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	Engineering and Design DAM SAFETY PREPAREDNESS	
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US Army Corps
of Engineers

ENGINEERING AND DESIGN

DAM SAFETY PREPAREDNESS

ENGINEER PAMPHLET

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

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Engineering and Design
DAM SAFETY PREPAREDNESS

1. Purpose. This pamphlet provides general guiidance and information concerting dam safety preparedness within the Corps of Engineers.

2. **Applicability.** This pamphlet applies to HQUSACE elements, major subordinate commands, districts, laboratories, and separate field operating activities having responsibility for civil works projects.

FOR THE COMMANDER:

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Chief of Staff

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

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Chapter 1
Introduction

1-1. Purpose

This pamphlet provides general guidance and information concerning dam safety preparedness within the Corps of Engineers.

1-2. Applicability

This pamphlet applies to HQUSACE elements, major subordinate commands (MSC), districts, laboratories, and separate field operating activities having responsibility for civil works projects.

1-3. References

Required and related references are listed in Appendix A.

1-4. Glossary

Abbreviations and terms which may not be familiar to the reader are defined in Appendix B.

1-5. Objective and Scope

The objective of this pamphlet is to provide necessary background information, a detailed summary of regulations and guidelines and appropriate references pertaining to dam safety. This pamphlet will assist USACE elements in their preparation for and implementation of the USACE Dam Safety Program. While it is intended for internal use, portions are applicable for use in dam safety support provided to Army, Air Force and Navy installations.

1-6. Organization of Manual

General considerations in dam safety, civil works project process, operation and maintenance, rehabilitation of dams, emergency action plans (EAP), and training are covered in Chapters 2 to 7, respectively. Design, construction, and research and development, as related to dam safety, are covered in Appendixes C to E, respectively.

Chapter 2
General Considerations

2-1. Introduction

Although it is impossible to quantify the overall safety of a dam, the way to achieve maximum dam safety is well understood, i.e., to apply the utmost care and competence to every aspect of design, construction, operation, and maintenance. Therefore, the most important prerequisite for safety of dams is the professional competence of persons associated with the dam over its life span. A dam with a record of safe performance may still experience failure due to undetected deficiencies in the dam or in the foundation. Dam safety must take precedence over all other considerations (International Commission on Large Dams 1987; National Research Council 1985; Jansen 1983, 1988b).

2-2. History of Dam Safety

a. *Early development of dams.* History indicates that dams have been a vital part of civilization for more than 5,000 years. Dams were constructed by the early settlers in the United States in the 1600's to provide water supply and power gristmills and sawmills. The oldest Corps of Engineers dams are six lock and dams on the Green and Kentucky Rivers built between 1836 and 1844 (Reed 1987, Walz 1990a).

b. Dam safety. Although construction of dams dates back many years, the history of dam safety covers a much shorter time span. Only a limited number of states had any type of law regulating dam safety prior to 1900. The failure of the South Fork Dam at Johnstown, Pennsylvania, in 1889 resulting in 2,209 deaths had limited influence on the dam safety programs. California initiated a dam safety program following failure of the St. Frances Dam in 1928. Failures of the Buffalo Creek Dam in West Virginia and the Canyon Lake Dam in South Dakota in 1972 contributed to Congress passing "The National Dam Inspection Act" in 1972. Failure of Teton Dam in Idaho in 1976 was followed by "The Reclamation Safety of Dams Act" in 1977. Failure of the Laurel Run Dam in Pennsylvania and the Kelly Barnes Dam in Georgia in 1977 set in motion the development of the "Federal Guidelines for Dam Safety" issued in 1979 by the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) (discussed in paragraph 2-3) (Federal Emergency Management Agency 1979). In 1979, President Carter created the Federal Emergency Management Agency (FEMA) and directed Federal agencies to adopt and implement the Federal Guidelines for Dam Safety and report their progress to FEMA on a biennial basis. In 1980, the Interagency Committee on Dam Safety (ICODS) was formed to coordinate Federal activities and work with the states to ensure implementation of dam safety practices. The Corps of Engineers is the Department of Defense representative on ICODS. In 1984, the Association of State Dam Safety Officials (ASDSO) was organized to provide a forum for the exchange of information and ideas on dam safety and to foster interstate cooperation (Association of State Dam Safety Officials 1989). Nongovernment agencies actively dealing with dam safety include the International Commission on Large Dams (ICOLD) and its United States affiliate, the United States Committee on Large Dams (USCOLD) and the Electric Power Research Institute (EPRI) (Colorado Division of Disaster Emergency Services 1987; Tschantz 1982; Reed 1987; Walz 1990a; Wiseman 1987; Jansen 1988a; Government Accounting Office 1977, 1978; Duscha 1984, 1986, 1990).

2-3. Federal Guidelines for Dam Safety

a. In 1977, President Carter issued a memorandum directing three actions:

(1) That all Federal agencies having responsibility for dams conduct a thorough review of their practices which could affect the safety of these structures and report their findings to the FCCSET.

(2) That FCCSET prepare the "Federal Guidelines for Dam Safety" for use by all Federal agencies.

(3) That ICODS be established to promote and monitor Federal and state dam safety programs.

b. In 1979, the "Federal Guidelines for Dam Safety" was published, and ICODS was given oversight responsibility for dam safety. The key management practices outlined in these guidelines are as follows (Federal Emergency Management Agency 1979):

(1) Establish a Dam Safety Officer and appropriate staff.

(2) Maintain an updated inventory of dams.

(3) Document design criteria and construction activities.

(4) Prepare initial reservoir filling plans and reservoir regulation criteria.

(5) Prepare operation and maintenance instructions and document activities.

(6) Maintain a training and awareness program.

(7) Prepare and maintain EAPs for each dam.

(8) Establish a program of periodic inspections and evaluation of dams.

(9) Monitor and evaluate the performance of each dam and appurtenant structure and provide remedial construction as necessary.

2-4. Administration of Dam Safety in the Corps of Engineers

a. Dam safety at HQUSACE. In February 1980, the Chief of Engineers appointed the Chief of Engineering Division, Directorate of Civil Works, as the HQUSACE Dam Safety Officer. The Dam Safety Officer chairs a standing committee composed of individuals having assigned responsibilities for dam safety (ER 1110-2-1156). The Corps' Dam Safety Officer is also the Corps' member of FEMA's ICODS (Federal Emergency Management Agency 1988b).

b. Dam safety organization. The Corps of Engineers maintains a decentralized organization of three levels. Each level is staffed with qualified and experienced personnel in areas of design, construction, and operations of dams and appurtenant structures. Each level has a Dam Safety Officer and organization as follows (ER 1110-2-1156):

(1) HQUSACE.

(a) Organization. The standing dam safety committee members are as follows:

- Chief, Engineering Division, Directorate of Civil Works, Chairman.
- Chief, Engineering Division, Directorate of Military Programs.
- Chief, Operations, Construction and Readiness Division, Directorate of Civil Works.
- Chief, Geotechnical and Materials Branch, Engineering Division, Directorate of Civil Works.
- Chief, Hydraulics and Hydrology Branch, Engineering Division, Directorate of Civil Works.
- Chief, Structures Branch, Engineering Division, Directorate of Civil Works.
- Chief, Electrical and Mechanical Branch, Engineering Division, Directorate of Civil Works.
- Chief, Construction Branch, Operations, Construction and Readiness Division, Directorate of Civil Works.
- Chief, Policy Development Branch, Policy Review and Analysis Division, Directorate of Civil Works.

(b) Responsibilities. The Dam Safety Officer is responsible for ensuring that the Corps of Engineers maintains a proactive dam safety program and is implementing the Federal Guidelines for Dam Safety (Federal Emergency Management Agency 1979) in policy and practice and other duties as described in ER 1110-2-1156. The committee periodically reviews and evaluates design, construction, operation, maintenance, and rehabilitation programs to improve internal practices related to dam safety; reviews the status of EAPs and dam safety training; and reviews research and development programs to ensure that the latest technology receives consideration and evaluation. The committee meets at least semi-annually and makes periodic inspections and field visits as necessary. The committee ensures that the inventory of dams is current and adequately maintained and reviews research and development programs to ensure that the latest technologies related to dam safety receive consideration and evaluation (ER 1110-2-1156).

(2) Major Subordinate Commands (MSC).

(a) Organization. The MSC Dam Safety Officer is the Director of Engineering and Technical Services. The standing committee contains the chiefs of the same disciplines as that in HQUSACE.

(b) Responsibilities. The MSC Dam Safety Officer and committee are responsible for quality assurance coordination and implementation of the dam safety program within the MSC. The committee will conduct a minimum of two meetings per year. Their responsibilities include establishing dam safety related work priorities within the MSC, monitoring the status of EAPs, ensuring dam safety training is being conducted, ensuring that adequate data are submitted for the inventory of Corps dams, and conducting dam safety exercises (see ER 1110-2-1156).

(3) District Commands.

(a) Organization. The District Dam Safety Officer will be the Chief, Engineering Division. The standing committee will comprise the same disciplines as that in the MSC. However, the Dam Safety Officer may be located in a district responsible for the technical aspects of projects located within another districts boundaries (should a district organization not include an engineering division).

(b) Responsibilities. The District Dam Safety Officer and committee are responsible for the execution of the dam safety program. A minimum of two meetings will be held annually. Responsibilities include establishing a public awareness program with information at each project and coordination with downstream local interests, monitoring and evaluating the performance of all dams and appurtenant structures and recommending remedial measures when necessary, establishing the priority of dam safety related work, conducting dam safety training, and ensuring that each dam has an adequate surveillance plan (ER 1110-2-1156).

2-5. Applicable Dams

a. Dam involvement. The Corps of Engineers involvement in dams can be categorized as follows (ER 1110-2-1156, Federal Emergency Management Agency 1992a):

(1) Dams which the Corps has designed, constructed, operates, and maintains. Ownership remains with the Corps of Engineers.

(2) Dams which the Corps has designed and constructed but are owned, operated, and maintained by others.

(3) Dams that are designed, constructed, operated, maintained, and owned by others in which flood control storage has been provided at Federal expense under the authority of the 1944 Flood Control Act.

(4) Dams for which the Corps has issued permits under its regulatory authority.

(5) Dams inspected and evaluated by the Corps under the authority of the National Program for the Inspection of Non-Federal Dams, PL 92-367.

b. Dam safety. In category 1, the Corps of Engineers has a definite responsibility for dam safety. For dams in category 2, the primary responsibility for dam safety is with the agency or sponsor which accepts the project. The Corps' responsibility in this case is a supporting consultant role. In category 3, the Corps should participate in inspections to ensure that the Federal flood control interest is being properly maintained. For categories 4 and 5, the Corps has no responsibility for dam safety (ER 1110-2-1156, Federal Emergency Management Agency 1992a).

2-6. Modification of Dams

a. Programs. The bulk of Corps of Engineers dams are over 30 years old, and many dams are over 60 years old. Aging structures and advances in technology impact on the safety of dams and require detailed reevaluation and, in some cases, modification. Rehabilitation of Corps of Engineers dams is accomplished through four programs (ER 1110-2-1155, ER 1130-2-417, ER 1165-2-119, Federal Emergency Management Agency 1992b, Walz 1990a):

(1) Major Rehabilitation Program. This program allows significant, costly, one-time structural rehabilitation or major replacement work. This work restores the project to its original condition to serve as originally intended. Work under the Major Rehabilitation Program includes dams, locks, powerhouses, and breakwaters (ER 1130-2-417).

(2) Dam Safety Assurance Program. This provides for modification of completed dams when deemed necessary for safety purposes due to new hydrologic or seismic data or changes in the state-of-the-art design or construction criteria. This program is under the authority of Section 1203 of the Water Resources Development Act of 1986 (PL 99-662) and permits the project to function effectively as originally intended. Examples of work under this program include enlarging existing facilities or constructing new facilities to provide for modifications resulting from new hydrologic or seismic data or changes in state-of-the art design or construction criteria deemed necessary for safety purposes.

(3) Modifications to completed projects. Completed Corps projects are observed and monitored to ascertain whether they continue to function in a satisfactory manner and whether potential exists for better serving the public interest. When it is found that changes in a completed project may be desirable, investigations are undertaken to document the need for and feasibility of project modifications. To the extent possible, modifications to completed projects are accomplished under existing authorities. Significant modifications to completed projects involving new Federal construction or real estate acquisition in order to serve new purposes, to in crease the scope of services of authorized purposes beyond that intended at the time of project construction, or to extend services to new beneficiaries, require authorization by Congress. Additional information including eligible works, local protection projects, justification and cost sharing, and multiple purpose projects is given in ER 1165-2-119.

(4) Operation and maintenance authority. To properly operate the project or minimize maintenance, reasonable changes and additions to facilities, within the project boundaries, are made as needed as part of the Corps' operations and maintenance program (ER 1165-2-119). Operation and maintenance are discussed in detail in Chapter 4.

b. Reporting sequence. Under the Major Rehabilitation and Dam Safety Assurance Programs, investigations are conducted and reports prepared to determine the need for and scope of remedial measures, and to form the basis for obtaining construction funds. Reports are followed by more detailed investigations which are reported in design memoranda. The design memoranda form the basis for preparing plans and specifications for the remedial work. More detail regarding the Major Rehabilitation and Dam Safety Assurance Programs is given in Chapter 5.

