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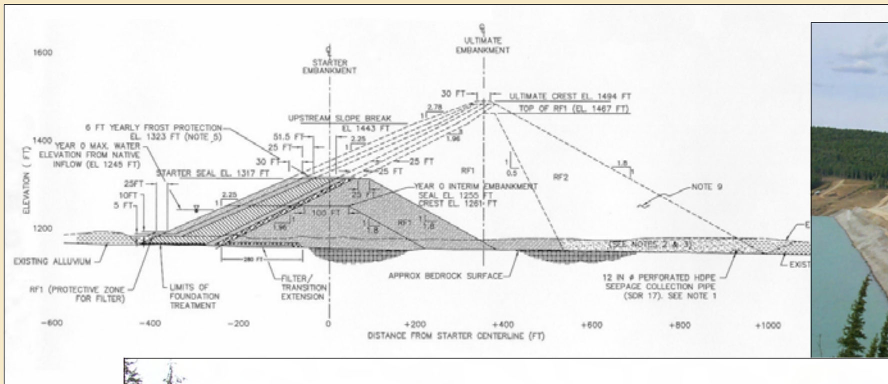
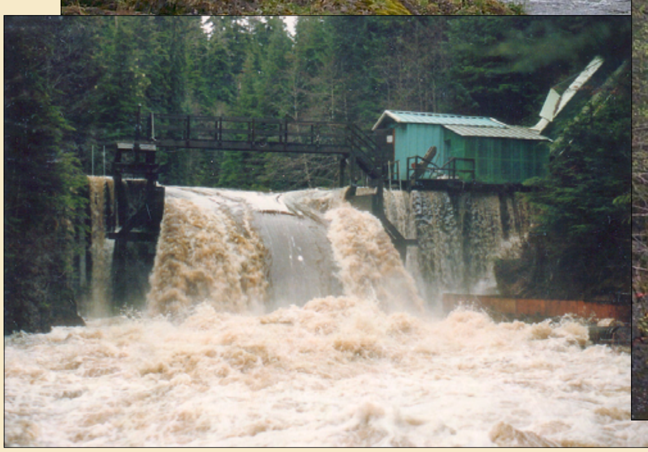
Guidelines for Cooperation with the Alaska Dam Safety Program





June 2005

Prepared by

Dam Safety and Construction Unit

Water Resources Section

Division of Mining, Land and Water

Alaska Department of Natural Resources

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Alaska Department of Natural Resources

June 30, 2005

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About the Cover

The cover photographs depict the five stages in the regulatory life of a dam, which are explained in Chapter 4.

Top left: **Application for New Construction**
A design cross section from the Fort Knox Tailings Dam located near Fairbanks.
Compliments of Clyde Gillespie and Fairbanks Gold Mining, Inc.

Top right: **Construction**
An interim raise under construction at the Fort Knox Tailings Dam.
Photograph by Charles Cobb.

Center: **Operation**
Steve Anderson conducting the visual inspection for a periodic safety inspection at the Cannery Creek Dam owned by the Alaska Department of Fish and Game and operated by the Prince William Sound Aquaculture Association.
Photograph by Charles Cobb.

Bottom Left: **Remediation**
A "five-year" flood overtopping the Kake Dam in Southeast Alaska indicates that remediation is needed to address an inadequate spillway capacity.
Photograph by Thomas Hanna.

Bottom right: **Closure**
The remains of the Kake Dam after the majority of the dam structure was removed following a breach in the dam that occurred during a high-water event.
Photograph by Charles Cobb.

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Acknowledgements

This project was developed through financial assistance from the National Dam Safety Program. Thanks to the Federal Emergency Management Agency and the Association of State Dam Safety Officials for their support of the Alaska Dam Safety Program. Special thanks are directed to Judy Griffin of Word Wrangling for her expert help in designing, formatting, editing, and revising these guidelines. Thanks to Brett Flint, Dan Johnson, Cecil Urlich, and others at URS Corporation for their efforts in developing the initial draft of this document. Thanks to John Magee and Bob Scher at R&M Consultants Inc. for their contributions to the final version. Thanks to Clyde Gillespie of Fairbanks Gold Mining Inc., Howard Weston of the City of Kodiak, and Stan Foo of the Alaska Department of Natural Resources for their time and comments on the final draft. Thanks to Gary Prokosch, Bob Loeffler, and all of my colleagues at the Division of Mining, Land and Water for their support of the Dam Safety and Construction Unit. Finally, thanks to all of the dam owners and operators for their cooperation with the Alaska Dam Safety Program.

Charles F. Cobb, P. E.
State Dam Safety Engineer
Alaska Department of Natural Resources

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ABBREVIATIONS

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ASDSO	Association of State Dam Safety Officials
ADSP	Alaska Dam Safety Program
AS	Alaska Statute
CQA	construction quality assurance
CQA/QC	construction quality assurance/quality control
CQC	construction quality control
CSI	Construction Specifications Institute
Dam Safety	Dam Safety and Construction Unit
DQA	design quality assurance
DQC	design quality control
EAP	emergency action plan
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
HMR-54	Hydrometeorological Report 54
IDF	inflow design flood
MCE	maximum credible earthquake
MDE	maximum design earthquake
NDSP	National Dam Safety Program
NPDP	National Performance of Dams Program
OBE	operating basis earthquake
O&M	operations and maintenance
PGA	peak ground acceleration
PMF	probable maximum flood

PMP	probable maximum precipitation
PSI	periodic safety inspection
TADS	Training Aids for Dam Safety
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USCOLD	U.S. Committee on Large Dams
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USSD	U.S. Society on Dams
WSDOE	Washington State Department of Ecology

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Guidelines for Cooperation with the Alaska Dam Safety Program

Chapter 1

WELCOME TO THE ALASKA DAM SAFETY PROGRAM

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Chapter 1

WELCOME TO THE ALASKA DAM SAFETY PROGRAM

In this chapter:

- Purpose of the Alaska Dam Safety Program
- Description of responsibilities assigned to various entities
- A disclaimer and discussion of liability

1.1 Introduction

Communication is the key to the safety of dams. Design drawings, operation and maintenance manuals, inspection reports, emergency action plans, and other documents are simply methods of communicating important information directly related to the safe design, construction, and operation of dams. Because dams are typically complex, unique, engineered structures with a long service life, the specific nature of this communication will be similarly complex and unique, and will occur during a long period of time.

The Alaska Dam Safety Program (ADSP) is administered as a cooperative effort between the Alaska Department of Natural Resources (ADNR) and the various persons, businesses, agencies, and other interests that are involved in the design, construction, and operation of dams. To foster cooperation, communication between these parties must be effective and efficient. These guidelines are intended to promote communication, understanding, and agreement by presenting an overview of the various aspects of the ADSP.

The Mission

The mission of the Alaska Dam Safety Program is to protect life and property in Alaska through the effective collection, evaluation, understanding and sharing of the information necessary to identify, estimate and mitigate the risks created by dams.

If cooperative relationships can be established, the entire community will benefit. By anticipating the scope of the communication, all of the entities involved will better understand the level of commitment necessary to accomplish the objectives of a particular project.

Safe dams are the ultimate objectives of the ADSP. To achieve these goals, the program must be rational, technically sound, balanced and equitable. The ADNR seeks to establish these attributes through the publication, review, and refinement of this document.

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1.2 Objectives of Guidelines

The *Guidelines for Cooperation with the Alaska Dam Safety Program* is intended to establish a consistent basis for communication between the ADNR, dam owners and operators, and various other entities involved in the planning, design, construction, operation, and regulation of dams in Alaska. This document is intended as a compendium for guidance purposes only—it is not a restatement of statutes and regulations, nor is it a detailed design guide. The objectives of these guidelines are described below:

- To define the administrative basis of the ADSP
- To outline the minimum information required to obtain the various certificates of approval necessary to construct and operate dams under program jurisdiction
- To outline an application and review process to obtain the various certificates of approval issued under the ADSP
- To provide a consistent template for the design, construction, and operation of dams in Alaska while still recognizing that every dam is unique
- To highlight important design aspects of dams that are unique to Alaska or otherwise merit specific attention
- To recommend acceptable design approaches, references, and performance levels based on the hazard potential classification of the dam
- To provide guidance on the preparation and implementation of an operations and maintenance (O&M) program and a periodic safety inspection (PSI) program
- To provide guidance on the preparation, implementation, training, and exercise of emergency action plans (EAPs)
- To outline other aspects of the ADSP
- To provide a forum for, and encourage communication and cooperation between, dam owners and ADNR to work together in siting, designing, constructing, repairing, modifying, operating, and closing dams in Alaska

About the Guidelines

These guidelines consist of text, lists, tables, figures, and sidebars. The format is intended to minimize boredom and maximize content, at the expense of nebulous or superfluous detail. Tables and figures contain important information that may require some study to understand. Sidebars are intended to present related noteworthy information that does not necessarily fit the flow of the section. References contain additional detailed information and guidance that may be used to accomplish the mission. Comments on these guidelines are welcome.

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1.3 Project Responsibilities

1.3.1 Alaska Department of Natural Resources

Alaska Statute (AS) 46.17.020 requires the ADNR to employ a professional engineer to "supervise the safety of dams and reservoirs" in Alaska. The State Dam Safety Engineer is the authorized representative of the commissioner of ADNR responsible for the following:

- Adopting regulations and issuing orders necessary for ensuring dam safety
- Providing routine administration of the ADSP and the Dam Safety and Construction Unit (Dam Safety) of the ADNR
- Classifying dams based on the potential hazard to lives and property created by the dam
- Approving the design, construction, operation, and inspection of dams through "certificates of approval," which are issued based on specific information submitted to Dam Safety for review
- Identifying unsafe dams that compromise the mission of the ADSP, and taking the necessary steps to mitigate those risks
- Raising the level of compliance for jurisdictional dams that are out of compliance with state dam safety regulations
- Enforcing the dam safety statutes and regulations through appropriate legal actions, if necessary, including issuing injunctions, assuming operational control of the dam, breaching the dam, or other activities necessary to mitigate the risk
- Providing information and educational material about dams in Alaska and dams in general, including the Alaska Dam Inventory, Training Aids for Dam Safety, conference proceedings, and other resources.

Levels of Authority at ADNR

Commissioner, ADNR

Director, Division of Mining, Land and Water

Chief, Water Resources Section

State Dam Safety Engineer, Dam Safety and Construction Unit

1.3.2 Owner of Dam

According to AS 46.17.900(6), the "owner" of a dam means a person who owns, controls, operates, maintains, manages, or proposes to construct a dam or reservoir, and includes a public utility and the appointed or authorized agents, employees, lessees, receivers, or trustees of an owner. The owner is ultimately responsible for the safety of the dam. As such, the owner bears all liabilities associated with the dam. Therefore, the owner is directly responsible for mitigating the risks created by the dam. The dam owner's responsibilities include the following:

- Understanding the risks created by the dam

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- Developing policies, plans, and procedures necessary for complying with the requirements of the applicable dam safety statutes and regulations
- Sustaining the project by providing all funding necessary to design, construct, operate, maintain, repair, and, if necessary, remove the dam at the end of the life of the project
- Hiring personnel qualified to manage and operate a dam in a safe manner

Typical Dam Owners in Alaska

Municipalities

State and federal agencies

Native corporations

Private and public owned businesses and corporations

- Retaining qualified engineering consultants and contractors to complete any work beyond the expertise of the owner or the owner's employees
- Ensuring the quality and success of the overall project

1.3.3 Operator of Dam

For purposes of these guidelines, the "operator" of a dam is considered to be that legal extension of the owner of the dam who is actually involved in the daily operation of the dam. As such, the operator of the dam is responsible for the following:

- Executing those policies, plans, and procedures, developed by the owner, necessary for complying with the requirements of the applicable dam safety statutes and regulations
- Developing and performing the requirements of the O&M program
- Monitoring the performance of the dam under all conditions (including routine and extraordinary inspections), reading instrumentation, and analyzing and reporting of data
- Developing and maintaining the EAP, activating the plan when necessary, executing the responsibilities of the operator outlined in the plan, and exercising and revising the plan on a regular basis to ensure that the plan is current
- Maintaining all records associated with the dam, including design and construction records, routine inspection records, PSI reports, incident reports, and certificates of approval
- Developing and implementing recurrent training programs to educate employees on their specific duties related to the dam

Typical Dam Operators in Alaska

Public works departments

Utilities

Mines

Fish hatcheries and processors

1.3.4 Qualified Engineer

Because a dam is a unique and complex engineered structure that has certain associated risks, an experienced engineer is required to assure that a dam is designed, built, and operated with appropriate concerns for safety. A "qualified engineer" is defined in the Alaska dam safety regulations under Title 11, Chapter 93, Section 193, of the Alaska Administrative Code (11 AAC

93.193). To meet the criteria for a qualified engineer, an individual must be a civil engineer currently licensed to practice in Alaska under the State Board of Registration for Architects, Engineers, and Land Surveyors. The regulations also state that the qualified engineer must have at least five years of experience as a licensed or registered professional civil engineer. In addition, an engineer who may certify hazard potential classifications, design engineering reports, design and construction drawings, construction completion reports, and construction record drawings must have "significant work experience in the design, construction, inspection and safety of dams" [11 AAC 93.193(a)(3)]. The regulations allow a slightly lower qualification for engineers who may conduct and certify PSIs of dams under 11 AAC 93.159. Those engineers must have "sufficient work experience to determine the safety of the particular dam being inspected and to make reliable recommendations regarding the operations and maintenance of that dam, inspections of that dam, and other matters related to the safety of that dam." AS 46.17.050 indicates that qualified engineers who conduct PSIs must be approved by Dam Safety.

Within these guidelines, references to the "engineer" are widespread and context dependent. A variety of engineers are referred to and described; examples are "engineer of record" and "construction inspection engineer." For purposes of these guidelines, references to the engineer assume a qualified engineer as defined by the regulations, within the context of the discussion. Generally speaking, the engineer is responsible for the following:

- Maintaining a curriculum vitae that demonstrates relevant experience to meet the qualifications described in 11 AAC 93.193
- Understanding the regulatory setting of a project, the intent of the regulations, and the work necessary to accomplish the desired outcome, without taking shortcuts that circumvent the regulations and compound the risks
- Becoming an "engineer of record" by placing a signature and seal on reports, drawings, specifications, and other engineering work products. ["Sealed" is defined in 11 AAC 93.201(12) to mean "prepared by an engineer or a person under that engineer's direct supervision, and bearing the signature and seal of that engineer as required by AS 08.48.221 and 12 AAC 36.185."]
- Recognizing personal limitations and assembling a team of engineers as required to address all of the broad range of engineering disciplines typically associated with a dam, including additional engineers of record to certify details associated with other disciplines such as electrical or structural components
- Locating and designing dams with safety as the primary goal by using technically sound and complete engineering methodology that represents the level of care exercised by professional engineers across the nation
- Observing and documenting the construction of dams in a manner consistent with the approved construction quality assurance plan

Typical Qualified Engineers in Alaska

Employees of engineering companies

Independent consultants

Employees of dam owners or operators

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- Communicating effectively with the owner, Dam Safety, and other entities with complete information packages that contain well-written reports and specifications and good-quality drawings
- Refining and executing the scope of work necessary to complete a detailed PSI of a dam and developing a clear, quality report
- Processing and analyzing monitoring and inspection data in a manner that leads to technically sound, defensible conclusions
- Recommending reliable, cost-effective solutions to mitigate problems discovered during the life of the project

1.3.5 Construction Contractors

Construction contractors must possess appropriate qualifications, licenses, permits, and authorizations specific to the project and as required for constructing dams or performing other related work such as repairs or construction of appurtenant structures. Contractors are responsible for the following:

- Performing the work in accordance with the approved plans and specifications without deviation, unless the engineer of record and Dam Safety have formally approved the change
- Identifying and reporting any aspect of the design or construction that could affect the safe performance of the finished product, or may need special attention or specialized construction techniques to accomplish design objectives
- Identifying and reporting any changed conditions that occur or are discovered during construction that require special attention or additional work to meet the intent of the design
- Developing and implementing a construction quality control plan that results in a good-quality product constructed in accordance with the plans and specifications
- Recording or assisting in the recording of all information necessary to develop a complete and accurate record of the construction, including record drawings, photographs, quality control test results, product brand names and specifications, and other important information
- Developing the additional plans necessary to complete the project in a manner that ensures the safety and protection of the site personnel and the downstream interests
- Cooperating with the engineers, quality assurance inspectors, and Dam Safety

Other Implied Responsibilities

The descriptions of responsibilities included in these sections are not comprehensive. Other responsibilities certainly exist. Each entity must understand its own obligations under the related statutes and regulations, business contracts, written and verbal agreements, and codes of ethics.

1.3.6 Emergency Responders

Entities that respond to a dam-related emergency may include the dam owner and operator, local fire and police departments, local emergency response managers and healthcare providers, civilian relief organizations, Alaska State Troopers, Alaska Division of Emergency Services, the National Weather Service, the United States Coast Guard, the Alaska Department of Environmental Conservation, the ADNR, and others. All entities that agree to participate as responders and are identified in an EAP for a dam are responsible for the following:

- Becoming familiar with the EAP and the potential impacts that could result if the dam were to fail
- Understanding their respective roles in an emergency and preparing adequately in advance to respond appropriately if an emergency situation develops
- Participating and cooperating in exercises of EAPs that are coordinated and conducted by the operator of the dam
- Reviewing the contents of the plan related to their respective responsibilities and contributing constructive advice on improvements to the plan
- Developing the necessary policies or procedures within their respective organizations so that knowledge of the EAP and associated responsibilities is prevalent within the organization, as appropriate

1.4 Disclaimer

This document is intended to provide only general guidance about the administration of the ADSP. It is not intended as a detailed design manual, specification, or regulation. The dam safety statutes and regulations (AS 46.17 and Article 3 in 11 AAC 93) are the legal governance for the ADSP. Dam Safety reviews each project on an individual basis and may require information, studies, and submittals that are not discussed herein, as deemed necessary to ensure that a dam is as safe as is reasonably possible.

The dam safety statutes provide indemnity to the ADNR regarding dams and reservoirs. AS 46.17.110 states:

> …A person may not bring an action against the state, the department, or agents or employees of the state, for the recovery of damages caused by the partial or total failure of a dam or reservoir, or by the operation of a dam or reservoir, or by an act or omission in connection with
>
> > (a) approval of the construction of a dam or reservoir, or approval of flood-handling plans during or after construction;

(b) issuance or enforcement of orders relating to maintenance or operation of a dam or reservoir;

(c) control or regulation of the dam or reservoir;

(d) measures taken to protect against failure of the dam or reservoir during an emergency; or

(e) investigations or inspections authorized under this chapter.

An exception is allowed for "the recovery of damages caused by an action undertaken by a dam owner that was negligently ordered by the state over the owner's objection." Nevertheless, the owner, operator, and engineer have primary responsibility for the safe design, construction, and operation of a dam. Historically, the standard of care that a dam owner exercises is closely examined by the courts when assessing the liability for the failure of a dam (Association of State Dam Safety Officials [ASDSO], undated).

Legally Speaking

Strict liability and negligence are legal concepts applied to dam owners by courts in the United States when ruling on liabilities associated with dams. Compliance with the Alaska Dam Safety Program is intended to establish a minimum standard of care; however, additional effort by the dam owner may be required to fully understand and manage the associated risks and liabilities of owning a dam.

Finally, references herein to textbooks, technical papers, guidelines, Web sites, and other resources do not imply endorsement by the ADNR or suitability for any specific purpose of the user. Each submittal to Dam Safety will be evaluated based on its individual and specific merit at the sole discretion of the commissioner of the ADNR.

Funding provided by the Federal Emergency Management Agency for the development and revision of this document does not imply their endorsement of the information contained herein.

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Guidelines for Cooperation with the Alaska Dam Safety Program

Chapter 2

BASIS FOR REGULATION OF ALASKA DAMS

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Chapter 2

BASIS FOR REGULATION OF ALASKA DAMS

In this chapter:

- The history of the Alaska Dam Safety Program
- Summary of Alaska dam safety statutes and regulations and the definition of a dam
- Discussion of the hazard potential classification for dams in Alaska

2.1 History of Dam Safety in Alaska

During the 1970s, several dams failed in both Alaska and the Lower 48. These incidents resulted in numerous deaths, including one in Alaska, and millions of dollars in property damage. In 1972, Public Law 92-367 was signed. This law required the U.S. Army Corps of Engineers (USACE) to inventory non-federal dams in America and make recommendations for a National Dam Safety Program.

As early as 1973, Alaska passed laws that attempted to regulate the construction of dams in the state. In 1975, Senate Bill 362 titled "An Act Relating to Supervision of Safety of Dams and Reservoirs" attempted to delegate responsibility to the Department of Public Works, but failed to pass the Ninth Legislative Session. On May 29, 1978, Governor Jay S. Hammond signed an agreement for the Alaska Department of Transportation and Public Facilities to jointly review specific dams with the USACE. Subsequent discussions within the state led to the conclusion that the ADNR had authority related to dam safety through the Water Use Act (AS 46.15) and 11 AAC 72.060, Dam Construction (1973). However, the ADNR expressed a great deal of concern because the statutes and regulations inadequately addressed important dam safety issues such as routine safety inspections, operation and maintenance, and liability.

On December 29, 1979, revised dam safety regulations became effective under Article 3 of 11 AAC 93, Dam Safety and Construction. By 1982, the Water Management Section of the Division of Land and Water Management began to organize the ADSP. The efforts of the entire staff of the central region Water Management Section were directed toward the dam safety program. Nevertheless, the section's civil engineer expressed concern about the ability of the ADNR to address important technical issues associated with dam safety, and the current regulations were again sharply criticized as inadequate. During the early 1980s, the ADNR (with support from consultants) conducted Phase I inspections and site visits of practically every dam that could be identified in the state, including those identified in the National Inventory of Dams. The USACE listed 175 dams in Alaska in 1981. By 1984, the ADSP was staffed with three positions and a $350,000 general fund budget.

In 1987, the state legislature passed the Alaska Dam Safety Act and AS 46.17, which elaborated on the basis for the state to "supervise" the safety of dams in Alaska. The state was required to employ a professional engineer for this purpose, but the staffing of the ADSP was reduced to that one individual and the budget was cut significantly. In 1989, the dam safety regulations were again promulgated under Article 3 of 11 AAC 93. These statutes and regulations were more comprehensive than previous versions, and were based on a model state dam safety program developed by the ASDSO and extensive review of dam safety regulations from other states.

The content of Article 3 of 11 AAC 93 was reviewed in detail and updated between 2000 and 2004. The regulations were revised to include important changes and clarifications about the hazard potential classification; dam owner's periodic safety inspections and emergency action plans; applications for construction, modification, repair, removal, and abandonment of dams; certificates of approval issued by the department; incident reporting; qualifications for dam design and inspection engineers; and other important information. The original publication of the *Guidelines for Cooperation with the Alaska Dam Safety Program* (September 2003) was based on a draft version of the revised regulations. The current guidelines (June 2005) are revised to be consistent with the current, final version of the regulations adopted in October 2004.

2.2 Dam Safety Statutes and Regulations

The current statutes and regulations are outlined and summarized in the subsections below.

2.2.1 Alaska Statutes

"Supervision of Safety of Dams and Reservoirs" is the heading of AS 46.17. Each section of the chapter is briefly summarized below.

Section 46.17.010, Purpose – Provides a statement of purpose for Chapter 17.

Section 46.17.020, Administration and Staffing – Provides the ADNR with a professional engineer and other employees to supervise the safety of dams in Alaska. Also allows the ADNR to hire engineering consultants to assist in its duties.

Section 46.17.030, Regulations and Orders – Allows the ADNR to adopt regulations and issue orders.

Section 46.17.040, Approval Required – Requires dam owners and operators to obtain approval from the ADNR to operate existing dams or to construct new ones.

Exemptions for Federal Dams

Federally owned and operated dams and dams regulated by the Federal Energy Regulatory Commission are exempt from the Alaska dam safety statutes and regulations. Dams that are designed and constructed by federal agencies and transferred to non-federal entities are not exempt.

Section 46.17.050, Inspections – Requires the periodic inspection of dams and allows the ADNR to conduct the inspection and charge the costs to the dam owner or require the dam owner to conduct the inspection to the department's standards using an approved, qualified engineer.

Section 46.17.060, Entry upon Property – Provides the ADNR access to inspect a dam or reservoir and related documents with either written notice or an administrative subpoena or under emergency conditions.

Section 46.17.070, Determining Danger – Allows the ADNR to consider the engineering integrity of the existing or proposed dam or reservoir to determine if there is a current or future danger, and allows the ADNR to order a dam owner to mitigate the danger.

Section 46.17.080, Injunction and Damages – Allows the ADNR, with the assistance of the attorney general, to seek an injunction and damages to enforce the dam safety statutes and regulations.

Section 46.17.090, Judicial Review – Subjects a final action of the ADNR to a judicial review as provided in the Administrative Procedures Act (AS 44.62).

Section 46.17.100, Other Government Agencies – Allows the ADNR to enter cooperative agreements with other government agencies to administer the chapter, with certain exceptions; exempts federally owned and operated dams and dams regulated by the Federal Energy Regulatory Commission (FERC) from the provisions of the chapter; and excludes any restrictions of the chapter on the powers of the Alaska Department of Environmental Conservation (ADEC) and the Alaska Department of Fish and Game (ADF&G).

Section 46.17.110, Action Against the State for Damages – Limits action against the state, its agents, and employees for damages in carrying out the provisions of the chapter.

Section 46.17.120, Duties of the Owner – Excludes any relief to a dam owner for the duties or liabilities incident to owning and operating a dam or reservoir.

Section 46.17.150, Penalties – Outlines violations related to the dam safety statutes and regulations that can result in a Class A misdemeanor.

Section 46.17.120, Definitions – Provides definitions of select terminology.

2.2.2 Alaska Administrative Code

Regulations governing dam safety are articulated in Article 3, Dam Safety, of 11 AAC 93. Brief summaries of the sections in Article 3 regulations follow.

Section 93.151, Applicability – States that the regulations apply to all dams in Alaska, except dams owned or operated by the federal government or regulated by the FERC, and clarifies hazard potential classifications that cause a dam to fall under state jurisdiction, regardless of the geometry of the dam or reservoir.

Section 93.153, Barrier Measurement – Specifies how dams are to be measured for determining regulatory jurisdiction.

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Section 93.157, Hazard Classification– Defines three classifications of dams based on the potential danger to lives and property caused by the dam; requires the owner, upon request of the ADNR, to provide information for use in a review of the hazard potential classification and allows the owner to propose the hazard potential classification based on that information; and allows the ADNR to reject an owner's proposed classification for certain reasons, and assign a hazard potential classification based on readily available information.

Section 93.159, Owner's Periodic Safety Inspection – Discusses the requirements for PSIs of dams based on the hazard potential classification, and allows the ADNR to order additional inspections, studies, or analyses; revoke a *Certificate of Approval to Operate a Dam;* or issue operation, maintenance, repair, shutdown, or removal orders, as necessary to protect life and property.

Transfer of Dam Jurisdiction

For dams under state jurisdiction that are transferred to Federal Energy Regulatory Commission (FERC) jurisdiction, Dam Safety will yield jurisdiction to the FERC under the following conditions:

- *The dam owner must submit a license application to the FERC.*
- *The FERC must provide a letter to the ADNR stating its assumption of dam safety regulatory responsibility.*

If a FERC license is not issued, Dam Safety jurisdiction will return to the state. For dams under FERC jurisdiction that are transferred to the state, an application for a Certificate of Approval to Operate a Dam *is required.*

Section 93.161, State Inspections – Outlines the conditions under which the ADNR may conduct inspections of dams and those under which ADNR may conduct the inspection and recover costs from the owner.

Section 93.163, Emergency Remedial Action – Allows the ADNR to take actions necessary to protect life and property, and outlines the conditions under which such action would be taken.

Section 93.164, Owner's Emergency Action Plan – Requires the owner of a Class I or II dam to develop an EAP, identifies required content of an EAP, requires revision of the plan at least every three years, and requires exercise of the plan on a frequency determined by the ADNR.

Section 93.167, Certification of Dams Constructed Before May 31, 1987 – Lists the requirements for obtaining certification for dams built before May 31, 1987.

Section 93.171, Dam Construction, Repair, or Modification – Lists the application requirements for obtaining a *Certificate of Approval to Construct a Dam* for new dams or a *Certificate of Approval to Repair or Modify* a Dam for existing dams.

Section 93.172, Dam Removal or Abandonment – Lists the application requirements for a *Certificate of Approval to Remove or Abandon a Dam* for existing dams, including mine tailings dams.

Section 93.173, Certificates of Approval – Outlines the circumstances under which the department may issue, deny, or revoke a certificate of approval, as well as conditions and administrative requirements for the various certificates of approval issued by the ADNR.

Section 93.175, Records – Lists the requirements for records to be kept by the owner of a dam.

Section 93.177, Reporting of Dam Incidents – Requires the dam owner to report certain incidents involving the dam to the ADNR.

Section 93.193, Qualified Engineers – Identifies the minimum qualifications of an engineer who can seal the following documents requiring ADNR approval: proposed hazard potential classifications, design engineering reports, design and construction drawings, construction specifications, construction completion reports, and other engineering documents. In addition, the qualifications of engineers who may be approved by the ADNR for conducting PSIs are identified.

Section 93.195, Inundation Maps and Inflow Design Flood Information – Lists requirements for the development of inundation maps and inflow design floods.

Section 93.197, Operation and Maintenance Manuals – Identifies the requirements for the contents of an operation and maintenance manual, which is required for all dams.

Section 93.201, Definitions – Provides definitions of select terminology.

2.3 Definition of a State Jurisdictional Dam

To determine if a dam is under state jurisdiction, AS 46.17.900(3) defines a dam as an "artificial barrier and its appurtenant works, which may impound or divert water" and which meets at least one of the following three descriptions:

- "(A) Has or will have an impounding capacity at maximum water storage elevation of 50 acre-feet and is at least 10 feet in height measured from the lowest point at either the upstream or downstream toe of the dam to the crest of the dam." A dam with a jurisdictional height (H) of 10 feet or taller and that stores 50 acre-feet or more of water meets this description, as illustrated in Figure 2-1.
- "(B) Is at least 20 feet in height measured from the lowest point at either the upstream or downstream toe of the dam to the crest of the dam." A dam that is 20 feet or more in height meets this description regardless of its storage capacity, as illustrated in Figure 2-2.
- "(C) Poses a threat to lives and property as determined by the department after an inspection." In other words, a barrier with a Class I (high) or Class II (significant) hazard potential classification is considered a dam, even if it does not meet the geometric criteria of A or B, above. See Section 2.4 for guidance in determining the hazard potential classification.

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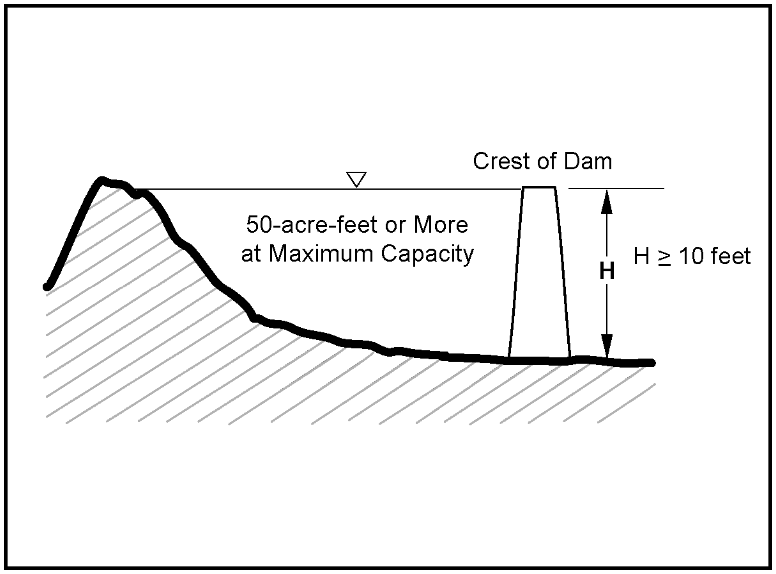

Figure 2-1. Jurisdictional Dam Based on Storage Capacity and Height

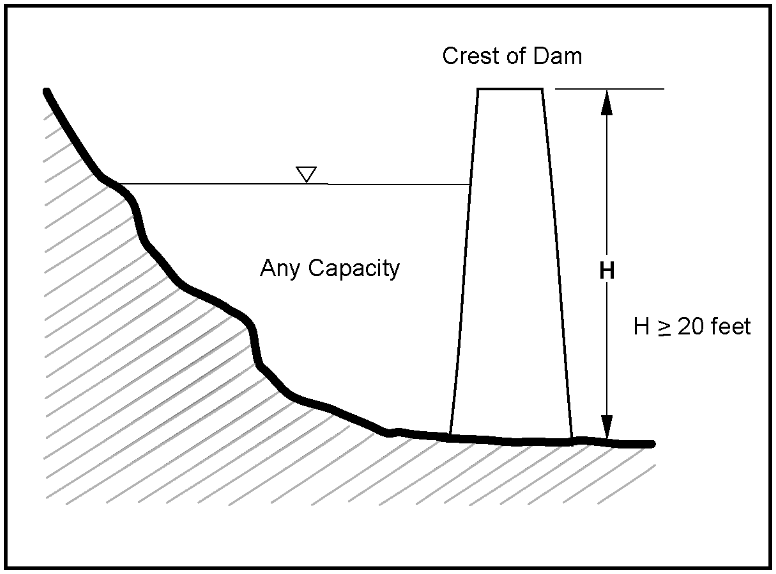

Figure 2-2. Jurisdictional Dam Based on Height Only

Another guide for determining whether a dam is under state dam safety jurisdiction is illustrated in Figure 2-3.

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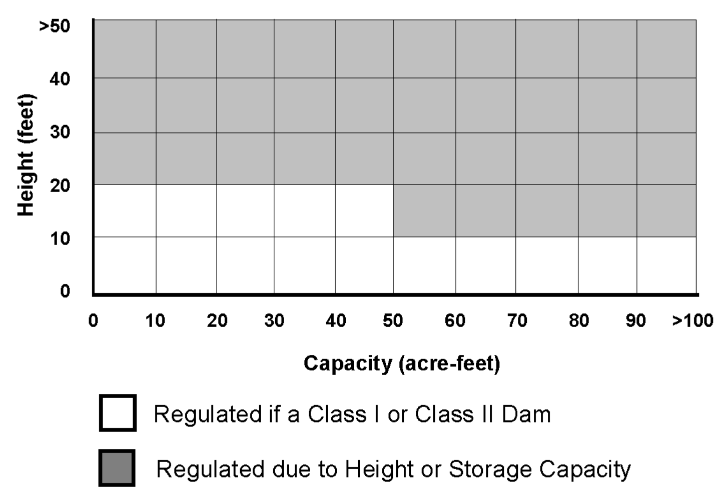


Figure 2-3. Summary of Conditions for State Jurisdiction of a Dam

Additional clarification is provided in the regulations under 11 AAC 93.153, Barrier Measurement. This section clarifies how barriers are to be measured with respect to a watercourse and states:

> …the height of the barrier will be measured as either
>
> (1) the maximum vertical distance from the natural bed of the watercourse at the upstream or downstream toe of the barrier, whichever yields the greater measurement, to the top of the barrier, or
>
> (2) if the barrier is not across a watercourse, the maximum vertical distance from the lowest elevation of the outside limit of the barrier to the top of the barrier.

Figures 2-4 through 2-7 present graphical interpretations of this section. Figures 2-4 and 2-5 illustrate a section and profile, respectively, of a typical, cross-valley dam.

Figure 2-7 is intended to illustrate a saddle dam or auxiliary dike in a situation for which measurement from the top of the dam to the "upstream" toe could result in a dam height that is taller than the height of the "downstream" toe. Figure 2-6 illustrates a dam that is not located across a watercourse, such as a ring

Water Supply Dams

A reliable supply of water is critical to the health and economy of a community. Primarily on the basis of experience with the Kake Dam failure in 2000, Dam Safety asserts that a community of 500 residents or more that depends on a dam for the primary water supply represents a risk sufficient to justify a Class II (significant) hazard potential classification of the dam, regardless of its geometry; therefore, such a dam and reservoir are under state dam safety jurisdiction.

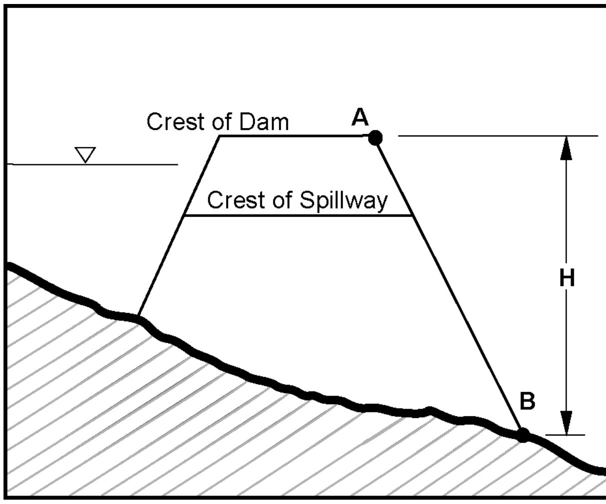


Figure 2-4. Typical Dam Section

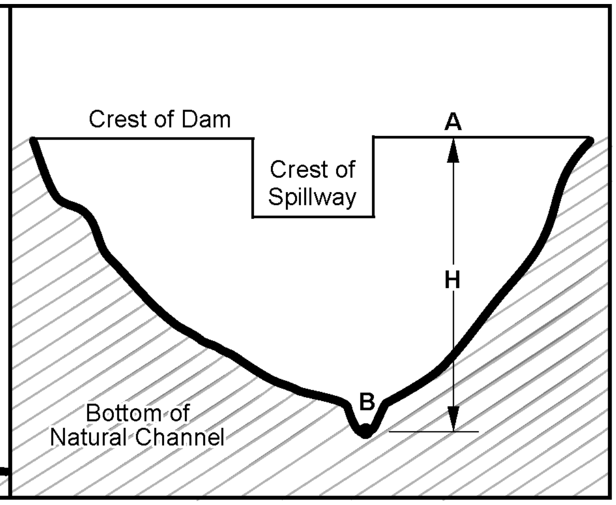


Figure 2-5. Typical Dam Profile

Figure 2-6. Ring Dike

H = Elevation A – Elevation B

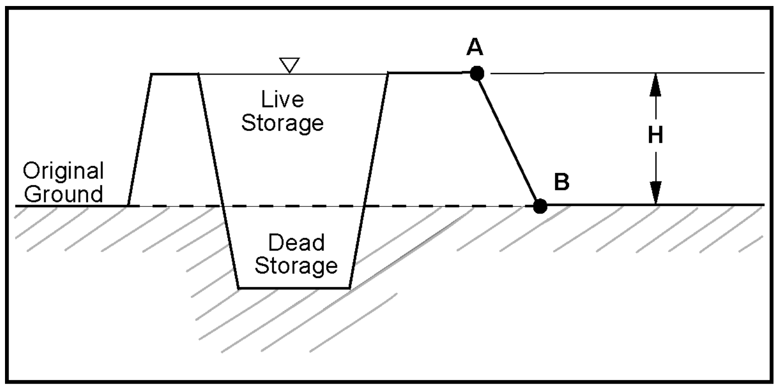
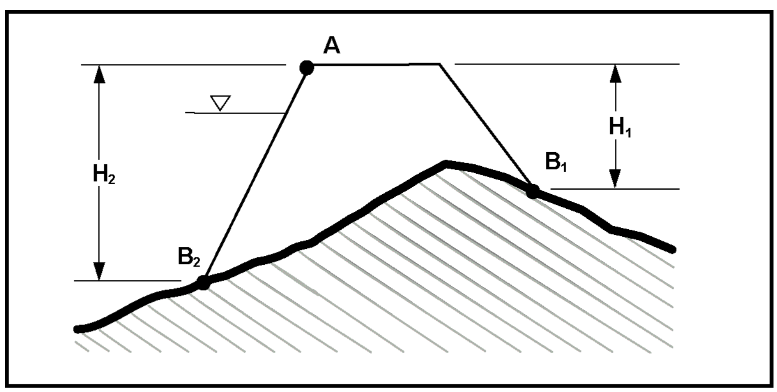


Figure 2-7. Saddle Dam or Off-Stream Dam

H = larger number
If $H_1 > H_2$, then $H = H_1$
If $H_2 > H_1$, then $H = H_2$



dike or a heap leach pad. In this case, the volume below original grade, or dead storage, would not be counted if H were between 10 and 20 feet and the volume calculation was required to determine jurisdiction.

