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ENGINEERING AND DESIGN

Engineering for Prefabricated Construction of Navigation Projects

ENGINEER MANUAL

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

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Engineering and Design
ENGINEERING FOR PREFABRICATED CONSTRUCTION OF NAVIGATION PROJECTS

1. Purpose. This manual provides guidance to help Districts in developing innovative plans to use precast concrete segments and other prefabricated elements for construction of navigation projects. The primary emphasis is on describing engineering activities necessary during the project development process that may differ from those needed for a project using traditional design and construction methods.

2. Applicability. This manual applies to all USACE commands having responsibility for civil works projects.

3. Distribution. Approved for public release; distribution is unlimited.

4. Discussion. Navigation projects have traditionally been constructed within cofferdams, which have often been overtopped during flood events. Also, construction and maintenance of cofferdams have been time consuming and costly. Technology exists, largely practiced in the construction of bridges and offshore oil facilities, that will permit some navigation projects to be constructed without cofferdams. This can be achieved by preparing foundations underwater, precasting/prefabricating the shells of major concrete components offsite, placing these thin precast elements on the prepared foundation, and then filling them with concrete. Other options include the use of floating segments that are delivered to the site afloat and remain afloat such as floating guide walls. Use of this technology can have benefits related to cost savings, rapid completion of construction, fewer delays due to weather or water conditions, less interference with existing traffic, and less environmental impact. Several USACE navigation projects have been or are currently being designed to use these construction methods (see Appendix B). Appendix C contains examples of the types of construction discussed in this manual.

FOR THE COMMANDER:

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MICHAEL J. WALSH
Colonel, Corps of Engineers
Chief of Staff

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Chapter 1
Introduction

1-1. Purpose

This manual provides guidance to help Districts in developing innovative plans to use precast concrete segments and other prefabricated elements for construction of navigation projects. The primary emphasis is on describing engineering activities necessary during the project development process that may differ from those needed for a project using traditional design and construction methods.

1-2. Applicability

This manual applies to all USACE commands having responsibility for civil works projects.

1-3. References

Required and related references are presented in Appendix A.

1-4. Distribution Statement

Approved for public release; distribution is unlimited.

1-5. Background

Navigation projects have traditionally been constructed within cofferdams, which have often been overtopped during flood events. Also, construction and maintenance of cofferdams have been time consuming and costly. Technology exists, largely practiced in the construction of bridges and offshore oil facilities, that will permit some navigation projects to be constructed without cofferdams. This can be achieved by preparing foundations underwater, precasting/prefabricating the shells of major concrete components offsite, placing these thin precast elements on the prepared foundation, and then filling them with concrete. Other options include the use of floating segments that are delivered to the site afloat and remain afloat such as floating guide walls. Use of this technology can have benefits related to cost savings, rapid completion of construction, fewer delays due to weather or water conditions, less interference with existing traffic, and less environmental impact. Several USACE navigation projects have been or are currently being designed to use these construction methods (see Appendix B). Appendix C contains examples of the types of construction discussed in this manual.

1-6. Policy

Navigation project construction is limited by the availability of Federal funds and cost-sharing trust funds. To ensure that the Nation's inland navigation system remains capable of providing necessary transportation services, it is essential that the cost of each proposed construction project be kept to a minimum. Therefore, it is mandatory that each study of expanding or constructing new navigation locks and dams includes an evaluation of prefabricated construction methods as a potential cost reduction measure. Even if potential cost savings are not possible, use of precast construction methods should be considered because of other potential benefits.

1-7. Scope

This manual describes the engineering management issues that will be significant during planning, design, and construction of navigation projects without cofferdams. In some cases, these will differ considerably from traditional methods of construction. Chapter 2 describes the various types of prefabricated construction and some of their relative advantages. Chapter 3 identifies aspects of the planning and design process that may require special attention or different resources from more traditional construction projects. Chapter 4 describes specific engineering and construction issues that must be addressed during project development. This manual does not include specific criteria applicable to the design of project features.

1-8. Mandatory Requirements

As a potential cost-saving measure, development of designs for major rehabilitation or new construction of inland navigation projects must include an evaluation of using prefabricated structural elements to eliminate the need for cofferdams. This manual contains no other mandatory requirements. However, the manual represents recommended USACE practice for project development utilizing these innovative concepts. Where other Corps guidance documents are referenced, the designer must review each document to determine which of its mandatory requirements are applicable to the design.

1-9. Conclusions

These types of construction methods have application for navigation projects. They have been used successfully on many heavy construction projects that serve as precedents for the design of navigation projects. The elimination/reduction of large cofferdams, the reduction of in situ construction time, and the reduction of delays to navigation during construction are among the largest benefits of these methods. Examples of these methods will become more numerous as more projects realize and use the benefits of such practices. Although these methods generally use common materials, the design, procedures, equipment, and possibly contracts are not common to Corps practice. Specialized and additional engineering resources and procedures will be required to develop a plan, design and construct the project, and inspect and maintain the completed project.

Chapter 2
Types of Prefabricated Construction

2-1. Introduction

a. Prefabrication methods of construction involve some degree of assembling or fabrication of components at a location other than their permanent one. This is commonly done for many project components. Many large components are delivered to their permanent site in some state of completion. For example, steel tainter gates are partially assembled offsite and then completed at their permanent location. Also serving as a precedent for prefabricated construction methods are precast concrete shell-like barges, docks, dry docks, offshore platforms, tunnels, floating approach walls, etc. Large sections can be made using segmental construction to connect precast concrete panels with bolts, closure pours of concrete, stressing cables, or some combination of each. In situ work would be performed to prepare the foundations in the wet, connect the superstructure to the foundations, and complete the monoliths. Various concrete components for navigation projects can be made of precast concrete construction that are either built near the site or built offsite and transported to their final destination.

b. Transportation may be by barge or the unit may itself float. Coast Guard classification may be needed for floating units. Transportation and access routes should be planned and restrictions researched. En-route mooring areas should be established for bad weather or otherwise lengthy delays. Towing of a unit over long distances will probably not be initiated until a reliable weather forecast is available for the whole journey or to the next mooring point. Any necessary restrictions or shutdowns of the waterway must be coordinated well in advance with industry partners for their consensus. Contingency plans for transportation mishaps should be developed. Such plans can include redundant towing anchor points or fittings, en-route mooring facilities, locking priorities (if applicable), standby towboats, etc. Sizes of prefabricated components may be controlled by the size of locks en route, draft restrictions (mussel beds, river depth, or other), bridge clearances, powerline clearances, foundation type and strength, monolith size and strength, stability requirements, space for operating equipment, and constraints created by existing project features, if any. During some stages of construction/fabrication, truck or rail transportation may be useful. The equipment that transports and handles the units may also be restricted by existing infrastructure.

c. In general, these construction methods reduce in situ construction time. They offer parallel construction of the foundation structure or substructure and the superstructure.

2-2. Construction Methods

The various construction methods in this manual can be categorized into one of the following: float-in, heavy lift-in, light lift-in, or combinations of construction methods. Descriptions of these construction methods, including traditional construction for purposes of comparison, are provided below.

a. Traditional, in-the-dry construction. This construction method refers to the traditional manner of constructing a Corps of Engineers navigation project at its permanent location inside a dewatered cofferdam. Most monolith-type construction is conducted in situ using mass concrete placements and conventional formwork. Cofferdams are relatively time consuming and costly to construct and dictate the sequence of certain construction activities. The start of onsite construction of a navigation structure is dependent on full completion of the cofferdam. Similarly for monolith construction, the placement of formwork, rebar, and concrete is dependent on the completion of foundation work. Most cofferdams require partial or full removal upon completion of the project. Construction procedures, inspection, and quality assurance/quality control (QA/QC) are readily conducted by visual inspection with minimal reliance on instrumentation or equipment.

b. Float-in construction. Float-in construction consists of the prefabrication of very large (entire monoliths or multiple monoliths) precast concrete shells that are built offsite and floated to their permanent location. Offsite fabrication can range from being nearby the construction area or a great distance away. The shells usually float either by themselves or with the aid of external pontoonlike flotation devices. The shells are positioned for attachment to their foundations and lowered through the water by ballasting that can be controlled with vertical restraining forces (referred to as negative buoyancy) provided from large cranes, winches, or other machinery. The foundations are prepared in the wet. Once the shells are positioned, there is usually a void to fill between the bottom of the shell and the top of the foundation bed. This void is commonly filled with grout or sand (although other materials such as bentonite may be usable) depending on design needs such as bearing, seepage cutoff, bond of piles to the shell, etc. The shells act as stay-in-place forms for fill concrete. Large cranes for handling the units, floating plant for transport and installation, and marine facilities are critical items for this method of construction. Also, a site is required for prefabrication of the components. Components can be outfitted with features required for construction such as grout pipes, working platforms, temporary bulkheads to add buoyancy, pile wells or driving templates, skirts for underbase grout containment, electrical wiring/ducts, access/inspection ports, leveling jacks, instrumentation to assist placing, etc. It must be noted that some features of in-the-wet work will require that inspection and QA/QC be done by means other than visual inspection. It may become necessary to devise nonvisual methods for confirming alignment tolerances and the end product of work completed underwater. More reliance on nonvisual diver inspection, instrumentation, adherence of the contractor to proper procedure, and equipment will be required.

c. Heavy lift-in construction (greater than 450 metric tons (500 tons)). Heavy lift-in construction consists of the prefabrication of very large precast concrete shells that form parts of monoliths or entire monoliths. The size of the units requires that they be handled with large cranes. Temporary flotation chambers within the components can reduce the effective weight by increasing buoyancy if required. They are built away from their permanent location and transported by barges to their permanent location. A remote precast yard or onsite facilities are possible locations to fabricate these units. These facilities are key aspects of the project. At their permanent location, the shells are lifted into place by a crane(s) onto their foundations. Pile foundations can be either predriven piles or piles driven through the shell while it is temporarily supported on pads or by support piles. The units are subsequently filled with concrete to connect them to the piles or to bedrock. Units can be outfitted similarly to float-in components as discussed in subparagraph *b* above. See *b* above for considerations for inspection and QA/QC.

d. Light lift-in construction (less than 450 metric tons (500 tons)). This method uses construction equipment that is smaller than that for heavy lift-in. Usually pieces are lighter and smaller to accommodate more standard equipment or different needs/features of individual projects. A remote precast yard or onsite facilities are possible locations to fabricate these units. These facilities are smaller than for heavy lift-in, which could make them less a problem. Generally, entire monoliths would not be placed in one crane pick. Multiple crane picks would be used to essentially construct a monolith in situ, although still in the wet. This method results in the connecting of more joints at the site and possibly under water. See *b* above for considerations for inspection and QA/QC.

e. Combinations of construction methods. Methods of construction can be combined. A component may be floated to a construction site under its own buoyancy. At the site, it may be set into place by a very large crane(s). Also, many small shells may be assembled into a much larger unit that is then floated to a construction site for installation. Individual elements may use offsite fabrication with near-site assembly or ballasting and in situ conventional construction (above water).

Chapter 3
Planning and Design Process

3-1. General

This part of the guidance addresses factors that are unique to the planning and design of prefabricated construction whereas Chapter 4 contains more specific engineering and construction issues. General guidance for the planning and design process is contained in ER 1110-2-1150.

3-2. Project Planing

Project planning will require combined efforts of the in-house planning, engineering, construction, operations, contracting, and real estate functions, and possibly the services of expert consultants. Project team and project schedule are two key elements of project planning. The planning process for the design shall be consistent with the District's Management Plan (MP) for the project.

a. Project development team. Planning and design for prefabricated construction of navigation projects requires the input and expertise of a multidisciplinary team. It will be necessary to establish the nucleus of the Design Team early including the assignment of the Project Manager (PM), Project Engineer, and key members from the technical/functional elements. Expert consultants and Architect/Engineer (A/E) partners should be selected early enough to influence the Reconnaissance Phase and the Feasibility Study for the project. The team is responsible for establishing the needs of the customer, the alternatives that will be considered, funding or other constraints, engineering requirements for the project (criteria), required investigations, evaluation of results, and the selection of the best solution. The project team is ultimately lead by and responsible to the PM. The type of technical leadership may change during the various stages of the project, but a senior engineer should lead the design or evaluation study effort. A collaborative effort is especially necessary for innovative and state-of-the-art solutions. This effort should include technical experts to provide guidance and advice on concepts, details of implementation, assessment and mitigation of risks, engineering and construction requirements, and evaluation of results. This team should establish the scope of the entire study early in the design or evaluation process to ensure that resources are being used efficiently and to ensure that the investigations are compatible and complete. Planning and design of prefabricated navigation projects is a rapidly evolving and highly complex field, which requires special expertise and substantial judgment. In many instances, the project team should augment the in-house staff with technical experts to assure independent review of methodology and results, to add credibility to the results, and to assure public acceptance of the conclusions. Careful selection of expert consultants is essential, and the experience and qualification of these individuals must be consistent with the work for which they will be responsible. Such experts should have recognized experience with innovative marine design and construction. These experts may be from within USACE, other government agencies, universities, or the private sector. Technical experts should be included in the early team planning sessions to assist in identifying the scope of problems, selecting approaches and criteria, reviewing results, and selecting interim and final parameters.

b. Project schedule. The PM, with input from the customer and team members, must develop a comprehensive schedule in the MP and maintain it throughout the project. The detail of the schedule shall be commensurate with the complexity of the work. Projects that employ innovative design/construction methods must thoroughly include all project requirements including planning, design, engineering, consulting engineer acquisition, construction, environmental and cultural resource, real estate acquisition, and proposed contracting strategy(ies), whether performed by USACE, the customer, or contract. It is important that the schedule is realistic and consistent with available funding and other resources. The Project Review Board will approve the baseline project schedule.

3-3. Reconnaissance Phase or System Study

The Reconnaissance Phase or System Study identifies the problems being addressed and potential solutions. During this phase, economic viability and Federal interest in the project are to be determined. Careful attention should be given to potential costs for each solution and associated risks. Prefabricated construction may require offsite construction and then near-site assembly of components. More widespread environmental, geotechnical, survey, and real estate studies may be required and identified in the Reconnaissance Report. A decision to proceed to a feasibility study is sometimes based on more conventional and perhaps higher cost alternatives, with other potentially less costly but more innovative solutions identified for future study. When the recommendation in the report hinges on more innovative and less costly solutions, this should be clearly addressed and supported by expert opinion in the study effort. Required investigations may need to be finished early to develop a complete understanding of the cost for the project. In all instances, investigations or unusual studies that will be required to complete future studies must be defined at this time.

3-4. Feasibility Study

This study phase shall include preliminary analysis and design of the key features of the project in sufficient detail to prepare the baseline cost estimate, determine the contingencies, and provide a recommended plan for project authorization. More effort and study are to be expected for prefabricated construction because the available examples usually relate to traditional projects. The preliminary analysis should also be of sufficient detail to develop a design and construction schedule and to allow detailed design on the selected plan to begin immediately following approval of the feasibility report. Complex features may be determined to drive the schedule for final design and can be addressed in the Feasibility Study in greater detail to help minimize later design schedule impacts. Consideration must be given to adequately defining factors affecting the economic analysis such as filling and emptying systems, which may deviate from traditional systems. The alternative concepts must be developed to an equivalent level of contingencies to allow a fair evaluation. A life-cycle analysis in accordance with ER 1110-2-8159 may be required. Criteria for selecting the recommended plan must be determined. Factors that are not normally measured in terms of dollars, such as environmental impacts, and risks should be included. Navigation project feasibility study effort may be performed as a stand-alone, single-site study or as part of a river system study.

3-5. Final Design

a. Design Documentation Report. A Design Documentation Report (DDR) documents the final design of a project feature(s). A DDR is prepared as part of the preconstruction engineering and design phase or during the construction phase for multicontract projects. Modifications during construction that require redesign should also be documented in a DDR. A brief narrative description of the project features and the design analysis methodology should be included. The narrative should also discuss the conceptual designs used as the basis for the selection of the features including type of structure, form or configuration, controlling loads, load combinations, and load paths. Temporary or intermediate construction stages and construction loads as well as final loads must receive special attention for prefabricated, precast navigation structures. All designs must be reviewed with respect to biddability, constructibility, operability, and environmental aspects. Materials and their properties used in the design of features should be clearly identified. Design information that is critical to the development of engineering considerations for construction and information for preparation of the Operation and Maintenance Manual should be included in the DDR. In some instances, models or mock-up construction may be necessary to determine construction methods and sequence prior to construction.

b. Plans and specifications. The development of plans and specifications for prefabricated construction projects can be considerably more complex, since significant additional information must be addressed in addition to the normal function of conveying project requirements. Some features of work will need to be prescriptive in order to meet mandatory requirements (see paragraph 1-8) that are applicable to the design. However, in order to limit risks and promote creativity of the construction industry, some elements of the designs will be better expressed in terms of performance-based requirements. The product delivery team (PDT) along with senior management must make an early decision with regard to how comprehensive and detailed the plans will be. Each feature, especially those that apply innovative techniques, should be reviewed to determine if they will be fully developed by the Government's PDT, or if performance based requirements will be provided to the contractors to complete the design of those features. Attention must also be given to developing a plan that does not unnecessarily constrain potential bidders/ offerers in areas such as equipment requirements for the construction effort. Precast prefabrication yard locations (including whether several projects might more effectively use a common location), and whether slipways or graving dock facilities are needed to "launch" large precast units, are among the issues that must be addressed. Transportation of units from the precast area to the final project location and minimizing construction interference with navigation traffic must be carefully planned. Construction and installation illustrations showing sequences and emphasizing critical procedures may be required to show intent to the potential bidders.

c. Acquisition strategy. The division of responsibility between the Government and contractor shown in plans and specifications is influenced by the acquisition strategy and contract method that is selected. Therefore, it is necessary for the PDT to make an early decision on the contracting method to be used. The completion of the Acquisition Plan early in the Feasibility Phase will help guide the level of detail design work that would be necessary. In general, a request for proposal method is applicable to most prefabricated construction of navigation projects. Selection criteria for award of the contract are important and must be developed by a comprehensive team, including engineering, construction, contracting, and other required expertise. For prefabricated construction, emphasis should be placed on criteria related to the demonstrated skill or experience of the contractor, access to heavy/special equipment, past overall construction experience, concepts for the project, and marine architectural expertise. The bidding period must allow time for contractor-designed items. Sealed-bid (low-bid) procurement methods should be limited to conventional projects or components of projects. Design-build contracting (ER 1180-1-9) is another possible acquisition strategy that has been used for a wide range of projects. This approach would require a clear, detailed definition of all of the performance requirements for the completed project.

3-6. Construction Phase

As more innovative and unique solutions are used in navigation construction, the designer must be more closely involved with the construction phase of the project. This includes assistance in assuring specification compliance, extensions of design engineering during construction, and addressing field problems. Any changes in fabrications, handling, storing, or transportation of prefabricated units must be closely coordinated with the designer. Funding, above that which would normally be expected, must be considered to account for a greater involvement of engineers and specialists. Revisions to construction concepts may take place through the value engineering contractor proposal program. Evaluation efforts will be required for Value Engineering Change Proposals.

3-7. Operations Phase

Requirements for periodic inspection or routine inspection by project personnel could be different for prefabricated elements compared with those for traditional construction. The final products of prefabricated navigation structures generally contain more connections than traditional construction; therefore, outward signs of distress may not be as obvious as for traditional construction. This may require more detailed periodic inspections. Certain areas may require more attention, such as post-tension areas and buoyancy chambers. Some areas could require specific lighting and possible air quality monitoring for safe entry into confined workspaces (such as floating approach walls). Engineering performance problems shown by signs of distress must be detected early in order to arrest problems. Instrumentation requirements during construction and for long-term monitoring must be assessed. Inspectibility and monitoring must be considered and incorporated into the design and monitored in the periodic inspection program. Operations and Maintenance manuals may specify the need for special automated or remote inspection features/tools. In some instances, prefabricated construction may improve operation and maintenance/repair opportunities because items such as gates may be removed intact and replaced with a like unit while maintenance/repair to the unit removed takes place elsewhere.

