the stream caused by spillway discharges are critical factors in the proper layout of the project--particularly for layout of the upstream and downstream approaches to the lock.

c. Basic project components for low- to medium-head dams. Lock and dam projects can be single-purpose and only consider navigation, or may be developed for multipurpose uses. The basic components of a low- to medium-head navigation project (a low- to medium-head dam is generally considered to be one with a normal lift or differential between upper and lower pool levels of

50 ft or less) could include one or more locks and several of the following dam features:

(1) Gated dam and spillway or sill with stilling basin and training and grade separation walls. The gates will typically be of the tainter type. However, in some instances, wicket or hinged-crest gates will be used in conjunction with or in lieu of tainter gates.

(2) Overflow embankment or weir.

(3) Navigation pass, which will normally serve as the above-mentioned weir, may include hinged-crest or wicket gates.

(4) Nonoverflow embankment or concrete or cellular walls (lock and dam separation and/or dam abutment).

(5) Gate operating machinery such as hoists and hydraulic systems.

(6) Maintenance and/or emergency bulkheads for the gates.

(7) Service bridge--typically limited to the tainter-gated portion of the dam.

(8) Drainage and grouting galleries.

(9) Seepage cutoff walls or other seepage control measures.

(10) Channel armoring usually consisting of derrick stone and riprap and, in some cases, concrete paving.

(11) Buildings which will normally be used to facilitate both lock and dam operation (visitors, recreation, administration, maintenance, storage, etc.).

(12) Electrical power generation using “run-of-the-river” flow--unless additional impoundment to extend the generating period is feasible. Currently, inclusion of power generation is a development of (and is funded by) entities other than the federal government. However, the generating component has to conform to navigation requirements and meet the stability and safety requirements of HQUSACE.

d. Project components for high-head dams. High-head dams (with a greater than 50-ft differential between upper and lower pools) will contain most of the features mentioned above for low- to medium-head dams, except they do not have navigation passes. (There will always be a permanent differential in upstream and downstream pools.) These high-head dams are not likely to contain hinged-crest or wicket gate sections. The following are important characteristics of high-head dams:

(1) Vertical-lift gates have typically been used in lieu of tainter gates because the structural dimensions for the lift gates and piers are less than required for tainter gates. However, tainter gates with supplemental sluice (vertical-lift) gates are likely to be used more extensively in the future as the procedures for operating the tainter gates are simple and require minimal attendant labor--unlike the vertical-lift gate.

(2) Power-generating facilities will normally be incorporated because there is typically a sufficient impoundment above the conservation pool to make power generation economically feasible. Also, these facilities may be subject to private development and operation--depending on the legal environment at the time of construction.

(3) Frequently, fish ladders will be provided if the species of fish in the dam’s locality are migratory in nature, such as those in the northwestern United States.

e. Multipurpose project components. The navigation project with multiple-purpose functions should accommodate each purpose as much as is economically justified and technically feasible with priority of purposes taken into account. Common multipurpose components are:

(1) Navigation lock(s) and dam.

(2) Flood control capability.

(3) A powerhouse.

(4) Fish passage facilities.

(5) Recreation facilities (boating and other water sports, enhanced fisheries, picnic facilities, etc.).

(6) Water supply intakes for municipalities and/or irrigation.

(7) Features to enhance water quality downstream of the dam, e.g., low flow controls and multilevel outlets.

(8) Water conservation.

2-6. Examples of Navigation Projects and Components of Dams

Except for the John Day Dam mentioned below, all of the following are features of low- to medium-head projects:

a. Plates 1 and 2 are provided to show a perspective and a section of a typical lock and dam on the Red River Waterway and the various structural features used in this dam. Primary control of flow is regulated by tainter gates. The crest gate spillway is not provided as a navigation pass but primarily to supplement the flow capacity of the tainter gate spillway during high river stages. The crest gates are lowered during high water to increase flow capacity and are used to fine-tune discharge rates when the river is in pool.

b. Plate 3 shows the proposed Olmsted Locks and Dam. This dam's primary feature is the wide navigation pass which is to be used by river traffic during a high percentage of the year. During low-water stages the upper pool will be maintained by wicket gates, and navigation traffic will pass through the lock. Typical sections through the navigable pass monoliths are shown in Plate 4.

c. The Melvin Price Locks and Dam project is presented in plan in Plate 5. This example includes nine identical, 110-ft-wide tainter gate bays with two of the nine used to separate the main and auxiliary locks. The overflow section on the Missouri side is not designed to function as a navigation pass. Plate 6 presents closeup views of the tainter gate bay features.

d. The Smithland Locks and Dam project is presented in Plates 7-9. This project is similar to the Melvin Price project mentioned in paragraph 2-6*c* above. It has 11 identical, 110-ft-wide tainter gates and a non-navigable fixed weir.

e. Examples of usage of earth-fill sections as a damming surface or element are shown in Plates 10 and 11.

f. Features of the John Day Dam, an example of a high-head dam with multiple-purpose functions, are presented in Plates 12 and 13. These features include tainter gate bays, a lock structure, a powerhouse section, and a fish ladder.