2-7. Regulatory Permit Program for Non-Federal Dams

a. Dams and dikes. Section 9 of the River and Harbor Act of March 3, 1899, charges the Chief of Engineers and the Secretary of the Army to regulate the construction of any dam or dike across any navigable water of the United States. The term "navigable waters of the United States" means those waters of the United States that are subject to the ebb and flow of the tide shoreward to the mean high water mark (mean higher high water mark on the Pacific coast) and/or those presently used or have been used in the past or may be susceptible to use to transport interstate or foreign commerce. The term "dike or dam" means any impoundment structure that completely spans a navigable water of the United States and that may obstruct interstate waterborne commerce. The term does not include weirs. Dams and dikes in navigable waters of the United States also require Department of the Army (DA) permits under Section 404 of the Clean Water Act of 1977, as amended (33 U.S.C. 1344). (U.S. Army Corps of Engineers, Office of the Chief of

Engineers 1977). Processing a DA application under Section 9 will not be completed until the approval of the United States Congress has been obtained if the navigable water of the United States is an interstate water body, or until the approval of the appropriate state legislature has been obtained if the navigable water of the United States is an intrastate water body (i.e., the navigable portion of the navigable water of the United States is solely within the boundaries of one state).

b. Dredged or fill material. Section 404 of the Federal Water Pollution Control Act Amendments of 1972 charges the Secretary of the Army, acting through the Chief of Engineers, to regulate the discharge of dredged or fill material in the waters of the United States. The construction of dams, dikes, etc., is considered to be a discharge of fill material under Section 404. On March 27, 1975, the U.S. District Court for the District of Columbia directed the Corps of Engineers to extend its responsibility to regulate the discharge of dredged or fill material under Section 404 to all waters of the United States (including territorial seas) and to revise its regulation accordingly. The term "waters of the United States" is a much broader term than "navigable waters of the United States." A final regulation was published on July 19, 1977 (U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977).

c. Documentation for safety. Safety is one of the factors considered in reaching public interest decisions on applications for permits. The applicant for a permit to construct a dam is required to furnish documentation in order that the Corps may verify that the proposed dam has been designed for safety. No specific design specification or criteria are prescribed, and no independent detailed engineering reviews are performed. Further information on permit regulation and dam safety is given in Permit Regulation 33 Code of Federal Regulation 320.4(k) (U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977).

Chapter 3
Civil Works Project Planning and Design Process

3-1. General

The civil works planning and design process for a new dam is continuous, although the level of intensity and technical detail varies with the progression through the different phases of project development and implementation. The phases of the process are reconnaissance, feasibility, preconstruction engineering and design (PED), construction and finally the operation, maintenance, repair, replacement and rehabilitation (OMRR&R). A brief description is given below. For more detailed guidance regarding each phase, refer to ER 1110-2-1150.

3-2. Problem Perception and Study Authorization

The typical civil works project has its beginning when a problem is perceived or experienced which is beyond the capability of local interests to alleviate and therefore Federal assistance is requested. At the request of one of its members, Congress may authorize a study of the problem (ER 1105-2-100).

3-3. Reconnaissance Phase

A reconnaissance study is conducted to determine whether or not the problem has a solution acceptable to local interests for which there is a Federal interest and if so whether planning should proceed to the feasibility phase. The reconnaissance study is Federally funded and is limited to 12 months with extension to 18 months under unusual circumstances. During the reconnaissance phase, engineering assessments of alternatives are made to determine if they will function safely, reliably, efficiently and economically. Each alternative should be evaluated to determine if it is practical to construct, operate, and maintain. Several sites should be evaluated and preliminary designs prepared for each site for cost estimating purposes. These preliminary designs should include the dam, the foundation for the dam and appurtenant structures and the reservoir rim. The reconnaissance phase consists of preparing and reviewing proposed project plans, structuring the project features into the code of accounts, developing preliminary cost estimates, holding a Reconnaissance Review Conference (RRC) with a Technical Review Conference (TRC), if appropriate, and developing the engineering effort and budget required for the feasibility phase and the Initial Project Management Plan (IPMP). The reconnaissance phase ends with certification of the reconnaissance report.

3-4. Feasibility Phase

A feasibility study is conducted to investigate and recommend a solution to the problem based on technical evaluation of alternatives and includes a baseline cost estimate and a design and construction schedule which are the basis for congressional authorization. The feasibility study is cost-shared with the local sponsor and should be completed in 3 to 4 years. All of the project OMRR&R and dam safety requirements should be identified and discussed with the sponsor and State during the feasibility phase. A turnover plan (discussed in paragraph 3-1h), for non-Federal operated dams, that establishes a definite turnover point of the dam to the sponsor should be documented in the IPMP and in the Feasibility Report (ER 1105-2-100).

3-5. Preconstruction Engineering and Design Phase

The PED phase is conducted to verify, complete and document detailed design studies of a project as authorized or proposed with the Feasibility Report. Design costs for the PED phase are shared in the same percentage as construction. During the PED phase, which generally requires a period of about 2 years, activities necessary to ready the project for construction including preparation of plans and specifications (P&S) for the first construction contract are completed. It may be determined during the PED phase that a General Design Memorandum (GDM) or General Reevaluation Report (GRR) is necessary because the project has changed substantially since administration review of the feasibility report (with engineering appendix) or authorization, the project was authorized without a feasibility report, there is a need to readdress project formulation, or there is a need to reassess project plans due to changes in administration policy (ER 1110-2-1150 will be followed).

3-6. Construction Phase

This phase not only involved the actual construction of the project features, but includes design and preparation of P&S for subsequent construction contracts, review of selected construction contracts, site visits, support for claims and modifications, development of operation and maintenance (O&M) manuals, and preparation and maintenance of as-built drawings (ER 1110-2-1150).

3-7. Operation and Maintenance Phase

The project is operated, inspected, maintained, repaired, and rehabilitated by either the non-Federal sponsor or the Federal government, depending upon the project purposes and the terms of the Project Cooperation Agreement (PCA). For PCA projects and new dams turned over to others, the Corps needs to explain up front the O&M responsibilities, formal inspection requirements, and responsibilities to implement dam safety practices.

3-8. Turnover of Completed Dam Projects to Local Sponsors

As a result of the Water Resources Development Act of 1986, a number of flood control and multipurpose dams have been authorized subject to the provision that the local sponsor is responsible for OMRR&R (see ER 1165-2-131).[1] All project OMRR&R and dam safety requirements must be identified and discussed with the local sponsor during the feasibility phase and documented in the IPMP and Feasibility Report. The local sponsor must comply with all State and Federal dam safety requirements. As the project design develops and the O&M manual is prepared, the sponsor should provide input and review the draft document. The sponsor should be made aware of its responsibilities for providing an adequate operational and technical staff or appropriate engineering services contract for project security, performance data, and timely remedial measures as required. The turnover of the project to the sponsor will occur immediately after the first periodic inspection. The sponsor must be made aware that after transfer of the project, the Corps is in a supporting role with respect to dam safety and will only participate in inspections and review performance data.

[1] Guidance on policy and procedures for the turnover of completed dam projects to local sponsors is given in Policy Guidance Letter No. 39, "Responsibilities of the Corps of Engineers and Local Sponsor to Ensure Safe Operation, Maintenance, Repair, Replacement and Rehabilitation for Flood Control and Multipurpose Dams Constructed Under the Provisions of PL 99-662," dated 13 November 1992.

Chapter 4
Operation and Maintenance

4-1. General

Problems may occur following many years of trouble-free operation of a dam. This is particularly so for flood control dams which may not be tested by a significant percentage of the maximum head for many years. Also, any period of prolonged severe storming or severe operation such as rapid drawdown warrants additional attention during and immediately after the operation. This is particularly true for control structures such as spillways, conduits, channels, and associated machinery. Another category of higher risk involves those dams of advanced age which may be progressively deteriorating. Rigorous and continuous vigilance, checking, and inspection, for as long as the dam is operational, are necessary for dam safety (James 1990, International Commission on Large Dams 1987, Morrison-Knudsen Engineers 1986, Schurer 1988). Dam operations management policy is covered in ER 1130-2-419.

4-2. Operation and Maintenance Manual

The O&M manual is prepared during the construction phase. The purpose of the O&M manual is to provide guidance and instructions to project personnel for proper operation and maintenance of the facility. A general outline for the O&M manual is given in Appendix I to ER 1130-2-304. The O&M manual contains a narrative summary of the critical features of the dam including design features with safety limits, the more probable failure modes that could lead to structure failure, and a history of problems and how they could adversely affect the structure under stress (ER 1130-2-419).

4-3. Instrumentation and Monitoring

All Corps of Engineers dams are required to have an adequate level of instrumentation to enable the designers to monitor and evaluate the safety of the structure during the construction period and under all operating conditions and furnish data on behavior for application to future designs. Eachstructureisprovided with minimum instrumentation to measure hydrostatic pressure, embankment seepage, and foundation underseepage and displacement of major elements of the structure. Strong motion accelerometers are installed in structures located in seismic regions. In the case of older structures, which were designed using criteria that have been revised due to changes in the state-of-the-art, instrumentation provides most of the data necessary to evaluate the safety of the structure with respect to current standards and criteria. After a project has been operational for several years, scheduled maintenance, repair, and replacement of instrumentation are included in the normal plan of operation (ER 1110-2-110). Detailed information on instrumentation for earth and rockfill dams is given in EM 1110-2-2300 and EM 1110-2-1908. Information on instrumentation for concrete dams is given in EM 1110-2-2200 and EM 1110-2-4300 (see also Lindsey et al. 1986, Keeter et al. 1986, Currier and Fenn 1986, and O'Neil 1989). Full reliance is not placed on instrumentation to forecast unsatisfactory performance, since it is impractical to install enough instrumentation to monitor every possible problem area. An extremely important adjunct to an adequate instrumentation program is visual observation to determine evidence of distress (Duscha 1982). Project personnel receive extensive training in basic engineering considerations pertaining to major structures, with procedures for surveillance, monitoring, and reporting of potential problems, and with emergency operations (discussed in Chapter 7).

4-4. Initial Reservoir Filling

a. General. The "initial reservoir filling" is defined as a deliberate impoundment to meet project purposes and is a continuing process as successively higher pools are attained for flood control projects. The initial reservoir filling is the first test of the dam to perform the function for which it was designed. In order to monitor this performance, the rate of filling should be controlled to the extent feasible, to allow as much time as needed for a predetermined surveillance program including the observation and analysis of instrumentation data (Duscha and Jansen 1988). A DM on initial reservoir filling has been required for all new Corps of Engineers reservoir projects since 1979.

b. Design memorandum. As a minimum, the DM on initial reservoir filling will include:

(1) The preferred filling rate and the available options to control the rate of reservoir rise.

(2) The surveillance necessary to detect most likely occurring problems.

(3) A plan for reading the instruments and evaluating the data.

(4) A plan for inspecting the dam and down stream areas.

(5) Instructions for observers on conditions that require immediate attention of personnel authorized to make emergency decisions.

(6) An emergency plan listing responsibilities, name, and/or positions, telephone numbers and radio frequencies to be used.

c. Existing Corps reservoir projects. Existing operational projects, where the maximum pool (top of flood pool) has not been experienced, will be reviewed for compliance with requirements as outlined in paragraph 4-4.*b*. For those conditions where contingency plans have not been documented and potential danger exists due to filling and/or impounded storage, a report is required outlining those plans. The document may be titled "Flood Emergency Plan" providing that additional initial filling requirements are deemed not to have significant potential impacts on the safety of the structure (EM 1110-2-3600).

4-5. Periodic Inspection and Continuing Evaluation

a. General. A formal program for periodic inspection and continuing evaluation of completed Corps of Engineers projects was established in 1965. Under this program, structures whose failure or partial failure would endanger the lives of the public or cause substantial property damage are periodically evaluated to ensure their structural safety, stability, and operational adequacy. Inspections and evaluations are performed by teams of experienced design, construction, and operations engineers. The evaluations are aided by instrumentation programs (Duscha 1982). Instructions for periodic inspection and continuing evaluation of dams are given in ER 1110-2-100. Additional information on inspection of dams is available (Federal Emergency Management Agency 1979, Colorado Division of Disaster Emergency Services 1987, Reed 1987). The periodic inspection program has one potentially dangerous aspect in that engineers might be tempted to place too much reliance on it and assume that a project once inspected has a guarantee of safety until the next inspection. The thorough occasional inspection is invaluable but cannot take the place of day-to-day observation by operating personnel for detection of potentially dangerous problems at an early and repairable stage (James 1990).

b. Scope of inspections. Corps of Engineers civil works structures such as dams, powerhouses, and appurtenant dam structures (intake and outlet works, spillways, and tunnels) will be periodically inspected in accordance with procedures in Appendix A of ER 1110-2-100 to detect conditions of significant distress or operational inadequacy.

c. Frequency of inspections. The first periodic inspection is carried out immediately after topping out and prior to impoundment of the pool for new earth and rock-fill dams. The initial inspection of concrete dams is accomplished immediately prior to impoundment of reservoir water. The second inspection for new earth and rock-fill dams is made at a reasonable stage of normal operating pool. The second inspection of concrete dams is made when the reservoir water attains the normal operating pool, and in either case no later than one year after initial impoundment has begun. Subsequent inspections for earth and rock-fill dams and concrete dams are made at one-year intervals for the following three years, at two-year intervals for the next four years and then extended to five-year intervals if warranted by the results of the previous inspections (ER 1110-2-100).

d. Procedure. A systematic plan is established for the inspection of features related to the safety and stability of the structure and to the operational adequacy of the project. Operational adequacy means the inspecting, testing, operating, and evaluation of those components of the project whose failure or failure to operate properly would impair the operational capability and/or usability of the structure. These components include, but are not limited to:

(1) Flood and outlet control gates (including flood gates in levees and flood walls).

(2) Navigation lock gates and valves.

(3) Emergency closure gates.

(4) Associated hoists and operating machinery (including safety devices such as limit switches and fail-safe interlocks).

(5) Flood control pumps and related equipment.

(6) Cathodic protection systems.

Details concerning the systematic inspection plan are given in Appendix A of ER 1110-2-100.

e. Reports.

(1) Pre-inspection brochure. A technical brochure is prepared in advance of each project inspection to familiarize inspection team members with general features of the project. This brochure includes a technical summary of the structural, material, and foundation conditions; instrumentation data; and a list of the deficiencies found in previous inspections, if pertinent, and the status of remedial actions recommended. Also, the brochure should include, as appropriate, pertinent project data, layout and typical section drawings, summaries of subsurface soil profiles and boring logs, and the checklist developed for conducting the inspection (ER 1110-2-100, Duscha and Jansen 1988).

(2) Initial and subsequent reports. A condition report will be prepared to present the results of each general project inspection. Report No. 1 (report of initial inspection) will provide a general project description and present the results of the initial inspection. Reports of subsequent inspections will be supplementary to the initial report and will focus on changed conditions noted since the previous inspection. A status report on recommended remedial measures not completed prior to approval of the previous inspection report will also be included (ER 1110-2-100, Duscha and Jansen 1988).