Chapter 4
Engineering and Construction Issues

4-1. General

Specialized engineering resources may be required for prefabricated methods of construction. Needs will vary during the many stages of development and must be anticipated in the budget and schedule. These construction methods require site-specific analysis of the main project site and possibly a similar analysis of a potential remote fabrication site. Testing, research, or additional design may be required to prove feasibility of designs. The design team must have thorough knowledge of structural design principles, material technologies, and heavy marine design and construction practices. Most of the existing design guidance is applicable to these methods of construction. Geotechnical guidance contained in EM 1110-1-1904 and EM 1110-1-1905 is still applicable. Hydraulic design guidance in EM 1110-2-1604 is applicable, as is general guidance in EM 1110-2-2602. Designers may find useful, but not complete, information in EM 1110-2-2104 and EM 1110-2-2906 for reinforced concrete and pile foundation design, respectively. Additional design information can be found in the following sources: Yao and Gerwick (2002); Tuholski et al. (2002); and Fehl, Gaddie, and Abraham (2003). Design criteria may have to be developed for tasks related to design of concrete shells since little guidance exists. Some construction tasks will vary from the traditional methods of construction mostly because of the need to work from floating plant. Much of the project will never be visually inspected, which will require nontraditional methods of assurance that specifications have been met. Assurance of a quality product requires experienced and trained inspectors. This chapter will identify project features/tasks that are unique to prefabricated methods of construction. In general, these features/tasks are emphasized because they either need to be started early in the design or require atypical engineering and construction resources.

4-2. Site-Specific Issues

a. Onsite issues.

(1) Work areas. Planning and selection of all necessary onsite project work areas is a very important consideration. Traditional construction of navigation projects generally is conducted by delivering relatively small components or raw materials to the site where they are assembled in situ. However, prefabricated methods of construction could involve the transporting, storing, handling, and maneuvering of large shells at the construction site. At the beginning of the Feasibility Study, planners, engineers, and key construction personnel should be included in the selection and evaluation of all onsite project work areas including laydown areas and supplemental work areas for construction of the project. It is essential that by the completion of the project Feasibility Study boundaries of the onsite project work areas be defined to the fullest extent possible. This will permit selection of necessary real estate (i.e., temporary or permanent) and allow real estate actions to proceed. Early resolution of these areas will also permit environmental/cultural resource/Hazardous, Toxic, and Radioactive Waste (HTRW) compliance studies to begin. Each area considered should be evaluated based on various key points including size, access, environmental characteristics, history of use, and potential for acquisition. Considerable space requirements may be needed for the larger components and vessels associated with prefabricated construction. Unique mooring requirements may be required for floating plant, floating shells, and storage of large lift-in shells delivered by waterborne transport. Floating plants may be more numerous or larger than traditionally used, therefore requiring special attention. Onsite storage of floating shells may be required. Dredging and other excavations that may disturb the environment should be evaluated. The addition, deletion, and/or adjustments in limits of onsite project work areas after the real estate actions and environmental/cultural/HTRW compliance studies have begun/finished will likely result in unwanted delays to the project schedule, and cost escalation in the project budget may occur.

(2) Real estate issues. Real estate acquisitions for onsite project areas shall be conducted in accordance with ER 405-1-12. Although the real estate acquisition work may be based on a valid plan, a contractor acting within a performance specification may develop an acceptable plan that crosses approved real estate bounds. Additional real estate action may result in time delays, but the technical merit of the plan may justify the delays. The contract documents should consider such a possibility.

(3) Delays to navigation during construction. The onsite construction of navigation structures could affect the performance of the navigation channel or existing lock(s) resulting in delays to the user. Frequent lock closures of short duration and infrequent closures of long duration have different economic impacts. Delays that cannot be avoided should be quantified for economic comparisons with other alternatives. The engineer should consult with Operations and the user on what types and/or timing of delays are less costly to the user. Scheduled lock outages can reduce economic impacts. For lock closures, scheduled outages are necessary for activities such as driving piling or excavating bedrock in the line of navigation. Subsurface investigations and pile driving tests that assist in developing production rates for foundation work would help quantify delays. This may supplement historical production rates that may not be fully applicable for in-the-wet and prefabricated methods of construction. Advice from experts on production rates and constructibility can be elicited for tasks that have little historical information (senior-level estimators from construction companies have been assembled to provide this type of information). Quantifying impacts to navigation involves determining the construction procedure and sequence, determining task durations and dependencies, and producing a construction schedule. This work serves as input to the economic analysis to determine the cost of the delays. During construction, temporary measures such as helper boats, temporary mooring areas, ready-to-serve policy, and industry self-help can help reduce lost efficiency of the lock. The usefulness of these measures can be project- and site-dependent. These measures must be considered in the cost estimate and economic analysis. The contract documents should include all navigation conditions during which the contractor will not be able to work. Full closure of either locks or the river must be included as well as periods that the contractor can temporarily block navigation either for crew, material, or equipment movement. Liquidated damages or other consequences must be considered for which the contractor will be liable in the event of inexcusable delays.

(4) Studies and investigations.

(a) Environmental concerns and cultural resources. An overall Environmental Impact Statement (EIS) will be developed as part of the project Feasibility Study. The EIS will address the environmental concerns and impacts associated with the project configuration and onsite project work areas. Public health regulations and/or special environmental constraints will be identified within the EIS, as will issues regarding HTRW handling and disposal. The EIS will also identify necessary permit actions and mitigation requirements. It is important that the project configuration and onsite work areas be as well defined as possible so that the EIS will be comprehensive to minimize the need for a Supplemental Environmental Impact Statement and/or an Environmental Assessment. Prefabricated construction methods will not have large cofferdams; therefore, the smaller footprint along with a shorter in situ construction period will reduce environmental disturbance. Realistically, the project features and onsite work areas will become refined as the design nears its completion. It is therefore important that environmental and cultural specialists responsible for preparation of the EIS and/or possible Supplemental Environmental Impact Statement and Environmental Assessment be updated on the project design, proposed construction operations, location and extent of project work areas, or other issues that could influence environmental and cultural concerns. These notifications are critical to project execution so that appropriate supplemental reports may be made and public notices issued in a timely manner with the least impact to the project schedule. In addition to these required studies, the Government will need applicable environmental State and/or local permitting to cover any land disturbance issues and water quality standards. The permits must be written as comprehensively as possible to include all potential construction activities. The permits generally will be written to make the Contractor a co-permitee or turn over the permit to the Contractor upon award of the construction contract. It must be noted that the Government should have in place methods to verify that the Contractor stays in compliance with the conditions of the permits throughout the construction period.

(b) Geotechnical. Typically, geotechnical investigations include a program of soil/rock sampling and testing to gather information to complete the designs for foundations and other related project features. Besides these traditional investigations, unique testing may be in order since prefabricated structures have foundation systems that are built in the wet. Systems of piles and drilled shafts are typical foundations used for innovative solutions. Full-scale field tests may be needed to investigate the soil/rock/structure interaction and the lateral and axial capacity of the piles. The full-scale test piles should be built in the wet to simulate actual field conditions accurately. The cost of full-scale field testing is justified if the results will help to optimize the final foundation system design, thus saving money during the actual construction. The full-scale field tests will also provide valuable information related to the methods and procedures to be used to build the foundations in the wet. Other types of field investigations may include soundings and underwater probing; evaluation of the susceptibility of foundation materials to scour; rippability of rock (for underwater excavation); drainage and seepage analyses; and investigations of stone and aggregate sources. The designers should consider performing these unique tests along with the typical exploratory investigations as early as possible in the design schedule, such as during the Feasibility Study. Test results may then be incorporated into the final design, thus eliminating the need to perform these investigations and tests during the construction as prerequisite work.

(c) Hydrology and hydraulics. Studies must be performed to ascertain the critical hydraulic characteristics that may affect the project design and construction. Velocities and water levels will likely be the most typical hydraulic concerns affecting the project. There will be a recurring pattern of river stages or tides that are typical to the area where the project is built. These patterns must be thoroughly understood to determine their effect on each particular feature of the work that involves in-the-wet construction. These water-level patterns will impose forces on the prefabricated subassemblies that affect loading cases. In general, water velocities will create forces on the subassemblies and final structures that will need to be considered in the design. In colder regions, ice flow and loads imposed by ice will create another condition to consider. River and tidal conditions will also influence the setting procedure and sequence. The effect of river velocities on positioning tolerances must be considered. Studies may also include investigations of Federal flood-control projects and hydroelectric projects that could be coordinated to control flow in the river. Hydrologic and hydraulic conditions can influence the duration of the construction contract and may dictate the best time to award the contract. Seasons having typically high flows may not be suitable for positioning and installation of structural components placed in the wet. All available hydrologic and hydraulic information must be carefully reviewed to determine conditions that might constrain construction activities. Where hydrologic information is insufficient, it must be completed to the necessary level of detail to thoroughly understand the hydraulic characteristics of the environment in which the project will be built. Sediment transport and deposition may also need investigation where this condition could affect dredging operations, excavations, and foundations. Physical constraints of the watercourse, such as the navigable width of river and swellhead that may affect floating plant or project features, must be considered. The Project Engineer must schedule any unique tests required to understand these conditions as early as possible in the design schedule, such as during the Feasibility Study, to assure that the necessary information is available when the final designs are formalized.

b. Offsite issues.

(1) Work areas. Offsite work areas may include a number of sites where various components of the project will be built or partially built and then delivered for assembly or further prefabrication. Large structural features such as miter gates, flow control gates, valves, and other miscellaneous structural fabrications will likely be built at existing fabrication yards and transported to the site. Similarly, large prefabricated subassemblies will be fabricated and transported, but will require a prefabrication site that may

need development and/or adaptation to meet the project requirements. This prefabrication site may be an existing facility that is already suitable with little or no adaptation, or may be one that requires complete development to accommodate the work. The site must be connected to the project site by navigable waters. There are two basic choices for the selection of the prefabrication site:

(a) Government-furnished prefabrication site: The Government must conduct all necessary planning and engineering to fully evaluate potential sites, whether they already exist or require development, and select a site for the project. Factors such as size of the site, proximity to the project site, subsurface conditions, flooding and land use history, and navigation impacts must be considered. The Government must complete all National Environmental Policy Act of 1969 (NEPA) (environmental/cultural/historical and HTRW) compliance investigations, and also conduct all necessary real estate actions for the site offered. The real estate action could involve acquisition of permanent and/or temporary land interest. The benefit of a Government-furnished prefabrication site is that all bidders will be developing their proposals based on a common prefabrication site. This will eliminate the need for contractors to seek out sites and secure the necessary real estate agreements, as well as the need for the contractor to expend time and costs for environmental permitting. The drawback is that the level of effort dedicated to the selection and acquisition of a prefabrication site will require significant time and must be funded appropriately. In addition, the contractors will not be given the flexibility of using lands or sites that they already may own or have land interest in. This could result in a higher total cost for the prefabrication site.

(b) Contractor-furnished prefabrication site: All work that the Government would perform in selecting a site falls to the contractor during the proposal phase. The benefit of this is that the contractors are given flexibility of using lands that they may already have land interest in, thus resulting in some cost savings. The drawback is that contractors will be forced to perform all the required NEPA (environmental, cultural, and historical) compliance investigations on their own, and secure all the necessary environmental permitting for the project. There will not be sufficient time during the proposal phase to complete all of this work. Therefore, there will be some uncertainty, or risk, associated with a contractor-furnished site. Upfront contract time could be squandered to complete the necessary NEPA compliance and permitting. There is also the risk that the contractor's site will not be usable as proposed.

NOTE: Prefabricated subassemblies have also been successfully constructed on large floating barges (Montezuma Slough) (see Appendix C). This could be a consideration if the Government or contractors are not able to find a suitable site proximate to the project site.

(2) Real estate issues. The process of acquiring any Government-furnished offsite project work areas is similar to those actions required for onsite project work areas.

(3) Impacts to navigation during construction. Construction of the prefabricated elements at the offsite project work area should not create adverse impacts to navigation. However, the impacts of launching and transporting these elements should be considered when planning the project schedule.

(4) Studies and investigations.

(a) Environmental concerns and cultural resources. The overall EIS that is developed as part of the project Feasibility Study should address the environmental, cultural, historical, and HTRW characteristics and impacts associated with any Government-furnished offsite project work areas. However, if the offsite work areas involve contractor-furnished sites, a Supplemental Environmental Impact Statement may be required.

(b) Geotechnical. Investigations will be similar to, although not as extensive as, those conducted for onsite project work areas. As before, the Government should consider performing as many upfront exploratory investigations and field tests as permitted by the design budget to eliminate the need of performing these investigations and tests during the contract as prerequisite work. Early investigations would be needed to discover if the soil at a potential prefabrication site is suitable for heavy construction.

(c) Hydrology and hydraulics. Hydrologic and hydraulic studies similar to those performed for onsite work areas should be conducted for the offsite project work area. Of particular concern will be the transportation constraints of the watercourse, such as the flows, navigable width, and available draft between the prefabrication site and the project site. These parameters should be investigated to at least a cursory level of detail leaving a detailed investigation to the contractor.

4-3. Engineering Issues

a. Conceptual designs. The development of conceptual designs begins with researching available information on all types of innovative construction techniques to increase the engineer's knowledge of what can be done. Thorough knowledge can provide more solutions to particular problem areas of a project. Prefabricated elements are a particular set of solutions. Some projects have used precast concrete shells as stay-in-place pile-driving templates and stay-in-place concrete forms. The use of shells and underwater concrete eliminates the need for large cofferdams. The connection of the shell to the foundation may often be done with concrete placed underwater. The shell can contain structural reinforcing steel requiring load to be transferred from the fill to the shell. Monoliths for navigation projects are generally large and may lend themselves to being assembled in pieces to reduce handling loads. Joints will occur between adjacent subassemblies and are generally areas in which to concentrate design efforts. Construction procedures and sequences are important aspects of conceptual designs. They require the engineer to think through the feasibility of the concept/project. Construction procedures and sequences along with other design assumptions could be included in the plans and specifications to convey the intent of the designer and to show the contractor that there is at least one feasible way to construct the project. Conceptual designs should be analyzed for construction requirements to determine their dependency on certain types of equipment. Dependency on special equipment may limit the number of contractors and/or raise the bids/proposals on the project. In general, limitations on size, transportation, productivity, etc., can be restricted by available equipment. Large-capacity crane barges, stiffleg derrick cranes, or possibly ringer cranes on barges could be required. Designing within the limits of available cranes should yield the most competitive bids. Two cranes could be used to hoist prefabricated elements. Along with crane barges, a significant amount of other floating plant may be required. Floating plant may be used to transport precast shells, shuttle materials, and manpower; support cranes, concrete conveyors, pumps, or tremie pipes; stage diver inspections/activities; drive piles, etc. Marine facilities have to be established to moor, repair, and modify vessels; load materials; transport workers, etc. Existing plant can be modified to suit successive phases of construction, or special equipment may have to be built for the project. The benefit of special equipment becoming Government property should be investigated. Catamaran barges for placing shells have been made from flat deck barges paired together with strongbacks. The strongbacks have hoisting capabilities to raise and lower shells. Lateral location of the catamaran is controlled by cable and winching of the barges in response to survey information. Large floating plants are less susceptible to movement from wind, currents, and waves. In summary, the development of alternative conceptual designs should include factors such as first cost, life-cycle cost, operation and maintenance cost, cost of delays to navigation during construction, constructibility, and equipment needs and availability.

b. Concrete materials and concrete investigations. A significant benefit of prefabricated construction will be the increased structural durability from using specially formulated concrete and grout mixtures. Concrete used for the fabrication of structures may include precast concrete, conventional cast-in-place concrete, and high performance concrete. Special grout mixtures may also be required. Standard-weight and lightweight concrete may be required for various parts of the structures to enhance flotation and handling. Concrete and grout mixtures will most likely be placed both in the dry and underwater. Concrete mixes placed underwater by tremie methods must flow freely, be self-consolidating, and may need to exhibit a resistance to washout. Most concrete mixtures will be composed of special formulations of cement, aggregate, pozzolans, and specialized admixtures. This will require that most proposed concrete design mixtures be trial batched and tested to verify that the required design strengths, as well as the physical characteristic, can be achieved. The thermal characteristics for concrete mixtures for precast concrete and mass concrete used to fill shell structures will also need to be studied. This information will be used to support a Non-Incremental Structural Analysis (NISA) to study the response of the structure to effects of concrete thermal activity. This could lead to design decisions related to reinforcing and possible prestressing/post-tensioning for strength and/or crack control. Field demonstrations of concrete placement methods may also be in order depending on the complexity of the proposed concrete placements. The project schedule and budget must have sufficient time and funds dedicated to permit the completion of these necessary concrete design studies. Structural durability will be increased through an enhanced program of quality control for all phases of concrete batching, mixing, and placement. The design should be investigated to determine where uncertain areas might be and how anticipated deficiencies could be repaired. Generally, the precasting of concrete results in a higher quality finished product. Adding to quality can be casting positions, match casting, preassembly to ensure fit, and possible indoor construction (clean rebar and controlled environment for placing and curing). Any precasting operations will need to conform to Precast Institute (PCI) criteria, but would not need to be PCI certified. The Government's QA of the Contractor's operations would need to confirm that ongoing precasting operations were in compliance with PCI. For a new precast facility, this certification could be time consuming. A contractor may opt to have a certified plant/precaster do the work or at least fabricate smaller sections that can be connected later. At the construction site, units/panels can be connected, or most would eventually require filling with concrete/grout. The voids to be filled cannot restrict the flow of the concrete. Means to ensure the quality and thoroughness of concrete placement should be specified.

c. Hydraulic investigations. This paragraph supplements paragraphs 4-2*a*(4)(c) and 4-2*b*(4)(c). Hydraulic investigations may be necessary to study boundary conditions (i.e., maximum flows) that dictate when the prefabricated structural elements can be handled and set. Investigations may help determine key loading conditions that are needed to complete designs, and they could provide important insight when conditions would be safe for divers and other construction personnel to work. Generally, physical models and numerical models will be used to acquire this information. The scale of physical models must be properly selected to assure that the appropriate parameters are measurable. Numerical models should be used to augment and/or supplement the information collected from physical models. It is important that scaled physical models of the project work site be developed. These models can be useful to understand key factors such as confinement of the river and/or navigable passage, set schemes and sequences for the prefabricated subassemblies, track paths for transport and positioning of the prefabricated subassemblies, and study the forces on elements as they are being placed. Other information gained from these models can be provided to the contractor for design of temporary structures such as mooring systems.

d. Cost engineering. Generally, the percentage of engineering costs relative to construction costs will be higher for prefabricated navigation projects. This must be determined and accepted in early stages and programmed in the District's management plan. Costs associated with specialized expertise, special testing, field mock-ups, models, and quality assurance during construction will generally exceed routine requirements. For the actual Government estimate, there will not be a comprehensive database to reference. Specialized expertise and additional time may be required to develop the cost estimate. Uncertainties must be reduced to an acceptable level. Contingency costs should not be used to cover uncertainty. Use of the construction sequence will facilitate identifying tasks. Costs for training designers and inspectors, and special equipment, special monitoring, and mobilization costs may be higher than those for traditional construction and must be considered in the project-funding plan. As projects utilize these methods, the database will be expanded.