2-7. Existing Conditions

Much of the following will not be applicable to major rehabilitation projects; however, the opposite is true for new projects. Once the need for a navigation dam is identified, a careful assessment must be made of the natural physical characteristics of a stream and its valley, as well as the conceivable dam sites. Various existing site conditions can have profound effects on cost, operational feasibility, and acceptability to numerous entities and interests.

a. Site conditions and restrictions. In long-settled and developed regions, existing maps, geological surveys, and hydrometeorological records may provide sufficient data for preliminary design purposes. In other regions, extensive field surveys and research of hydrological and climatological records will be required before the project can be designed. This subject is discussed more extensively in EM 1110-2-2602.

b. Climate.

(1) Range of temperature. Temperature extremes of either heat or cold will influence the general dam design and the detailed design of operating components and structural features. In cases of extreme cold, the possibility of ice formation must be considered. Structural design should include allowance for ice thrust on the structural features exposed to the pool surfaces and on gates, as well as the impact and abrasion of running ice. Floodway openings must be designed to pass large volumes of ice to minimize the danger of ice jams forming. In extremely cold climates, heating systems may be required for winter operation of gates.

(2) Humidity. The degree of humidity inherent to location on a water course must be considered in design of electrical services, machinery, and corrosion protection. The occurrence of frequent or prolonged fog or a tropical combination of heat and humidity may present major problems in design and maintenance of electrical machinery and a structure's metal parts.

(3) Climatological records. In the United States, climatological data such as precipitation, evaporation, wind speed and direction, and temperature are archived in various formats by the National Oceanic and Atmospheric

Administration (NOAA), a unit of the U.S. Department of Commerce.

c. Topography. The plan for a navigation dam structure should conform to the topographical features of the project area. If the required information is not already available, maps should be prepared to show the pertinent data based on surveys conducted for this purpose. Data required for planning and design of the project include but are not limited to the following:

(1) Information in regard to populated areas (location, elevation, and other items) which will indicate possible effects from project construction.

(2) Locations of railroads, highways, power lines, natural gas pipe lines, flood protection projects, levees, sewer outlets, water-supply intakes, pumping stations, and input from the owners of those features which may be affected by the proposed project.

(3) Locations of fishing and hunting preserves and input from the owners of those features which may be affected by the proposed project.

(4) Locations and pertinent data on bridges, dams, dikes, wharves, pleasure resorts, and all other features that might be affected by the project.

(5) Channel soundings, high and low water marks, gage and historical river gage data.

d. Hydrologic and hydraulic.

(1) Hydrologic studies. A watershed hydrology study is one of the first needs in developing a navigable waterway. The hydrologic conditions along the waterway length will determine required lift needed for a dam to establish reliable navigation. Hydrologic studies for a river basin identify the discharge frequencies and duration a dam structure (located at any particular point within the basin) must be designed to accommodate. Minimum, normal, and maximum discharges are all significant to the dam design.

(2) Hydraulic studies. Hydraulic studies for navigation dam design generally cover two distinct phases. The first phase establishes the stage-discharge relationship and its effect on the entire area affected by the proposed project under both existing and postproject conditions. The second phase of hydraulic studies involves the design of dams and other structures (i.e., their type, shape, size, and siting to ensure satisfactory hydraulic performance). A more detailed coverage of all aspects of hydrology and hydraulics, as these items relate to navigation dams, including existing data and record sources, is found in ER 1110-2-1404, ER 1110-2-1458, EM 1110-2-1604, ER 1110-2-1461, and EM 1110-2-1605. For guidelines that cover special hydraulic features of a project, see EP 25-1-1.

e. Geology. To properly evaluate the suitability of a site for location of the navigation dam and lock structures, it is necessary to assemble and evaluate all the available geologic information and perform new core drilling, probings, and soundings. Composition and depth of overburden, quality and type of underlying rock, and quality and type of exposed rock are extremely important factors. Subsequent foundation studies, based on the assembled geologic information, will help determine whether the structure should be founded on rock, soil, or piling. Also, the geology of the stream bed will influence sediment transport and stream-bed stability requirements.