In all cases for which the volume calculation is required, the "maximum water storage elevation" is assumed to occur at the crest of the dam, as indicated in Figures 2-1 and 2-6, unless the spillway is sufficient to pass the design flood (defined later in these guidelines). In this case, the volume should be calculated at the elevation of the maximum stage during the flood. The height of the dam would still be measured to the crest of the dam to include freeboard.

If a dam is to be used for storing substances other than clean water, such as sewage, sludge, or mine tailings, but which still have the ability to flow similarly to water under certain conditions, the principles outlined above still apply. If the failure of the dam could result in the release of substances that could create a significant danger or risk to public health, that dam will be considered at least a Class II (significant) hazard dam.

To reach agreement on which dams meet the statutory definition of a dam and, therefore, fall under the jurisdiction of the ADSP, Dam Safety developed the Hazard Potential Classification and Jurisdictional Review Form presented in Appendix A. Additional information about the hazard potential classification is presented in the following section, and dam failure analysis is presented in Section 9.3.

2.4 Hazard Potential Classification

The hazard potential classification is the main parameter for determining the level of attention that a dam requires throughout the life of the project, from conception to removal. The hazard potential classification represents the basis for the scope of the design and construction effort, and dictates the requirements for certain inspections and emergency planning. The ADSP uses three classifications for dams based on the potential impacts of failure or improper operation of a dam:

- Class I (high)
- Class II (significant)
- Class III (low)

The hazard potential classifications are explained in detail in 11 AAC 93.157 and are summarized in Table 2-1.

Dams are classified based on theoretical estimates of the potential impact to human life and property if the dam were to fail in a manner that is typical for the type of dam under review, or if improper operation of the dam could result in adverse impacts. The actual or perceived quality of design and construction and the condition of the dam are irrelevant for the classification, but may influence other requirements such as the frequency of monitoring, the scope of PSIs, and the content of O&M manuals and EAPs.

To determine the hazard potential classification consistently and equitably for projects, Dam Safety developed the Hazard Potential Classification and Jurisdictional Review Form in Appendix A, as previously mentioned. This form should be completed by a qualified engineer based on the existing or proposed configuration of the dam, and submitted to Dam Safety for review and concurrence.

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Table 2-1. Hazard Potential Classification Summary

Hazard Class	Effect on Human Life	Effect on Property
I (High)	Probable loss of one or more lives	Irrelevant for classification, but may include the same losses indicated in Class II or III
II (Significant)	No loss of life expected, although a significant danger to public health may exist	Probable loss of or significant damage to homes, occupied structures, commercial or high-value property, major highways, primary roads, railroads, or public utilities, or other significant property losses or damage not limited to the owner of the barrier Probable loss of or significant damage to waters identified under 11 AAC 195.010(a) as important for spawning, rearing, or migration of anadromous fish
III (Low)	Insignificant danger to public health	Limited impact to rural or undeveloped land, rural or secondary roads, and structures Loss or damage of property limited to the owner of the barrier

The form presented in Appendix A is designed as a "tickler" to remind the engineer of important aspects that should be considered in the review. In addition, the form is designed to be progressive. Three levels of review are available:

- **Preliminary** – An initial, conservative assignment based on a visual inspection of the dam, the reservoir, the downstream reach, and other limited, readily available information such as aerial photography and topographic maps
- **Qualitative** – A limited engineering evaluation that may involve crude hydrological estimates, simplistic peak discharge calculations for a dam failure or mis-operation, open-channel flow calculations, elevation or cross-section surveys, and simplistic data used with conservative assumptions
- **Quantitative** – A detailed dam failure analysis that includes failure mode evaluation, computerized dam-break and hydraulic-routing models, detailed hydrological estimates, and good-quality input data

Potential Future Development and Hazard Potential Classification

A hazard potential classification determines the standard for the design, construction, and operation of the dam during the life of the project. If additional downstream development is likely, the dam should be designed and constructed to standards for the higher classification, although the dam may be classified and managed for existing conditions until the future development occurs.

The higher levels of analyses and detail carry more credibility in the assignment of the classification. For example, a preliminary assignment of a Class II (significant) hazard potential could be overruled if a qualitative or quantitative review demonstrates that the potential for adverse impacts is actually low. In another example, if new development occurs below an existing Class III (low) hazard dam, a qualitative analysis may be used to upgrade the dam to a Class I (high) hazard, whereas a quantitative analysis may demonstrate that a Class II

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(significant) hazard is the appropriate classification. Additional information about dam failure analysis is presented in Section 9.3.

The ADSP hazard potential classifications were modified in the current regulations to be consistent with guidance contained in the following source:

- *Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams*, published by the Federal Emergency Management Agency (1998b)

Admittedly, much of the terminology used in 11 AAC 93.157 is not specific; for example, "probable" is not currently defined. Dam Safety will consider arguments presented by dam owners for hazard potential classifications that are in dispute, including risk assessments that quantitatively assign probabilities to certain outcomes. Nevertheless, those arguments should be cooperatively developed, technically sound, and justifiable. Additional information about risk assessments is presented in Section 12.3. The following references may also be helpful in assigning the hazard potential classification:

- *Evaluation Procedures for Hydrologic Safety of Dams,* published by the American Society of Civil Engineers (1988)
- "Dam Break Inundation Analysis and Downstream Hazard Classification," Technical Note 1, in *Dam Safety Guidelines,* published by the Washington State Department of Ecology (WSDOE) (1992)

2.5 Associated Permits and Regulatory Agencies

This publication provides guidance only for the permits and submittals associated with the ADSP. In addition to the design and construction submittals discussed in Chapter 5, only the following information is required by 11 AAC 93.171 before Dam Safety will issue a *Certificate of Approval to Construct a Dam*:

- For dams and reservoirs to be located partially or completely on property not owned by the dam owner, the property owners must provide legal permission to construct the dam or reservoir. A copy of the land use permit must be provided to Dam Safety.
- Proof of a water right or water right application, as required by AS 46.15.

Coordination of Permits

Dam Safety will not typically withhold a certificate of approval pending coordination with or conditional to any other permits that may be required from local, state, or federal agencies. However, those other permits may be required before construction can actually occur. Dam Safety will work within the framework of the Alaska Department of Natural Resources Large Mines Project Team and the Alaska Coastal Management Program for associated projects that include dams. Coordination of permits for other projects is the responsibility of the applicant.

The owner of the dam is ultimately responsible for securing all permits necessary for the construction and operation of the dam. The following state and federal agencies should be contacted for more information:

- Local municipality or borough
- Alaska Department of Natural Resources
- Alaska Department of Environmental Conservation
- Alaska Department of Fish and Game
- State Historic Preservation Office
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency

The following is a useful reference for federal permitting associated with dams:

- *Environmental Permitting for Dam Projects* (1996), published by the ASDSO

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Guidelines for Cooperation with the Alaska Dam Safety Program

Chapter 3

CERTIFICATES OF APPROVAL

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Chapter 3
CERTIFICATES OF APPROVAL

In this chapter:

- The certificates of approval issued by Dam Safety
- Policies and procedures of Dam Safety for applications and issuing certificates
- Application and fee information

Permits issued by Dam Safety under 11 AAC 93 are referred to as "certificates of approval" for a particular activity. These certificates are required for routine operation of a dam and certain construction activities related to the dam. A separate certificate is required for each of the following actions:

- Operation
- Construction
- Modification
- Repair
- Removal
- Abandonment

Additional information on these certificates is provided in the following sections.

3.1 Operation

***Certificate of Approval to Operate a Dam* –** This permit is required for all jurisdictional dams in service as of May 31, 1987, and all jurisdictional dams constructed after that date. To receive a *Certificate of Approval to Operate a Dam*, the following information must be submitted to Dam Safety for review and approval:

- Operations and maintenance manual
- Current PSI report
- Record drawings
- EAP for Class I and II dams
- Construction completion report for new construction

The *Certificate of Approval to Operate a Dam* is dated to expire after each PSI and is typically reissued after the PSI report is completed and approved. The expiration date may be extended when a PSI report is submitted for review. The O&M manual and the EAP may also require updating before a current certificate will be issued. Additional information about the required documents is presented in subsequent sections of these guidelines.

For new construction, major modifications or repair, a new *Certificate of Approval to Operate a Dam* is typically required before the reservoir may be filled or additional impoundment may occur above the level currently permitted. Additional information about construction-related certificates is included in the following section.

All *Certificates of Approval to Operate a Dam* include standard conditions, and special conditions are noted in Attachment A of the certificate. The special conditions typically include the hazard potential classification and the due date of the next PSI. They may also include operating limitations and other restrictions or requirements unique to the dam and its appurtenances. A sample of a *Certificate of Approval to Operate a Dam* is presented in Appendix B.

3.2 Construction

Certificate of Approval to Construct a Dam – This permit is required to build a new jurisdictional dam.

Certificate of Approval to Modify a Dam – This permit is required for a modification on a jurisdictional dam. Defined in 11 AAC 93.201(8), modification refers to an "enlargement or alteration" that may affect the safety of the dam. Examples include raising the height of the dam, increasing the storage capacity, or changing valves on an outlet pipe.

Certificate of Approval to Repair a Dam – This permit is required to repair a jurisdictional dam. Repair is defined in both AS 46.17.900(8) and 11 AAC 93.201(11) as a repair that could affect the safety of the dam, but excludes routine maintenance. Repair in this sense could include slip-lining a low-level outlet, rebuilding the spillway, or repairing an overtopped or breached dam.

> **Breach of Conditional Approvals**
>
> *Any breaches or deviations from the conditions of any certificate of approval must be reported to and approved by Dam Safety in writing.*

Certificate of Approval to Remove a Dam – This permit is required to remove a jurisdictional dam.

Certificate of Approval to Abandon a Dam – This permit is required to abandon a jurisdictional dam in place without removing the structure of the dam.

These certificates also include standard conditions, and special conditions are noted in Attachment A of the certificate. Special conditions may include design and construction restrictions, construction quality assurance requirements, post-construction monitoring and inspection requirements, or other important conditions. A sample of a *Certificate of Approval to Construct a Dam* is presented in Appendix C.

A signed, certificate of approval must be issued by Dam Safety before the construction, modification, repair, removal, or abandonment begins.

3.3 Applications for Certificates of Approval

The application process provides an opportunity for communication between Dam Safety and the applicant. This communication should begin early in the project planning because the process can become extended and complicated, depending on the magnitude and complexity of the project. A number of submittals must be made to Dam Safety for review to receive a certificate of approval. Dam Safety will comment on the submittals during the application process to promote dialogue and understanding of the project. A certificate of approval is issued at the end of the review period as appropriate.

The remainder of the information provided in this section highlights specific policies and procedures of Dam Safety that are intended to establish consistency with respect to which certificates require applications and how certificates are issued. Chapter 4 presents a detailed outline of a hypothetical sequence of the regulatory process during the life of a dam to allow all parties involved to plan effectively.

Applications for Dams Built Before 1987

- An application for a *Certificate of Approval to Operate a Dam* and fee is only required for dams built before May 31, 1987, that are not registered with Dam Safety.
- The information listed in Section 3.1 that must accompany an application is described in additional detail in subsequent sections.
- An application and fee are required for all certificates listed in Section 3.2, regardless of the original construction date, except for the construction certificate.

Applications for All Other Dams

- A specific application for a *Certificate of Approval to Operate a Dam* is not required for dams built after May 31, 1987, that received a *Certificate of Approval to Construct a Dam*.
- An application and fee are required for all certificates listed in Section 3.2.
- For new dam construction, a *Certificate of Approval to Operate a Dam* will be issued after post-construction submittals are reviewed and approved by Dam Safety.
- For existing dams that are repaired or modified, post-construction submittals are also required, and the *Certificate of Approval to Operate a Dam* may be reissued with revised special conditions.
- A PSI may be required after the first year of operation for new dams or for dams with major modifications or repairs.
- O&M plans and EAPs must be revised as appropriate for dams with major modifications or repairs.

Dams Without Construction Certification

If a dam was built after May 31, 1987, without a Certificate of Approval to Construct a Dam, *the special circumstance must be resolved individually with Dam Safety.*

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Issuance of Certificates of Approval

Dam Safety will issue a draft certificate of approval in a spirit of cooperation to give the dam owner or operator the opportunity to comment and agree on the conditions of the permit. After an agreement is reached, a final certificate is executed and sent by certified mail to the applicant. In some cases, a final certificate may be issued without agreement; for example, a certificate may include a condition imposed by Dam Safety that the operator feels is especially onerous. In any case, a final, formally executed certificate issued by Dam Safety carries the full weight and authority of the ADNR under the dam safety statutes and regulations. Appeals may be filed with the commissioner of ADNR in accordance with 11 AAC 02.

3.4 Application Fee

The permit application requires a nonrefundable filing fee, as described below and in 11 AAC 05.010(a)(8)(I and J). Additional detail about the fees follows.

Certificate of Approval to Operate a Dam – According to 11 AAC 05.010(a)(8)(I), for a dam constructed before May 31, 1987, the fee is based on the height of the dam (as defined in Section 2.3), multiplied by $50 per foot.

Certificate of Approval to Construct, Modify, Repair, Remove, or Abandon a Dam – According to 11 AAC 05.010(a)(8)(J), the fee is based on a scale of the estimated project cost. A non-refundable deposit on the application fee, which is based on estimated costs, is required with the Initial Application Package, as described in Section 5.1.3. An application fee supplement based on a certified cost estimate is required with the Final Construction Package, as described in Section 5.4.4, before a final certificate of approval will be issued.

Planning for the Application and Review

Dam Safety established the submittal packages and review times shown in Chapter 4 as targets to allow dam owners and operators to plan effectively. However, every dam is unique and deviations and delays may be required for a variety of reasons. The objectives of Dam Safety are to conduct the review in the most expeditious manner possible to meet the project schedule, without compromising the mission of the ADSP. Consistency and conformance with the suggested approach will help accomplish this objective.

The minimum fee is $500, which applies to projects that are estimated to cost less than or equal to $25,000. If the project is expected to cost more than $25,000, Table 3-1 should be used to calculate the application fee. According to 11 AAC 93.171(f)(4)(D), the estimated cost of the project must include the following:

- Labor and materials for the construction of the dam, reservoir, and appurtenant works
- Site investigations, which include geological and geotechnical investigations and laboratory testing
- Engineering and surveying

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- Construction supervision and quality assurance
- Other direct costs associated with the design and construction activities

Table 3-1. Application Fee Calculation

Portion of Project Cost	Project Cost Amount	Multiplier	Fee Amount
The first $100,000	$	0.02	$
The next $400,000	$	0.01	$
The next $500,000	$	0.005	$
Balance of cost	$	0.0025	$
Total project cost:	***$***	***Total Fee:***	***$***

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Guidelines for Cooperation
with the
Alaska Dam Safety Program

Chapter 4

FIVE STAGES IN THE REGULATORY LIFE OF A DAM

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Chapter 4

FIVE STAGES IN THE REGULATORY LIFE OF A DAM

In this chapter:

- The five stages in the regulatory life of a dam
- A list of regulatory requirements that occur in each stage of the dam's life
- The regulatory review process for design, construction, and operation

This section identifies the types of information that are exchanged during the regulatory life of a hypothetical dam and the point in time at which the exchange typically occurs. For presentation purposes, the life of the dam is divided into five stages:

- Application for new dam construction
- Construction
- Operation
- Remediation
- Closure

The following sections present key aspects of each stage with respect to submittals to Dam Safety that are typically required, as well as other important considerations. For the first three stages, the exchange of information between the various parties cooperating in the overall safety of the dam is graphically illustrated in the form of a schedule. The remainder of the guidelines present additional detailed information related to this section.

> **Application Requirements for Existing Dams**
>
> *The application requirements discussed in Section 4.1 cover a complete application process, needed for construction of a new dam, to provide the greatest detail. Some information outlined here may not be required when the activity consists of repair or modification of an existing dam.*

4.1 Application for New Dam Construction

To receive a certificate of approval listed in Section 3.2, an application must be submitted to Dam Safety. As indicated in 11 AAC 93.171, the application must include a substantial amount of technical information. Dam Safety requests that the application process occur in the increments listed below. The items to be included with each incremental submittal are indicated. Additional detail is provided in subsequent sections. Figure 4-1 illustrates a suggested permitting process for new construction.

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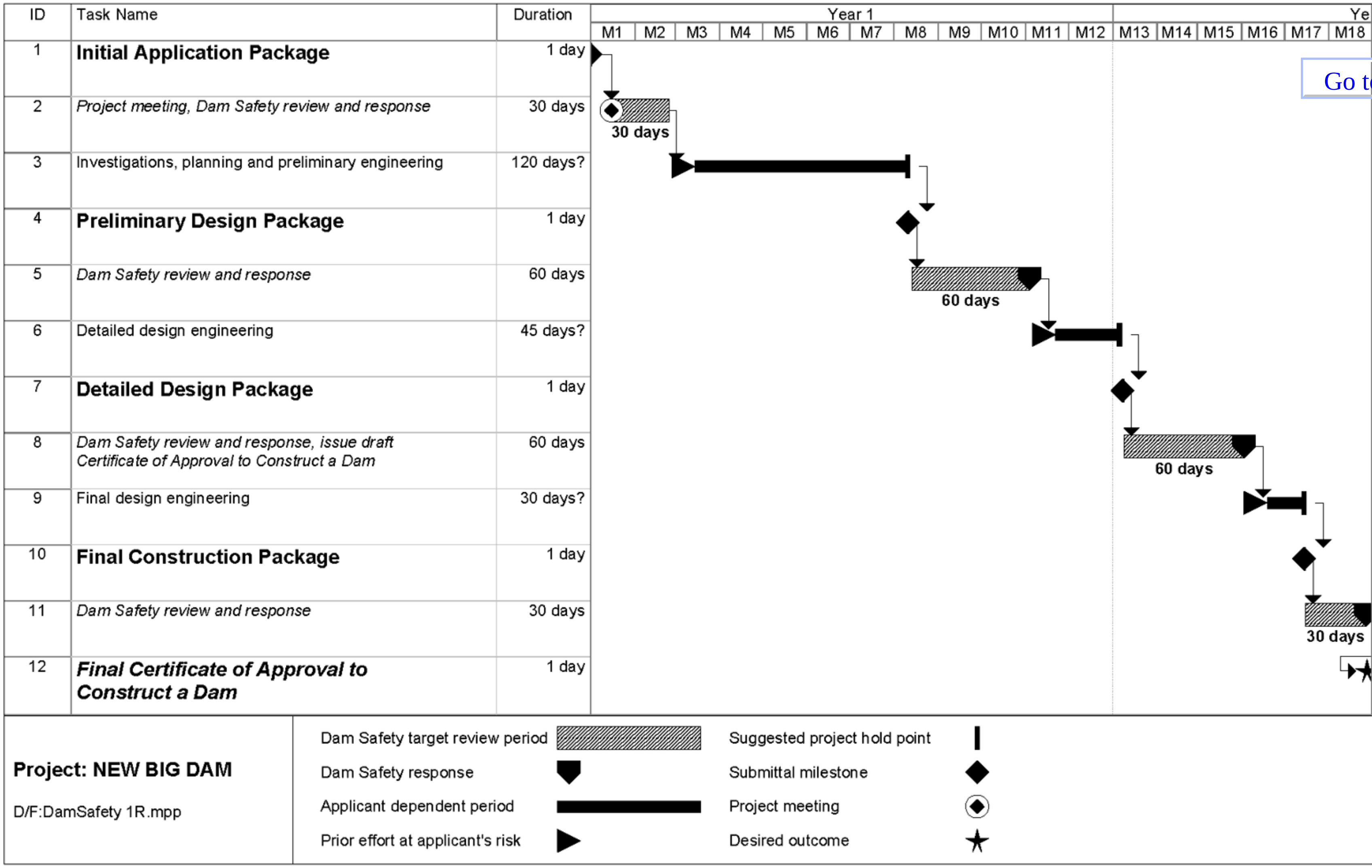

Figure 4-1. Dam Safety Application Review Process

Italic font indicates action by Dam Safety.
Bold font indicates submittals from applicant or permits from agency.

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- **Initial Application Package** (See Section 5.1.)
  - Letter of intent (See Subsection 5.1.1.)
  - Application form (See Subsection 5.1.2 and Section 3.3.)
  - Application fee deposit (See Subsection 5.1.3 and Section 3.4.)
  - Proposed schedule (See Subsection 5.1.4.)
  - Hazard Potential Classification and Jurisdictional Review Form (See Sections 2.4 and 9.3, Subsection 5.1.5, and Appendix A.)
  - Feasibility and siting studies for new construction of Class I and II dams (See Subsection 5.1.6.)
  - Design scope proposal (See Subsection 5.1.7.)

> **Striving for Simplicity**
>
> *The complexity of the application process is expected to reflect the hazard potential classification of the dam and the complexity of the work for which approval is required. The objective of this submittal outline is to simplify the process as much as possible for every project while promoting the standard of care appropriate for the hazard potential classification of the dam.*

- **Preliminary Design Package** (See Section 5.2.)
  - Proof of water and land use rights (See Section 2.5 and Subsection 5.2.1.)
  - Proposed method to demonstrate financial ability to pay for certain costs (See Section 5.2.2)
  - Topographic map of the dam site (See Subsection 5.2.3.)
  - Preliminary drawings (See Subsection 5.2.4.)
  - Engineering science reports (See Subsection 5.2.5.)
  - Revised proposed schedule (See Subsection 5.2.6.)
- **Detailed Design Package** (See Section 5.3.)
  - Engineering design report (See Subsection 5.3.1.)
  - Design drawings (See Subsection 5.3.2.)
  - Draft construction specifications (See Subsection 5.3.3.)
  - Construction quality assurance/quality control (CQA/QC) plan (See Subsection 5.3.4 and Section 7.2.)
  - Revised proposed schedule (See Subsection 5.3.5.)
- **Final Construction Package** (See Section 5.4.)
  - Final construction drawings (See Subsection 5.4.1.)
  - Final construction specifications (See Subsection 5.4.3.)

- Construction schedule (See Subsection 5.4.5.)
- Certified cost estimate (See Subsection 5.4.4.)
- Application fee supplement, if required (See Subsection 5.4.5.)
- Demonstration of financial ability (See Subsection 5.4.6.)

4.2 Construction

Construction of the new dam or the repair or modification of an existing dam may begin only after Dam Safety issues the appropriate certificate of approval. In some cases, certain preconstruction documents may be listed as a condition to the certificate, and the submittal will be required before construction actually begins. Required by 11 AAC 93.171, these documents are usually prepared by the contractor, but can have an important effect on the mission of the ADNR and the safety of the dam. Additionally, cooperation and communication are required during the construction process, and post-construction submittals are critical to receive the *Certificate of Approval to Operate a Dam*. Figure 4-2 illustrates the regulatory review during the construction process, which is outlined below and discussed in additional detail in Chapter 7.

- **Before construction**, the following additional submittals to Dam Safety are typically required:
  - Water diversion plan (See Subsection 7.1.1.)
  - Erosion control plan (See Subsection 7.1.2.)
- **During construction**, the following activities typically occur:
  - CQA/QC monitoring, field testing, sample collection, and laboratory testing (See Section 7.2.)
  - Design changes that require approval by Dam Safety (See Subsection 7.2.4.)
  - Field inspections conducted by Dam Safety (See Section 10.5.)
- **After construction**, the following submittals are required:
  - Construction completion report that includes record drawings, inspection reports, photographs, and other information (See Subsection 7.3.1.)
  - Operation and maintenance manual (See Subsection 7.3.3 and Chapter 8.)
  - EAP for Class I and II dams (See Subsection 7.3.4 and Chapter 9.)

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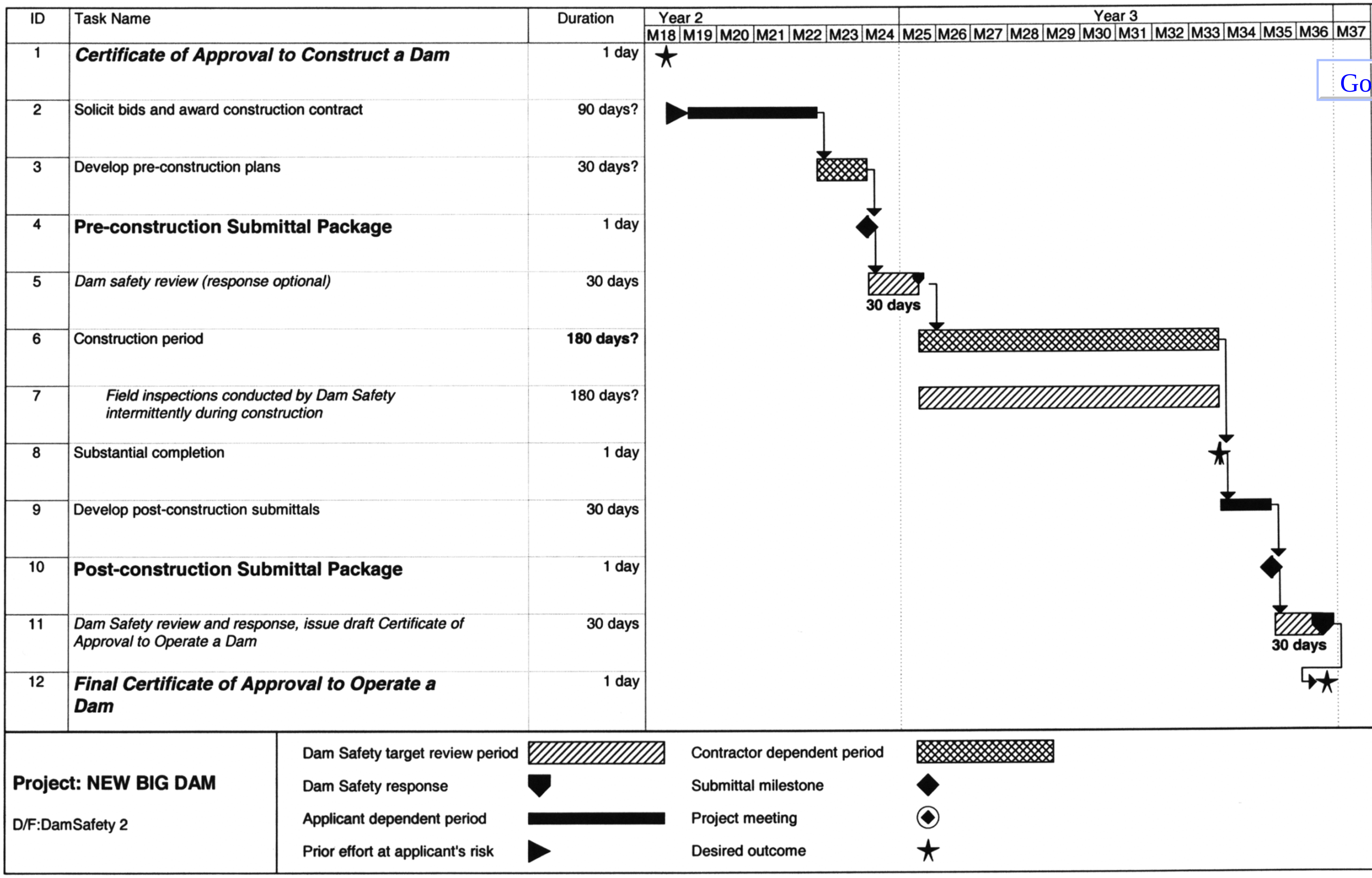

Figure 4-2. Dam Safety Construction Review Process

Italic font indicates action by Dam Safety.
Bold font indicates submittals from applicant or permits from agency.

4.3 Operation

After the post-construction submittals previously listed are reviewed and approved, Dam Safety will issue a new *Certificate of Approval to Operate a Dam*. The activities listed below are then expected to occur:

- First fill of reservoir and temporary monitoring (See Section 7.3.)
- Routine operations, inspections, monitoring, and maintenance (See Chapters 8 and 10.)
- EAP exercises (See Chapter 9.)
- PSIs (See Section 10.4.)
- Incident reporting (See Chapter 11.)

> **Recurrent Certification and Revision During Operation**
>
> *A new* Certificate of Approval to Operate a Dam *is issued after each PSI, with revised special conditions as appropriate. O&M manuals are revised as needed and reviewed during the PSI cycle. EAPs are reviewed during the exercise process, and revised as needed.*

Figure 4-3 illustrates the regulatory life of the dam during the first year of the operational stage, with emphasis on the PSI and references to subsequent years of operation.

4.4 Remediation

After a period of time, a dam may require remedial efforts for a number of reasons, including deterioration, damage, or hazard potential classification change (which could affect the design basis). In some cases, typically for older dams, the need for remediation may be due to an inadequate design aspect that is discovered and determined to represent a sufficient risk to justify remedial action.

The following activities are likely to occur:

- Assessment of need (See Section 10.4 and Chapter 12.)
- Design and construction of the solution

At this point, the regulatory life of the dam may loop back to Sections 4.1 (except that the application is for a *Certificate of Approval to Modify, or Repair a Dam*), 4.2, and 4.3, or proceed to Section 4.5.

4.5 Closure

Closure of a dam and reservoir may occur for a number of reasons and may result in one of the following actions, either of which requires an application for a certificate of approval:

- Removal
- Abandonment

Details for these options are presented in Chapter 13.

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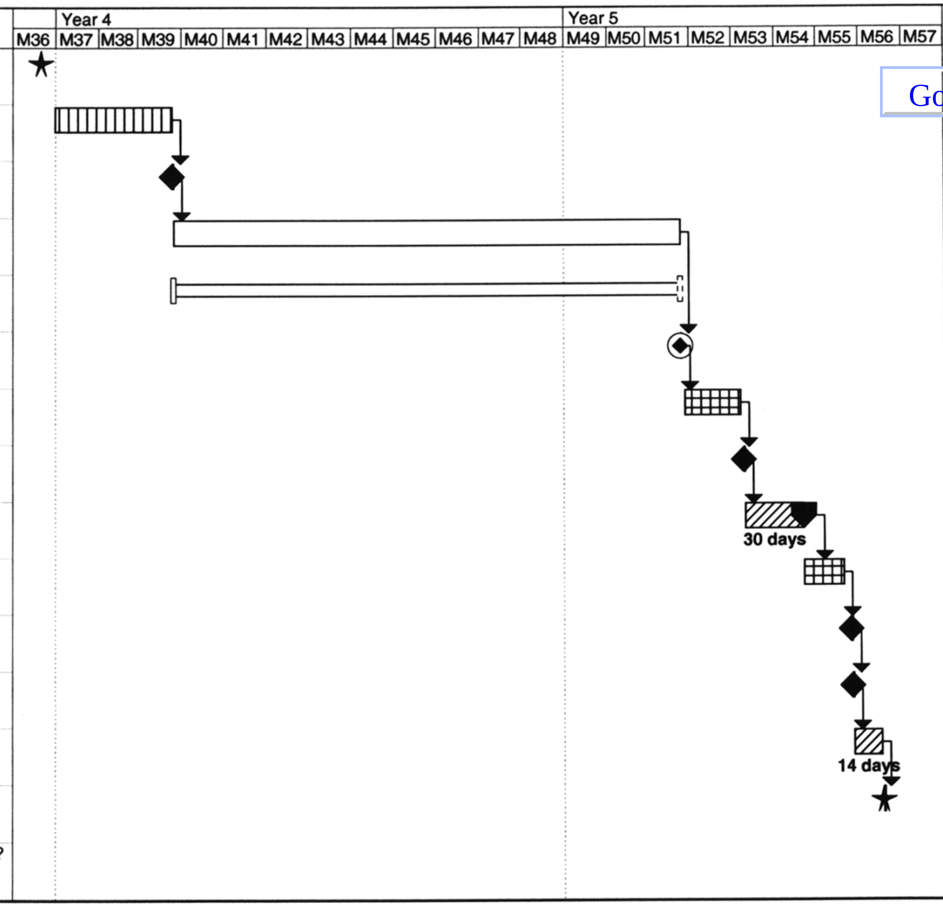
ID	Task Name	Duration
1	***Certificate of Approval to Operate a Dam***	1 day
2	First filling period (to normal pool)	60 days?
3	**First Filling Incident Report**	1 day
4	First year of operation	260 days
5	Routine monitoring and inspections based on O&M manual for life of project	260 days
6	Visual inspection for PSI by professional engineer	1 day
7	Develop PSI report	30 days
8	**Draft PSI Report**	1 day
9	*Dam Safety review and response, issue draft Certificate of Approval to Operate a Dam*	30 days
10	Finalize PSI report	21 days
11	**Final PSI Report**	1 day
12	Revised O&M manual (if necessary)	1 day
13	Dam Safety review	14 days
14	***Revised Certificate of Approval to Operate a Dam***	1 day
15	Subsequent PSIs on 3 to 5 year intervals, depending on hazard classification (return to line 6)	1095 days?



Project: NEW BIG DAM

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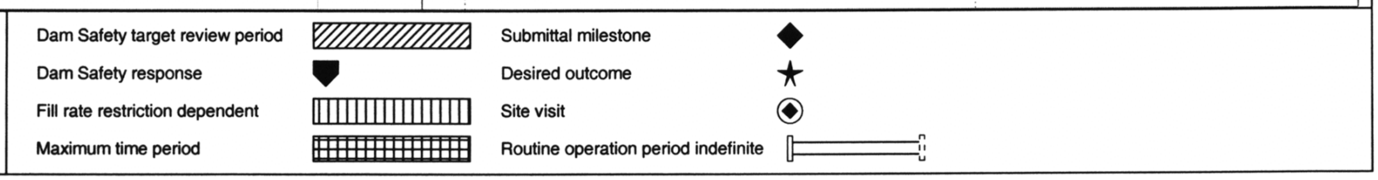

Figure 4-3. Dam Safety Operations Review Process

Italic font indicates action by Dam Safety.
Bold font indicates submittals from applicant or permits from agency.

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Guidelines for Cooperation with the Alaska Dam Safety Program

Chapter 5

CONSTRUCTION APPLICATION DETAILS

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Chapter 5

CONSTRUCTION APPLICATION DETAILS

In this chapter:

- Detailed description of the requirements for construction of a new dam and repair and modification of an existing dam
- Outlines of the contents of submittals that accompany an application
- Standards for submittals

The following sections provide details about the preferred development, format, and presentation of various types of information usually considered in the application process for a *Certificate of Approval to Construct a Dam*. Much of the information also applies to repairs or, modifications of dams, and the submittals to Dam Safety should be modified as appropriate. Not all of the information may be required. Because every project is unique, it is impossible to anticipate and outline all design and construction issues that may arise in a generic format. Consequently, the following information is intended to encourage communication and agreement early in the planning process to limit costly revisions and delays. Figure 5-1 illustrates the incentive for accomplishing these objectives.

The design and analysis of a dam consists of extensive technical work. The presentation of this work will reflect the quality of the entire project. Engineering reports should clearly document the methodology, assumptions, parameters, calculations, computer programs, references, results, engineering judgment, and recommendations used in the evaluation process. Drawings should contain the definition and detail necessary to relay critical information for permitting and construction. Poor quality or incomplete submittals may be rejected.

The following sections discuss important aspects of the information developed in the construction application process and the preferred standards for submittals to Dam Safety.

5.1 Initial Application Package

The Initial Application Package submitted to Dam Safety is the first step in the application process and is intended to establish agreement on important information early in the project planning. Detailed guidelines for certain submittals that should be included in the Initial Application Package are presented in the following subsections.

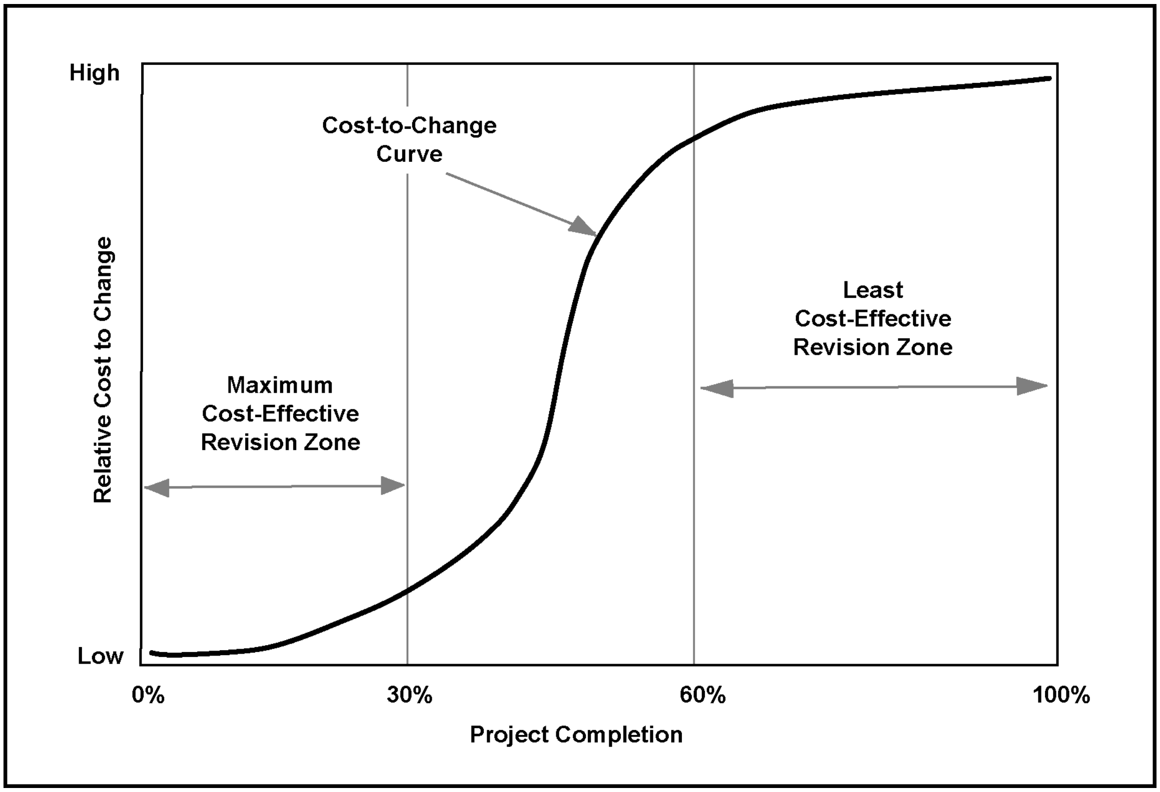

Figure 5-1. Relative Cost-to-Change Curve
Adapted from ASDSO, 2003

5.1.1 Letter of Intent

A letter that introduces the project and includes the following information is requested to notify Dam Safety of the applicant's intent:

- Description of the proposed project or work to be completed under the anticipated certificate of approval
- Identity of the applicant and contact information
- Identity of the dam owner and operator, if other than the applicant
- Identity and qualifications of the engineer of record responsible for certifying the design. (See Subsection 1.3.4.) For complex projects, an engineering team comprised of more than one engineer of record may be required for the design. In those cases, all engineers of record should be included.
- A list of attachments

5.1.2 Application Form

- The most current application form available from Dam Safety should be used. The most current form may be downloaded from www.dnr.state.ak.us/mlw/forms/. The application must be signed by the owner of the dam.
- Any technical information requested on the form may be based on the conceptual design for new construction or existing or proposed values for all other applications.

5.1.3 Application Fee Deposit

- A preliminary cost estimate developed by the applicant may be used to calculate the nonrefundable fee deposit, as indicated in Section 3.4 and Table 3-1.
- The fee deposit should be included with the Initial Application Package.
- The check should be made payable to the "State of Alaska" and submitted with the application to Dam Safety.
- For fees that exceed $2,000, the fee may be considered a statutory designated program receipt, and all expenses by the ADNR related to the project will be billed to the respective account.

5.1.4 Proposed Schedule

A proposed schedule that shows the approximate dates for the following should be submitted with the Initial Application Package:

- Preliminary Design Package submittal (See Section 5.2.)
- Detailed Design Package submittal (See Section 5.3.)
- Final Construction Package submittal (See Section 5.4.)
- Beginning of construction

The proposed schedule should allow for the Dam Safety target review times indicated in Figure 4.1. Dam Safety will cooperate as much as possible to accommodate the proposed schedule.

5.1.5 Hazard Potential Classification

Early agreement on the hazard potential classification of a dam is imperative to conserve the design and investigation budgets. A Hazard Potential Classification and Jurisdictional Review Form, described in Section 2.4, should be completed for the proposed dam and included with the Initial Application Package.

In some cases, a qualitative or quantitative evaluation may be required, even if the dam is in the preliminary stages of planning. For example, if some development exists downstream of the proposed dam site, a Class III (low) hazard potential classification may not be approved by Dam Safety unless a technical demonstration is made to show that the flood wave from a failure of the conceptual dam is attenuated or inconsequential to the existing development, as well as to any potential future development that may be reasonably anticipated.