4-4. Design Criteria

a. Structural design criteria. As of this writing, most existing criteria have been developed for traditional, in-the-dry methods of construction. Existing criteria may not always be applicable for these construction methods, but should be used when possible. Existing criteria and guidance that prescribe general design requirements, concrete finishes, stability requirements, life-cycle cost analysis, etc., should be usable. Prefabricated methods of construction can result in projects looking the same as traditionally constructed projects and capable of complying with existing criteria. Where criteria do not exist, resources should be allocated for their development. The needs for design criteria should be identified after the recommended conceptual design is determined. In general, there is little guidance for tasks related to the design of the shell itself. Crack control criteria are important for appearance, integrity of buoyancy chambers, and protection of reinforcing steel. Other sources for criteria can be found in design documents for projects using prefabrication methods, such as American Petroleum Institute (1995) Standard ISO 13819-1; American Concrete Institute (1988) Standard ACI 357.2R; American Concrete Institute (1984) Standard ACI 357R; American Association of State Highway and Transportation Officials standards; PCI publications, etc.

b. Loads and load combinations. Prefabricated methods of construction require careful attention to the many different loads and load combinations on the shell as it is being built up and the strength of the developing structural system to resist the loads. Loads will change during the various stages of shell fabrication, transportation and handling, installation, and concreting of the units. Unlike traditional concrete construction for which the loads and load combinations from concrete placement and the design of shoring are generally the responsibilities of the contractor, the design engineer should consider these aspects as part of the shell design. The principles of naval architecture will be required to determine the forces on floating shells resulting from wave action. The buoyancy forces keeping the unit afloat are transient due to waves. This is referred to as sagging and hogging. The design wave, which is characterized by its return period, wave length, frequency, and height, will often control the design of the floating unit and the locale where it is constructed. For example, wave design assumptions on inland waterways would not result in a unit that is strong enough to transit the open seas. To reduce draft during transportation, the shell may require supplemental buoyancy tanks that will impart their own loads to the shell. Designers should consider that some chambers in floating units might accidentally flood. During the installation of shells, forces due to ballasting the unit to its position should be considered along with the forces from landing the shell onto its landing pads or foundation. Since large units can be constructed in segments, the design should consider loading conditions on segment connection details. Thermal loads resulting from the heat of hydration from concrete fill should be considered because these forces can crack the shell.

4-5. Structural Systems

a. General. Traditional structural systems do not necessarily change with the use of prefabricated methods. Gravity and U-frame monoliths will remain as the likely end product even though prefabricated methods are used for their construction. Also, thin-walled monoliths have been considered as alternatives and are constructible with prefabricated methods. Large monoliths can be built up using smaller precast concrete shells or panels. Load transfer between shells can occur through the shells or fill concrete. Floating approach walls offer another system composed of a floating superstructure connected to anchor points at its ends and possibly at intermediate points. Further discussion is divided into superstructures and substructures. Precast concrete shells are presented for describing structural systems.

b. Superstructures. Structural systems for precast shells will consist of typical structural elements such as beams, slabs, brackets, panels, shear walls, etc. These elements are connected together to form a shell that is floated or lifted onto its foundation. Connections between units/elements should be designed for ease of construction, strength, and durability. Prestressing, post-tensioning, and conventional reinforcement will be used in some combination to make connections along with strengthening and controlling cracks in concrete. Shells must be designed to minimize weight for handling by cranes or to reduce the draft for floating shells. Localized strengthening of the shell with steel shapes or thickened concrete at attachments for mooring/handling lines or to act as a hull (for floating units) may be required. The structural system could be designed to use only sand fill to resist impact, uplift, or otherwise stabilize a monolith. Bonding concrete fill to the shell would be required if the shell cannot resist the applied loads. Surface preparation/cleanliness, material compatibility, material strength, joint details, dowel strength, and placement techniques influence the bond of fresh concrete to hardened concrete. Also, the shell should be configured not to impede the flow of fill concrete (usually tremie); therefore, consideration must be given to ancillary items/features, such as temporary supports, corners, and grout supply and vent tubes. These or similar items, as well as items added by the contractor, must be scrutinized. Using specified criteria, the construction inspector should inspect underwater forms just before they are submerged. Construction joints should be located in areas of low stress and may require special seal details if watertightness is required. Joints should generally be watertight to contain cement paste. Units may be constructed segmentally and post-tensioned together while afloat or on a slipway. The structural load-resisting system and the load on the system will probably change as the shell is built up. For example, the shell could serve as a cofferdam by pumping it out after it is sealed to its foundation using tremie concrete. The construction/fabrication sequence should be analyzed for such occurrences.

c. Substructures and foundations.

(1) Foundation materials and preparation. Prefabricated methods of construction require that the foundation excavation and other in situ preparation be done in the wet. Excavations are susceptible to scour, siltation, and slope stability problems. Soil foundation materials will likely be susceptible to scour from naturally occurring river velocities and/or induced high velocities created by constricted flow of water around shells. To help prevent scour, the natural material can be overexcavated and replaced with scour stones, articulating concrete mattresses, or bags filled with sand or stone. Stone provides other benefits in that it can be screeded to achieve a level surface for subsequent construction and if underwater concrete is to be placed against the foundation. The stone will not mix with the concrete as much as sand or other finer material. Rounded stones are more easily screeded than crushed stones. Underwater excavations may also be difficult to maintain due to migration of the riverbed. River hydraulics and bed-load characteristics would help identify scour and deposition potentials. For rock foundations, unsuitable rock can be excavated. Experience has shown that both production and tolerances can be met using large hydraulic excavators that can rip relatively weak bedrock and also excavate it. There are a limited number of these excavators because they are very expensive, but large jobs may justify the purchase of such equipment by the contractor. The foundation design would have to accommodate reasonable tolerances for excavation of rock underwater. Alternatively, drilled shafts can be used to reach through poor rock to layers of sound rock, minimize rock removal, and provide lateral strength.

(2) Pile and drilled shaft installation in the wet. Piles are typically installed in the wet for prefabricated methods of construction. Piles can be driven from floating plant using various hammers with fixed or swinging leads. The depth that a pile is to be driven will dictate the need for the use of followers during pile driving. Conventional impact and vibratory hammers are utilized above water. Recent introduction into the United States of underwater impact hammers has provided unique capability for installation of pile foundations above and below the water surface. The design of a pile foundation should take into consideration the tolerances that can be reasonably achieved between individual pile elements. Achieving tighter tolerances will be reflected in the cost for installation due to the preparation and quality control during pile driving. Site characteristics will certainly influence the driving of different types of piling. Soil densities that are very high will be less receptive to displacement piles whereas soils with low densities will benefit from the same types of piling. Site characterization is a must for any site where installation of a pile foundation is anticipated. Densities, size of particles, frictional capacities, end

bearing capacities, and depth to rock or firm strata are a few of the characteristics that are important in the design and installation of pile elements. Based on the subsurface conditions, pile tips may be terminated at varying elevations resulting in different elevations for the pile tops. Pile lengths should be set with close tolerance to avoid the necessity to cut piles to proper length underwater. Design concepts that feature shells and are designed to prevent bottom heave will allow piles to be cut off in the dry.

(3) Substructure to superstructure interface. Regardless of the type of foundation material or preparation, load transfer of a completed monolith to its foundation will be required. Generally, concrete would be placed in the shell and against the foundation structure to connect the two. Prior to placement, it would be verified that the unit is sealed against the foundation in order to contain the subsequent fill concrete and that the conditions of the surfaces and formwork meet specifications. Assumptions for resistance to sliding at a rock-to-concrete interface require careful attention. Bearing pressures may not be uniform due to unequal cleaning/preparation of the bedrock. Assumptions for design values of bearing on bedrock need to be made. For pile foundations, the piles are either predriven or are driven through the shell or through pile wells in the shell. Loads are transferred to the pile system through concrete fill or grouted connections. Tension piles can be developed into the concrete by welding beads on the pile that perform a function similar to deformations on rebar. This practice, used for offshore platforms, eliminates the interference to pile driving by devices such as tension transfer weldments.

d. Connections. Prefabricated elements are generally assembled into a final shell using various types of connections. Connections must be designed with careful attention to detail. Key design aspects of connections are the accounting for tolerances in the placement of adjoining pieces and the need to transfer loads across the joints. The transfer of loads through connections may be more critical than for conventional cast-in-place construction. The combination of axial, shear, moment, and torsion reactions at a connection need to be determined. Some connections will be made underwater or otherwise hidden from view. The connecting of critical joints in the wet should be minimized. The designer must anticipate the resulting quality of such a connection and provide reserve capacity and/or redundancy accordingly. There are methods to confirm the quality of a connection such as diver verification and/or acoustic sounding. Connections of the superstructure to pile foundations and to adjoining elements are of paramount significance. Large elements, such as immersed tubes and floating bridges, have been connected with post–tensioned rods that are threaded through preformed holes in adjoining walls. Sealed voids between immersed tubes have been dewatered allowing external hydrostatic pressure to force the two tubes together. Rods are then tensioned to positively adjoin the two tubes. The long-term performance of connections may require an investigation into the fatigue and fracture characteristics of the connections. Also, joints may have to be watertight to ensure that the cement paste from contained concrete does not wash out. The durability of a project is dependent on details such as these connections.

4-6. Construction Issues

a. Project construction schedule. A construction schedule should be developed for each project alternative during the Feasibility Study. The content should be consistent with the detail necessary for the decision process. When project schedule is an important consideration in the decision process, extra detail may be needed for the Feasibility level construction schedule. A more detailed project construction schedule, using a Network Analysis System (NAS) approach, must be completed later for the selected project alternative during the design phase. This schedule must be as thorough as practical and must assure that the correct tasks, durations, and dependencies associated with the proposed innovative techniques are addressed. The schedule should be formulated from input gathered from design team members in planning, engineering, construction, and operations, as well as A/E firms and/or expert consultants. The construction schedule should thoroughly and clearly identify activities at the onsite project work areas and offsite project work areas, such as critical construction periods, contingency plan schedules, lock closure periods, and periods of reduced lock efficiency, etc. The schedule must reflect periods of river conditions (i.e., river stages and velocities) during which work will be affected or will not be possible. Environmental factors such as fish migration and spawning periods must also be duly considered in the construction schedule. ER 1-1-11 provides policy on the use of the various schedule management methods.

b. Contractor Quality Control (CQC). Separate CQC staffs will be needed for projects involving offsite fabrication. One staff will be stationed at the project site, while the second staff will be located at the prefabrication site. The use of the same CQC staff for both locations would be recommended only if the project site and prefabrication sites were reasonably close to each other. One CQC Manager should be able to supervise and manage both staffs, unless the project site and prefabrication site are far apart. Two CQC Managers may be considered. Qualifications and performance expectations of the CQC team must be identified and clearly specified in the contract specifications. The contract specifications must also entitle the Government to review and approve all CQC personnel. Because of the uniqueness and complexity of prefabricated construction, the level of coordination must increase. Progress meetings and safety meetings will need to be conducted more frequently. Construction mock-ups that simulate the actual construction methods and sequence may be required where the task is highly complex and critical in nature. Nontypical inspections such as commissioning trials (float-in structures) and other inspections to document responsibility in the event that the structure fails or is damaged during handling, transport, or placement will most likely be needed. Specialized training for construction inspectors may be required. It may be necessary for the contractor to supply a third-party trainer for his CQC staff.

c. Quality Assurance. The Government will perform QA of all CQC measures in accordance with ER 1180-1-6. Adequate Government QA staff will be needed for both the project site and prefabrication site. If the prefabrication site is some distance from the project site, two Government QA staffs may be needed. Much of the work involving prefabricated construction will require specialized construction knowledge to properly assure the adequacy of the contractor's work and CQC program. Government construction representatives will need to be specially trained. Some of this training may be provided through available sessions offered through the Huntsville Training Center, associations (i.e., American Concrete Institute, PCI/Portland Cement Association), or other accredited educational institutions. However, most training for innovative construction techniques is probably not available and will need to be developed. An accurate logging of "lessons learned" will facilitate training of Government inspectors for future projects. Another tool to inform Government construction representatives of key aspects of the critical project design and construction issues is through a formal "Engineering Considerations and Instructions to Field Personnel" report as explained in Appendix E of ER 1110-1-12. Although in-house personnel will serve to staff the majority of the Government's QA program, specialized expert staff may be needed to supplement the in-house Government staff. Supplemental specialized staff may be procured through A/E service contracts or through direct hire of an expert consultant.

d. Adverse weather. The advantage of prefabricated construction is that significant portions of the structure can be built under controlled and protected conditions. For instance, precast concrete can be manufactured within temporary climate-controlled enclosures permitting protection of the precast elements along with ideal curing conditions. Another benefit of using prefabricated offsite construction is that the prefabrication site can be better protected from adverse weather and most river conditions compared to the exposure if the structure was built inside a cofferdam. The Project Team must thoroughly understand the adverse weather patterns associated with the project site and prefabrication site so that the project schedule allows for the expected adverse weather patterns at these sites. A well-thought-out schedule must account for or mitigate adverse weather effects on vulnerable processes/activities.

e. Contractor submittals. Numerous unique submittals will be required from the contractor. Many of these submittals will require review by specialized experts. There is a possibility the contractor may submit alternative designs that must be thoroughly reviewed by qualified personnel to assure that the design intent is preserved. The designer must thoroughly review the work and compare it with the Government-proposed construction sequence, created during the plans and specifications, to identify when a contingency plan is required. Contingency plans will be submitted for features of work that are critical or those that may be affected by adverse weather or other unforeseen occurrence that is out of the control of the contractor or Government. The designer may also establish performance-based specifications for such plans and include these in the contract tender documents, but the contractor will ultimately be made responsible for development of the plan.

f. Safety. These methods of construction require heightened safety awareness due to the need for heavy lifts with large equipment, confined spaces within the shell, high-pressure lines for jacks, and the majority of the work having to be performed over water. The construction procedures should be examined for safety of personnel and for protection of the environment. Contract documents should make the contractor aware of times for heightened safety awareness. The designer should consider safety throughout the design and develop safety-related instructions for the field. When divers are required, approved dive safety plans should be followed. The project may specify a dedicated rescue squad to increase safety. The contract documents should state the environmental limits such as flow conditions, daylight, and temperature that will control dives. The contractor's approved plan should include goals of careful planning and organization to increase safety. For example, prior to heavy lifts, safety meetings should be held so everyone understands the lift procedure, the sequence of events, personal responsibilities, and any back-up plans.

4-7. Tolerances

a. General. Assembly and underwater installation of prefabricated elements is a challenging endeavor that requires diligent and detailed planning and engineering. The complexity of assembly, transport, and installation of prefabricated elements is governed by a variety of factors, including physical size and weight of the elements and environmental factors such as currents, tides, and depth of water. Prefabricated units are typically assembled as large as practicable to take advantage of buoyancy and to minimize the number of in situ structural connections required. These large units must be transported, positioned, and interconnected with very little or no real-time visual confirmation; therefore, tolerances become far more important than for conventional construction. The appropriate selection of construction equipment and procedures is essential to assure that necessary tolerances are achieved without undue construction expense, complete reliance on divers, or delays. The following discussion on tolerances is divided into topics related to prefabrication, installation, connections, site preparation, and operations.

b. Prefabrication tolerances. Fabrication tolerances must be carefully considered not only to ensure proper mating, but also for weight control. Weight control is an important aspect of prefabrication tolerances for units that are to be floated or lifted into place. Practical and obtainable tolerances are a function of such factors as the quality of the forms used, the use of match casting, and the degree of accuracy of the survey systems for assembly.

c. Installation tolerances. Installation tolerances on the order of 25 mm (1 in.) have been routinely achieved for prefabricated units up to 50,000 tonnes (55,100 tons); however, achieving these levels of tolerance requires careful planning and attention to engineering details. During installation, tolerances must be engineered to match the environmental requirements along with the inherent accuracy of the positioning system. Environmental concerns include water plane stability, both global and local hydraulic forces, and possibly the use of station keeping systems. Station keeping and positioning systems include mooring lines, spotter jacks, compensating lowering systems (such as the use of nitrogen gas over hydraulic fluid in rams for heave control), dolphins/spud piles, taut lines, prepositioned stabbing guides, and helper boats. Station keeping systems are frequently used together with feedback survey systems to improve positioning accuracy thus allowing tighter tolerances. In addition to dynamic feedback survey systems, the following sequence of survey considerations should be addressed when determining installation tolerances:

- Survey of prefabricated units in the yard, which allows for correction and/or shimming of units before transport.

- Underwater survey of the installation site, which allows for correction and/or adjustment of the landing/contact points prior to installation.

- Use of survey towers that extend above water, thus allowing the use of abovewater optical survey equipment together with instrumentation on the towers such as inclinometers and gyroscopes.

Furthermore, when determining installation tolerances, it is important to consider the potential for adjusting the units after set-down by such means as underpressure to move the unit laterally or downward, underwater rams, and underwater lines. Landing pads, smaller and more easily placed units, are typically used to allow more accurate positioning of large elements. Positioning of elements can also be monitored with electronic surveillance equipment. The use of self-centering guides, such as cup-and-cone or similar stabbing guides, are also common and highly recommended methods of guiding elements precisely into final position, while allowing reasonable set-in tolerances during positioning. Global Positioning Systems (GPS), along with sonar and related technologies, have been used for position control in marine environments. Diver verification of fit-up can be used following installation, but should be limited in scope and requires special attention to safety.

d. Connection/interface tolerances. Connections/interfaces with foundations, existing structures, previously placed units, floating structures, electrical systems, and mechanical units must be designed with sufficient simplicity, leeway, and/or adjustability to allow reasonable tolerances while ensuring full functionality. The use of underwater tremie concrete and grouts can greatly simplify the detailing of such connections. For connections to previously placed units, guides can be used such as a tapered pin and matching hole.

e. Tolerances associated with underwater site preparation. Obtaining and maintaining these tolerances against environmental disruptions are critical to the success of prefabricated construction. Consideration must be given to positioning of any piles and/or sheet piles, excavation/dredging tolerances, backfill tolerances, tolerances for drainage systems, screeding tolerances, and the potential use of inflatable mattresses and seals between shells that can relax the tolerances demanded. Furthermore, once the site has been prepared to the appropriate tolerance, it must be protected from such factors as scour, sedimentation, and debris by such means as temporary scour stone, protective mats, flow deflectors, and screens. Final dredging of sedimentation may be required.

f. Tolerances a*ssociated with key operational elements or systems*. Operability can be ensured not only by controlling tolerances, but also by preparing the construction plan appropriately. A thorough construction plan should include the following:

- Avoiding joints at critical locations and/or relocating key elements so that they avoid crossing construction joints.

- Allowing key apparatus (such as trunnions, secondary concrete placements, and machinery) to be installed in the dry with the use of minimal or no cofferdams.

- Making reliable provisions for electrical wiring to pass across joints.

- Allowing key elements to be referenced to each other.

- Allowing for secondary adjustment of elements after they have been positioned.

