Training
Aids for
Dam
Safety

MODULE:

DAM SAFETY PROCESS

TADS

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PREFACE

There are presently more than 80,000 dams in use across the United States. Like any engineering works, these dams require continual care and maintenance, first to ensure that they remain operational and capable of performing all intended purposes, and then to preclude endangering people and property downstream.

The safety of all dams in the United States is of considerable national, state, and local concern. Given that, the principal purpose of the TADS (Training Aids for Dam Safety) program is to enhance dam safety on a national scale. Federal agencies have responsibility for the safe operation, maintenance, and regulation of dams under their ownership or jurisdiction. The states, other public jurisdictions, and private owners have responsibility for the safety of non-Federal dams. The safety and proper custodial care of dams can be achieved only through an awareness and acceptance of owner and operator responsibility, and through the availability of competent, well-trained engineers, geologists, technicians, and operators. Such awareness and expertise are best attained and maintained through effective training in dam safety technology.

Accordingly, an ad hoc Interagency Steering Committee was established to address ways to overcome the paucity of good dam safety training materials. The committee proposed a program of self-instructional study embodying video and printed materials and having the advantages of wide availability/marketability, low per-student cost, limited or no professional trainer involvement, and a common approach to dam safety practices.

The 14 Federal agencies represented on the National Interagency Committee on Dam Safety fully endorsed the proposed TADS program and have underwritten the cost of development. They have also made available technical specialists in a variety of disciplines to help in preparing the instructional materials. The states, through the Association of State Dam Safety Officials, also resolved to support TADS development by providing technical expertise.

The dam safety instruction provided by TADS is applicable to dams of all sizes and types, and is useful to all agencies and dam owners. The guidance in dam safety practice provided by TADS is generally applicable to all situations. However, it is recognized that the degree to which the methods and principles are adopted will rest with the individual agency, dam owner, or user. The sponsoring agencies of TADS assume no responsibility for the manner in which these instructional materials are used or interpreted, or the results derived therefrom.

ACKNOWLEDGMENTS

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International Boundary and Water Commission

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Association of State Dam Safety Officials
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UNIT I. OVERVIEW

I. OVERVIEW: INTRODUCTION

INTRODUCTION

A safe dam is one that performs its intended functions without imposing unacceptable risks to the public by its presence.

The objective of a dam safety program is to ensure that dams perform as intended and do not present unacceptable risks to public safety, property, and welfare. This requires identifying structures that do pose unacceptable risks and taking corrective actions to reduce or eliminate those risks in an efficient and cost-effective manner.

DAM SAFETY AS A CONTINUING PROCESS

Responsibility for dam safety does not end with the design and construction of a dam. To be effective, dam safety must be considered as an ongoing process. The elements of an effective dam safety process are as follows:

- Taking inventory of all dams owned and/or operated or under your jurisdiction. This includes obtaining basic information about the dams in your program.

- Creating and maintaining a Dam Safety File for each dam, which contains all information relevant to the safety of the dam, such as:

  - Design and construction data
  - Geologic and hydrologic data
  - Photographs
  - Drawings and maps
  - Instrumentation data
  - Inspection and analysis reports
  - Other pertinent data

- Assigning hazard classifications that categorize the potential for loss of life and property damage if a dam were to fail.

- Conducting regularly scheduled dam safety inspections to identify potential deficiencies that could affect the safety of a dam. This includes reviewing and evaluating project data, including instrumentation data.

- Analyzing potential deficiencies identified from dam safety inspections to confirm the existence and severity of the dam safety concerns.

I. OVERVIEW: INTRODUCTION

DAM SAFETY AS A CONTINUING PROCESS (Continued)

- Taking corrective action to remedy dam safety deficiencies, which includes:
    - Developing corrective action alternatives.
    - Evaluating and selecting the appropriate corrective action alternative.
    - Implementing the appropriate corrective action alternative.
- Monitoring the dam by means of instrumentation and periodic inspections to ensure that the corrective actions taken have remedied the deficiencies, and to identify any new deficiencies that may develop.

UNIT II. DAM INVENTORY

II. DAM INVENTORY: OVERVIEW

INTRODUCTION

The first step in the dam safety process is to identify all dams owned or operated by your organization or agency, or under your jurisdiction. All dams, which should be in your Dam Safety Program, need to be identified, and basic information about them compiled to create a dam inventory. The inventory then can be organized into a dam inventory file.

The number of dams in your inventory will determine the scope of your Dam Safety Program and the resources needed to maintain an effective Dam Safety Program.

NUMBER OF DAMS

The owner or operator of several dams must allocate resources among those dams. To match resources to needs, criteria must be developed for prioritizing dams for program activities.

A Dam Safety Program that includes a large number of dams could make good use of a computerized inventory file. A variety of computerized dam inventory programs are available.

During the 1970's and early 1980's, the Corps of Engineers conducted a national inventory and inspection program. This effort compiled data on most Federal and privately owned dams above a certain size. Identification numbers were assigned to dams, and basic technical data were recorded. Survey results were reported in *National Program of Inspection of Non-Federal Dams, Final Report to Congress*, submitted to Congress in 1982 (P.L. 92-367).

II. DAM INVENTORY: BASIC INFORMATION

INTRODUCTION

For each dam in your inventory, you should compile certain basic information. Information from the Corps of Engineers survey can serve as a basis for building your dam inventory file. The Association of State Dam Safety Officials (ASDSO) has developed a methodology to update the Corps inventory, including a standard file format. The updated inventory is titled the National Inventory of Dams, or NATDAM. (NATDAM is now on a computerized data base.) Table II-1 shows the data items included in the NATDAM file. Contact your State dam safety agency to determine whether NATDAM inventory data could be used to build your dam inventory file. (The data should be checked for accuracy before being incorporated into your file.)

II. DAM INVENTORY: BASIC INFORMATION

INTRODUCTION (Continued)

TABLE II-1. NATIONAL INVENTORY OF DAMS DATA ITEMS

NATIONAL INVENTORY OF DAMS DATA ITEMS			
Field #	**Field Label**	**Field Type**	**Field Size**
1	Dam Name	Alphanumeric	65 var*
2	Other Dam Names	Alphanumeric	65 var
3	State ID	Alphanumeric	15 var
4	National ID	Alphanumeric	7
5	Latitude Deg	Number	2
6	Latitude Min	Number	4 var
7	Latitude Sec	Number	2
8	Longitude Deg	Number	3
9	Longitude Min	Number	4 var
10	Longitude Sec	Number	2
11	Section, Township, Range Location	Alphanumeric	30 var
12	County	Alphanumeric	30 var
13	River or Stream	Alphanumeric	30 var
14	Nearest City-Town	Alphanumeric	30 var
15	Distance Nearest City-Town (Miles)	Number	3 var
16	Owner Name	Alphanumeric	50 var
17	Owner Type	Alphanumeric	1
18	Priv Dam On Fed Prop	Alphanumeric	1
19	Dam Type	Alphanumeric	6 var
20	Purposes	Alphanumeric	8 var
21	Years Completed	Number	4
22	Dam Length (Feet)	Number	7 var
23	Dam Height (Feet)	Number	6 var
24	Structural Height (Feet)	Number	6 var
25	Hydraulic Height (Feet)	Number	6 var
26	Maximum Discharge (Cu Ft/Sec)	Number	7 var
27	Maximum Storage (Acre-Feet)	Number	10 var
28	Normal Storage (Acre-Feet)	Number	10 var
29	Surface Area (Acres)	Number	8 var
30	Drainage Area (Square Miles)	Number	10 var
31	Downstream Hazard	Alphanumeric	1
32	Emergency Action Plan	Alphanumeric	2
33	Phase 1 Inspection	Alphanumeric	1
34	Inspection Date	Date	11 var
35	State Regulatory Agency	Alphanumeric	30 var

*The field size 65 var designates a variable field size, within the range 1 - 65. The actual field size is set by the State, within the designated range, to accommodate State data.

II. DAM INVENTORY: BASIC INFORMATION

COMPILING INFORMATION

You may obtain physical data on the dams for which you are responsible through surveys and measurements at the damsite.

Possible data sources for adding to the information compiled in the National Inventory of Dams include:

- Aerial photography
- Permit and license files
- Field measurements
- Soil Conservation Service inventory
- Counties (for inventories of public facilities)

Your dam inventory file should include at least the following data:

- National Inventory of Dams information (verify the data: some are incorrect)
- Hazard classification
- Names and telephone numbers of owners/operators

There are a number of established formats for dam inventory files. Inventory files may be in alphabetical order by dam name, or in numerical order, with each dam assigned an identification number. Compare several different types and choose a format that best fits the needs of your program.

National Inventory of Dams identification numbers are useful in setting up dam inventory files. But as new dams are added to an inventory, new identification numbers have to be assigned. An alphabetical cross-reference list is needed when data about dams are kept in consecutively numbered files.

Other sources of information include:

- Records kept at each dam
- Files from other organizations or agencies
- Federal agencies ıesponsible for resource management
- Private engineering firms
- Federal and State governments
- Universities
- Correspondence and legal documents
- Maps and photographs
- Previous owner's records (if the dam was previously owned)

II. DAM INVENTORY: PRIORITIZING WORK

INTRODUCTION

As the number of dams in an owner's or organization's inventory increases, it becomes more difficult to accomplish inspections and investigations and remedial work that may be necessary at all the dams at once because of economic limitations, manpower limitations, or other limitations. Therefore, the work must be prioritized.

ESTABLISHING PRIORITY FOR DAM SAFETY INSPECTIONS

Initially, little information on the dams for which you are responsible may be available. Consequently, basic information on conditions and damage potential can be used to prioritize the dams for inspection purposes. For example, dams where deficiencies are known to exist or are suspected should be inspected before dams without evident problems.

Factors typically used to prioritize inspections are:

- **Condition of the Dam.** Even before an inspection of a dam occurs, you may be aware that certain dams in your inventory have a history of problems or that a potential dam safety deficiency exists. These dams should be given priority for inspection.

- **Hazard Classification.** Each dam included in your dam inventory file should have a hazard classification assigned in the National Inventory of Dams, or by a Federal or State regulatory agency, or by your own agency. High-hazard dams generally should be inspected first.

  It is important to review hazard classifications, because new downstream development may result in increased hazards and a higher classification. A reasonable interval for reviewing hazard classifications is every 5 years.

  The Bureau of Reclamation and other agencies have published guidelines on assigning hazard classifications. Information and hazard evaluation is available from the American Society of Civil Engineers and the Association of State Dam Safety Officials. Also, the TADS module entitled Evaluation Of Hydrologic Adequacy provides information on factors considered when assigning a hazard classification.