For the Initial Application Package, the level of the evaluation for the hazard potential classification should be in accordance with the guidance in Table 5-1. Not all situations may be addressed in the table. In addition, a more detailed evaluation may be required after final design for complex systems or to develop an EAP. Additional information on dam failure analysis is provided in Section 9.3. Dam Safety should be contacted for specific guidance.

Table 5-1. Acceptable Levels of Evaluation for Proposed Hazard Potential Classifications

Proposed Class	Dam Type and Location	Description of Downstream System	Acceptable Level of Evaluation
III (low)	Any rural water dam	No development	Preliminary
III (low)	Any rural water dam	Limited or heavy existing development or high potential for development	Qualitative or quantitative
II (significant)	Any dam located on an important salmon stream, at a primary water supply for a community with more than 500 residents, or for retention of mine tailings	No residential development	Preliminary
II (significant)	Any dam in a rural or urban setting	Limited or heavy existing residential development or high potential for development	Qualitative or quantitative
I (high)	Any dam in a rural or urban setting	Limited or heavy development or high potential for development	Preliminary
I (high)	Any dam with a large impoundment in a rural or urban setting	Complex system with development in extended downstream reach	Quantitative

5.1.6 Feasibility and Siting Studies

Feasibility and siting studies are required under 11 AAC 93.171 for new construction of Class I and II dams. These studies typically occur early in the planning process, often well in advance of the application for a certificate of approval.

Feasibility Study

To obtain a *Certificate of Approval to Construct a Dam* for a Class I or II dam, a feasibility study that justifies the risks created by the dam is requested. The following general guidelines are recommended:

- At least four alternatives, including the no-action alternative, should be considered.

- At least one alternative should include a lower hazard potential classification dam or an alternative that does not require a dam.
- A Class I dam alternative should include the potential economic and lethal impacts of a dam failure in the analysis.
- Justification for the Class I dam alternative must not be based on inaccurate data, false assumptions, exaggerated importance, speculation, or baseless information.
- The benefit-to-cost ratio for the Class I dam alternative should be greater than one and exceed the other alternatives.

Applications for a *Certificate of Approval to Construct a Dam* for a Class I or II dam that are not preceded by an Initial Application Package with a feasibility study will be returned. Feasibility and siting studies conducted as part of an environmental assessment, environmental impact statement, or other document under the National Environmental Policy Act (NEPA) process or other formal process are acceptable as long as the above guidelines are followed.

Siting Study

A siting study is required for Class I and II dams to justify that the proposed location of the dam is the best location for the type and configuration of the dam to be constructed. Siting studies should include the following considerations:

- Type of dam
- Geology and hydrogeology of bedrock and overburden
- Construction material borrow sources
- Local and regional hydrology
- Local and regional seismic setting and faulting
- Opportunities for mitigation of dam break flood waves
- Suitability for construction

> **Units of Measurement**
>
> *Units of measurement in all submittals should be in conventional, English format, except for permeability or hydraulic conductivity, which may be reported in centimeters per second. Metric standards may be included in brackets at the applicant's convenience. Otherwise, unit systems should not be mixed.*

A siting study may be included with the feasibility study if the appropriate siting criteria are considered. Dam owners are encouraged to conduct a siting study for Class III dams, but submittal of that study to Dam Safety is not specifically required by the regulations.

5.1.7 Design Scope Proposal

The purpose of the design scope proposal is to define important design standards and the scope of work proposed to determine certain parameters used in the detailed design. The proposed scope of work and related design criteria should be defined in advance for the following subject areas at a minimum:

- Hydrology and hydraulics
  - Methods for determining inflow design flood (IDF) and spillway capacity (See Section 6.1.)
- Stability
  - Evaluation method with proposed safety factors for static and pseudo-static stability analysis, deformation analysis, or finite element analysis, as appropriate (See Section 6.2.)
- Seismicity
  - Level of sophistication and approach to studies necessary to define seismic parameters for location of the dam, including maximum credible earthquake (MCE), maximum design earthquake (MDE), operating basis earthquake (OBE), and potential ground motions (See Section 6.3.)
- Seepage
  - Methods to determine foundation and dam permeability, seepage analysis, and gradient control (See Section 6.4.)

Planning the Design

Planning the design is one of the most important first steps in the regulatory life of a dam. Early agreement on the scope of the design will maximize the efficiency of the permitting process. The design scope proposal is not intended to define the parameters used in the design, but to define the proposed level of work, methodologies, levels of analysis, and approaches to determine and evaluate those parameters that are required for the safe design and construction of the dam.

Additional details about these important aspects are included in Chapter 6.

The design scope proposal should also specify the level of design quality assurance (DQA) and design quality control (DQC) to be conducted during the design. For example, for new Class I dams, a design review board may need to be established. A detailed discussion of DQA/DQC is beyond the scope of these guidelines, but additional information may be found in *Quality Management* by the USACE (1993).

5.2 Preliminary Design Package

Detailed guidance on the development of the information required for the Preliminary Design Package is provided in the following subsections.

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5.2.1 Water and Land Use Rights

The following information must be submitted with the Preliminary Design Package.

- Proof of a water use permit or other water right, as required by AS 46.15.
- For construction of new dams or modifications that increase the reservoir size or raise the hazard potential classification, proof of land ownership or other documented legal permission to construct the dam, appurtenant works, and reservoir.

The applicant must provide copies of the respective permits or a letter describing the status of the permitting process to the ADNR.

5.2.2 Proposed Financial Demonstration

Constructing and operating a dam is an expensive and long-term commitment. A dam owner must demonstrate to the ADNR the financial ability to responsibly manage the facility during the life of the project. A demonstration of financial ability is required for construction of new dams or for modifications that increase the size of the reservoir or raise the hazard potential classification. If financial ability cannot be demonstrated, a *Certificate of Approval to Construct a Dam* will not be issued.

In the Preliminary Design Package, the dam owner must propose the methods for which the financial ability will be demonstrated for certain costs, depending on whether the applicant is a government agency or not. The proposed methods for demonstrating financial ability must be approved by the ADNR, as indicated in 11 AAC 93.171(d).

The Public versus Private Dam Paradox

For demonstrating financial ability, the assumption is that a government agency will only operate a dam that provides some public benefit over an indefinite period of time, and routine operation and maintenance costs must be budgeted and funded. In contrast, a privately owned dam is for the primary benefit of the dam owner at his own expense. However, if that entity goes bankrupt, funds for the cost of mitigating the risk of the dam must be available.

The following language is included in the regulations under 11 AAC 93.171(f)(2)(C):

> (i) For a government agency, financial ability may be demonstrated through taxing authority or other revenue generating ability, and by the pertinent bond, ordinance, resolution, or law as may be required to provide sufficient money to pay the costs of operating and maintaining the dam in a safe condition and complying with the requirements of 11 AAC 93.151 - 11 AAC 93.201;
>
> (ii) For an applicant other than a government agency, the owner must provide a performance bond or other financial assurance adequate to provide sufficient money to pay for the costs of safely breaching the dam at the end of the dam's service life and restoring the stream channel and reservoir land to natural conditions, or for the costs of performing reclamation and post-closure monitoring and maintenance, as required under 11 AAC 93.172.

For dam owners that are not government agencies and for which a performance bond or other form of financial assurance is required to demonstrate financial ability, the agreement and instrument should be prepared and executed to account for all design and construction costs for the following:

- Dewatering the reservoir
- Safely breaching the dam to a point at which there is no longer any impoundment under any flood conditions
- Restoring the stream channel and reservoir land to natural conditions
- Reclamation and post-closure monitoring and maintenance, if appropriate

For certain facilities where the dam is not breached or removed, such as a mine tailings dam, the financial assurance required is specified in 11 AAC 172(a)(6)(c) as a "performance bond or other financial assurance adequate to provide sufficient money to pay for the costs of post-closure monitoring, operation, maintenance, and inspection." See Section 13.2.2 for more information.

5.2.3 Topographic Map of Dam Site

A topographic map of the dam location should be included in the Preliminary Design Package and should incorporate the following presentation and content details:

- Legible engineering scale
- Legible contour interval
- Reservoir area at normal and maximum water storage levels
- Survey datum
- Coordinate system
- Property lines and other boundaries
- Locations of spillways, outlet works, borings, test pits, and material sites

5.2.4 Preliminary Drawings

A preliminary drawing package should be submitted with the Preliminary Design Package. These drawings may be in a draft form, sometimes referred to as 35% complete. The following drawings should be included at a minimum:

- Profile view of dam along dam axis, showing elevation of the crest of the dam, locations and elevations of spillways and outlet works, and geological investigation information
- Cross section views of the dam at the maximum height, spillways, and outlet works, including elevation and width of crest, slopes of upstream and downstream faces, thickness of erosion control structures and zoned fills, and locations of underdrains, cutoff walls, and bonding trenches

Suggested Drawing Conventions

- *Left and right abutments looking downstream*
- *Water flows from left to right in cross sections*
- *North arrow toward the top of page on plan views*
- *Use of engineering scale*
- *Inclusion of a bar scale on all drawings*

Submittal Standards

Two copies of the preliminary drawing package should be submitted.

Drawings that are 11 inches by 17 inches are acceptable if they are legible and to scale (no off-scale reductions).

Larger drawings should be submitted if necessary for clarity.

The survey datum coordinate system and contour intervals should be clearly identified.

5.2.5 Engineering Science Reports

The following engineering science reports and the details indicated should be submitted as part of the Preliminary Design Package:

- **Geological and geotechnical investigation report** for the dam site, reservoir area, spillways, outlet works, appurtenant works, and material sites
  - Location and geological maps
  - Locations and logs of borings and test pits
  - Geological cross sections along dam centerline and perpendicular to centerline
  - Material analyses and laboratory test results
  - Recommendations for foundation treatment, stability analyses, and seepage control
  - Other relevant information
- **Seismic report**
  - See Section 6.3 for detailed information about the seismic report.

- **Hydrology design report**
  - Methods and references used to determine the IDF
  - Drainage basin characteristics
  - Streamflow and precipitation data
  - Reservoir inflow and outflow hydrographs
  - Estimate of flood event impacts on areas downstream, including an incremental damage assessment, if conducted
  - Other relevant information

Submittal Standards

Engineering science reports may be combined into one binder. Two copies should be submitted.

The reports should be sealed by the engineer of record.

Electronic Submittals

Dam Safety encourages electronic submittals to help expedite distribution and review of important documents. Unlocked Adobe Acrobat files are most convenient for viewing, commenting, and transmitting both text and drawings through computer mediums. MSWord and Excel files are acceptable. Dam Safety does not support AutoCAD or other drawing file formats. In any event, paper copies, as described in the text of these guidelines, are required.

5.2.6 Revised Proposed Schedule

The proposed schedule submitted with the Initial Application Package should be updated and resubmitted with the Preliminary Design Package. The revised proposed schedule should give approximate dates for the following:

- Detailed Design Package submittal (See Section 5.3.)
- Final Construction Package submittal (See Section 5.4.)
- Beginning of construction

The revised proposed schedule should allow for the Dam Safety target review times indicated in Figure 4.1. Dam Safety will cooperate as much as possible to accommodate the revised proposed schedule.

5.3 Detailed Design Package

The Detailed Design Package should contain the majority of the information needed for Dam Safety to make a determination of the safety of the dam and appurtenant works. It is not necessary to resubmit information contained in the Initial Application Package and Preliminary Design Package, although revised documents or supplements may be included or previous submittals can be rolled into the Engineering Design Report, as convenient to address review comments from Dam Safety. References to previous submittals should be specified as appropriate. Supplemental information or addenda may be requested by Dam Safety based on a technical review of the final submittals. Additional details about the submittals in the Detailed Design Package follow.

5.3.1 Engineering Design Report

The engineering design report should contain all information necessary to support the design that has not been addressed in the previous submittals. This report typically includes the following items:

- A description of all methodologies, references, formulas, and assumptions used in developing the design criteria and engineering evaluations
- An evaluation of the structural stability of the dam, foundation, and appurtenant features
- An evaluation of the performance of the dam, foundation, and appurtenant features during a seismic event
- Descriptions, physical analyses, and permeability analyses, as appropriate, of the materials used in the construction of the dam
- A seepage analysis for the dam and foundation, including filter criteria to prevent piping of fine-grained materials
- Design criteria, calculations, and rating curves for the spillways and outlet works, including freeboard and other hydraulic evaluations such as energy dissipators
- A storage-versus-depth curve and a storage-versus-area curve for the reservoir
- Recommendations for diverting water during construction, as appropriate
- Recommendations for special construction considerations, first filling of reservoir, operations, maintenance, instrumentation, and monitoring
- Design evaluations and recommendations for other features of the dam and appurtenant works

Submittal Standards

Two copies of the engineering design report should be submitted.

The report should be sealed by the engineer of record.

For Class I and II dams, the report should contain backup data such as calculation sheets and input and output data for final computer runs.

5.3.2 Design Drawings

Design drawings may be submitted in a draft format, often referred to as 95% complete. The design drawings should include the drawings submitted in the Preliminary Design Package, plus the additional drawings necessary to completely describe the project, including the following:

- Additional cross sections of the dam
- Spillway plan views and cross sections

- Detail drawings as needed
- Design drawings for appurtenant structures
- Construction sequence drawings, if required
- Other drawings as necessary

Submittal Standards

Two copies of the design drawing package should be submitted.

Drawings that are 11 inches by 17 inches are acceptable if they are legible and to scale (no off-scale reductions).

Larger drawings should be submitted if necessary for clarity.

Drawings should include the following:

- Cover sheet that identifies the project, dam owner or operator, engineer, and location
- Index of drawings, legends, drafting standards, conventions, abbreviations, codes, or other information necessary to interpret the drawings, including specific datum and coordinate references
- Title block with unique drawing numbers, initials for designers and engineering review, revision numbers, and dates
- Stamp or mark on all drawings stating "Issued for Agency Review" or similar language

5.3.3 Draft Construction Specifications

Construction specifications also may be submitted in draft form, but should at least indicate all sections necessary for bidding and construction.

Submittal Standards

The specifications should include a cover sheet with the project name and date.

The format of the Construction Specifications Institute (CSI) is recommended.

The specifications must include a table of contents.

5.3.4 Construction Quality Assurance/Quality Control Plan

A plan to control the quality of the construction work and assure its compliance with the drawings and specifications is required. The scope of the plan depends on the complexity and hazard potential classification of the dam. The development of a CQA/QC plan is discussed in Section 7.2.

5.3.5 Revised Proposed Schedule

The revised proposed schedule submitted with the Preliminary Design Package should be updated again and resubmitted with the Detailed Design Package. The revised proposed schedule should give approximate dates for the following:

- Final Construction Package submittal (See Section 5.4.)
- Requested date for *Certificate of Approval to Construct a Dam*
- Bid deadline and notice of award
- Beginning and end of construction – estimated period of construction

The revised proposed schedule should allow for the Dam Safety target review times indicated in Figure 4.1. Dam Safety will cooperate as much as possible to accommodate the revised proposed schedule.

5.4 Final Construction Package

A Final Construction Package that includes the information described in the following subsections should be submitted to Dam Safety. After this information is received and approved, Dam Safety will issue the *Certificate of Approval to Construct, Modify, or Repair a Dam.*

5.4.1 Final Construction Drawings

The final construction drawings should include the final versions of the drawings submitted in the Detailed Design Package completed to the detail necessary to construct the dam in accordance with the intent of the design and the hazard potential classification of the dam.

Submittal Standards

One copy of final construction drawing package should be submitted.

Drawings that are 11 inches by 17 inches are acceptable for submittal if they are legible and to scale (no off-scale reductions).

Larger drawings should be submitted if necessary for clarity and should be provided to the contractor for construction.

Each drawings should include the following:

- Seal and signature of the engineer of record
- Stamp or mark stating "Issued for Construction" or similar language
- Current revision number and date

5.4.2 Final Construction Specifications

The final version of construction specifications must be submitted with the Final Construction Package and include all sections necessary for construction.

Submittal Standards

The specifications should include a cover sheet with the project name, revision number, date, and the seal and signature of the engineer of record.

5.4.3 Construction Schedule

A schedule for dam construction that includes the following specific information should be provided with the Final Construction Package:

- Key elements of construction
- Milestones, including beginning of construction and the estimated date for substantial completion
- Mandatory inspection points (See Subsection 7.2.3.)

If the construction is not accomplished according to schedule, the construction schedule must be revised and resubmitted at the request of Dam Safety. This schedule may or may not be the contractor's construction schedule, at the discretion of the applicant. However, Dam Safety may require the contractor's construction schedule as a condition to the *Certificate of Approval to Construct a Dam*, especially for a large or complex project. A contractor's construction schedule should also include the key elements of construction, milestones, and mandatory inspection points.

5.4.4 Certified Cost Estimate

The certified final cost estimate should be submitted with the Final Construction Package. This estimate should be based on the following information:

- Actual accrued engineering costs, including design, site investigation, laboratory testing, and surveying
- Estimated cost of additional engineering and surveying, construction supervision, CQA/QC, and other direct costs associated with design and construction
- Either the estimated cost of construction based on the contractor bid or a cost estimate prepared by a professional construction cost estimator, the engineer, or the chief financial officer of the dam owner or operator

Certifying the Cost Estimate

The requirement for a certified cost estimate for calculating the application fee is intended to provide equity among applicants while assuring the ADNR that the fee is appropriately calculated. The certification should be provided by a professional construction cost estimator, the engineer, or the chief financial officer of the dam owner or operator.

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5.4.5 Application Fee Supplement

A non-refundable supplement for the application fee should be included with the Final Construction Package if the certified cost estimate exceeds the estimated cost used for the application fee deposit described in Subsection 5.1.3. See Section 3.4 for information about the fee calculation.

5.4.6 Demonstration of Financial Ability

The Final Construction Package should include the demonstration of financial ability approved by the ADNR, as discussed in Subsection 5.2.2. A *Certificate of Approval to Construct a Dam* will not be issued if financial ability cannot be demonstrated to the satisfaction of the ADNR.

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Guidelines for Cooperation with the
Alaska Dam Safety Program

Chapter 6

DESIGNING A DAM IN ALASKA

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Chapter 6

DESIGNING A DAM IN ALASKA

In this chapter:

- A brief review of design issues important to the ADSP
- Limited design guidance for important performance parameters
- References to other detailed design guidance resources

The mission of the ADSP is to protect life and property, as stated in Chapter 1. The mission does not include dictating how a facility is designed and constructed, except to the extent necessary to ensure that the dam is safe. For this purpose, Dam Safety desires to establish a reasonable standard of care and performance in order to administer the program in a technically sound and equitable manner that leads to the success of the mission.

Review and approval of designs submitted for the purpose of receiving a certificate of approval are completed on an individual basis and approved or disapproved based on the merits of the particular project and the submitted information. Designs that follow accepted industry standards and procedures are desirable. Acceptable design standards are provided by the following:

- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Reclamation (USBR)
- U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (formerly the Soil Conservation Service)
- Federal Emergency Management Administration (FEMA)
- Federal Energy Regulatory Commission (FERC)
- U.S. Society on Dams (USSD) (formerly U.S. Committee on Large Dams [USCOLD])
- American Society of Civil Engineers (ASCE)

Many acceptable design guidance documents exist. Dam Safety does not wish to discourage new or innovative design approaches that may be technically sound. Nevertheless, all designs, especially those that do not follow accepted industry standards, must be accompanied by references, analyses, and technical justification sufficient to show that the design approach is sound and will meet the intent of the dam safety regulations.

The following sections present limited information about selected design issues that are important to the ADSP and in some cases unique to Alaska.

6.1 Hydrology and Hydraulics

Data compiled by the National Performance of Dams Program (NPDP) at Stanford University indicate that flooding is the leading cause of dam failures in the nation (NPDP, 2000). Dam failure data compiled by Dam Safety indicate that Alaska is not an exception. Figure 6-1 shows Alaska data compared to national statistics. Failures caused by flooding can generally be attributed to an inadequate understanding of the hydrology and an insufficient hydraulic capacity of the spillway system on the dam. The hydrological and hydraulic designs are two of the most important aspects of a dam.

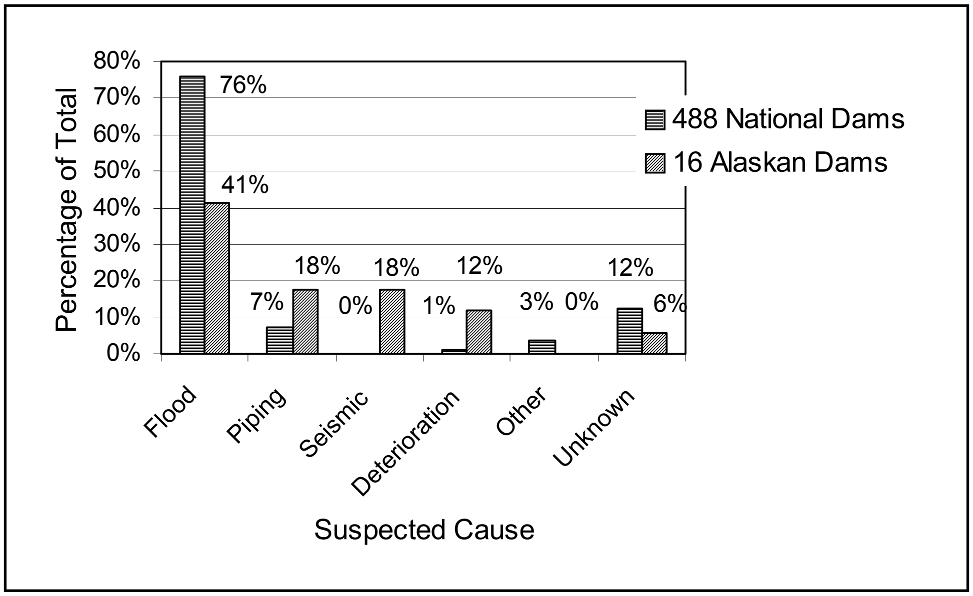

Figure 6-1. Comparison of Dam Failures in the United States and Alaska

Note: National data reflect 2,127 incidents reported between 1989 and 1998 (NDPD, 2000). Alaska data are based on documented failures since 1964.

6.1.1 Inflow Design Flood

The IDF is the primary objective of the hydrological portion of the design. It is defined in 11 AAC 93.195(c) as "the flood flow above which the incremental increase in the downstream flood caused by a failure of the dam does not result in any additional danger downstream." As indicated in 11 AAC 195(b)(1 and 2), information for determining the IDF should be developed in substantial accordance with either of the following:

- *Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams*, published by the FEMA (1998d)
- Methods approved by Dam Safety that adequately assess and characterize the design hydrology and are based on the hazard potential classification of the dam

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In summary, the FEMA report recommends the following standards for the IDF:

- **Minimum standard for Class III (low) hazard potential dam** – IDF based on a storm event with a return frequency selected to "protect against loss of benefits during the life of the project and to keep O&M costs to a minimum…" In general, the IDF with "an average return frequency of less than once in 100 years," also known as the 100-year flood, or a flood with a probability of occurrence of 0.01 (1%) in any given year, is adequate for Class III dams.
- **Maximum standard for all hazard potential class dams** – IDF based on probable maximum flood (PMF) based on probable maximum precipitation (PMP).
- **Calculated standard for all hazard potential class dams** – IDF based on "incremental hazard evaluation," sometimes referred to as an incremental damage assessment. In other words, the IDF is the flood with a magnitude at which the failure of the dam simultaneously with the peak of the IDF hydrograph does not contribute to any additional flood damage downstream. For purposes of these guidelines, this definition of the IDF is considered the same as the definition given in 11 AAC 93.195(c).

Acceptable methods for determining the IDF hydrograph include the following:

- Hydrologic modeling programs, such as HEC-HMS (preferred) or HEC-1 published by the Hydrologic Engineering Center of the USACE
- *Urban Hydrology for Small Watersheds*, Technical Release 55 (TR-55), published by the USDA Soil Conservation Service (1986)

For Class III (low) hazard potential dams located in any area of Alaska, the IDF may be calculated by using the regression equations in the following useful reference:

- *Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada* (Jones and Fahl, 1994), published by the U.S. Geological Survey (USGS)

Correction factors for standard errors should be considered. In any case, the accuracy of the calculated values and the suitability to the proposed project must be verified.

The IDF may be determined by using other methods proposed by the designer in the design scope proposal and approved by Dam Safety. (See Section 5.1.7.)

Water Management at Tailings Dams

Managing water at tailings dams represents a unique challenge for designers and operators. During the operating phase, an emergency spillway might not exist and the reservoir must then retain the full volume of the IDF. In this case, a detailed water balance methodology must be developed to carefully monitor and maintain a reserve storage capacity. For closure, the facility must be modified to safely handle an IDF, typically the PMF or some other extreme event. See Subsection 13.2.2 for other important closure details that should be considered in the initial design of a tailings dam.

6.1.2 Precipitation and Snowpack

Unfortunately, current and reliable hydrological information in Alaska is limited. Records are available for select locations such as urban areas or major streams, and some projects are required to collect data for other purposes. Preferably, site-specific rainfall data or stream flow records such as those available from the USGS should be used in a hydro-meteorological analysis to develop the design storm. If sufficient data are available, this approach must be used for Class I and II dams. References must be cited for data and evaluation methodologies, and raw data must be presented in the hydrology report.

In the absence of sufficient data, or for comparison to calculated values, the following documents are available for determining frequency-based precipitation and PMP events:

- *Probable Maximum Precipitation and Rainfall Frequency Data for Alaska for Areas to 400 Square Miles, Durations to 24 Hours, and Return Periods from 1-100 Years*, Technical Paper 47 (TP-47) (Miller, 1963)
- *Probable Maximum Precipitation and Snowmelt Criteria for Southeast Alaska*, Hydrometeorological Report 54 (HMR-54) (Schwartz and Miller, 1983)

For Class I dams in Southeast Alaska, snowpack should be considered in accordance with HMR-54.

For Class I dams in the remainder of Alaska, the effects of snowpack should be considered in accordance with the following:

- Chapter 10 of *Engineering and Design – Runoff from Snowmelt*, published by the USACE (1998)

6.1.3 Hydraulics

Limited guidance on hydraulics is also given in the FEMA guidelines (1998d), including recommendations for the following:

- IDF reservoir routing
- Spillway and outlet works
- Freeboard

Additional references may be required for the detailed design and evaluation. Details of hydraulic calculations and references should be included in the engineering design report for all hazard potential classification dams.

6.2 Stability

Stability must be demonstrated for all types and hazard potential classification dams under a variety of loading conditions. Many acceptable empirical and numerical methods are available for evaluation of the stability of dams. The scope of the stability analysis should be defined in the design scope memorandum, including methods of analysis and verification and references for proposed safety factors, or objectives of deformation analyses or finite element analyses.

The general guidance shown in Table 6-1 should be considered when defining the scope of the stability analysis in the design scope proposal. (See Section 5.1.7.)

The stability analysis requirements for hazard potential classification dams are summarized below.

- **Class I (high) hazard potential dams –** Detailed stability analysis is required. All computer stability analyses must be verified with manual calculations or other approved methods.
- **Class II (significant) hazard potential dams –** Detailed stability analysis is required. Graphical or empirical evaluations may be used to verify computer results.
- **Class III (low) hazard potential dams –** Published empirical or graphical methods may be adequate for small embankment dams less than 25 feet in height. Embankment dams greater than 25 feet in height should be evaluated in the same manner as Class II dams. Other types of dams, such as concrete, steel, or timber frame dams, may require a combination of methods.

For any given analysis, all input data and results must be clearly documented, including assumptions, sources of information, references, and computer outputs.

Table 6-1. General Guidance for a Stability Analysis

Hazard Potential	Dam Type	Computer Analysis	Graphical or Empirical Analysis	Manual Analysis	Finite Element Analysis
Class I	All	P		V	S
Class II	All	P	V		S
Class III	Earth and rock fill, <25 feet tall	O, S	P	O	
Class III	Earth and rock fill, 25 feet or taller	P	V		
Class III	All others	S	O	O	S

P = Primary method of analysis
S = May be required under special circumstances
V = Verification of primary method
O = Optional method of analysis

6.3 Seismicity

Evaluation and design of all new dams, or major modifications of existing dams should consider the effects of seismicity on the stability and performance of the facility, including appurtenant structures, reservoir, and associated equipment. A study to assess the seismicity is required for all dams. Depending on the complexity of the project, this study may require an interdisciplinary team that includes seismic, geologic, geotechnical, and structural engineering specialists.

6.3.1 Minimum Scope

The scope and detail of each seismic study will depend on the dam hazard potential classification and location, the regional seismic environment, and the site-specific geologic and topographic conditions. However, each study should address the following four key elements:

- Define the seismic environment such as regional earthquake sources, historical activity, and recurrence rates, and characterize the levels of potential ground motions such as duration, frequency, amplitude and predominant period of ground vibrations, and peak ground accelerations, as needed for design and monitoring during operation
- Evaluate the potential for fault movements rupturing the surface at or near the dam, liquefaction, lateral ground spreading and cracking, and overtopping caused by seiches or waves induced by slope failures around the reservoir
- Analyze the dynamic response of the dam to inertial forces and potential reductions or loss of strength and stiffness in the foundation and dam materials as a function of the design ground motions
- Analyze the facility to verify that each element, including embankments, foundations, appurtenances, and reservoir, will adequately resist translational (sliding wedge or block), rotational or flow-type slides, or excessive settlements and deformations during the design earthquakes

6.3.2 Design Earthquake Levels

Two levels of design earthquake must be established:

- **Operating basis earthquake** (OBE) represents the ground motions or fault movements from an earthquake considered to have a reasonable probability of occurring during the functional life-time of the project. All critical elements of the project (such as dam, appurtenant structures, reservoir rim, and equipment) should be designed to remain functional during the OBE, and any resulting damage should be easily repairable in a limited time. The OBE can be defined based on probabilistic evaluations, with the level of risk (probability that the magnitude of ground motion will be exceeded during a particular length of time) being determined relative to the hazard potential classification and location of the dam.
- **Maximum design earthquake** (MDE) represents the ground motions or fault movements from the most severe earthquake considered at the site, relative to the acceptable

Maximum Credible Earthquake

The terminology used for describing various design earthquakes and seismic hazards is inconsistent in the various references. The maximum credible earthquake (MCE) is defined herein as the greatest earthquake that reasonably could be generated by a specific seismic source, based on seismological and geologic evidence and interpretations. The MDE and OBE are defined in the text. Other terminology may be acceptable, but specific references and definitions must be included.

consequences of damage in terms of life and property. All critical elements of the dam and appurtenant structures for which the collapse or failure could result or precipitate an uncontrolled release of the reservoir must be designed to resist the MDE. In addition, the dam and appurtenances must be designed to resist the effects of the MDE on the reservoir and reservoir rim. The MDE may be defined based on either deterministic or probabilistic evaluations, or both.

Table 6-2 provides a range of probabilistic return periods (risk) considered appropriate for defining the OBE and MDE, as a function of the hazard potential classification of the dam. Within the context of these ranges, the OBE return period for a given project should be selected in direct correlation with the frequency of regional earthquakes, the useful life span of the facility, and the difficultly of quickly accessing the site for repairs. The return period selected for the MDE should be selected in direct correlation with the magnitude of the maximum credible earthquake (MCE) for the known or suspected regional sources; the dam type, size, and geometry; and the reservoir capacity. Further guidelines for selecting the ground motions associated with these two levels of seismic hazard are provided in Dobry et al. (1999) and USCOLD (1999).

Table 6-2. Operating- and Safety-Level Seismic Hazard Risk

Dam Hazard Classification	Return Period, Years	
	Operating Basis Earthquake	Maximum Design Earthquake
I	150 to >250	2,500 to MCE
II	70 to 200	1,000 to 2,500
III	50 to 150	500 to 1,000

6.3.3 Seismic Study Phases

Seismic studies for new dam design should be conducted in two phases, which are described below.

- **Seismic report phase** – This phase should occur early in the planning of the project and be included with the Preliminary Design Package submittals described in Subsection 5.2.5. The seismic report will include preliminary evaluations as needed to establish an understanding of the potential influence of the OBE and MDE on the type, geometry, and size of the dam and reservoir. Given the preliminary nature of this phase, evaluations can generally be based on published information and simplified methods. After the risks have been established, preliminary values for the OBE and MDE parameters can be estimated based on regional geologic mapping (for example, USGS publications and Plafker and Berg, 1994) and seismological studies (for example, Wesson et al., 1999; and USGS National Seismic Hazard Mapping Project – Interactive Deaggregation, 2003). Evaluations of the potential for liquefaction should be presented based on the local geology, historical record, and simplified methods with the use of standard penetration test values from the geotechnical evaluation (for example, Seed et al., 2001; and Youd and Idriss, 1997). Evaluations of the response and stability of the dam should be presented by using limit-equilibrium or linear-elastic analysis and generic response spectra found in applicable design codes or standards (see methods in Kramer, 1996).

The seismic report phase should also refine the scope and detail of the evaluations to be performed during the subsequent design evaluations of the facility conducted in the second phase of the seismic evaluation of the dam. If the associated risks are high because of the location of the dam and its hazard potential classification, more sophisticated analyses may be required (USCOLD, 1999); for example, with deterministic and probabilistic evaluations or acceleration time histories.

- **Seismic design phase** – This phase should occur during the detailed design of the project and be included in the engineering design report submitted as part of the Detailed Design Package and described in Subsection 5.3.1. The seismic design phase of the seismic study will include formal evaluations of each critical element of the dam as needed to assure that the facility meets the performance requirements under the OBE and MDE. The effort and sophistication of the work conducted during this phase of the seismic study will depend on the hazard potential classification of the dam, and the magnitude of the OBE and MDE. For example, the dynamic and stability evaluations for all Class I and II dams located in a highly seismic region (with peak ground accelerations greater than about 30% to 40% of gravity or peak shear strains greater than about t2%) should utilize advanced one- and two-dimensional site response analysis techniques (for example, Lee & Finn, 1978; and Idriss et al., 1973) to more accurately model the nonlinear behavior of soil subject to earthquake loading. On the other hand, the dynamic stability evaluations for Class III dams or Class II dams located in regions with low seismicity (with peak ground accelerations less than about 5% to 10% of gravity) can utilize the same simplified methods followed in the seismic report phase, and no additional detailed evaluation may be required. However, the simplified methods presented in the seismic report should be reviewed with respect to the final design of the dam, and should be revised if necessary. Evaluations of Class I and II dams located in regions of moderate seismicity can utilize techniques between these ranges, such as equivalent-linear, one-dimensional, site response analysis (for example, Idriss and Sun, 1992).

6.4 Seepage

Seepage must be considered for all hazard potential classification dams; however, the scope of the analysis depends on a number of factors, including the size and type of dam and the foundation and construction materials. The following are conditions and suggested levels of evaluation based on the hazard potential classification of the dam.

- **All hazard potential class dams**
  - The material properties, including permeability, must be estimated for both the foundation and construction materials.

- Filters must be included in all embankment dams between core materials and drains. Soil filter criteria must be demonstrated based on actual gradation tests. References to filter criteria standards must be included.
- Appropriate seepage cutoff or reduction measures must be included to limit gradients and prevent piping and erosion.
- All dams must include the appropriate drainage features to control seepage pressures and gradients, including uplift.
- Phreatic surfaces must not daylight on the downstream face of embankment dams.
- Appropriate measures to control seepage along penetrations through the dam or at contact planes between different materials, such as the interface between concrete and soil fill, must be included.

❑ **Class III (low) hazard potential dams**

- Empirical evaluations combined with engineering controls may be used to address seepage.
- Published values for material properties may be used in lieu of laboratory testing to a limited extent; however, sufficient index testing must be completed to accurately classify all materials to be used in construction.

❑ **Class II (significant) hazard potential dams**

- Foundation conditions must be thoroughly evaluated in the geotechnical program, including rock coring and packer testing, as appropriate.
- Laboratory testing must be used to determine permeability and index properties of the core, filter, and drainage materials. Published permeability values may be used for coarse-grained drainage materials. In situ soil and rock, excavated material to be reused, and borrow sources must be tested.
- Appropriate foundation preparations, such as cleaning, slush grouting, pressure grouting, and dental concrete, must be included in the construction specifications.
- A numerical analysis may be required for certain Class II dams for which seepage control is a primary performance parameter.

❑ **Class I (high) hazard potential dams**

- All Class II conditions apply.

Seepage Monitoring

All dams should be monitored for seepage. Increases in seepage rates or turbidity can be key indicators of a developing failure situation. Seepage monitoring requirements should be specified by the engineer and included in the operations and maintenance manual discussed in Chapter 8. Seepage monitoring software is available from the Federal Emergency Management Agency's National Safety Program. Contact Gene Ziezel at (202) 646-2802 for more information.

- Geotextile filters may not be used as primary filters in critical components of Class I dams.
- A numerical analysis must be completed.

6.5 Cold Regions

When designing a dam in Alaska, the effects of extreme cold must be considered in siting, construction, and operation. These issues must be addressed during the planning stages. Additional information is provided in the following subsections.

6.5.1 Siting

Large areas of the state have permafrost that ranges from discontinuous areas to continuous zones that are hundreds of feet thick. The presence of permafrost at a proposed project area constitutes a key design element and performance parameter. Disturbance of the ground surface above permafrost alters the thermal regime of the area, resulting in changes to the permafrost. Clearing vegetation, excavation, construction, or the impoundment of water or tailings can affect permafrost. Thawing of permafrost soils can result in loss of bearing capacity, excessive settlement, or increased seepage, which can lead to the failure of the dam.

Consequently, the potential for permafrost must be considered when siting a dam. If permafrost is present at the preferred location of the dam, the geotechnical and geological investigation must thoroughly classify the extent and nature of the permafrost and include recommendations for the design. The design report must evaluate the effects on permafrost caused by of the construction and operation of the dam and reservoir, and must include a thermal evaluation that uses approved methodologies.

6.5.2 Materials of Construction and Construction Process

Cold temperatures can also influence the selection of construction materials and the quality of work that occurs during construction. Design details and construction specifications must address the affects of freezing temperatures on the following items, at a minimum:

- Specifying and installing geomembranes, plastic pipes, or other materials that may be sensitive to cold
- Placing and compacting fill
- Pouring and curing concrete
- Welding steel or geomembrane

Ice Load Design

CEA Technologies Inc., sponsored by the Canadian Electric Association, recently published Static Ice Loads on Hydroelectric Structures: Ice Load Design Guide. *The following sections of the report may prove useful for designing dams in Alaska:*

- *Summary Report*
- *Ice Load Design Guide*
- *Ice Load Prediction Computer Program*

For more information, visit the company Web site at www.ceatech.ca.

6.5.3 Operation

The design of a dam must consider and address the following issues that can affect dams during routine operations:

- Runoff from snowmelt
- Ice loading on dam and appurtenances
- Freeze/thaw effects on concrete dams and appurtenances
- Cold-temperature effects on exposed plastic pipes or geomembranes
- Ice lens formation in fine-grained soils
- Frost jacking of buried pipes, piles, or other appurtenances

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Guidelines for Cooperation with the
Alaska Dam Safety Program

Chapter 7

CONSTRUCTING THE DAM

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Chapter 7

CONSTRUCTING THE DAM

In this chapter:

- Details for submittals required before construction actually begins
- Requirements for CQA/QC based on the hazard potential classification
- Details for submittals required after construction is complete

The proper construction of a dam is critical to the short- and long-term safety of the dam. Once a *Certificate of Approval to Construct a Dam* has been issued by Dam Safety, construction may proceed. However, the communication and cooperation among the various parties must continue. This chapter outlines the regulatory communication that must occur during the construction period.

7.1 Preconstruction Plans

The additional plans described in the subsections below may be required before construction can begin, even though a *Certificate of Approval to Construct a Dam* may be issued. The required plans will typically be listed as a condition to the certificate of approval because these plans are often developed by the construction contractor.

7.1.1 Water Diversion Plan

The water diversion plan is required to control surface water during construction. The plan contents must address the following elements:

- Design drawings and specifications for cofferdams, spillways, conduits, or other temporary features that may be required to control the water
- Stability analysis of the cofferdam, both in normal and probable flood conditions, with supporting hydrologic data
- Hydraulic and stability analyses for conduits, spillways, or other temporary features used for diversion during construction
- Control and pumping of seepage during construction
- After construction is complete, removal of cofferdams, conduits, spillways, or other temporary structures used for water diversion during construction

Generally speaking, these plans should be developed by the contractor based on limited information supplied by the engineer. The engineer must consider water diversion planning during the design. The design storm for the construction period, including the estimated

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volume or flow rate that must be managed during construction, should be clearly specified. The contractor should be allowed the flexibility to develop the methods and means to divert the water in coordination with other aspects of the construction, but the safety of the diversion must be ensured. In any case, the water diversion plan must be prepared in advance of construction and submitted to Dam Safety for review, as indicated in the certificate of approval.

7.1.2 Erosion Control Plan

The erosion control plan should include a description of measures used during and after construction to limit erosion both within the site and the downstream channel in the vicinity of the construction.