4-8. Construction Contractor Acquisition Planning

a. Acquisition methods. Invitations for Bids (IFBs) and Request for Proposals (RFPs) are two basic forms of acquisition used for most procurements. IFBs are competitive procurements that do not allow the Government to evaluate the technical merits of the contractor's proposal and qualifications. An IFB procurement would not be a recommended acquisition method where a significant part of the contract documents is performance based. IFBs are more suited to contract documents that are entirely prescriptive, routine, or constructed by conventional techniques. For these reasons, an IFB would not be the recommended choice for a project involving innovative designs and construction concepts. Alternatively, RFP acquisitions will permit the Government to evaluate the technical merits of the contractor's proposal along with the contractor's qualifications and experience. An example of RFP procurement is a "best value" procurement, which provides a method to balance the technical merits of the contractor's proposal against the cost of performing the work. Best value is a two-phase procurement process. In the first phase, the contractors submit their qualifications, experience, and a technical approach. The Government evaluates and ranks the firms based on established evaluation criteria. The second phase of the procurement solicits final proposals, including cost, from the most highly ranked contractors. The contract is awarded to the contractor with the best value proposal, considering a combination of cost, technical merit, experience, schedule, risk, and other appropriate factors.

b. Acquisition team. A team should be formed to prepare the acquisition plan, develop the acquisition schedule, prepare the necessary acquisition documents, and evaluate proposals. Suitable time and funding need to be built into the project schedule and budget for this team to evaluate proposals.

c. Acquisition schedule. A suitable schedule must be developed for the chosen method of acquisition for the project. The schedule must have sufficient time allotted for securing bids or proposals and for evaluations and subsequent negotiations with the selected contractor. Sufficient time must be allotted to conduct preproposal or prebid meetings, respond to inquiries from contractors, and issue addenda to the solicitation.

d. Development of price schedules. The development of the contract price schedule is an important consideration from the following points: project acquisition, contract administration, and development of a cost database for innovative construction techniques. The price schedule must break down the work into a number of bid items so the work is biddable, negotiable, and reasonably administered.

(1) Project acquisition. Prefabricated methods of construction could require rather unique bid items. The number of bid items and level of detail may provide a clear breakdown of the work, but must be weighed against the complexity and the additional work required to complete the cost proposal. A more detailed price schedule makes it easier to isolate a specific area of difference during negotiations. Some believe that more bid items result in higher bids, but this is not necessarily correct. A clear and thorough breakdown of the work will help prevent hidden costs, leave fewer questions as to what is to be included in "all-inclusive" type payment items, and should help lessen the number of claims during execution of the contract. A preconstruction meeting with potential contractors could be beneficial. This can be accomplished by issuing a DRAFT RFP that provides key information about the crucial features of work. After the DRAFT RFP is issued, a follow-up preconstruction meeting with contractors will permit discussions and the airing of concerns. The advanced solicitation permits the prime contractor to align and team with the necessary subcontractors and consultants. The Acquisition Team must permit ample time during the proposal phase for contractors to evaluate and complete the price schedule. The PDT must also thoroughly review and coordinate all Unit Price Schedule items with the plans and specifications to ensure that it is clear which costs will be included with which payment items. The price schedule may also need to be structured to conform to funding profiles, and may include optional work items and/or alternatives if the contractor is going to be permitted to bid alternates to the tender documents.

(2) Contract administration. The impacts and effect that the price schedule has in the administration of the contract must also be considered. The schedule must differentiate between items that can be administered as a job sum and those that will require measurement for payment. Distinct, well-defined features of work such as the prefabricated structure and the prefabrication yard may be paid for on a lump sum basis. Uncertain or variable work such as exploratory drilling, dredging, and some concrete items, where final quantities may vary from the theoretical quantities, must be paid for on a unit price basis. The price schedule should be structured so that all onsite work and all offsite work are identified separately.

(3) Cost databases. Since prefabricated methods of construction are new to most Districts, it will be important to begin the development of a cost database for innovative work. The price schedule should have separate items for each innovative construction item. This may create a lengthier price schedule, but such a schedule will be beneficial for later procurements.

4-9. Division of Responsibility Between the Government and the Contractor

a. Design. For projects involving innovative designs and construction methods, contract specifications will probably be a mixture of performance-based and prescriptive requirements. Decisions must be made as to how much of the designs will be fully completed by the Government and which will be required of the contractor. This will also be true for construction procedures and sequences for the various features of work. Plans and specifications must be developed so that they are consistent with the selected method of acquisition, and, specifically, any selection criteria. From a design perspective, it may be more clear-cut that most, if not all, of the critical structures should be completed by the Government, whereas minor structures or features may be presented more conceptually and left for the contractor to complete. There may ultimately be many possible ways to complete various features of the work; therefore, the contract documents should not be overly restrictive. The degree to which the contract plans and specifications are prescriptive or performance-based will directly affect bids and contingency costs in the contractor's bids. It is therefore essential that the project is reviewed by the design team and construction staff to identify areas where performance-based or prescriptive requirements are to be used.

b. Construction schedule and contract duration. The contract duration should be determined in consideration of delays created from probable flood events and weather. The onsite installation of float-in and lift-in construction will not be protected by a cofferdam and will be exposed to fluctuating water levels and various river velocities. Work will need to be scheduled and performed during specific periods when the weather, river, and tides permit the work to be accomplished. The contract duration must consider periods of adverse weather, high water, and other natural occurrences that will affect project execution.

Appendix A
References

A-1. Required Publications

ER 1-1-11
Progress, Schedules, and Network Analysis Systems

ER 405-1-12
Real Estate Handbook

ER 1110-1-12
Quality Management

ER 1110-2-1150
Engineering and Design for Civil Works Projects

ER 1110-2-8159
Life Cycle Design and Performance

ER 1180-1-6
Construction Quality Management

ER 1180-1-9
Design-Build Contracting

EM 1110-1-1904
Settlement Analysis

EM 1110-1-1905
Bearing Capacity of Soils

EM 1110-2-1604
Hydraulic Design of Navigation Locks

EM 1110-2-2104
Strength Design for Reinforced - Concrete Hydraulic Structures

EM 1110-2-2602
Planning and Design of Navigation Locks

EM 1110-2-2906
Design of Pile Foundations

American Concrete Institute 1984
American Concrete Institute. 1984. "Guide for the Design and Construction of Fixed Offshore Concrete Structures," ACI Manual of Concrete Practice 357R, Committee 357, Offshore and Marine Concrete Structures, Farmington Hills, MI.

American Concrete Institute 1988
American Concrete Institute. 1988. "State-of-the-Art Report on Barge-Like Concrete Structures," ACI Manual of Concrete Practice 357.2R, Committee 357, Offshore and Marine Concrete Structures, Farmington Hills, MI.

American Petroleum Institute 1995
American Petroleum Institute. 1995. "Petroleum and natural gas industries -- Offshore structures -- Part 1: General requirements," ISO 13819-1, Washington, DC.

A-2. Related Publications

ER 5-1-11
U. S. Army Corps of Engineers Business Process

ER 200-2-3
Environmental Compliance Policies

ER 415-1-11
Biddability, Constructibility, Operability and Environmental Review

ER 1105-2-100
Planning Guidance Notebook

ER 1110-2-112
Required Visits to the Construction Sites by Design Personnel

ER 1110-2-1200
Plans and Specifications for Civil Works Projects

ER 1110-2-1302
Civil Works Cost Engineering

EP 11-1-4
Value Engineering: A Profitable Partnership

EM 385-1-1
Safety and Health Requirements Manual

American Petroleum Institute 1995
American Petroleum Institute. 1995. "Recommended Practice for Planning, Designing and Constructing Structures and Pipelines for Arctic Conditions," ANSI/API RP 2N, Washington, DC.

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Canadian Standards Association. "Concrete Structures - Offshore Structures," S474-94, Mississauga, Ontario.

Federation Internationale de la Precontrainte 1985
Federation Internationale de la Precontrainte. 1985. "Design and Construction of Concrete Sea Structures," American Society of Civil Engineers, New York.

Fehl, Gaddie, and Abraham 2003
Fehl, B, D., Gaddie, T. W., and Abraham, K. 2003. "Investigative Study for Underwater Construction of Lock Floors and Culverts," ERDC/ITL TR-03-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Norwegian Council for Building Standardization
Norwegian Council for Building Standardization. "Design of Concrete Structures," Norwegian Standard N.S. 3473, Oslo, Norway.

Tuholski et al. 2002
Tuholski, N. J., Gluver, H., Cornell,C. A., Gerwick, B. C., Jr., Patev, R. C., and Padula, J. A. 2002. "Risk Assessment Procedures for Innovative Navigation Projects," ERDC/ITL TR-02-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Yao and Gerwick 2002
Yao, S. X., and Gerwick, B. C. 2002. "Positioning Systems for Float-In and Lift-In Construction in Inland Waterways," ERDC/GSL TR-02-22, prepared by Ben C. Gerwick, Inc., San Francisco, CA, for U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Appendix B
USACE Navigation Case Histories

The following case histories represent examples of planned or executed U.S. Army Corps of Engineers projects using offsite prefabrication construction technology. These case histories should not be viewed as the only ways to employ offsite prefabrication technology, but rather they should be studied for the lessons learned from them. Applicable figures in Appendix C are referenced. The following non-SI units of measurement used in this appendix may be converted to SI units as follows: to convert feet to meters, multiply by 0.3048; to convert inches to millimeters, multiply by 25.4; to convert miles to kilometers, multiply by 1.609344; and to convert tons to tonnes, multiply by 0.9071847.

B-1. Braddock Dam

a. The new Braddock Dam (Figures C-10 through C-15) was designed to replace an existing fixed-crest dam on the Monongahela River near Pittsburgh, Pennsylvania. The new gated dam is approximately 750 ft long; 600 ft of the structure comprises one fixed weir bay, one water quality gate bay, and three tainter gate bays. A closure weir comprising cellular sheet-pile cells and a concrete weir complete the remainder of the dam structure. The signature feature of this project is the offsite prefabrication of two large concrete dam segments that were floated to the project site and set down onto preinstalled foundations. Segments were fabricated in a two-level casting basin built in Leetsdale, Pennsylvania, along the Ohio River about 27 miles downstream of the actual Braddock project site. Each segment was launched by flooding the casting basin, then towing each segment to a location near the site for final outfitting. Following this step, the segments were delivered to the site, immersed, and filled with concrete. Another part of the project involved the left closure weir, which was completed in the wet. Placement of downstream scour protection and upstream stone training dikes and removal of the existing fixed crest dam complete the project. Design of the dam was completed in November 1998. Construction began in August 1999. The new dam became fully operable in the fall of 2003. Completion of the entire project is scheduled for spring 2004.

b. Some of the more significant engineering challenges on the project include the following:

(1) Design and development of a two-level casting basin and launch facility for the two prefabricated floating dam segments.

(2) Design and construction of two concrete shells, one 333 ft long by 104 ft wide, another 265 ft long by 105 ft wide, with sufficient strength for launch, transport, and immersion while maintaining a maximum draft at float-out of only 10 ft. Over 400 precast concrete panels were manufactured and erected to form the exterior and internal diaphragm walls of the segments. Bottom and top slabs and the intersections of panels were cast in place. To control segment weight and draft, both lightweight and normal-weight concrete was used. The 11,000-ton Segment 1, which measured 333 ft by 104 ft, was launched on July 10, 2001, and towed to the project site on July 26, 2001. The second and smaller 9,000-ton segment, measuring 265 ft by 104 ft, was completed and towed to the project site in February 2002.

(3) Developing a transportation, positioning, and immersion plan that can safely accommodate a 500-year flood at any time with only a 48-hr notice.

(4) Developing a positioning and alignment system for landing the segments in a 3-ft/sec current and meet a tolerance of ±1/4-in. vertically and ±2 in. horizontally. Following outfitting and preparations for immersion, each segment was transported from the outfitting area, about 1-1/2 miles downstream, to the damsite for set-down. After initial positioning for set-down was achieved using towboats, each segment was attached to mooring piles with winches and cables for final positioning. Using a designed ballasting

sequence, water was added to the hollow compartments of the segment in a controlled manner to slowly lower it down onto the drilled shaft foundation. After each segment was set down, they were joined at a common pier with a grouted post-tensioned connection. All alignment tolerances were met. Segment 1 was set down onto its foundation system in December 2001. Segment 2 was set down in June 2002.

(5) Developing designs and construction procedures for a drilled shaft foundation system that will assure accurate location of all drilled shafts to within ±6 in. horizontally and ± 2 in. vertically. The basic dam foundation system comprises upstream and downstream cutoff walls, a graded gravel base, and a system of drill shafts. Eighty-nine reinforced concrete drilled shafts serve as the foundation for the new dam. Each shaft measures 78 in. in diameter and about 40 ft in depth with 15 to 20 ft of each shaft drilled into the bedrock. A series of steel bearing piles form the foundations for the dam tailrace area. All foundation work was completed by the end of August 2001.

(6) Developing unique design mixes for underwater concrete/grouts for filling the dam underbase and infilling the concrete dam segments. Mixes must be acceptable to control thermal cracking of the precast dam segments. Some mixes must flow up to 25 ft without segregation in test conditions.

(7) Concurrent construction at the prefabrication site and project site. While the two float-in segments were being fabricated offsite, work continued concurrently at the Braddock project site to complete the dam foundation system.

(8) Design and construction of tailrace in the wet using precast concrete panels and a program of underwater concrete infill placement. Thirty-one panels, weighing up to 65 tons each, were match cast near the project site for the dam tailrace. Each panel was designed and manufactured to interlock with the next adjoining tailrace panel and connect to a specially designed groove that was cast into the downstream edge of the float-in dam segments. The panels will be supported along their downstream edge by the pipe piles, which were incorporated into the design of the downstream cutoff wall. Panels were installed by cranes mounted on floating plant using a guide frame to assist in accurate setting of the panels. The void beneath each tailrace panel was then filled with tremie concrete to create a mass concrete tailrace section that is supported by the previously installed H-pile foundation system.

(9) Fabrication and in-the-wet installation of tainter gates in one piece. The new steel tainter gates of the dam were installed in four of the five gate bays. Each tainter gate is 110 ft long. Three of the four gates are standard tainter gates at 21 ft high while the remaining shorter water quality gate is 12 ft high. All gates were fabricated, shipped, and installed in one piece. Erectors along with engineers evaluated this approach to assure that erection sequences, equipment, rigging, and other necessary measures were properly designed and addressed so these structures were safely and accurately installed.

(10) The upper 40 ft of the five dam piers were completed above the waterline in the dry with conventional jump forming systems. Extension of the concrete piers and other features of work such as tainter gates and footbridges were completed by crews using equipment mounted on floating plant.

(11) Following completion of the new dam, the existing fixed-crest concrete dam that is located about 600 ft downstream was completely removed to the riverbed. The demolished concrete materials were placed in downstream locations as fish habitat.

c. For additional information contact the U.S. Army Corps of Engineers, Pittsburgh District, William S. Moorhead Federal Building, Pittsburgh, PA 15222.

B-2. Chicago Harbor Lock

a. The sector gates and gate bays were rehabilitated in the wet for Chicago Lock, Illinois, in 1996. This work was conducted at night while traffic used the lock during the day. The work included the provision of new bulkhead slots, new gate sill surfaces, new pressure relief holes, and temporary and permanent culvert closures.

b. Significant aspects of this work included the following:

(1) The work for the new bulkhead slots was conducted within blister cofferdams attached to the lock walls.

(2) The work for the new gate sill surfaces was conducted using precast concrete panels placed underwater and underbase grouting with special washout-resistant cement grout.

(3) New pressure-relief holes were provided in the bottom of the gate bays between the maintenance bulkheads to prevent uplift problems when the bays are dewatered to work on the sector gates.

This work was completed successfully with minimal impact on traffic through the lock.

c. For additional information contact the U.S. Army Corps of Engineers, Chicago District, 111 North Canal Street, Chicago, IL 60606.

B-3. Inner Harbor Navigation Canal Lock

a. Innovative construction of a concrete float-in lock for the Inner Harbor Navigation Canal (IHNC) lock replacement project has been authorized. The replacement lock will be located on the canal about 0.5 mile north of the existing lock. The innovative float-in concept was selected to address the space restrictions imposed by construction within an urban site of historic buildings, to permit continuous navigation within the canal, and to reduce costs. The lock is located within the City of New Orleans on the Gulf Inner Coastal Waterway (GIWW) and connects the Mississippi River with major navigation routes and the Port of New Orleans. Two lock configurations were considered: a recommended 1,200-ft by 110-ft by 36-ft ship lock and a baseline 900-ft by 110-ft by 22-ft barge lock. The ship lock was selected; the local sponsor will pay the difference for the larger ship lock. The Feasibility Study was completed in 1996 and the project authorized in 1998. As of August 2003, the detailed lock design was 30 percent complete, and it is anticipated that plans and specifications will be completed in late 2006.

b. The structure will be a pile-founded U-frame constructed in five modules. The modules will be supported independently of one another such that no load transfers between modules. The piles are 48-in.-diameter steel pipe piles. There will be two gatebay modules and three chamber modules. The module base and lower walls will be a hollow concrete shell similar to a concrete barge. Upper wall design is incomplete; designers are investigating a precast shell wall and a cast-in-place mass concrete wall. The lock filling system is unique in that sector gates will be used in lieu of the more typical miter gates. The sector gates were economical in this project because they can operate against the reverse head that exists a small percentage of the year. Initially, miter gates were included in the design; however, four sets were needed because of the reverse head. A sidewall culvert filling and emptying shall be used to control the water levels. Eliminating the culvert system by using the sector gate end filling was considered. Model tests done at the U.S. Army Engineer Research and Development Center indicated that end filling would take considerably longer than the culvert system.

c. The sequencing of construction would generally be as follows:

(1) The canal will be widened to provide a temporary bypass navigation channel, and temporary vessel impact protection structures will be built.

(2) A graving site (prefabrication facility) will be constructed on the waterway system within a few miles of the site.

(3) Float-in precast concrete segments approximately 400 ft long will be partially completed within the graving site.

(4) The lock site will be prepared by dredging, installing piles, and preparing set-down pads.

(5) Each segment will then be moved to the installation site and ballasted to the bottom. Tremie concrete will be placed to join the structure and the pile foundation.

(6) Second-stage construction will be performed at the lock site after the base section is set onto the predriven piles; there will be no intermediate staging area. The contractor may elect to build a tall section at the graving site prior to float-out or construct a braced cofferdam above the lower walls. The available 35 ft of draft permits heavier float-out sections than what can be considered for most inland waterways. For this reason, low-density concrete was not used.

(7) The sector gates will be fabricated offsite and installed after the module upper walls are complete.

(8) The new lock will be tied to the levees, the bypass channel will be backfilled, and the existing lock will be removed.

B-4. Olmsted Locks–Floating Approach Walls

a. The walls (Figure C-17) consist of four pontoons ranging in length from 159 to 1,667 ft, as well as a single fixed wall (the lower land wall), which is 567 ft long. After the design of the floating walls had begun, a meeting with representatives of the towing industry resulted in the addition of the short (159 ft long) lower middle wall, which replaces the guard cell previously planned. The pontoons vary in width from 38 to 42 ft, and are typically 14 ft 6 in. high with parapet walls 3 ft 6 in. high. Each of the longer pontoons is to be constructed in segments with length in the 300- to 400-ft range. The pontoons have isolated compartments every 20 ft, and each pontoon is restrained laterally by a pylon at each end. The pylons are 13 ft square and constructed of precast concrete supported on concrete-filled drilled shafts jacketed in steel. At the lock end of the pontoons, the pylons are part of the lock monoliths. There is no mechanical connection between the pontoons and the pylons; however, electric power transmission to the pontoons is accomplished by the use of motorized cable reels. High-mast lighting is provided for all of the walls. Life rescue boats (which will be lowered into the water with jib cranes) are provided on both the upper middle wall and lower middle wall. Access is provided to all portions of all structures with stainless steel ladders. Fall protection is provided at each ladder in accordance with EM 385-1-1.

b. Construction of the approach walls will occur at three separate locations. The drilled shafts for the nose piers, pylons, and lower land wall will all be constructed at the Olmsted site. The precast elements of the nose piers, pylons, and lower wall were precast at an existing precast plant in Mt. Vernon, Indiana, on the Ohio River. The pontoons will be cast in a graving dock, to be constructed on Tennessee River bottomland near the junction with the Ohio River at Paducah, Kentucky.

c. Once the pontoons have been cast and cured, they will be post-tensioned. The next step is for the pontoons to be floated out of their casting beds. The concrete slabs that compose the casting beds will be coated with a special bond breaker that will assure that the pontoon bottom slabs will cleanly separate from the casting beds. The pontoons will be pushed to the site with towboats and moored until the integration process begins. The contractor will use the completed Olmsted Locks chambers as a quiet water location to perform the critical integration of the individual pontoons into the long floating walls. The pontoon segments will be integrated with high-strength, 3-in.-diameter bolts, which are post-tensioned. After post-tensioning of the bolts, the bolt sleeves and the space between the pontoon end walls will be grouted. After the pontoons have been integrated, they will be installed in their final position between the pylons using a combination of towboats, cables, and winches.

d. The construction contract for the Olmsted Approach Walls was awarded on August 26, 1999, for a total cost of $98,980,610.00. The duration of the construction contract is 39 months.