II. DAM INVENTORY: PRIORITIZING WORK

ESTABLISHING PRIORITY FOR DAM SAFETY INSPECTIONS (Continued)

- **Other Factors.** Other factors that may be used to establish inspection order are:

  - Size of dam and reservoir
  - Type of dam
  - Age of dam
  - Spillway type (controlled or uncontrolled)

ESTABLISHING PRIORITY FOR CORRECTING DEFICIENCIES

After detailed technical information gained from one or more dam safety inspections has been obtained for the dams in your inventory, the dams should be reprioritized to reflect the significance of the problems or deficiencies at each dam. This reprioritization should be performed before proceeding with technical analyses and corrective action.

The basis of prioritization should be:

- An evaluation of the likelihood of dam failure.
- The hazard potential represented by downstream development and population.
- An assessment of the feasibility of implementing interim measures, such as warning systems, to reduce the potential for loss of life and property damage if the dam were to fail.

UNIT III. DAM SAFETY FILE

III. DAM SAFETY FILE: OVERVIEW

INTRODUCTION

A Dam Safety File is essentially a compilation of all information pertinent to the safety of a specific dam. A thorough and timely assessment of the safety of a dam cannot be made without ready access to this information. Organizations generally have their own guidelines concerning the structure of Dam Safety Files. Some organizations establish a separate Dam Safety File for each dam, while others rely on a compilation of existing project files.

Establishing A Separate Dam Safety File

A separate Dam Safety File can be established with information that is pertinent to dam safety taken from the project files. Often the files from which the dam safety information is extracted contain information that is not relevant to dam safety. An abbreviated file, dedicated solely to dam safety, may be easier to use, maintain, update, and store. This abbreviated file is sometimes assembled in a notebook and called a Technical Data Book.

Using Existing Project Files

The Dam Safety File for a particular dam may simply be the storage of all project files or copies of project files in one location. Often, this is the case when limited information is available, the organization is responsible for a small number of structures, or there is no one person responsible for records management. When existing files are used as the Dam Safety File, an index of the files' contents and a statistical summary of the project should be prepared. The index will make it easier to locate specific dam safety information.

III. DAM SAFETY FILE: CONTENTS

INTRODUCTION

The function of the Dam Safety File is to provide ready access to information that can be used to help you . . .

- Prepare for conducting a dam safety inspection.
- Evaluate the observations made during an onsite inspection.
- Prepare investigation programs for evaluating dam safety concerns.
- Conduct analyses of dam safety concerns.
- Develop appropriate corrective measures for dam safety deficiencies.
- Have pertinent information available in case of an emergency or serious problem.

CONTENTS OF THE DAM SAFETY FILE

Table III-1 lists the information that may be included in a Dam Safety File.

TABLE III-1. INFORMATION THAT MAY BE INCLUDED IN A DAM SAFETY FILE

INFORMATION CATEGORY	TYPICAL ITEMS THAT MAY BE INCLUDED
Background Information	. Statistical Summary . Aerial Photographs of the Dam . Historical Events (during construction and operation) . Facility Emergency Preparedness Information . Correspondence
Geologic Information	. Regional Information . Site Information . Seismicity . Correspondence
Hydrologic Information	. Design Flood . Current Inflow Design Flood . Correspondence

III. DAM SAFETY FILE: CONTENTS

CONTENTS OF THE DAM SAFETY FILE (Continued)

TABLE III-1. INFORMATION THAT MAY BE INCLUDED IN A DAM SAFETY FILE (Continued)

INFORMATION CATEGORY	TYPICAL ITEMS THAT MAY BE INCLUDED
Foundation Information	. Description . Design and Analyses . Treatments . Construction Records, Changes, and Modifications . Instrumentation . Deficiencies (e.g., seepage, etc.) . Correspondence
Dam Structure	. Description . Design and Analyses . Treatments . Construction Materials . Construction Records, Changes, and Modifications . Instrumentation . Deficiencies (e.g., cracking, etc.) . Correspondence
Other Features Spillways Outlet Works Mechanical Systems	. Description . Design and Analyses . Construction Records, Changes, and Modifications . Reservoir Drawdown Capability . Restrictions . Operation . Deficiencies . Correspondence
Reports	. Previous Inspection Reports . Special Studies . Instrumentation Data . Operation and Maintenance Reports
Drawings	. Design, As-Built, and Modification Drawings of Major Structures and Features . Topographic Maps

III. DAM SAFETY FILE: CONTENTS

CONTENTS OF THE DAM SAFETY FILE (Continued)

If a Dam Safety File does not exist for the project you will be inspecting, one should be developed from the information gathered for the data review, and from the inspection report developed after the inspection is complete.

The TADS module entitled Preparing To Conduct A Dam Safety Inspection provides additional information on establishing and maintaining a Dam Safety File.

UNIT IV. HAZARD CLASSIFICATION

IV. HAZARD CLASSIFICATION: OVERVIEW

INTRODUCTION

A dam's hazard classification is an expression of the potential for death and destruction to downstream population and property if a dam were to fail. The dam's condition, or potential for failure, has no bearing on hazard classification.

IMPORTANCE OF HAZARD CLASSIFICATION

Compared to dams with lower hazard classifications, higher hazard dams may:

- Be inspected more frequently, depending on owner or regulating agency policy.
- Receive a greater share of maintenance funds.
- Be given a higher priority for any necessary corrective actions.

HAZARD CLASSIFICATION SYSTEMS

Hazard classification systems vary, but usually consist of three or more categories, defined by the consequences of sudden failure of a dam and uncontrolled release of the reservoir. The extent of anticipated property damage and loss of life determines the categories. Specific numbers of lives and the dollar value of property damage may not be defined. (Normally, property damage does not include loss of the dam itself nor loss of the economic benefits of the dam.) A typical hazard classification scheme is:

- High-hazard dams are those whose failure would cause large loss of life and extensive property damage.
- Moderate-hazard or significant-hazard dams are those whose failure would cause moderate property damage and the loss of a few lives.
- Low-hazard dams are those whose failure would cause little property damage and no loss of life.

IV. HAZARD CLASSIFICATION: ASSIGNING A HAZARD CLASSIFICATION

INTRODUCTION

The hazard classification assigned to a dam should be based on the consequences resulting from the failure condition that will result in the greatest potential for loss of life and property damage. For example, failure of a dam that maintains a low reservoir during normal operating conditions may result in the released water being confined to the river channel, indicating a low-hazard potential. But, if the dam were to fail due to overtopping, the result may be high loss of life and extensive property damage, representing a high-hazard potential. The appropriate hazard classification for the dam would, therefore, be high.

PRELIMINARY HAZARD CLASSIFICATION

A preliminary assessment of the hazard classification of a dam can be made on the basis of a field reconnaissance and a review of available data, including topographic maps. The purpose of the field reconnaissance is to reconnoiter the downstream area to see what potential hazards exist and their proximity to the stream channel. The likelihood of people and property being affected by dam-break flooding is then empirically assessed, and a preliminary classification assigned.

FORMAL HAZARD CLASSIFICATION

When the hazard classification is not readily apparent from a preliminary assessment, a formal hazard assessment is required wherein a dam-break inundation study is performed. The dam-break study is used to predict the depth and velocity of the failure flood wave at potential hazard locations downstream. Inundation maps are usually developed during dam-break inundation studies. These maps show the areas that would be inundated by the uncontrolled release of reservoir water.

Periodic assessments of the hazard classification should be made that take into consideration changes in downstream development or habitation.

UNIT V. DAM SAFETY INSPECTIONS

V. DAM SAFETY INSPECTIONS: OVERVIEW

INTRODUCTION

Dam safety inspections are conducted to determine the status of a dam and its features relative to its structural and operational safety. The type of inspection conducted will depend upon the purpose of the inspection.

TYPES OF DAM SAFETY INSPECTIONS

There are five general types of dam safety inspections:

- Formal dam safety inspections
- Periodic or intermediate dam safety inspections
- Routine dam safety inspections
- Special inspections
- Emergency inspections

Formal Dam Safety Inspections

Formal dam safety inspections include an in-depth review of all available data pertinent to the safety of the dam to be inspected. Design, construction, and performance data are evaluated relative to current criteria or the state-of-the-art in order to identify:

- Potential dam safety problems that may not be apparent from a visual inspection.
- Areas of the dam that should receive particular attention during the visual inspection.

A thorough visual inspection of the dam and appurtenant features is conducted and an attempt is made to operate all mechanical equipment through their full operating range, under as close to full design load (i.e., naximum reservoir elevation) as possible. The initial or first inspection of a dam is usually a formal-type inspection.

An optimal frequency for inspections cannot be substantiated from a study of dam performance versus inspection frequency. In theory, the shorter the interval between inspections, the greater the chance of observing the development of adverse conditions. However, as in other areas of engineering, economics must be considered. Consequently, the interval between inspections is determined by engineering judgment. Such subjective judgment is reflected in the differing statutes governing inspection frequency of various regulatory agencies.

V. DAM SAFETY INSPECTIONS: OVERVIEW

Formal Dam Safety Inspections (Continued)

Formal inspections are recurring. Ideally, subsequent formal inspections would coincide with advancements in the state-of-the-art in design, analysis, and construction that are applicable to the dam under review. Recognizing that advancements in the state-of-the-art are unpredictable, and generally occur gradually, establishing a frequency for formal inspections is somewhat arbitrary. A reasonable frequency might be every 10 to 12 years.

Periodic or Intermediate Dam Safety Inspections

Periodic or intermediate dam safety inspections are inspections that are conducted between formal inspections. A periodic or intermediate dam safety inspection differs from a formal inspection because while all available data are reviewed (in order to become thoroughly familiar with the dam and its features), they are not compared to the current state-of-the-art. The data review focuses on the current status of the dam and its features.

A comprehensive visual inspection is conducted; however, all of the mechanical equipment may not be test operated during any one inspection. An alternating schedule to test operate equipment may be set up whereby certain equipment are tested during one inspection, and the remaining equipment are tested at another time or during the next scheduled inspection.

For intermediate inspections, some agencies are willing to accept documentation of operation, such as an entry in a facility log describing when the different equipment had been tested or operated. If logs are used to document equipment operation, it is important to make sure the equipment was test operated within the frequency and according to the conditions specified in the Standing Operating Procedures or the manufacturer's instructions for the equipment.

The frequency of periodic or intermediate inspections varies among organizations from more than once per year to less than once every 5 years. Such factors as hazard classification and the risk of failure associated with a particular dam often figure into establishing the inspection interval. In general, an inspection frequency for intermediate-type inspections on the order of 1 to 2 years prevails.

Routine Dam Safety Inspections

The purpose of routine dam safety inspections is to provide a check on the condition of a dam and its associated features as continuously as possible. Routine inspections are therefore typically conducted by operators or other onsite personnel. Data may not be reviewed and evaluated prior to this type of inspection, depending on the inspector's familiarity with the dam and its features.