7.2 Construction Quality Assurance/Quality Control

The purpose of this section is to define terminology associated with CQA and construction quality control (CQC), indicate the level of CQA/QC that should occur based on the hazard potential classification of the dam, discuss key inspection points for the CQA/QC inspectors and engineers, and provide guidance on design changes that may occur during construction.

7.2.1 Definitions

For purposes of this guidance document and the ADSP, the following definitions are used:

Construction quality assurance (CQA) – Actions taken by the owner or operator of the dam, including retaining a qualified engineering consultant (if required), to ensure that the project is completed by the construction contractor in accordance with the approved plans and specifications. These actions may include approving construction materials, conducting independent field and laboratory testing, inspecting the work during and after construction, surveying, and documenting the construction process.

Construction quality control (CQC) – Actions taken by the construction contractor to control the quality of work to meet the requirements of the approved plans and specifications. These actions may include surveying, borrow pit investigations, field and laboratory materials testing, construction methodology, scheduling, and documentation.

CQA or CQC plan – A formal document that outlines the scope of the activity to be conducted during construction to control or assure the quality of the finished project. A CQA/QC plan that includes the requirements for both CQA and CQC may be developed, but the responsibilities for specific work must be clearly delineated. The scopes of the CQA and CQC plans depend on the complexity and hazard potential classification of the dam. Guidance on the recommended contents of these plans is beyond the scope of these guidelines. However, a CQA/QC plan is required under 11 AAC 93.171(f)(3)(D). Dam Safety will review the contents of the plan under the Detailed Design Package. (See Section 5.3.4.) A draft submittal is recommended.

Third-party CQA – A CQA provided by an engineering consultant, independent from the owner or the contractor, who is qualified in the construction inspection of the type of dam and appurtenant works under construction. The third party could be the engineering design consultant.

Construction Inspection Engineer – According to 11 AAC 93.173(c)(2), except for the removal or abandonment of a Class III (low) hazard potential dam, a qualified engineer is required to "observe and inspect the work for compliance with the approved plans, drawings, and specifications." The construction inspection engineer is responsible for the CQA activities described above, the key inspection items discussed in Subsection 7.2.3, and preparation and certification of the construction completion report and record drawings described in Section 7.3.

7.2.2 Level of CQA and CQC

Table 7-1 indicates the general level of CQA/QC that is required based on the hazard potential classification of the dam.

Table 7-1. CQA/QC Levels Based on Hazard Potential Classifications

Required Level of CQA/QC	Hazard Potential Classification		
	I	II	III
CQA plan	Yes	Yes	Optional
CQC plan	Yes	Yes	Yes
Owner's CQA	Optional	Yes	Yes
Third-party CQA	Yes	Optional	Optional
CQC	Yes	Yes	Yes
Engineering inspection	Yes	Yes	Yes

7.2.3 Key Inspection Items

The design engineer should identify key inspection items for various aspects of construction based on the type of dam and its hazard potential classification. Some of these items must be inspected before additional work may proceed; for example, the foundation must be inspected before any fill is placed, or rebar may need inspection before concrete is poured. These items must be clearly identified in the construction specifications as mandatory inspection points so that the contractor can make appropriate allowances. Other key inspection items, such as fill compaction or concrete testing, may occur over time. All key inspection items that are critical to the design or could affect the contractor should be clearly indicated in the construction specifications or on the final construction drawings. These inspections must be conducted by the construction inspection engineer (as discussed in Subsection 7.2.1), the engineer of record, or another engineer or geologist under the supervision of the construction inspection engineer or the engineer of record.

7.2.4 Design Changes

All design changes that are proposed after a *Certificate of Approval to Construct, Modify, or Repair a Dam* is issued must be reviewed by Dam Safety. In some cases, depending on the nature of the proposed change, additional submittals may be required and written approval may need to be obtained from Dam Safety before the change is implemented. In all cases, the design change must be approved in writing by the engineer of record who certified the design.

7.3 Post-Construction Submittals

The following post-construction documents must be submitted to Dam Safety after completion of the dam construction, modification, or repair.

7.3.1 Construction Completion Report

A construction completion report is required for Class I, II, and III dams. The scope of the construction completion report will depend on the complexity of the project. The report content should include the following:

- Description of how the plans and specifications were followed or deviated from, including the types of materials used for construction, brand names or catalog sheets of components, and other descriptive information
- Description of unexpected conditions encountered
- Inspection reports
- Field and laboratory test results, including sample locations and test standards or methodologies
- Photographs documenting construction progress and final conditions
- Seal and signature of the construction inspection engineer defined in Subsection 7.2.1
- Record drawings, as described in Section 7.3.2

Submittal Standards

One copy of the completion report should be submitted.

Before Filling the Reservoir

The post-construction submittals must be approved by Dam Safety before a Certificate of Approval to Operate a Dam *is executed. No impoundment may occur until this certificate is issued. For modified dams, impoundment may be restricted to a certain elevation until this certificate is issued. In some cases, a first fill plan may be required based on guidance from the design engineer. The plan may specify the maximum rate of filling and a temporary monitoring schedule. A first fill incident report may be requested. (See Chapter 11).*

7.3.2 Record Drawings

Record drawings are mandatory for Class I, II, and III dams. These drawings must contain a complete record of the construction, including actual elevations, changes in major design components or details, and appurtenant construction.

Submittal Standards

One copy of final record drawing package should be submitted.

Drawings that are 11 inches by 17 inches are acceptable if they are legible and to scale (no off-scale reductions).

Larger drawings should be submitted if necessary for clarity.

Drawings should include the following:

- Seal and signature of the construction inspection engineer defined in Subsection 7.2.1
- Stamp or mark on all drawings stating "Construction Record Drawing" or similar language
- Current revision number and date

7.3.3 Operation and Maintenance Manual

An O&M manual is mandatory for Class I, II, and III dams to receive a *Certificate of Approval to Operate a Dam*. Details about the O&M manual are provided in Chapter 8.

7.3.4 Emergency Action Plan

An EAP is mandatory for Class I and II dams. For new construction, this plan must be included with the post-construction submittals to receive a *Certificate of Approval to Operate a Dam*. Details about the EAP are provided in Chapter 9.

Guidelines for Cooperation
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Chapter 8

OPERATIONS AND MAINTENANCE PROGRAM

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Chapter 8

OPERATIONS AND MAINTENANCE PROGRAM

In this chapter:

- Requirements for O&M planning and an O&M manual
- Monitoring requirements for dams based on hazard potential classification
- Recommendations and references for dam operator training

Next to proper design and construction, O&M planning is the most important aspect of an owner's commitment to the safety of the dam. Because of the importance of O&M planning, Dam Safety will not issue a *Certificate of Approval to Operate a Dam* for a dam of any classification until an O&M manual is submitted by the dam operator. Important aspects of O&M planning are discussed in additional detail in the following sections. The following is a useful resource for O&M planning:

- *Training Aids for Dam Safety Module: How to Organize an Operation and Maintenance Program*, published by the USBR (1990)

This useful document defines an "O&M program" as "a systematic means of ensuring that a dam is operated and maintained adequately … for ensuring the continued safe operation of the dam [and] the continued productive use of the reservoir."

As mentioned in Section 1.3, it is the responsibility of the owner and operator of the dam to ensure that an O&M program for the dam and all appurtenances is properly developed and funded for the life of the facility.

8.1 Operations and Maintenance Manual

Proper O&M is crucial for dams and reservoirs to operate safely and efficiently. An O&M manual is an essential component of the O&M program that describes procedures for operating the dam under normal and extreme reservoir level and flow conditions. It also provides technical guidance and procedures for monitoring, inspection, and long-term maintenance programs.

The complexity of the O&M manual is highly dependent on the complexity of the dam and its related features. The O&M manual should be presented as simply as possible, however, so that it is easy for the operator to understand its contents and implement its requirements.

According to 11 AAC 93.197, the O&M manual must describe in detail how a dam will be operated, inspected, and maintained. Required components include the following:

- Physical description of the dam

- Any operating limitations on the dam
- Critical design criteria, including the Project Data Sheet (See Appendix D.)
- Schedule and procedures for routine safety inspections, monitoring, and maintenance of the dam
- Detailed instructions and maintenance procedures for operating valves, gates, or other equipment
- Maintenance procedures, calibration information, and instructions for instrumentation and for monitoring and alarm systems
- Site-specific visual inspection checklists and monitoring data collection forms
- Other information requested by Dam Safety to provide sufficient detail about dam operation, inspection, and maintenance for the protection of life and property

In addition, Dam Safety recommends that O&M manuals contain descriptions of unusual conditions that are most likely to occur at the dam and the operating procedures that should occur under those conditions, including extraordinary inspections (see Section 10.3) and incident reporting as required by 11 AAC 93.177 (see Chapter 11).

The O&M manual and actual practices should be consistent. Organizations such as municipal public works departments that use computerized O&M task managers should incorporate the requirements of the O&M manual for the dam into the system.

An O&M manual should be reviewed on a regular basis and updated as necessary. The manual must be titled and dated and should include revision numbers for accurate reference. A record of revisions should be included.

Appendix E contains a sample outline for a simple O&M manual. Additional guidance is available in the previously cited reference (USBR, 1990).

8.2 Monitoring

Monitoring equipment, procedures, and instrumentation may be required to accomplish the following:

- Confirm that the structure is performing in accordance with the design
- Determine if a problem exists that may require remediation
- Provide timely notice of an adverse change in the state of the dam or reservoir

Changes in seepage character, abnormal settlement patterns, and slope movements are often symptoms of deterioration in the embankment and foundations. Unusually high water levels can indicate an immediate problem is developing. Baseline monitoring is critical to determine whether change is occurring. Instrumentation must be combined with responsible recording and analysis of the data to identify significant trends in the performance of the dam.

The following are key elements of a successful monitoring plan:

- An O&M manual that requires the diligent implementation of the observation and data collection procedures
- The timely analysis and evaluation of inspection records and data for significant changes or adverse trends in anticipated behavior
- Procedures in the O&M manual to follow when monitoring indicates significant changes or unusual conditions are occurring

Effective tools for monitoring the condition of a dam include the following:

- Visual inspection checklists with comments
- Photographs of key features taken from a consistent perspective over time
- Automatic data loggers connected to critical instrumentation
- Alarm systems connected to full-time monitoring devices such as water level indicators
- Internal review procedures to ensure that monitoring data are properly evaluated

Table 8-1 recommends minimum levels of monitoring and instrumentation based on the hazard potential classification of the dam.

Table 8-1. Suggested Monitoring and Instrumentation Levels

	Hazard Potential Classification		
Monitoring Item	I	II	III
Routine visual inspection checklist	Yes	Yes	Yes
Reservoir staff gauge	Yes	Yes	Yes
Water level data loggers	Yes	Optional	
Water level alarms	Yes	Optional	
Precipitation gauge	Yes	Optional	
Settlement/displacement indicators	Yes	Yes	
Seepage/under-drain weirs	Yes	Yes	
Piezometers	Yes	Yes	
Thermistors	Yes	Yes	

Note: Specific monitoring and instrumentation should be based on an engineering evaluation of the dam. For example, strain gauges or crack monitors may be required on a Class I concrete dam.

8.3 Operator Training Program

The owner and operator of a dam are responsible for understanding all technical aspects of the system that are necessary to operate the dam in a safe manner. A training plan should be included in the O&M program to provide employees with the proper expertise that will enable them to perform their respective duties. Training should be required initially for new employees and recurrently for all employees during the life of the project, as appropriate. Training should be progressive so that it will cover the wide variety of topics typically associated with operation, maintenance, inspection, and monitoring of dams.

The following training references, listed by source, are highly recommended by Dam Safety:

- **Training Aids for Dam Safety (TADS)** – TADS is a comprehensive collection of notebooks and videos published by the USBR. TADS modules are available for these and other topics:
  - Dam Safety Awareness
  - Identification of Visual Dam Safety Deficiencies
  - Inspection of Embankment Dams
  - Inspection of Concrete and Masonry Dams
  - Inspecting and Testing of Gates, Valves, and Other Mechanical Systems
  - Inspection of Spillways and Outlet Works
  - Evaluation of Seepage Conditions
  - Documenting and Reporting Findings from a Dam Safety Inspection

  Contact the USBR in Denver Colorado at (303) 236-4308 or (303) 236-2946 for ordering information.
- **Association of State Dam Safety Officials** – ASDSO is a national, nonprofit organization that promotes dam safety on behalf of its members, which consist of state and federal agencies, dam owners and operators, engineering consultants, contractors, vendors, research institutes, and others. ASDSO sponsors regional and national training seminars and conferences on an annual basis. Special training programs, including workshops specifically geared toward dam owners and operators, can be scheduled. The ASDSO Web site includes news, an on-line bibliography and bookstore, and links to numerous other dam-related Web sites. Membership in ASDSO is encouraged by Dam Safety. For more information, contact ASDSO in Lexington, Kentucky, at (859) 257-5140 or visit the organization's Web site at www.damsafety.org.
- **Alaska Dam Safety Program Library** – The ADSP maintains a limited library of information that is available for loan to dam owners, operators, engineering consultants, and students in Alaska. The library houses the following relevant training materials:
  - Complete TADS modules, including notebooks and videotapes
  - Publications from the U.S. Society of Dams (USSD) (formerly USCOLD)
  - Interagency Committee on Dams (ICODS) training videos published by the National Dam Safety Program
  - Select ASDSO regional and annual conference proceedings since 1999

- Miscellaneous design and operation guidance published by agencies such as the FEMA, FERC, , USACE , USBR, WSDOE, and Portland Cement Association
- Classic textbooks such as *Design of Small Dams* (USBR, 1987), *Handbook of Dam Engineering* (Golze, 1977), and *Seepage, Drainage, and Flow Nets* (Cedergren, 1989)

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Chapter 9

EMERGENCY ACTION PLANNING

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Chapter 9

EMERGENCY ACTION PLANNING

In this chapter:

- Discussion of the purpose, format, and content of EAPs for Class I and II dams
- Descriptions of EAP exercises
- Guidelines for conducting a dam failure analysis

Dam failures can have devastating impacts on people and property. For these reasons, it is vital to be prepared in advance of an emergency situation. An EAP prepared by the dam owner is required by 11 AAC 93.164, 93.167, and 93.171 for Class I and II dams. This section describes the purpose and requirements for an EAP, outlines the EAP contents based on the hazard potential classification, recommends EAP exercise levels and schedules, and provides guidance on dam failure analysis.

The following are purposes of the EAP:

- Protect lives and property if an emergency condition develops at a dam
- Prepare owners, operators, and emergency management personnel for the emergency event, in advance
- Detail the actions and measures that will be taken by all parties that are responsible for responding to an emergency
- Facilitate the coordination and cooperation of the various emergency responders

An emergency condition is assumed to exist if either of the following conditions exist:

- An impending or actual release of water, mine tailings, or other substances caused by improper operation, accidental damage, sabotage, or general failure of a dam, penstock, or other appurtenances
- An impending flood condition, even when the dam is not in danger of failure

These conditions may develop slowly or occur suddenly. Emergency action planning in advance is the only way to be prepared.

9.1 Emergency Action Plans

The regulations in 11 AAC 93.164(b) identify the following specific requirements for an EAP for Class I and II dams regulated under the ADSP:

- Adequately protects life and property, given the particular risks to the life or property if the dam fails or in anticipation of dam failure
- Provides adequately for coordination of emergency responders in the community
- Contains information that Dam Safety considers necessary to minimize danger to life and property, which may include these components:
    - Detailed inundation map (See Section 9.4.)
    - Dam break analysis (See Section 9.3.)
    - Schedule for exercise and revision of the plan (See Section 9.2.)
- Review of the EAP at least annually and submittal of any revisions to Dam Safety for approval
- Exercise of the EAP to a level specified by Dam Safety to maintain adequate preparation for an actual emergency
- Revision of the EAP after exercise to address any areas needing improvement
- Distribution of revised EAPs to all persons with responsibilities identified in the EAP
- Revision of the EAP at least every three years or as determined by Dam Safety as sufficient to maintain adequate preparation for an actual emergency

The following are general recommendations for all EAPs:

- Simple, effective, and user-friendly content
- Site-specific information reflecting realistic anticipation of the most likely emergency conditions or failure scenarios for the dam
- Clearly identified potential impacts of a dam failure, including nonfailure-related flooding;
- Clearly identified potentially affected parties
- Clearly outlined responsibilities of the emergency responders
- Availability to and ability to be understood by all emergency response personnel involved, including dam operators; local, state, and federal emergency response agencies; and other parties with responsibilities listed in the plan
- Identification that includes site-specific title, date, and revision number
- Submittal in both paper and electronic (Adobe) formats

9.1.1 Emergency Action Plans for Class I Dams

The regulations in 11 AAC 93.164(b)(4) specifically require the development and maintenance of the EAP for Class I dams in general accordance with either of the following:

- *Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners* (FEMA, 1998c)
- Other requirements determined by Dam Safety to be necessary to protect life or property

The format recommended by the FEMA is consistent with guidance provided by the FERC. This format is adopted by the ADSP to promote consistency for emergency managers who may be responsible for responding to dams owned by different entities, even in a single community. Alternative formats may be acceptable for use in matching local emergency response plans for general emergencies. Any alternative formats must be specifically approved by Dam Safety.

The following format promoted by the FEMA is recommended for Class I dams:

Title Page/Cover Sheet

Table of Contents

I. Notification Flowchart

II. Statement of Purpose

III. Project Description

IV. Emergency Detection, Evaluation, and Classification

V. General Responsibilities Under the EAP

VI. Preparedness

VII. Inundation Maps

VIII. Appendices

A. Investigation and Analysis of Dam Break Flood

B. Plans for Training, Exercising, Updating, and Posting the EAP

C. Site-Specific Concerns

D. Approval of the EAP

Specific guidance on select aspects of the EAP follows.

- **Notification flowcharts –** The content of these flowcharts is determined by the magnitude of the anticipated failure and the number of emergency response personnel or agencies identified in the plan. A flowchart should be prepared for the following scenarios:
  - A non-failure emergency condition
  - A potential failure situation developing
  - An imminent or actual failure in progress

  Each flowchart should clearly indicate priority notifications for emergency initiators and delegation of responsibilities for secondary and tertiary notifications. Potential victims that require immediate notification should be included, and locations of detailed lists of other potential victims should be referenced.

- **Inundation maps and dam break analysis –** See Section 9.3 and 9.4 for more detailed information. Topographical maps are not required for inundation maps, even though they are used to analyze dam-failure scenarios.
- **Plans for training, exercising, updating, and posting the EAP –** Training related to the EAP should be included in the training plans of the dam owner and operator, as recommended in Section 8.3. The EAP should be reviewed annually for current contact information, applicability, and other concerns and should be revised as needed. The EAP should also be revised to reflect improvements identified through exercises, comments from responsible parties, and actual emergency events. Exercises should be conducted regularly. The following levels and frequencies of exercises are recommended:
  - Orientation exercise (all responsible parties) – annually
  - Drill exercise (dam operator only) – annually
  - Tabletop exercise (all responsible parties) – every three years
  - Functional exercise (all responsible parties) – upon request of Dam Safety for Class I dams

  Additional detailed guidance on EAP exercises is provided in Section 9.2

9.1.2 Emergency Action Plans for Class II Dams

Because there is a low probability for loss of life associated with a Class II dam, Dam Safety is inclined to allow some flexibility in the scope of the EAP. For Class II dams, the EAP may be included in the O&M manual or in a site emergency operations plan. The requirements and recommendations indicated in Section 9.1 still apply, as appropriate.

9.2 Emergency Action Plan Exercises

According to 11 AAC 93.164, the owner is responsible for exercising the EAP. The dam owner and operator should develop and implement the policies and programs to ensure that the EAP is properly exercised on a regular basis. The schedule for EAP exercises is typically included as a condition to the *Certificate of Approval to Operate a Dam*, as indicated in the example certificate presented in Appendix B. The FEMA (1998c) recommends five types of exercises that can be included as part of the exercise program. The various levels of exercises (ranging from simplest to most complicated) are identified below:

- **Orientation seminar –** Involves bringing together individuals with a role or interest in the EAP to discuss the EAP and initial plans for an annual drill or more in-depth exercises
- **Drill –** Tests and develops the skills of the dam operator to respond in an emergency situation

- **Tabletop exercise –** Involves a meeting of dam operator and emergency management officials in a conference room environment. A simulated event is described and the respective actions of each participant are discussed.
- **Functional exercise –** Involves a stress-induced environment with time constraints in a controlled setting wherein participants must respond to a simulated dam failure and other specified events
- **Full Scale exercise –** Includes field mobilization and movements as participants "play out" their roles in a dynamic and open setting that provides a high degree of realism

These exercises are described in detail in FEMA (1998c) and FERC guidance (2000). In addition, the FERC also provides guidance on designing an EAP exercise. Dam Safety can also be contacted for assistance in planning EAP exercises, and will attend and participate in exercises whenever possible. Except under special circumstances, Dam Safety will not typically require a functional or full-scale exercise.

9.3 Dam Failure Analysis

A conservative understanding of the potential impacts of a dam failure is critical to the mission of the ADSP. An evaluation of a hypothetical dam failure is the process that is used to assign the hazard potential classification; however, a detailed and accurate dam failure analysis is a complex and expensive engineering endeavor that may only be required under certain circumstances. As discussed in Section 2.4, Dam Safety recognizes three levels of dam failure analyses for determining the hazard potential classification. The circumstances for which these levels of evaluation may be appropriate are outlined below.

Preliminary

- Initial assignment of hazard potential classification for discussion purposes
- Class III (low) assignment for rural water supply, sanitary waste, or hydroelectric dams with no development downstream and no anadromous fish
- Initial Class I assignment for large dams or reservoirs upstream from highly developed areas
- Initial Class II assignment to mine tailings dams that meet the geometric parameters that define a dam as discussed in Section 2.3, a dam located on an anadromous fish stream, or a primary water supply dam for a community with 500 or more residents
- Conservative assignment of classification under which all parties agree to comply with the respective requirements

Qualitative

- Disputed hazard classification assignments for which limited development exists downstream and a technically sound, qualitative review results in a conservative conclusion

Quantitative

- Disputed hazard classification assignments for which a qualitative analysis does not result in a conservative conclusion
- Disputed hazard classifications for which compliance with the conservative assignment results in substantial economic burdens on the dam owner and the most accurate analysis is justified
- Certain systems for which the results of a dam failure are not apparent, such as a relatively large dam or reservoir located a long distance upstream from a development that may not be in an apparent floodplain
- For emergency action planning of Class I or II dams if development of an inundation map requires detailed flood stage, flood wave travel times, or duration and quantity of flooding from the improper operation or failure of the dam

General guidance on conducting a dam failure analysis for each level of review is included in the following subsections. Specific guidance on dam failure analyses is presented in Subsection 9.3.4.

9.3.1 Preliminary

A preliminary dam failure analysis is based on a review of limited information about the dam and the downstream system. This information may include a visual inspection of the dam, reservoir, and the downstream reach; conceptual design drawings; and other limited, readily available information such as aerial photography and topographic maps. The primary basis for the analysis is engineering judgment.

9.3.2 Qualitative

A qualitative dam failure analysis is a limited engineering evaluation that may involve rudimentary hydrological estimates; simplistic calculations to estimate the peak discharge from a dam failure such as weir equations or graphical solutions; open-channel flow calculations at discrete cross sections along the downstream channel near the development; elevation or cross-section surveys; and other simplistic data used with conservative assumptions.

Useful information for conducting a qualitative dam failure analysis is included in the "Dam Break Inundation Analysis and Downstream Hazard Classification," Technical Note 1, of the *Dam Safety Guidelines* published by the WSDOE (1992).

9.3.3 Quantitative

A detailed dam failure analysis that includes a computerized dam breach and hydraulic routing model, detailed hydrological estimates, and good-quality input data is considered a quantitative analysis. Although this level of engineering carries the greatest level of credibility in the scale of dam failure evaluations, a numerical evaluation is subject to the old computer axiom "Garbage in equals garbage out." A computerized dam break analysis that uses gross assumptions does not carry the same credibility as an analysis in which input data are detailed and verifiable, but may be more credible than a qualitative analysis. Such input data may be derived from field surveys, site-specific hydrological analysis, as-built construction drawings, laboratory testing, or other relatively high quality data. In other words, the higher level of engineering detail contributes to the greatest level of understanding about the most likely effects of a dam failure. For any quantitative dam failure analysis, all methodologies, assumptions, data sources, and references must be clearly documented.

Dam Safety recommends the most current versions of following models developed by the USACE for a quantitative dam failure analysis:

- HEC-HMS by the USACE
- HEC-RAS by the USACE

These models are Windows-based computer programs that are current, modern, and sophisticated. HEC-HMS is a hydrologic model that includes dam breach subroutines and generates a dam-break flood hydrograph. HEC-RAS is a hydraulic model that routes the dam-break flood hydrograph downstream.

Other computer models that may be used for a quantitative analysis include the following:

- HEC-1 published by the USACE
- DAMBRK published by the National Weather Service, most recently in 1992
- FLDWAV published by the National Weather Service in 1997

The application of any of these programs should be specifically discussed with Dam Safety before they are used for modeling.

9.3.4 Guidance on Dam Failure Analysis

A dam failure analysis at any level should consider the following:

Hydrologic Conditions

- **Sunny day dam break** – Assumes that the dam fails with the reservoir level, inflow, and discharge at normal operating levels
- **Flood stage dam break** – Assumes the dam fails with the reservoir and spillway discharge at maximum capacity, and flooding is occurring based on the 100-year flood or on some percentage of the probable maximum flood or another technically justifiable value such as the IDF

Guidance from an Expert

For detailed guidance on dam failure analysis, see the DVD "Dam Breach and Flood Wave Modeling" by Dr. Danny L. Fread, published in 2004 by the Interagency Committee on Dam Safety, the U.S. Bureau of Reclamation, and FEMA. Copies are available from ASDSO.

In some cases, an incremental damage assessment may be required to determine the point at which the additional flooding that occurs from the failure of the dam is insignificant. An incremental damage assessment should be conducted in accordance with *Evaluation Procedures for Hydrologic Safety of Dams* published by the American Society of Civil Engineers (1988).

Failure Mode and Configuration

The dam failure analysis should consider the mode in which the dam is most likely to fail. The modes to be considered for select types of dams follow:

- **Embankment dams -** Breach caused by overtopping or piping failure
- **Concrete gravity dam –** Displacement of at least one full monolith
- **Concrete arch dam –** Displacement of full width of arch
- **Timber frame dams –** Complete destruction of face between two spans of bents
- **Timber cribbing dams -** Full breach as indicated in Table 9-1

Acceptable values for the breach configuration are included in Table 9-1. Dam breach software such as BREACH (Fread, 1987) may be required for a quantitative analysis.

A detailed failure mode and effects analysis may be required for complex, Class I (high) hazard dams. Dam Safety can be contacted for additional information.

Table 9-1. Acceptable Dam Breach Parameters

Type of Dam	Average Breach Width (feet)	Breach Side Slope; Ratio Horizontal:Vertical	Time to Failure (hours)
Arch	Crest length	0:1 (vertical) to slope of valley wall	less than 0.1
Buttress	Multiple slabs	0:1 (vertical)	0.1 to 0.3
Masonry, gravity monoliths	Width of one or more sections or monoliths, usually less than one-half crest length	0:1 (vertical)	0.1 to 0.3
Rock fill	Height of dam to 5 times height of dam	0.25:1 to 1:1	0.1 to 1.0
Timber crib	2 to 4 times height of dam	0:1 (vertical)	0.1 to 1.0
Earthen (non-engineered)	2 to 5 times height of dam	0.25:1 to 1:1	0.1 to 0.5
Earthen (engineered)	0.5 to 5 times height of dam	0.25:1 to 1:1	0.1 to 1.0

Comments:

Average breach width depends on cross-sectional shape of breach and is not necessarily the bottom width.

Shape of breach is less critical than average width of breach.

Time to failure is a function of height of dam and location of breach. The greater the height of the dam and the storage volume, the greater the time to failure and probably the greater the average breach width.

The bottom of the breach should be at the foundation elevation.

See Chapter II, Selecting and Accommodating Inflow Design Floods for Dams, Appendix II-A, Dambreak Studies, in the 1993 Federal Energy Regulatory Commission report *Engineering Guidelines* for further comments and commentary.

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Flood Wave Attenuation

In a qualitative analysis, if the downstream channel adjacent to development will not pass a dam break peak discharge without flooding, the peak discharge, Q_P, may be attenuated, as shown in Figure 9-1 (WSDOE, 1992). The attenuated flow, Q_x, at the location of the development at a distance, x miles downstream, is compared to the channel capacity at the development. If flooding occurs, cross-section and elevation surveys or a more detailed evaluation such as a quantitative analysis may be required.

In either qualitative or quantitative analyses, the area downstream of the dam must be considered to a distance at which the flood wave is attenuated sufficiently so that the effects of the increased flow are inconsequential.

Effects on Important Fish Habitat

In some cases for Class II dams in which potential damage to important fish habitat may occur, erosion and scour damage or sedimentation may need to be considered, even if the channel capacity is adequate or flooding is otherwise irrelevant.

Multiple Dams

The domino effects of a dam failure on dams located downstream must be taken into account. If the failure of the dam under review would cause the failure of a dam downstream, the value of that structure must be considered in the hazard potential classification of the upstream dam. Furthermore, the combined failure of the two dams must be considered. In other words, the upper dam must at least carry the hazard potential classification of the lower dam, and could carry an even higher classification if the impacts of the combined failure are significantly greater than the failure of the lower dam alone.

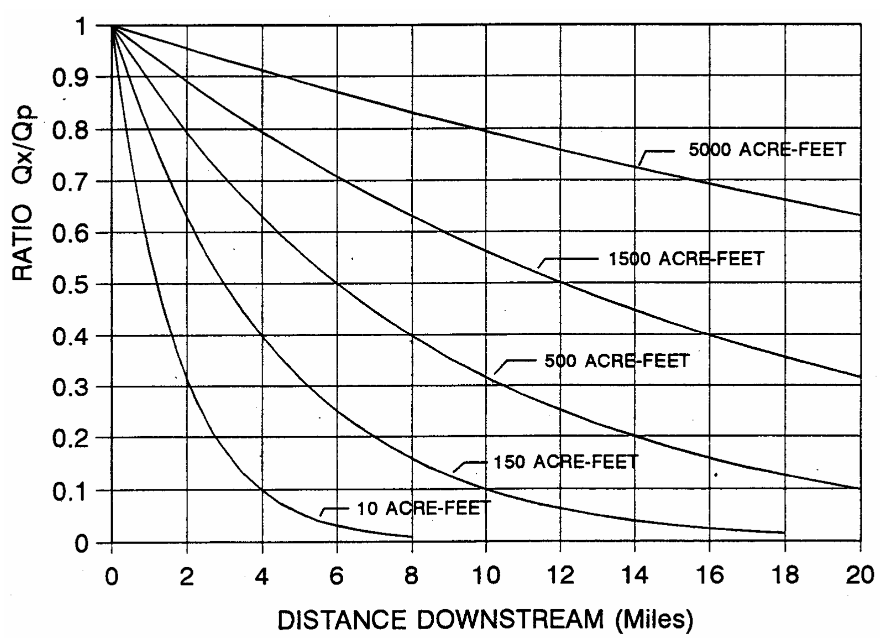

Figure 9-1. Attenuation of Flood Peak Following a Dam Break

Source: WSDOE, 1992

If the upstream dam could fail without adversely affecting the lower dams, the hazard potential classification of the upstream dam may be determined based on an independent dam failure analysis of the upstream dam. In this case, the attenuating affects of downstream reservoirs may be included in the analysis.

9.4 Inundation Maps

Inundation maps should be good-quality graphic illustrations that use current maps or aerial photographs. Although topographic maps may be required for a dam break analysis and for developing an inundation map, topography is not a required component of the inundation map in an EAP because the additional lines may reduce the legibility. Regulations in 11 AAC 93.195 indicate that the map should be prepared on the basis of a dam break analysis, if required, and should identify the following information:

- Extent of flooding below a dam after failure under the following conditions:
  - Normal operating level of the reservoir
  - Inflow design flood
  - Other scenarios that Dam Safety considers necessary to evaluate danger to life and property
- Downstream structures or other development at risk
- Flood wave depth and arrival times
- Roads, evacuation routes, safe zones, and staging areas
- Other information required by Dam Safety to minimize danger to life and property

Guidelines for Cooperation
with the
Alaska Dam Safety Program

Chapter 10

INSPECTIONS

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Chapter 10
INSPECTIONS

In this chapter:

- Description of five types of inspections associated with dams
- Detailed description of the PSI review process
- Guidance on conducting a PSI and on the format of the PSI report

Inspecting the dam on a regular basis during construction and operation is critical to ensure the safety of the dam during the life of the project. The ADSP recognizes five types of inspections:

- Construction inspections conducted during the construction of the dam by a qualified engineer as defined in 11 AAC 93.193(c) (see Subsection 1.3.4) or by CQA or CQC personnel under the direct supervision of a qualified engineer
- Routine inspections conducted by the dam operator
- Extraordinary inspections conducted by dam operator
- Periodic safety inspections (PSI) conducted by an approved, qualified engineer as defined in 11 AAC 93.193(b) (See Subsection 1.3.4.)
- Field inspections conducted by Dam Safety

Additional information is provided in the following sections.

10.1 Construction Inspections

Construction inspections are critical for use in documenting how the dam is constructed and the conditions under which construction occurred. These inspections are typically performed by the CQA and CQC personnel, under the direct supervision of the construction inspection engineer defined in Subsections 1.3.4 and 7.2.1. Observations of construction inspectors must be documented and included in the construction records. See Section 7.2 and Subsection 7.3.1 for more information.

10.2 Routine Inspections

Routine inspections are necessary for the dam operator to become familiar with normal operating conditions and to provide early warning of developing problems that can affect the safety of the dam. These inspections must be diligently conducted in accordance with the schedule specified in the O&M manual, as described in Chapter 8. The frequency of routine inspections depends on the following attributes:

- Hazard potential classification
- Type of dam
- Complexity and criticality of dam features and appurtenances
- Condition of the dam
- Instrumentation monitoring program

The frequency for routine inspections should be recommended by a qualified engineer.

Routine inspections may include the following:

- Casual inspections such as a daily walk or drive through the facilities
- Recorded inspections that rely on a checklist, completed by the inspector, that includes site-specific features that can be readily observed for normal or abnormal conditions

A visual inspection checklist tailored to the specific dam is recommended for recorded, routine inspections. This checklist should be short and specific to the performance parameters of the dam as identified by a qualified engineer. An example of a site-specific visual inspection checklist is included with the sample outline of an O&M manual in Appendix E.

> **Required Routine Inspections**
> *Routine inspections must be conducted and recorded for all hazard classification dams. The frequency for routine inspections must be specified in the O&M manual. Visual inspection checklists or other records must be filed and available for review upon request by Dam Safety and as part of the periodic safety inspection described in Section 10.4*

Routine inspections are conducted by staff members of the dam owner or operator trained in the unique aspects of the dam that is under review. The inspector must be familiar with visual clues that could indicate a problem, as well as monitoring procedures for instrumentation that may be included in the routine inspection. The checklist is completed by the inspector and then reviewed by the inspector's supervisor. The checklist is then stored as a record of the routine inspection in the project file at the nearest office of the dam operator. Other methods of conducting and recording routine inspections such as PDAs or laptop computers may be acceptable. Regardless of the method used, the routine inspection and record keeping procedures must be outlined in the O&M manual.

10.3 Extraordinary Inspections

Extraordinary inspections should be conducted by the dam operator whenever a situation or event occurs that could cause or indicate that a problem could be developing at the time. Extraordinary inspections should occur as a result of the following:

- Earthquakes

- Heavy or extended precipitation
- Suspected or reported vandalism
- Increased threat levels of terrorism activity or terrorist attacks
- Unusual or irregular instrumentation readings or visual observations
- Alarms from automatic monitoring devices

The O&M manual should indicate when an extraordinary inspection should occur. In some cases, the EAP may require activation. If an abnormal situation that is beyond the ability of the dam operator to evaluate is discovered, a qualified engineer must be consulted for additional expertise. Records of extraordinary inspections must be developed and filed. In certain cases, an incident report must be submitted to Dam Safety. See Chapter 11 for guidance on incident reporting.

10.4 Periodic Safety Inspections

The PSI is another form of communication that is extremely important during the operational stage in the regulatory life of the dam. PSIs are mandated by 11 AAC 93.159 for all dams under the jurisdiction of the ADSP. The regulations require Dam Safety to provide written guidelines for the inspection and to approve the PSI report. In addition, the inspection must be conducted by an engineer approved by Dam Safety who meets the qualifications under 11 AAC 93.193(b). The PSI for all dams under state jurisdiction should be conducted in accordance with the guidelines contained in this section.

The PSI is required at the following intervals based on the hazard potential classification:

Class	Interval
I and II	Three years
III	Five years

To facilitate approval and foster communication, the following review process is suggested:

- The qualifications of the engineer should be submitted for review and approval by Dam Safety before the inspection is conducted. The engineer must meet the appropriate requirements, as described in Subsection 1.3.4.
- If different from the approved scope of work outlined in Subsection 10.4.2, the scope of the PSI should be pre-approved by Dam Safety.
- Two draft copies of the PSI report should be provided within 30 days of the field inspection for review by Dam Safety. Dam Safety will review the draft and return a copy to the engineer with comments in redline on the pages of the report.
- The engineer will review the comments from Dam Safety and revise the draft to appropriately address any outstanding concerns. At least two final versions of the PSI report with the engineer's seal and signature should then be submitted to Dam Safety.

- Dam Safety will approve the final version of the report, assuming any comments or concerns indicated on the draft version are satisfactorily addressed. One copy of the report will be retained for Dam Safety records and any additional copies will be returned to the engineer with an approval signature from the State Dam Safety Engineer.

Figure 4-3 illustrates the typical inspection and review process for the PSI of dams under the jurisdiction of the ADSP. The following subsections provide guidance on conducting the PSI, outline an approved scope of the PSI , and suggest the format of the PSI report, regardless of the hazard potential classification assigned to the dam.

10.4.1 Guidance on Conducting the PSI

This subsection provides guidance on conducting the PSI. The PSI is intended to be a comprehensive review of the dam and appurtenances with the specific intent of determining potential problems that could lead to malfunction or failure of the dam. The unique aspects of the dam that could lead to a failure should be identified, as well as the parameters that should be investigated or monitored to determine the current and future performance of that aspect of the dam. These performance parameters may require special attention or focus during the review process. Identifying and reporting on the performance parameters of the dam is one of the primary functions of the engineer during the PSI. See *Performance Parameters for Dam Safety Monitoring* in Appendix F for more information (USBR, 1995).

> **Building the Base of Information**
>
> *The PSI adds to the base of the previous information known about the dam. If the design and construction were not properly developed and documented, the first PSI and subsequent studies may be quite involved. As the performance parameters are understood, the subsequent PSIs may be less extensive. Subsequent PSIs may build on the information contained in previous PSI reports, assuming that those previous reports are reviewed with the same objectives as any historical information is reviewed.*

The PSI should identify and review the potential problems and performance parameters from the following perspectives:

- **Historical** – The PSI should look back to determine whether the design and construction of the dam appropriately addressed specific concerns associated with the performance parameters. For example, if the stability of the upstream slope of an embankment dam is a concern, a number of questions may arise:
  - Was a slope stability analysis conducted in the design or subsequently?
  - Is the analysis still valid?
  - Was the analysis comprehensive and include alternative scenarios such as rapid draw down conditions?
  - Were the input values assumed or were laboratory tests results from site-specific materials used?

- Are those values appropriate?
- Is the safety of the dam sensitive to those parameters?
- Are additional investigations, tests, and analyses required?

In another example, if seepage is a potential problem, these questions may arise:

- Is seepage cloudy or clear?
- Do observations or monitoring data show an increase in flow rate?
- Are the frequencies and methods of monitoring adequate?
- Were blanket drains included in the design and construction records?
- Were filters installed?
- Do fill materials meet gradation criteria for filters?

The historical portion of the PSI should include a review of records such as design reports, construction reports, record drawings, previous PSI reports, photographs, routine visual inspection checklists, and monitoring data.