B-5. Olmsted Dam

a. Construction of Olmsted Dam (Figures C-4, C-5, C-16) will start from the right (Illinois) side of the river adjacent to the lock and will incrementally advance toward the left (Kentucky) side of the river Construction will consist of the following:

(1) A 20-ft-long isolation structure between the lock and tainter gate section.

(2) A 5-bay, 564-ft-long tainter gate section.

(3) A 15-ft-long isolation structure between the tainter gate structure and the right boat abutment.

(4) A 55-ft-long right boat abutment.

(5) A 1,400-ft-long wicket gate navigable pass.

(6) A small isolation structure joint between the navigable pass and the left boat abutment.

(7) A 207-ft-long left boat abutment.

(8) A three-cell cellular fixed weir.

b. During construction, the over-water work is scheduled to be performed from mid-June to November, while fabrication of precast concrete segments in the precast yard is planned to be conducted all year round. The entire construction is scheduled for completion within 2200 days after award of contract. The construction period is divided into five phases. The Phase 1 construction activities are mobilization, establishment of a precast yard, and fabrication of the initial tainter gate section precast concrete segments and steel tainter gate section. In Phase 2, the first 2-1/2 tainter gate bays will be constructed. The last 2-1/2 tainter gate bays will be constructed in Phase 3. The right boat abutment and half of the navigable pass will be constructed in Phase 4. The rest of the navigable pass, the left boat abutment, and fixed weir not constructed under the lock contract will be built in Phase 5.

c. There are six main stages that involve most major construction activities:

(1) Prefabrication of concrete segments, up to 4,200 tons, in a precast yard.

(2) Riverbed preparation and construction of the pipe pile foundation and sheet pile walls.

(3) Placement of precast concrete modules with a heavy-lift crane barge and riprap placement.

(4) Onsite tremie concrete construction activities.

(5) Installation of tainter gates, access bridges, mechanical and electrical devices.

(6) Navigation control.

d. Some of the more significant engineering challenges on the project include the following:

(1) Developing an offsite prefabrication facility that can handle up to 4,200-ton segments.

(2) Construction in an uncontrolled river environment with a sandy bottom and environmentally sensitive species nearby.

(3) Design of the dam to resist a Maximum Design Earthquake with a horizontal zero period acceleration of approximately 0.85g with a 1,000-year recurrence period.

(4) Developing an efficient construction plan using large floating equipment for heavy lifting of shell segments, pile driving, screeding, and concrete production.

(5) Developing designs and construction procedures for a driven pile foundation system that will assure pile location tolerances of ± 3 in. horizontally and ± 4 in. vertically.

(6) Developing unique design mixes for underwater concrete for infilling the dam segments. Mixes must be acceptable to control thermal cracking of the precast dam segments. Some mixes must flow over 25 ft without segregation.

e. Design of the dam is completed. A request for proposals for the construction contract award was originally issued in the fall of 2002 under a fixed price contract. Although interest was expressed by contractors, especially with this "world class" project, there were many concerns associated with risk on the part of the contractors. This risk included variability in river and weather conditions that could impact the schedule in ways that are difficult to overcome without substantial risk to the contractor. Also, the long-term, large project with variable world conditions that could affect supply and demand was considered a risk factor. In general, firm fixed-price ways of dealing with changes were perceived as problematic on the part of some potential bidders because of their perceived notion that the Government believes that the contractor is responsible because the firm bid the completed job. The use of construction methods that included some unfamiliar details such as coordinating very heavy lifts were viewed with concern. Virtually all contractors indicated an unwillingness to take on any design responsibility for finished project features. Another factor that influenced the potential bidding pool was the size, specialization, and complexity of the river work for this project, which generally resulted in a combination of several contractors into joint ventures, which further limited potential competition. Although an amendment was issued that moderated the concerns by potential bidders, it was still questionable that there would be bidders because of the high level of concern that remained in the technical, contractual (delay), and contract administration areas. Many of these concerns would have existed for any method of constructing this project, not just the heavy lift-in method. (In fact, several large river construction projects within the Corps have received only a small number of bids or proposals in recent years.) Discussions then turned more specifically to the type of contracting for the work effort. Consideration was given to splitting the contract into multiple smaller ones, but potential impact of one contractor affecting another was judged worse rather than better. A search of requirements used nationwide for somewhat similar large-scale, complex, and potentially variable projects led to the conclusion that risk could be better managed with a cost-reimbursable type contract. This type of contract affords greater flexibility for both the Government and contractor to overcome unusual conditions. It also requires a higher degree of involvement and shared decision-making by both parties as well as increased administrative oversight. This change has been made and the solicitation has been reissued. Bidder interest has increased substantially to date. Corps expertise outside the Louisville District has reviewed and commented on revised documents. Cost Reimbursement training is scheduled for the implementation team. Utilization of this type of contracting is not new within the Corps, but it is for such a large civil works project. Lessons learned with this type of contract and teamwork that is developed should be useful for future projects of a similar nature.

f. For additional information contact the U.S. Army Corps of Engineers, Louisville District, 600 Dr. Martin Luther King Jr. Place, Louisville, KY 40201.

B-6. Ohio River Main Stem Study

*a. General***.** Float-in construction techniques are proposed for several lock elements in the Ohio River Main Stem Systems Study (Figure C-20). These elements include a middle wall intake monolith, lower land wall and miter gate monoliths, cross-over culverts, and the upper and lower floating approach walls.

b. Float-in monoliths:

(1) The first stage is to construct or use an offsite facility for construction of the base portions of the float-in structure. This offsite facility could be either a submersible barge or a dry dock facility. Either the dry dock facility would have to be constructed, or a previously developed site could be used. The submersible barge involves construction of the floating raft base on the deck of a barge that is specially equipped to be submersible. The base for the float-in element would be constructed, and then the barge would be moved into an area with sufficient water depth and sunk. The float-in base would then be moved to the site for the next phase of work. For the dry dock operation, the float-in base is constructed in the dry dock. Once it is completed, the dock is flooded and the base is floated to the site. For both the submersible barge idea and dry dock operation, the base can be constructed only to the level for which the allowable draft is reached and floating stability requirements are met.

(2) The second stage involves the construction of an onsite temporary workstation that will be required for the deep-draft construction stages of the float-in structures. First, a construction access road will be required to connect the existing road to the onsite workstation. The onsite workstation will be composed of a dredged area and channel, a work platform, and mooring dolphins. Once this is complete, the float-in bases constructed offsite in the first stage are floated to the onsite workstation for placement of additional concrete. Once they are at the onsite workstation, construction of the shell of the monolith is continued. It is important to note that the onsite workstation is far enough away from the existing lock chambers not to adversely affect existing navigation traffic during construction of the float-in structures.

(3) The third stage involves floating the shell structure from the onsite workstation to its final position. This will involve some preliminary in-water excavation and bedding preparation to ensure that the base is adequate to accept the float-in structure. The preparation will consist of underwater removal of the existing weathered rock, cleaning by airlift or similar method, and a quality check of the area prior to placing the shell. Positioning and sinking the shell should take only a day; however, the underbase grouting required once it is sunk will take approximately 3 weeks for some of the larger sections. Once the shell is placed and the base is securely grouted, the final phase of the float-in construction can begin.

(4) The final phase is the completion of the structure. Tremie concrete will be placed within the shell to form the monolith below the water level. Traditional concrete will be placed above the water level to complete the monolith to its final height.

c. Approach walls. The approach walls will consist of floating, longitudinally post-tensioned, precast concrete boxes called pontoons, which will be anchored to individual drilled-shaft type pylons. The approach wall will be bounded by the lock structure at one end and a nose pier at the other end. The nose piers will be composed of three drilled shafts, a steel shell structure, and concrete infill. The pontoons are constructed offsite and floated into place. The same type of offsite construction noted in the first stage for the float-in monolith construction will be used to construct the pontoons.

d. Contact. For additional information contact the U.S. Army Corps of Engineers, Louisville District, 600 Dr. Martin Luther King Jr. Place, Louisville, KY 40201.

B-7. McAlpine Lock

a. The construction laydown area at the McAlpine Lock (Figures C-18 and C-19) will be small due to the location of the project within the city of Louisville, Kentucky. Therefore, the use of prefabricated elements that can be constructed offsite and delivered on an as-needed basis has been incorporated into the project as much as possible. These elements include the T-beams for a fixed-access bridge, the walls of a 6-l/2-ft by 3-ft drainage culvert, the slab beams for the deck of a wharf structure, and the facing beams of the approach walls. The use of precast elements in the culvert and baffles of the innovative center longitudinal filling and emptying system of the project is also being considered.

b. The approach walls are provided upstream and downstream of the lock chamber to facilitate alignment of vessels entering and exiting the lock chamber. These walls will be constructed using concrete-filled PS27.5 circular sheet-pile cells founded on bedrock with precast concrete beams spanning between cells to form the approach wall face. This method is similar to the method used for the approach walls at Melvin Price Lock and Dam, Alton, Illinois, and allows the walls to be constructed without erecting a cofferdam. The approach walls will be equipped with standard check posts and line hooks, ladders, handrailing, and a wall armor rubbing surface.

c. An alternate type of approach wall was also allowed in the bid documents. The alternate wall consisted of drilled caisson supports capped by a precast shell beam that was then infilled with concrete. The portion of the wall above water (normal) was cast-in-place concrete. Both options were bid by different contractors. Significant cost savings with the use of the floating wall concept were identified. However, operational problems with grounding clearances and dredging, particular to the site of the McAlpine Lock lower approach, lead to the conclusion that floating approach walls should not be used. Therefore, approach walls consisting of precast beams supported on sheet-pile cells were recommended.

B-8. Upper Mississippi River – Illinois Waterway System Navigation Study (UMR-IWS)

a. Because the existing locks on these two rivers are only 600 ft long but are subjected to heavy river traffic consisting mainly of 1,200-ft-long tows, they cause congestion. The long tows must break into two parts to complete lockage. Adding locks to these existing sites on the Mississippi River that generally have only one lock has been studied since the early 1970's. Alternative locations for placing a second lock at a typical site have included landward of the existing lock, in the existing auxiliary miter gate bay (partial provisions for a second lock from the original construction in the 1930's), through the gated portion of the dam, through the fixed portion of the dam, and along the opposite bank line. Many of these alternatives were addressed in the Upper Mississippi River Navigation Study Reconnaissance Report, 1991 (available from St. Louis District, ATTN: CEMVS-ED-DA). This report considered the use of mostly traditional lock construction techniques, such as within a dewatered cofferdam. It addressed extending the existing lock to 1,200 ft, but determined it to be impractical because of the lengthy lock closure period caused by the cofferdam. The reconnaissance report identified costs of feasible lock locations and alternatives to be in the $380 million range. In the years following 1991, engineers from HQUSACE, Districts, and Divisions formed a team to investigate innovative lock designs and methods to construct less costly locks. This marked the advent of innovative lock design and construction in the Corps of Engineers. From 1994 to 1996, the Engineering Work Group (EWG) of the UMR-IWS used the results from the innovative lock team as a starting point to develop new lock concepts that were more economical than traditionally constructed locks. In addition, the EWG determined that it was possible to extend the existing lock despite claims to the contrary in the 1991 Reconnaissance Report. Lock extension concepts developed to ensure feasibility included float-in and lift-in methods of construction. The alternative to extend an existing lock maximizes the reuse of existing features and minimizes costs, estimated to be around $150 million. The economic costs of delays to navigation during construction were considered based on in-the-wet construction procedures. Constructing most features during the winter months on the Mississippi River, when ice prevents most river traffic from navigating the river, can minimize delay costs. Wintertime construction productivity reductions were considered. This example is included to point out that float-in and lift-in methods of construction can be used to make a project feasible that would otherwise be infeasible, such as the extension of a lock and providing for concurrent navigation traffic.

b. For additional information contact the U.S. Army Corps of Engineers, St. Louis, 1222 Spruce Street, St. Louis, MO, 63103-2833.

Appendix C
Graphics and Photographs

C-1. Introduction

This appendix contains diagrams, photographs, and brief descriptions of projects representative of the types of construction methods in this manual. Some of the projects are discussed in Appendix B.

Figure C-1. Radial gate structure under construction for the Montezuma Slough Salinity Barrier

C-2. Montezuma Slough Salinity Barrier

The Montezuma Slough Salinity Barrier was designed and constructed for the California Department of Water Resources to prevent saline water from moving up the Sacramento River from San Francisco Bay into the Montezuma Slough estuary. The radial gate structure, shown under construction in Figure C-1, was one of three float-in precast concrete structures that formed the barrier. The radial gate structure has three 11-m- (36-ft-) wide gates and is used to regulate water flow in the slough. The other two structures are a 20.1-m- (66-ft-) wide flashboard opening to allow for unrestricted vessel passage when the structure is not in operation; and a boat lock structure with a 6.1-m-wide by 21.3-m-long (20-ft-wide by 70-ft-long) lock chamber to allow passage of vessels when the flashboard opening is closed. The precast structures were fabricated in turn on a ground barge, then floated near the site on the barge, and then launched off the barge by tilting the barge down. The structures were then floated to the site and sunk into position. The structure was completed in 1988 at a cost of approximately $12.5 million versus an estimated cost of $25 million for constructing the structure "in the dry."

C-3. I-205 Columbia River Bridge

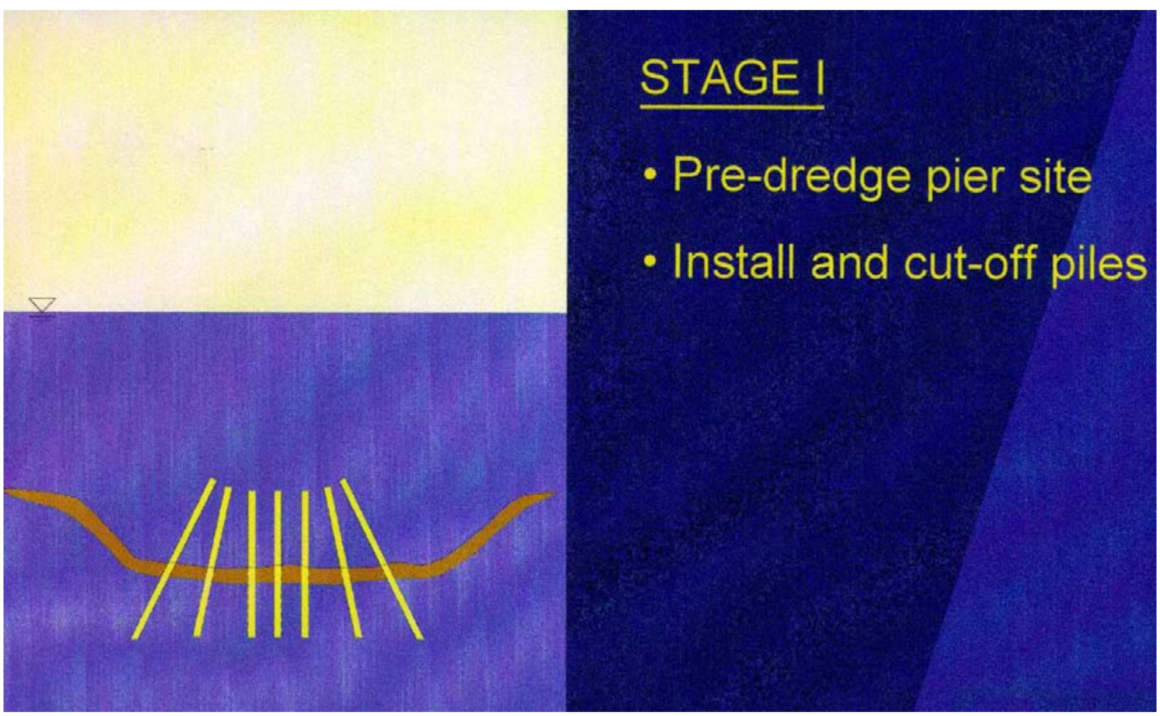
a. In Stage 1 (Figure C-2a) of the construction sequence for a typical pier for the I-205 Columbia River Bridge between Oregon and Washington, the pier site was first dredged and then H-piles were driven and cut off to the proper elevation. The H-piles were driven through a bottom-founded template that was floated into position to ensure accuracy of the pile positions.

b. In Stage 2 (Figure C-2b), a nominally 450-tonne (500-ton) capacity catamaran crane barge called the Super-Lift was used to install a preassembled reinforcing steel cage into a prefabricated pier form.

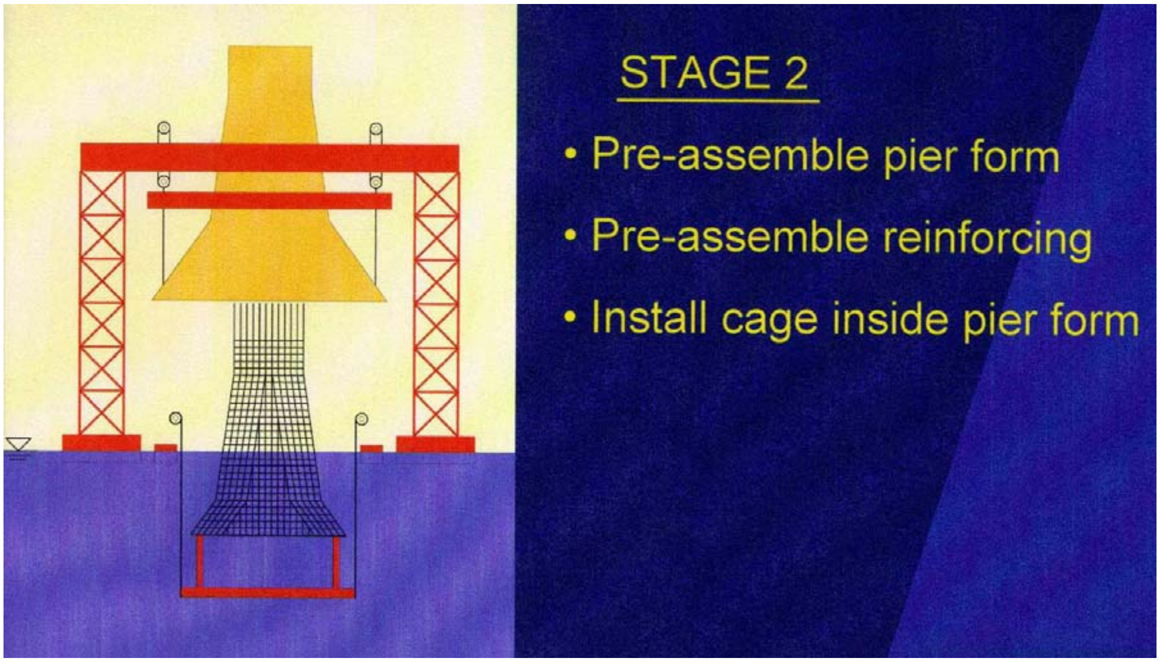
c. In Stage 3 (Figure C-2c) the form was then positioned over the predriven H-piles, and temporary spud piles were driven both to carry the load of the form and to act as a guidance system during installation.

d. In Stage 4 (Figure C-2d) the catamaran then lowered the form to grade, and the weight of the form was transferred to the spud piles in preparation for the tremie concrete placement operations.