f. Existing land ownership and usage. The consideration of real estate is not limited to the amounts and locations of that needed for the project and the associated costs but must also include the current land uses and the environmental and social issues associated with these uses. Some real estate usage is so sensitive that development of a project based on usage of such “sensitive” real estate would never come to fruition in today’s political and legal climates. Real estate requirements for the project features are discussed in more detail in paragraph 2-14.

g. Environmental setting. Information on existing environmental conditions will be necessary to prepare the compliance documents required by existing federal regulations. Early and continuing communication with agencies charged with protection of the environment is essential. A finding of no significant impact (FONSI) is a prerequisite to project development and construction. Careful planning to maintain or enhance the environmental quality and mitigation measures may preclude or set aside the potential negative impacts that would render the project infeasible or not allow its approval. Also, high quality resource management plans plus improved design and operation procedures will help maximize environmental benefits and help attain environmental quality objectives.

2-8. Navigation and Pool Operational Considerations

a. General. In general, the lock features and location prevail in importance to other project features and purposes. However, the following considerations associated with the dam and approach channels will have considerable bearing on good navigational approach conditions.

b. Channel depth and width. Navigation will be enhanced by providing channel depths and widths for movement and maneuvering of vessels at the desired speeds, eliminating hazardous currents, and providing pools stable enough to allow development of suitable terminal facilities by navigation interests. The efficiency of navigation can be enhanced by including navigation passes for low-head dams and mooring facilities at locations remote from the dam to ensure that unattended tows are not drawn into the dam and do not drift into the path of river traffic. The bases for channel depth, channel width, and lock dimensions are established by study of a number of factors, including types and probable future tonnage of traffic, types and sizes of vessels in general use on connecting waterways, and developments on other waterways which may be indicative of the type and size of vessels likely to use the channel.

c. Control of hazardous currents. The slack-water pools created by dams will reduce current velocities from those existing in the stream's natural state and, in general, will eliminate hazardous rapids. However, new hazards may be created. Vessels entering or leaving the locks will have limited steering control at required low speeds and can be drawn out of control by currents set up by the spillway section of the dam. Approach walls and other protection, for a considerable distance above or below the lock, may be required to hold tows in line. Some restriction on the use of spillway gates adjacent to the lock may be necessary. Maximum velocities and channel depths usually will be found along the outer bank of bends, and even slight curvature will tend to fix the natural deepwater channel closer to the outer bank. A lock aligned with the natural deepwater channel will usually provide the best navigation characteristics; locations in sharp bends and where the lock structure will deflect a substantial part of the flow should be avoided. Model studies and advice of experienced masters and pilots should be considered in preparing a lock and dam layout to avoid hazardous current conditions.

d. Regulation of upper pool.

(1) General. In addition to the flooding impacts of the selected pool, consideration should be given to the pool's operational stability. A navigation dam should ordinarily provide a fixed pool elevation with little stage variation. Dependable minimum upper pool stages promote navigational reliability, growth in waterway traffic, and simplified development of port facilities. To maintain the upper pool elevation at as near a constant level as possible, gated spillway bays are usually provided in navigation dams so that, by controlled gate operation, both normal and flood flows can be passed downstream through the bays.

(2) Configuration of dam. The regulation of all flows from the impounded pool in the most efficient and nondetrimental manner requires that careful consideration be given to the functional shape, elevations, lengths, and widths of the dam structures.

(3) EM 1110-2-1605 provides information on spillway capacity, spillway shape, spillway gates, stilling basins, pier nose shape, abutments, overflows, and selection of the optimum upper pool elevation.

e. Hinged pool operation.

(1) A principal purpose of the hinged pool operation is to eliminate or minimize impacts which would otherwise result from increasing stages and/or stage frequencies upstream of the dam over those which existed before dam construction. This operation takes into account the flow of water and does not rely on a flat pool operation. Hinged pool operation involves lowering the pool of the dam several feet, usually 2 to 5 ft below normal upper pool level during higher flows where adequate navigation depths are available at the upper end of the pool. When discharge falls the pool is raised to extend the backwater effect above the critical reach to maintain navigation depths.

f. Open river navigation.

(1) General. Where hydraulic conditions allow, it may be desirable to provide a navigable pass across a low damming structure to avoid the tow going through the locking process each time it passes through the navigation facility. Avoiding lockage can provide a substantial time savings for both upbound and downbound tows. Stages high enough to permit open-river navigation for a significant portion of the year, individual high-water periods usually of considerable duration, and a gate regulating system commensurate with the rate of river rise and fall are necessary. A navigation pass weir or other section of the dam, with or without crest gates, is necessary to accommodate open river navigation.