V. DAM SAFETY INSPECTIONS: OVERVIEWN

Routine Dam Safety Inspections (Continued)

Routine inspections may be structured or unstructured. Structured routine inspections may be performed weekly, monthly, or at whatever interval conditions at the facility may warrant as deemed appropriate by the owner or as recommended by a regulatory agency. Structured routine inspections may encompass the entire facility or a particular feature at one time and another feature at another time. Unstructured routine surveillance, which consists simply of making a conscious effort to be aware of surrounding conditions, is performed in conjunction with routine tasks at the facility, and as such, the frequency of occurrence is dictated by those tasks.

Special Inspections

A special inspection is conducted when only a particular feature of a dam is to be inspected. Often, a unique opportunity exists to inspect this feature which otherwise is not easily inspected. For example, if the upstream slope of a dam will be dewatered, an inspection of that slope may be scheduled. Or, if divers are needed to inspect features generally under water, that inspection may be scheduled as a special inspection.

Emergency Inspections

An emergency inspection is performed when the immediate safety of the dam is of concern, or in the event of unusual or potentially adverse conditions at the dam (e.g., during a large flood or immediately following an earthquake).

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

INTRODUCTION

Reviewing and evaluating project data provides essential information relative to:

- The type of dam
- How the dam was designed and constructed
- The features of the dam and how they were designed to function
- The geology of the damsite and reservoir area
- Adverse conditions that might not be apparent from a visual inspection
- Conditions noted from previous inspections

LEVEL OF DATA REVIEW

The extent of data review and evaluation depends upon the type of dam safety inspection to be conducted. The amount of data available on individual dams will vary among dams. For large or modern dams, voluminous data may be available, whereas there may be a limited amount or no data available for older or smaller structures. Table V-1 describes the level of data acquisition and evaluation required for each type of dam safety inspection.

TABLE V-1. LEVEL OF DATA REVIEW

TYPE OF INSPECTION	LEVEL OF DATA REVIEW
Formal Inspection	Requires an in-depth review of all pertinent data available on the dam. Design and construction data are evaluated relative to current criteria or state-of-the-art.
Periodic or Intermediate Inspection	Requires an in-depth review of all pertinent data available on the dam so the inspector can become thoroughly familiar with the dam and its features. However, data are not compared to the current state-of-the-art.
Routine Inspection	Because routine inspections are usually conducted by dam personnel, data may or may not be reviewed before a routine inspection.
Special Inspection	Data review is limited to the area or features of the dam on which the special inspection will focus. The data review should include previous inspection reports concerning the particular area or feature to be inspected.
Emergency Inspection	Requirements vary, depending on the nature of the emergency. A review of readily available data may be performed for an emergency inspection to help provide comprehensive field coverage under adverse conditions.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

PRELIMINARY AND COMPREHENSIVE DATA REVIEWS

There are basically two levels of data review: a preliminary data review and a comprehensive data review. The approach to doing preliminary and comprehensive data reviews is similar whether conducting a formal or an intermediate dam safety inspection. However, for a formal inspection, the design and construction data are compared to the current state-of-the-art. Whereas for an intermediate dam safety inspection, the emphasis of the data review is on the current condition of the dam.

Preliminary Data Review

A preliminary data review is an initial look at general information about the dam to be inspected. The information reviewed helps in . . .

- Selecting the appropriate records to review in depth later.
- Scheduling the inspection (time of year for the desired operating condition, and the amount of time the inspection will take).
- Selecting appropriate members of the inspection team.
- Making arrangements for operation of equipment and inspection of certain features.

The preliminary data review provides an overall picture of the dam, and helps identify areas for which further investigation and preparation are needed.

The preliminary data review should:

- **Identify the owner of the dam.** The owner may be your own organization, a Federal or State agency, a municipality, a private individual, or individuals. If the owner is not known, you may locate the owner by requesting a title search, or by searching:
  - State inventory records
  - Other agencies' files
  - A Federal or State dam safety computerized data base
  - Local government records
  - Plat books

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Preliminary Data Review (Continued)

- **Determine the location of the dam.** The location of the dam is needed to obtain the appropriate maps and other information on the area. If you are an owner or regulator, this information should be available in your files. If not, you might search:

  - Other agencies' files
  - State inventory records
  - U.S. Department of Agriculture aerial photographs
  - U.S. Geological Survey quadrangle maps
  - State and county maps
  - National Inventory of Dams data base

- **Determine the type of inspection to be performed.** If you are an owner or regulator of a dam to be inspected, the type of inspection should be part of any written or verbal instructions within your organization. If you are a consultant performing a dam safety inspection, the exact requirements of the inspection should be outlined by the organization requesting the inspection.

- **Identify the features of the dam.** It is necessary to identify the various features of the dam to be inspected so that appropriate inspection plans can be made. Certain features require special preparation, equipment, personnel, or arrangements to properly inspect. Information on the features of the dam may be found in your organization's files, the Dam Safety File, or as part of the owner information.

- **Identify changes in upstream and downstream conditions.** Over time, situations or conditions may occur upstream or downstream of a dam that have an effect on the dam and the reservoir. An example of an upstream changed condition that could affect the dam is the construction of another dam that affects the inflow of water into the reservoir. A downstream changed condition might be development in the flood plain that would change the dam's hazard classification.

  Any new conditions or changes in existing conditions should be identified prior to conducting a dam safety inspection. The following resources can be checked for information on upstream and downstream conditions:

  - Topographic maps
  - Aerial photographs
  - Watershed (drainage area) maps
  - Inundation maps

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Preliminary Data Review (Continued)

- **Determine the timeframe for the inspection.** There are two aspects of determining the timeframe for a dam safety inspection: the time of year (or season) in which the inspection should take place, and the time it will take to perform the actual inspection.

  The time of year or season in which the inspection should take place should be based on the objectives of the inspection, including what features of the dam are to be inspected. For example, to inspect features that are generally under water most of the year, the inspection should take place when the reservoir is at its lowest point. However, if certain features are to be tested or inspected as close to full design load as possible, the inspection should occur when the dam is at its normal yearly maximum elevation.

  The amount of time a dam safety inspection will take is dependent on a number of factors, namely:

  - The type of inspection being conducted.
  - The number and complexity of appurtenances to be inspected, and what will be test operated during the inspection.
  - The size of the structure.
  - The size of the inspection team.
  - Whether the reservoir rim will be inspected in addition to the dam, and what method of inspection will be used (by boat, on foot, etc.).

  ☞ **TIP:** After you have determined what features of the dam will be inspected as well as the general scope of the project, review the records of past inspections to get an idea of how long the inspection will take. Experience will also aid you in estimating how long an inspection will take.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Comprehensive Data Review

Conducting a comprehensive data review involves gathering and reviewing all pertinent information about the dam to be inspected.

In addition to what was reviewed during the preliminary data review, a comprehensive data review should identify . . .

- The underlying and surrounding geologic conditions and any past problems (either during construction or operation) that need to be addressed during the inspection.
- Design and construction data pertinent to the safety of the dam.
- Conditions that might, at some point, affect the structural integrity of the dam (e.g., fault zones, lack of drainage features, alkali-aggregate reactive concrete, increasing seepage, etc.).
- Past problems with the performance or operation of the dam or any of its features that need to be investigated during the inspection.

If a comprehensive data review is being done in preparation for a formal dam safety inspection, then design and construction details should be compared to current criteria or state-of-the-art practices to determine whether materials or procedures used at the time the dam was constructed pose a threat to the safety of the dam when compared to current standards.

REVIEWING AND EVALUATING THE DATA

A complete review and evaluation of the data regarding a specific dam should cover each of nine general categories of information. These categories are:

- Site conditions (geologic)
- Hydrology
- Design documents
- Construction records
- Operation and maintenance records
- Facility emergency preparedness
- Instrumentation records
- Past inspection reports
- Maps and photographs

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

REVIEWING AND EVALUATING THE DATA (Continued)

The Dam Safety File should contain this information, but it may have to be obtained by researching other sources. These categories of information are described below.

Site Conditions (Geologic)

During the pre-design phase of most dam construction projects, numerous site investigations are conducted, and the results of those investigations are recorded. This data should be reviewed to become familiar with . . .

- Regional and site geology, including characteristics of foundation rock and soil.
- Geologic features of the dam foundation, abutments, and reservoir rim.
- Relationship of the geologic features to the components of the dam.

Hydrology

Hydrologic information is used to design the capacities of the outlet works and spillways, and to determine how much freeboard is needed. Logging and other land usage will affect rainfall runoff. Rainfall and runoff projections are considered when designing the hydrologic capacity of the dam.

Over time, there may be changes in land use or in estimating the magnitude of potential rainfall events. These changes could affect the amount of water entering the reservoir. If a formal or periodic dam safety inspection is to be conducted, look at how the hydrologic design was developed. If the information is dated, recommend that a hydrologist look at the data and methodology used to determine if changes need to be made based upon current c. iteria for determining hydrologic design.

During a visual inspection, look for changes in the drainage basin that would impact the hydrologic design for the dam.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Design Documents

Design documents are the record of the original design of the dam and all appurtenant structures, as well as any changes made to the design to accommodate site conditions. Review design documents to become familiar with . . .

- The type and quality of data available at the time the dam was designed.
- The type and configuration of the dam and appurtenances constructed at the site and why they were selected.
- What decisions were made that influenced the design and why they were made.
- What analyses were performed, the methodologies used, and the results.
- Any areas where the underlying foundation and abutment conditions might affect the stability of the dam.
- How the dam was intended to be operated.
- The types and locations of instruments and why they were installed.

Evaluate the design documents to identify areas to emphasize during the inspection, and as a basis for detecting performance that is not in accordance with design expectations.

Construction Records

Construction records are the documentation of the construction phase, from the inspector's daily reports to as-built drawings. Review construction records to become familiar with . . .

- Actual foundation conditions and whether they differed from design expectations.
- Actual types and quality of materials used to construct the dam.
- Construction methods and tests of placed material used to construct the dam.
- Problems encountered during construction and how they were resolved.
- Foundation treatment methods, including excavation of unsuitable material, surface treatment of the exposed foundation, grouting, and drainage techniques.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Construction Records (Continued)

- Field changes that were necessary to treat unforeseen conditions, and what those conditions were.
- As-built drawings of the dam and its various features.

Operation And Maintenance Records

Operation and maintenance records document the ongoing operation and maintenance of a dam. Review operation and maintenance records to become familiar with . . .

- The operational history of the dam (reservoir elevations over time, gate operations, etc.) so that an inspection can be scheduled that will achieve objectives relative to accessibility of features and operation of equipment.
- Any problems that have occurred with operation of the dam and how they were resolved.
- Repairs and minor modifications made to the dam.
- The intended and actual operational capabilities of gates, valves, generators, and other equipment.
- The configuration and capabilities of electrical and mechanical equipment required to operate the different mechanical features.
- Any past performance or maintenance problems with the operating equipment so that a determination can be made on the extent to which operating and testing of equipment will be necessary.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Facility Emergency Preparedness

A review of existing data should include information on facility emergency preparedness, including the site conditions and procedures and emergency preparedness equipment. This information may be contained in the Standing Operating Procedures and the Emergency Action Plan for the dam. Review information on facility emergency preparedness to become familiar with . . .