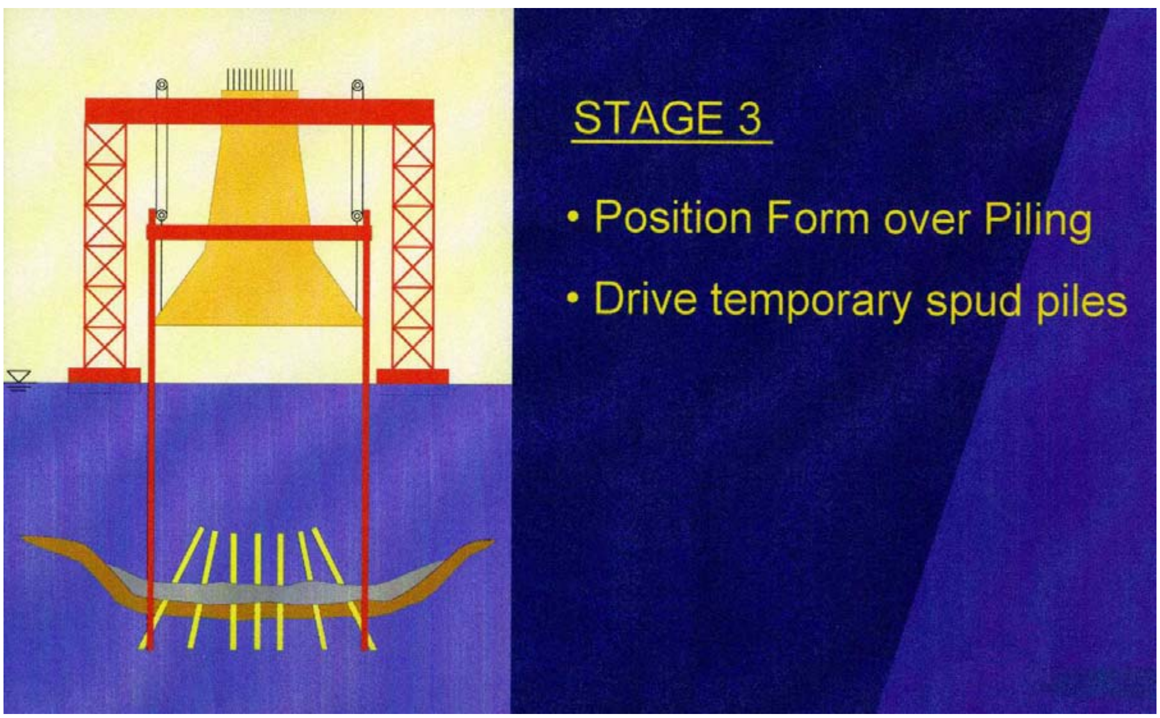
e. In Stage 5, a 2.7-m- (9-ft-) thick tremie concrete seal pour was made (Figure C-2e). Then, the form was dewatered, the top of the concrete was cleaned, a bottom reinforcing mat was placed, and the remaining concrete was placed in the dry. Then the form was stripped in one piece and the spud piles were removed.



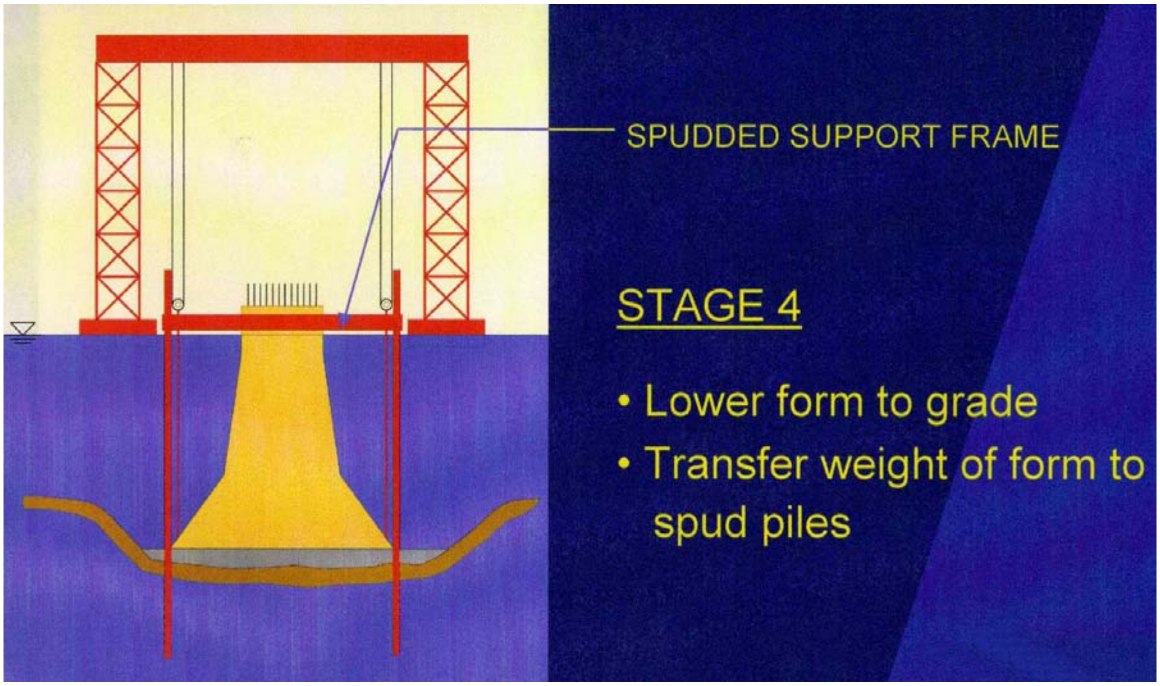
a. Stage 1
Figure C-2. Construction sequence for a typical pier for the I-205 Columbia River Bridge (Sheet 1 of 3)



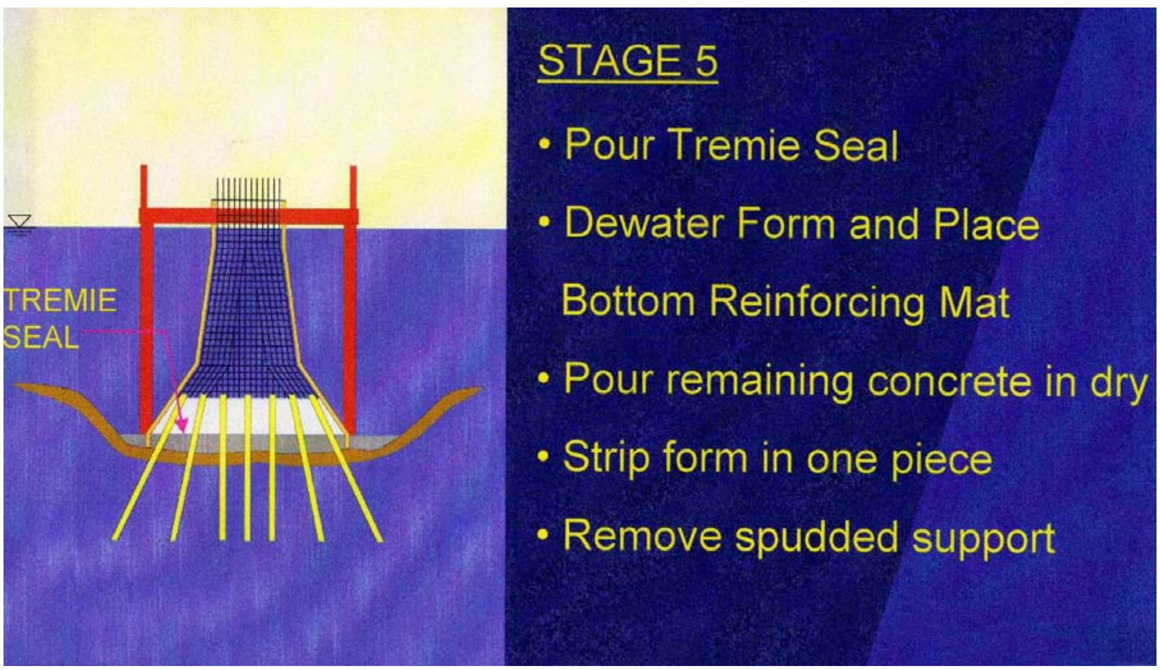
b. Stage 2



c. Stage 3
Figure C-2. (Sheet 2 of 3)



d. Stage 4



e. Stage 5
Figure C-2. (Sheet 3 of 3)

C-4. Eastern Scheldt Storm Surge Barrier

The Eastern Scheldt (Oosterschelde) storm surge barrier (Figure C-3) was the last stage of the Netherlands' Delta project designed to protect the Dutch lowlands from the sea. The Eastern Scheldt storm surge barrier was designed with 62 hydraulically actuated lift gates so that normally water could circulate into the estuary and the gates would be closed only during periods of storm surge to prevent flooding. The storm surge barrier is approximately 3 km (1.9 miles) long across three different tidal channels. It was completed in 1986. The site had a sandy foundation, which required vibro-densification, controlled dredging, and scour/piping protection by both sand/gravel-filled geotextile fabric and articulated concrete block mattresses. Following installation of the mattresses, the nominally 8,000-tonne- (8,800-ton-) capacity catamaran crane barge *Ostrea* lifted, transported, and placed on top of the mattresses partially buoyant prefabricated prestressed concrete pier shells that weighed up to 18,000 tonnes (19,840 tons).

Figure C-3. The Netherlands' storm surge barrier for the Eastern Scheldt

C-5. Prefabrication Facility Concept, Olmsted Dam

The feasibility level prefabrication facility shown in Figure C-4 is for the construction of precast concrete shells and associated items for the Olmsted Dam on the Ohio River. Although this facility is conceptual in nature, it exhibits several features that are important for the Olmsted Dam offsite prefabrication method:

a. Land-based skidways that allow precast concrete shells weighing up to 3,630 tonnes (4,000 tons) to be stored and moved forward as needed.

b. A marine skidway that allows the shells to be moved down the riverbank into water at various river stages.

c. A deep-water site that allows the shells to be partially submerged so that a nominally 2,540-tonne- (2,800-ton-) capacity crane barge can lift up to 3,630-tonne (4,000-ton) shells.

d. Provisions for auxiliary functions such as concrete production, reinforcing steel cage assembly, mattress fabrication, and fleeting areas.

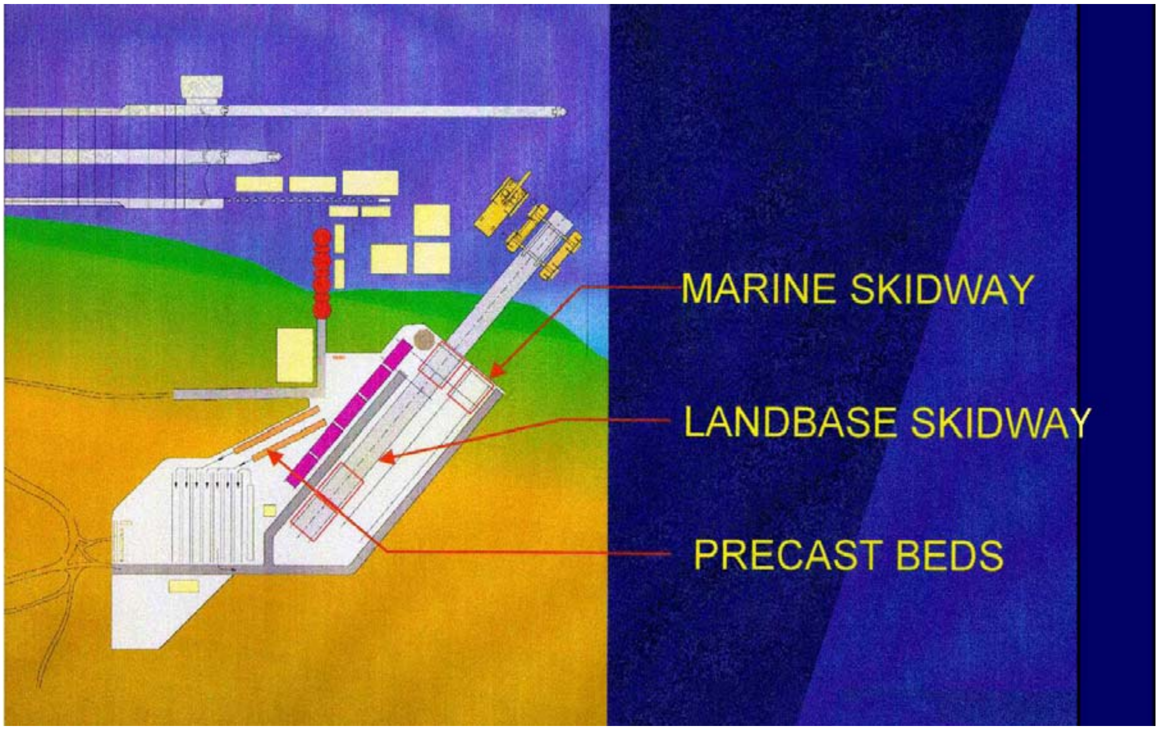


Figure C-4. Feasibility level layout of prefabrication facility for Olmsted Dam construction

C-6. Tremie Concrete Placement Concept, Olmsted Dam

The tremie concrete placement represented in Figure C-5 for the Olmsted Dam construction has several key aspects including the following:

- The tremie concrete is designed for low heat generation and uses blast furnace slag.
- The tremie concrete has good workability with a slump in excess of 254 mm (10 in.).
- Laitance from the tremie concrete is expelled through holes in the top of the shells.
- The tremie placement pattern is designed to reduce tremie concrete pressures on the shells, minimize the potential for the formation of voids in the tremie concrete, and assist with the placement of the tremie concrete from fixed points.

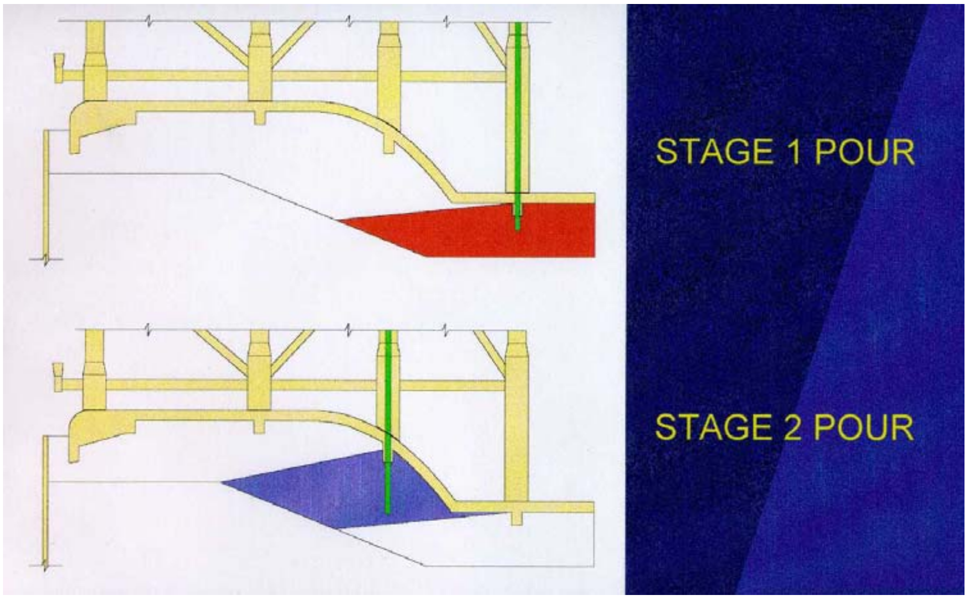


Figure C-5. Representative tremie concrete placements for Olmsted Dam

C-7. Wilbur Mills Dam

The Wilbur Mills Dam in Arkansas sustained severe damage to its stilling basin when floodwaters overtopped the dam. On an emergency basis, an in-the-wet method of repair was developed that used several used steel barges as stay-in-place forms for tremie concrete that was used together with preplace aggregate to fill the sunken barges. Figure C-6 shows how a nominally 1,450-tonne- (1,600-ton-) capacity catamaran crane barge was used to lower the barges weighted with concrete ballast to the bottom.

Figure C-6. Emergency repair operations for the Wilbur Mills Dam

C-8. Oresund Bridge

The Oresund Bridge crosses a strait in the Baltic Sea from Denmark to Sweden. The precast concrete caissons shown in Figure C-7 were cast in a graving dock. When the graving dock was flooded, a specialized catamaran crane barge floated over the caissons and lifted them, with the aid of self-buoyancy from the caissons, and transported them to the bridge site. Linear jacks on the catamaran were attached to the vertical pipes attached to the caissons (see Figure C-7). The rigidity of this lifting system helped to minimize the cross-bracing requirements for the catamaran.

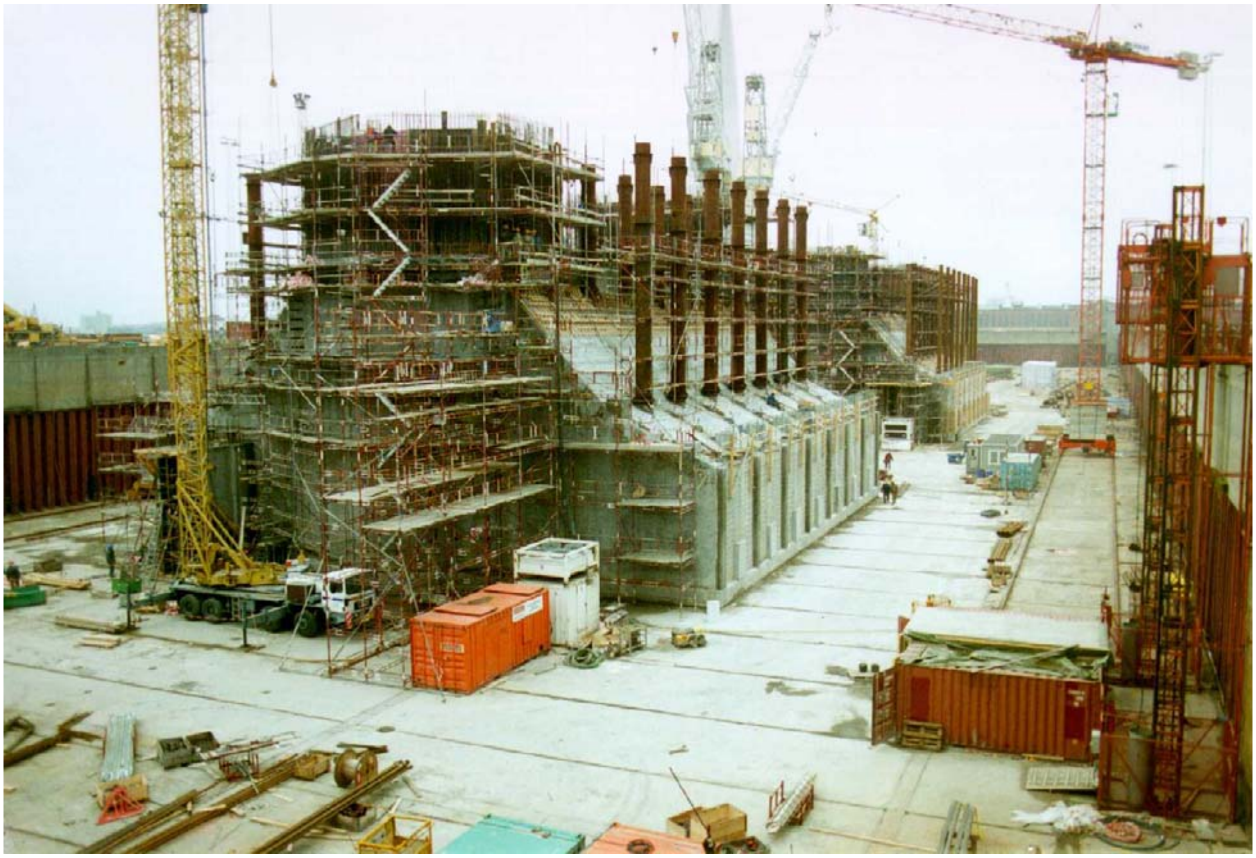


Figure C-7. Prefabrication of concrete bridge pier caissons for the Oresund Crossing

C-9. Immersed Tube Installation

The immersed, precast concrete tube segment shown in Figure C-8 illustrates several features typical of European-style designs and installation procedures, including the following:

- The tube segments typically use prestressed concrete with "Gina”-type rubber joint seals.