(2) Dimensional criteria for a navigable pass. The design must provide sufficient width for safe passage of

tow traffic, including poorly aligned tows. In addition, the pass must have sufficient depth for tows of the authorized draft, including a buffer for overdraft, tow squat, etc. A model study should be considered in the design of a navigable pass. At the present time (1993), the Corps is operating dams with navigable passes on the Ohio, Ouachita, and Black Rivers. Pass widths vary from 200 ft on the Ouachita and Black Rivers to 932 and l,248 ft on the Ohio River. Two new navigable pass dams, Olmsted on the Ohio River and Montgomery Point on the Arkansas River, are in the planning stages. In addition, the Corps operates dams on the Illinois Waterway, at which tows transit the regulating wicket section during higher stages. Gate types for navigable passes are discussed in Chapter 5. Further material relative to open river navigation can be found in EM 1110-2-1605.

g. Swellhead. The impacts of swellhead (differential head resulting from the flow restriction in the waterway created by the lock and dam) during open river conditions must be considered in the following instances:

(1) When tows are to navigate across a navigation pass, the swellhead in the pass must be small enough to permit the tows to pass through under adequate power to move upstream and otherwise control their alignment. Hydraulic studies must determine the optimum elevation at which the top of the lock wall is to be inundated and the area for flow through (over) the dam components, all to provide flow capacity adequate to minimize swellhead.

(2) Swellhead at most low-head dams, regardless of whether open river navigation is to be provided, can influence the real estate requirements. Swellhead greater than 1 ft may be allowed if open river navigation is not provided and if the costs of associated additional real estate requirements are less than the costs of associated additional flow capacity required to reduce the swellhead.

2-9. Hydraulic Design Considerations

a. General. Much of the basis for hydraulic design has been discussed above under the topics “Existing Conditions” (paragraph 2-7) and “Navigation and Pool Operational Requirements” (paragraph 2-8). Also, the topic “Model Studies” (paragraph 2-10), discussed below, is extremely relevant to hydraulic design. The following items are intended to either reinforce or supplement the content of these referenced topics.

b. Discharge and stages. Hydrologic studies for a river basin identify the discharge which a dam structure must be designed to control in order to satisfy the navigational objectives of the project. The hydraulic studies for navigation dam design cover two phases: establishing the stage-discharge relationship over the entire area affected by the proposed project under both existing and postproject conditions; and designing the dams and other structures, i.e., their type, shape, size, and siting to ensure satisfactory hydraulic performance, including navigation approach conditions and maintenance requirements (i.e., dredging).

(1) Seasonal variations. Project areas subject to periods of low runoff alternating with long periods of high runoff are ideal sites for constructing a navigation dam. However, detailed hydrologic and hydraulic studies must be conducted in all cases to confirm this.

(2) Low flows. A properly functioning navigation project must have sufficient water during low-flow periods to satisfy evaporation losses, seepage from the pool, seepage under the dam, and leakage past the spillway gates, in addition to providing adequate water for lockages. Some projects may also have requirements for water supply, irrigation, hydropower, and environmental needs.

(3) Flood heights. In recent years, the Corps has emphasized providing enough spillway capacity in navigation dams to pass the PMF. However, low-head and medium-head dams of up to 50 ft will usually have an overflow weir, and flood flows may go overbank unless levees are provided. High-head dams of over 50 ft should be provided with enough spillway capacity to pass the PMF.

c. Spillway design.

(1) Low- to medium-head dams. Typically, low- to medium-head navigation dams will be designed to pass flood flows utilizing not only the main spillway section normally located within the river channel but also supplemental spillways located across the overbank. However, on some low-head projects, extreme floods will overtop the lock walls, and navigation will be directed to cease operations.

(2) High-head dams. Spillways for high-head navigation dams are generally designed to pass the PMF flows. They should also be designed in accordance with other requirements contained in EM 1110-2-1603.

d. Ice conditions. It is necessary to determine the volume and duration of ice conditions at navigation dams so that ice control methods can be developed. Historical records coupled with site monitoring will be helpful. On a stream where heavy ice formations are present, the spillway bays should be made as wide as practical to aid in passing the ice downstream so that it does not wedge and build up against the structures.

e. References. More detailed descriptions of all the above items, with information on where existing data are available, are contained in EM 1110-2-1605. EM 1110-8-1(FR) and EM 1110-2-1612 provide information and methods of estimating ice situations, growth, and duration using winter air temperatures.