- The facility's site conditions and procedures, including:
  - Downstream hazard classification
  - Access to the site in case of emergency
  - Security systems
  - Standing Operating Procedures
  - Emergency Action Plan
- The emergency preparedness equipment used at the facility, including:
  - Communication systems
  - Warning systems
  - Auxiliary power systems
  - Remote operation systems/equipment
  - Reservoir drawdown capability

The TADS module entitled Evaluation Of Facility Emergency Preparedness provides detailed information on assessing facility emergency preparedness.

Instrumentation Records

Instrumentation installed at a dam provides information on the dam's response to loading. Instrumentation can often detect developing problems that cannot be observed or the existence of a problem before there is any visual indication of a problem. Review the instrumentation records to become familiar with . . .

- The kinds and locations of instruments installed at the dam.
- Performance expectations for the behavior being monitored by instrumentation.
- Graphical presentations of the instrumentation data.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Instrumentation Records (Continued)

- Analyses and interpretation of structural performance of the dam and associated features based on instrumentation.

- Any problems or concerns identified previously.

- Projections of future performance of the dam based on the instrumentation record.

Evaluate the instrumentation program and data to . . .

- Decide whether the instrumentation at the dam is appropriate relative to type, location, and quantity.

- Decide whether the reading schedule is appropriate.

- Decide if the presentation and interpretation of data are appropriate.

- Identify instrument readings or trends considered to reflect unusual behavior or potential problems with the feature being monitored so that the feature can be observed carefully during a visual inspection.

- Identify data readings that are unrealistic, indicating either that an instrument should be checked to determine if it is functioning properly, or that a data reading was taken incorrectly.

Past Inspection Reports

A review of past inspection reports will be helpful in evaluating conditions at a dam. Review past inspection reports to become familiar with . . .

- Any problems or concerns that have been identified previously. Documentation of concerns over time permits evaluation of whether conditions are worsening.

- The condition of the dam and appurtenances at earlier points in time, providing a frame of reference for any new concerns that are identified. Inspection report photographs can be helpful in this respect.

V. DAM SAFETY INSPECTIONS: REVIEW AND EVALUATION OF PROJECT DATA

Past Inspection Reports (Continued)

- Conclusions regarding the condition of each feature of the dam.
- Dam safety recommendations and the status of these recommendations.
- Repairs or modifications that may not have been inspected since they were completed.

Maps And Photographs

Maps and photographs of the vicinity of the dam can provide information on the topography and geologic conditions of the damsite. If site conditions were not explored by drilling and sampling before the dam was constructed, or if records of these investigations cannot be located, examine topographic and geologic maps to get an idea of the type of foundation upon which the dam is constructed.

If dam-break inundation maps are available, you should be able to determine the hazard classification. Mineral extraction maps can help you locate areas of potential subsidence or sinkholes.

Construction photographs may help you to evaluate the construction of the dam. If other construction information is unavailable, you may be able to at least get some idea of the methods used to construct the dam. This may help explain some of the observations made during an onsite inspection. Construction photographs can also be used to identify such things as the kinds of equipment used to construct the dam or the condition of the foundation prior to receiving the dam structure. This type of information provides valuable clues to the dam's integrity.

Photographs taken over the life of the dam provide a chronological record of the changes that have occurred.

V. DAM SAFETY INSPECTIONS: INSPECTION PERSONNEL

INTRODUCTION

The members of an inspection team will vary, depending upon the:

- Requirements and the resources of the organization conducting the inspection
- Type of inspection being performed
- Findings from the data review
- Special requirements of the inspection

INSPECTION TEAM MEMBERS

The type of inspection to be performed will usually affect the number and required expertise of individuals who participate in a dam safety inspection. Table V-2 lists the different types of inspections and suggests members of the inspection team. These cases are ideal, and may not be realistic for some organizations or in some instances.

TABLE V-2. INSPECTION TEAM MEMBERS

TYPE OF DAM SAFETY INSPECTION	MEMBERS OF THE INSPECTION TEAM
Formal Inspection	Generally performed by a: . Civil Engineer . Mechanical Engineer . Geologist Based on the pre-inspection data review, one or more of the following individuals may also be included: . Geotechnical Engineer . Structural Engineer . Electrical Engineer . Hydraulic Engineer . Instrumentation Specialist

V. DAM SAFETY INSPECTIONS: INSPECTION PERSONNEL

INSPECTION TEAM MEMBERS (Continued)

TABLE V-2. INSPECTION TEAM MEMBERS (Continued)

TYPE OF DAM SAFETY INSPECTION	MEMBERS OF THE INSPECTION TEAM
Periodic or Intermediate Inspection	Usually performed by a Civil Engineer, who may sometimes be accompanied by a: . Mechanical Engineer . Geologist Based on the pre-inspection data review, one or more of the following individuals may also be selected: . Geotechnical Engineer . Structural Engineer . Electrical Engineer . Hydraulic Engineer . Instrumentation Specialist
Routine Inspection	May be performed by one or more of the following: . Civil Engineer . Mechanical Engineer . Technician (including various operation and maintenance personnel)
Special Inspection	Based on the objectives of the inspection, one or more of the following individuals may be selected: . Civil Engineer . Mechanical Engineer . Geologist . Geotechnical Engineer . Structural Engineer . Electrical Engineer . Hydraulic Engineer . Instrumentation Specialist
Emergency Inspection	Depending on the urgency and reason for the inspection, one or more of the following individuals may participate: . Civil Engineer . Mechanical Engineer . Geologist . Geotechnical Engineer . Structural Engineer . Electrical Engineer . Hydraulic Engineer . Instrumentation Specialist

V. DAM SAFETY INSPECTIONS: INSPECTION PERSONNEL

Other Inspection Team Members

Other individuals may participate in a dam safety inspection. These participants will vary, depending on the particular dam being inspected, the responsibilities of the dam owner, and any special inspection requirements.

Other inspection team members may include:

- An owner or an owner's representative
- Government agency representative(s)
- Design and construction representatives
- Inspection divers

Table V-3 presents other inspection team members and the reasons why they may be included in a dam safety inspection.

TABLE V-3. OTHER INSPECTION TEAM MEMBERS

OTHER TEAM MEMBERS	REASONS FOR INCLUSION
Owner's Representative (may include): . Dam Operator . Staff or consulting engineers . Workers to accommodate special needs of the inspection team	An owner or an owner's representative should be present at an inspection, regardless of who is performing the inspection or the type of inspection. The owner or owner's representative should: . Provide access to certain inspection areas, if needed. . Operate equipment. . Provide information about the dam. . Receive preliminary results of the inspection at the conclusion of the inspection.
Government Agency Representative	If a certain Government agency has financial, regulatory, or licensing responsibility for a dam, it may elect to send a representative to accompany the inspection team.
Design and Construction Representative	It may be appropriate to include a representative of the design and/or construction organization if it is separate from the owner or regulator who is performing the inspection. This may be done as a matter of: . Courtesy . Project agreement . Necessity due to a problem noted in the pre-inspection data review

V. DAM SAFETY INSPECTIONS: INSPECTION PERSONNEL

Other Inspection Team Members (Continued)

TABLE V-3. OTHER INSPECTION TEAM MEMBERS
(Continued)

OTHER TEAM MEMBERS	REASONS FOR INCLUSION
Inspection Divers	Various features of a dam are usually or periodically submerged. Underwater features are no less important to dam safety than those above the water's surface. These features generally should be inspected with the same regularity. Such areas will either have to be dewatered and inspected in-the-dry or examined by qualified inspection divers. Divers must be qualified to dive safely at hydro projects and preferably should be technically qualified to perform an inspection. If a diver is not a technically qualified inspection diver, he or she should perform the inspection under the direction of a qualified inspector.

The TADS module entitled Preparing To Conduct A Dam Safety Inspection provides information about inspection team members, as well as information on preparing a field inspection plan.

V. DAM SAFETY INSPECTIONS: DOCUMENTATION

INTRODUCTION

Without proper documentation at the time of a dam safety inspection, it is extremely difficult to write a complete and accurate inspection report later. It is important, therefore, to use various techniques to record information that you will present in your report. The most commonly used and accepted methods for recording information include:

- Written or tape-recorded notes
- Visual records
  - Photographs
  - Videotapes
  - Annotated drawings and sketches

Proper documentation of a dam safety inspection is important. It allows you to record both in written and visual form all of your observations and findings. Good documentation provides the information that is needed to write an inspection report. Therefore, the better the notes taken during the documentation process, the easier it will be to write a complete and accurate dam safety inspection report.

SMPL

Good documentation of a dam safety inspection takes the "SMPL" approach:

S **SKETCH** what you have observed if a photograph cannot capture important aspects of the deficiency.

M **MEASURE** and record the dimensions of the deficiency in your notes.

P **PHOTOGRAPH** the deficiency and describe its characteristics in your notes.

L **LOCATE** the deficiency in relation to some standard reference point (e.g., a feature of the dam or permanent monument) and record the precise location in your notes.

Complete and accurate documentation of an inspection is essential when it comes time to actually write a dam safety inspection report. The TADS module entitled Documenting And Reporting Findings From A Dam Safety Inspection provides detailed information on documentation techniques and writing the inspection report, and sample inspection reports for each type of dam safety inspection are provided in the appendix to that module.

UNIT VI. ANALYSIS

VI. ANALYSIS: OVERVIEW

INTRODUCTION

Potential dam safety deficiencies are usually first identified during onsite inspections or during the accompanying review and evaluation of project data, including instrumentation data. However, before appropriate corrective action can be undertaken, suspected problems must be confirmed, and the extent or severity of the problems clearly defined. Visual or instrumented monitoring is often insufficient in this regard, and investigations and analyses of the suspected problems may be needed to verify whether they actually do threaten the safety of the dam and to what extent. A number of aspects of the performance of the dam, appurtenances, and reservoir may be involved in the investigations and analyses, including:

- Hydrologic adequacy
- Hydraulic adequacy
- Static stability
- Dynamic stability
- Seepage/leakage stability
- Settlement stability
- Reservoir siltation

In order to minimize the effort, time, and costs associated with studies undertaken to confirm and better define potential dam safety problems, investigations and analyses may be approached in a progressively more involved fashion, halting the studies when enough is known to prescribe appropriate remedial measures, if they are found to be necessary.

VI. ANALYSIS: PHASE I ANALYSIS

INTRODUCTION

The first step or phase of an investigation and analysis of suspected dam safety problems is to perform an assessment of the condition of the dam based solely on the existing knowledge and data concerning the dam.