4-6. Reporting Distress

a. Guidance. Evidence of distress at, or potential failure of, dams is to be reported in accordance with the guidance set forth in ER 1110-2-101. Evidence of distress will be immediately reported to the district office. Where engineering evaluation of the evidence of distress indicates the need for immediate remedial action, the district commander will immediately report such conditions through command channels to the HQUSACE Dam Safety Officer who is the Chief of the Engineering Division, Directorate of Civil Works. Each USACE Command will also establish procedures for notification of the major subordinate command and district Dam Safety Officer and coordination of all information with their counterparts in the Emergency Management element. The HQUSACE Dam Safety Officer will notify the Director of Civil Works, and the Commander, USACE. If the HQUSACE Dam Safety Officer cannot be contacted, the reporting field office will follow the notification sequence as outlined in Appendix A of ER 1110-2-101.

b. Examples. Examples of evidence of distress include, but are not limited to:

(1) Significant sloughs, settlement, or slides in embankments such as earth or rockfill dams, urban levees, and bridge abutments or slopes of spillway, channels, locks, and dam abutments.

(2) Evidence of piping, muddy water boils in the area of a structure such as embankments, abutments, dam monoliths, lock walls, or cofferdams.

(3) Abnormal increase or decrease of flow from foundation drains, structural joints, or face drains of concrete dams.

(4) Any increase in seepage quantities through or under embankments or in abutments.

(5) Any increase or decrease in pore water pressure in either embankments or their foundations or abutments.

(6) Any increase or decrease in uplift pressures under concrete structures.

(7) Unusual vertical or horizontal movement or cracking of embankments or abutments.

(8) Significant cracking of mass concrete structures either during construction or after completion.

(9) Sinkholes or localized subsidence in the foundation of or adjacent to embankments or other structures.

(10) Excessive deflection, displacement, or vibration of concrete structures (e.g. tilting or sliding of intake towers, bridge piers, lock wall, floodwalls).

(11) Erratic movement, binding, excessive deflection, or vibration of outlet and spillway gates.

(12) Significant damage to any structure (e.g., barge damage to bridge piers or lock walls or ice flow damage to intake towers and access bridge piers).

(13) Significant damage to, or changes in, structures, foundations, reservoir levels, groundwater conditions, and adjacent terrain as a result of seismic events of local or regional areas. Special inspections of such damages will be made immediately following the event as described in ER 1110-2-1802.

(14) Any other indications of distress or potential failure that could inhibit the operation of a project or endanger life or property.

(15) Excessive vibration, binding, unusual noises, movements, or deflections of gate hoist operatiing equipment.

(16) Actual hydraulic equipment operating pressure in excess of 125 percent of the normal operating pressure. Electric motor operating equipment overheating or stalling.

(17) Erratic movement or unusual sounds, such as bumping, jumping, or popping of lock miter gates.

(18) Wire rope lifting cables or lifting chains having broken strands or deformed, worn, or severely corroded links.

(19) Frequent power interruptions.

(20) Excess movement of penstock flexible couplings.

(21) Penstocks or turbine spiral cases that show signs of distress such as deformation or cracking.

(22) Failure of major mechanical or electrical equipment at local flood protection projects.

Chapter 5
Rehabilitation and Modification of Dams

5-1. Dam Safety Rehabilitation

Rehabilitation or modification of Corps of Engineers dams for safety purposes is accomplished through the Major Rehabilitation Program and the Dam Safety Assurance Program.

5-2. Major Rehabilitation Program

The Major Rehabilitation Program is to allow accomplishment of significant, costly, one-time structural rehabilitation or major replacement work (other repairs related to dam safety are accomplished under the normal Operation and Maintenance program). The work under this program restores the project to its original condition to serve as originally intended. An example of dam safety work under this program would be the installation of a "cut-off" wall to control seepage through a dam. Projects approved for major rehabilitation require budget justification and other supporting data similar to the budget information prepared for construction projects. The Major Rehabilitation Program is limited to the major repair or restoration of main structures such as dams, locks, and powerhouses, exclusive of electrical, mechanical, and other equipment, except that such equipment may be included where it is essential to and integral with the feature of the project being rehabilitated. The Major Rehabilitation Program is not applicable to local protection projects, dams, or other works turned over to local interests for operation, maintenance, and major replacement (U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977; ER 1130-2-500; Federal Emergency Management Agency 1992b; Wiseman 1987).

5-3. Dam Safety Assurance Program

a. General. The Dam Safety Assurance Program provides for modification of completed Corps of Engineers dam projects which are potential safety hazards in light of current engineering standards and criteria. This program is one part of the Corps' numerous dam safety activities. The problems generally fall into two categories: hydrologic and seismic. The program is intended to facilitate upgrading of those project features which have design or construction deficiencies related to dam safety in order to permit the project to function effectively and as originally intended. In order to qualify, the modifications must be within the Chief of Engineers' discretionary authority and also must be such that they cannot be accomplished under routine maintenance. Projects approved for Dam Safety Assurance will require budget justification and other supporting data similar to the budget information prepared for construction projects. The Dam Safety Assurance Program may also be used to modify dams built by the Corps of Engineers and turned over to local interests to operate, maintain, replace, rehabilitate, and repair (ER 1130-2-419, ER 1165-2-119, ER 1110-2-1155, Walz 1990a).

b. Policy on hydrologic criteria. Since the Corps of Engineers began building dams, the policy has been that failure of a Corps of Engineers dam should not significantly increase the downstream hazard over the hazard which would have existed if the dam had not failed. However, new policy requires more analysis and documentation from the field offices when recommending improvements to hydrologically deficient dams (Duscha 1986). Additional background information on hydrologic criteria is available (National Research Council 1985; Federal Emergency Management Agency 1986a, 1986c; Wiseman 1987; Lave, Resendiz-Carrillo, and McMichael 1990; Task Committee on Spillway Design Flood Selection, Committee on Surface Water Hydrology, Hydraulics Division, American Society of Civil Engineers 1988). The following policy is used to make decisions on the merits of dam safety modifications to meet current hydrologic criteria given in ER 1110-8-2(FR) (ER 1110-2-1155).

(1) Planning for a dam safety modification will consider combination of structural design modifications as well as nonstructural measures, including downstream actions and changes in water control plans. The recommended plan should be for the dam safety modification which meets or exceeds the base safety condition (BSC). The BSC will be met when a dam failure related to hydrologic capacity will result in no significant increase in downstream hazard

(loss of life and economic damages) over the hazard which would have existed if the dam had not failed. Recommendations for any modifications that would accommodate floods larger than the flood identified as the BSC must be supported by an analysis that presents the incremental costs and benefits of the enhanced design in a manner that demonstrates the merits of the recommendation. Such enlargement of project scope may require Congressional authorization.

(2) Determination of the flood that identifies the BSC will require definition of the relationship between flood flows and adverse impacts (loss of life and economic damages) with and without dam failure for a range of floods that fully utilizes the existing structure up to the probable maximum flood (PMF). Selection of a BSC predicated on the hazard to life from dam failure will require supporting information to demonstrate that the safety of the population would actually be threatened. The evaluation should distinguish between total population downstream of a dam and the population that would likely be in a life threatening situation given the extent of prefailure flooding, warning time available, evacuation opportunities, and other factors that might affect the occupancy of the incrementally inundated area at the time the failure occurs. Appropriate freeboard necessary to accommodate potential wind and wave conditions will be included for all flood evaluations. The evaluation consists of two phases. Phase I is a comparative hazard analysis in which the threshold flood and the BSC are established. Phase II is the risk-cost analysis required if modifications for a flood larger than the BSC is recommended (ER 1110-2-1155). Examples of the analysis required to develop the base condition are illustrated in "Guidelines for Evaluating Modifications of Existing Dams Related to Hydrologic Deficiencies," Institute for Water Resources Report 86-R-7 (Stakhiv and Moser 1986).

(3) Selection of a recommended level of modification also should reflect concern for economy. Modification costs in the vicinity of the scale of improvement identified as the BSC should be examined for sudden increases in the cost/scale of improvement relationship. This type of change could occur, for instance, when a costly highway relocation is encountered near the scale of improvement identified as the BSC. An adjustment in the level of fix recommended may be warranted under these conditions. On the other hand, the large increase in costs may be justified if a significant reduction in the hazard, with and without dam failure, is achieved.

(4) Measures to accommodate floods larger than the BSC may be warranted in some cases. When the project benefits that would be lost, and repair costs for failure are large enough, costs for structural modifications to prevent failure may be economically justified in spite of the low probability of the floods involved.

(5) Conduct of the analysis requires careful application of professional judgment for determining those parameters where data and modeling capability are limited. Therefore, the importance of documenting the logic assumptions, critical to the conclusions and recommendations drawn from the analysis, cannot be over-emphasized. Also, the evaluation should produce a significant amount of information needed throughout the decision making process, particularly in those cases where it is appropriate to proceed beyond the base condition. The information must be displayed in a format that assists the decision maker when evaluating the important trade-offs involved.

c. Policy on seismic criteria. The following policy is used to make decisions on the merits of dam safety modifications related to current earthquake design criteria (ER 1110-2-1155).

(1) Projects that retain or have the potential to retain a permanent pool, failure of which would result in loss of life, substantial property damage, or indirect loss such as the loss of essential emergency services provided by the dam, are required to survive and remain safe during and following the maximum credible earthquake event. Such projects shall additionally be capable of remaining operational with only minor repair during and after an operating basis earthquake (OBE). In the case of projects intended for short-term temporary flood storage, including those with low permanent pools, risk based assessments may be warranted. Combining a rare earthquake event with a rare hydrologic event demonstrates extremely low risk and therefore unwise use of funds.

(2) Technical requirements for selecting seismic design values and performing design analyses are contained in ER 1110-2-1806 (see also Federal

Emergency Management Agency 1985b). These criteria, along with current state-of-the-art techniques, are intended to be used in such studies and analyses. Criteria levels, safety factors, and design methods are the same as that for new projects.

(3) Since judgment of ground motion parameters for design is based on geologic and seismic history, future strong seismic events may raise the design values against which stability should be analyzed. Should such a situation occur, the district, if convinced that the ground motion parameters have changed significantly enough to affect the safety of the project, shall prepare an evaluation report as detailed in paragraph 5-4.*a*.

(4) Strong motion accelerometers that have been placed on or around Corps dams are intended as a check on the design seismic resistance of the structure. If these instruments record ground motion parameters that, after analysis, are found to be below the values used in design but yet the structure received damage, a letter report (in the case of no expected future remedial action) or an evaluation report (in the case of anticipated remedial action) shall be written describing the situation and containing the district's recommendation.

(5) Seismic stability of auxiliary structures and devices, such as regulating outlet towers, spillway gates, retaining walls, hydraulic equipment, and electric lines, shall be upgraded where necessary to provide for dam safety, including requirements for dams to remain operational following the OBE. Auxiliary structures that do not affect dam safety or operational safety shall be judged for modification on economic or other grounds rather than dam safety.

(6) Seismic stability assessment for dam safety may also involve reservoir rim slides, effects of dam overtopping, movements of critical retaining walls, foundation or abutment changes, susceptibility of embankment dams to liquefaction, or any other feature that might contribute to dam failure.

5-4. Procedural Requirements

In order to identify and process work for inclusion in the Dam Safety Assurance Program, reporting and design procedures given in ER 1110-2-1155 will be followed.

a. Dam Safety Assurance Evaluation Report. A reconnaissance will be conducted and a report prepared covering preliminary evaluation of work items considered necessary to upgrade the project. Format and content of the evaluation report will follow the requirements given in Appendix C of ER 1110-2-1155. Detailed field investigations and office studies will be kept to a minimum. The report will be designed to develop a basis for decision on:

(1) The need for and justification of the modification for dam safety.

(2) The appropriateness of funding under the Dam Safety Assurance Program.

(3) Whether the work requires additional authorization.

(4) Whether the work is subject to cost-sharing and identification and the views of the cost sharing partner.

(5) The scope and cost of subsequent investigations.

(6) The scope and cost of design requirements.

(7) The estimated cost for construction.

If a determination on whether a problem exists cannot be made during the preparation of the evaluation report, then the need for special engineering investigation(s) will be identified and justified in the report. In those instances where there is need for both a special engineering investigation and follow-on investigations of known problems, both will be identified in the report. In addition, a plan of study and cost estimate for the special engineering investigation(s) will be included. Special engineering investigations are those extensive and complex investigations that may be required to determine the need for and/or scope of remedial construction. Special investigations include hydraulic modeling and geological and seismic investigations.

b. Design memorandum. For major dam safety modifications, a DM is usually prepared following approval of the evaluation report and any special investigations. Content of the DM will follow the requirements given in Appendix D of ER 1110-2-1155. The initial DM will present the results of the evaluation report and any special engineering investigations and make final recommendations concerning the need for and/or scope of the proposed modification. Included with this recommendation will be the estimated cost, schedule for construction, and design of the approved plan. This will provide the basis for preparation of plans and specifications.

Chapter 6
Emergency Action Plans (EAP)

6-1. General

a. Definitions.

(1) Emergency - An emergency, in terms of dam operation, is defined as a condition which develops unexpectedly, endangers the structural integrity of the dam and/or downstream property and human life, and requires immediate action.

(2) EAP - An EAP is a plan of action to reduce the potential for property damage and loss of life in an area affected or about to be affected by a dam failure or large flood. It includes both the portion of a dam safety plan prepared by the Corps of Engineers and the complementary evacuation plan prepared by non-Federal interests.

b. Background. Corps of Engineers major subordinate command offices were instructed in March 1978 to begin preparation of flood EAPs for dams under their jurisdiction. Initially the effort was directed to delineate areas downstream from the dams that would be flooded in the event of dam failure. The product of these efforts was inundation area maps (ER 1130-2-419). In June 1980 the Corps of Engineers issued detailed instructions for the preparation of flood EAPs (U.S. Army Corps of Engineers, Hydrologic Engineering Center 1980, 1982). Subsequently, in August 1983, the Corps of Engineers distributed case studies of an EAP and evacuation plan to field offices (U.S. Army Corps of Engineers, Hydrologic Engineering Center 1983a, 1983b).

6-2. Scope of Emergency Action Plan

Guidance (U.S. Army Corps of Engineers, Hydrologic Engineering Center 1980) has been provided for preparation of EAPs to deal with potential emergencies caused by

a. Spillway discharges sufficiently large to cause flooding in downstream areas.

b. Flooding upstream of dams due to backwater effects or high pool levels.

c. Dam failure.