2-10. Model Studies

a. General. Physical model studies of the hydraulic and navigational characteristics of the layout of the dam, the dam spillway, training walls, channels, dikes, slope protection, streambed protection, locks, and lock approaches are an extremely important part of the planning and design for a navigation dam project. The physical model can be either fixed bed or movable bed and should include specific site conditions. Mathematical models, which are likely to be more economical than physical models, are being used to a greater extent as more accurate techniques are developed. The U.S. Army Engineer Waterways Experiment Station (WES) usually conducts these model studies. During preliminary planning stages when alternative layouts and locations are being considered, WES may be able to furnish information based on its experience on other navigation dam projects.

b. Spillway. The navigation dam spillways provide the necessary waterway openings for passing high and low flows to maintain the upper pool level in a range suitable for navigation. In addition to the guidance contained in EM 1110-2-1603, further information for design of the number of spillway bays is required. The width of the bay; the elevation, length, and shape of the spillway crest; pier extensions (separation walls); stilling basin baffles; and end sill can be found in EM 1110-2-1605. This EM contains tabulations of model tests relating to the above-listed items along with comparisons of calculated results versus model study results.

c. Forces on structural components. In some instances, it may be necessary to determine the downpull loading, the buoyancy effect, or possibility of vibration of a structural steel bulkhead or vertical lift gate when the item is being lowered or raised in free-flowing water. A scale model of the structure can be model-tested by WES, and information on loadings, uplift, and vibration tendencies can be obtained.

d. Cofferdams. A movable bed model can be used to examine the different stages of cofferdam construction for a navigation dam project where the cofferdam (e.g., sheet pile cellular type) is located in the existing waterway. The last-stage cofferdam situation can be the most important stage to examine in the model, because this stage will cause an increase in the velocity of the water going through the narrowed river opening. This increased velocity can cause excessive movement of the river bed material all across this location and undermine the river arm of the cofferdam. The modeling results will indicate specifically where the problem locations are. Thus, the cofferdam may be configured with deflectors to shunt the scour away from the cofferdam proper, and the stream bed of the narrowed space where the final dam structure is to be installed can be protected against scour with stone or a weighted lumber mattress.

e. Sediment, debris, and ice handling.

(1) Sediment. A physical movable bed model can be used successfully to determine shoaling and danger points when a stream transports a heavy bed load of sediment. The model cannot predict amounts accurately but can indicate locations where sedimentation is likely to occur if suitable measures are not implemented. Rock dikes, wing dikes, operating procedures, or other preventative measures can be designed into the project.

(2) Debris. The best method for passing debris, especially keeping it away from the upstream lock approach and chamber, can be determined through model studies, and appropriate operating recommendations can be adopted based on the results of these studies.

(3) Ice. Where ice buildup poses a threat to dam structures, physical models of ice control methods can be made at the Ice Engineering Laboratory at the Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH. EM 1110-2-1612 provides additional information on ice control methods.

f. Stone protection. Physical movable bed models are helpful in determining the locations where stone protection is necessary and in sizing the stone required to protect the river bed and banks from the scouring velocity of the flowing water and wave wash.

2-11. Miscellaneous Engineering Considerations

a. General. This paragraph is not intended to cover all “engineering” requirements but is intended to address some of the engineering topics not otherwise covered in this chapter. However, inclusion of some items in this paragraph is intended to reinforce information provided elsewhere in this chapter.

b. Summary of principal functional requirements.

(1) The general requirement that dams should cause the least possible delay to movement of traffic may be satisfied by a small number of high nonnavigable dams or a larger number of low dams with navigable passes where practicable. The type of dam selected must be consistent with the flow regimen of the stream and the height of dam permitted by topography and available foundations.

(2) The dam should be sufficiently watertight to maintain the desired pool level at the lowest probable discharge.

(3) Movable spillway gates should be capable of sufficiently rapid and flexible operation to be opened for passage of minor flash floods as well as major floods without excessive fluctuation in pool levels or increase in flood heights, and to be closed in time to hold the desired pool level on a falling flow. Remote operation of gates and individual operating machinery for each gate should be considered.

(4) Floodway openings should be sized to provide for passage of ice floes and drift likely to occur.

(5) The dam should be capable of passing sedimentary material which cannot be permitted to accumulate in the pool.

(6) Design should not induce flooding on the waterway if at all avoidable. If unavoidable, some form of remediation will be required.

c. Location of dam with respect to lock.

(1) General. Unless the navigation lock is in a channel separate from the dam or there is some anomaly in the waterway to dictate a large separation, the dam will typically be located adjacent to the lock and in line with the upstream lock gates. Also, the preferable access to the lock and dam for operation and maintenance is from the lock-side of the waterway, so the dam will typically be located on the side of the lock opposite from the primary operation and maintenance access. Detailed layout requirements, as related to navigation and hydraulics, are provided in EM 1110-2-1611.