PHASE I ANALYSIS

In performing a phase I analysis, a concerted effort should be made to assemble accurate information about the dimensions, configuration, properties, etc. of the dam, but without incurring the time and expense of field investigations and laboratory testing. When information or data are lacking to conduct an analysis, such as internal water levels and pressures or material properties, conservative assumptions are made regarding these parameters. Sometimes parametric studies are conducted to determine the sensitivity of analysis results to changes in various parameters. If results vary little with changes in certain parameters, then there is probably no reason to define those parameters precisely through investigations.

Phase I analyses conducted under these conditions may yield three types of conclusions:

- **The dam is safe on the basis of conservative analysis.** If a potential dam safety concern is found not to threaten the safety of the dam based on a conservative evaluation, then the dam should also be found safe under a more rigorous assessment using actual parameters obtained through investigations and testing, and such investigations and analyses would not be necessary.

- **A dam safety concern is indicated by conservative analysis.** When phase I analysis results suggest that a problem does exist, it is prudent to confirm this with more rigorous analysis. However, in some circumstances, it can be more cost effective to initiate corrective action rather than study the condition further. Also, the nature of the deficiency may suggest that there is significant risk associated with delaying corrective action until investigations and further analyses are completed.

- **Conservative analysis is inconclusive.** Very often a phase I analysis can neither verify nor refute the existence of a dam safety concern, and additional studies are needed.

When additional investigation is required because a phase I analysis is inconclusive, the phase I analysis should identify what field data and laboratory testing are needed to conduct a more definitive phase II analysis.

VI. ANALYSIS: INVESTIGATIONS

INTRODUCTION

If additional investigation is necessary to determine whether a suspected adverse condition exists or the severity of a particular condition, experienced engineers, geologists, and/or other specialists should be retained to conduct the investigation.

Some general considerations when conducting investigations and selecting a method of analysis include:

- How complex the problem is
- What information is available
- What information can be obtained or is required, and at what cost
- Whether the problem is urgent or there is time for detailed analysis

There are two basic types of investigations:

- Field exploration and sampling

- Laboratory and in-place field testing

FIELD EXPLORATION AND SAMPLING

Field exploration and sampling is conducted to try to identify causes of known deficiencies, and to identify the actual site conditions.

When considering additional exploration and sampling, you should identify the intended use of data that will be obtained, to be certain that the following conditions are met:

- Samples of the proper type and size are obtained
- Samples are collected in the proper locations
- Appropriate data are logged
- Appropriate tests are requested

VI. ANALYSIS: INVESTIGATIONS

LABORATORY AND IN-PLACE FIELD TESTING

Laboratory and in-place field testing can be conducted to obtain actual material properties. Table VI-1 lists some of the laboratory tests that may be conducted, the purposes of the tests, and the kinds of samples needed.

TABLE VI-1. SELECTED LABORATORY TESTING

TEST	PURPOSE OF TEST	Type of Sample	
		U*	D*
GEOTECHNICAL			
Shear Testing	Analyzing stability of foundations, abutments, and reservoir slopes	X	
Consolidation Testing	Analyzing settlement of foundations and abutments	X	
Permeability Testing	Analyzing seepage in foundations and abutments	X	
Gradation Analysis	Confirming gradation of required drainfills		X
Classification	Correlating borings and undisturbed sample testing		X
Chemical Testing	Identifying aggressive or detrimental chemicals (sodium sulphates, acids, dispersive soils)		X
Resistivity/pH Testing	Identifying corrosion potential		X
CONCRETE			
Compressive Strength and Density Testing	Evaluating in-place compressive core samples	X	
Tensile Testing	Evaluating in-place tensile strengths in core samples	X	

U = Undisturbed Sample
D = Disturbed Sample

VI. ANALYSIS: INVESTIGATIONS

LABORATORY AND IN-PLACE FIELD TESTING (Continued)

TABLE VI-1. SELECTED LABORATORY TESTING
(Continued)

TEST	PURPOSE OF TEST	Type of Sample	
		U*	D*
CONCRETE (Continued)			
Shear Testing	Evaluating in-place tensile strengths	X	
Modulus of Elasticity	Evaluating in-place moduli of elasticity (static and dynamic)	X	
Poisson's Ratio	Evaluating the in-place Poisson's ratio	X	
Aggregate Testing	Testing size, gradation, hardness, durability, reactivity, impurities		X
Chemical Analysis	Identifying chemical content of cement mortar constituents, impurities, undesirable chemical reactions		X
Density, Permeability Testing	In-place density, permeability, and freeze-thaw testing	X	

U = Undisturbed Sample
D = Disturbed Sample

VI. ANALYSIS: INVESTIGATIONS

LABORATORY AND IN-PLACE FIELD TESTING (Continued)

In addition to laboratory testing, the following types of in-place testing may be conducted:

- Geotechnical
  - In-place density testing
  - In-place permeability testing
  - In-place bearing capacity or strength testing
  - Various moduli
- Concrete
  - In-place soundness testing with Swedish hammers
  - In-place testing for reinforcing steel locations and cover
  - Various moduli

For detailed information on various types of tests and investigations, refer to the TADS modules in the Data Review, Investigation and Analysis, and Remedial Action for Dam Safety Components.

VI. ANALYSIS: PHASE II ANALYSIS

INTRODUCTION

Once investigation and testing programs which define the site conditions and relevant material properties have been completed, a phase II analysis can be conducted which utilizes these more definitive parameters to confirm the existence and scope of deficiencies.

PHASE II ANALYSIS

A phase II analysis is more involved than the preceding phase I studies. Actual site conditions and material properties obtained through investigations and testing programs permit a more rigorous evaluation of the suspected problems to determine whether they actually exist and what the magnitude or severity of the deficiencies are.

In addition, in order to justify corrective action, it is necessary not only to confirm the existence of the deficiencies, but to clearly demonstrate that there is a reasonable probability the dam would fail as a result of the identified deficiencies considering the anticipated loading conditions. Reasonably probable dam failure implies that given the condition and loadings to which the dam could be exposed, and using technically sound engineering principles, a prudent, experienced engineer would conclude that the dam would likely fail.

So that the appropriate level of protection for confirmed dam safety deficiencies can be decided, it may be necessary to determine what the incremental consequences are due to dam failure for each failure mode. Incremental consequences are the loss of life and property attributable to release of the reservoir. For static and seismic dam failure scenarios, the incremental consequences are equal to the total adverse consequences of dam failure, i.e., loss of life and property would be due solely to dam failure. But for some hydrologically inadequate dams, the potential for loss of life and property during flooding above a certain magnitude may be wholly attributable to the flood event itself, with no significant contribution to losses added by release of the reservoir during the flood. This is particularly true for large floods and small reservoirs.

UNIT VII. CORRECTIVE ACTION

VII. CORRECTIVE ACTION: OVERVIEW

INTRODUCTION

The goal of corrective action should be to reduce or eliminate unacceptable risks to public safety, property, and welfare in the most efficient and cost effective manner possible. A dam owner must take corrective action when deficiencies are confirmed that threaten the safety of a dam, which in turn, poses a significant risk to life.

The need for corrective action is established by . . .

- Direction from a regulatory agency.
- Recommendations from staff engineers.
- Recommendations of consulting engineers.

Reasons that may necessitate corrective action include . . .

- Structural deficiencies are found to exist.
- Changes in engineering criteria, such as methods for computing dynamic stability, updated hydrologic data, or advancements in the state-of-the-art understanding of dam performance that call into question a dam's continued safe performance.

The findings from inspections and evaluation of a dam's condition, along with any changes in hazard classification, should determine the dam's priority for corrective action. Dams posing the greatest risk of failure and the greatest public hazard should be given top priority for corrective action.

Corrective actions undertaken to alleviate the threat of failure from remote events, such as floods, should not substantially increase the risk to life from more frequent events for which protection is currently provided. For example, if the spillway for a dam is enlarged to permit safe passage of a larger inflow design flood, the passage of lesser floods, for which protection was previously provided, should not as a consequence substantially increase the risk to the downstream populace.

Implementing a corrective action begins with developing alternatives to alleviate the condition threatening the dam. These alternatives must then be evaluated based on risk reduction versus cost, and considering environmental, social, and political factors. After choosing the appropriate alternative, it is implemented. Lastly, the dam is monitored to determine whether the corrective action has adequately alleviated the problem, and to identify any new potential concerns.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

INTRODUCTION

There are usually a number of possible corrective action alternatives that will alleviate a deficiency. Alternatives may be grouped into two broad categories:

- Structural Corrective Action:

    - Construct new structures
    - Modify existing structures
    - Make extensive repairs to existing structures

- Nonstructural Corrective Action:

    - Assume risk of dam failure (do nothing)
    - Remove hazards (people and property)
    - Make operational changes, including restricting the reservoir level
    - Install an early warning system

Nonstructural measures should always be fully considered when developing corrective action alternatives. If structural corrections are determined to be necessary, nonstructural measures may also be used in combination to reduce total costs.

STRUCTURAL CORRECTIVE ACTION

A structural correction may be considered the best alternative for correcting a deficient dam. Reasons for structural corrective action include . . .

- Repair or replacement of damaged or deteriorated components (for example, by lining a badly rusted outlet works conduit).

- Modifying the structure so that it will meet current engineering criteria (for example, by increasing spillway capacity or increasing the freeboard).

- Modifying the structure to meet standards for a higher hazard classification caused by new downstream development (for example, by increasing spillway capacity).

One structural corrective action, breaching the dam, results in taking the dam out of service rather than correcting the deficiency through repair or modification. The costs for constructing the breach and environmental restoration, and lost project revenue may be less than for other corrective actions for some smaller dams with marginal benefits.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

STRUCTURAL CORRECTIVE ACTION (Continued)

If appropriate, a dam owner should evaluate the possibility of breaching a dam when evaluating alternatives for correcting a deficiency. In some cases, the most economical solution is to take the dam out of service. But breaching a dam also requires engineering to ensure that the remnant will not impound water during heavy flows or floods. An Environmental Impact Statement may be required. Also, there likely will be the expense of reclaiming the reservoir area, and the problem of stabilizing a silted-in reservoir. Finally, development may have encroached on the downstream channel once protected by the dam from floods. Removal of the dam may subject the development to flooding even during small storms.

NONSTRUCTURAL CORRECTIVE ACTION

Nonstructural corrective action should always be considered to remedy a problem. Most nonstructural corrective actions are solutions that require minimal funding, but could result in environmental damage or lost benefits from the reservoir. Examples of nonstructural corrections include:

- Establishing a reservoir restriction that will alleviate the deficiency.
- Restricting development in the flood plain.
- Installing an automatic early warning system along with an enhanced Emergency Action Plan.
- Removing homes or other development downstream from the dam to eliminate the hazard. (In some cases, this solution would be far less expensive than modifying or repairing the dam.)