6-3. Components of Emergency Action Plan

The principal components of EAPs (including agency responsible for preparation) are as follows (U.S. Army Corps of Engineers, Hydrologic Engineering Center 1980):

a. Emergency identification subplan (Corps of Engineers). The object of this subplan is to describe procedures and means for ensuring reliable identification and evaluation of existing or potential emergencies. The major elements of the subplan are:

(1) Listing of the conditions which could indicate an existing or potential emergency.

(2) Description of the data and information collection system, monitoring arrangements, inspection procedures, and other provisions for early detection of conditions indicating an existing or potential emergency.

(3) Procedures, aids, instructions, and other provisions for interpreting information and data to assess the severity and magnitude of any existing or potential emergency.

b. Emergency operations and repair subplan (Corps of Engineers). The objectives of this subplan are to guide immediate operational decisions in the event of various types of emergencies; identify the need for equipment, material, labor, and other necessities for carrying out emergency repairs; and describe the procedures for securing and employing needed equipment, material, labor, and other necessities. The major elements of the subplan are:

(1) Identification of the appropriate response to the type and severity of existing or potential emergencies.

(2) Emergency gate operation.

(3) Reservoir dewatering plan.

(4) Description of equipment and materials to be stockpiled for use in carrying out emergency operations and repairs.

(5) Assignments of responsibilities for carrying out emergency operations and repairs.

(6) Description of needs for equipment, material, and labor not available at the site which are needed to carry out each type of emergency operation or repair.

(7) Listing of nearby contractors and other sources of needed equipment, material, and labor and description of procedures for securing their assistance on an emergency basis.

c. Notification subplan (Corps of Engineers and non-Federal). The objective of this subplan is to describe the procedures and means for prompt notification of appropriate parties concerning existing or potential emergencies. The major elements of the subplan are:

(1) Inundation maps which show the area likely to be inundated and time of onset of dangerously high flows for each emergency condition for which plans are made (Corps of Engineers).

(2) Listing of vital services and facilities outside the area of inundation which will or may be disrupted by the level of inundation associated with each emergency condition for which plans are made (non-Federal).

(3) Listing of major secondary problems resulting from the level of inundation associated with each emergency condition for which plans are made (non-Federal):

(4) Evacuation maps which show (non-Federal):

(a) All areas which should be evacuated because of inundation, secondary problems, loss of services, isolation, or other reasons which are associated with each emergency condition for which plans are made.

(b) Major evacuation routes.

(c) Areas requiring priority in evacuation.

(d) Potential obstacles to timely evacuation.

(5) Listing of persons to be notified about each emergency condition for which plans are made and procedures for notification including description of primary and secondary means of communication to be used, listing of telephone numbers and addresses, and other information needed for reliable and prompt contact for (Corps of Engineers):

(a) Notifications internal to the Corps.

(b) Notifications from the Corps to principal local officials.

(c) Notifications from the Corps to other Federal officials.

(d) Distribution of warnings from the Corps to officials responsible for dissemination to the general public.

(e) Dissemination of warnings by the Corps directly to the general public in the immediate vicinity of the dam and reservoir.

(6) Example press releases for each emergency condition for which a plan is prepared and instructions for adaptation before their use to the specifics of an emergency situation including but not limited to (Corps of Engineers):

(a) Exact nature of emergency and degree of danger.

(b) Remedial action under way.

(c) Expected course of events and timing.

(d) Appropriate action for public to take.

(7) Description of the procedure and means for dissemination of warnings directly to the general public in the immediate vicinity of the dam and reservoir (Corps of Engineers).

d. Evacuation subplan (non-Federal). Non-Federal officials are to be encouraged to develop evacuation subplans as a complement to the portion of dam emergency plans prepared by the Corps. The objectives of the evacuation subplan are to provide for the timely and safe evacuation of threatened areas and the minimization of property damage. The major elements of the subplan are:

(1) Description of traffic control arrangements to expedite evacuation and passage of emergency vehicles and prevent accidental travel into dangerous areas.

(2) Provisions for any necessary assistance to evacuees such as transportation and aid to invalids.

(3) Arrangements for sheltering, feeding, and other care of evacuees.

(4) Description of actions to be taken to reduce damages and other losses.

(5) Arrangements for security of evacuated areas.

(6) Arrangements addressing other aspects as required for the case at hand.

6-4. Number of Emergency Action Plans Required

A large number of hypothetical emergencies could be conceived by combining various causes for and assumptions about emergencies of one type or another. It is obviously impractical to prepare completely separate plans to address each potential emergency condition which might be postulated. Instead, each major portion of the emergency plan must be considered individually with respect to how many separate versions are necessary (U.S. Army Corps of Engineers, Hydrologic Engineering Center 1980):

a. Emergency identification subplan (Corps of Engineers). Only one emergency identification subplan is required.

b. Emergency operations and repair subplan (Corps of Engineers). The emergency operations and repair subplan consists of guidance and procedures for dealing with a variety of emergencies. One subplan is sufficient. The portion of its contents dealing with emergency responses should be divided according to the type of emergency addressed or action to be taken as, for example, the following:

(1) Wave erosion.

(2) Excess seepage.

(3) Piping.

(4) High pool conditions.

(5) Malfunction of control gates.

(6) Failure of discharge facilities.

(7) Upstream dam failure.

(8) Downstream dam failure.

c. Notification subplan (Corps of Engineers and non-Federal). Notification subplans are to be prepared for three basic emergency conditions including: spillway design discharge without failure, spillway design discharge with failure, and failure at normal high pool level (top of flood control pool). Separate notification subplans are required for each emergency condition because:

(1) Identification of the local officials to be notified of an existing or potential emergency depends on the area requiring evacuation which is associated with each emergency condition.

(2) The need to notify other Federal agencies, the public in the immediate vicinity of the dam and reservoir, and other parties varies according to the nature of the existing or potential emergency.

(3) The appropriate text of news releases depends on the emergency condition for which they are prepared.

d. Evacuation subplan (non-Federal). Evacuation subplans will be prepared for conditions of:

(1) Spillway design flood.

(2) Spillway design flood with dam failure.

(3) Dam failure with normal high pool level (top of flood control pool).

6-5. Emergency Action Plan Exercises

a. General. Testing of the EAP involving all participants is necessary to ensure that the plan is up-to-date and workable in practice under real-life conditions (Basinger 1990, Mahoney 1990, Gotzmer 1991).

b. Corps of Engineers requirements. ER 1130-2-419 states:

> Division Commanders are directed to implement a dam safety training program for O&M personnel, with retraining every four years...Upon completion of initial safety training sessions for each project, operational training exercises for emergency situations shall be developed. These exercises shall be based on the more probable emergency situations that might occur on each major dam feature. A record shall be maintained at the project showing date, subject material, and personnel involved for each exercise conducted.

According to the "Emergency Action Planning Guidelines for Dams" developed by the Interagency Committee on Dam Safety and adopted by the Corps of Engineers (Federal Emergency Management Agency 1985, 1990b):

> The dam owner should prepare scenarios for slowly developing, rapidly developing, and instantaneous emergencies and test the state of training and readiness of key personnel responsible for actions during an emergency to assure that they know and understand the procedures to be followed and actions required. Any special procedures required for nighttime, weekends, and holidays should also be included. The tests should include a drill simulating emergenc condition. Coordination and consultation with local government, law enforcement officials, and other organizations involved is desirable in order to enhance the realism of the test. Their involvement will perfect the close coordination with agencies necessary for a successful execution of the plan in an actual emergency. The test should be critiqued in writing and the plan should be revised to correct any deficiencies noted.

c. Types of exercises. FEMA has identified five types of exercises that constitute an exercise program, with each one building on the concepts of the previous exercise. These five types of exercises are (Federal Energy Regulatory Commission 1991; Federal Emergency Management Agency 1989a, 1989b; Gotzmer 1991):

(1) Orientation seminar. This involves bringing together persons with a role or interest in the EAP for discussion and to initiate plans for the annual drill or more in-depth exercise, and to become familiar with the roles, procedures, and responsibilities of those involved.

(2) Drill. A drill is the lowest level exercise. A drill test develops or maintains skills in a single emergency response procedure. The in-house drill tests the state of training and readiness of key personnel to ensure that they are fully cognizant of the procedures and actions required during an emergency. The drill should simulate an emergency condition at the dam under which the EAP would be implemented. Special procedures required for nighttime, weekends, and holidays should also be considered when developing the scenario. Testing of remote sensing instrumentation should be included. Coordination with local government, law enforcement officials, and other organizations involved is desirable. This will enhance the realism of the drill and ensure the accuracy of telephone numbers of persons to be notified. While a planned drill will allow persons involved to rehearse their roles, a surprise drill can be more educational and expose flaws in the EAP. Immediately following the

drill the responses to the emergency scenario at all levels will be reviewed and a critique prepared. The purpose of the critique is to identify lessons learned and deficiencies in the EAP including notification, priorities, and responsibilities assigned.

(3) Tabletop exercise. The tabletop exercise involves low stress, little attention to real-time, lower level of preparatory effort, and only rough attempts to simulate actual conditions. The tabletop exercise is conducted once a year. The focus is on training and familiarization with roles, procedures, responsibilities, and personalities of the persons involved. The tabletop exercise consists of discussion in a meeting format through one or more facilitators. The facilitator leads the conduct of the tabletop exercise and makes sure every participant responds to at least one message (described below) during the exercise. Effectiveness is determined by the impact of feedback from the participants on evaluating and revising policies, plans, and procedures. There is no deployment of resources or utilization of equipment. A narrative (or scenario) sets the scene for the simulated event by briefly describing what has happened and what is known up to the time of the exercise. The participants are provided with messages as the exercise progresses. The purpose of the messages is to provide updated information to the participants so that they will respond with an action or a decision. Once the exercise is completed, the results will be evaluated. An immediate post-exercise critique should be held followed by an evaluation report. The critique will be both oral and written and will provide the participants with a forum to gather and share information about what happened during the exercise, to describe what went right, and to identify what went wrong. The formal evaluation of the exercise consists of a written report based on observations and recommendations that come out of the critique, as well as the report(s) of the facilitator(s). Follow-up (the process of implementing the recommendations) is the final and critical stage of the exercise process. The advantage of a tabletop exercise is the modest commitment of time, cost, and resources. It provides an effective method of reviewing plans and implementing procedures and policies, and provides an opportunity for key personnel to become acquainted and review emergency responsibilities and procedures. The disadvantages of a tabletop exercise are that the tabletop lacks realism and does not provide a true test of participants' capabilities.

(4) Functional exercise. The functional exercise is the highest level test that does not involve full activation of field personnel and facilities. The functional exercise is conducted once every 4 years. The functional exercise tests capabilities of the participants under a stress-induced environment with time constraints. Whereas a tabletop exercise provides opportunities throughout the exercise to stop and discuss actions and responses, the functional exercise is a time constrained test with limited opportunity for discussion. The functional exercise simulates actual emergency situations and responses of the participants without actual field deployment. The exercise is conducted with the participants co-located or located at their own facilities, with communications through expected emergency communication links. The functional exercise is based on a simulation of an emergency including a description of the situation, a master sequence of events list, a timed sequence of messages, and communication between participants and simulators. There are five functions or capabilities which should be included in a functional exercise:

(a) Alert, notification, and warning. This function tests the communication system and the messages to determine if they are appropriate and clearly understood. It verifies names and phone numbers on the notification list. Remote sensing equipment should be tested at the start of the exercise.

(b) Direction and control function. This function tests and evaluates the emergency operations capability and timely response. It includes the response to health problems, fire, downed power lines, and loss of life, including drownings.

(c) Evacuation. This capability is a key issue in the exercise as it tests the participants' understanding of the inundation maps. Experience indicates the inundation boundaries and the road names may not always be clear and fully understood (for example, road names used by local officials are often different from those on Geological Survey maps or state route maps). Maps are often revised as a result of this information.

(d) Shelters. This function reveals those shelters that should not be used because they are in the flood plain.

(e) Public information. This function tests the capability to issue accurate information during a dam failure event. Activation of the emergency operations center at the state or local level, as appropriate, should be encouraged. Apart from the actual participants in the functional exercise there are the exercise controller, exercise simulators, and exercise evaluators. The controller monitors the sequence of events as they unfold, the flow of messages, and the overall conduct of the exercise. The simulators send prescribed messages at the scheduled time, respond to unanticipated actions by participants with spontaneous messages, and maintain contact with the controller during the exercise. The evaluators observe the actions and decisions of the participants during the exercise and contribute, along with the exercise participants, to writing the evaluation report. As with the tabletop exercise, the critique, the evaluation report, and the follow-up to the recommendations in the report are important aspects of the functional exercise.

(5) Full-scale exercise. The full-scale exercise is the most comprehensive test and is intended to evaluate the operational capability of the emergency management system in a stress environment with mobilization of emergency workers, equipment, and resources to demonstrate coordination and response capability. Full-scale exercises draw media and community attention to emergency preparedness; teach by doing; test total coordination, not only among policy and coordination officials, but also field forces; and point out physical resource capabilities and/or limitations. For agencies or local communities, full-scale exercises require considerable preparation and provide practical tests of "first-in" responders, including police, fire, and medical personnel. They test triage (allocation of treatment to disaster victims to maximize the number of survivors) procedures, on-scene management of resources, and coordination and communication through field command posts. As with the functional exercise, the controller is responsible for ensuring that the exercise starts on schedule. Simulators and evaluators keep a log of all significant events. During a full-scale exercise at Garrison Dam, North Dakota, conducted in August 1987, personnel were stationed at several locations in the District Office and at Garrison Dam to monitor and document phone and radio communications, decision making, and repair efforts (U.S. Army Engineer District, Omaha 1987). Each participant should log his actions as much as possible. Videotaping the exercise and critique is beneficial. The media should be included in any exercise plan to increase realism. At the conclusion of the full-scale exercise, the critique and evaluation report are important so that necessary follow-up action can be taken.