(a) Most waterways in the continental United States that have the potential for navigational usage are already developed. Thus, much of the future dam construction is likely to involve rehabilitation or replacement, and it will be done in a manner to facilitate use of portions of the existing navigation features to the maximum extent practical, and will likely involve innovative techniques. The required techniques may not be in total agreement with the preferred layouts discussed in EM 1110-2-1611. For example, the Upper Mississippi River-Illinois Waterway System Navigation Study by the Corps of Engineers North Central Division considers an increase in navigation capacity by building an additional lock chamber through an existing dam with the resulting layout being much different than if the two chambers had been included in the original construction.

(b) From the viewpoint of navigation, siting of the lock is probably more important than siting of the dam because it is desirable to locate the lock within that portion of the channel which will provide the best possible conditions for navigation to approach the lock. Thus, the dam location will usually be controlled by the lock location. Unless flow from the dam is diverted from the downstream lock approach by a physical barrier or there is a large separation between the lock and dam structures, the dam cannot be located near the downstream lock gate bay due to the adverse effects of the dam discharge on navigation. Also, if the dam is located adjacent to the downstream lock gate bay, provisions for chamber discharge are limited to within the downstream entrance to the chamber and/or to the side of the lock opposite from the dam.

(c) Where conditions warrant, highway or railroad bridges may be located over the lock structure. In such cases, the lock walls and/or the dam piers may serve as bridge pier supports. The elevation of low-steel on a fixed-span bridge can be minimized if the bridge is located just below the downstream gates of medium- to high-lift locks. The vertical clearance for navigation at that location will be determined by the tailwater elevation rather than the upper pool elevation. If the dam piers are to be used to support a fixed-span bridge, the best overall location of the dam is likely to be just below the downstream lock gate. Barkley Lock and Dam near Grand Rivers, KY, on the Cumberland River is an example in which the dam is located at the downstream lock gate and the dam piers provide support for a railroad bridge.

(d) From the perspective of structural stability and design, it is usually advantageous to have the majority of the lock chamber in the lower pool. This is particularly true for the condition with the lock unwatered when the lock wall stability is controlled by uplift and by water pressures tending to push the lock walls toward the chamber centerline. Additionally, this placement of the lock chamber reduces the length of the lock wall that acts as a damming surface.

(2) Factors to be considered in regard to lock and dam separation. In addition to those factors discussed elsewhere herein, the following should be considered:

(a) Typically, there will be minimum separation between the lock and dam in order to minimize construction costs and to promote efficiencies through keeping the operations and maintenance activities for the lock and the dam in close proximity.

(b) In those waterways in which the suspended sediment load is expected to be large, small separations are advantageous for transport of sediment, because limiting the size of the channel cross section will make velocity of flow greater than in a larger channel with the net result of less chance of sediment deposition.

(c) Locating the dam close to the lock may induce scouring of the lock's foundation. If the lock and dam cannot be separated sufficiently to avoid this, solutions such as paving the channel adjacent to the lock with concrete or heavy derrick stone or other special solutions may be required.

(d) As stated above, flow through the dam will influence navigation approach conditions unless there is a large separation between the lock and dam or a physical barrier to divert the flow from the approach. Model studies will best predict the effects on navigation where the dam is adjacent to the lock.

d. Geotechnical design.

(1) General. The design will be based on the geotechnical conditions at the selected site. Except for the probable necessity of rock excavation, rock foundations for dams may be the most desirable. Where rock suitable for founding structures does not exist, soil or pile foundations may be required.

(2) Properties of soil and rock. In the case of earthfill dam sections and concrete dams on earth or pile foundations, consideration must be given to the stability, drainage, and compaction properties of the fill and foundation materials, and probable settlement of the foundation when loaded. Drilled caissons and excavation-type caissons are two alternatives for unusual foundation material situations. Foundation settlement will be of major importance where two dissimilar structures such as earthdike and masonry sections abut. Seepage from upper to lower pool must also be considered.

(3) Rock foundation requirements and other geotechnical considerations. A sound rock foundation at a reasonable depth is frequently desirable and/or available for a concrete navigation dam. Extensive geotechnical exploration and examination must be made of rock materials to determine suitable founding levels, shear strengths, and allowable bearing pressures. Foundation investigations should also include possible grouting requirements for seamy or cavernous rock, and the possible effect of saturation or passage of water through granular deposits, seams, and other susceptible material. Final verification of founding elevations for rock foundations is usually done as part of the construction contract.