- Spotting towers are typically used to help locate the segments during submergence.

- Segmental pontoons are commonly used on top of the segments for both water plane stability and supplemental buoyancy during submergence.

Figure C-8. Typical European-style concrete immersed tube segment

C-10. Float-in, U-Frame Lock

The feasibility level concept shown in Figure C-9 for a float-in precast concrete lock extension was examined during a study for the Upper Mississippi River and Illinois Waterway System Navigation Study. For many of the locks in this area it is not feasible to shut down the single existing lock for an extended period while the lock is being extended. Key features of this concept are as follows:

- The U-shaped hull results in a stiff structure that can resist variations in water head with a minimum of lateral stiffness from the foundation.

- Once the foundations are complete, the entire lock extension can be floated in, set down, and stabilized in as little as a day.

- The individual segments composing the whole lock extension can be joined afloat to minimize the size of the offsite prefabrication facilities.

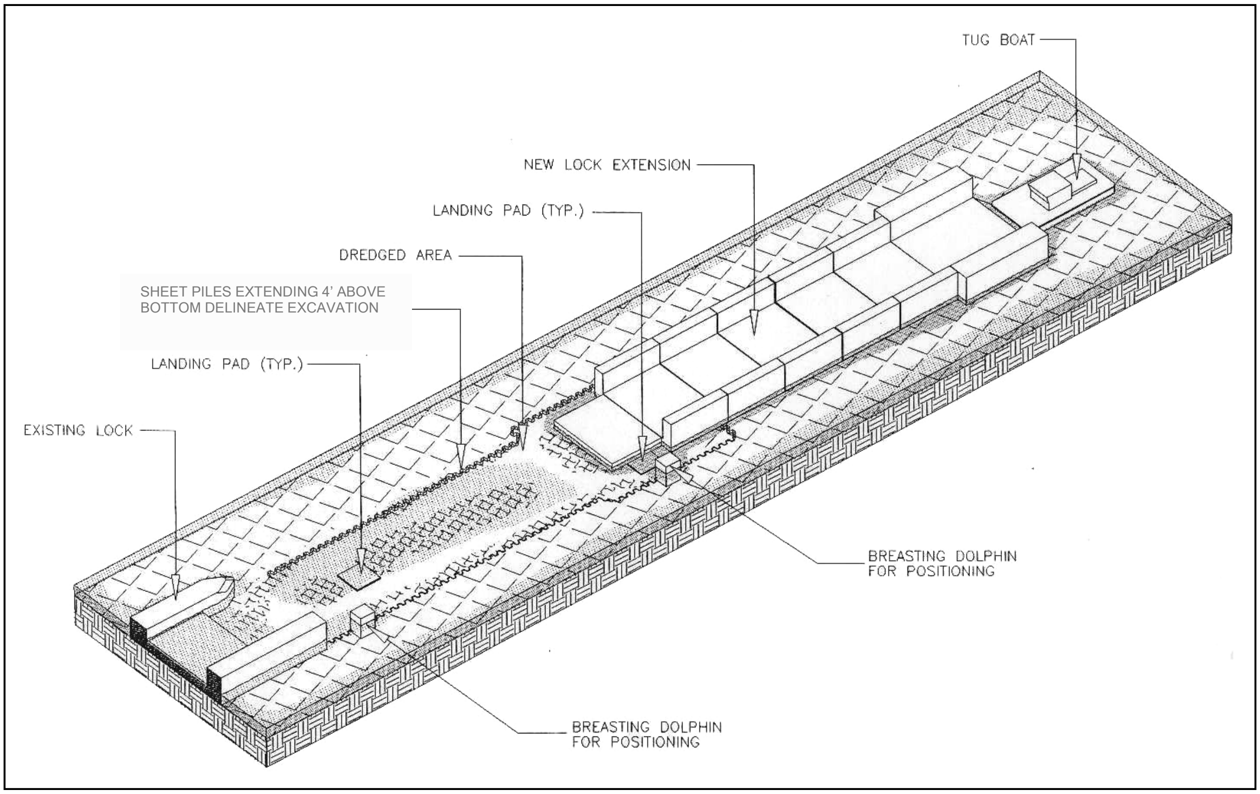


Figure C-9. Representation of a float-in U-shape concrete hull for a lock extension

C-11. Braddock Dam

a. Figure C-10 shows the offsite prefabrication of the Braddock Dam segments. This method of construction is designed to accommodate variations in river stage, while minimizing excavation and reducing the effects/delays from long-term flooding of an alternative such as a graving site. The casting basin is built in two levels so that the segments are built at the upper level. The casting basin is then flooded so that the segment can float over the lower level, where the water level is brought into equilibrium with the river stage, and the closure gate is removed so that the segments can be towed to the site.

b. Figure C-11 shows two images of segment assembly at the casting facility. Over 400 precast concrete panels were manufactured on this site and connected to form the walls of the two float-in dam segments. The bottom and top slabs of the segments and the joints between panels were completed with cast-in-place concrete placements. A combination of lightweight and normal-weight concrete was used to conserve weight for draft requirements.

c. Figure C-12 shows float-in dam segment transport along the inland waterways navigation system. The float-in segments were transported 43 km (27 miles) from the casting facility to the project site. The segments were appropriately sized to allow lockage through existing facilities.

d. Figure C-13 shows positioning of the float-in dam segment for Braddock Dam on the Monongahela River in Pennsylvania. A preinstalled mooring/positioning system further helps to control positioning of the units during the set-down operations.

e. Figure C-14 depicts a light lift-in approach used for completion of the Braddock Dam tailrace. Thirty-one panels weighing up to 60 tonnes (65 tons) complete the new dam tailrace. A program of tremie concrete infill provides for a solid mass beneath the panels. All installations were controlled with dive crews.

f. Figure C-15 shows the one-piece float-in installation of a tainter gate. This application varied from traditional methods in that field-assembled pieces of the gates were constructed within a dewatered gate bay.

a. Prefabrication site, Leetsdale, PA

b. Float-out or launch of the first segment of the dam
Figure C-10. Braddock Dam Casting Facility

a. Construction of dam Segment 1 within the two-level casting basin

b. Construction of dam Segment 2 within the two-level casting basin
Figure C-11. Assembly of float-in Braddock Dam at casting facility

a. Open-river transport of a dam segment

b. River miles from fabrication site to outfitting dock
Figure C-12. Segment transport of Braddock Dam

a. Initial positioning of dam Segment 1

b. Close-up of initial positioning of dam Segment 1
Figure C-13. Positioning of the first segment for Braddock Dam

Figure C-14. In-the-wet tailrace panel installation for Braddock Dam

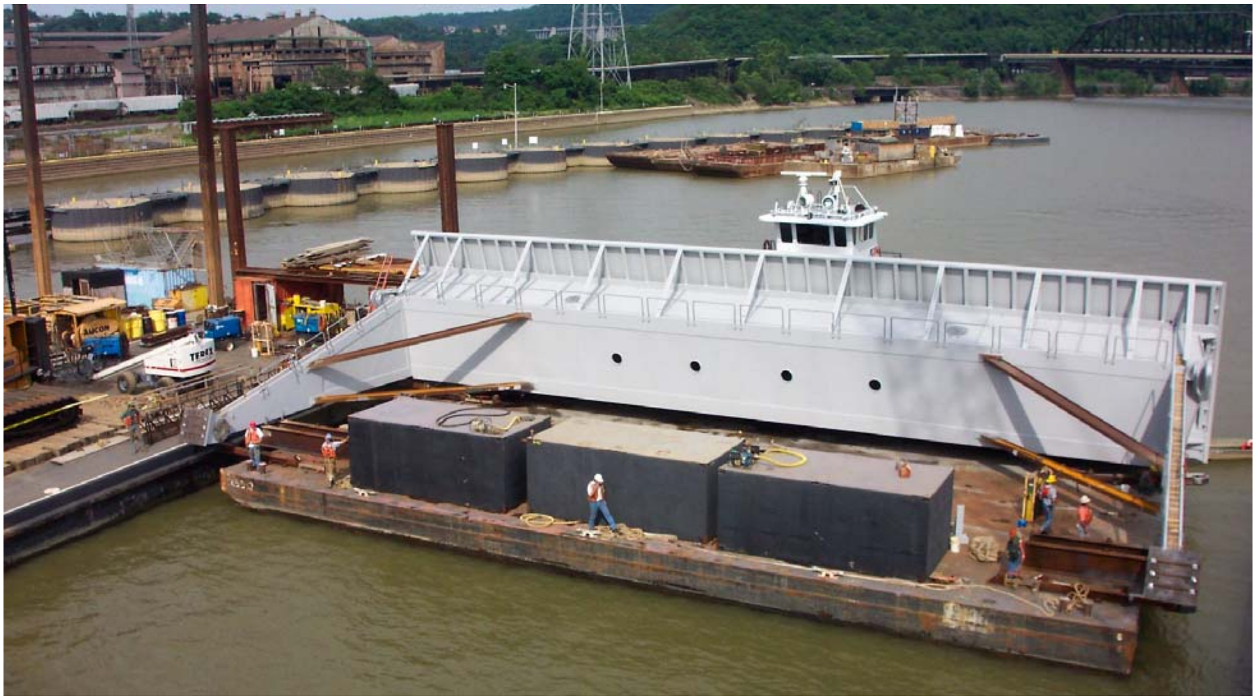


Figure C-15. One-piece float-in installation of tainter gate for Braddock Dam

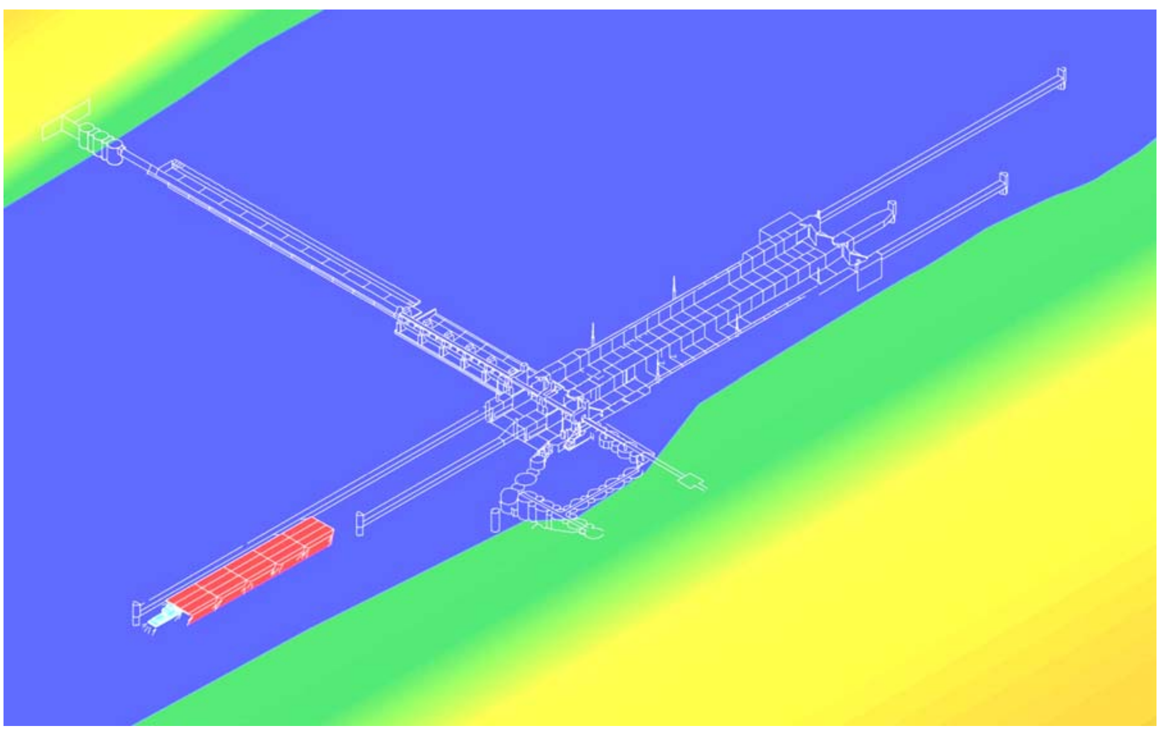
C-12. Olmsted Locks and Dam, Conceptual Construction Features

a. The Olmsted Locks and Dam Project (Figure C-16a) on the Ohio River is estimated to cost over one billion dollars. It will be the first locks and dam facility encountered when traveling upstream from the Mississippi River. The locks, with twin 3,936-m- (1,200-ft-) long chambers, were built within a sheet-pile cellular cofferdam, whereas both the approach walls and the dam are planned to be built using offsite prefabrication.

b. Figure C-16b illustrates how a catamaran crane barge can be used to install a precast concrete pier wall segment for Olmsted Dam. The pier wall segment is carried at the front of the crane barge to avoid interference with the previously built locks, which are not shown.

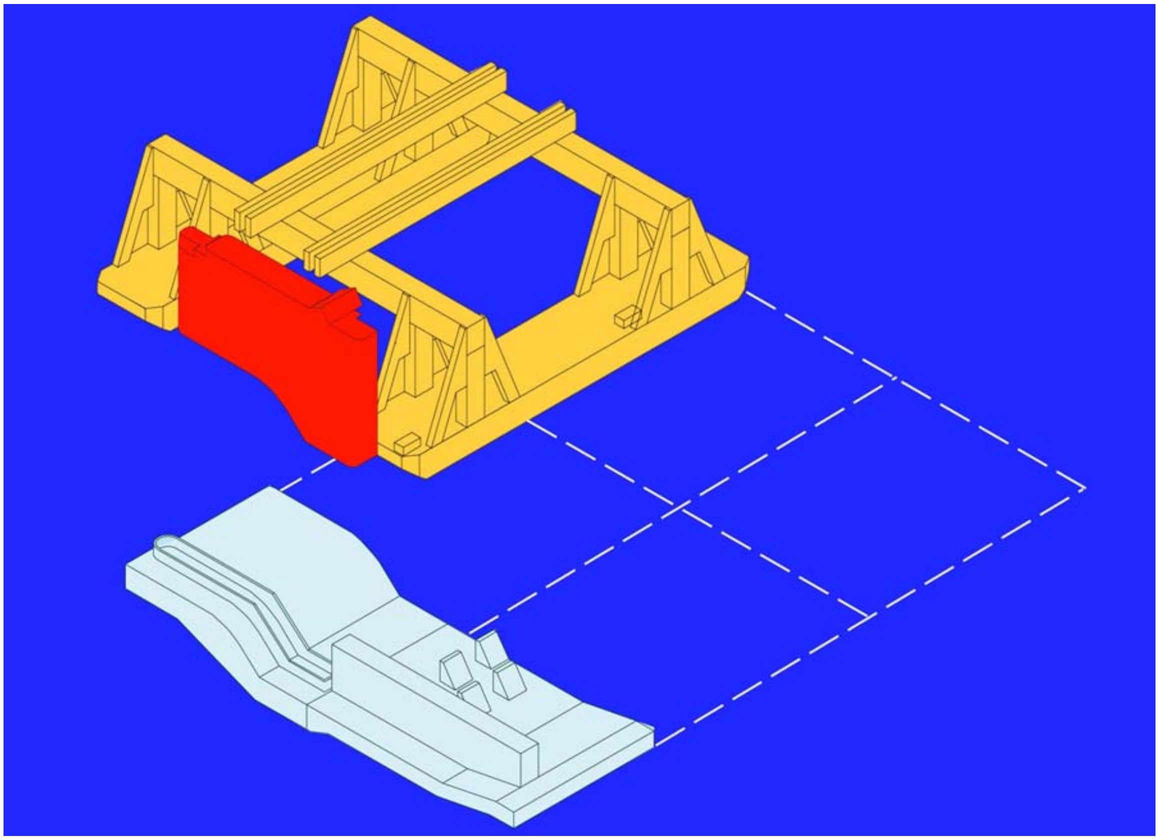
c. Figure C-16c illustrates several key aspects of a typical construction sequence for Olmsted Dam:

- Dredging and backfill operations are first executed for the sandy riverbed.
- The backfill is screeded to the appropriate tolerance.
- A mattress is then set down and piles are driven through it.
- Then, the shell is installed and tremied in place.

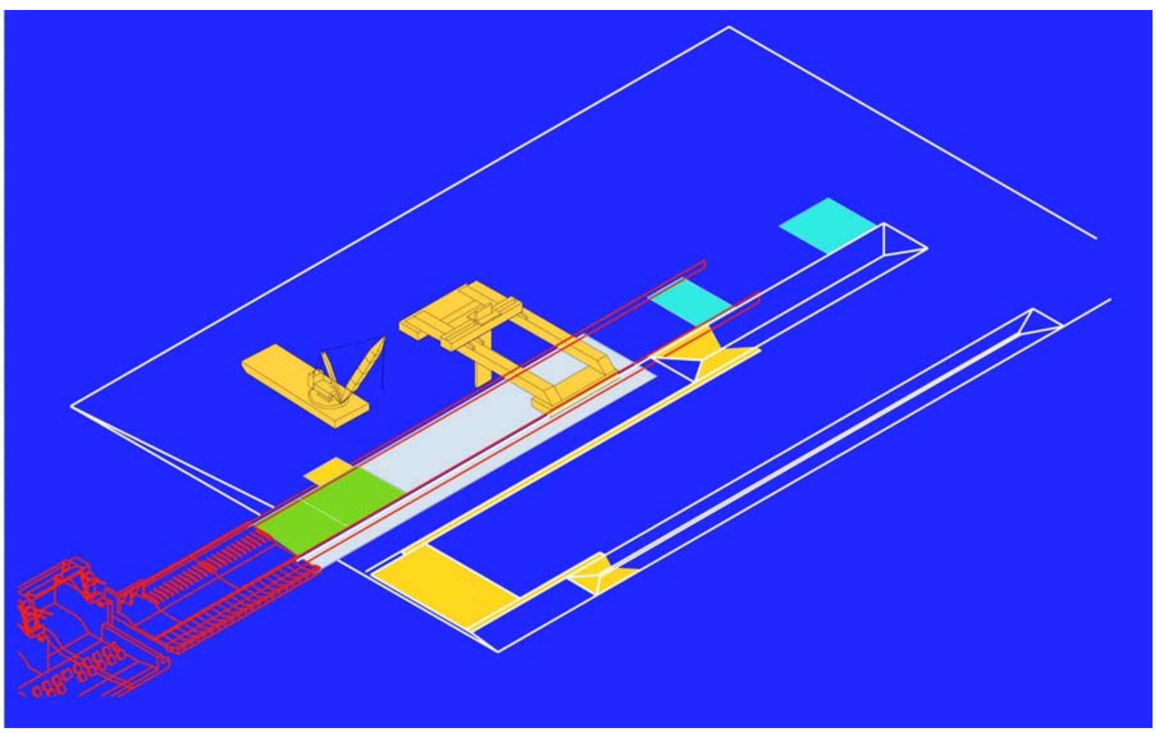


a. Representative overview

Figure C-16. Conceptual construction of Olmsted Locks and Dam, Ohio River (Continued)



b. Representation of the installation of a precast pier wall segment



c. Representation of the construction sequence for the navigable pass
Figure C-16. (Concluded)

C-13. Other Examples of Prefabricated Methods of Construction

Figures C-17 through C-22 illustrate projects that represent applications of the innovative construction methods described in this manual.