Chapter 7
Training

7-1. Overview

The Corps of Engineers has an extensive program for training its personnel in all matters related to its mission in water resources development. Much of the training is directly or indirectly related to dam safety. A comprehensive training program is conducted for dam operation and maintenance personnel. This program is designed to acquaint project personnel with basic engineering considerations pertaining to the major structures, with procedures for surveillance, monitoring and reporting of potential problems, and with emergency operations. The Corps of Engineers has a training course on "Design and Safety Surveillance of Embankment Dams" and supported the development of the Training Aids for Dam Safety (TADS) Program (Walz 1990b). In 1991, the Federal Energy Regulatory Commission initiated a training course on "Emergency Action Plan" (Gotzmer 1991). A listing of Government sponsored training courses relating to dam safety was prepared by the Interagency Committee on Dam Safety (ICODS) Subcommittee on Training (Federal Emergency Management Agency 1986b).

7-2. Training Program for Operations and Maintenance Personnel

a. Dam safety. Recognizing the important role which onsite operations and maintenance personnel have in dam safety, major subordinate command commanders were directed in 1978 to develop a training program which addresses the following items (ER 1130-2-419, United States Committee on Large Dams 1982):

(1) Discussion of basic typical design considerations for various types of construction, including hydraulic considerations and foundation factors.

(2) Procedures for monitoring potential problem areas.

(3) Dam safety features in design and construction.

(4) Normal operation, surveillance, monitoring, and reporting procedures.

(5) Emergency operations, surveillance, monitoring, and reporting procedures.

b. Exercises. Upon completion of the initial safety training at a new project, EAP exercises are developed based on the most probable emergency situations that might occur on each major dam feature. Operations and maintenance personnel are retrained every 4 years.

7-3. Corps of Engineers Training Course on Dam Safety

The Corps of Engineers Proponent Sponsored Engineer Corps Training (PROSPECT) program offers a course titled “Dam Safety in the Corps of Engineers”. Through lectures, case histories, and structured student discussions, the course covers all aspects of a dam safety program. The course outlines technical considerations (hydrologic, seismic, geotechnical, electrical/mechanical and structural) as well as the operational requirements (operation, maintenance, surveillance, preparedness, training, and notification). The scope and implementation details of the Dam Safety Assurance Program are covered in detail. Presentations, video modules, case histories, and a walk-through inspection are used to effectively present a multidiscipline approach to the successful monitoring and evaluation of Corps of Engineers dams.

7-4. Training Aids for Dam Safety

a. Background. In 1986, the Corps of Engineers, along with 13 other Federal Agencies, all members of the Interagency Committee on Dam Safety, joined forces to develop a professionally prepared TADS Program. The TADS materials, as shown in Table 7-1, are arranged in three components that cover dam safety inspections, dam safety awareness and program development, and evaluations and remedial actions (Federal Emergency Management Agency 1992b, Veesaert 1990).

b. Structure. The entire package consists of 21 self-paced individual instruction modules that focus on performance of job tasks. Each module features a workbook text. The material is presented in a straightforward, easy-to-manage manner. Each workbook contains a glossary of terms and a list of references from which to obtain additional information. Nine of the modules are supplemented with videotapes that illustrate certain concepts. Because the modules are self-contained, individuals may tailor a learning program to meet specific work requirements or personal needs (Federal Emergency Management Agency 1992b, Veesaert 1990).

c. Utilization of the program. The TADS Program promises to offer a standardized approach to dam safety training. The Corps of Engineers, as one of the primary sponsors of the TADS Program, distributes the TADS materials to each Corps of Engineers field office through the Engineering Division, Directorate of Civil Works, HQUSACE. All MSCs and districts should have a complete set of modules including the videotape supplements.

Table 7-1
Training Aids for Dam Safety Modules

Safety Inspection of Dams
(for engineers with little or no inspection experience and technicians with some familiarity with dams)

- Preparing to Conduct a Dam Safety Inspection
- Documenting and Reporting Findings From a Dam Safety Inspection
- Inspection of Embankment Dams *
- Inspection of Concrete and Masonry Dams *
- Inspection of the Foundation, Abutments, and Reservoir Rim
- Inspection of Spillways and Outlet Works *
- Inspection and Testing of Gates, Valves, and Other Mechanical Systems *
- Instrumentation for Embankment and Concrete Dams *
- Identification of Material Deficiencies *
- Evaluation of Facility Emergency Preparedness

Dam Safety Awareness, Organization, and Implementation
(for dam owners and operators, with some applicability for inexperienced engineers, technicians, administrators, and the general public)

- Dam Safety Awareness *
- How to Organize a Dam Safety Program
- How to Organize an Operation and Maintenance Program
- How to Develop and Implement an Emergency Action Plan *
- Identification of Visual Dam Safety Deficiencies *

Data Review, Investigation and Analysis, and Remedial Action for Dam Safety (for engineers with some applicability for dam owners and operators)

- The Dam Safety Process
- Evaluation of Hydrologic Adequacy
- Evaluation of Hydraulic Adequacy
- Evaluation of Concrete Dams Stability
- Evaluation of Embankment Dams Stability and Deformation
- Evaluation of Seepage Conditions

* Modules have videotape supplements.

Appendix A
References

A-1. Required Publications[1]

PL 99-662
Water Resources Development Act of 1986

ER 5-7-1(FR)
Project Management

ER 415-2-100
Construction Management Policies, Procedures, and Staffing for Civil Works Projects

ER 690-1-304
Employment of Experts and Consultants for Personal Services

ER 1105-2-100
Guidance for Conducting Civil Works Planning Studies

ER 1110-1-1801
Construction Foundation Report

ER 1110-2-100
Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures

ER 1110-2-101
Reporting of Evidence of Distress of Civil Works Structures

ER 1110-2-110
Instrumentation for Safety Evaluations of Civil Works Projects

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

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

ER 1110-2-1155
Dam Safety Assurance Program

ER 1110-2-1156
Dam Safety - Organization, Responsibilities, and Activities

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

ER 1110-2-1802
Reporting Earthquake Effects

ER 1110-2-1806
Earthquake Design and Evaluation for Civil Works Projects

ER 1110-2-1901
Embankment Criteria and Performance Report

ER 1110-2-1925
Field Control Data for Earth and Rockfill Dams

ER 1110-8-2(FR)
Inflow Design Floods for Dams and Reservoirs

ER 1130-2-304
Manuals

ER 1130-2-417
Major Rehabilitation Program and Dam Safety Assurance Program

ER 1130-2-419
Dam Operations Management Policy

ER 1165-2-119
Modifications to Completed Projects

ER 1165-2-131
Local Cooperation Agreements for New Start Construction Projects

ER 1180-1-6
Construction Quality Management

EP 715-1-2
A Guide to Effective Contractor Quality Control (CQC)

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Instrumentation of Earth and Rock-fill Dams - Parts 1 and 2

EM 1110-2-1911
Construction Control for Earth and Rock-fill Dams

EM 1110-2-2006
Roller-Compacted Concrete

EM 1110-2-2200
Gravity Dam Design

EM 1110-2-2300
Earth and Rock-Fill Dams - General Design and Construction Considerations

EM 1110-2-3600
Management of Water Control Systems

EM 1110-2-4300
Instrumentation for Concrete Structures

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Appendix B
Glossary

B-1. Abbreviations

ADAS . . . . Automated Data Acquisition System

ASDSO . . Association of State Dam Safety Officials

BSC . . . . . Base Safety Condition

CAGE . . . . Computer Applications in Geotechnical Engineering

COE . . . . . Corps of Engineers

CQC . . . . . Contractor Quality Control

DA . . . . . . Department of the Army

DM . . . . . . Design Memorandum

EAP . . . . . Emergency Action Plan

EPRI . . . . . Electric Power Research Institute

FCCSET . . Federal Coordinating Council for Science, Engineering, and Technology

FCSA . . . . Feasibility Cost Sharing Agreement

FEMA . . . . Federal Emergency Management Agency

GDM . . . . General Design Memorandum

HQUSACE . . Headquarters, U. S. Army Corp of Engineers

ICODS . . . Interagency Committee on Dam Safety

ICOLD . . . International Commission on Large Dams

IDF . . . . . Inflow Design Flood

IPMP . . . . Initial Project Management Plan

IRC . . . . Issue Resolution Conference

MCE . . . . Maximum Credible Earthquake

MDE . . . . Maximum Design Earthquake

MSC . . . . Major Subordinate Commands

O&M . . . . Operation and Maintenance

OBE . . . . Operating Basis Earthquake

OMRR&R . . . . . . Operation, Maintenance, Repair, Replacement and Rehabilitation

P&S . . . . Plans and Specifications

PCA . . . . Project Cooperation Agreement

PED . . . . Preconstruction Engineering and Design

PMF . . . . Probable Maximum Flood

PMP . . . . Probable Maximum Precipitation

PROSPECT . . . . . Proponent-Sponsored Engineer Corps Training

QA . . . . Quality Assurance

REMR . . . . Repair, Evaluation, Maintenance, and Rehabilitation

SDF . . . . Spillway Design Flood

SEE . . . . Safety Evaluation Earthquake

SEF . . . . Safety Evaluation Flood

TADS . . . . Training Aids for Dam Safety

TRC . . . . Technical Review Conference

USACE . . . . United States Army Corps of Engineers

USCOLD . . . . U.S. Committee on Large Dams

VE . . . . Value Engineering

WES . . . . U.S. Army Engineer Waterways Experiment Station

B-2. Terms

Abutment
That part of the valley side against which the dam is constructed. An artificial abutment is sometimes constructed as a concrete gravity section to take the thrust of an arch dam where there is no suitable natural abutment. The left and right abutments of dams are defined with the observer viewing the dam looking in the downstream direction, unless otherwise indicated.

Acre-foot
A unit of volumetric measure that would cover 1 acre to a depth of 1 foot. It is equal to 43,560 cubic feet.

Adit
A nearly horizontal underground excavation in an abutment having an opening in only one end. An opening in the face of a dam for access to galleries or operating chambers.

Appurtenant structure
Ancillary features of a dam such as inlet and outlet works, spillways, tunnels, or powerplants.

Axis of dam
The vertical plane or curved surface, chosen by a designer, appearing as a line, in plan, or in cross-section, to which the horizontal dimensions of the dam are referenced.

Baffle block
A block, usually of concrete, constructed in a channel or stilling basin to dissipate the energy of water flowing at high velocity.

Base thickness
Also referred to as base width. The maximum thickness or width of the dam measured horizontally between upstream and downstream faces and normal to the axis of the dam, but excluding projections for outlets, or other appurtenant structures.

Batter
Angle of inclination from the vertical.

Bedrock
The consolidated body of natural solid mineral matter which underlies the overburden soils.

Berm
A nearly horizontal step in the sloping profile of an embankment dam. Also a step in a rock or earth cut.

Borrow area
The area from which material for an embankment is excavated.

Breach
An eroded opening through a dam which drains the reservoir. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening which allows uncontrolled discharge from the reservoir.

Catastrophe
A sudden and great disaster causing misfortune, destruction, or irreplaceable loss extensive enough to cripple activities in an area.

Channel
A general term for any natural or artificial facility for conveying water.

Cofferdam
A temporary structure enclosing all or part of the construction area so that construction can proceed in the dry. A diversion cofferdam diverts a river into a pipe, channel, or tunnel.

Compaction
Mechanical action which increases the density by reducing the voids in a material.

Conduit
A closed channel to convey water through, around, or under a dam.

Construction joint
The interface between two successive placings or pours of concrete where bond, and not permanent separation, is intended.

Contact grouting

Filling, with cement grout, any voids existing at the contact of two zones of different materials, e.g., between a concrete tunnel lining and the surrounding rock.

Contractor Quality Control (CQC)
The construction contractor's system to manage, control, and document his own, his supplier's, and his subcontractor's activities to comply with contract requirements.

Core
A zone of low permeability material in an embankment dam. The core is sometimes referred to as central core, inclined core, puddle clay core, rolled clay core, or impervious zone.

Core wall
A wall built of relatively impervious material, usually of concrete or asphaltic concrete, in the body of an embankment dam to prevent seepage.

Crest of dam
See top of dam.

Cross section
An elevation view of a dam formed by passing a plane through the dam perpendicular to the axis.

Cutoff trench
A foundation excavation later to be filled with impervious material so as to limit seepage beneath a dam.

Cutoff wall
A wall of impervious material usually of concrete, asphaltic concrete, or steel sheet piling constructed in the foundation and abutments to reduce seepage beneath and adjacent to the dam.

Dam
A barrier constructed across a watercourse for the purpose of storage, control, or diversion of water.

a. Afterbay dam. See regulating dam.

b. Ambursen dam. A buttress dam in which the upstream part is a relatively thin flat slab usually made of reinforced concrete.

c. Arch dam. A concrete or masonry dam which is curved upstream so as to transmit the major part of the water load to the abutments.

d. Buttress dam. A dam consisting of a watertight part supported at intervals on the downstream side by a series of buttresses. A Buttress dam can take many forms, such as a flat slab or a massive head buttress.

e. Cofferdam. A temporary structure enclosing all or part of the construction area so that construction can proceed in the dry. A diversion cofferdam diverts a stream into a pipe, channel, tunnel, or other watercourse.

f. Crib dam. A gravity dam built up of boxes, crossed timbers, or gabions filled with earth or rock.

g. Diversion dam. A dam built to divert water from a waterway or stream into a different watercourse.

h. Double curvature arch dam. An arch dam which is curved vertically as well as horizontally.

i. Earth dam. An embankment dam in which more than 50 percent of the total volume is formed of compacted earth material generally smaller than 3-inch size.

j. Embankment dam. Any dam constructed of excavated natural materials or of industrial waste materials.

k. Gravity dam. A dam constructed of concrete and/or masonry which relies on its weight and internal strength for stability.

l. Hollow gravity dam. A dam constructed of concrete and/or masonry on the outside but having a hollow interior and relying on its weight for stability.

m. Hydraulic fill dam. An earth dam constructed of materials, often dredged, which are conveyed and placed by suspension in flowing water.

n. Industrial waste dam. An embankment dam, usually built in stages, to create storage for the disposal of waste products from an industrial process. The waste products are conveyed as fine material suspended in water to the reservoir impounded by the embankment. The embankment may be built of conventional materials but sometimes incorporates suitable waste products.

o. Masonry dam. Any dam constructed mainly of stone, brick, or concrete blocks jointed with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

p. Mine tailings dam. An industrial waste dam in which the waste materials come from mining operations or mineral processing.

q. Multiple arch dam. A buttress dam composed of a series of arches for the upstream face.

r. Overflow dam. A dam designed to be overtopped.

s. Regulating dam. A dam impounding a reservoir from which water is released to regulate the flow downstream.

t. Rockfill dam. An embankment dam in which more than 50 percent of the total volume is composed of compacted or dumped cobbles, boulders, rock fragments, or quarried rock generally larger than 3-inch size.

u. Roller-compacted concrete dam. A concrete gravity dam constructed by the use of a dry mix concrete transported by conventional construction equipment and compacted by rolling, usually with vibratory rollers (EM 1110-2-2006, Hansen and Reinhardt 1991).[1]

v. Rubble dam. A stone masonry dam in which the stones are unshaped or uncoursed.

w. Saddle dam (or dike). A subsidiary dam of any type constructed across a saddle or low point on the perimeter of a reservoir.