Remedial Investigations and Repairs

To limit the scope of the PSI for economic reasons, remedial investigations that the PSI identifies as being necessary to further understand a potential problem may be listed as a recommendation in the PSI report. For situations that are not urgent, Dam Safety encourages a thorough understanding of the potential problem and the best solution, before construction dollars are spent trying to mitigate the problem. The subsequent Certificate of Approval to Operate a Dam *will list the remedial investigation as a condition to be completed within the timeframe agreed upon. If a situation is determined to be urgent, and the dam owner or operator does not take immediate steps to resolve the problem, Dam Safety may be compelled to issue an order in accordance with 11 AAC 93.159(d). See Section 12 for additional information.*

- **Current** – The PSI should observe and report on current conditions at the dam, including all performance parameters previously and currently identified, as well as other aspects that may be subtle or apparent. The current portions of the PSI will include the following:
  - Visually inspecting and photographing the dam and its appurtenant structures and facilities
  - Observing operational procedures such as opening and closing gate valves or testing alarms
  - Reading instrumentation such as piezometers or surveying monuments

  The current portion of the PSI should include comparing the current observations to the historical observations for change.

- **Future** – The PSI should process and evaluate the information that is collected and anticipate the behavior of the performance parameters under anticipated and unanticipated future conditions. Examples are provided below:
  - If the comparison of current to historical information indicates a deteriorating condition, will the performance of the system be jeopardized during normal or extreme operating conditions?
  - If the expected performance is not acceptable or uncertain, is a remedial investigation, repair or modification required?

  The PSI should include specific conclusions about the status and safety of the dam and include recommendations for any additional work that may be required.

10.4.2 Scope of the PSI

The following is a generic scope of a typical PSI that is approved by Dam Safety:

- Complete the Hazard Classification and Jurisdictional Review Form. (See Section 2.4.) Describe the potential impacts of a dam failure on the community, and if required, the suggested scope of an EAP if one is not available.
- Review any available historical information such as:
  - Previous PSI reports
  - Hydrological and stability evaluations
  - Design and construction reports
  - Certificates of approval for dam construction, operation, or both
- Determine if the design is contemporary, design assumptions are valid, and construction occurred according to the design
- Determine whether compliance occurred for previous recommendations for maintenance, inspections, or repairs
- Review routine inspection records, monitoring data, and surveys; provide discussion, summary tables, and charts of any data analysis; and include raw data in appendices, as appropriate

> **Visually Inspecting a Dam**
>
> *To properly conduct a visual inspection as part of a PSI, the dam must be visible. Consequently, the visual inspection must be conducted when the dam is clear of snow, excessive brush, and tall grass that may impede the inspection. In addition, all operational and emergency controls on the dam should be exercised during the PSI, so that the inspector can see whether the controls are operating properly.*

- Visually inspect the dam, reservoir, spillways, outlet works, and other appurtenant structures and complete the appropriate sections of the ADSP Visual Inspection Checklist (included in Appendix G and available from Dam Safety as an Excel spreadsheet upon request). Any anomalies should be noted on the checklist and discussed in the PSI report.

- Collect and include key photographs in the PSI report with identifying captions
- Review the O&M manual for currency and relevancy to the dam, including any and all available records for compliance with routine and special monitoring or maintenance requirements of the manual. Review the project data sheet, confirm the information listed therein, and include in the appendices if updated.
- Describe and discuss key elements of the dam, appurtenant structures, foundation, abutments, reservoir rim, and other features that are critical to the safe performance of the dam
- List and discuss the critical performance parameters associated with the dam, including hydrology and hydraulics, geology and geotechnical considerations, seepage, static and seismic stability, and other performance parameters such as deferred maintenance or deterioration
- List specific conclusions about the condition and safety status of the dam, pertinent observations, and professional opinions, with appropriate references to methodologies, calculations, publications, textbooks, or other information used to justify any opinions
- List specific recommendations for additional studies, analyses, inspections, monitoring, maintenance, or repairs, if required for any potential problems that are identified
- Certify the PSI report with the signature and seal of the engineer conducting the inspection

10.4.3 Format of PSI Report

The following general format is requested for PSI reports:

Title Page

Dam name and NID number

Certification, and Approval Sheet

Engineer's seal and signature and the date

Lines for the ADNR approval signature and date

1. Introduction

Location and ownership

Reference to approved scope of the inspection

Project description

Hazard potential classification review

2. History

General background

Construction history

Design history

Inspection history

Dam Safety Inspection Training

The U.S. Bureau of Reclamation presents the Safety Evaluation of Existing Dams (SEED) seminar annually in Denver, Colorado. This excellent seminar is an intensive one-week training opportunity that is highly recommended for engineers, dam owners, and dam operators. Contact the USBR at (303) 445-2740 for more information.

3. **Current Field Inspection**

   Date and inspection personal

   Description of environmental conditions during the inspection

   Highlights of visual inspection, including unusual conditions or problems

4. **Operations and Maintenance Review**
5. **Monitoring Data Review**
6. **Discussion of Key Elements of the Dam and Appurtenances**
7. **Review of Performance Parameters**
8. **Conclusions on the Safety of the Dam and Future Performance**
9. **Recommendations for Additional Work**

Appendices

A. Hazard Classification and Jurisdictional Review form

B. Photographs

C. Visual Inspection Checklist

D. Project Data Sheet (if updated)

E. Other appendices as needed, such as technical evaluations or monitoring data

10.5 ADNR Field Inspections

The State Dam Safety Engineer or other members of the ADNR may conduct a field inspection in accordance with AS 46.17.060 and 11 AAC 93.161 or 11 AAC 93.173(c)(3). A field inspection is defined herein as a limited inspection conducted onsite by the ADNR before, during, or after construction. Field inspections may also occur during routine operation or emergency conditions at the dam. Field inspections may include the dam and reservoir, appurtenant works such as spillways and penstocks, detailed construction activity, and records. Assuming a cooperative relationship exists between Dam Safety and the dam owner or operator, written notice of the inspection will not occur as indicated in the statutes and regulations if the visit is prearranged.

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Guidelines for Cooperation
with the
Alaska Dam Safety Program

Chapter 11

PERFORMANCE AND INCIDENT REPORTING

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Chapter 11

PERFORMANCE AND INCIDENT REPORTING

In this chapter:

- Purpose and description of dam performance and incident reporting
- Guidelines for reporting dam incidents
- Description of incidents for which reporting is required

Regulations under 11 AAC 93.177 require the reporting of certain incidents at dams to Dam Safety. Collecting information about the performance of dams is important for understanding the condition of dams in Alaska and to evaluate the effectiveness of design and inspection standards. In addition, performance and incident reporting allows Dam Safety to participate with and contribute to the NPDP at Stanford University in California. Finally, performance and incident reporting provides assurance that dam owners and operators are inspecting dams during and after extraordinary circumstances.

Reporting guidelines in this section are generally based on the *Guidelines for Reporting the Performance of Dams* (NPDP, 1994). Those guidelines define an incident as follows:

> Events (e.g. load/performance scenarios, dam operations during extreme or emergency conditions) which are of engineering interest due to the insights they provide on operational and structural performance of dams and public safety. This definition includes cases involving failure (i.e. breach and uncontrolled release of the reservoir), as well as a broader scope of events.

The regulations paraphrase these guidelines and provide the following definitions of an incident:

> (1) the satisfactory or unsatisfactory performance of a dam during extreme loading periods caused by extraordinary seismic or hydrologic events;
>
> (2) the uncontrolled release of water from a dam due to improper operation, overtopping, excessive seepage, or piping, regardless of whether downstream flooding occurs;
>
> (3) indications of stress in structural features or appurtenant works that could potentially affect the structural or operational integrity of the dam;
>
> (4) severe deterioration or erosion of structural elements or materials of construction, including concrete, steel, timber, soil, rock, geosynthetics, pipes, and valves;

(5) modifications or repairs to the dam required to satisfy regulatory requirements or other deficiencies that may be identified in the dam or the original design basis.

Table H-1 in Appendix H-1 provides additional detailed guidance from the *Guidelines for Reporting the Performance of Dams* (NPDP, 1994) to determine whether an incident has occurred.

11.1 Reporting Guidelines

If an incident occurs, the dam incident notification (DIN) form presented in Appendix H-2 should be completed and submitted to Dam Safety along with a dam incident documentation report (DIDR) that includes the following information:

- A chronology of events before, during, and after the incident
- A description of the satisfactory or unsatisfactory performance of the dam, reservoir, and related appurtenances during the incident, including photographs and a detailed description of any damage caused by the incident to the dam or appurtenances
- A description of the effects of the incident on downstream interests
- Actions taken by the dam owner, dam operator, or emergency response agencies during and after the incident
- Activities following the incident, including a description of repairs, or plans for future work or operating changes resulting from the incident
- Estimate of the economic and social impacts of the incident to the dam owner and other affected interests

11.2 Reporting Requirements

Incident reporting is mandatory for all dams. Table 11-1 recommends minimum reporting requirements based on the hazard potential classification and the nature of the incident. Reports should be submitted to Dam Safety within 30 days of the incident.

Table 11-1. Reporting of Dam Incidents Based on Hazard Potential Classification

Incident Type	Hazard Potential Classification		
	I	II	III
Seismic	X	X	X
Hydrologic	X	X	X
Failure or breach	X	X	X
Deterioration	X	X	
Mis-operation	X	X	
EAP activation	X		

Hydrologic incident reporting shall be conducted in accordance with the guidance presented in Appendix H-3.

Seismic incident reporting shall be conducted in accordance with the guidance presented in Appendix H-4.

Dam Safety may request incident reporting for any classification dam for any incident. Additional reporting guidance will be provided at the time of the request.

A complete copy of the NPDP *Guidelines for Reporting the Performance of Dams* (1994) can be obtained from the NPDP at Stanford University. Information is available through the following Web address: http://npdp.stanford.edu/index.html.

All incident reports will be forwarded to the NPDP, unless written justification for confidentiality is submitted by the dam owner.

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Chapter 12

REMEDIAL INVESTIGATIONS AND DECISION MAKING

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Chapter 12
REMEDIAL INVESTIGATIONS AND DECISION MAKING

In this chapter:

- Discussion of remedial investigations and repairs
- Outline of priorities when making decisions under emergency situations
- Review of decision-making techniques that are useful for dam safety purposes

A variety of circumstances associated with dams may warrant special consideration in deciding about the proper course of action. From choosing an appropriate location for a dam, to remedial construction on a deteriorated dam, to breaching a dam under emergency conditions, decisions about dams can be expensive, complex, and even a matter of life and death. The purpose of this section is to outline methodologies for making decisions that may be required to meet the intent of the dam safety regulations or that may be otherwise useful in making important decisions about dams.

12.1 Remedial Investigations and Repairs

Routine inspections, PSIs, or special engineering evaluations may indicate that certain repairs are necessary to reduce the probability for failure for the long-term safety of the dam. However, the repairs may not be required immediately. For example, the dam may not be in immediate danger of failing, but may not withstand certain loads imposed by some probability-based event such as heavy precipitation or earthquakes. In this case, remedial investigations may be prudent to determine the magnitude of the problem, the optimum solution, or both. Rather than proceed with a costly construction project, the dam owner may prefer to conduct additional monitoring or evaluations. In some cases, a remedial investigation may be ordered by Dam Safety under the authority of AS 46.17.070, 11 AAC 93.159(d), 11 AAC 93.161, or 11 AAC 93.163.

The hazard potential classification and the apparent condition of the dam are the primary factors in determining the level of urgency for non-emergency repairs. Dam Safety will consider arguments presented by the dam owner to defer construction costs; however, additional studies, such as more detailed engineering evaluations and limited risk assessments, or mitigating measures, such as EAP development and exercises, may be required in the interim. Generally speaking, Dam Safety encourages a thorough understanding of the problem before construction dollars are spent in an attempt to remediate the dam.

In any event, the following requirements should be considered before remedial investigations and repairs of dams begin:

- All repairs should be reviewed with Dam Safety to determine if a *Certificate of Approval to Repair a Dam* is required.
- Intrusive investigations should be reviewed with Dam Safety before they are initiated.
  - The location and potential effects of the reservoir level and phreatic surface in the dam must be evaluated before intrusive investigations or repairs.
  - Test pits conducted on dams must be backfilled with compacted soil similar to in situ conditions.
  - Boreholes in dams must be backfilled with cement grout.
- Collateral effects of the proposed repair must be considered in the evaluation. For example, if a leaking, corrugated metal, low-level outlet pipe is slip-lined and grouted, the seepage through the embankment may be adversely affected.

In other words, care must be given to the level of intervention necessary to avoid harming the patient (the dam) during the diagnosis and treatment of the illness.

Remedial investigations should be conducted in accordance with guidance provided in the most current version of the following reference:

- *Safety Evaluation of Existing Dams* by the USBR (1995)

12.2 Emergency Actions

As discussed in Chapter 9, Dam Safety is requiring the development of EAPs for Class I and II dams and encouraging the inclusion of unusual occurrence procedures in O&M manuals for all dams regulated under the ADSP. These documents should provide predetermined responses to certain situations that will reduce the decision-making burden at the time of the emergency. Recognizing that real-life situations are almost always different than theoretical simulations, emergency decisions may require a different approach from those anticipated.

The primary motivation for any decision made under emergency conditions is to protect life and property. The following information, in a descending order of priority, should be considered when making emergency decisions:

- Does the decision protect life and property from an impending failure of the dam or uncontrolled release of water?
- Can actions occur that will prevent a failure of the dam without diverting resources that are required to protect life and property?
- Can any actions be taken to relieve any stress on the dam in a controlled manner that will reduce or eliminate the threat of failure?
- Can the reservoir be lowered or the dam breached in a controlled manner that does not result in the same consequences as if the dam were to have failed anyway?

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In all cases, Dam Safety reserves the authority given to the ADNR under 11 AAC 93.163 to take the remedial action necessary to mitigate the risks posed by the operation or failure of the dam until the emergency passes. Such emergency action may include breaching the dam intentionally or other construction-related activity. If the owner refuses to conduct the work ordered by Dam Safety under emergency conditions, Dam Safety may retain contractors, consultants, or other entities to conduct the work, in which case the owner will be liable for the incurred costs. Except as identified in AS 47.17.110, a person may not bring an action against the state, the ADNR, or its agents or employees for "measures taken to protect against the failure of a dam or reservoir during an emergency." For purposes of clarification, a controlled breach of the dam is not considered to be a "failure of a dam or reservoir," but may be the only practicable solution to prevent the failure of the dam or reservoir under certain conditions.

12.3 Techniques for Making Decisions

12.3.1 Risk Management

Generally speaking, the ADSP uses a standards-based approach to manage the risks posed by dams, rather than a formal risk management program that includes risk assessment, risk analysis, and risk evaluation. A detailed discussion of these topics is outside the scope of these guidelines. However, dam safety management is intrinsically risk based, because the standards are keyed to the hazard potential classification, which is assigned based on the relative risk that the dam represents. The challenge is that the actual risks are not always quantified and, therefore, may be poorly understood by the various parties responsible for making important decisions about the dam.

One primary purpose of the PSI is to identify deficiencies that indicate an increase in the risk created by the dam; however, the costs to address those deficiencies with the use of a standards-based approach may be extremely high, and the benefits, or reduction in risk, may not be readily apparent. In this case, a formal risk assessment may be used to accomplish the following:

- Gain a more clear understanding of the risks posed by the dam and its related deficiencies
- Set priorities for the mitigation efforts necessary to reduce the risk
- Compare the risk reductions of construction versus non-construction options
- Determine if operating restrictions or decommissioning may be more practical than remedial construction

Failure Mode and Effects Analysis

A risk assessment focused on a dam may take the form of a failure mode and effects analysis (FMEA). The FMEA is a detailed look at all possible ways in which the dam may fail and the potential effects of each type of failure from a broad perspective. For each failure mode, the likelihood of occurrence is assigned. The probability of failure combined with the potential consequences allows decisions on utilizing resources to be made with higher levels of confidence. For more information about the FMEA, see the Association of State Dam Safety Officials (1999) or Robertson (2003) references in Chapter 14.

The risk assessment may also be used to understand and quantify the risks created by a dam, even though no deficiencies are apparent.

Formal risk assessments are complex and expensive, but may yield useful and justifiable results when properly conducted. Dam Safety will consider a risk assessment submitted by a dam owner if it is appropriately conducted by a team that includes a qualified engineer familiar with the dam and a qualified and experienced risk assessment consultant.

Additional information about risk assessment as a tool for managing dam safety is included in a technical paper (Bowles et al., 1997) presented in Appendix I. Dam Safety agrees with the following conclusion by the authors:

> The true nature of dam safety management is intrinsically a problem in risk management and decision making under uncertainty… The risk management approach should treat dams as integral structures whose safety should be managed in a holistic manner… Adopting a "decision driven" approach to risk assessment will provide a basis for appropriate and justifiable limits on the level and detail of risk assessment efforts with the goal of reaching a quality, well communicated and highly defensible dam safety decision… When properly implemented, risk assessment can serve as a valuable tool within a comprehensive risk management framework for effective dam safety management. We further suggest that such a comprehensive and systematic approach is necessary for the proper exercise of duty of care of a dam owner and to assist in meeting due diligence [sic].

12.3.2 Decision Matrices

Decision matrices can be simple, useful devices for making decisions without the expense of comprehensive risk assessments. Decision matrices are encouraged in feasibility and siting studies because of the clarity they provide in outlining and evaluating multiple criteria that can influence the decision. Decision matrices contribute to a systematic and clearly communicated approach for selection of a preferred alternative.

In developing a decision matrix, the following guidelines should be considered:

- The criteria to be evaluated should be comprehensive, logically organized, and clearly presented.
- The rating values should be simplistic and match the level of detail available; for example, rating values of 1, 2, or 3 are better than 1 through 10 if sufficient information is not available for all of the criteria to assign a finer rating system.
- Rating assignments should be listed for each criterion.
- Weighted and unweighted summations, as appropriate, should be included.
- Weighting assignments should be simplified and clearly explained.

An example of a simple decision matrix is presented in Appendix J.

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Guidelines for Cooperation with the
Alaska Dam Safety Program

Chapter 13

CLOSURE

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Chapter 13
CLOSURE

In this chapter:

- Guidelines for the removal or abandonment of dams
- Considerations for the closure of tailings dams, from design to closure
- Review of other issues associated with dam removal and current references

When the life of a dam approaches the end of its usefulness, safety must be a primary factor when closure of the facility is planned. Therefore, an application for a certificate of approval is required under 11 AAC 93.172 to remove or abandon a dam. All applications should include the following information:

- An application fee based on the cost of the engineering, construction or demolition, and erosion control calculated in accordance with Section 3.4
- Design drawings and specifications for the final configuration of the dam and reservoir site
- For Class I and II dams, seal and signature of a qualified engineer on the drawings and specifications
- Method and means to dewater or stabilize the reservoir and breach, remove, or abandon the dam

For any case, the following submittals must be submitted to Dam Safety within 30 days after the closure work is completed:

- Description of how removal or abandonment activities were conducted
- Description of unexpected conditions encountered
- Photographs documenting construction or demolition progress and final conditions

Additional information about removal and abandonment follows, including a discussion on the abandonment of dams at mine tailings storage facilities and references on dam removal.

13.1 Removal

Removal of the complete dam structure is the preferred alternative for closure of a jurisdictional dam; however, removal of the entire structure may be cost prohibitive in some cases. The following are important requirements for the partial or complete removal of a dam:

- The dam must be breached to the point that the dam no longer impounds a reservoir.

- The breach must be sufficient to pass a design storm event such as the PMF without restricting the flow and backing up water.
- The breach must not be susceptible to clogging from sedimentation or woody debris.
- The sides of the breach must be stable over the long term.
- Erosion in the area of the breach must be controlled.
- Erosion from sediments in the reservoir must be evaluated and controlled if necessary.

An application for a *Certificate of Approval to Remove a Dam* must be submitted to Dam Safety. A copy of the application form is available upon request. The following additional information should be included with the application:

- Method and means to control erosion at the site during and after breaching or removing the dam, including these specific details:
    - Control of sediment transport from the reservoir area
    - Restoration of the reservoir bed and stream channel or other reclamation
- If the entire structure is not removed, these additional specific elements:
    - Hydrologic and hydraulic evaluation of the proposed final configuration of the dam or barrier during the probable maximum flood or other IFD
    - Stability evaluation of the proposed final configuration of the dam or barrier under static and dynamic (seismic) conditions
    - O&M requirements for the proposed final configuration of the dam or barrier
    - Statement about whether the final configuration of the dam or barrier constitutes a dam as defined under AS 46.17.900 and remains under jurisdiction of the Alaska dam safety regulations

13.2 Abandonment

In some cases, a dam may be abandoned without removing the dam. The dam may either be removed from state dam safety jurisdiction or remain under state jurisdiction indefinitely. These alternatives are discouraged for water dams; however, a mine tailings dam is a special situation for which abandonment is the ultimate fate of the dam from the beginning. The circumstances for which abandonment may be acceptable are discussed in the following subsections.

13.2.1 Water Dams

Abandonment may be approved for a water dam if the reservoir is full of sediment, there is no opportunity for impoundment to occur, and other safety considerations are evaluated such as stability of the system and public safety. In this case, the sediment must be naturally occurring, such as bed load in an aggrading stream. Under no circumstances will the abandonment of a dam be approved based solely on opening the low level outlets and draining the reservoir. Any abandonment of a dam approved by Dam Safety in no way relieves the dam owner of any other obligations that may be required under other statutes and regulations.

13.2.2 Tailings Storage Facilities

Dams at tailings storage facilities are unique because the service life of the dam is infinite, generally speaking. When the reservoir is full of tailings and the facility is closed, the dam must remain in place and continue to retain the substance for an indefinite period of time while withstanding the effects of surface runoff and groundwater as the system is transformed from an active, operational condition to an inactive, closed condition.

The closure of a tailings dam is typically included in a mine reclamation plan; however, the engineering details in reclamation plans are usually limited because of the difficulty of planning for a long period in advance. Consequently, it is imperative that the initial design and construction address the detail necessary to ensure the long-term safety of the structure after closure. Furthermore, mining operations must also occur in a manner to facilitate closure. Nevertheless, such preplanning must retain a certain degree of flexibility to accommodate changes in the economic, social, and regulatory setting at the time of closure. The additional detail necessary for closure must therefore be provided in an application for a *Certificate of Approval to Abandon a Dam* submitted to Dam Safety. The guidelines presented in Chapter 4 and 5 are recommended for this application also.

Complete guidance on tailings dam design and closure is beyond the scope of this document. Although many design principles of tailings dams are consistent with those for water dams, tailings dams represent certain challenges that require professionals with significant relevant experience. A failure rate for tailings dams that is statistically higher than for water dams is addressed in the following excerpt from “Tailings Dam Failures – the Human Factor” by Alan H. Gipson (2003):

> When compared to water dams the current failure rate of tailings facilities is unacceptable. In my view the primary reason for the failure rate is that owners, engineers, designers and operators are not performing their work in accordance with the standards of practice that should be followed. Utilizing knowledgeable experienced professionals for policy setting, planning, design, construction and operation of tailing facilities with appropriate internal peer reviews and regulatory oversight by trained and experienced professionals with appropriate levels of funding can lead to the goal of zero failures. [sic]

To promote development of safe and effective tailings dams, Dam Safety offers the following regulatory perspective on tailings dam design and closure.

Initial Design and Construction

See Chapters 6 and 7 for general design and construction guidance that is applicable to tailings dams. The following closure concerns should be addressed in the initial design and construction of a tailings dam:

- The phreatic surface within the dam and tailings during operation and closure
- The amount and effects of tailings consolidation during operation and closure
- The internal drainage system of the dam, such as chimney drains, blanket drains, and toe drains to control seepage throughout operation and closure
- The conceptual, final configuration of the dam and tailings impoundment with respect to land forms, erosion, pollution control, residual ponds, and surface water runoff
- Dam safety regulations that may remain in effect because of the configuration of the remaining impoundment, including both the residual pond and the tailings

Closure Design

The following closure concerns should be addressed in a detailed design before closure:

- Potential failure modes of the dam and tailings storage system in the final configuration, possibly including a risk assessment
- Hydrology and hydraulic aspects necessary to determine and accommodate an IDF equal to the PMF or some other extreme storm event
- Current data on the chemical and geotechnical nature of the tailings
- Long-term expectations for consolidation of the dam and tailings, the phreatic surface within the dam and tailings, the performance of the dam underdrain, and the quantity and characteristics of seepage

Precedent for Tailings Dam Closure

The precedent for closing tailings dams in Alaska is extremely limited, although a number of important projects in the state will have to address this problem in the near future. Dam Safety is interested in the precedent for this activity in other areas, both in practice and in regulatory requirements. For example, the Web site for the Nevada Division of Water Resources (http://water.nv.gov/Engineering/damsafety.htm) *indicates that when a tailings facility is closed, "the mining company is responsible for breaching the dam or otherwise rendering the dam incapable of impounding any* ***mobile*** *material" (emphasis added). The Washington Administrative Code (WAC) provides for the regulation of any dam that contains more than 10 acre-feet "which contains any substance in combination with sufficient water to exist in a liquid or slurry state at the time of initial containment" (Chapter 173-175, WAC Dam Safety, October 24, 1995); however, the code is silent on the closure of a dam containing such substances.*

- Stability of the system under static and seismic conditions, by using appropriate seismic parameters for a long-term condition
- Grading and soil stabilization, including contour maps and cross sections of the final configuration
- O&M requirements for the dam and reservoir in a closed condition, including regulatory requirements if the closed configuration represents a dam and reservoir as defined in AS 46.17.900

Bonding

An appropriate bond or other form of financial assurance may be required to cover the O&M costs, regulatory inspections, and other expenses after the facility is closed. A written agreement that outlines the management of the financial instrument during the life of the project and after closure when the funds are utilized, including long-term responsibilities, must also be established. See Subsection 5.2.2 for more information.

13.3 Other Issues

Other issues that are important to the closure of dams include the following:

- Funding the removal or abandonment
- River restoration and fisheries
- Social and economic impacts

These issues are important and contemporary, but beyond the scope of this document to address. However, the following recent publications may be useful:

- *Dam Removal: A New Option for a New Century*, published by the Aspen Institute (2002)
- *Paying for Dam Removal: A Guide to Selected Funding Sources* by Betsy Otto, published by American Rivers (2000)
- *Dam Removal Success Stories: Restoring Rivers Through Selective Removal of Dams That Don't Make Sense,* published by American Rivers, Friends of the Earth, and Trout Unlimited (1999)

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Guidelines for Cooperation
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Chapter 14

REFERENCES

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Chapter 14

REFERENCES

In this chapter:

- References used in the development of this document
- References for other useful resources related to dams

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Appendix A

Hazard Potential Classification and Jurisdictional Review Form

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Alaska Dam Safety Program

HAZARD POTENTIAL CLASSIFICATION
AND
JURISDICTIONAL REVIEW

This form is used to review and indicate the hazard potential classification of an artificial barrier in accordance with 11 AAC 93.157 and to determine if the barrier is a dam under the jurisdiction of the Alaska dam safety regulations, based on the definition articulated under Alaska Statute 46.17.900 (3), and summarized as follows:

"Dam" includes an artificial barrier, and its appurtenant works, which may impound or divert water and which...

- has or will have an impounding capacity at maximum water storage elevation of 50 acre-feet and is at least 10 feet in height measured from the lowest point at either the upstream or downstream toe of the dam to the crest of the dam; or
- is at least 20 feet in height measured from the lowest point at either the upstream or downstream toe of the dam to the crest of the dam; or
- poses a threat to lives and property as determined by the department after an inspection.

In accordance with 11 AAC 93.151, an artificial barrier with a Class I or Class II designation is determined to meet the third definition of a dam, regardless of its geometry.

Please complete items 1 through 21. Attach additional information as necessary. This form must be certified and stamped on page 3 by an Alaska-registered professional engineer, qualified in accordance with 11 AAC 93.193.

1. Name of barrier: ______________________________

National Inventory of Dams (NID) number:______________ (Assigned by Department)

Name of stream: ______________________________

General location and region: ______________________________

Legal location: Township _____ Range _______ Section ______ Meridian ____________

Purpose and type of barrier:______________________________

This barrier is: ❑ Existing ❑ Proposed ❑ Under construction

Current hazard potential classification: ❑ I ❑ II ❑ III ❑ Not assigned

2. Owner: ______________________________

Address: ______________________________

____

____

Contact name: ______________________________

Phone: ____________________

3. Is barrier federally owned, or regulated by the Federal Energy Regulatory Commission?

❑ Yes (stop here) ❑ No (complete form)

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4. Maximum crest height of barrier: ____________ feet
   Measured from: ❑ Upstream toe ❑ Downstream toe ❑ Offstream toe
   Basis of height: ❑ Conceptual design drawing ❑ Detailed design drawing
   ❑ As-built drawing ❑ Field measurement ❑ NID data

5. Maximum impoundment volume: __________________ acre-feet
   Surface area of reservoir at maximum storage: __________________ acres
   Average depth of reservoir above bottom of barrier: _______________feet (live storage)
   Basis of volume estimate:
   ❑ Surface area multiplied by average depth
   ❑ Bathymetry
   ❑ NID data
   ❑ Other: ___________________

6. Downstream development: ❑ Yes ❑ No ❑ Unknown
   Type of development (check all that apply):
   ❑ Homes
   ❑ School
   ❑ Community halls, churches, etc.
   ❑ Industrial or commercial property
   ❑ Major highway
   ❑ Primary roads
   ❑ Secondary or rural roads
   ❑ Railroads
   ❑ Power or communication utilities
   ❑ Water or wastewater treatment facilities or lines
   ❑ Overnight campgrounds
   ❑ Public parks or trails
   ❑ Fish hatchery or processor
   ❑ Barrier owner's property or facilities
   ❑ Other utilities:________________
   ❑ Other development:__________________

   Basis of observations: ❑ Ground reconnaissance ❑ Aerial reconnaissance
   ❑ Aerial photo ❑ Other: _________________
   Date of observations:_____________________

7. Proximity of development to downstream channel (add maps or other information as necessary):
   Distance downstream from barrier: ________________________
   Distance from stream bed: ________________________
   Relative elevation above streambed: ________________________

8. Is development in the inundation zone of a flood from an uncontrolled release of water from the barrier?
   ❑ Yes ❑ No ❑ Unknown

9. Was a dam break analysis conducted? ❑ Yes ❑ No
   Basis of determining inundation zone:
   ❑ Simplified DAMBRK model
   ❑ DAMBRK model
   (Please attach calculations)
   ❑ NWS FLDWAV model
   ❑ HEC-1 model
   ❑ Other:_____________________________
   Maximum depth and velocity of flow through development: ____________________________

10. Is development at risk from improper operation or a "sunny day" failure?
    ❑ Yes ❑ No ❑ Unknown

11. Is development at risk from an incremental increase in the flood if the barrier fails under flood conditions?
    ❑ Yes ❑ No ❑ Unknown
    Flood condition evaluated: ❑ 100 year ❑ ½ PMF ❑ PMF ❑ Other_____________________

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12. Could an uncontrolled release cause other significant property damage or loss?
❑ Yes ❑ No ❑ Unknown
Description: ____

13. Could an uncontrolled release effect public health? ❑ Yes ❑ No ❑ Unknown
Description: ____

14. Is the reservoir created by the barrier the primary water supply for a community of more than 500 residents? ❑ Yes ❑ No ❑ Unknown

15. Is a backup water supply available? ❑ Yes ❑ No ❑ Unknown

16. Is barrier located on waters important to anadromous fish? ❑ Yes ❑ No ❑ Unknown

17. Are anadromous fish waters at risk of damage or loss if an uncontrolled release occurs?
❑ Yes ❑ No ❑ Unknown

18. Proposed hazard potential classification: ❑ Class I (High) ❑ Class II (Significant) ❑ Class III (Low)

19. Basis of classification:
❑ Quantitative - Numerical dam break analysis conducted
❑ Qualitative - Limited engineering calculations
❑ Preliminary - No engineering calculations

20. Comments: ____
____
____
____
____
____

21. Certified by: ______________________ (Print name)

Date: ______________

Company: ______________________________

Phone: ______________

Engineer's Seal and Signature

Notes:

1. *This form must be certified and stamped by an Alaska-registered professional engineer qualified in accordance with 11 AAC 93.193.*
2. *The information presented in this form may be overruled based on current data that reveals a higher level of confidence in the quality of information necessary to make the appropriate determinations.*
3. *Anadromous fish waters are determined in accordance with 11 AAC 195.010 (a).*
4. *Alaska dam safety regulations are articulated under 11 AAC 93.151 through 11 AC 93.291 (Article 3).*

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FOR DEPARTMENT USE ONLY

Jurisdictional Status of Barrier:

❑ Dam under state jurisdiction

Reasons:
- ❑ Height
- ❑ Height and storage volume
- ❑ Hazard potential classification
- ❑ Anadromous fish stream
- ❑ Other:__________________

❑ Barrier is not a dam under state jurisdiction

Reasons:
- ❑ Height
- ❑ Height and storage volume
- ❑ Hazard potential classification
- ❑ Federal ownership or regulation
- ❑ Other:___________________

Concur with proposed hazard potential classification: ❑ Yes ❑ No

Hazard potential classification based on current information: ❑ Yes ❑ No

Official hazard potential classification:

❑ Class I (High) ❑ Class II (Significant) ❑ Class III (Low)

Comments:____
____
____
____

Reviewed by: ______________________________________

Title: ______________________________________

Signature: ______________________________________

Date: ______________________________________

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Appendix B

Example of *Certificate of Approval to Operate a Dam*

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STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF MINING, LAND AND WATER
DAM SAFETY AND CONSTRUCTION UNIT

Certificate of Approval to Operate a Dam

The **State of Alaska** under AS 46.17, and the regulations adopted under this statute, grants to:

Dam Owners, Inc.

The approval to operate the following structure on _______ **Creek** in accordance with the terms and conditions contained in this certificate:

Name of Dam (NID ID#AK00XXX)

The location of this project is: TXXS, RXXE, SXX, _________ Meridian

The holder of this certificate shall:

- ❑ Operate the ___________ Dam and appurtenance works in accordance with accepted practice and Version X of the Operation and Maintenance Manual dated ______ and approved by the Department concurrent with this certificate.
- ❑ Except for the claims or losses arising from the negligence of the State, defend and indemnify the State against, and hold it harmless from any and all claims, demands, legal actions, loss, liability and expense for injury or death of persons, and damages to or loss of property, arising out of or connected with the exercise of the approval granted by this certificate.
- ❑ Comply with all applicable laws, regulations and conditions.
- ❑ Allow representatives of the Department to inspect the work and records covered by this certificate at all times determined necessary by the Commissioner.
- ❑ Follow special conditions that apply to the operation of this dam as found in Attachment A, attached hereto and made a part hereof.

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CERTIFICATE OF APPROVAL TO OPERATE A DAM
Name of Dam

This *Certificate of Approval to Operate a Dam* supersedes any other *Certificate of Approval to Operate a Dam* for the ______ Dam and shall become invalid 30 days after the Periodic Safety Inspection date specified under Attachment A. A valid certificate shall be issued with revised special conditions based on information contained in a current Periodic Safety Inspection Report approved by the Department and dam safety regulatory standards current at the time of the inspection.

This *Certificate of Approval to Operate a Dam* is granted subject to the pertinent statutory provisions in AS 46.17 and in Administrative Regulations in 11 AAC 93.

APPROVED BY: Charles F. Cobb, P. E.

TITLE: State Dam Safety Engineer
Division of Mining, Land and Water

SIGNATURE: ______________________________

DATE: ______________________________

State of Alaska)
) SS.
Third Judicial District)

This is to certify that on ___________________, 200X, before me appeared ___________________________________, known by me to be the Director or Authorized Representative of the Division of Mining, Land and Water, Alaska Department of Natural Resources, and acknowledged to me that this Certificate of Approval was voluntarily executed on behalf of the State of Alaska.

____

Notary Public in and for the State of Alaska

My Commission expires: _______________________

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Attachment A - Conditions

1. Inspect and maintain the _________ Dam in accordance with the procedures outlined in Version X of the Operations and Maintenance Manual dated ______. Inspect the dam after all significant seismic or precipitation events. Maintain records of the inspections.

2. Perform a Periodic Dam Safety Inspection as required by 11 AAC 93.159 on the _________ Dam and appurtenance works by DATE. The frequency for Periodic Safety Inspections shall be at ___ year intervals as required by regulation for a Class _____ downstream hazard dam.

3. The Periodic Safety Inspection must be performed by an approved, Alaska registered, professional engineer. Approval of the inspection engineer and the scope of the inspection must be obtained in advance from the Department.

4. An Emergency Action Plan (EAP) shall be maintained for the ____ Dam in accordance with the document titled "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners" (FEMA 64) published by the Federal Emergency Management Agency (October, 1998). The EAP shall be reviewed, exercised, and revised in accordance with the following schedule:

DATE	ACTION
Annually	Internal review (distribute updated pages)
By June 30, 200X	Orientation, drill or table top exercise
By September 30, 200X	Revise as needed and redistribute
By June 30, 200X	Subsequent level of exercise for revised plan

5. Notify Dam Safety at least 14 days prior to the EAP exercises.

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Appendix C

Example of *Certificate of Approval to Construct a Dam*

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STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF MINING AND WATER MANAGEMENT

DAM SAFETY AND CONSTRUCTION UNIT

Certificate of Approval to Construct a Dam

The **State of Alaska** under AS 46.17, and the regulations adopted under this statute, grants to:

Dam Owners, Inc.

The approval to construct the following structure on the ________ **Creek** in accordance with the terms and conditions contained in this certificate:

Name of Dam

The location of this project is: Section Township Range Meridian

The holder of this certificate shall:

- ❑ Construct the dam and appurtenance works in accordance with the plans and specifications dated ______ approved by the Department concurrent with this certificate.
- ❑ Except for the claims or losses arising from the negligence of the State, defend and indemnify the State against, and hold it harmless from any and all claims, demands, legal actions, loss, liability and expense for injury or death of persons, and damages to or loss of property, arising out of or connected with the exercise of the approval granted by this certificate.
- ❑ Comply with all applicable laws, regulations and conditions.
- ❑ Allow representatives of the Department to inspect the work and records covered by this certificate at all times determined necessary by the Commissioner.
- ❑ Follow special conditions that apply to the construction, modification, removal, or abandonment of this dam as found in Attachment A, attached hereto and made a part hereof.

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CERTIFICATE OF APPROVAL TO CONSTRUCT A DAM
Name of Dam

This *Certificate of Approval to Construct a Dam* is granted subject to the pertinent statutory provisions in AS 46.17 and the Administrative Regulations in 11 AAC 93.

APPROVED: ______________________________________

TITLE: State Dam Safety Engineer
Division of Mining, Land and Water

State of Alaska)
) SS.
Third Judicial District)

This is to certify that on ___________________, 200X, before me appeared ___________________________________, known by me to be the Director or Authorized Representative of the Dam Safety and Construction Unit of the Division of Mining, Land and Water, Alaska Department of Natural Resources, and acknowledged to me that this Certificate of Approval was voluntarily executed on behalf of the State of Alaska.

____

Notary Public in and for the State of Alaska

My Commission expires: _______________________

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Attachment A - Conditions

1. Notify the Dam Safety and Construction Unit at least six (6) weeks in advance of the beginning of the excavation for the foundation of the dam.

2. Submit for review and approval, the following pre-construction plans:
   - Water diversion plan
   - Erosion and sediment control plan
   - Pollution control plan

3. Submit a construction schedule, including mandatory inspection points.

4. Submit a construction quality assurance and construction quality control plan.

5. Submit for review and approval, plans and specifications for any modifications to the dam or appurtenant works approved by this certificate.

6. All work associated with the dam and appurtenant works must be supervised by an engineer with experience in the construction of a dam.

7. Submit record drawings, a completion report, an Operation and Maintenance Manual, and for Class I and II dams, an Emergency Action plan, within 30 days of substantial completion of the project.

8. No water may be impounded behind the dam until a *Certificate of Approval to Operate a Dam* is issued by the department. A *Certificate of Approval to Operate a Dam*, including any pertinent terms and conditions, will be issued upon review and approval of the submittals required under the previous condition.

9. Commence construction by the first day of June of the second calendar year after the date of this certificate. If construction does not begin by this date, an updated application must be submitted for review and approval by the Dam Safety and Construction Unit, including application fees required under 11 AAC 05.010.

End of Attachment A

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Appendix D

Project Data Sheet

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PROJECT DATA SHEET

NID No.

A. GENERAL

Dam Name		
NID Number		
Hazard Potential Class		
Purpose		
Year Built		
Year Modified		
Location		lat/long (GPS)
Reservoir Name		
River or Creek Name		
Owner		
Owner Contact		

B. DAM

Type		
Core Type		
Crest Length		feet
Crest Width		feet
Crest Elevation		feet
Crest Height (from d/s toe)		feet
Hydraulic Height		feet

C. PRIMARY SPILLWAY

Type		
Location		
Spillway Crest Elevation		feet
Top Width		feet
Bottom Width		feet
Length		feet
Discharge Capacity at Dam Crest		cfs

D. EMERGENCY SPILLWAY

Type		
Location		
Spillway Crest Elevation		feet
Top Width		feet
Bottom Width		feet
Length		feet
Discharge Capacity at Dam Crest		cfs

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PROJECT DATA SHEET

NID No.