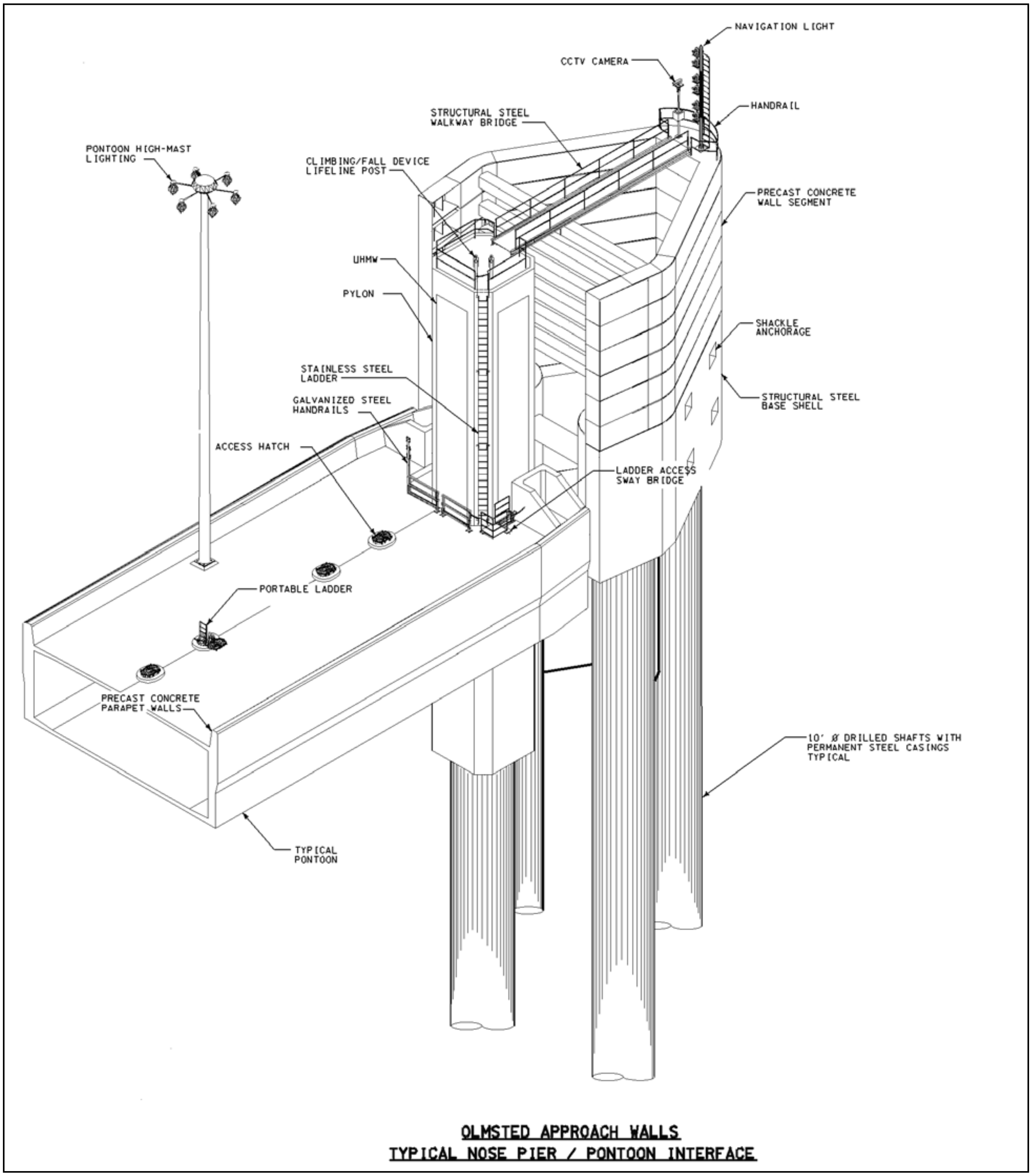


Figure C-17. Detail view of floating approach wall connection to nose pier, Olmsted approach walls. Approach wall is a hollow precast concrete shell fabricated offsite and connected to preinstalled piers

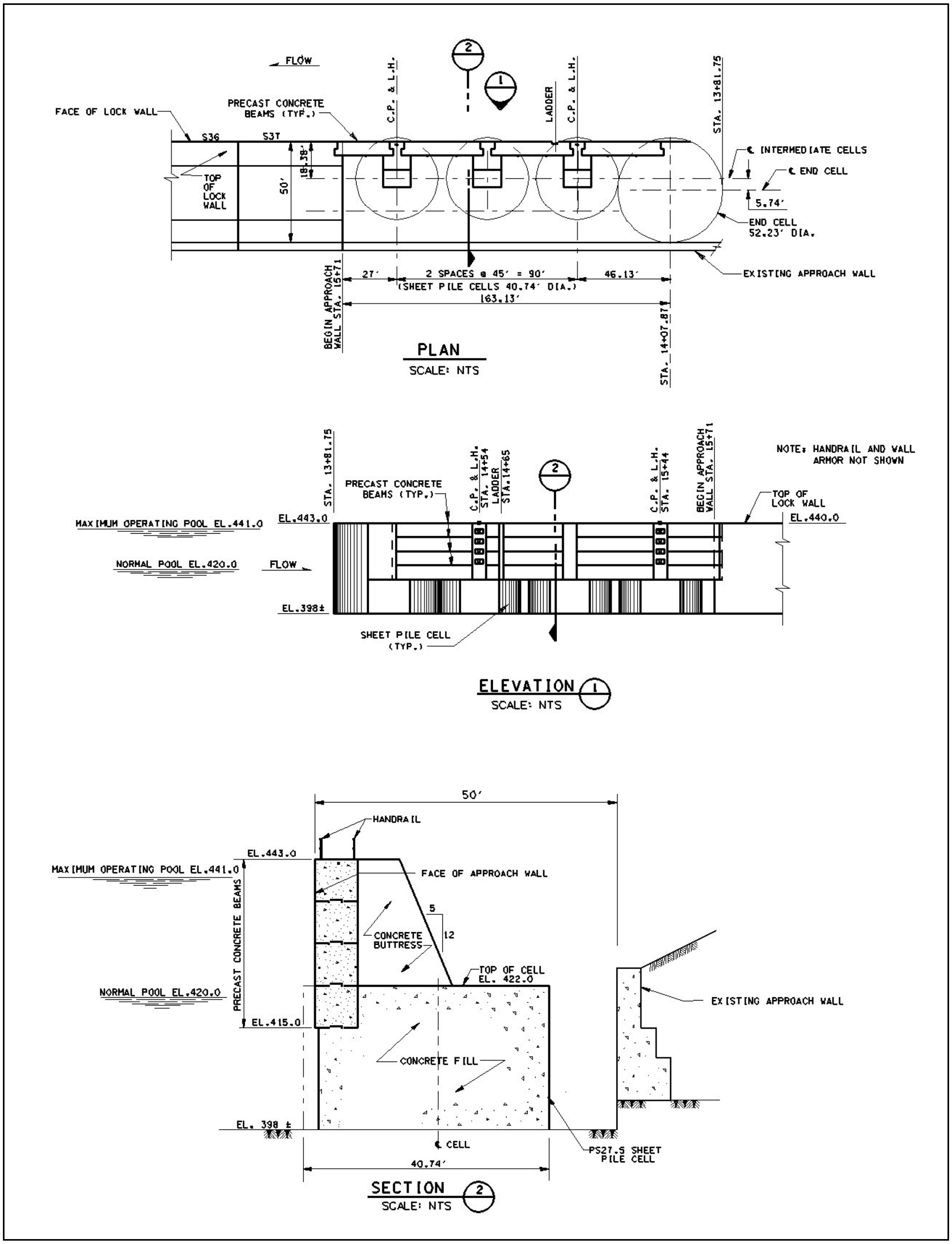


Figure C-18. McAlpine Lock upstream approach wall. Substructure is a concrete-filled sheet-pile cell founded on bedrock. The cell is installed in the wet and is outfitted to receive the first precast beam. The concrete buttress is built in the dry and transfers barge impact loads to the substructure

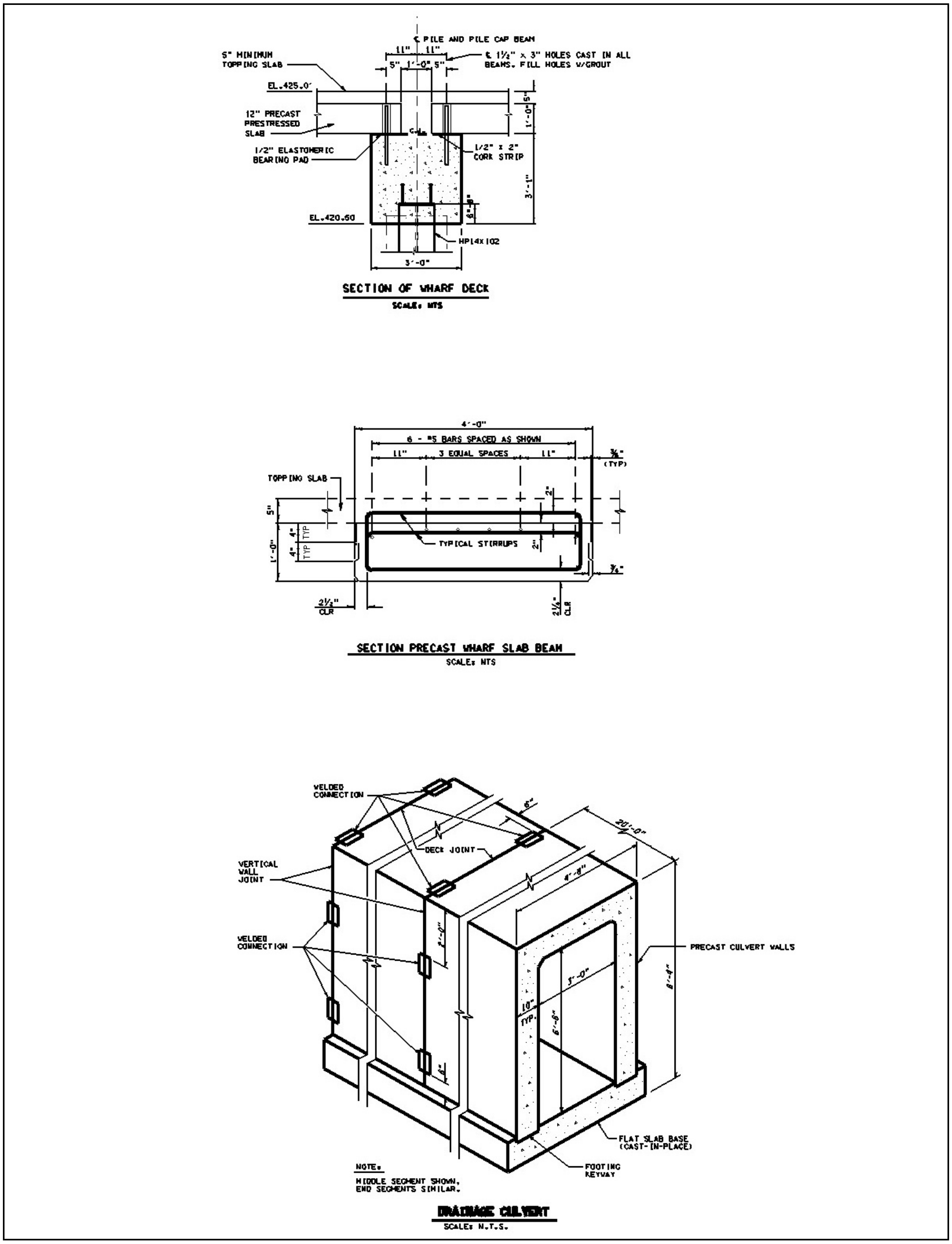


Figure C-19. McAlpine miscellaneous precast elements. Examples of other precast elements on McAlpine Lock

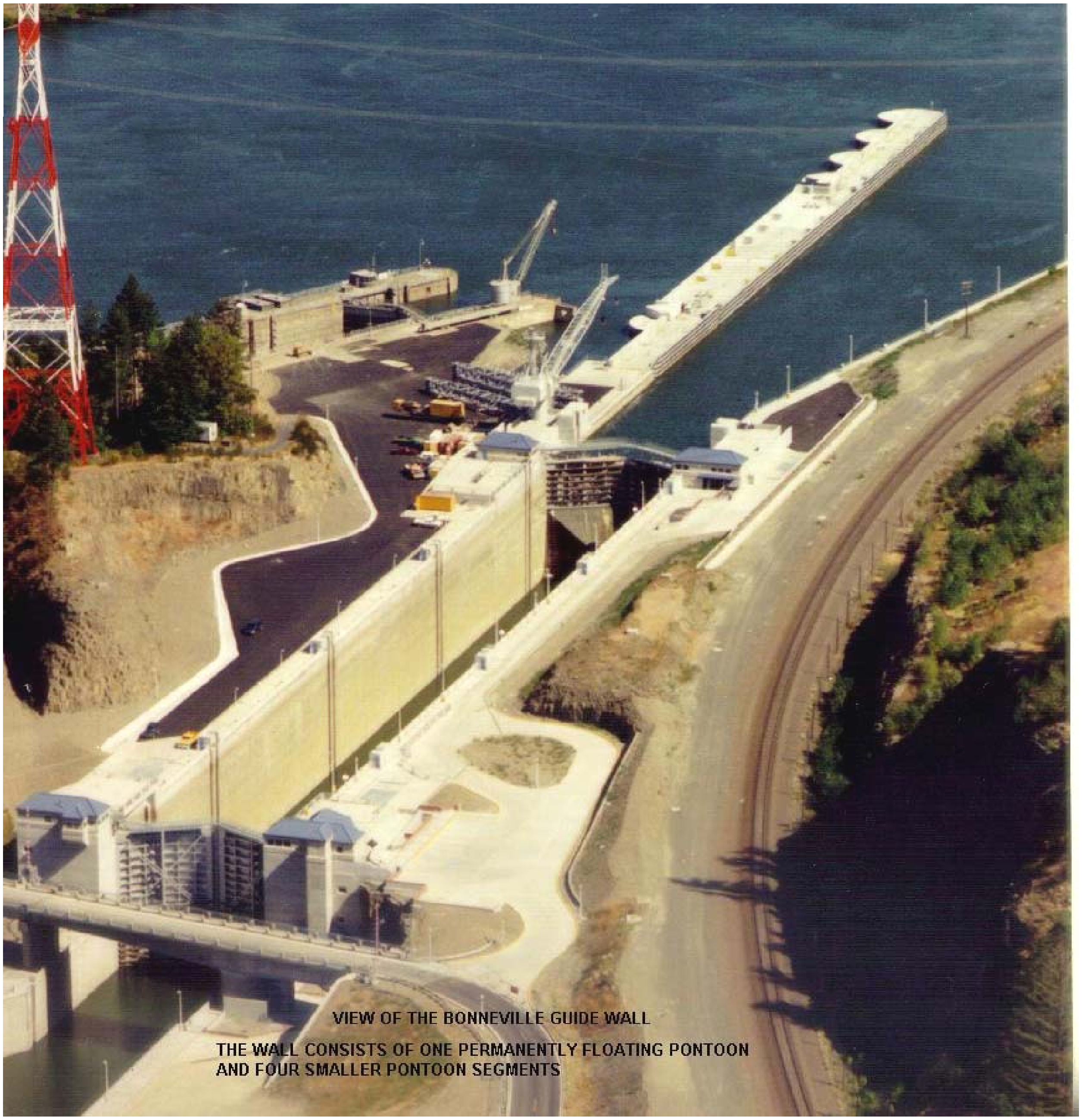


Figure C-20. General view of Bonneville Lock and floating upper approach wall

Figure C-21. Precast yard in Bordman, Oregon, for Bonneville Project. The contractor constructed a graving dock. The pontoons were fabricated, the site was flooded, and the pontoons were towed to Bonneville for installation

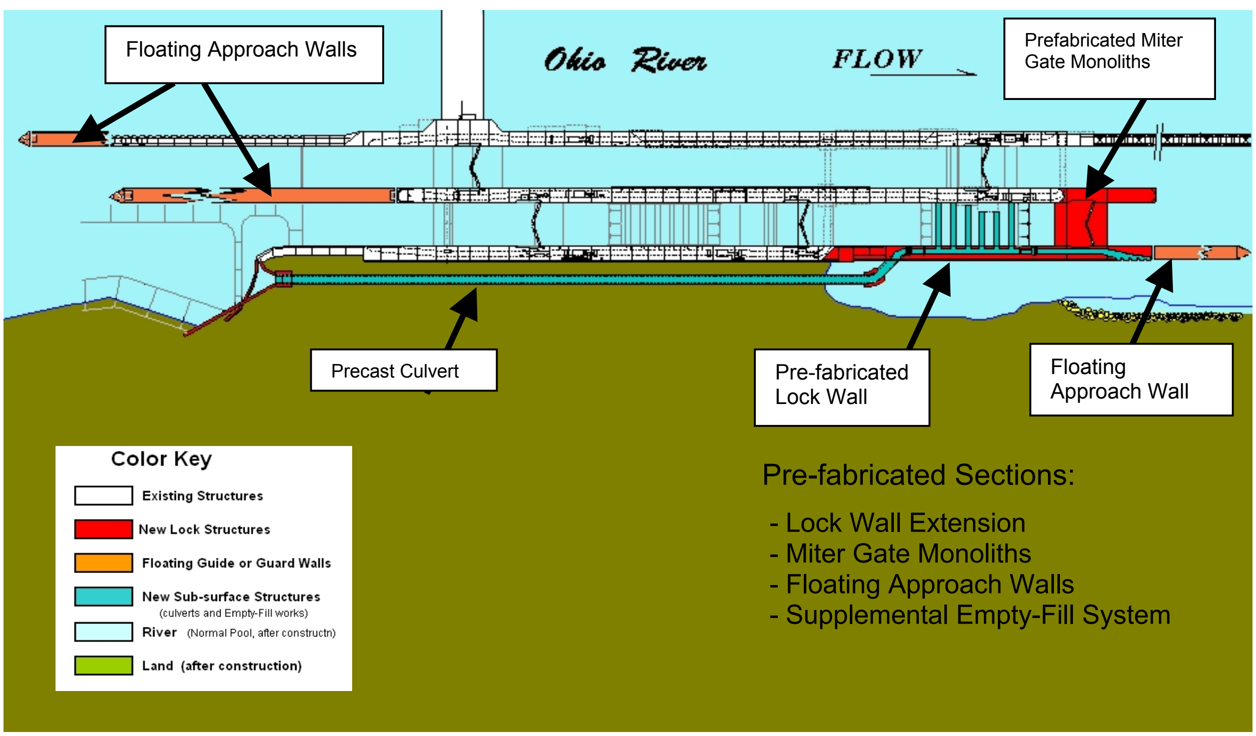


Figure C-22. Overview of prefabricated elements to be used for the Ohio River Main Stem Study