[1] References cited in the appendixes are listed in Appendix A.

x. *Tailings dam*. See mine tailings dam.

Dam failure
The uncontrolled release of impounded water. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters which adversely affect a dam's primary function of impounding water is properly considered a failure. They are, however, normally amenable to corrective action.

Dam safety
This term not only covers the safeguarding of human life and downstream property but also the satisfactory operation of the structure. The safety of a dam manifests itself in being free of conditions that could lead to the deterioration or destruction of the dam. The margin which separates the actual conditions of a dam from those leading to its damage or destruction is a measure of its safety. To be safe, a dam has to have appropriate reserves, taking into account all scenarios of normal utilization and exceptional hazard which it may have to withstand during its life (International Commission on Large Dams 1987).

Dam safety preparedness
The quality or state of being prepared to deal with emergency conditions which endanger the structural integrity of the dam and/or downstream property and human life.

Design water level
The maximum water elevation including the flood surcharge that a dam is designed to withstand.

Design wind
The most severe wind that is reasonably possible at a particular reservoir for generating wind setup and runup. The determination will generally include the results of meteorologic studies which combine wind velocity, duration, direction, and seasonal distribution characteristics in a realistic manner.

Diaphragm wall (membrane)
A sheet, thin zone, or facing made of an impervious material such as concrete, steel, wood, or plastic. Also see core wall.

Dike
See saddle dam.

Diversion channel, canal, or tunnel
A waterway used to divert water from its natural course. The term is generally applied to a temporary arrangement, e.g., to by-pass water around a damsite during construction. "Channel" is normally used instead of "canal" when the waterway is short.

Drain, blanket
A layer of pervious material placed to facilitate drainage of the foundation and/or embankment.

Drain, chimney
A vertical or inclined layer of pervious material in an embankment to facilitate and control drainage of the embankment fill.

Drain, toe
A system of pipe and/or pervious material along the downstream toe of a dam used to collect seepage from the foundation and embankment and convey it to a free outlet.

Drainage area
The area which drains to a particular point on a river or stream.

Drainage curtain
Also called drainage wells or relief wells. A line of vertical wells or boreholes to facilitate drainage of the foundation and abutments and to reduce water pressure.

Drawdown
The difference between a water level and a lower water level in a reservoir within a particular time. Used as a verb, it is the lowering of the water surface.

Earthquake
A sudden motion or trembling in the earth caused by the abrupt release of accumulated stress along a fault.

Earthquake, Maximum Credible (MCE)
The most severe earthquake that can be expected to occur at a given site on the basis of geologic and seismological evidence.

Earthquake, Maximum Design (MDE)

A postulated seismic event, specified in terms of specific bedrock motion parameters at a given site, which is used to evaluate the seismic resistance of man-made structures or other features at the site.

Earthquake, Operating Basis (OBE)
The earthquake(s) for which the structure is designed to resist and remain operational. It reflects the level of earthquake protection desired for operational or economic reasons and may be determined on a probabilistic basis considering the regional and local geology and seismology.

Earthquake, Safety Evaluation (SEE)
The earthquake, expressed in terms of magnitude and closest distance from the dam site or in terms of the characteristics of the time history of free-field ground motions, for which the safety of the dam and critical structures associated with the dam are to be evaluated. In many cases, this earthquake will be the maximum credible earthquake to which the dam will be exposed. However, in other cases where the possible sources of ground motion are not easily apparent, it may be a motion with prescribed characteristics selected on the basis of a probabilistic assessment of the ground motions that may occur in the vicinity of the dam. To be considered safe, it should be demonstrated that the dam can withstand this level of earthquake shaking without release of water from the reservoir.

Earthquake, synthetic
Earthquake time history records developed from mathematical models that use white noise, filtered white noise, and stationary and nonstationary filtered white noise, or theoretical seismic source models of failure in the fault zone. (White noise is random energy containing all frequency components in equal proportions. Stationary white noise is random energy with statistical characteristics that do not vary with time).

Embankment
A raised structure to hold back water or to carry a roadway.

Emergency
An emergency, in terms of dam operation, is a condition which develops unexpectedly, endangers the structural integrity of the dam and/or downstream property and human life, and requires immediate action.

Emergency Action Plan (EAP)
A plan of action to be taken to reduce the potential for property damage and loss of life in an area affected by a dam failure or large flood.

Energy dissipator
A device constructed in a waterway to reduce the kinetic energy of fast flowing water.

Epicenter
The point on the earth's surface located vertically above the point of origin of an earthquake.

Fault
A fracture or fracture zone in the earth crust along which there has been displacement of the two sides relative to one another.

Fault, active
A fault which, because of its present tectonic setting, can undergo movement from time to time in the immediate geologic future.

Fault, capable
An active fault that is judged capable of producing macroearthquakes and exhibits one or more of the following characteristics:

a. Movement at or near the ground surface at least once within the past 35,000 years.

b. Macroseismicity (3.5 magnitude Richter or greater) instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.

c. A structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other.

d. Established patterns of microseismicity which define a fault, with historic macroseismicity that can reasonably be associated with the fault.

Fetch
The straight line distance across a body of water subject to wind forces. The fetch is one of the factors used in calculating wave heights in a reservoir.

Filter (filter zone)
One or more layers of granular material graded (either naturally or by selection) so as to allow seepage through or within the layers while preventing the migration of material from adjacent zones.

Flashboards
Structural members of timber, concrete, or steel placed in channels or on the crest of a spillway to raise the reservoir water level but that may be quickly removed in the event of a flood.

Flip bucket
An energy dissipator located at the downstream end of a spillway and shaped so that water flowing at a high velocity is deflected upwards in a trajectory away from the foundation of the spillway.

Flood
A temporary rise in water levels resulting in inundation of areas not normally covered by water. May be expressed in terms of probability of exceedance per year such as one percent chance flood or expressed as a fraction of the probable maximum flood or other reference flood.

Flood routing
A process of determining progressively over time the amplitude of a floodwave as it moves past a dam or downstream to successive points along a river or stream.

Flood, antecedent
A flood or series of floods assumed to occur prior to the occurrence of an inflow design flood.

Flood, base safety standard (BSS)
The inflow design flood where there is no significant increase in adverse consequences from dam failure compared to non-failure adverse consequences.

Flood, Safety Evaluation (SEF)
The largest flood for which the safety of a dam and appurtenant structure is to be evaluated.

Flood, Inflow Design (IDF)
The flood used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works, and for determining maximum temporary storage and height of dam requirements.

Flood, Probable Maximum (PMF)
The most severe flood that is considered reasonably possible at a site as a result of meteorologic and hydrologic conditions.

Floodplain
An area adjoining a body of water or natural stream that has been or may be covered by floodwater.

Freeboard
Vertical distance between the design water level and the top of dam.

Full pool
The reservoir level that would be attained when the reservoir is fully utilized for all project purposes, including flood control.

Gallery
A passageway in the body of a dam used for inspection, foundation grouting, and/or drainage.

Gantry crane
A fixed or traveling bent-supported crane for handling heavy equipment.

Gate
A movable, watertight barrier for the control of water in a waterway.

a. *Bascule gate*. See flap gate.

b. *Bulkhead gate*. A gate used either for temporary closure of a channel or conduit before dewatering it for inspection or maintenance or for closure against flowing water when the head difference is small, e.g., for diversion tunnel closure.

c. *Crest gate (spillway gate)*. A gate on the crest of a spillway to control the discharge or reservoir water level.

d. *Drum gate*. A type of spillway gate consisting of a long hollow drum. The drum may be held in its raised position by the water pressure in a flotation chamber beneath the dam.

e. Emergency gate. A standby or auxiliary gate used when the normal means of water control is not available. Sometimes referred to as guard gate.

f. Fixed wheel gate (fixed roller gate or fixed axle gate). A gate having wheels or rollers mounted on the end posts of the gate. The wheels bear against rails fixed in side grooves or gate guides.

g. Flap gate. A gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and fish belly gates so called from their shape in cross section.

h. Flood gate. A gate to control flood release from a reservoir.

i. Outlet gate. A gate controlling the flow of water through a reservoir outlet.

j. Radial gate (tainter gate). A gate with a curved upstream plate and radial arms hinged to piers or other supporting structure.

k. Regulating gate (regulating valve). A gate or valve that operates under full pressure flow conditions to regulate the rate of discharge.

l. Roller drum gate. See drum gate.

m. Roller gate (stoney gate). A gate for large openings that bears on a train of rollers in each gate guide.

n. Skimmer gate. A gate at the spillway crest whose prime purpose is to control the release of debris and logs with a limited amount of water. It is usually a bottom hinged flap or Bascule gate.

o. Slide gate (sluice gate). A gate that can be opened or closed by sliding in supporting guides.

Gate chamber
Also called valve chamber. A room from which a gate or valve can be operated, or sometimes in which the gate is located.

Geotextiles
Any fabric or textile (natural or synthetic) when used as an engineering material in conjunction with soil, foundations, or rock. Geotextiles have the following uses: drainage, filtration, separation of materials, reinforcement, moisture barriers, and erosion protection.

Groin
The area along the contact (or intersection) of the face of a dam with the abutments.

Grout
A fluidized material that is injected into soil, rock, concrete, or other construction material to seal openings and to lower the permeability and/or provide additional structural strength. There are four major types of grouting materials: chemical, cement, clay, and bitumen.

Grout curtain
One or more zones, usually thin, in the foundation into which grout is injected to reduce seepage under or around a dam.

Grout blanket
An area of the foundation systematically grouted to a uniform shallow depth.

Grout cap
A concrete pad constructed to facilitate subsequent pressure grouting of the grout curtain.

Hazard classification
The rating for a dam based on the potential consequences of failure. The rating is based on potential for loss of life and damage to property that failure of that dam could cause. Such classification is related to the amount of development downstream of a dam.

Head, static
The vertical distance between two points in a fluid.

Head, velocity
The vertical distance that would statically result from the velocity of a moving fluid.

Headrace

A free-flow tunnel or open channel that conveys water to the upper end of a penstock; hence, the terms "headrace tunnel" and "headrace canal."

Heel
The junction of the upstream face of a gravity or arch dam with the ground surface. For an embankment dam the junction is referred to as the upstream toe of the dam.

Height, above ground
The maximum height from natural ground surface to the top of a dam.

Height, hydraulic
The vertical difference between the maximum design water level and the lowest point in the original streambed.

Height, structural
The vertical distance between the lowest point of the excavated foundation to the top of the dam.

Hydrograph, breach or dam failure
A flood hydrograph resulting from a dam breach.

Hydrograph, flood
A graphical representation of the flood discharge with respect to time for a particular point on a stream or river.

Hydrograph, unit
A hydrograph with a volume of 1 inch of runoff resulting from a storm of a specified duration and areal distribution. Hydrographs from other storms of the same duration and distribution are assumed to have the same time base but with ordinates of flow in proportion to the runoff volumes.

Hypocenter
The point or focus within the earth which is the center of an earthquake and the origin of its elastic waves.

Inclinometer
An instrument, usually consisting of a metal or plastic tube inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within the tube. This measures at different points the tube's inclination to the vertical. By integration, the lateral position at different levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement during embankment construction (Bartholomew, Murray, and Goins 1987). A reference benchmark is used to establish the top of the inclinometer casing. The instrument probe is lowered to each slip joint in the casing, and the depth to each joint is read directly off the tape. Settlement measurements are made as each section of casing is added during embankment construction.

Initial reservoir filling
A deliberate impoundment to meet project purposes (a continuing process as successively higher pools are attained for flood control projects).

Instrumentation
An arrangement of devices installed into or near dams (i.e., piezometers, inclinometers, strain gages, measurement points, etc.) which provide for measurements that can be used to evaluate the structural behavior and performance parameters of the structure.

Intake
Any structure in a reservoir, dam, or river through which water can be discharged.

Inundation map
A map delineating the area that would be flooded by a particular flood event.

Length of dam
The length along the top of the dam. This also includes the spillway, powerplant, navigation lock, fish pass, etc., where these form part of the length of the dam. If detached from the dam these structures should not be included.

Liquefaction
A condition whereby soil undergoes continued deformation at a constant low residual stress or with low residual resistance, due to the buildup and maintenance of high pore water pressures, which reduces the effective confining pressure to a very low value. Pore pressure buildup leading to liquefaction may be due either to static or cyclic stress applications

and the possibility of its occurrence will depend on the void ratio or relative density of a cohesionless or slightly cohesive soil and the confining pressure.

Logboom
A chain of logs, drums, or pontoons secured end to end and floating on the surface of a reservoir so as to divert floating debris, trash, and logs.

Maximum flood control level
The highest elevation of the flood control storage.

Maximum pool
The highest pool elevation resulting from the inflow design flood.

Maximum wave
The highest wave in a wave group.

Minimum operating level
The lowest level to which the reservoir is drawn down under normal operating conditions.

Observation well
A hole used to observe the groundwater surface at atmospheric pressure within soil or rock.

Outlet
An opening through which water can be discharged.

Outlet works
A device to provide controlled releases from a reservoir.

Parapet wall
A solid wall built along the top of a dam (upstream or downstream edge) used for ornamentation, for safety of vehicles and pedestrians, or to prevent overtopping caused by wave runup.

Penstock
A pressurized pipeline or shaft between the reservoir and hydraulic machinery.

Phreatic surface
The free surface of water seeping at atmospheric pressure through soil or rock.

Piezometer
An instrument used for measuring fluid pressure (air or water) within soil, rock, or concrete.

Piping
The progressive development of internal erosion by seepage.