(4) Geotechnical exploration of the waterway. Sufficient information must be gathered along the length of navigable waterway to determine dredging or channel realignment requirements. The characteristics of the material (rock or soil) must be identified, as this may have a significant impact on project cost.

e. Structure types.

(1) Low- to medium-head dams. The majority of the dam structure itself will likely be composed of reinforced concrete and may be founded on earth, rock, or piling--depending on the geology of the selected site. Portions not exposed to turbulent flow may be composed of roller-compacted concrete, soil cement, and earth and rockfill embankments. In many cases, overflow sections may be composed of cellular structures (sheet piling filled with granular materials, grouted riprap, etc.). The life of these cellular structures will likely be controlled by the longevity of the sheet piling, which can exceed 50 years under favorable conditions. The gates will typically be of structural steel. However, some experimentation is being conducted to use fiberglass, plastics, and similar materials for the wicket gates. The service bridge will normally be of precast, prestressed girders topped with cast-in-place concrete.

(2) High-head dams. Stability requirements for high-head dams will usually exclude or minimize use of such features as earth and rockfill embankments, soil

cement construction, and cellular structures as used on low- to medium-head dams. Typically, unreinforced gravity concrete will be used, and it is likely the dam will be founded on rock due to the typical geological and topographical conditions which lead to use of high-head dams.

f. Materials availability. The types, suitability, sources, and costs of principal construction materials should be identified in early planning stages. Of particular importance is the identification of materials that are not readily available or available from a number of domestic sources.

g. Structural criteria. Early in the design process, it is essential to develop reliable project feature dimensions and identify the operational requirements (e.g., pool elevations, ranges of pool stages, probable structure types, and foundation requirements). As the project development evolves, this information must be kept up-to-date so as to use available design resources efficiently. Divisions and HQUSACE should be involved early in the planning process to obtain the best overall design with the fewest revisions during the planning and design period.

h. Topographical considerations and mapping requirements. Accurate survey information is necessary for the development and layout of a navigation project. Information at the dam site and within the limits of the navigable reach of water will normally be required. This may require aerial photography and onsite surveys.

i. Real estate requirements and considerations. Numerous real estate considerations are associated with a navigation facility as stated elsewhere in this chapter. Project details should be developed with sufficient accuracy so as not to have to expand the number of right-of-way procurements as the project design develops.

2-12. Cofferdams and Other Temporary Construction Requirements

a. General. In addition to design and construction activities associated with permanent features, the following are some of the temporary features which must be considered in planning and design.

b. Diversion alternatives. Depending on the circumstances, the dam may be built within the confines of the streambed within a cofferdam, or it may be built within a new channel that cuts off a bendway within the existing waterway. The first method involves diversion of flow within a zone contiguous with the construction site. In the latter method, the construction site is isolated from the existing waterway until the project is completed and the flow is diverted through the cutoff channel. More detailed information relating to diversion is covered in paragraph 2-10 of this manual and in EM 1110-2-2602, which considers related diversion requirements for navigation locks.

c. Cofferdams. As mentioned above, hydraulic model studies may be needed to configure the cofferdam layout if construction is to be within the confines of the existing waterway. The cofferdam arrangement, used for construction of Melvin Price Locks and Dam and shown in Plate 14, is an example of cofferdam usage in staged construction. However, if the dam is to be constructed within a cutoff, the cofferdam is likely to consist of an earthfill embankment. An important consideration is the effective height of the cofferdam. The effective height relates to the risks that are to be taken with regard to the waterway stage at which the cofferdam will overtop and the costs of overtopping; i.e., it must be determined when the cost resulting from overtopping would be less than the cost of raising the height of the cofferdam to minimize the risk of overtopping. A more in-depth discussion of cofferdams for locks is provided in EM 1110-2-2602. Other specific guidance may be found in ER 1110-2-8152, EM 1110-2-1605, and EM 1110-2-2503.

d. Alternate methods of construction. The use of alternate methods to construct a navigation dam (other than within conventional cofferdams) may have significant advantages over conventional types of construction, in both initial construction costs and required construction time.

(1) Alternative ways to construct a dam can include construction “in-the-wet” or a reusable type of cofferdam or a combination of methods. Construction in-the-wet usually involves underwater excavation and foundation preparation (including piles). The structure is then floated into place and sunk or hoisted onto the foundation, usually in segments to maintain a manageable size. The segments may be filled with tremie concrete, or steel shells may be used which are later filled with tremie concrete. Consideration must be given to the requirements for constructing the segments in a yard and transporting them to the site, or providing a dry dock type of facility (usually near the site). Large precast piers have also been set in place with specialized equipment (Dutch tidal barrier).