Relying on warning systems involves some element of risk, since there is no guarantee that all affected persons will be warned and respond in time to reach safety. Therefore, regulatory agencies are likely to scrutinize this type of action and impose strict conditions.

PUBLIC INVOLVEMENT

It is a basic premise of democracy that people have the opportunity to participate in the decisions that affect them. Public involvement in taking corrective action on a dam is in the best interests of both the owner of the dam and the general public. Public involvement is a process, or processes, by which interested and affected individuals, organizations, agencies, and governmental entities are consulted and included in decisionmaking.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

PUBLIC INVOLVEMENT (Continued)

Involving the public is different from informing the public in that the purpose of public involvement is both to **inform** the public and **solicit public response** regarding the public's needs, values, and evaluations of proposed solutions to dam safety problems.

One measure of an effective public involvement program is that you will be able to identify specific ways in which the final decision is responsive to public comment. If, after a public involvement program, nothing has changed, the likelihood is that this has been a public involvement program that met the letter of the law, but not the spirit of public involvement.

For the public to provide informed comment, it is necessary for the public to receive information from the dam owner. No one can evaluate alternatives unless they have been adequately informed about what the alternatives are and the consequences of each alternative. So public information is always a central element in any public involvement program.

Informing the public requires that the public be informed of specific proposed decisions or actions and be given general information about water resources management.

In addition, public comment must be solicited in such a manner that it contributes to making a decision which is feasible, environmentally sound, and enjoys the support of a significant segment of the public.

The primary goals of public involvement are:

- **Credibility.** By creating an open and visible decisionmaking process to which everyone has equal access, public involvement provides a means of making the decisionmaking process credible to groups with highly divergent viewpoints.

- **Identifying Public Concerns and Values.** Because various interest groups may have fundamentally different points of view, they will evaluate any proposed action from different perspectives. Public involvement provides a mechanism by which a dam owner can understand the problems, issues, and possible solutions from the perspectives of the various interests.

- **Developing a Consensus.** One implication of highly divergent public viewpoints is that there is no single philosophy on which there is a consensus that can guide all the owner's actions. Rather, consensus must be formed on an issue-by-issue basis. Public involvement provides a process by which such a consensus can evolve around specific owner actions.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

PUBLIC INVOLVEMENT (Continued)

Because there is no single formula for the amount and kind of public involvement activities that should be offered, these activities should be guided by the level of public interest and by the owner's need for public input.

Some issues may be of interest only to a few special interest groups, and thus may call for public involvement directed primarily at those groups. Other issues may draw interest from the broad general public, and would thus call for public involvement activities designed to reach that broader public.

Public involvement generally can be related to the decisionmaker's range of options at various stages of project planning, construction, and operation. Generally speaking, the more flexibility a decisionmaker has, the greater the potential for public participation.

Stages of Public Involvement

Several stages can be identified to assist in structuring public involvement. These stages are common to most decisionmaking processes, although some, such as planning studies, involve more individual steps.

Stage 1: Issue Identification and Sensing Public Interest

One frequent complaint about public involvement has been that the public is not included early enough in the process. Yet attempts to involve the broad general public during the earliest stages frequently meet with failure and criticism. Accordingly, unless the decision or recommendation to be reached has broad general interest at the outset, public involvement during the earliest stages should be aimed primarily at individuals and groups who are known to be directly affected by the decision or recommendation and who are known to have some familiarity with the issues. This would include local community leaders; special-interest groups; local, State, and tribal governments; and other Federal agencies.

Ample publicity efforts should be made to announce opportunities for participation to anyone who chooses to do so. Normally, large public meetings or other major efforts to reach the general public are not appropriate at this stage. To avoid subsequent criticism that participation opportunities were not provided, a record of the efforts to encourage participation should be maintained.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

Stages of Public Involvement (Continued)

<u>**Stage 1: Issue Identification and Sensing Public Interest**</u> (Continued)

Examples of techniques which might be appropriate at this stage include interviews with individuals or groups, informal speeches to community groups, and informational workshops. While the choice of public involvement techniques is discretionary, they should be chosen to offer equal opportunity for participation by individuals and groups of all viewpoints and interests within the community.

A public involvement plan will normally be prepared at the end of this stage.

<u>**Stage 2: Formulate Alternatives**</u>

Formulation of detailed alternatives is normally a consultative process involving other agencies, organized groups, and community leaders. Individuals may be the source of ideas that can be developed into alternatives through additional technical work. During this stage, it should be understood that ideas from the public usually do not provide complete, technically accurate details. However, fragmentary or incomplete ideas can sometimes be translated by technical personnel into valuable alternatives, and may help identify measures to mitigate negative impacts.

The range of alternatives to be considered as part of each decisionmaking process should be determined by the interests and ideas of the public, and should not be limited by initial impressions of, or doubts about, the practicability of the public's ideas. The public should be able to perceive that a full range of alternatives has been considered.

Examples of effective public involvement techniques to employ during this stage might include informational workshops, field trips, and informal consultation with task forces or work groups.

<u>**Stage 3: Evaluate Alternatives**</u>

This normally will be the stage at which the greatest participation will occur. A variety of public involvement opportunities should be provided during this stage, which will precede the selection of a preferred alternative or plan. Unless alternative methods of public involvement are used, a public meeting should be held during this stage. Public involvement opportunities also should precede any hearings conducted to review the adequacy of environmental impact statements.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

Stages of Public Involvement (Continued)

Stage 3: Evaluate Alternatives (Continued)

Examples of techniques that might be effective at this stage include large public meetings, informational workshops, media events, speaking engagements with groups, and continuing consultation with task forces or work groups.

Stage 4: Decisionmaking

The decisionmaking stage may require continued discussions and negotiations among the individuals, groups, and agencies most critically affected. Because this stage primarily involves the most directly affected individuals, groups, or agencies, public involvement techniques are likely to be limited to such activities as interviews, informational workshops, and small meetings. While some negotiations during this stage may require confidentiality, every effort should be made to provide the same information to all groups or individuals.

Contents of a Public Involvement Plan

The determination of need for and the preparation of a public involvement plan are necessary at the start of every public involvement program. The public involvement plan may vary in length from a single page to many pages, depending on the complexity of the program.

Public involvement plans should contain:

- A description of the preliminary informal consultation activities that led to development of the public involvement plan, including the agencies, groups, and individuals consulted.

- An analysis of the major issues likely to be addressed in the decisionmaking process.

- An assessment of the level of public interest likely to be generated by the action under consideration.

- A list of agencies, groups, and individuals most likely to be interested in the action under consideration.

VII. CORRECTIVE ACTION: DEVELOPING ALTERNATIVES

Contents of a Public Involvement Plan (Continued)

- An identification of the public involvement staff participation that may be needed from various organizational units.

- A schedule of planned public involvement activities integrated with the decisionmaking process and coordinated with related elements, as applicable, such as the preparation of planning reports or environmental impact statements.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

INTRODUCTION

Once alternatives for remedying a dam safety deficiency have been developed, the alternatives must be evaluated and a decision made as to what corrective action to take. Many factors are considered when deciding on the appropriate corrective action, including the risk to downstream development, the cost of corrective action, and environmental, social, and political issues.

The following types of decisionmaking processes may be used when choosing a corrective action:

- **Subjective,** in which a dominant bias controls the decision.

- **Deterministic,** in which an apparent solution is studied in detail. Other solutions are dismissed without formal evaluation.

- **Qualitative,** in which generalized rating parameters are used. Simplicity is traded for sensitivity.

- **Quantitative,** in which site-specific considerations of loading, response, and consequences are used to evaluate alternatives.

DECISION ANALYSIS

Decision analysis is a quantitative approach to deciding on appropriate corrective action. Other approaches to decisionmaking will not be discussed.

Decision analysis consists of an organized investigation and presentation of alternatives for accepting or reducing potentially adverse consequences and/or the risk associated with system failure or emergency operation.

The following points should be considered when choosing an alternative corrective action:

- **Cost.** Cost is generally the most important consideration in choosing an alternative. Cost studies should be performed to determine the cost associated with each identified alternative.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

DECISION ANALYSIS (Continued)

- **Consequences.** Environmental, political, social, and economic consequences may play a significant role in choosing an alternative.

- **Risk.** Risk is the probability of occurrence of an adverse event. Risk analysis compares the monetary cost of making a particular modification to the damages that may be avoided by implementing that modification. A continuum of alternatives with increasing costs and decreasing risks is evaluated during this procedure.

Two major phases in the formulation of information for a decision analysis are:

- Hazard assessment
- Risk cost analysis of alternatives

A hazard assessment is performed to evaluate the consequences attributable to dam failure and/or emergency operation (e.g., loss of life, economic loss, environmental impact, etc.) for a given dam safety problem. This information is used to select the level of protection required.

The results of a hazard assessment usually indicate the need for corrective action when the adverse consequences are due solely to failure of the dam. For dam failure due to deficiencies such as seepage, instability, or liquefaction caused by earthquake loading, the adverse consequences are solely attributable to the dam. But for hydrologic inadequacy, the contribution in damages from a dam failure may not exceed the adverse consequences that would have occurred from the flood had the dam not been present.

Because the cost differences are usually relatively low, new structures generally are designed for maximum loading conditions.

A hazard assessment is often effective in identifying likely corrective action alternatives. If an appropriate solution to a dam safety problem is identified and adequately justified at this stage, then a risk cost estimate for various alternatives would not be required.

Once the level of protection has been identified (based on appropriate input from the decisionmaker), corrective action alternatives may be compared using risk cost analysis on the basis of:

- The reduction in adverse consequences identified in the hazard evaluation, and

- The cost and continued benefits protected by the corrective actions.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

DECISION ANALYSIS (Continued)

Depending on the results of the hazard assessment, a risk cost analysis may also be performed to determine whether a greater level of protection is economically justifiable, or to determine which corrective action alternative reduces the consequences of dam failure the most for the cost.

The results of the hazard assessment and any required risk cost analysis form the basis for presenting information to the decisionmaker so that the existing situation and the corrective action alternatives are well understood.

Decision Analysis Process

The decision analysis process may be broken down into individual steps. These steps are described below.

Step 1: Define the Problem

The first step in the decision analysis process is to define the problem to be addressed. In the case of an existing dam, a situation may develop that causes some concern for the integrity of the structure and the safety of people downstream. For example, a revised probable maximum flood (PMF) may be much larger than the dam and appurtenant structures were originally designed to accommodate, or a dam safety inspection may have identified an area of potential piping.

Step 2: Describe the Pertinent Site Conditions

A description of the dam and appurtenant structures is essential in evaluating the problem. The description should also include information on the surface and subsurface geology of the site. Review of the dam safety file should reveal much of this information.