(continued)

E. OUTLET WORKS

Type		
Location		
Inlet Invert Elevation		feet
Outlet Invert Elevation		feet
Diameter		inches
Length		feet
Outlet Type		
Discharge Capacity at Dam Crest		cfs

F. RESERVOIR

Normal Water Surface Elevation		feet
Normal Storage Capacity		acre-feet
Maximum Water Surface Elevation		feet
Maximum Storage Capacity		acre-feet
Maximum Surface Area at Dam Crest		acres
Surface Area at Spillway Crest		acres

G. HYDROLOGY

Drainage Basin Area		sq. miles
Average Annual Rainfall		inches
100 Year/24 Hour Rainfall		inches
100 Year Flood		cfs
Probable Maximum Precipitation		inches
Probable Maximum Flood		cfs
Flood of Record		cfs
Inflow Design Flood		cfs

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Guidelines for Cooperation with the Alaska Dam Safety Program

Appendix E

Sample Outline for a Simple Operations and Maintenance Manual for a Small Dam

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SUGGESTED OUTLINE
FOR
OPERATIONS AND MAINTENANCE MANUAL
FOR
SMALL DAM
(Incomplete Draft)

Title: Operations and Maintenance Manual for ____ Dam in ____, Alaska
Revision 1.X
Date

I. Operations

a. Identify and briefly describe facility, purpose, control systems, valve locations and functions, instrumentation, alarm systems, etc.
b. List critical operating limitations, e.g. maximum water levels, drawdown rates, discharge flows, etc.
c. Project Data Summary Sheet

II. Maintenance

a. Clear brush on dams, dikes, and abutments annually, etc. (and other recommendations in current Periodic Safety Inspection)
b. Exercise mechanical equipment, gates, valves, etc. and service or lubricate (as required) weekly, monthly, quarterly, semi-annually, etc. Include service instructions or reference service manual.
d. Other maintenance items such as clear spillways, clean intakes or trash racks, paint handrails, grade access roads, etc.

III. Routine Inspections

a. Identify routine inspection items and schedule for inspection. Include specific details on how the inspection should occur, if required.
b. Complete the attached routine inspection checklist weekly, monthly, quarterly, semi-annually, etc. and after major precipitation or seismic events and file at specified location.
c. Monitor instrumentation (piezometers, weirs, thermistors, survey monuments, etc.) weekly, monthly, annually etc.

IV. Unusual Occurrences

a. High water: Open spillway gates, low level outlets, etc.
b. Excessive seepage: Lower water level, add fill, etc.
c. Notify the following if any abnormalities are noted:
    1. City Engineer or Public works director, etc.
    2. State Dam Safety Engineer 907-269-8636

Attachment: Project Specific Routine Visual Inspection Checklist

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My Dam Weekly Visual Inspection Checklist

Date____________________ Reservoir level___________

	Circle One		Remarks
a. Main Dam			
1. Downstream slope	OK	Not OK	____________
2. Seep at left abutment	Clear	Cloudy	____________
3. Seep at toe	Clear	Cloudy	Weir level________
b. Spillway			
1. Primary spillway	OK	Obstructed	____________
2. Emergency spillway	OK	Obstructed	____________
c. Outlet Works			
1. Intake screen	Clean	Clogged	____________
2. Sluice gate	Open	Closed	____________
e. Other appurtenances			
1. Gates	Locked	Unlocked	____________
2. Restricted access signs	Legible	Shot up	____________

f. Additional comments ____

____

____

____

g. Actions required____

____

____

h. Inspected by ____________________________

i. Reviewed by supervisor ____________________ Date ____________________

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Appendix F

Performance Parameters for Dam Safety Monitoring

An excerpt from the notebook titled *Safety Evaluation of Existing Dams Seminar,* U.S. Bureau of Reclamation, Denver, Colorado, 1999.

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PERFORMANCE PARAMETERS FOR DAM SAFETY MONITORING

by Jay Stateler, Larry Von Thun, Gregg Scott, and Jim Boernge
U.S. Bureau of Reclamation, Denver, Colorado

Introduction

To promote efficient and effective monitoring for dam safety purposes, the Bureau of Reclamation has begun developing and documenting performance parameters for each of its dams. It is anticipated that these documents will be the foundation of the future Reclamation dam safety program. In a nutshell, the performance parameter document addresses the question: "What should be done to properly look after the dam in the future, from a dam safety perspective, given what we know today?" To adequately and appropriately address this question, the following process is followed:

1. Identify the most likely failure modes for the dam.

2. Identify the key parameters to monitor that will provide the best indication of the possible development of each of the identified failure modes, and define an instrumented and visual monitoring program to gather the necessary information and data.

3. Define the ranges of expected performance relative to the instrumented and visual monitoring program, and define the action to be taken in the event of unexpected performance.

Each of these steps in the process will be discussed briefly below, and then six of the most commonly encountered failure modes will be presented and discussed to illustrate the concepts, approach, and process.

Identify The Most Likely Failure Modes

The goal is to prevent circumstances where uncontrolled releases from the reservoir cause loss of life or significant economic losses in downstream areas. The most effective initial step toward this goal is to identify potential failure modes for the dam. This is done in light of the information and analyses that are currently available concerning the dam and damsite, the current state-of-the-art in dam design and evaluation, and the record and available knowledge regarding past dam failures. As an initial step, a careful review is made of the following site-specific information:

1. Site geologic conditions.

2. Design of the dam and appurtenant features.

3. Construction methods and records.

4. Performance history, based on instrumentation data and visual observations.

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5. Current design earthquake and flood loadings.

A focused discussion involving individuals that have had significant involvement with the dam (e.g. had involvement during design/construction, performed analysis work, performed site inspections, reviewed instrumentation data, etc.) can be a very effective means of developing a list of potential failure modes. Synergy during such a session can lead to results superior to those that might otherwise be achieved.

Clearly the failure mode evaluation is very site specific. The search is for failure modes that are physically possible (or cannot reasonably be ruled out) given the information available. The potential failure mechanisms need to be described as precisely and specifically as possible, so that the remainder of the performance parameter process can be effectively carried out. The most probable location(s) for development of each potential failure mode needs to be specifically identified, along with the manner in which the failure mode would likely initiate.

The identified failure modes are presented in order of apparent threat or likelihood, to help establish which modes deserve the most energy, effort, and attention in the monitoring efforts. It is important to understand that the identification of potential failure modes does not necessarily mean they are likely to occur. If the likelihood was viewed to be more probable than "remote," then a dam safety deficiency exists, and dealing with the situation by merely employing future attentive monitoring would not be appropriate. Structural modification of the dam and/or use of a well-designed Early Warning System (EWS), if appropriate, would be indicated in these cases. The concept of being "physically possible, but of low likelihood" may be difficult in some instances, but the fundamental reality is that there is inherent risk associated with every dam (generally very low), no matter how apparently well-designed and "safe" it may appear, and it is that reality that is being addressed by a continued vigilant monitoring program for the dam.

<u>Identify Key Parameters To Monitor Relative To Each Failure Mode</u>

The next step in the process is to look at each potential failure mode and ask the question: "What clues should we look for to detect the possible development of this failure mode?" The clues can fall into two categories: (1) those that provide early warning of the possible onset of the failure mode, and (2) those that indicate the presence of conditions conducive to the development of the failure mode. The monitoring of the parameters can be accomplished by observation for specific visual clues, and/or by instrumented monitoring. In addition to specifying what parameter should be monitored, how, and where, the monitoring frequencies also need to be established. It is important from the standpoint of efficiency and credibility of the monitoring program that the scale of the program be appropriately balanced with the risks and consequences associated with the potential failure mode. Appropriate explanations of the program should be provided to those that will perform and/or pay for the monitoring so as to give a good understanding of why the program is justified. It is vital that the monitoring program be effective, but efficiency and common sense is also important so as to achieve acceptance and sustainability.

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If an instrumented monitoring program is already in place at the dam, it is necessary to determine which instruments should be retained, which are of limited current value and are no longer needed, what additional instruments are needed, and what adjustments should be made to existing reading frequencies. It is typical to utilize existing instruments in the newly defined monitoring program to the extent possible, both for economic reasons and to take advantage of the existing database for these instruments that provides a valuable baseline for comparison with future data.

Identify Expected And Unexpected Performance

This stage of the process is intended to make the work of the "operators" of the routine monitoring program efficient and effective. Regarding routine visual inspections performed by on-site personnel, definition is provided concerning what observations would be in line with expected performance, and what needs to be promptly reported and evaluated. Regarding instrumented monitoring, definition is provided concerning what readings are within the bounds of expected behavior, and what readings should be promptly checked, and investigated further if confirmed. Routine computerized real-time comparison of instrument readings to established limits, that are a function of reservoir level, tailwater level, air temperature, and/or other relevant parameters, is in no way intended to replace necessary human reviews of data, but instead can serve as a valuable "coarse sieve" for the data to allow much of the anomalous data to be readily identified.

Illustration of the Methodology Using Example Failure Modes

Six of the most commonly encountered potential failure modes are discussed below to illustrate the thought process associated with the three-step approach to developing performance parameters, and to promote better understanding of these important failure modes. The first two relate to failures that can occur under normal operating conditions, while the last four concern failure under extreme loading conditions (floods and earthquakes).

Example Failure Mode 1 -- Piping or Subsurface Erosion of Embankment Core Materials

Historical experience and performance parameter failure mode identification to date show that by far the most prevalent potential failure mode for an embankment dam, absent an extreme loading condition due to an earthquake or flood, is the threat of piping or subsurface erosion of embankment core materials. Current embankment design practice adequately protects against this failure mode, but older embankments generally do not incorporate all the necessary defenses. The following questions can be used to assess the adequacy of the protection against this failure mode:

1. Where embankment core material was placed directly upon bedrock, was the surface of the bedrock treated with slush grouting to seal off all exposed joints and fractures? This would prevent transport of core materials into the bedrock.

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2. Where embankment core material was placed directly upon bedrock, was the surface of the bedrock excavated and/or treated with dental concrete to provide a reasonably regular surface upon which to place the embankment (e.g. free of significant "steps")? This would reduce the risk of development of cracks in the core material due to arching effects and/or differential settlements.

3. Where embankment core material was placed directly upon overburden materials, was the filtering capability of the range of overburden materials to be encountered checked relative to the core material, and were sufficiently thick filtering zones provided, where needed, to prevent transportation of core material into the overburden materials by seepage flows?

4. In the embankment, was a filter zone provided downstream of all portions of the embankment core, and do all embankment zones downstream of the embankment core meet current filter criteria requirements with the zone immediately upstream?

5. Were properly filtered drains provided to safely intercept and discharge seepage that passed through the embankment?

If these questions reveal that the necessary defenses are not totally present, or if it is unknown or unclear if the necessary defenses are in place, then potential failure mechanisms associated with piping or subsurface erosion need to be addressed by the routine monitoring program. The severity of the threat posed by the identified failure mechanisms may be reduced if one or more of the following conditions are present:

1. The embankment core material has significant plasticity, such that it is not easily erodible.

2. The hydraulic gradients are not high in the areas of concern.

3. The seepage quantities are low, such that if erosion of core materials is taking place, failure of the embankment would take a long time, providing ample opportunity for recognition and response to the developing problem.

4. The seepage path involves flow through joints in competent rock, meaning that the cross-sectional area of the flow is effectively limited by the size of the joints, and can not readily increase over time.

5. An exit point for the seepage, that permits removal of the material transported by the seepage flow from the site, does not exist, <u>and</u> areas for possible redeposition of transported material, such as within coarse embankment zones or within coarse foundation overburden deposits, are limited in terms of volume or access. Such a failure mechanism would be self-limiting, as in time the downstream end of the seepage path would become increasingly obstructed, and no alternative path would be available that has an exit point or large capacity for redeposition of materials.

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In addition to the above discussion of general site conditions that could give rise to problems, several special cases relating to this potential failure mode might be encountered.

One special case is for the piping or erosion to occur along the outlet works, spillway, or other appurtenant structures, particularly in the event of differential settlement or movement between the embankment and the structure that produces gaps, areas of lesser seepage resistance, etc. In some instances, cracks or flaws in the appurtenant structure may provide an exit point for seepage flows, though the development of the failure mode typically would be significantly constrained by the available flow area at the exit point. In other rare instances, flaws, cracks, or leaks in an appurtenant structure could lead to the introduction of seepage water into the embankment at high pressure, with great potential to move even fairly erosion-resistant materials, due to the high hydraulic gradients involved. When these "special" exit and entrance points are not present, and when a downstream filter zone has been provided (that meets current filter criteria), then the potential for this special case of the failure mode is greatly reduced, if not essentially eliminated.

Another special case is that the filter zone immediately downstream of the core material is sometimes not extended all the way to the crest of the dam, as the anticipated level of the phreatic surface is far below the dam crest elevation at the downstream edge of the core material. At many such sites there is the possibility of development of transverse cracks near the crest, extending to a depth below the maximum reservoir elevation, due to desiccation of core materials, differential settlement due to abrupt changes in embankment/foundation contact elevation, seismic shaking, or other causes. Seepage flow through such transverse cracks could erode core material and carry it into and through the downstream shell materials as these zones rarely meet current filter criteria with the core material.

Yet another special case involves seepage flow through untreated joints in the foundation bedrock or abutment rock, at and just beneath the embankment/foundation contact. Such flows could contact and carry core material into the joints in the foundation. Effective foundation grouting could greatly reduce the risks associated with this mechanism, but some ungrouted joints must always be assumed. This "contact" mechanism is a lesser threat than the typical failure mechanism that postulates flow passing from the core material into the joints in the foundation (across, not along the interface). The "contact" mechanism is a lesser threat because it generally would be expected to progress at a slower rate than would the "typical" mechanism.

With a good understanding of the possible failure scenarios associated with this potential failure mode, the locations of prime concern relative to routine dam safety performance monitoring should be clear. Parameters to monitor are as follows:

1. Visual observation for evidence of materials transport with seepage or drain flows. Where natural sediment trap locations are available, such as in manholes and at the stilling pools in front of weirs, they should be carefully monitored (after being cleaned out so as to start with a "clean slate"). General awareness should be maintained for discolored seepage or drain

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water, and for any evidence of material deposits in the vicinity of the flowing water.

2. Visual observation for new seepage areas, for changes in the conditions at existing wet areas or seepage areas that cannot be quantitatively monitored, and for transverse cracks at the crest of the dam. If the failure mechanism involves flow through joints in the bedrock, the visual observations should be extended a significant distance downstream of the embankment, as new seepage areas will not necessarily exit near the toe or groin of the embankment.

3. Flow rate monitoring at toe drains, other drains, and known seepage areas that can be quantitatively monitored. Any evidence of increased flows at comparable reservoir elevations would be cause for concern and would need to be promptly investigated.

4. Monitoring of appropriately located piezometers and observation wells for any changes in their historical relationship with reservoir elevation, and for changes in the relative piezometric levels at adjacent instruments. The water pressure data, being representative of conditions over only a limited area, are frequently of lesser value than the information obtained by the three previously noted methods, that are more global in scope.

Note that monitoring relative to item 1 above provides direct evidence of the occurrence or non-occurrence of this potential failure mode. All the other monitoring described above provide indirect evidence concerning this failure mode.

The monitoring frequencies for items 1-3 above generally are all the same, as typically they should all be done during the same "tour" of the dam and appurtenant structures. Frequencies can range from 4 times per year for low risk situations to weekly or several times per week for high risk circumstances. A monthly frequency would be fairly typical. For item 4, monitoring frequencies typically are the same, or somewhat less frequent than for the other items, with a minimum frequency of 3 times per year to establish a basic correlation with reservoir elevation. Monitoring frequencies for item 4 may be less frequent than for the other items because the other items typically provide the most valuable information, and provide monitoring coverage of the entire dam, as opposed to only limited areas, as noted previously. Since the risks of this failure mode increase with increasing reservoir elevation, it is common to institute more frequent monitoring when the reservoir is unusually high.

Example Failure Mode 2 -- Foundation Failure of a Concrete Dam

Historical experience and performance parameter failure mode identification to date show that by far the most prevalent category of potential failure modes for a concrete dam are those related to loss of foundation support for the dam. For both gravity and arch dams, adequate support from the rock against which the dam was built is fundamental to the structural well-being of the dam. For arch dams, thrust support provided by the abutments is particularly crucial, given the high loadings transmitted to

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them. Significant loss of this foundation support induces concrete stresses for which the dam was not designed. This leads to cracking of the dam, and potentially its failure.

Sliding along weak discontinuities in the foundation rock is the most commonly encountered scenario related to this potential failure mode. Sliding is most likely to occur: (1) parallel to bedding planes or planes of schistocity, (2) on low strength layers within the foundation (such as shale or bentonite seams), (3) at contacts between different rock units, or (4) at other continuous (or nearly continuous) planes of low shear strength in the foundation. For a block of rock to move, it must have "release" planes on all sides. Such release planes typically are formed by jointing in the rock, possibly in combination with fault or shear zones. The presence of reservoir seepage water in the rock leads to lower effective normal stresses, and therefore lower frictional resistance, along the slide plane(s). The water can also, in some instances, result in shear strength loss in foundation materials.

Another potential scenario related to this failure mode is for structural distress to the dam to result from significant differential compressibility of rock units in the foundation, that were not accounted for in the dam design. Resulting differential movements in the dam could overstress the concrete, leading to cracking and potentially dam failure. This failure scenario is mainly relevant to relative to dams where potential future loads imposed on the foundation rock may be significantly greater than loads experienced to date.

Obviously a good understanding of the site geology is important relative to this failure mode. Where geologic information is not comprehensive for a site, it is important that reasonably possible geologic defects be appropriately considered if they cannot be ruled out.

With a good understanding of the possible failure scenarios associated with this potential failure mode, the routine dam safety performance monitoring can be established. Key monitoring parameters are as follows:

1. Visual evidence of structural distress to the dam would be direct evidence of the possible development of this failure mode. Evidence of offsets at contraction joints or new cracking of the dam (apparently structural rather than temperature-related) would be the primary visual evidence of concern. Both the exterior faces of the dam and the interior gallery surfaces should be observed. Scribing sets of crisp lines across contraction joints is a simple, cost-effective way to aid visual monitoring for offsets. Scribe lines should be provided to detect both horizontal and vertical relative movements.

2. Instrumented evidence of structural distress to the dam would also constitute direct evidence of the possible development of this failure mode. Unusual settlements or deflections of the dam, that vary from the historical patterns of behavior, would be evidence of concern. Also, any instrumented monitoring of relative movements at contraction joints (or other locations) that departed from historical trends would be evidence of behavior that would be of concern.

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3. Evidence of changed water pressure conditions in the foundation would increase the likelihood of development of this failure mode. Such evidence could include new seepage areas on the abutments, increased seepage flows on the abutments, increased or decreased seepage flows from drains in the dam, as well as increased water pressures measured in the abutments or beneath the dam. Such evidence would not be direct evidence of the possible development of this failure mode, but instead would only indicate an increased likelihood of its development. Stability analyses could give indications of water pressure levels that produce unacceptable calculated factors of safety against movement, and therefore would be of serious concern.

The monitoring frequencies for the key monitoring parameters noted above generally would all be the same, as typically they should all be performed during the same "tour" of the dam. A frequency of four times per year would be common. Surveying of measurement points may be less frequent if other means of monitoring for structural movements are also available at the dam. In this case, annual surveys of the measurement points might be typical, though circumstances might indicate that even this monitoring frequency is not warranted, and surveys performed every several years may be sufficient. For arch dams, it is not uncommon to read plumbline instruments monthly so that the dual impact of seasonal temperature variations and reservoir level variations on deflection data can be better accounted for and understood when trying to determine if historical deflection patterns are being followed.

Example Failure Mode 3 -- Flood-Induced Failure of an Embankment Dam

A flood can lead to the failure of an embankment dam in a number of different ways:

1. The dam is overtopped, and the overtopping flows erode the crest and downstream slope such that breaching of the dam results.

2. Peak water levels are just below the crest of the dam, and "splashover," due to wind setup and wave action, causes erosion that leads to breaching of the dam.

3. Peak water levels are just below the crest of the dam, but above the top of the embankment core material that lies more than a foot or two below the dam crest elevation. Flow through pervious materials above the top of the core material erodes the core material, eventually leading to breaching of the dam.

4. High flows through the spillway (or outlet works) lead to damage to the structure, perhaps due to cavitation, or due to erosion of the downstream channel undermining the stilling basin and chute structures. The erosion and damage work their way back toward the crest structure until finally the structure is completely lost and uncontrolled release of the reservoir occurs.

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5. High flows through the spillway (or outlet works) are not properly conveyed away from the toe of the dam such that erosion of the embankment ensues, leading to undermining and eventual breaching of the dam.

The failure scenarios above may occur in combination during one flood event, increasing the potential for breaching of the dam. It is also possible that the spillway and/or outlet works will not be operated as expected during the flood event, due to stuck or inoperable gates, lack of power (and backup power), loss of access to the site, operator error, etc. This may transform a flood that could have been safely handled into a flood that causes dam failure.

The value of performance parameter work relative to extreme events, such as floods and earthquakes, comes largely from steps taken in advance of the event to recognize and deal with possible deficiencies, so that the failure scenarios can be avoided. Some other comments that generally apply to all failure modes related to extreme loading conditions (floods and earthquakes) are as follows:

1. The routine monitoring program associated with flood events and earthquake events generally consists of obtaining a good baseline of pre-event conditions, so that whenever the event may occur, sufficient information is available for comparision to post-event conditions to determine changes that occurred.

2. Careful monitoring during lesser magnitude earthquake or flood events can identify performance problems that could result in dam failure during a larger event (the design event). Such "full-scale prototype testing" can provide valuable information, obtainable in no other way, if appropriate advance preparations have been made to appropriately document performance during these events.

3. In some instances, an Early Warning System (EWS) may be used as the primary defense against loss of life in downstream areas if the reliability of the EWS to minimize loss of life supports such an approach. If an EWS is used, the performance parameters should define a program of periodic operational checks of the EWS to ensure that it functions as designed in the event that it is needed.

The above comments apply to each of the next three failure modes that will be discussed, but will not be repeated in those sections.

Obviously, relative to flood events at embankment dams, it is important to be dealing with current crest elevations of structures, rather than design elevations, as post-construction settlement and camber allowances need to be considered. Crest surveys can identify low spots on the embankment where flood damage may first occur. Embankment areas near the abutments frequently are the low areas because little or no camber was provided. These areas near the abutments would be of particular concern as erosive flows down the groins would be concentrated into a small area.

Heightened instrumented monitoring is generally warranted during a flood event, as the likelihood of failure mode scenarios involving high uplift pressures, piping and/or subsurface erosion, etc. increases. Daily visual monitoring for evidence of onset of

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these failure modes, as well as for the five flood-related failure mode scenarios noted above, typically is warranted. Following the flood event, a thorough inspection of the dam and appurtenant structures should be performed, and all instruments should again be read. If there are indications of possible settlements or deflections of embankments or appurtenant structures, any measurement points located on them should be promptly surveyed.

Example Failure Mode 4 -- Earthquake-Related Failure of an Embankment Dam

An earthquake can lead to failure of an embankment dam in three basic ways:

1. Deformations of the embankment/foundation due to seismic shaking lead to lowering of the dam crest and overtopping of the dam at one or more locations. The deformations may be due to liquefaction of embankment and/or foundation materials, potentially resulting in a large flow slide. However, significant deformations of the dam and lowering of the dam crest can also occur without the occurrence of liquefaction. Depending on the deformations experienced, and the reservoir level, overtopping of the dam could rapidly lead to complete dam failure. Alternatively, rapid loss of reservoir water may not occur initially. Instead, over time overtopping flow at one or more locations would erode the embankment, eventually resulting in a "full breach" condition. Then, rapid loss of the remaining reservoir water would occur.

2. Deformations of the embankment/foundation due to seismic shaking (or fault displacement) lead to transverse cracks through the embankment, that lead to erosion of embankment material by seepage flows following the cracks. This situation could progress rapidly to breaching of the dam and dam failure. However, if the seepage quantity through the new crack is not high and/or the core material of the dam is plastic and not highly erodible, it is possible that it may take a fair amount of time before dam failure would occur (if failure would occur at all). If an appropriately designed filter zone has been provided downstream of the embankment core material that would not "sustain" a crack (would collapse rather than stand as an open crack), then the risk of this failure scenario is negligible. Similarly, if the core material itself is "self-healing" and would not likely sustain a crack, then the risk of this failure scenario diminishes substantially.

3. Seiche waves overtopping the dam. This situation is most relevant when the fault that experienced movement is within the reservoir, with a significant portion of the reservoir being on the "up-thrusted" side, while the dam, or a portion of the dam, was on the side of the fault that was "down-thrusted."

A rapid earthquake response, leading to commencement of reservoir evacuation and/or evacuation of the downstream populace could mitigate damages relative to scenarios 1 and 2, since actual catastrophic release of the reservoir could potentially lag the earthquake by hours or even days. Failure scenarios 1 and 3 may result in rapid

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failures where only a fully functioning Early Warning System would have any chance of mitigating adverse downstream consequences, and then only if there was adequate time between the time when the dam breached and when the flood wave reached the population at risk.

The routine monitoring program associated with an earthquake-related failure of an embankment dam generally consists of having adequate baseline information relative to: (1) seepage data and conditions at the site, (2) the general overall appearance of the dam and appurtenant structures, (3) survey data from available measurement points on the dam and appurtenant structures, (4) data from any other deformation-monitoring instruments that may be present at the site, and (5) water pressure data from piezometers and observation wells at the site. Immediately following an earthquake, a thorough inspection of the dam and appurtenant structures should be performed, and the instruments should be promptly read. If there are indications of possible settlements or deflections of embankments or appurtenant structures, any measurement points located on them should be promptly surveyed. If there are any instruments indicating elevated water pressures, potentially due to liquefaction of embankment or foundation materials, then these instruments should be read daily until they stabilize and additional visual inspections should be performed as appropriate.

If the reservoir is not at a high level at the time of the earthquake, it is important to recognize that failure scenario 2 may not begin developing until a future time of higher reservoir elevations (when water can pass through cracks relatively high up on the dam). Depending on the apparent level of damage sustained by the dam, it may be appropriate to institute more frequent routine monitoring of the dam until satisfactory performance at high reservoir levels has been demonstrated.

Example Failure Mode 5 -- Flood-Induced Failure of a Concrete Dam

In virtually all cases, the dam safety concerns associated with overtopping of a concrete dam relate to possible erosion of the foundation of the dam by the overtopping flows that impinge near the dam/foundation contact. Such erosion could undermine the dam, causing loss of foundation support, structural distress, and eventual failure of the dam. Also, it is conceivable that the erosion and undermining could lead to release of the reservoir at the location of undermining, with the dam bridging over the "gap" in the foundation.

Judging the degree of erosion of foundation materials that may occur during a limited period of dam overtopping, and the consequences this may have on the dam, is often very difficult. Consequently, it is important to be well-prepared to monitor and document what occurs during a lesser flood event at the site, so that analyses relative to larger events can be more definitive. Having on file a good quality aerial survey of the damsite, along with adequate photographic documentation of foundation areas where overtopping flood flow may impinge, will provide adequate information concerning pre-flood site conditions.

During a flood, there may be concerns about potential damage to the spillway or outlet works under high flow conditions. Damage resulting from cavitation typically would be

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the primary concern, though erosion and undercutting, beginning at the outfall location, may also be of concern. Such damage could lead to greater overtopping depths, and a longer duration of overtopping, due to less efficient handling of flows being passed than expected. This conceivably could transform a flood event that the dam theoretically could handle without difficulty into a failure situation along the lines described above. It is also possible that damage to a tunnel conduit (spillway or outlet works) could directly threaten the structural integrity of the dam if the location of such potential damage is such that it could negatively impact the abutment/foundation support that the dam relies upon.

Following a flood, a thorough inspection of the dam and damsite should be performed, and all the instruments at the site should be read. If there are indications of possible settlements or deflections of the dam, any available measurement points on the dam should be promptly surveyed. If appropriate, a new aerial survey of the site should be performed so that the post-flood topography can be compared to the pre-flood conditions.

High foundation and abutment water pressures associated with a flood could conceivably trigger a foundation-related failure as described previously relative to Example Failure Mode 2. Consequently it may be appropriate to take frequent instrument readings and perform frequent visual inspections during the period of flooding to monitor the key monitoring parameters noted in the discussion concerning Example Failure Mode 2.

Example Failure Mode 6 -- Earthquake-Related Failure of a Concrete Dam

Shaking during an earthquake can lead to three basic categories of failures of concrete dams:

1. The earthquake shaking triggers or activates a slide in the foundation. The failure mechanism would be as discussed previously relative to Example Failure Mode 2. The extreme loading condition associated with an earthquake may destablize a situation that may otherwise be stable under static loading conditions.

2. The earthquake shaking results in high shearing stresses and/or reduced normal stresses at the lift lines in the mass concrete. If the lift lines are weakly bonded or disbonded, then downstream sliding of the upper portion of the dam may occur relative to the base of the dam. "Keying" at lift lines and/or contraction joints can substantially reduce the potential for sliding. This failure scenario is really only relevant for gravity dams, since the shape of an arch dam generally would prevent downstream translation of the top half of the dam.

3. The earthquake shaking results in high tensile stresses in the dam that lead to serious cracking of the concrete. In an extreme case, the cracking is sufficient to allow sliding and loss of a portion of the dam (usually the upper central portion), which results in a sudden loss of reservoir containment (to

the elevation of the bottom of the missing block). Side release planes for the block of concrete could be provided by contraction joints in a gravity dam, but generally not in an arch dam due to wedging. Vertical cracks in an arch dam typically would be needed to provide side release planes.

For some dams, the failure mechanisms described in scenarios 2 and 3 above may act in combination to produce dam failure.

The routine monitoring program associated with an earthquake-related failure of a concrete dam generally consists of having adequate pre-earthquake baseline information relative to: (1) the key monitoring parmeters identified relative to Example Failure Mode 2, if applicable, (2) structural cracking of the dam, (3) offsets at contraction joints, (4) survey data from available measurement points on the dam, and (5) data from any other deformation-monitoring instruments that may be present on the dam. Immediately following an earthquake, a thorough inspection of the dam should be performed, and all of the instruments at the dam should be promptly read. If there are indications of possible deflections of the dam, any measurement points should be promptly surveyed.

Performance Monitoring Program

When all the various failure modes of concern have been identified, and appropriate parameters for monitoring determined, an integrated program covering all the parameters that need to be monitored for the dam can be defined. Standard elements of the program are as follows:

1. Routine visual monitoring by on-site personnel.- A one-page (front and back) inspection checklist form is typically developed, specific to the needs of each dam. The form is set up such that any question answered with a "YES" means something unexpected has been noted that needs to be investigated.

2. Routine instrumented monitoring.- To the extent possible, provisions should be made so that data can be checked against the limits of expected behavior at the time the instruments are being read.

3. Periodic examination by inspection specialists.- This represents an opportunity for a "fresh set of eyes" to look for anomalous performance, particularly relative to failure modes that are not the current focus of attention. Additionally, this represents an excellent opportunity to discuss the failure modes of concern with on-site personnel, and assist them with any questions they may have relative to performing the routine visual monitoring.

4. Earthquake response and flood response.- Performance monitoring actions that are to be carried out in the event of an extreme loading condition are defined.

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Documentation of Performance Parameters Work

The completed performance parameters document includes discussion of the following topics: (1) description of dam and appurtenant structures, (2) site geology, (3) review of design and construction (4) design flood and earthquake loadings, (5) potential failure modes, (6) key monitoring parameters associated with each potential failure mode, (7) discussion of the monitoring program, including locations of instruments, discussion of past performance, and documentation of the revised monitoring program, (8) presentation and discussion of expected performance, including specific ranges of expected values for the instruments, and (9) action to be taken in the event of unexpected performance. Additionally, a "contact list" is provided to promote open communication among all involved parties, and a 2-4 page "Focused Summary" is provided that briefly presents the key points of the document. Several copies of the summary are laminated in plastic for posting at the dam for quick reference.

Lessons Learned From Performance Parameter Work To Date, and Other Comments

1. Performance parameter work makes clear the importance of routine visual monitoring by on-site personnel. The majority of the key monitoring parameters relate to visual observations. It obviously is preferable that these observations be made frequently by personnel routinely at the dam, rather than relying upon infrequent visits by inspection specialists. To promote effective performance of the routine visual monitoring program, the performance parameters document needs to clearly present the "what" and the "why." Every opportunity needs to be taken to cultivate and foster the routine visual monitoring program when designers and inspectors have a chance to meet or talk with on-site personnel.

2. On several occasions, performance parameters work has identified items that have been overlooked or inadequately addressed by the dam safety analysis/evaluation work done to date by Reclamation, indicating that employing this process at the start of such work would be a good idea. It is striking how often questions, such as whether a particular embankment zone meets current filter criteria requirements with the upstream zone, or what is the clay content of the embankment core material, still exist at dams where recent exploration to obtain foundation samples for liquefaction analyses put drill holes through the zones in question, without sampling them.

3. A central premise of performance parameters work is that "you won't find what you aren't looking for." This approach is the opposite of "let's put in some instruments and see what happens."

4. Efficiency, as well as effectiveness, is important in dam safety monitoring work, given current fiscal realities. Scribing crisp, thin lines across contraction joints of concrete dams to aid visual monitoring for horizontal and vertical relative movements is inexpensive, but very effective. Staking the limits of downstream wet areas is a cheap, effective way to look for significant changes with time. At the other end of the spectrum, routine

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chemical analysis of water samples obtained at seepage locations is expensive, yet provides information concerning only a specific moment in time. Since sediment transport by seepage flows can be a process that proceeds in "spurts," more effective (and inexpensive) monitoring for sediment transport can be achieved using continuous monitoring approaches such as observing for deposited materials in stilling pools associated with weirs or specially provided "catch basins", at sediment trap locations in manholes, in filter socks placed on discharge pipes, etc.

5. Some justifiable monitoring of dams cannot be directly tied to a particular failure mode, but instead falls in the category of "general health monitoring." On-site examinations by inspection specialists every few years is an example, as are surveys of measurement points located on the dam and/or appurtenant structures that are performed every few years, or regular seepage monitoring in the galleries of a concrete dam. Monitoring for "general health" opens the door somewhat to possible abuse, so a "low cost, high value" test is applied to such monitoring proposals.

6. In-depth evaluations of instrumentation data can not only provide valuable insight concerning the performance of the dam (such as patterns of seepage flow through an embankment), but also insight as to whether a particular instrument is providing sufficiently consistent, reliable data that it is worthy of being retained in the future monitoring program. Plots of reduced instrument readings versus associated reservoir elevations can be particularly valuable for these evaluations. In some instances such plots may look discouraging, but in fact may reflect failings of reading and/or maintenance procedures (that can be rectified in the future) rather than failings of the instrument itself.

7. The fact that a dam has experienced many years of apparently satisfactory performance is important information relative to assessing its risks. However, if the monitoring program is not capable of obtaining useful information concerning the key monitoring parameters, the "satisfactory" track record has much less significance. For example, an embankment dam that has significant ponds and swampy areas at its downstream toe may never have given any indication of piping/subsurface erosion problems, but since the key monitoring areas can not be effectively monitored, who knows what may be going on unseen. Similarly, if the toe drains for an embankment dam are not located at a low enough elevation to intercept all seepage flow of concern, the data collected will provide an incomplete picture of actual seepage performance.

8. In some cases, significant structures in the "shadow" of more significant structures receive less dam safety attention than they deserve. Dikes associated with larger dams, and wing dikes associated with concrete dams, are examples of structures that might get more attention if they were independent of their associated, more major structure.

Summary

The performance parameters process provides a cost-effective means of achieving effective and efficient dam safety monitoring programs by providing focus and integration to monitoring efforts. The justification for the monitoring efforts is concisely provided to those who fund the monitoring activities, and to those who perform them. Important information can be effectively obtained from and conveyed to on-site personnel, and personnel who routinely review instrumentation data, concerning: (1) the most likely failure modes, (2) how the monitoring efforts relate to these failure modes, and (3) what constitutes unexpected performance that requires prompt investigation.

Guidelines for Cooperation
with the
Alaska Dam Safety Program

Appendix G

Alaska Dam Safety Program
Visual Inspection Checklist

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ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

NID ID#_________
SHEET __ OF __

GENERAL INFORMATION

NAME OF DAM:	POOL ELEVATION:
NATIONAL INVENTORY OF DAMS ID#:	TAILWATER ELEVATION:
OWNER:	CURRENT WEATHER:
HAZARD POTENTIAL CLASSIFICATION:	PREVIOUS WEATHER:
SIZE CLASSIFICATION:	INSPECTED BY:
PURPOSE OF DAM:	INSPECTION FIRM:
O & M MANUAL REVIEWED:	DATE OF INSPECTION:
EMERGENCY ACTION PLAN REVIEWED:	

ITEM	YES	NO	REMARKS
RESERVOIR			
1. Any upstream development?			
2. Any upstream impoundments?			
3. Shoreline slide potential?			
4. Significant sedimentation?			
5. Any trash boom?			
6. Any ice boom?			
7. Operating procedure changes?			
DOWNSTREAM CHANNEL			
1. Channel			
a. Eroding or Backcutting			
b. Sloughing?			
c. Obstructions?			
2. Downstream Floodplain			
a. Occupied housing?			
b. Roads or bridges?			
c. Businesses, mining, utilities?			
d. Recreation Area?			
e. Rural land?			
f. New development?			
EMERGENCY ACTION PLAN			
1. Class I or Class II Dam?			
2. Emergency Action Plan Available?			
3. Emergency Action Plan current?			
4. Recent emergency action plan exercise?			**DATE:**
INSTRUMENTATION			
1. Are there			
a. Piezometers?			
b. Weirs?			
c. Observation wells?			
d. Settlement Monuments?			
e. Horizontal Alignment Monuments?			
f. Thermistors?			
2. Are readings			
a. Available?			
b. Plotted?			
c. Taken periodically?			

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SHEET __ OF __

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

SAFETY

ITEM	YES	NO	REMARKS
SAFETY			
1. ACCESS			**TYPE:**
a. Road access?			
b. Trail access?			
c. Boat access?			
d. Air access?			
e. Access safe?			
f. Security gates and fences?			
g. Restricted access signs?			
2. PERSONNEL SAFETY			
a. Safe access to maintenance and operation areas?			
b. Necessary handrails and ladders available?			
c. All ladders and handrails in safe condition?			
d. Life rings or poles available?			
e. Limited access and warning signs in place?			
f. Safe walking surfaces?			
3. DAM EMERGENCY WARNING DEVICES			
a. Emergency Action Plan required?			
b. Emergency warning devices required by EAP?			**TYPE(S):**
c. Emergency warning devices available?			
d. Emergency warning devices operable?			
e. Emergency warning devices tested?			
f. Emergency warning devices tested by owner?			**WHEN:**
g. Emergency procedures available at dam?			
h. Dam operating staff familiar with EAP?			
4. OPERATION AND MAINTENANCE MANUAL			
a. O & M Manual reviewed?			
b. O & M Manual current?			**DATE:**
c. Contains routine inspection schedule?			
c. Contains routine inspection checklist?			

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NID ID#__________
SHEET __ OF __

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

EMBANKMENT DAMS

ITEM	YES	NO	REMARKS
EMBANKMENT DAMS			**TYPE:**
1. CREST			
a. Any settlement?			
b. Any misalignment?			
c. Any cracking?			
d. Adequate freeboard?			
2. UPSTREAM SLOPE			
a. Adequate slope protection?			
b. Any erosion or beaching?			
c. Trees or brush growing on slope?			
d. Deteriorating slope protection?			
e. Visual settlement?			
f. Any sinkholes?			
3. DOWNSTREAM SLOPE			**TYPE:**
a. Adequate slope protection?			
b. Any erosion?			
c. Trees or brush growing on slope?			
d. Animal burrows?			
e. Sinkholes?			
f. Visual settlement?			
g. Surface seepage?			
h. Toe drains dry?			
i. Relief wells flowing?			
j. Slides or slumps?			
4. ABUTMENT CONTACTS			
a. Any erosion?			
b. Seepage present?			
c. Boils or springs downstream?			
5. FOUNDATION			**TYPE:**
a. If dam is founded on permafrost			
(1) Is fill frozen?			
(2) Are internal temperatures monitored?			
b. If dam is founded on bedrock			**TYPE:**
(1) Is bedrock adversely bedded?			
(2) Does rock contain gypsum?			
(3) Weak strength beds?			
c. If dam founded on overburden			**TYPE:**
(1) Pipeable?			
(2) Compressive?			
(3) Low shear strength?			