Plunge pool
A natural or artificially created pool that dissipates the energy of free falling water.

Pore water pressure
The interstitial pressure of water within a mass of soil, rock, or concrete.

Probability
The likelihood of an event occurring.

Probable Maximum Precipitation (PMP)
Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location.

Pumped storage reservoir
A reservoir filled entirely or mainly with water pumped from outside its natural drainage area.

Quality (as related to construction)
Conformance to properly developed requirements.

Quality Assurance (QA)
The procedure by which the Government fulfills its responsibility to be certain the contractor's quality control is functioning and the specified end product is realized.

Quality Management
All control and assurance activities instituted to achieve the product quality established by the contract requirements.

Reservoir
A body of water impounded by a dam and in which water can be stored.

Reservoir regulation (or operating) procedure
Operating procedures that govern reservoir storage and releases.

Reservoir surface area
The area covered by a reservoir when filled to a specified level.

Riprap
A layer of large uncoursed stone, precast blocks, bags of cement, or other suitable material, generally placed on the upstream slopes of an embankment or along a watercourse as protection against wave action, erosion, or scour. Riprap is usually placed by dumping or other mechanical methods and in some cases is hand placed. It consists of pieces of relatively large size as distinguished from a gravel blanket.

Risk
The relationship between the consequences resulting from an adverse event and its probability of occurrence.

Risk assessment
As applied to dam safety, the process of identifying the likelihood and consequences of dam failure to provide the basis for informed decisions on a course of action.

Rock anchor
A steel rod or cable placed in a hole drilled in rock, held in position by grout, mechanical means, or both. In principle, the same as a rock bolt, but usually the rock anchor is more than 4 meters long.

Rock bolt
A steel rod placed in a hole drilled in rock, held in position by grout, mechanical means, or both. A rock bolt can be pretensioned.

Runup
The vertical distance above the setup that the rush of water reaches when a wave breaks on the dam embankment.

Seepage
The interstitial movement of water that may take place through a dam, its foundation, or its abutments.

Significant wave height
The average height of the one-third highest waves of a given wave group.

Sill
A submerged structure across a river to control the water level upstream. The crest of a spillway. A horizontal gate seating, made of wood, stone, concrete, or metal at the invert of any opening or gap in a structure; hence, the expressions "gate sill" and "stoplog sill."

Slope
Inclination from the horizontal. Sometimes referred to as batter when measured from vertical.

Sluice
An opening for releasing water from below the static head elevation.

Spillway
A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

Spillway, auxiliary
Any secondary spillway which is designed to be operated very infrequently and possibly in anticipation of some degree of structural damage or erosion to the spillway during operation.

Spillway, primary (or service)
A spillway designed to provide continuous or frequent releases from a reservoir without significant damage to either the dam or its appurtenant structures.

Spillway Design Flood (SDF)
See Flood, Inflow Design.

Spillway channel
An open channel or closed conduit conveying water from the spillway inlet downstream.

Spillway chute
A steeply sloping spillway channel that conveys discharges at supercritical velocities.

Spillway crest

The lowest level at which water can flow over or through the spillway.

Spillway, fuse plug
A form of auxiliary spillway consisting of a low embankment designed to be overtopped and washed away during an exceptionally large flood.

Spillway, shaft
A vertical or inclined shaft into which water spills and then is conveyed through, under, or around a dam by means of a conduit or tunnel. If the upper part of the shaft is splayed out and terminates in a circular horizontal weir, it is termed a bellmouth or morning glory spillway.

Stilling basin
A basin constructed to dissipate the energy of rapidly flowing water, e.g., from a spillway or outlet, and to protect the riverbed from erosion.

Stoplogs
Large logs, timbers, or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit so as to provide a cheaper or more easily handled means of temporary closure than a bulkhead gate.

Storage
The retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas, as in the progression of a flood wave through a natural stream channel. Definitions of specific types of storage in reservoirs are:

a. Dead storage. The storage that lies below the invert of the lowest outlet and that, therefore, cannot readily be withdrawn from the reservoir.

b. Inactive storage. The storage volume of a reservoir between the crest of the invert of the lowest outlet and the minimum operating level.

c. Active storage. The volume of the reservoir that is available for some use such as power generation, irrigation, flood control, or water supply. The bottom elevation is the minimum operating level.

d. Live storage. The sum of the active and the inactive storage.

e. Reservoir capacity. The sum of the dead and live storage of the reservoir.

f. Flood surcharge. The storage volume between the top of the active storage and the design water level.

Surcharge
Any storage above the full pool.

Tailrace
The tunnel, channel, or conduit that conveys the discharge from the turbine to the river; hence, the terms "tailrace tunnel" and "tailrace canal."

Tailwater level
The level of water in the tailrace at the nearest free surface to the turbine or in the discharge channel immediately downstream of the dam.

Threshold Flood
The flood that fully utilizes the existing dam, i.e., the flood that just exceeds the design maximum water surface elevation at the dam.

Thrust block
A massive block of concrete built to withstand a thrust or pull.

Toe of dam
The junction of the face of a dam with the ground surface. For concrete dams, see heel.

Top thickness (top width)
The thickness or width of a dam at the level of the top of dam (excluding corbels or parapets). In general, the term thickness is used for gravity and arch dams, and width is used for other dams.

Top of dam
The elevation of the uppermost surface of a dam, usually a road or walkway excluding any parapet wall, railing, etc.

Trashrack
A device located at an intake to prevent floating or submerged debris from entering the intake.

Tunnel
A long underground excavation with two or more openings to the surface, usually having a uniform cross section used for access, conveying flows, etc.

Uplift
The uplift pressure in the pores of a material (interstitial pressure) or on the base of a structure.

Upstream blanket
An impervious blanket placed on the reservoir floor and abutments upstream of a dam. For an embankment dam, the blanket may be connected to the core.

Valve
A device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway so as to control or stop the flow.

a. Hollow jet valve. A device for regulating high-pressure outlets. Essentially, it is half a needle valve in which the needle closure member moves upstream toward the inlet end of the valve to shut off flow. As there is no convergence at the outlet end, the flow emerges in the form of an annular cylinder, segmented by several splitter ribs for admitting air into the jet interior to prevent jet instability.

b. Regulating sleeve valve. A valve for regulating high pressure outlets and ensuring energy dissipation. Inside the valve there is a fixed-cone, pointed upstream, which ensures dispersion of the jet. Outside the valve a cylindrical sleeve moves downstream to shut off flow by sealing on the periphery of the cone.

Volume of dam
The total space occupied by the materials forming the dam structure computed between abutments and from top to bottom of dam. No deduction is made for small openings such as galleries, adits, tunnels, and operating chambers within the dam structure. Portions of powerplants, locks, spillway, etc., should be included only if they are necessary for the structural stability of the dam.

Watershed divide
The divide or boundary between catchment areas (or drainage areas).

Waterstop
A strip of metal, rubber, or other material used to prevent leakage through joints between adjacent sections of concrete.

Wave runup
Vertical height above the stillwater level to which

water from a specific wave will run up the face of a structure or embankment.

Weir
A notch of regular form through which water flows.

a. Weir, broad-crested. An overflow structure on which the nappe is supported for an appreciable length in the direction of flow.

b. Weir, measuring. A device for measuring the rate of flow of water. It generally consists of a rectangular, trapezoidal, triangular, or other shaped notch, located in a vertical, thin plate over which water flows. The height of water above the weir crest is used to determine the rate of flow.

c. Weir, ogee. A reverse curve, shaped like an elongated letter "S." The downstream faces of overflow spillways are often made to this shape.

Wind setup
The vertical rise in the stillwater level at the face of a structure or embankment caused by wind stresses on the surface of the water.

Appendix C
Design

C-1. Introduction

Dams are unique because the design function can never be considered finished as long as the dam remains in place. Because of the many unknowns usually encountered, construction (and operation) must be a continuation of design. Foundation and borrow work during construction provide far better exploration than is available during design, and changes which impact safety are common. Design personnel should visit the site during construction to confirm that site conditions conform to those assumed in design or to determine if design changes are required to suit the actual conditions. Operational design inspections should continue throughout the life of the project. The design function includes planning dam instrumentation to be installed during construction and/or operation to monitor conditions that could potentially threaten the safety of the dam (Federal Emergency Management Agency 1979). The general design and construction of earth and rock fill dams are discussed in EM 1110-2-2300 and EM 1110-2-1911. The design of gravity dams is given in EM 1110-2-2200.

C-2. Design Review

All designs accomplished by an Engineering District will be reviewed by an independent, multi-discipline team. About 80 percent of Corps dam designs are accomplished internally and about 20 percent are accomplished externally by contract with private engineering firms (Federal Emergency Management Agency 1992b; U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977).

C-3. Instrumentation Plan

a. General. All Corps of Engineers dams are required to have an adequate level of instrumentation to enable the designers to monitor and evaluate the safety of the structure during the construction period and under all operating conditions. Visual observations and the interpretation of instrumentation data provide the primary means for engineers to evaluate dam safety. Recently, technology of devices for measuring seepage, stresses and movements and pore water pressures in dams has improved significantly with respect to accuracy, reliability and economics. The planning, design, and layout of an instrumentation program is an integral part of the project design. Guidance on the selection and use of various types of instrumentation for earth and rockfill dams is given in EM 1110-2-2300 and EM 1110-2-1908. Guidance on the instrumentation for concrete dams is given in EM 1110-2-1908 and EM 1110-2-4300 (see also Lindsey et al. 1986, Keeter et al. 1986, Currier and Fenn 1986, O'Neil 1989). Additional information on instrumentation of dams is available (United States Committee on Large Dams 1984 and 1986, Colorado Division of Disaster Emergency Services 1987, Federal Energy Regulatory Commission 1991, Carpenter et al. 1988).

b. Types of instrumentation. The type, number, and location of required instrumentation depend on the complexity of the project. For earth and rockfill dams, the types of measurements generally include the following (EM 1110-2-2300 and EM 1110-2-1908):

(1) Piezometers (open tube, such as the Casagrande type, electrical, vibrating wire, or occasionally closed systems; located in the foundation, abutment, and/or embankment).

(2) Surface monuments.

(3) Settlement plates within the embankment.

(4) Inclinometers (slope indicators).

(5) Movement indicators (at conduit joints, outlet works, and intake tower).

(6) Internal vertical and horizontal movement and strain indicators.

(7) Earth pressure cells.

(8) Strong motion accelerometers (in areas of seismic activity).

(9) Weirs, flow meters and flumes to measure seepage clarity and quantity.

For concrete dams, the types of measurements (and instruments) include (EM 1110-2-2200 and EM 1110-2-4300):

(1) Strain and deflection (internal and/or external gages).

(2) Crack or joint movement (internal and/or external gages).

(3) Stress and pressure (stress meter, pressure gage, pressure cell).

(4) Uplift pressure (standpipe and/or diaphragm uplift cell, water level indicator).

(5) Hydraulic leakage from foundation drains, joint drains and face drains (v-notch weir and/or critical depth meter).

(6) Plumbness and levelness (plumb lines, optical plummets, electolevel and water level meter).

(7) Alignment, settlement, and distance (laser, theodolite, triangulation, trilateration and electronic distance meters).

(8) Seismic time history and magnitude (strong motion and peak reading accelerometers and hydrodynamic pressure gages).

(9) Temperature (resistance thermometer and thermocouples).

c. Automatic data acquisition. Consideration should be given to providing a computer-based automated data acquisition system (ADAS) to provide cost-effective real time data collection from the dam. General guidance for developing an ADAS for earth and rockfill dams is presented in Appendix D of EM 1110-2-2300. A comprehensive review of ADAS for concrete structures was made under the Corps of Engineers Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Program (Lindsey et al. 1986, Keeter et al. 1986, Currier and Fenn 1986, O'Neil 1989). Topics covered include design requirements, signal conditioning and processing, data transmission and reduction, system installation and maintenance, retrofitting existing instruments to automation and computer hardware and software used to drive the automated instruments and reduce and report the collected data (U.S. Army Corps of Engineers 1987). A data base for automated geotechnical and some structural instrumentation at Federal and non-Federal projects is maintained under the Corps of Engineers Computer Applications in Geotechnical Engineering (CAGE) Program.

d. Instrumentation plan and records. During the initial project design, or reevaluation in the case of existing structures, the physical properties of the construction materials, design data, loading conditions and the appropriate factors of safety will be utilized to determine the desired threshold limits for the design condition. Quantitative values will be established for these limits that can be accurately translated into measurements that are readily obtained in the field, which will enable the designers and operators to evaluate the behavior and performance of the structure. The threshold limits along with the predicted performance levels will be addressed in the project instrumentation design memorandum. General guidance on preparation of the instrumentation design memorandum is given in EM 1110-2-2300 and ER 1110-2-110. ER 1110-2-1925 prescribes the forms to use in recording instrumentation observations. Additional information on instrumentation and monitoring is given in Chapter 4.

C-4. Coordination Between Design and Construction

Close coordination between design and construction personnel is necessary to thoroughly orient the construction personnel as to the project design intent; ensure that new field information, acquired during construction, is assimilated into the design; and ensure that the project is constructed according to the intent of the design (U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977).

a. Report on engineering considerations and instructions to field personnel. Design personnel (geologists, geotechnical engineers, structural engineers, etc.) will prepare a report to aid the construction engineers in supervision and inspection of the construction of the dam (ER 1110-2-1150).

b. Preconstruction orientation. Preconstruction orientation for the construction engineers by the designers is necessary for the construction engineers to be aware of the design philosophies and assumptions regarding site conditions and function of project structures, and to understand the design engineers' intent concerning technical provisions in the P&S (Federal Emergency Management Agency 1979).

c. Construction milestones which require visit by designers. Visits to the site by design and design review personnel are required to ensure the following (ER 1110-2-112, ER 1110-2-1150):

(1) Site conditions throughout the construction period are in conformance with design assumptions and principles as well as contract P&S.

(2) Project personnel are given assistance in adapting project designs to actual site conditions as they are revealed during construction.

(3) Any engineering problems not fully assessed in the original design are observed, evaluated, and appropriate action taken.

Specifically, site visits are required when the following occur (ER 1110-2-112):

(1) Excavation of cutoff trenches, foundations, and abutments for dams and appurtenant structures.

(2) Excavation of tunnels.

(3) Excavation of borrow areas and placement of embankment dam materials early in the construction period.