Step 3: Identify Potential Loading Conditions

Identify the range of potential loading conditions that may result in adverse consequences. The loading conditions that need to be considered include both large magnitude, infrequent events and longevity-related changes that occur during normal operation. Examples of large magnitude, infrequent events are floods and earthquakes. During normal operation, loading conditions may cause a dam failure to occur as a result of deterioration of materials or by acting on structural defects inherent in the dam.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

Decision Analysis Process (Continued)

Step 4: Determine System Response

The condition of the structure and other site conditions determine the types of system responses to be expected over the range of potential loadings. In this step, it is necessary to consider the entire range of loads to which a dam is exposed and how a dam responds to these loads.

Variables such as reservoir level prior to loading may be an important factor in a system response. For example, overtopping may occur if a large flood enters a full reservoir, but may not occur if it were to enter an empty reservoir.

As part of a system response determination, you should identify the potential adverse outcomes. Possible outcomes to a system response may include no dam failure, partial dam failure, or complete dam failure. Even if dam failure does not occur, the project may be required to make emergency releases resulting in significant adverse consequences.

Another possible consequence is a rise in reservoir elevation that produces flooding of upstream areas. In some cases, the assessment of risk and consequences might be satisfactorily made by assuming a complete and instantaneous breach of the dam; while in most cases, such an assumption will yield an unrealistic overestimation of damages due to dam failure.

The precise manner of development or cause of future internal problems under normal operation loading conditions is difficult to determine because evidence of a problem is often meager or nonexistent. Considerable investigation and frequent monitoring may be required to assess future dam performance under normal loading conditions.

The primary issue to be resolved at this point is whether the system will fail, and what will be the mode of failure. If it is determined that the system will not fail, there may be no need to continue with the decision analysis.

If it is determined that the system will fail, the decision should include:

- Identification of possible action required to reduce the potential for dam failure, and
- The priority for additional studies.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

Decision Analysis Process (Continued)

Step 5: Perform Hazard Assessment

A hazard assessment is performed to evaluate the consequences of dam failure and/or emergency operation. The adverse consequences of dam failure or emergency operation are determined based on the full range of loading conditions and system response. Adverse consequences may result either from large flood releases into the flood plain downstream of the dam or inundation of upstream areas due to flood surcharge.

There are two central issues to be resolved at this point. One is based on whether the consequences due to dam failure are worse than the nonfailure consequences for the loading conditions considered. If there is no significant difference, then there is likely no need for continuing the decision analysis process. If there is a difference, a decision should be made regarding the minimum acceptable level of protection.

The second issue is based on whether an economic risk cost analysis is required to further define the minimum level of protection, and/or whether it will be necessary to perform an evaluation of alternative courses of actions. If no risk analysis is determined to be necessary, it will not be necessary to calculate risk costs. If a risk analysis is required, the risk costs must be calculated.

Step 6: Calculate Risk Costs

To estimate the risk associated with the existing conditions and the risk reduction accomplished by the various corrective actions, a quantitative risk cost assessment is conducted by comparing proposed actions and needs on various dams. However, the process of attempting to quantify the risks associated with a dam results in numerous questions. The answers or lack of answers to these questions lead to a good understanding of the nature of the problem at each site.

Quantitative risk assessment requires consideration of . . .

- The likelihood of adverse loading,
- The likely system response to the loading,
- The likelihood of an adverse response to the loading, and
- The consequences (threat to life and property damage) resulting from dam failure.

The summation of expected losses from potential dam failure is the total risk cost.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

Decision Analysis Process (Continued)

Step 6: Calculate Risk Costs (Continued)

The potential loss of life cannot be quantified in monetary terms, and therefore is not actually a risk cost. However, the probability parameters used to determine risk of loss of life are similar to those for risk cost.

The potential loss of life estimate is presented as a particular condition (for example, up to 10 people camping in an area 10 to 12 miles downstream), and a probability of that particular loss.

The probability of the threat to life occurring is the sum of the product of:

Each Load Event Probability	X	**Failure, Given Load Probability**	X	**Likelihood of Loss of Life Condition Existing**

The steps used to develop the parameters for calculating the risk cost for a given alternative (corrective action) are the same as those used in a hazard assessment, except that risk (or probability of occurrence) is also considered.

☞ NOTE: It is important to remember that risk costs are "expected values" based on the probability of occurrence, not true values. In reality, dam failure will either occur or not occur, and the damages and losses produced will be greater than or less than the total risk cost, depending on when failure occurs.

Step 7: Develop and Evaluate Alternative Actions

Alternatives are developed based on the requirements of a particular problem (deficiency). The results of the hazard assessment and risk cost values will provide guidance when developing corrective actions.

All alternatives selected for comparison should be described in terms of cost, environmental impacts due to construction, reduction in threat to life, and other factors that are important to the decision for a particular dam.

Analysis results should illustrate the impact of each proposed modification or risk reduction both in economic terms and potential loss of life terms.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

Decision Analysis Process (Continued)

Step 7: Develop and Evaluate Alternative Actions (Continued)

At this point, an objective, comprehensive, and easily understood presentation of all relevant information should be developed to assist decisionmakers in selecting a course of action.

The presentation may contain data or study results for the following factors that influence the judgmental decisions on modification:

- Loss of life potential
- Potential property damage condition
- Probability of dam failure under a given load
- Magnitude of impact
- Benefit-cost economic analysis
- Magnitude and nature of modifications
- Any other factors

Step 8: Prepare Appropriate Documentation

The various studies involved in a decision analysis should be documented.

ENVIRONMENTAL CONSIDERATIONS

The implementation of corrective action to remedy dam safety deficiencies can result in environmental impacts ranging from very minor for some repairs or changes in operation, to major impacts for activities such as breaching a dam, substantial structural modifications, or replacement of a dam. Potential impacts can also vary with time. Some alternatives will have an immediate effect on natural resources, while other alternatives may impact resources at some future time.

Dam safety corrective actions must comply with the National Environmental Policy Act (NEPA), the Fish and Wildlife and Coordination Act (FWCA), and other pertinent environmental regulations. The compliance process begins with an assessment of the environmental impacts associated with each viable structural and nonstructural corrective action alternative. The environmental assessment may yield a Finding of No Significant Impacts (FONSI), or that there do appear to be impacts. In the latter case, a more rigorous Environmental Impact Statement (EIS) must be prepared and approved. Permit requirements under sections 402 and 404 of the Clean Water Act Amendments of 1977 must be considered in the EIS.

VII. CORRECTIVE ACTION: DECISION ANALYSIS

ENVIRONMENTAL CONSIDERATIONS (Continued)

Potential impacts to environmental resources that are not quantifiable in monetary terms should be evaluated with other procedures to ensure their consideration in the development and selection of alternatives. Also, to the extent that economic values do not fully represent the value of environmental resources, additional evaluation in nonmonetary terms should be included.

VII. CORRECTIVE ACTION: IMPLEMENTING CORRECTIVE ACTION

INTRODUCTION

Following selection of the appropriate corrective action alternative, the next step is implementing that alternative.

Assuming that the corrective action involves some repair or modification of the dam, then a dam owner must . . .

- Obtain financing for the proposed remedial action.
- Select a contractor.
- Monitor the work under the contract to verify that work is being performed as specified.

OBTAINING FINANCING

Correcting dam safety deficiencies can be costly. Some corrective measures are very simple, and can be made by in-house staff. However, major repairs or modifications can run into the millions of dollars.

Conscientious private dam owners will set aside funds for the time when repairs will be needed, but costly major modifications generally cannot be anticipated. Many dam owners are faced with the dilemma of having a dam needing expensive corrective measures, but they lack the financial resources to undertake what is needed.

There are potential sources of financial assistance, including Federal, State, local government, and private sources. However, chances of obtaining governmental financial assistance are remote and complicated by such factors as the dam location, type of ownership, jobs created, and the like.

Public-Sector Funding

Obtaining Federal funding often requires meeting complex and varied requirements. The successful use of government programs requires the dam owner to present the project with innovation and sophistication. In addition, most programs require local matching funds, while private projects must utilize funds from private sources.

VII. CORRECTIVE ACTION: IMPLEMENTING CORRECTIVE ACTION

Public-Sector Funding (Continued)

The U.S. Department of Agriculture, Farmers Home Administration (FMHA) has several different programs to assist dam owners with renovation projects. The agency functions as a lender of last resort, only when private-sector funding is not available at reasonable terms.

The Environmental Protection Agency (EPA), through its Office of Research and Development, offers a series of grants related to energy and water quality. Other programs are available through the Soil Conservation Service and the U.S. Forest Service.

The U.S. Department of Commerce, Economic Development Administration, provides business development assistance loans under three different programs to businesses and industries. Hydroelectric power projects may qualify if they are generating power for new or expanded business and industrial operations.

The U.S. Department of the Interior, Bureau of Reclamation, serves the 17 westernmost contiguous States and offers several financing programs to publicly and privately owned dams in that region. The Bureau's Regional and Washington offices may be contacted for additional information on the following programs:

- Irrigation Distribution System Loans
- Irrigation Systems Rehabilitation and Betterment Loans
- Small Reclamation Projects

State government funds may be requested for dam repair projects. Since these programs are constantly changing, any definitive statement regarding the availability of funding from State sources is not possible. Contact your State dam safety agency for information on available funding programs.

Private-Sector Funding

Dam owners are most often faced with funding dam repair projects without government assistance. Owner-generated funding could come from conventional sources such as commercial banks, savings and loan organizations, insurance companies, or private foundations.

In order to tap such conventional funding sources, the borrower must "sell the project." This generally will require the owner to retain specialists in the field of dam repair and modification to assure that proper engineering and construction practices are followed.

VII. CORRECTIVE ACTION: IMPLEMENTING CORRECTIVE ACTION

Private-Sector Funding (Continued)

A dam owner whose dam benefits others may attempt to spread the costs of dam maintenance and repair by forming a lake management district, a nonprofit organization or unit of government. In this way, dues from the membership could be used to finance dam repair projects.

It is recommended that a dam owner establish a fund in preparation for the time when repairs or modifications to the dam will be necessary.

Hydroelectric Potentials

With the rising cost of fossil fuels and the high cost of nuclear generated energy, there is renewed interest in the use of water to generate electricity. Currently, there are many dams that are retired hydroelectric sites or dams that could be retrofitted to hydroelectric generation. A dam owner may want to research the possibilities of retrofitting the site for the purpose of generating electricity. The biggest benefit from retrofitting is that the dam may become income-producing and hence self-supporting. Revenue can vary greatly, depending on the flow characteristics of the river, environmental constraints, size of the dam, and other variables.

Hydroelectric sites are often expensive to develop. Besides the conventional sources previously listed, there are hydroelectric developers who specialize in financing and developing these projects.

There are certain Internal Revenue code benefits that apply to small hydroelectric projects. Also, investment tax credits may be available. However, as is the case with Federal legislation, changes in the law can occur, and thus specialists knowledgeable in these areas should be consulted regarding specific projects.