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ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

TIMBER DAMS

ITEM	YES	NO	REMARKS
TIMBER DAMS			**TYPE:**
1. CREST			
a. Any settlement?			
b. Any misalignment?			
c. Adequate freeboard?			
d. Deck timbers sound?			
2. ABUTMENT AND FOUNDATION CONTACTS			
a. Any erosion?			
b. Seepage present?			
c. Boils or springs downstream?			
d. Exposed bedrock?			
e. Is bedrock deteriorating?			
f. Visible displacements?			
3. STRUCTURAL AND CRIB TIMBERS			**TYPE:**
a. Any deterioration?			
b. Are ends broomed or checked?			
c. Are timbers preservation treated?			
d. Are timbers pinned or bolted?			
4. CRIBS			
a. Are cribs filled with rock fill?			
b. Is rock fill sound rock?			

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NID ID#__________
SHEET __ OF __

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

SPILLWAYS

ITEM	YES	NO	REMARKS
SPILLWAYS			**TYPE(S):**
1. CREST			**TYPE(S):**
a. Any settlement?			
b. Any misalignment?			
c. Any cracking?			
d. Any deterioration?			
e: Exposed reinforcement?			
f. Erosion?			
g. Silt deposits upstream?			
2. CONTROL STRUCTURES			
a. Mechanical equipment operable?			
b. Are gates maintained?			
c. Will flashboards trip automatically?			
d. Are stanchions trippable?			
e. Are gates remotely controlled?			
3. CHUTE			
a. Any cracking?			
b. Any deterioration?			
c. Erosion?			
d. Seepage at lines or joints?			
4. ENERGY DISSIPATERS			
a. Any deterioration?			
b. Erosion?			
c. Exposed reinforcement?			
5. METAL APPURTENANCES			
a. Corrosion?			
b. Breakage?			
c. Secure anchorages?			
6. EMERGENCY SPILLWAY			
a. Adequate grass cover?			
b. Clear approach channel?			
c. Erodible downstream channel?			
d. Erodible fuse plug?			
e. Stable side slopes?			
f. Beaver dams present?			

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ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

LOW LEVEL OUTLET

ITEM	YES	NO	REMARKS
LOW LEVEL OUTLET			**TYPE**
1. GATES			
a. Mechanical equipment operable?			
b. Are gates remotely operated?			
c. Are gates maintained?			
2. CONCRETE CONDUITS			
a. Any cracking?			
b. Any deterioration?			
c. Erosion?			
d. Exposed reinforcement?			
e. Are joints displayed?			
f. Are joints leaking?			
3. METAL CONDUITS			
a. Is metal corroded?			
b. Is conduit cracked?			
c. Are joints displaced?			
d. Are joints leaking?			
4. ENERGY DISSIPATERS			
a. Any deterioration?			
b. Exposed reinforcement?			
5. METAL APPURTENANCES			
a. Corrosion?			
b. Breakage?			
c. Secure anchorages?			

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INTAKES

ITEM	YES	NO	REMARKS
INTAKES			
1. EQUIPMENT			
a. Trash racks			
b. Trash rake?			
c. Mechanical equipment operable?			
d. Intake gates?			
e. Are racks and gates operable?			
f. Are gate operators operable?			
2. CONCRETE SURFACES			
a. Any cracking?			
b. Any deterioration?			
c. Erosion?			
d. Exposed reinforcement?			
e. Are joints displaced?			
f. Are joints leaking?			
3. CONCRETE CONDUITS			
a. Any cracking?			
b. Any deterioration?			
c. Erosion?			
d. Exposed reinforcement?			
e. Are joints displaced?			
f. Are joints leaking?			
4. METAL CONDUITS			
a. Is metal corroded?			
b. Is conduit damaged?			
c. Are joints displaced?			
d. Are joints leaking?			
5. METAL APPURTENANCES			
a. Corrosion?			
b. Breakage?			
c. Secure anchorages?			
6. PENSTOCKS			**TYPE MATERIAL:**
a. Material deterioration?			
b. Joints leaking?			
c. Supports adequate?			
d. Anchor blocks stable?			

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ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

CONCRETE DAMS

ITEM	YES	NO	REMARKS
CONCRETE DAMS			**TYPE OF DAM:**
1. CREST			
a. Any settlement?			
b. Any misalignment?			
c. Any cracking?			
d. Any deterioration?			
e. Exposed reinforcement?			
d. Adequate freeboard?			
2. UPSTREAM FACE			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Deterioration?			
e. Exposed reinforcement?			
f. Displacement?			
g. Loss of joint fillers?			
h. Damage to membranes?			
i. Silt deposits upstream?			
3. DOWNSTREAM FACE			**TYPE:**
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Deterioration?			
e. Exposed reinforcement?			
f. Inspection gallery?			
g. Foundation drains?			
h. Foundation drains clear and flowing?			
i. Seepage from joints?			
j. Seepage from lift lines?			
4. ABUTMENT & FOUNDATION CONTACTS			
a. Exposed bedrock?			
b. Erosion?			
c. Visible displacement?			
d. Seepage from contact?			
e. Boils or springs downstream?			

Guidelines for Cooperation with the Alaska Dam Safety Program

Appendix H

Reporting the Performance of Dams

Excerpts from *Guidelines for Reporting the Performance of Dams,* by the National Performance of Dams Program, Stanford University, 1994.

H-1 Guidance for Determining Whether a Dam Incident Has Occurred

H-2 Dam Incident Notification Form

H-3 Hydrologic Incident Reporting Guidance

H-4 Seismic Incident Reporting Guidance

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Appendix H-1

Guidance for Determining Whether a Dam Incident Has Occurred

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Table 3—Guidance for Determining if a Dam Incident Has Occurred

Key Words	Incident Category
Inspection Findings	The findings of a dam safety inspection that identifies a previously unreported (to the Center) incident of unsatisfactory or unsafe conditions at a dam (exclusive of ordinary maintenance and repair and findings of inadequacies relative to current design criteria.)
Damage, Signs of Distress, Instability	Observations of damage, signs of distress or instability of the dam or appurtenant structures[1].
Dam Breach, Dam Failure	Dam breach (partial or complete)
Controlled Breach	Planned (non-emergency, non-incident initiated) breach of the dam. Possibly carried out to remove the dam from service or to make major repairs.
Downstream Release—Controlled or Uncontrolled	Uncontrolled release of the reservoir (e.g., appurtenant structure misoperation), or controlled release with damage.
Inflow Floods, Earth-quakes	The performance of a dam (satisfactory or unsatisfactory, anticipated or unanticipated) generated by a nearby seismic event or inflow flood.[1]
Misoperation, Operator Error	Misoperation of appurtenant structures such as during a hydrologic event.
Equipment Failure	Failure of mechanical or electrical equipment to perform the dam safety functions for which they were intended.
Deterioration	Deterioration of concrete, steel or timber structures that jeopardizes the structural/functional integrity of the dam or appurtenant structures[1].
Dam Safety Modification	Modifications to improve the safety of the dam or appurtenant structures such as might be required due to changes in the design criteria. Note: Repairs following an incident are reported as part of a follow-up report.
Reservoir Incidents	Events that occur in the reservoir (e.g., landslides, waves) that may impact the safety of the dam[1].
Emergency Action Plans	Implementation of the Emergency Action Plan (or emergency actions) in part or whole.
Regulatory Action	The regulator has determined an unsafe condition exists, or the dam does not meet applicable design criteria (e.g., inadequate spillway capacity), and requires action to be taken by the owner (e.g., reservoir restriction, safety modification).

[1] *Consult the Guidelines Reference for specific reporting criteria*

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Appendix H-2

Dam Incident Notification Form

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Dam Incident Notification

Date: ______________

NATDAM ID: ______________ State ID: ____________

Dam Name: ____

Note: For incidents involving multiple dams, submit one DIN for each dam or attach a NATDAM list of the dams involved.

Incident Summary

Incident Date(s): ______________________

- ❑ Flood
- ❑ Seismic Event
- ❑ Deterioration
- ❑ Seepage/Piping
- ❑ Dam Operations
- ❑ Modification/Repair
- ❑ Reservior Incident
- ❑ Other ____________________________

Remarks[1] ____

____

____

Cost Summary

Dam/Appurtenant Structures

- ❑ Breach
- ❑ Damage
- ❑ No Apparent Damage

Reservior Status[2] ________________________

____

Downstream/Upstream

- ❑ Fatalities (No.) ____________________
- ❑ Injuries (No.) ____________________
- ❑ Property Damage
- ❑ No Damage

Remarks[1] ____

____

____

Prepared By

Telephone: (___) ______________

Name: ______________________________ Fax: (___) ______________

Organization: ____

Address: ____

____

____

Do Not Write Below This Line

Date Rec'd: ____________ Date Rev'd: ____________ Rev'd By: ______________

[1] *This space can be used to describe the checked boxes. Additional pages can be used as necessary.* *DIR-001*

[2] *For example: level restrictions imposed, empty, etc.*

Figure 3-2—Dam Incident Notification Form

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Appendix H-3

Hydrologic Incident Reporting Guidance

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Guidelines Reference—Reporting Dam Incidents

Section 8—Hydrologic/Flood Events

8.1 Introduction

This section provides the Reporting Criteria and Requirements for inflow flood events that challenge the integrity of dams. The Reporting Criteria establish the guidelines to determine whether an inflow flood is an event of engineering interest. The Reporting Requirements define the information that should be provided to thoroughly and consistently document inflow floods.

An inflow flood to a dam can be caused by heavy rainfall and/or snowmelt in a watershed, or the failure or large release from an upstream dam. When a large flood[1] occurs, a dam may experience its highest recorded pool level and/or largest flow through its outlet system. Furthermore, it may be the only true test of a dam's design. Thus, given the occurrence of an inflow flood of engineering interest, the performance, ***satisfactory*** or ***unsatisfactory***, of a dam under these conditions should be documented. Documentation should include information on the inflow flood at the dam and its as-built structural and hydraulic characteristics.

Subsection 8.2 summarizes the flood events and damage that can occur. Subsection 8.3 provides Reporting Criteria for flood events. Subsection 8.4 describes the Reporting Requirements to document an inflow flood and the performance of the dam.

Section 6 describes the Reporting Requirements to document the performance of appurtenant structures. At dams where the operation of outlets is required to provide sufficient outlet capability, the performance of dam operations (operators, procedures) should be reported. Section 7 describes the Reporting Requirements to document dam operations.

8.2 Flood Incidents

In the event of a flood, failure or severe damage to a dam can occur as a result of the following types of hazards:

- dam and/or spillway overtopping,
- high flow rates in spillways and outlet works, and
- high pool levels.

---

[1]The term "large flood" is used here in a relative sense to indicate the magnitude of an event in comparison to a dam's outlet and storage capacity

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Each hazard has the potential to affect the dam in a different way, depending on the type of dam, its design, and the magnitude of the hazard. Overtopping can cause damage to the embankment, dam foundation, spillway, and other appurtenant structures. Large flows can damage spillways, stilling basins, and outlet works, and can cause downstream inundation. High pool-levels can increase seepage pressure, affect structure stability or damage unprotected areas of the upstream slope. Table 8-1 lists modes of failure and damage that can occur in the event of a large flood.

8.3 Reporting Criteria

This subsection provides the Reporting Criteria that define when a flood incident has occurred at a dam. The criteria are based on the magnitude of the inflow to the dam, the dam outlet capacity, and the occurrence of damage to the dam or appurtenant structures. The criteria include both overtopping and non-overtopping events, independent of whether damage or failure of the dam or its appurtenant structures occurs.

Table 8-1—Modes of Dam Failure/Damage Due to Hydrologic/Flood Events

(High Pool Level and/or Large Floods)

Structure Type	Failure/Damage Mode
Earth or Rockfill Dams	Breaching by overtopping Piping/seepage due to inadequate cutoff, upstream lining, or internal drainage Upstream slope damage/erosion Appurtenant structure damage/failure Downstream slope failure due to high seepage pressures
Concrete or Other Types of Dams	Overturning due to inadequate buttress, increased uplift pressure Sliding/cracking due to inadequate foundation or abutment support
Spillways	Structure collapse/erosion due to inadequate lining, stilling basin, underdrainage, foundation support Slab instability due to excessive uplift, seepage Cavitation
Outlets	Cavitation Structure damage due to vibration
Foundation	Erosion Seepage/piping

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Inflow flood incidents are categorized in three groups. The following are defined as dam incidents:

1. **Overtopping Events**[2] - any inflow which overtops all or a portion of a dam.
2. **Non-overtopping Events** - A flood which exceeds the 100-year event; or which causes the spillway[3] to flow at a depth of one-half full or greater, regardless of the flood frequency.
3. **Any flow that causes damage to the dam or appurtenant structures that poses a potential safety hazard.**

In all cases, the performance of a dam is documented whether dam failure occurs or not.

☞ *Special consideration is given to report hydrologic/flood events that occur at small dams that have limited outlet capacity (i.e., less than 100-year flood), of which there are many. In order to limit the number of DIRs that would involve small dams and low flows (i.e., much less than a 100-year event), the Reporting Criteria for non-overtopping flows consider only events where damage to the dam or its appurtenant structures occurs, regardless of the magnitude of the flood.*

Figure 8-1 illustrates the hydrologic/flood Reporting Criteria. An event is reported if any of the above criteria are met at one or more dams.

In the case of large areal precipitation events or extreme river flows (possibly due to a large release from an upstream dam) many dams may be affected. Under these circumstances, the following apply:

1. The performance of all dams that satisfy the Reporting Criteria described above should be reported.
2. For events involving multiple dams on a river system that contribute to downstream release, the performance of all dams should be reported separately.

2 This includes dams which were designed to be overtopped or were modified at a later date to be protected against overtopping (e.g., RCC, gabions, concrete, concrete block, etc.)

3 For dams with an emergency spillway and small principal spillway, this criterion refers to the emergency spillway.

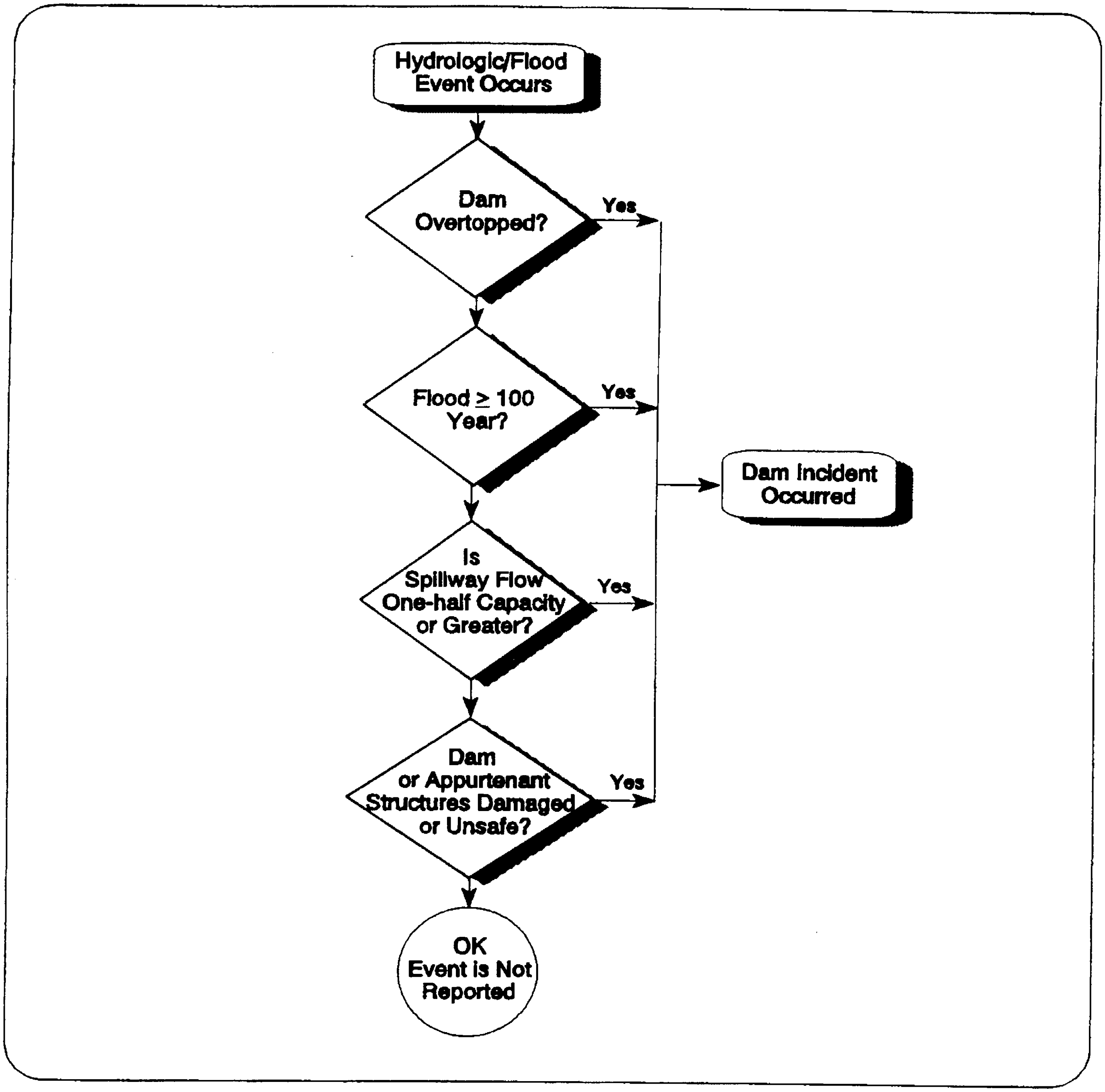

Figure 8-1—Flow chart for reporting hydrologic/flood events.

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An example where the second consideration applies would be in a case where a dam has failed due to overtopping as a result of extreme rainfall. If the inflow to the dam was affected by the operation of dams upstream, the performance of the upstream dams should be reported as well.

8.4 Reporting Requirements

The DIDR for a flood event should include information on:

1. the type and magnitude of the flood that occurred,
2. precipitation data if the flood was generated by rainfall and/or snowmelt, and
3. the performance of the dam, which includes the operation of dam outlets, performance of appurtenant structures, and post-incident actions.

To facilitate the reporting process, a checklist and a limited number of data forms are provided to document a flood incident. The DIDR for a flood incident should, as a minimum, include the incident checklist and supporting documentation. The data forms are provided as an alternative reporting format. As noted in Section 2, it is anticipated that most, if not all, of the listed information will be generated by the engineer during an investigation of the incident. Furthermore, it is preferable that the DIDR include information in its basic form (i.e., incident inspection reports, field notes).

Figure 8-2 shows the Hydrologic/Flood Incident Checklist for reporting information on flood events. This checklist, which is completed for each dam involved in the flood event, should be used in conjunction with the Incident Documentation Checklist (DIR-003). The following incident-specific documentation should be provided:

- List and identification of dams affected by the hydrologic/flood event
- Project hydrologic/hydraulic design criteria and capacity and as-built information (including any modification after construction)
- Information which documents the type and magnitude of the flood hydrograph (type refers to upstream release/breach vs. rainfall/snowmelt generated)
- Rainfall/snowmelt event information, if applicable (see Fig. 8-3)
- Capacity of the dam to safely pass the flood (i.e. pool level, storage, and spillway flow data)
- Overtopping data, if applicable (see Fig. 8-4)
- Documentation of damage (overtopping, erosion, structural, increased seepage pressure due to hydraulic loading, etc) by means of field notes, photos, inspection reports, marked-up scale drawings showing distressed areas and dimensions of damage
- Post-incident actions taken during and after event by the dam owner/operator (includes operations required and/or performed)
- Eyewitness reports, if available

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Hydrologic/Flood Event Checklist

NATDAM ID: ____________ Date: ____________

State ID: ____________ Prepared By: ____________

Dam Name: ____________ Incident ID: ____________

Flood Incident Type

- ❑ Rainfall/Snowmelt
- ❑ Upstream Dam Failure
- ❑ Upstream Dam Release
- ❑ Other ____________

Dam Performance Data

- ❑ List of Dams Affected by the Flood Event
- ❑ Dam Overtopping/Spillway Flow (see DIR-011)
- ❑ Reservoir Storage Data
- ❑ Dam Operations
- ❑ Reservoir Level Data
- ❑ Damage Report
- ❑ Other ____________

Upstream Flooding

- ❑ Hydrologic/Hydraulic Design Report
- ❑ Design Rainfall Depth, Area and Duration
- ❑ Watershed Hydrologic Data
- ❑ Hydraulic Rating Curve
- ❑ Flood Routing Data
- ❑ Inflow Hydrograph
- ❑ Other ____________

Remarks ____________

DIR-010

Figure 8-2: Checklist for reporting hydrologic/flood events

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Rainfall/Flood Data Summary

NATDAM ID: ______________ Date: ______________

State ID: ______________ Prepared By: ______________

Dam Name: ______________ Incident ID: ______________

Rainfall Data

Period of Rainfall: ______________ to ______________

______________ to ______________

Recorded Rainfall

Location	Amount

Snow Depth (in.) ______________

Prior Hydrologic Condition ______________

____

Flood Data

Period of Flooding: ______________ to ______________

______________ to ______________

❑ Inflow flood hydrograph

Flow Summary

Location	Amount (cfs)

DIR-011

Figure 8-3 Rainfall/Flood Data Summary

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Overtopping Data Checklist

NATDAM ID: ____________________ Date: ______________________________

State ID: ________________________ Prepared By: ______________________

Dam Name: ______________________________________ Incident ID: ________________________

Dam Overtopping Data

Peak Depth of Overtopping (ft.) ______________________________ Time Overtopping Began ____

Peak Reservoir Elevation (ft. msl) ____________________________ Duration of Overtopping[1] _________________________________

Other ____

[1]Prior to breaching the dam

Upstream Flooding

Principal		Secondary (Emergency Spillway)	
Depth (ft.)	______________________	Depth (ft.)	______________________
Flow (cfs)	______________________	Flow (cfs)	______________________
Velocity (ft/sec)	______________________	Velocity (ft/sec)	______________________

Remarks ____

____

____

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____

DIR-012

Figure 8-4: Overtopping Data Checklist

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- Any follow-up reports/studies which were undertaken as a result of the event (i.e., a comparison of spillway design hydrograph with actual hydrograph, failure analysis)

☞ *Note: Reporting Requirements for documenting downstream flooding and damage are provided in Sections 11 and 12, respectively.*

List of Dams Affected by the Flood Event - A number of different dams can be affected by a flood event. A rainfall/snowmelt event can cover a large area, or a flood caused by a breach or upstream release could affect several dams in a series. All dams which satisfy the Reporting Criteria should be reported on. The affected dams should be identified in accordance with requirements in Section 2.

Project Design and As-Built Information - General project design and as-built information should be submitted as noted under this section. However, design information specific to a dam's ability to pass a flood should be included. Usually a Hydrologic/Hydraulic Design Report will be available or past inspection reports will have analyzed the watershed hydrology and hydraulic capacity of the dam. Provide the following information in the DIDR:

- Watershed hydrologic information (area, land use, unit hydrographs, runoff, CN, soil type)
- Inflow hydrographs
- Reservoir storage data
- Spillway-rating curves (includes dam overtopping)
- Flood routings
- Design precipitation data

Type and Magnitude of the Flood Event—A flood can be generated by a rainfall/snowmelt event, a large release from an upstream reservoir or dam breach. A flood is recorded by collecting or determining the flow hydrograph. The volume of runoff can be important as it relates to available flood storage in the reservoir. Flow versus time can be obtained from river gage or depth-velocity measurements taken immediately upstream or downstream (outflow hydrograph) of the reservoir. Reservoir pool level versus time data can also be helpful in determining storage, spillway flow, and comparing flood routing methods. Upstream release may be known and/or dam break analysis could be used to simulate a dam breach to determine an inflow hydrograph. Any data of this type should be submitted with the DIDR or in a follow-up report.

Rainfall/Snowmelt Event Information—Rainfall data is recorded by rainfall gages present in the watershed area. These gages may be simple garden store collector types or the more sophisticated official weather bureau gages which record the amount and intensity of rainfall. Data may also be collected by performing a "bucket survey", which involves a house to house canvasing of the affected area to determine point

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rainfall amounts. Based on Weather Service reports or Soil Conservation Service snow reports, snow depth amounts are usually known. Other information which might be available could be isoheytal maps and meteorological summaries of the storm. Actual runoff will be determined by watershed area, slope and cover, soil type (infiltration rates), and the previous hydrologic condition of the watershed, i.e. was the ground wet from prior rainfall, frozen, or covered by snow.

Overtopping Data - If the dam is overtopped during the flood event, data related to the amount of overtopping and the performance of the dam should be reported. This should include (see Fig. 8-4):

- Maximum depth of overtopping
- Length of dam which was overtopped
- Top of dam profile, crest width, upstream and downstream slope
- Time after the start of the storm or flood when overtopping began
- Duration of overtopping (prior to the breach/failure, if applicable)
- Cover and the condition of the dam crest and downstream slope
- Actions taken by the dam tender/operator and/or regulatory officials
- Any other significant observations

Figure 8-4 shows a data form that can be used to document overtopping.

Documentation of Damage - Guidelines for reporting damage is given in Section 2. Most damage incurred will be clearly visible. However, response of the embankment or structure to temporary high pool-levels and increased seepage pressure through the dam and/or foundation may not be as easily detected and may cause damage that shows up at a later time. This type of damage should also be reported when it is detected.

Post-Incident Actions - During or immediately following the flood or the post-event inspections, the dam owner/operator or regulatory agency may take actions to provide for the safety of the dam and/or downstream areas. Reporting Requirements for some of these actions may also be covered in the section on Dam Operations (Section 7). Section 3 should be consulted when reporting post-incident actions and/or the implementation of an Emergency Action Plan.

8.5 Follow-up Reports

When additional information and the results of post-event investigations have been completed, report(s) and/or other appropriate documentation covering the following topics should be provided:

- Flood frequency or hydrologic investigations
- Reports on the cause of failure, if applicable

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- Documentation of revisions to the design basis of the dam or appurtenant structures, or to operating procedures or other aspects, as a result of the event.

Refer to Subsection 3.4 and Table 3-2 for general guidance on follow-up information that should be reported in the DIFR.

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Appendix H-4

Seismic Incident Reporting Guidance

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Guidelines Reference—Reporting Dam Incidents

Section 9—Seismic Events

9.1 Introduction

When a seismic event occurs, a dam and its appurtenances are subjected to a brief period of potentially extreme dynamic loads. The earthquake simultaneously challenges the integrity of all components in the dam/reservoir system (i.e., dam, appurtenant structures, equipment items, reservoir rim). To develop a complete and detailed understanding of their seismic performance, it is important to gather data that documents episodes when dams are exposed to levels of ground motion of engineering interest.

Earthquakes can vary in size from events which are barely felt and have no engineering significance, to major events such as the magnitude 7.1, 1989 Loma Prieta earthquake, which generated high levels of ground motion at a number of dams in California. While earthquakes are most common in the western U.S. (WUS) (principally in California), they, in fact, occur throughout the country. In the central and eastern U.S. (CEUS) earthquakes occur less frequently; however, some of the largest historic events have occurred there (e.g., the series of New Madrid earthquakes in 1811 and 1812 had magnitudes of 7.8, 8.0 and 8.2). Furthermore, due to the nature of wave propagation in the CEUS, strong levels of ground shaking are felt over a much larger region than similar-size events in the WUS. This is illustrated in Figure 9-1.

This section provides the Reporting Criteria and Requirements for documenting the performance of dams during earthquakes. It provides:

- criteria that define the size of earthquakes of engineering interest,
- criteria for identifying the dams in proximity to an earthquake whose performance should be reported, and
- Reporting Requirements that identify data that should be provided to document the size of the earthquake, the hazards at each dam site, and the performance of the dam and appurtenant structures.

In 1983 the U.S. Committee on Large Dams (USCOLD) published guidelines for inspection of dams following a seismic event[1]. The USCOLD report provides a concise description of the types of seismic hazards and damage that can occur at a dam, and the modes of dam failure. The user of these Guidelines should be familiar with this document, as well as basic earthquake engineering terminology.

[1] *U.S. Committee on Large Dams, "Guidelines for Inspection of Dams Following Earthquakes", Denver, Colorado, August 1983*

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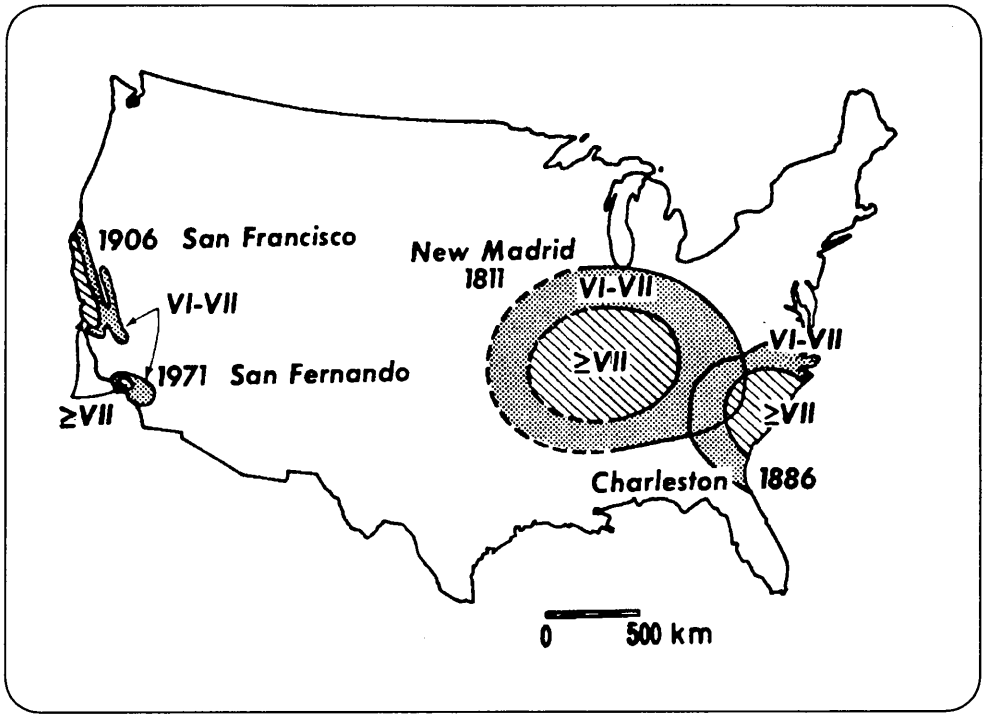

Figure 9-1 Illustration of the difference in ground motion experienced during earthquakes of similar size in the WUS and the CEUS (Reproduced from EPRI[1]).

Subsection 9.2 identifies the hazards that can be generated by a seismic event. Subsection 9.3 provides the Reporting Criteria that define the earthquakes of engineering interest and the procedure for identifying the dams located nearby whose performance should be reported. Subsection 9.4 provides the Reporting Requirements to document the characteristics of the earthquake, the performance of embankment and concrete/masonry dams, appurtenant structures, and emergency actions. Subsection 9.5 identifies the Follow-Up Reports that should be reported.

The engineer should refer to Sections 11 and 12 which give the Reporting Requirements for documenting the characteristics of the dam breach and downstream flooding, and the costs of the dam failure, respectively.

9.2 Seismic Hazards - Descriptions

Hazards that may be generated by a seismic event include:

- strong ground motion at the dam site,

[1] *Electric Power Research Institute, "Engineering Model of Earthquake Ground Motion," EPRI NP-6074, Palo Alto, California, October 1988*

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- ground offset or fault movement at or near the dam foundation or abutments, or in the reservoir,
- liquefaction of the dam foundation,
- seiche in the reservoir,
- landslides in the reservoir which create wave action,
- landslides or rockfalls that affect the spillway, powerhouse, outlet facilities or other appurtenant structures, and
- upstream dam failure.

Each hazard has the potential to damage a dam and appurtenant structures, depending on the type of dam and the magnitude of the hazard. Dam settlement, sliding and cracking, as well as dangerous new leakage, can be caused by strong ground motion, ground offset or fault movement, or liquefaction of the dam foundation or embankment. A landslide in the reservoir can create a wave that overtops and damages or fails a dam. A landslide at the dam or appurtenant structures also can cause structural damage or impair outlet capacity.

In the event of an earthquake, failure or severe damage to a dam or its appurtenances can occur in a number of ways. Short of an instantaneous breach of the dam or dramatic failure of appurtenant structures, damage or incipient failure are evident in signs of visible distress or changes in uplift pressures. Table 9-1 summarizes potential damage that can occur to dams, appurtenant structures and mechanical/electrical equipment items due to seismic events.

9.3 Reporting Criteria

In the event of an earthquake, criteria are provided to determine whether the performance of dams located nearby should be reported. First, the earthquake must be of sufficient magnitude (M) to be of engineering interest. Second, when an earthquake occurs, the level of ground motion decreases with distance from the epicenter. Therefore, beyond some limiting distance, R(m), which is defined as a function of earthquake magnitude, ground motions are no longer of engineering interest. The performance of ***all*** dams located within this distance are reported since satisfactory performance is as enlightening as unsatisfactory performance. Due to differences in the attenuation of ground motion in the WUS and the CEUS[2], R(m) is specified for each part of the country.

The performance of ***all*** dams should be reported that satisfy the following Reporting Criteria:

1. The earthquake has a magnitude equal to or greater than 5.0, and

[2] *The boundary between the WUS and the CEUS is defined as approximately 105° W longitude.*

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Table 9-1—Description of Potential Damage Due to Seismic Events

Component	Damage Description
Earth or Rockfill Dams	Slope Instability Liquefaction/slope instability Excessive seepage Overtopping due to embankment slump/subsidence of the dam crest, seiche or landslide-induced wave Increased pore water pressures Shifting of sediment up against the dam
Concrete and Other Types of Dams	Overstressing of concrete Sliding/movement at the foundation
Spillways	Failure of concrete walls or slabs Damage to gates, hoists or other mechanical equipment
Outlets/Equipment	Obstructions Damage to valves or outlet pipes
Foundation	Subsidence Liquefaction Movement along a fault trace Excessive seepage/removal of soluble material
Reservoir Rim	Landslide into the dam or reservoir

2. The dam must be located within the distances listed in Tables 9-2 and 9-3. These tables define R(m) for earthquakes that occur in the WUS and CEUS, respectively. The distances in Tables 9-2 and 9-3 are determined on the basis that the free-field, average-peak ground acceleration (PGA) at the dam will equal or exceed 0.10g (where g is the acceleration due to gravity, 981.5 cm/sec[3]).

Figure 9-2 illustrates the seismic Reporting Criteria.

[3] Due to differences in the geologic and seismologic characteristics of the WUS and CEUS, different magnitude scales are used by the U.S. Geological Survey to report the size of an earthquake. In the WUS earthquakes are generally reported in terms of Richter Local Magnitude, ml, or surface-wave magnitude, M_S. In the CEUS earthquake magnitudes are reported in terms of the body-wave magnitude, m_b, or Lg-wave magnitude, m_b,L_g.

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The distances in Tables 9-2 and 9-3 are used to define a circular region about the earthquake epicenter. This is shown in Figure 9-3a. The U.S. Geological Survey in Golden, Colorado can provide the geographic coordinates of the earthquake epicenter shortly after it occurs.

In the WUS, earthquakes above approximately magnitude 6.0 are often accompanied by an area of extended rupture on the causative fault. In this case, the engineer should identify the dams that may experience strong ground motion by defining a region whose boundary is a fixed distance, R(m), from a surface projection of the segment of the fault that ruptured. This is shown in Figure 9-3b. In most cases, earthquakes that occur in the CEUS do not have areas of extensive fault rupture. Exceptions include large events such as those which could occur in the New Madrid seismic zone.

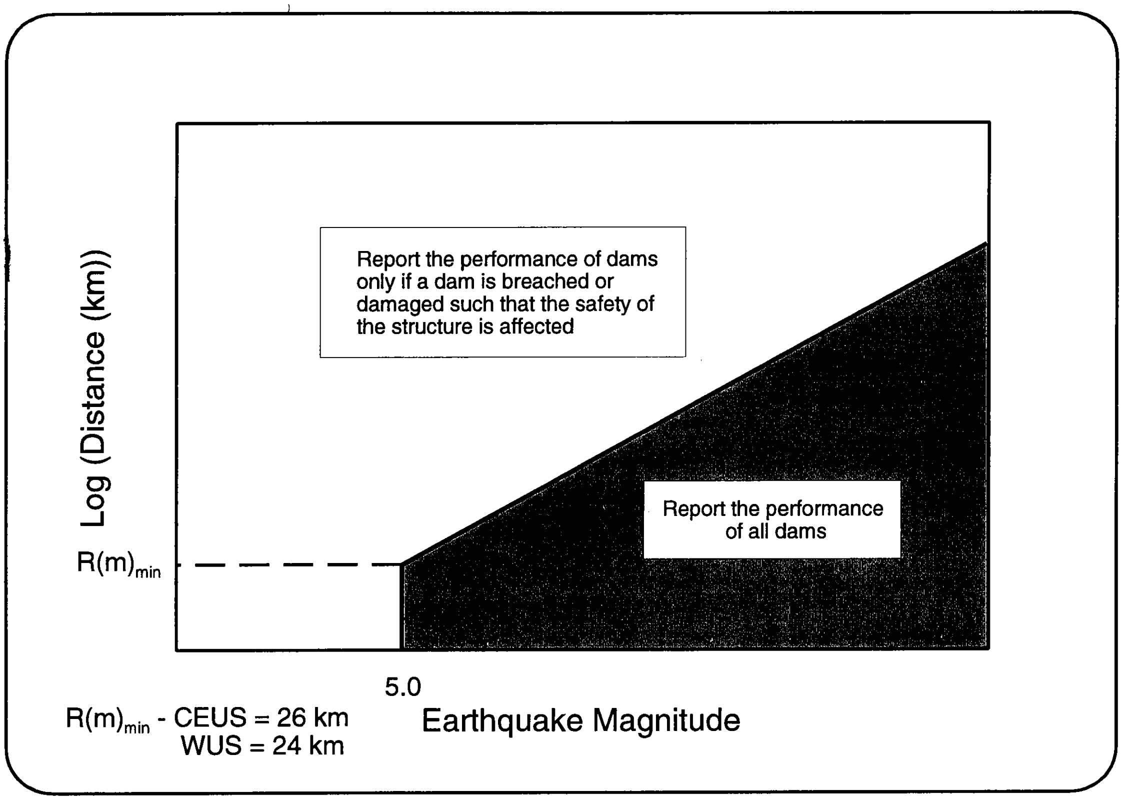

Figure 9-2 Illustration of the magnitude - distance criteria for reporting the performance of dams during seismic events.

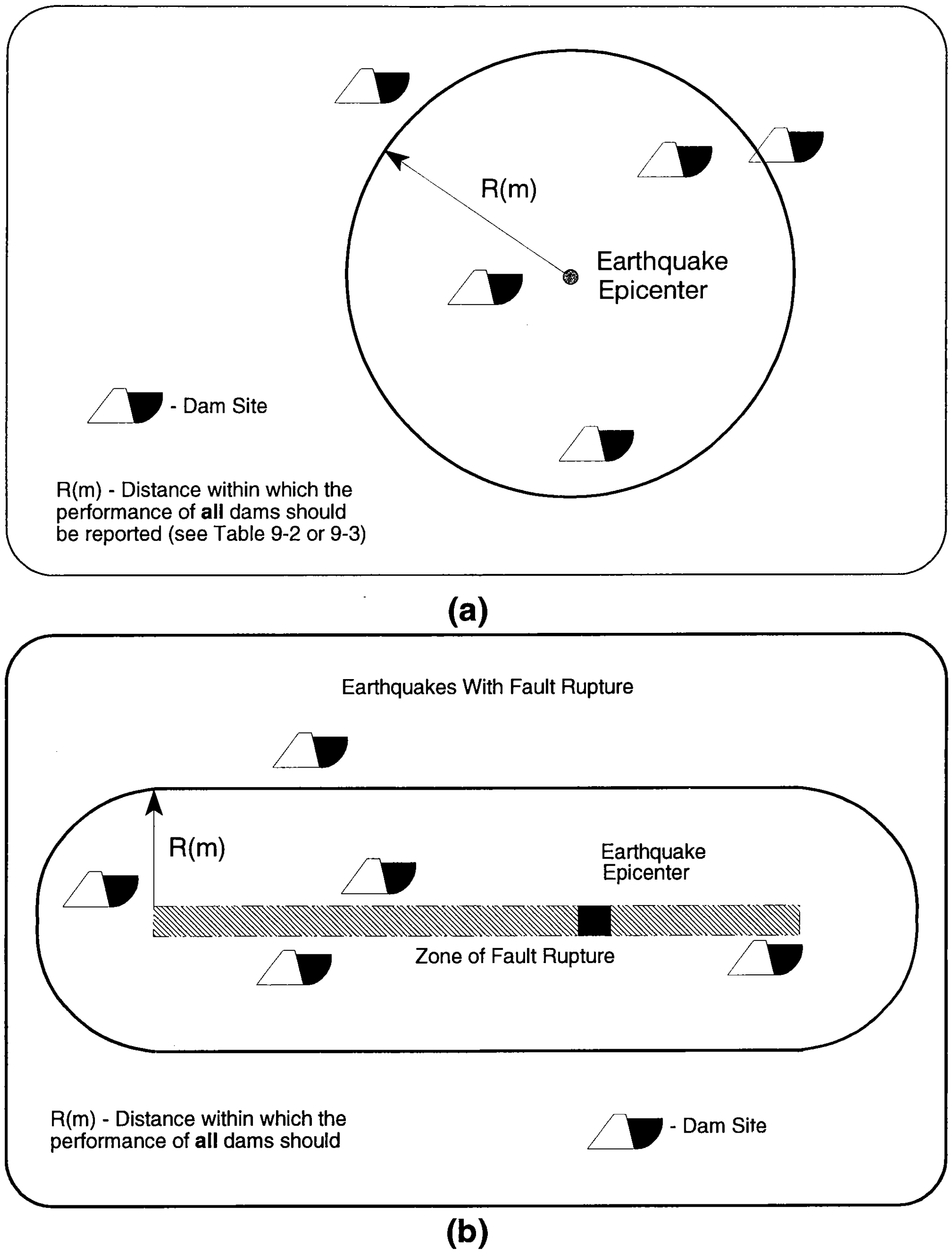

Figure 9-3 Illustration of the region near an earthquake within which the performance of dams should be reported for events in the CEUS and WUS earthquakes without extended fault rupture and (b) for events above magnitude 6.0 in the WUS where extended fault rupture occurs.damage to a dam that affected its safety, this event and the performance of the dam should be reported. Therefore, certain exceptions (or additional criteria) are considered.