(4) Observation of field conditions that are significantly different from those assumed during design.

d. Ensure project is constructed according to intent of design. The Corps of Engineers has several cost-saving programs. One of these programs which can affect dam safety is Value Engineering (VE). The VE process provides for a multi-discipline team of engineers to develop alternative designs for some portion of the project. The construction contractor can also submit VE proposals. Any VE proposal affecting the design is to be evaluated by design personnel prior to implementation to determine the technical adequacy of the proposal. VE proposals must not adversely affect the long-term performance or condition of the dam. A potential safety problem exists if design personnel do not have the opportunity for evaluation (U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977).

Appendix D
Construction

D-1. General

Construction is a critical phase in achieving a safe dam because operational problems often go back to mistakes made in design and construction (James 1990). Projects must be continuously evaluated and "re-engineered," as required, during construction, to ensure that the final design is compatible with conditions encountered during construction (Federal Emergency Management Agency 1979). Construction considerations of earth and rock fill dams are discussed in EM 1110-2-2300 and EM 1110-2-1911.

D-2. Construction/Design Interface

Dam safety is an integral part of the planning, design, construction, and operation of a dam. Construction/design interface is essential. This is accomplished through the report on engineering considerations and instructions to field personnel, preconstruction orientation for the construction engineers by the designers, and required visits to the site by the designers.

D-3. Problems to Watch for During Construction

Specific problems with safety implications to watch for during construction include (James 1990):

a. Contacts between fill and rock or concrete.

(1) Problems due to dissimilar compressibility leading to differential settlement and voids or cracks within the embankment.

(2) Critical areas at rock abutments (particularly for steep slopes or slope breaks), spillway contacts, adjacent to conduits, and at contacts with existing fill which have had time to undergo settlement.

(3) Problems of placement and compaction complicated because of restricted access.

(4) Initial fill placement on rock foundation.

b. Failure to detect and remove localized areas of soft foundation material.

(1) Potential differential settlement and cracking.

(2) Important factor in stability of dam and foundation.

c. Preparation and treatment of cutoffs in foundations and abutments - one of the most important factors in embankment dam construction.

(1) Failure to achieve an adequate cutoff to sound rock or an impervious strata.

(2) Failure to achieve adequate reduction in seepage volume or pressure with grout curtain or to seal off large channels or voids.

(3) Failure to achieve adequate surface treatment of joints, potholes, treatment of overhangs, loose rock on abutments, or inadequate bond between embankment and foundation.

d. Construction problems during installation of drains and filters.

(1) Piping can result from failure to achieve filter criteria due to segregation of material which may occur in transition to rockfill or in exit details.

(2) Inadequate drainage capacity because of improper gradation, dirty (excessive amount of fines) materials, material breakdown during placement, or contamination of the filter with impervious material from the adjacent core due to traffic or due to surface erosion caused by rainfall.

e. Failure to detect critical zones such as voids or strata, or lenses, of pervious materials in foundations without cutoffs.

(1) Inadequate or no pressure relief.

(2) Lack of control over exits.

D-4. Obtaining Quality Construction

a. Definitions (ER 1180-1-6).

(1) Quality is conformance to properly developed requirements. In the case of construction contracts, these requirements are established by the contract specifications and drawings.

(2) Quality management is all control and assurance activities instituted to achieve the product quality established by the contract requirements.

(3) Contractor quality control (CQC) is the construction contractor's system to manage, control and document his own, his supplier's and his subcontractor's activities to comply with contract requirements.[1]

(4) Quality Assurance (QA) is the procedure by which the Government fulfills its responsibility to be certain the CQC is functioning and the specified end product is realized.

b. Policy. Obtaining quality construction is a combined responsibility of the construction contractor and the Government. The contract documents establish the level of quality required in the project to be constructed. In contracts of $1,000,000 or greater, detailed CQC will be applied and a special clause will be included in the contract. Guidance in preparing this clause is given in Appendix A of ER 1180-1-6. QA is required on all construction contracts. The extent of assurance is commensurated with the value and complexity of the contracts involved. QA testing is required (ER 1180-1-6).

c. Contractor responsibility. Contractors shall be responsible for all activities necessary to manage, control, and document work so as to ensure compliance with the contract plans and specifications (P&S). Contractor's responsibility includes ensuring that adequate quality control services are provided for work accomplished by his organization, suppliers, subcontractors, technical laboratories and consultants. For contracts of $1,000,000 or greater, contractors will be required to prepare a quality control plan (see Appendix A of ER 1180-1-6) (ER 1180-1-6).

d. Government responsibility. QA is the process by which the Government assures end product quality. This process starts well before construction and includes reviews of the P&S for biddability and constructibility, plan-in-hand site reviews, coordination with using agencies or local interests, establishment of performance periods and quality control requirements, field office planning, preparation of QA plans, reviews of quality control plans, enforcement of contract clauses and acceptance of completed construction (ER 1180-1-6).

e. Quality assurance for procedural specifications. Some QA testing in the case of earthwork embankment and concrete dam structures must be conducted continuously. A comprehensive QA testing program by the Government is necessary when specifications limit the contractor to prescriptive procedures leaving the responsibility for end product quality to the Government (ER 1180-1-6).

D-5. Construction Records and Reports

a. General. Engineering data relating to project structures will be collected and permanently retained at the project site as specified in Appendix A of ER 1110-2-100 and EM 1110-2-2300. This information has many uses such as determining the validity of claims made by construction contractors, designing future alterations and additions to the structure, familiarizing new personnel with the project and providing guidance for designing comparable future projects. These documents will include as many detailed photographs as necessary. This information is crucial to dam safety because it provides the basis for analysis and remedial action in the event of future distress.

[1] Additional information is given in EP 715-1-2, "A Guide to Effective Contractor Quality Control (CQC)" and International Commission on Large Dams Bulletin 56 "Quality Control for Fill Dams" (International Commission on Large Dams 1986).

b. Field control data. As required byEM 1110-2-2300, records including field control data on methods of compaction, in-place unit weight and moisture content, piezometers, surface monuments and slope indicators are kept for use in construction, operation and maintenance of the project. Instructions regarding specific forms to use for field data control are given in ER 1110-2-1925.

c. As-constructed drawings. As construction of a project progresses, plans will be prepared showing the work as actually constructed. Changes may be indicated in ink on prints of the construction drawings or the tracings may be revised and new prints made to show the work as constructed, as specified in ER 1110-2-1200.

d. Embankment criteria and foundation report. Earth and earth-rockfill dams require an embankment criteria and foundation report to provide a summary of significant design assumptions and computations, specification requirements, construction procedures, field control and record control test data and embankment performance as monitored by instrumentation during construction and during initial reservoir filling. This report is usually written by persons with first hand knowledge of the project design and construction. The written text is brief with the main presentation consisting of a set of identified construction photographs, data summary tables, and as constructed drawings. This report is important to dam safety because it provides in one volume the significant information needed by engineers to familiarize themselves with the project and to reevaluate the embankment in the event unsatisfactory performance occurs (see ER 1110-2-1901).

e. Construction foundation report. In addition to an embankment criteria and foundation report, all major and unique dams require a construction foundation report to be completed within 6 months after completion of the project or part of the project for which the report is written (see Appendix A of ER 1110-1-1801 for a suggested outline for foundation reports). This report documents observations of subsurface conditions encountered in all excavations and provides the most complete record of subsurface conditions and treatment of the foundation. The construction foundation report is important to dam safety because it saves valuable time by eliminating the need to search through voluminous construction records of the dam to find needed information to use in planning remedial action should failure or partial failure of a structure occur as a result of foundation deficiencies.

f. Photographs and video tape taken during construction. Embankment criteria and foundation and construction foundation reports should be supplemented by photographs that clearly depict conditions existing during embankment and foundation construction. Routine photographs should be taken at regular intervals, and additional pictures should be taken of items of specific interest, such as the preparation of foundations and dam abutments. For these items, color photographs should be taken. The captions of all photographs should contain the name of the project, the date on which the photograph was taken, the identity of the feature being photographed and the location of the camera. In reports containing a number of photographs, an alternative would be an index map with a circle indicating the location of the camera with an arrow pointing in the direction the camera was pointing, with each location keyed to the numbers on the accompanying photographs (EM 1110-2-1911). Consideration should be given to using video tape where possible to document construction of the dam.

Appendix E
Research and Development

E-1. Introduction

a. General. A strong research and development effort is necessary to reduce the uncertainties still present in dam engineering. Few research projects to date, exceptions are in risk analysis and hydrologic design parameters, have been undertaken in the name of dam safety. Alternately, many research projects may provide a better understanding of site investigation and characterization, geotechnical and/or hydraulic considerations, construction methods, natural phenomenon and structural performance, all of which contribute to the safety of dams (Federal Emergency Management Agency 1979, Interagency Committee on Dam Safety Research Subcommittee 1982).

b. Definition. The Interagency Committee on Dam Safety (ICODS) Research Subcommittee has taken a liberal approach and defined dam safety research as that research which can help enhance the safety of dams (Interagency Committee on Dam Safety Research Subcommittee 1982).

c. Assessment of needs in dam safety research.

(1) Interagency Committee on Dam Safety Report. In 1980 the Research Subcommittee of ICODS was organized and charged to identify current dam safety research to develop a 5-year projection of research needs and to establish priorities for the research needs. In a report issued in May 1982, the Research Subcommittee, for the first time, presented consolidated information on research projects and needed dam safety research (Federal Emergency Management Agency 1982).

(2) Electric Power Research Institute and Federal Emergency Management Agency Workshop. A workshop on dam safety needs, sponsored by the Electric Power Research Institute (EPRI) and the Federal Emergency Management Agency (FEMA) was held in Denver, CO, in July 1985 to study research needs in dam safety. The workshop excluded seismic disturbance predictions and their influence on dam safety and hydrological considerations that would lead to predictions of the probable maximum flood that the dam might have to withstand because these topics had received extensive treatment in a previous study by the National Research Council of the National Academy of Sciences issued in March 1985 (National Research Council 1985).

(a) The most important needs for dam safety research identified by the workshop participants included (Karadi and Landis 1986) overtopping of dams (primarily earth and rock-fill dams), and the development of rational uplift criteria for concrete dams.

(b) Almost as much importance was placed on a second set of issues including development of a data base for earth and rock-fill dams and technology transfer, research on seepage and permeability as well as grouting, development of prediction techniques for inception and progression of erosion, evaluation of seismic behavior of concrete dams, and experimentation on natural and synthetic materials to define erosion and erosion control parameters.

d. Overview of dam safety research. The Government, industry and the academic community recognize the necessity for research in dam safety. During the 1980's numerous dam safety research was initiated to study problems such as spillway adequacy, foundation defects, and piping (Thomas 1987).

E-2. Dam Safety Research in the Corps of Engineers

a. Civil works program. The Corps of Engineers for many years has had an extensive research program seeking solutions to problems encountered in its civil works program for water resource development (Federal Emergency Management Agency 1988b).

b. Repair, Evaluation, Maintenance, and Rehabilitation Program. The Corps of Engineers has recently completed a 6-year major multidisciplinary research and development program entitled "Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Program." The primary objective of the REMR program was to identify and develop effective and affordable technology for maintaining and extending the service life of existing Corps civil works structures. The REMR program covered a wide range of techniques for inspection, evaluation, repair, and rehabilitation of hydraulic structures including dams. Many of the research studies provide knowledge and techniques needed in many aspects of dam safety. An overview of the REMR program is available (U.S. Army Corps of Engineers 1990). A follow-on 7-year REMR-II program was started in Fiscal Year 1992 to address new and different needs identified by Corps field offices. Research conducted under REMR-II will have applicability to dam safety.

c. Dam Safety Risk Analysis Research Program. This program, conducted from 1984 to 1990, was managed by the Corps' Institute for Water Resources. The program consisted of numerous work units for dam safety risk analyses, including a work unit for hydrologic risk analyses conducted at the Corps' Hydrologic Engineering Center (Stakhiv and Moser 1986; Federal Emergency Management Agency 1988b; Duscha 1984, 1986; Von Thun 1984; Lave, Resendiz-Carrillo, and McMichael 1990). Studies of socioeconomic considerations and multiobjective risk partitioning in dam safety risk analysis were conducted (Cochrane, Ferrell-Dillard, Baumann 1987; Haimes et al. 1988).

E-3. Dam Safety Research by Other Federal Agencies

Significant effort goes into research on dam safety by other Federal agencies. General exchange of information and coordination of efforts are discussed in paragraph E-4.

a. Agencies. The agencies that manage the major part of Federal research and development activities related to dam safety (Federal Emergency Management Agency 1988b) are U.S. Army Corps of Engineers, Bureau of Reclamation, and Federal Emergency Management Agency.

b. Programs. Specialized research and development programs are conducted or sponsored by the Soil Conservation Service and the Electric Power Research Institute.

E-4. Coordination Among Federal Agencies

a. Technology. The technology for design, construction, operation, and maintenance of dams is constantly changing due to new developments from research; unique experience with projects under design, construction, or operation; new developments in laboratory testing and equipment and/or field investigation practices and procedures; and development of new analytical methods (U.S. Army Corps of Engineers, Office of the Chief of Engineers 1977; Federal Coordinating Council for Science, Engineering and Technology 1978).

b. Federal Agency exchange. Exchange of information and coordination of efforts on dam safety research among Federal agencies is accomplished through the ICODS Subcommittee on Safety Research and through the biennial Interagency Research Coordination Conferences (Federal Emergency Management Agency 1979, 1988b).

E-5. Transfer and Integration of New Technology

a. Transfer of new technology. There is no single, most successful, method of technology transfer. What works well for one type of technology and one type of user may not work as well for other users. Therefore, a successful technology transfer effort must use a combination of methods (U.S. Army Corps of Engineers 1990). Methods used to transfer dam safety technology include articles in technical journals, technical reports (written and/or video), information exchange bulletins, newsletters or technical notes, workshops and conferences, demonstrations of new technology on site, and electronic bulletin boards.

b. Integration of new technology. Various methods are used to integrate new technology into dam safety. Some of those methods are input to engineer manuals, engineer regulations, engineer technical letters, etc., PROSPECT course on dam safety, TADS program, training program for operations and maintenance personnel, use of experts or consultants, and computer data bases and expert systems.

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