CONTRACTING

If a dam owner has an in-house engineering staff with the necessary capability, repairs or other corrective action can be designed in-house. In some cases, it may be desirable to have a specialized consultant or consultants assist and advise the in-house staff.

In most cases, however, the dam owner will need to employ private firms to do the design and construction work. Selection of an appropriate firm is important both to assure that the remedial action will be successful and to protect the owner's financial and legal interests.

Repairs to dams owned by Federal, State, or local government should follow appropriate guidelines for selecting a contractor, as set forth by law.

VII. CORRECTIVE ACTION: IMPLEMENTING CORRECTIVE ACTION

SELECTING A DESIGN ENGINEERING FIRM

In selecting an engineering firm, the owner should consider the qualifications required to do the work and the cost of the work. The firm should demonstrate that its staff has the appropriate experience for the specific type of work or that appropriate specialists will be retained to assist. A negotiated selection based on both qualifications and the proposed fee of several firms generally is recommended.

There are often advantages in retaining a local firm, if they have the appropriate capability, because communication and response is faster and travel costs, etc., less. In most cases, design work will require field work such as surveying and mapping, subsurface and materials investigations, sampling, and testing. There may also be a need for environmental and archeological assessments and permits from various regulating agencies and all of these factors must be considered in developing the scope of the work.

It may also be desirable to have the design firm oversee construction. Note that whoever designs and develops the contract documents should have a role in the construction to assure that:

- Design intent is carried out.
- Design assumptions and actual conditions found during construction are compatible and, if not, that necessary modifications are developed and included in the construction.

It is also desirable that design and construction documents be reviewed and approved. Some regulatory agencies require that the work be submitted for their review and approval before construction can start. If not, it is in the owner's best interests to assure that design meets current engineering standards and that the contract documents will result in the desired product while protecting the dam owner's financial and legal interests. If the owner doesn't have the capability to review and approve the contract documents, another firm or specialist should be considered to review the work and provide recommendations.

SELECTING A CONSTRUCTION FIRM

Construction of remedial actions can be accomplished by either in-house personnel or by a contract. There are many advantages to using in-house personnel, particularly for small jobs, including much greater flexibility in scheduling, modifying, and completing the work. If skilled personnel are available, it is often feasible to rent any extra or special equipment needed.

VII. CORRECTIVE ACTION: IMPLEMENTING CORRECTIVE ACTION

SELECTING A CONSTRUCTION FIRM (Continued)

In most cases, however, particularly for major repairs, the work is contracted in one of several ways:

- **Low Bid.** The usual method for public agencies is to solicit sealed bids from several contractors and award to the low bidder. If necessary, one can include specific experience requirements for subcontractors and supervisory personnel if the work merits special concern.

- **Prequalification of Bidders.** Prospective bidders are screened on a well-defined, uniform basis for specialized experience, and the work is awarded to the low bid from the acceptable bidders.

- **Negotiated Bid.** This type of contract is commonly used by private owners and has the advantage that both qualifications to do the work and price can be considered. It can be used by some public owners by following specific procedures, and is desirable for selecting a contractor for specialized work.

- **Cost Plus.** This implies that the owner pays all actual costs plus overhead plus a negotiated percentage of profit. This type of contract is usually expensive and only used where work must be expedited (as for emergency repairs) or when the nature of the work is very uncertain.

General things to remember include:

- A public agency may have to follow specific legal procedures for contracting.

- The contractor who gets the work should have experience in the type of work and be capable of completing the work within the time requirements of the contract. (There are certain types of work such as grouting, cutoff walls, dewatering, etc. which are best performed by specialty contractors.)

- Construction by contract must be carefully administered and supervised to protect the owner's legal and financial interests, and to assure that the contractor's work will provide the remedy intended by design, modified as necessary to accommodate any changed conditions discovered during the construction process.

VII. CORRECTIVE ACTION: IMPLEMENTING CORRECTIVE ACTION

CONSTRUCTION MANAGEMENT

If the dam owner does not have capable in-house staff, then a construction manager should be employed. Several factors must be considered in construction management. Contract administration includes such factors as evaluating contractor scheduling and progress, work placement, periodic and final payments, negotiation of modifications, and evaluation of contractor claims. Accurate, detailed records must be kept to protect the owner's legal and financial interests.

The contractor's work must be inspected by experienced personnel to assure that the work meets the requirements of the contract. Frequency of inspection may vary from occasional to full time, depending on the activity and progress. As a rule of thumb, nothing should be covered up without inspection. Inspection activity, observation directives to the contractor, problems, etc., should be routinely documented by written reports.

In most cases, the contractor is required to provide materials, equipment, structural components, or use specified procedures. Various submittals or shop drawings must be reviewed and various materials such as concrete, slope protection, and earthfill must be tested for compliance with contract requirements. Review and testing must be done by experienced personnel and results, approvals, or disapprovals, etc., documented. Frequency of testing should be in accordance with accepted practice or as needed to assure compliance.

There generally will be modifications and changes to the design during construction. These may be the result of mistakes or a better way to do something. In remedial work for dams, the design is often based on what can be seen or interpretation of conditions from borings and testing of samples. During construction, the actual conditions uncovered may not be the same as interpreted or assumed for design. **It is absolutely essential that experienced designers look at actual conditions as construction progresses to determine whether the design remedy is compatible with actual conditions. If not, the design must be modified to fit the actual conditions.**

If remedial construction is of any consequence, the details of design and construction are vital to understanding and monitoring behavior of the dam. Consequently, documentation of design, contract documents, as-built drawings, foundation reports, test data, photographs, etc., must become part of the permanent files for the dam.

A regulatory agency having jurisdiction over the dam may have rules and requirements concerning construction of remedial action or other modifications that must be followed. That may include periodic progress reports, on-site inspection of construction, and submission of as-built drawings and other information upon completion of inspection.

VII. CORRECTIVE ACTION: MONITORING

INTRODUCTION

Following implementation of a structural modification to remedy a dam safety deficiency, the dam and corrected condition should be carefully monitored to ensure that the corrective measure has been successful in alleviating the problem. Monitoring can be accomplished by either, or preferably both, visual inspection and instrumentation.

MONITORING STRUCTURAL MODIFICATIONS

Visual inspections and instrumented monitoring should, of course, be included as a part of the regular dam safety process to monitor the overall condition of the dam, but following corrective action, particular attention should be given to those areas that had experienced distress previously. Oftentimes additional instrumentation will be installed along with a corrective measure to monitor its performance. Consideration should be given to increasing the frequency of visual and instrumented monitoring for a period of time to assure that a safe condition has been achieved.

With certain deficient conditions, an iterative corrective action process may be employed. This approach may be tried in certain economic situations and when there is likely to be difficulty in determining the cause of the deficient condition. Definitive investigations and analyses may have a low probability of success and be more costly than a trial-and-error approach of trying successive corrective measures until a remedy is achieved. With this strategy, a less expensive fix is tried first. Conditions are then monitored, and if necessary, increasingly more sophisticated and expensive measures are implemented until monitoring indicates the problem is corrected. Obviously, the key to the success of this approach is the monitoring program.

The success of corrective measures for hydrologic and seismic deficiencies may only be known when there is an occurrence of the relatively infrequent event(s) for which the measures were installed. Monitoring of the dam following these events is still essential.

APPENDIX A

GLOSSARY

GLOSSARY

ABUTMENTS - Those portions of the valley sides that underlie and support the dam structure, and are usually also considered to include the valley sides immediately upstream and downstream from the dam.

APPURTENANT STRUCTURES - Auxiliary features of a dam that are necessary to the operation of the dam project. These may include spillways, outlet works, gates and valves, power plants, tunnels, and switchyards.

BREACH - An eroded opening through a dam that drains the reservoir. A controlled breach is a construction opening. An uncontrolled breach is an unintentional opening that allows uncontrolled discharge from the reservoir.

CONDUIT - A pipe or box structure constructed by joining sections of pipe or conduit in an excavated trench, inside a tunnel, on the ground surface, or supported on cradles.

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

DAM FAILURE - The uncontrolled release of impounded water. There are varying degrees of failure.

DAM SAFETY FILE - A compilation of all information pertinent to the safety of a specific dam. A separate Dam Safety File may exist; however, some organizations consider a compilation of existing project files to be the Dam Safety File.

DEFICIENCY - An anomaly or condition that affects or interferes with the proper and safe operation of the dam.

DOWNSTREAM FACE - The inclined surface of a concrete dam that faces away from the reservoir.

EMERGENCY - A condition that develops unexpectedly, endangers the structural integrity of a dam and/or downstream property and human life, and requires immediate action.

EMERGENCY ACTION PLAN (EAP) - A formal plan of procedures designed to minimize consequences to life and property, and requires immediate action.

FAILURE - The catastrophic breakdown of a dam, characterized by the sudden, rapid, and uncontrolled release of impounded water.

GLOSSARY

FLOOD - A temporary rise in water levels resulting in inundation of areas not normally covered by water. Hypothetical floods 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.

FOUNDATION - The portion of the valley floor that underlies and supports the dam structure.

FREEBOARD - The vertical distance between a stated water level and the top of a dam or spillway crest.

GATE - An adjustable device used to control or stop the flow of water in a waterway. A gate consists of a leaf or member that is moved across the waterway from an external position.

HAZARD CLASSIFICATION - A rating (e.g., low, moderate/significant, or high hazard) that is a representation of the probable loss of life and property damage downstream from a dam based on the results of breaching studies of the dam, and an identification of the area downstream that would be inundated.

INSTRUMENTATION - An arrangement of devices installed into or near dams (e.g., piezometers, inclinometers, strain gauges, measurement points, etc.) that provide measurements used to evaluate the structural behavior and performance of the structure.

LEAKAGE - The undesirable flow of water through joints, cracks, and openings in hydraulic structures.

OUTLET - An opening through which water can be discharged.

OUTLET WORKS - A system of dam components that regulates or releases water impounded by a dam. Components of an outlet works include an entrance channel, intake structure, conduit, gate or valve housing, energy dissipators, and return channel.

PIPING - The progressive internal erosion of embankment, foundation, or abutment material.

PROBABLE MAXIMUM FLOOD (PMF) - The flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin under study.

RESERVOIR - The body of water impounded by a dam.

SEEPAGE - The passage of water through embankment, foundation, or abutment material.

GLOSSARY

SPILLWAY - A structure over or through which flood flows are discharged. If the rate of flow is controlled by mechanical means, such as gates, it is considered a controlled spillway. If the elevation of the spillway crest is the only control, it is considered an uncontrolled spillway.

STANDING OPERATING PROCEDURES (SOP) - Written guidelines to be followed for normal and emergency operation of the components of a dam.

VALVE - An adjustable device used to control or stop the flow of water in a waterway. A valve is fixed permanently within the waterway, and has a closure member that is either rotated or moved transversely or longitudinally in the waterway in order to control or stop the flow.

APPENDIX B

REFERENCES

REFERENCES

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