(2) The dam or portions of it may also be constructed within dewatered boxes, which can be reused, or

a more sophisticated mobile cofferdam may be used which consists of a double-walled steel box that can be floated, advanced, sunk, and dewatered with a self-contained system and can also incorporate mechanized concrete forming and delivery systems.

(3) Currently (1993), advanced studies are being completed considering two alternative methods of constructing the Olmsted Dam to be built on the Ohio River, in addition to a conventional cellular cofferdam type of construction. One method would involve preparing the foundation and drive piles in-the-wet and using a mobile cofferdam to construct the dam sill and install gates and machinery in conjunction with setting precast concrete stilling basin shell elements filled with tremie concrete. The mobile cofferdam would be floated, moved into position, sunk, layered with tremie concrete, and dewatered when the tremie attained sufficient strength. Construction of that segment of the sill would be completed in-the-dry. The mobile cofferdam would then be flooded and floated and the cycle repeated. The second alternate method would be similar except large precast sill elements containing gates and machinery would be set in place on bearing beams (and later grouted) with a large special-built crane. Additionally, the fixed-weir segment of the dam would be constructed in-the-wet utilizing cellular sheet pile structures as has been common for several years.

(4) New technology or technology borrowed from other fields should be considered when determining the best way to build a dam in a riverine environment. Alternative methods may also be advantageous environmentally and hydraulically, and may minimize navigational difficulties during construction. The method used to construct a dam, the materials used, and the design chosen are closely related and must be considered together.

e. Rights-of-way. Rights-of-way remote from the project may be required for access to borrow sources, staging, and other purposes. This may or may not be a government responsibility. However, careful planning should be done to ensure that there are adequate rights-of-way at the project site so that the contractor can use standard construction procedures if at all practicable.

2-13. Environmental and Aesthetic Considerations

Environmental requirements were briefly addressed in paragraph 2-7. Unless the dam is remote from the lock, aesthetic considerations should be consistent for both the lock and the dam. Guidance relative to these subjects is essentially the same as for a navigation lock and is available in EM 1110-2-2602.

2-14. Real Estate Considerations

Numerous real estate considerations are associated with a navigation facility, and those concerning the dam site itself may form only a small part of the picture. In the investigation phases, the government may need temporary access to private property to perform surveys and foundation exploration; assess possible requirements for highway, railroad, and utility relocations; determine access-road alternatives; and for other reasons. In the site selection stage, temporary access will be needed at a number of locations to obtain adequate data for determining the best site for the structure. Project construction and/or operation purposes will require real estate for staging construction activities and for project-induced flooding of lands adjacent to the upstream channel, channel work, navigation structure, access roads, and support facilities. Surveys should be performed to identify the need to mitigate damages from levee underseepage due to changed pool conditions. Mitigation may involve compensating a landowner for estimated damages for changed industrial and agricultural land use over the project life. An alternative to mitigation may be the need for levees, pumping stations, and drainage structures to handle increased water levels and induced underseepage from changed pool conditions. Other considerations which may pose major concerns include the following:

a. Determining the types of rights-of-way required (including easements and fee title properties).

b. Establishing the entity responsible for obtaining real estate and performing relocations.

c. Estimating the lead times required to obtain rights-of-way and perform relocations.

d. Identifying lands for mitigation of changed environmental conditions.

2-15. Site Selection

Site selection is one of the most important considerations and is closely related to the other technical and procedural considerations presented above. Selection of the dam site is closely tied to selection of the site for the companion lock, and the items that are important for one are important for the other. Briefly, the selection process should consider the following:

a. A site which accommodates good approach conditions to the lock.

b. The characteristics and history of the existing stream including, but not limited to, hydraulic and hydrologic considerations.

c. The stability of the stream bed, i.e., whether the stream carries a large sediment bed load and whether the stream bed is stable or meanders.

d. Existing topographic and geologic conditions.

e. Existing uses of the waterway which may be impacted by the raised pool level, such as levees, municipal water intakes, etc.

f. The effects of the waterway on the natural environment, i.e., wildlife, vegetation, fisheries, etc.

g. Whether there is potential for hydropower development.

h. Whether other desired multiple purpose waterway usage is accommodated.

i. Whether construction at a site would produce fewer adverse impacts (environmental, flooding, etc.) than at another.

j. A site that is conducive to economical construction and operation while satisfying the above objectives.

k. A site that will provide net project benefits and is consistent with the national economic development (NED) plan, as appropriate.