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Exceptions

There may be exceptions to the above criteria. For example, while not expected, if an earthquake of magnitude less than 5.0 occurs and either breaches or causes damage to a dam or its appurtenant structures, this event and the performance of the dam should be reported. To account for circumstances such as these, certain exceptions (or additional criteria) are considered.

For earthquakes with a magnitude less than 5.0 or for dams located at distances greater than R(m) as listed in Tables 9-2 and 9-3, the performance of dams should be reported, if either of the following conditions apply:

- if breach occurs, or
- sufficient damage occurs that, in the opinion of the inspecting engineer, poses a potential safety hazard to the dam or appurtenant structures,

Since Tables 9-2 and 9-3 do not apply for earthquakes with $M < 5.0$, a value of R(m) must be defined. In this case R(m) is set to the distance corresponding to the location of the dam farthest from the earthquake epicenter that was breached or damaged during the earthquake. For earthquakes with $M \geq 5.0$, if a dam is breached or damaged and is located at a distance greater than R(m) as listed in Table 9-2 or 9-3, R(m) must be redefined. In this case, R(m) is defined as the distance corresponding to the dam farthest from the earthquake epicenter that was breached or damaged. Figure 9-4 illustrates the steps in the Reporting Criteria for seismic events.

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Table 9-2—Distances Within Which the Performance of Dams Should Be Reported in the Western U.S. (west of 105É W)1

Magnitude	Distance(km)[2]
5.0	24
5.2	27
5.4	30
5.6	33
5.8	36
6.0	39
6.2	43
6.4	47
6.6	51
6.8	55
7.0	59
7.2	64
7.4	69
7.6	75
7.8	80
8.0	86
8.2	92
8.4	99
≥ 8.5	102

[1] *For intermediate magnitudes the appropriate distance can be interpolated.*

[2] *The distance is measured from the earthquake epicenter or from the surface projection of the area of rupture on the fault (See Figs. 9-3a & 9-3b).*

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Table 9-3—Distances Within Which the Performance of Dams Should Be Reported in the Central and Eastern U.S. (east of 105° W)[1]

Magnitude	Distance (km)[2]
5.0	26
5.2	32
5.4	38
5.6	46
5.8	54
6.0	64
6.2	74
6.4	86
6.6	99
6.8	114
7.0	129
7.2	146
7.4	165
≥ 7.5	174

[1] *For intermediate magnitudes the appropriate distance can be interpolated.*

[2] *The distance is measured from the earthquake epicenter.*

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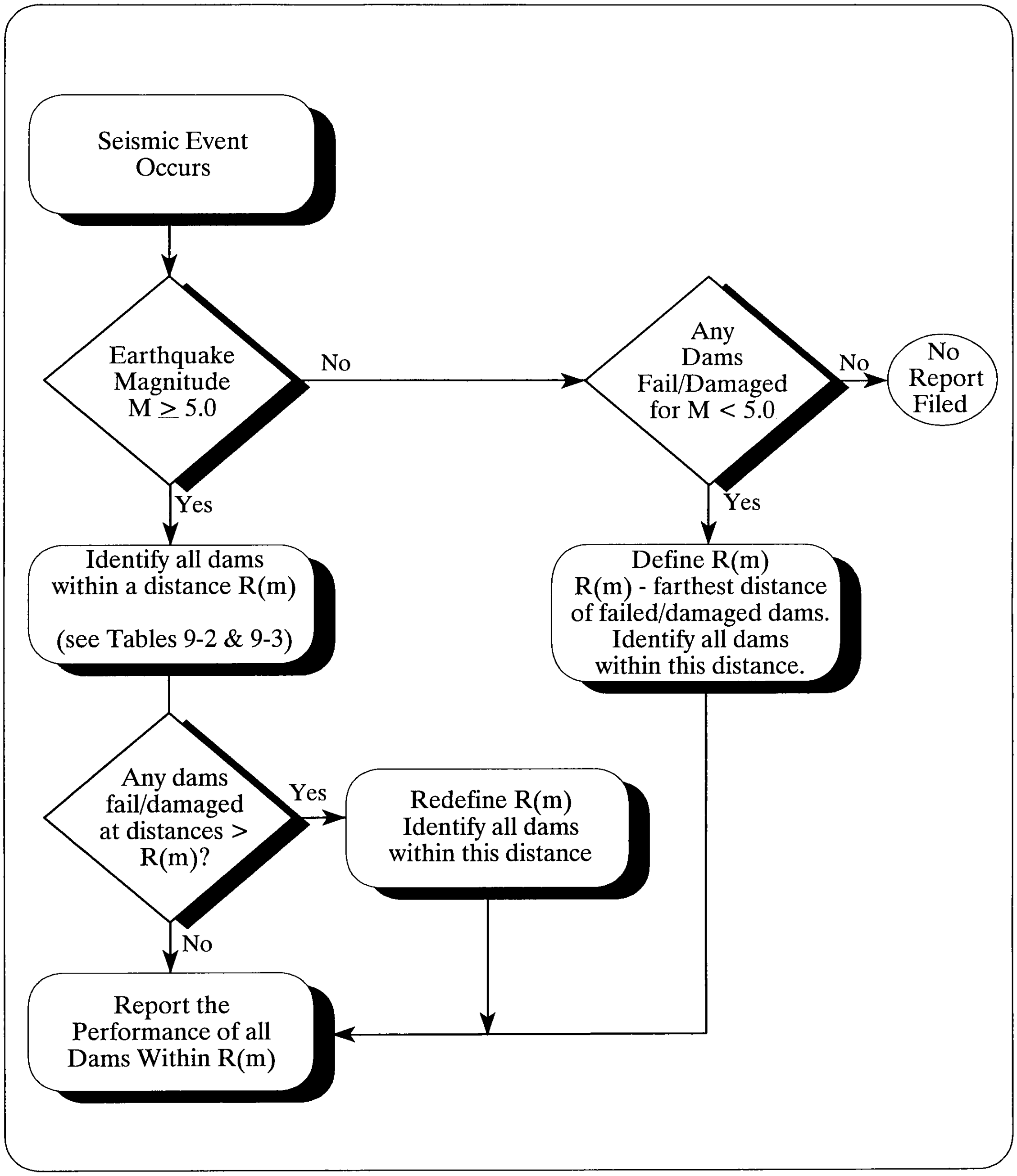

Figure 9-4 Flow diagram of the Reporting Criteria for seismic events.

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9.4 Reporting Requirements

This subsection provides the Reporting Requirements for documenting the performance of dams during a seismic event. The requirements apply to *all* dams in an area defined by R(m) (see Fig. 9-3).

☞ *The Reporting Requirements are used to document the satisfactory and unsaftisfactory performance of dams during an earthquake.*

The DIDR for a seismic event should contain the following:

1. Transmittal Sheet (DIR-002)
2. Seismic Event Checklist (DIR-013)
3. Dam Seismic Performance Checklist (DIR-014)
4. Supporting documentation for each dam

Figure 9-5 shows the Seismic Event Checklist (and data form). The checklist identifies the information that should be provided to document a seismic event. Information listed on the checklist includes:

- **Earthquake Characteristics** - The location and magnitude of the earthquake reported.
- **Dam Performance Data** - The engineer should provide a list of all the dams that were inspected (by state inspectors, dam owners, etc.) following the earthquake whose performance is being reported[4]. This list may be a printout of a program that sorted through an inventory of dams, a copy of the NAT-DAM file for each dam, etc. A DIDR should be provided for each dam that is listed.

Figure 9-6 shows the checklist for reporting the performance of a dam during a seismic event. This checklist and supporting documentation should be provided for each dam. The checklist identifies the following information to be provided:

- Description of seismic hazards at the dam site (e.g., seiche, fault displacement).
- Documentation of damage (ground and structure cracking, movement, landslides) to the dam, appurtenant structures, and reservoir rim by means of photos and/or video tape, along with thorough descriptions (e.g., photo logs).
- Copy of strong-motion recordings obtained at or near the dam or reference to a state or federal agency where these records can be obtained.
- Eyewitness reports (see Section 2).

[4] *Note, a list of dams that were inspected was also provided with the DIN. An updated list should be provided in the DIDR.*

- A copy of the post-event inspection report, including field notes and sketches, if available.
- Marked-up scale drawing(s), indicating where damage (cracking, slides, movements, etc.) occurred, as well as the general dimensions of the distressed areas.
- Post-incident actions (i.e., reservoir draw-down, implementation of emergency procedures).
- As-built design information, including seismic design parameters, estimated factors of safety (see Section 2)

In the case of dam failure (i.e., breach of a dam), requirements for reporting data on the breach and downstream inundation and costs of the incident are given in Sections 11 and 12, respectively.

When preparing a DIDR following a seismic event, it is important to document the damage, if any, to the dam or appurtenant structures in a timely manner. This ensures that information which is initially available is not lost or misinterpreted.

As-Built Characteristics and Seismic Design Parameters - The report for each dam that experiences the earthquake should include information on the seismic design and as-built characteristics. The checklist in Figure 3-5 identified the basic information that should be reported to document the as-built characteristics of a dam. When reporting a seismic event, this should include the seismic design basis (e.g., maximum credible earthquake and design motions) and engineering reports that document the results of seismic evaluations (i.e., estimated factor of safety).

Strong Ground Motion Records - In order to permit an understanding of their dynamic response, many dams have been instrumented to record the strong earthquake ground motion at the dam site and the dynamic response of the dam itself. To document the earthquake ground motion experienced at a dam, the following information should be provided:

- A summary of the strong motion instrumentation at the dam (if any), indicating the location of the instrument(s), instrument type/model number,
- number of channels of data and a description of the instrument foundation characteristics (bedrock, alluvium, etc.). Figure 9-7 shows a data form that can be used to summarize the characteristics of the instrumentation system and the recorded data.
- A copy (plot) of the strong motion records obtained from each channel should be reported. Initial reports may include a copy of the record (unprocessed trace) and estimated peak values. Follow-up reports can provide the processed digital time history, response spectrum data, etc. when they are available.

Seismic Event Checklist

Date: ____________________
Prepared By: ____________________

Earthquake Name: ____
Date: ____________________ Time: ____________________ (EST, CST, etc.)

Earthquake Characteristics

Earthquake Location: Latitude: ______________ Longitude: ______________

Causative Fault: ____

Hypocentral Depth: ______________ (miles, km)

Earthquake Magnitude[1]

M_S ______________ m_{blg} ______________ m_b ______________

m_L ______________ **M** ______________ M_o ______________

MMI ______________

Dam Performance Data

Distance Range[2] (R(m)): ______________________________

Basis (i.e., Table 9-2 or 9-3, other): ______________________________

❑ List of Dams Reported ❑ Other ______________________________

Remarks ____

[1]Fill-in all that are known. M_S - surface-wave magnitude; m_{blg} - Lg-wave magnitude; m_b - body-wave magnitude; m_L - Richter local magnitude; **M** *- moment magnitude; M_o - seismic moment; MMI - Modified Mercalli Intensity, (report the epicentral intensity)*

[2]Distance used to identify dams for inspection

DIR-013

Figure 9-5 Seismic event checklist

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Dam Seismic Performance Checklist

NATDAM ID: ____________ Date: ____________

State ID: ____________ Prepared By: ____________

Dam Name: ____________ Incident ID: ____________

Site Seismic Hazards[1]

- ❑ Strong Ground Motion
- ❑ Ground Offset or Fault Movement
- ❑ Foundation or Embankment Liquefaction
- ❑ Reservoir Seiche
- ❑ Upstream Dam Failure
- ❑ Landslides
- ❑ Other ____________

[1]*Check those that apply*

Incident Documentation Data

- ❑ Site Strong Motion Data (see DIR-015)
- ❑ Loading Conditions
- ❑ Foundation Performance
- ❑ Dam Performance (Crest Settlement, Instability)
- ❑ Appurtenant Structure Performance (Concrete Structures, Mechanical and Electrical Equipment)
- ❑ Post-Earthquake Inspection and Damage Reports
- ❑ Post-Incident Actions
- ❑ Other ____________

Operating Records[2]

- ❑ Instrumentation Records
- ❑ Reservoir Levels
- ❑ Leakage Data
- ❑ Other ____________

[2]*Both pre- and post-earthquake*

Design/Construction Information

- ❑ Soils and Other Material Properties
- ❑ Seismic Design Evaluation
- ❑ Other ____________

Remarks ____________

DIR-014

Figure 9-6 Checklist for reporting dam performance during a seismic event

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Strong-Motion Data Summary

NATDAM ID: ____________________ Date: ______________________________

State ID: ____________________ Prepared By: ______________________

Dam Name: ______________________________________ Incident ID: ______________________

Earthquake Name: ____

Instrumentation

Type: ____

Manufacturer: ____

No. of Channels: Horizontal: _________ Vertical: _________ Date Installed: __________

Recorded Data[1]

Data Form: ____
(scaled from plots, uncorrected, processed/corrected, etc.)

Channel No.	Location	Direction	Peak Value Units ( )

[1] *Use additional pages as necessary*

DIR-015

Figure 9-7 Strong-motion data summary form

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Alternatively,

- If there are no strong-motion recordings obtained at the dam site, information (similar to that described above) on the nearest recording station within 20 km should be provided. In some instances there may be multiple recordings within 20 km. Data on each station should be provided.

The following paragraphs identify specific aspects of a dam or appurtenant structure response that should be documented for types of dams, foundations, etc. This guidance parallels the post-earthquake inspection guidelines published by USCOLD[5].

Embankment Dams - For earth and rockfill dams, information should be reported that documents the following aspects of the dam response to the earthquake:

- deformations in the dam and foundation
- dam and foundation pore water pressure
- damage due to seiche overtopping (if applicable)

The following summarizes the information that should be documented in these categories.

Deformations in the Dam and Foundation - The location and dimensions of deformations in the dam and foundation should be reported, including:

- crest settlement,
- crest movement upstream or downstream,
- slope movements (i.e., bulging, slumping, sliding, cracking),
- effects on slabs, parapet walls, if any, and
- ground offset or fault movement in the foundation.

If no discernible effects to the dam or foundation have been observed, this should be documented as well.

[5] *U.S. Committee on Large Dams, "Guidelines for Inspection of Dams Following Earthquakes, Denver, Colorado, August, 1983*

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Dam and Foundation Hydraulic Effects - The following should be reported:

- observed changes in seepage flow, locations and turbidity (provide measurements, if available),pore pressure changes observed in piezometers,
- occurrence of sinkholes or boils, or
- no discernible changes in seepage or pore pressure patterns.

Occurrence of a Seiche - If a reservoir seiche was directly observed or, if not observed, evidence of a seiche was present after the event, the following should be reported:

- maximum surge height of the reservoir,
- dam crest overtopping data, including depth and number of occurrences (if applicable), and
- damage experienced to the dam, appurtenant structures, reservoir rim, etc.

Concrete and Other Types of Dams

Movements in the Dam and Foundation - The locations and magnitudes of movements or signs of distress in the dam and foundation should be reported, including, but not necessarily limited to:

- mass movements upstream or downstream,
- mass settlement of the dam,
- tilting and differential movements,
- cracking or joint openings,
- ground offset or fault movement in the foundation, or
- no visible discernible effects.

Dam and Foundation Hydraulic Effects - The following should be reported:

- observed changes in seepage flows and locations (provide measurements, if available),
- pore pressure changes observed in piezometers,
- occurrence of sinkholes or boils, or
- no discernible changes in seepage or pore pressure patterns.

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Appurtenant Structures - Damage to concrete portions of spillways, intake structures, outlet conduits, outlet control structures, power plants, and pumping stations:

- Identify and describe the location and nature of damage (total collapse, cracking, settlement, movement, joint offsets or separations), mode of failure and possible causes.
- Identify effects of damage on the project operation.
- Describe any emergency action required to maintain dam safety or restore normal operation.

Damage to mechanical and electrical equipment including, but not limited to gates, valves, piping, trashracks, mechanical equipment (i.e., motors, generators) and supporting equipment such as fuel tanks, batteries, electrical substations and equipment:

- Identify and describe the location and nature of the damage to the above-listed facilities, the mode of failure and the possible causes.
- Identify effects of damage on project operations.
- Describe any emergency actions required to maintain project safety or restore normal operations.

☞ *Note: If no damage occurred to the appurtenant structures and equipment, this satisfactory performance should be documented.*

Post-Earthquake Actions - Immediately following the earthquake or the post-event inspection, the dam owner may be required to take significant actions related to the safety of the dam and/or downstream populations. These actions should be documented. They include, but are not necessarily limited to:

- drawdown of the reservoir,
- follow-up inspections and monitoring,
- emergency repairs, and
- implementation of emergency procedures, if any, and the results of those procedures.

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9.5 Follow-Up Reports

At the appropriate time, when additional information and the results of post-event investigations and/or repairs have been completed, please forward report(s) and/or other appropriate documentation covering the following topics:

- Recommendations made by state regulatory officials or outside consultants for follow-up investigations.
- Processed strong-motion records, if not available with the initial transmittal of data.
- Reports that document post-earthquake analyses of the dam response to the earthquake (field or laboratory tests and analytical studies).
- Documentation of revisions required to the design of the dam or appurtenant structures, or to emergency operating procedures or other aspects, as a result of the event.
- Information (reports, plans and specifications, published articles) concerning project damage incurred, modifications required to the dam and appurtenant structures, and related repair costs resulting from the effects of the earthquake.
- Reports on the response of the dam or appurtenant structures instrumentation (other than strong-motion recordings) to the earthquake.

Refer to Subsection 3.4 and Table 3-2 for general guidance on follow-up information that should be reported in the DIFR.

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Guidelines for Cooperation
with the
Alaska Dam Safety Program

Appendix I

A Role for Risk Assessment in Dam Safety Management

An excerpt from "A Role for Risk Assessment in Dam Safety Management," by D.S. Bowles, L.R. Anderson, and T.F. Glover in *Proceedings of the 3rd International Conference HydroPower '97,* Trondheim, Norway, June 30 – July 2, 1997.

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Proceedings of the 3rd International Conference HYDROPOWER '97, Trondheim, Norway, June 30 - July 2, 1997

A role for risk assessment in dam safety management

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ABSTRACT: In this paper we examine various factors which have lead to the trend for using the risk based approach to support dam safety decision making. The relationship between the standards based and risk based approaches is reviewed. Dam safety management is cast in the context of comprehensive risk management. The importance of defining the decision process, the role of decision criteria, and the involvement of owners and stakeholder in a "decision-driven" and staged risk assessment process is presented. The role of risk assessment in short term (emergency) dam safety decisions is addressed, in addition to long term decisions on meeting extreme events.

1 INTRODUCTION

Risk assessment is still a relatively new approach in the field of dam safety evaluation and decision making. When properly conducted it can provide valuable information which may not otherwise be available from conventional approaches. Quantitative examples include: estimated probabilities of dam failure and the consequences of failure; and estimates of risk reduction for various structural and non-structural rehabilitation alternatives. In addition, the process of conducting a risk assessment can provide qualitative benefits such as insights into the relative importance of various failure modes and loading types and ranges, and the potential value of additional analyses or field investigations. Even for high hazard dams, where tolerable risk considerations may lead to the adoption of "worst case" design (evaluation) events, the systematic risk assessment process can be useful as a quality assurance tool for identifying risk reduction options in the design of rehabilitation measures, project operation, or emergency action planning. Also, the open display of information obtained from a risk assessment can be a very useful means of conveying the implications of highly technical issues to non-technical owners and to the general public.

Dam safety management is intrinsically a problem in risk management and decision making under uncertainty. In the past we have tended to view dam safety as primarily an engineering problem. In many countries engineering standards approaches are leading to requirements for very costly remedial measures at existing dams. As a result, the underlying foundations for these standards are being examined and risk assessment approaches are being adopted to make explicit tradeoffs of risks, costs, and benefits. This leads us to ask the following questions. Are the standards based and risk based approaches incompatible? What is driving the trend towards risk based approaches? How should risk assessment approaches fit into the broad framework of dam safety decision making in a world in which regulations are becoming less prescriptive, dams are being moved from public to private responsibility, there is growing competition for financial resources, and the pubic is becoming more risk averse and wants to be more involved in decisions which affect their well being?

In this paper we seek to address these questions based on the current state-of-the-practice in dam safety risk assessment and our experience in performing such assessment for public and private sector clients in the USA and other countries. For a discussion of risk assessment procedures and several case studies the interested reader is directed to Bowles (1990).

2 COMPREHENSIVE RISK MANAGEMENT

As dam safety evaluation is to dam safety management, so is risk assessment to risk management. A comprehensive dam safety risk management program should include many other components in addition to risk assessment for evaluating existing dam safety and alternative remedial actions. These other components should include the following:

1. Provision of an appropriately designed, well maintained, and regularly exercised emergency warning system and emergency action plan.
2. A comprehensive monitoring and surveillance program with clear assignment of responsibilities for timely review and follow-up on collected data and reports.
3. A well trained operations and maintenance staff.
4. A well planned, adequately funded, and properly executed maintenance program.
5. Routine inspections and periodic in-depth inspections and comprehensive dam safety reviews and updates of any previously conducted risk assessments that are being relied upon for dam safety decisions.
6. An effective public consultation program.

All of these are important interrelated components in a comprehensive risk management program for any high hazard dam. Each is necessary for the proper exercise of duty of care of the owner and each should play a coordinated role in managing dam safety risks. A fragmentary approach to dam safety management can lead to overlooking the implications of information held in other program components. Dams are integral structures and their safety should be managed in a holistic manner (Perrow 1984).

The on-going aspects of a comprehensive dam safety program, such as monitoring and surveillance, should play an important and complementary role to periodic comprehensive dam safety reviews. Neither the engineering analysis tools that are used in these reviews nor the monitoring and surveillance programs provide perfectly accurate or complete insights into dam performance (Fanelli 1992). Analysis tools are based on idealized representations of complex structures and their foundations and must rely on estimates of materials properties and postulated loading conditions. Monitoring and surveillance of actual performance can be important in verifying the results of theoretical analyses. They can also provide valuable information where no analysis tools currently exist. However,

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monitoring and surveillance cannot always directly measure or observe the parameters which are of direct importance, and it takes time and expertise to make interpretations. Analysis tools must often be used as part of the interpretation process for monitoring data, or for predicting the limits of acceptable behavior against which satisfactory performance is judged. Thus in an overall risk management program both on-going observations and on-going analysis are important for developing confidence that a dam is, or is not, performing satisfactorily. Observations and analyses complement each other, and neither can be entirely substituted for the other.

It is normal practice to perform comprehensive dam safety reviews approximately every five years (ICOLD 1987). In part, the purpose of such reviews is to assess the effects on dam safety of any changes in technical standards or the state-of-the-art. If a risk based approach is adopted, the risk assessment should be updated as part of the comprehensive review. Any changes to risk assessment inputs, such as loading conditions, factors that would affect predicted performance of the dam, the consequences of failure, or other operational outcomes should be updated. In this way a risk assessment becomes a "living document" which can be used by decision makers to periodically reassess their current duty of care position in light of changing business considerations, evolving community values, and other factors.

3 TREND TOWARD RISK BASED APPROACH

Interest in the potential for applying risk based approaches to dam safety decision making has accelerated in the last two decades. An increasing number of organizations have begun to routinely use risk based approaches in dam safety evaluation. These now include the U.S. Bureau of Reclamation (Von Thun and Smart 1996), the Government of South Africa (Oosthuizen et al 1991), the Government of the Netherlands (CUR 1990), various Australian dam owners and regulators (SMEC/RAC 1995), and B.C. Hydro (1993). Many other organizations are actively considering using the risk based approach.

Some factors which have lead to the increasing use of risk based approaches are common to dam owners and operators in different countries. They include the following:

1. The absence of functional features, which are now considered to be the state-of-the-art in dam design, but which were not incorporated in many existing dams (e.g. downstream filters in embankments to dissipate pore pressure in the event of significant seepage).

2. The greater magnitude of extreme (worst case) evaluation (design) flood and earthquake events (i.e. PMF and MCE, respectively), which are prescribed using today's standards based approaches, compared with those for which existing dams were designed, or are capable of accommodating.

3. The high cost of correcting state-of-the-art and extreme event "deficiencies", which has lead to questions the justification for the standards, cost effectiveness, and due diligence from a legal and overall business perspective.

When considering the need for remedial works to address state-of-the-art "deficiencies" under a risk based approach, the goal should be to confidently predict that the dam will perform satisfactorily under a full range of loading conditions. Satisfactory performance can be defined using tolerable

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risk criteria such as those summarized in Section 6.

One of the following four outcomes could result from a risk based evaluation of an existing dam with state-of-the-art and extreme event "deficiencies":

1. Accept the existing dam, without modification, if it can be demonstrated, with sufficient confidence, that the existing dam can be expected to perform satisfactorily, even though it might not meet current standards.

2. Modify the existing dam, so that the modified dam would be expected to perform satisfactorily, with sufficient confidence, but not necessarily to current standards.

3. Remove and reconstruct the dam, so that the new dam would be expected to perform satisfactorily, with sufficient confidence, and meet current standards.

4. Decommission the dam so that it no longer poses a threat to downstream populations at risk.

The costs and risks associated with the drastic action of removing an existing dam and reconstructing it would often be unacceptably large, and the resulting benefits might be questionable or difficult to prove. Nevertheless, in some cases this may be the only way to achieve the goal of satisfactory predicted performance with sufficient confidence.

Satisfactory performance under loading conditions that are within the range experienced at an existing dam, may be demonstrated through a combination of monitoring, surveillance, and engineering analysis. For extreme floods, earthquakes, and static loading conditions, which are outside of the range that has been experienced since a dam was constructed, the sole use of monitoring and surveillance to demonstrate satisfactory performance is problematic. However, testing of material properties, structural and stability analyses, and the transfer of experience from similar dams can all be used to predict performance under extreme loading conditions.

The degree of confidence in performance predictions can often be improved with additional testing, monitoring, and analysis. Risk based approaches focus on predicting dam performance and the confidence (or uncertainty) associated with these predictions. In contrast, the sole use of traditional approaches emphasizes factors of safety and compliance with standards provides only vague indications of the level of confidence that is being attained in achieving satisfactory performance. Thus it is seldom clear if the level of confidence is unjustifiably excessive or undesirably small.

The magnitudes of extreme evaluation events have increased over the past few decades for various reason, including the following:

1. The "unknowable" nature of worst case events.

2. Changing methodologies which tend to produce increasingly more conservative design events.

3. Difficulty in determining the plausibility of combinations of contributing factors used to calculate worst case events (e.g. very small loss rates coinciding with worst case precipitation to define a probable maximum flood event).

4. The tendency for design professionals to favor more conservative definitions of worst case events.

5. An improved understanding of the potential for inadequate performance of dams and their foundations under dynamic seismic loads.

A danger of focusing dam safety studies on worst case scenarios is that deficiencies associated with lower magnitude, more

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frequently occurring, loading conditions, may be given too little attention. Thus, by focusing on the most unlikely fraction of one percent of the event magnitudes, one might overlook the range of events which are much more likely to cause failure of an existing dam. An example would be focusing on the capability of a spillway to cope with a PMF while deficiencies under static (water) loads are given little attention.

4 STANDARDS *V.* RISK BASED APPROACHES

We use the term, "standards based approach", to refer to the approach to design and evaluation of dams in which a satisfactory safety condition is defined by either: a) compliance with prescribed performance measures or loading conditions; or b) use of the current state-of-the-art (or practice), meaning the generally accepted present-day approach to dam design, evaluation, and construction.

The term, "risk based approach", is used to refer to the approach to design and evaluation of dams in which an acceptable safety condition is defined using information provided from a risk assessment and other decision inputs. Risk assessment is a systematic process, wherein experienced dams engineering professionals, provide decision maker(s) with estimates of the risks and associated uncertainties of system responses, outcomes, and consequences, which characterize the performance of an existing dam and various remedial action alternatives, under a full range of loading conditions.

It might appear that the choice between a standards based *v.* a risk based approach is between a "clear cut" standards approach, and a risk based approach which might lead to the acceptance of a higher risk of failure than would be the case under the standards approach. However, a standards based approach is not necessarily as clear cut as it might first appear. For example, under the standards based approach professional opinions and practice can vary over the selection of appropriate design criteria. A standards based approach does not ensure a "zero risk" solution to a dam safety concern. Furthermore, a standards based approach involves "blind" risk tradeoffs whereas these tradeoffs can be made more explicit under the risk based approach. If a purely standards based approach is used, it is unlikely that the implied risk tradeoffs will be understood by the decision makers, their technical advisors, other stakeholders, and their legal and financial advisors. In contrast, a properly conducted and well communicated risk assessment can be expected to provide all parties with valuable understanding and insights into these potential risk tradeoffs. In addition, risk assessment can be expected to provide: a basis for prioritizing remedial works; a clearer picture of the potential benefits of non-structural measures, such as emergency warning systems; and a basis for deciding on temporary operating restrictions.

In some cases the outcome of a risk assessment could be a decision to adopt standards based design criteria. In fact, the standards based approach can be thought of as a prescribed point on a continuum of different performance standards or design (evaluation) loading conditions. The risk based approach can be readily used to examine a range of these performance measures or loading conditions to evaluate the effects on reliability, consequences, cost effectiveness, and due diligence, of deviating from the standards based approach. In this way the risk based approach can be used to explore the

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appropriateness of a standards based approach. Sole use of a standards based approach without risk assessment can lead to the adoption of design criteria which might be unjustifiably conservative or lax for a particular dam.

There is an important difference between the way in which the standards and risk based approaches treat different worst case event estimates. The standards based approach tends to treat less conservative and more conservative estimates of evaluation events without recognition that they differ in their likelihood of occurring. In the risk based approach smaller probabilities of occurrence (annual exceedance probabilities) can be associated with more conservative estimates of extreme events. In this way, risk assessment provides a framework within which differences in the degree of conservatism in extreme event estimates can be accounted for in selecting and justifying an evaluation event for a particular dam. This can be done using the joint probability distribution for the occurrence of various contributing factors which define an evaluation event (e.g. initial reservoir level and antecedent moisture levels for a flood event). It also provides a means for quantifying the uncertainties that exist in defining worst case event scenarios. Other benefits of using a risk based approach are presented in Bowles (1996b) and Bowles (1987).

5 DEFINING THE DECISION PROCESS

In our experience it is important to clearly define the decision process that will be used to make a dam safety decision. Ideally this should be done before a risk assessment is commenced so that the risk assessment can be designed, in consultation with the stakeholders, to provide information inputs that will be useful at each stage in the process, and on an agreed-upon schedule. The National Research Council (1996) refers to this type of approach to risk assessment as "decision driven". Adopting such an approach will provide a basis for appropriate and justifiable limits on the level and detail of risk assessment efforts. This is important since there is virtually no end to the amount of effort which could be put into a detailed risk assessment. It is therefore important to remember that risk assessment should become an end in itself; the end should be a quality, well communicated and highly defensible dam safety decision.

In clearly defining the decision process the following questions should be addressed:

1. Who are the decision makers?

2. What will be the role for community consultation and for the various stakeholders in the decision process?

3. What decision criteria will be used by the decision makers? This should include an evaluation of the entire framework in which the dam safety decision will be made including regulatory, legal, financial, business, economic, environmental, social, and other considerations.

4. What information from risk assessment is needed by the decision makers and stakeholders throughout the decision process?

6 DECISION CRITERIA

Various criteria can be useful to judge results from a risk assessment when a long term dam safety decision (Bowles 1996a) is to be made (for a short term decisions see Section 9). They include life safety, economic, and other types of criteria. Care must be taken that the selected criteria are consistent with the dam

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safety decision framework and that they serve the dam safety decision process which is identified at the outset of the risk assessment (see Section 5). A search for internationally applicable dam safety risk criteria could result in criteria which do not serve all dam owners in all countries equally well. This is particularly true if, as is often the case with a strict standards approach to accommodating extreme events, the focus is on selecting and meeting a criterion, rather than prioritizing a sequence of risk reduction measures, giving consideration to the cost effectiveness of each measure.

Life safety is always an important consideration. It can be evaluated using both societal and individual tolerable risk criteria such as those in the ANCOLD (1994) Guidelines on Risk Assessment and by B.C. Hydro (1993). Societal criteria are commonly expressed as F-N curves of cumulative frequency, F, of life loss exceeding various magnitudes, N. It provides a means of judging the scale of potential life loss from individual failure modes, or combinations of failure modes, for a single dam. Overall life loss can also be evaluated against an expected annual life loss criterion as in USBR (1997). In either case it is still important to evaluate individual life safety criteria to assess the potential for individuals to be excessively exposed to the risk of dam failure.

Public and private investments are typically evaluated against a benefit/cost or rate of return criterion. Dam safety projects seldom fair well in such evaluations because the probability of failure is often small and thus the expected benefits are very small relative to the certain investment of capital and maintenance funds. Out of more than seventy dam safety risk assessments that we have completed only one has shown a benefit/cost ratio greater than unity. Benefit/cost ratios could be increased by adding a value for human life to the assessment of benefits. However, we feel that this raises serious ethical and moral issues and we do not recommend such an approach to evaluating the benefits of increased public safety.

We have found that a useful approach to considering the benefits of increased public safety is to evaluate the cost effectiveness of structural and non-structural alternatives. This can be done by calculating a cost-per-life-saved for each alternative and comparing these with similar costs for other facilities which expose the public to risk of life loss. By pursuing alternatives with costs-per-life-saved which are less than those in these other fields, an owner is at least being consistent with the extent to which these other field invest in public safety. Care must be exercised in selecting fields in which risks are similar in nature to those created by dams. The U.S. Office of Management and Budget (OMB 1992) argued that the cost effectiveness approach is a "sensible" way to justify the investment of federal government dollars, or private funds as the result of regulations, in public health and safety measures.

Cost effectiveness measures can also provide a very useful basis for prioritizing dam safety investments such that those which are expected to result in the greatest reductions in risk for a given level of available funding are undertaken first. When this approach is applied to a portfolio of dams it should maximize the rate of (public) risk reduction to which the dam owner is exposed. Typically one can expect that such an approach to prioritization will lead to a high priority being given in a dam safety program to implementation of early warning system (EWS). In this case EWSs would not necessarily be used as a substitute for

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structural options, but as an early and typically very cost effective step in improving public safety. If structural measures are subsequently implemented, an EWS might be retained as a supplement to structural measures.

In addition to these life safety and economic criteria, consideration should be given to financial, business, legal, and other factors which the owner and other stakeholders must take into account in their decision process. This should include an appropriate role for community consultation in the overall decision process so that the dam owner meets its social responsibilities as well as its business objectives and regulatory requirements.

7 STAGED APPROACH TO RISK ASSESSMENT

Much of the information needed to perform a risk assessment is commonly developed in the course of a traditional periodic comprehensive dam safety review. However, some additional work is always required to provide the necessary inputs for a risk assessment. The amount of additional work depends on the scope and level of detail of the risk assessment.

In conventional engineering analysis it is common practice to select parameters conservatively. In performing these analyses to provide inputs to risk assessment, it is usually desirable to rerun these analyses using best estimates of parameters to obtain realistic performance predictions. Also, it may be useful to analyze steps,partially failed sections in the case of progressive failure mechanisms that would be expected to result from foundation liquefaction, for example. In addition, sensitivity analyses using ranges of values for key input parameters, can provide valuable information upon which to base risk assessment inputs and judgements that experienced engineers are expected to make in conducting risk assessments.

We advocate using a staged approach to risk assessment. Under this approach, later more detailed stages are performed only if warranted by the potential value added to the dam safety decision making process through reductions in the level of uncertainty in risk assessment outputs. More detailed stages of risk assessment usually require that more detailed inputs be obtained from additional field investigations, testing, or engineering analyses. Before proceeding with a more detailed risk assessment, the extra cost that it will entail should be weighed against the expected improvement in the quality of the decision that is to be made using risk assessment outputs. This another example of making dam safety risk assessment a "decision driven" activity.

8 OWNER AND STAKEHOLDER INVOLVEMENT

We have had direct experience with involving water users groups, regulators, owners, operators, legal advisors, senior management, and politicians in the dam safety decision process using risk assessment. So far our involvement with community groups has been mainly through our clients. However, we have found that in most cases the understanding provided by the systematic and transparent risk assessment process has been acclaimed by all parties. In our experience it has been important to involve these groups throughout the process and not just in a presentation of a final report. Such a process of continual involvement presents communications challenges and one must be

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careful in presenting preliminary risk assessment results to lay audiences. Credibility can be shaken if significant changes occur in these results in later stages of the risk assessment. Of course similar difficulties can exist with a standards based approach if conclusion based on preliminary analyses are made public and significantly different conclusions are released after additional analyses are completed. The open and honest communication of uncertainties is highly recommended. Also it is recommended that the technical risk assessment team enlist the assistance of experts in risk communication and community consultation.

Where they exist, community consultation requirements contained in environmental impact assessment processes might be used to provide for community consultation in dam safety decision making. However, care should be taken to avoid diluting dam safety issues.

We have repeatedly found that it is difficult for lay people, and in many cases technical people, to have a holistic and balanced perspective on dam safety issues when a purely standards based approach is used. The difficulty is that the standards approach often masks the true nature of dam safety management which is intrinsically a problem in risk management and decision making under uncertainty. When a standards approach is used, there is a danger of misleading the public into thinking that the adoption of standards based design (evaluation) criteria will provide absolute protection against the risk of dam failure (i.e. zero risk). This is obviously false and the fact that dams that have been built to meets standards have failed proves the point. Even though following a risk based approach presents challenges in risk communication, we have found that the additional effort is well worthwhile considering the benefits of sharing a more complete and honest picture of the true risks and uncertainties that are inextricably associated with dam safety decisions. This has been repeatedly borne out by client testimonials such as Waite (1989).

9 LONG TERM AND SHORT TERM DECISIONS

Dam safety risk assessments have most commonly been conducted to provide inputs to long term decisions on the level and priority of remedial works needed to meet extreme events. Risk assessment can also be used to provide useful inputs to short term decisions, including emergencies and the need for reservoir operating restrictions (for example, USBR 1996). Three time frames can be distinguished for such decisions:

1. Prior to construction of remedial works;
2. During construction of each phase of remedial works; and
3. At the completion of each phase of remedial works.

The outcome of these short term decisions can be used to establish reservoir level restrictions during each phase of remedial work, and perhaps the timing of the works with respect to seasonal reservoir inflows. At the completion of each phase of remedial works, risk assessment can be used to provide inputs to the decision to allow increased reservoir levels as a result of the additional margin of safety added by those remedial works.

In long term decision applications of risk assessment the emphasis is on balancing risks, costs and benefits over a long period of time when selecting an appropriate level of protection against extreme events. When using risk assessment in support of short term decisions the concern is for the immanent

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development of a failure condition. In this case the long term time frame cannot be counted on for balancing risks, costs and benefits. We suggest that when used in support of short term decisions, risk assessment should be used for the following primary purposes:

1. To identify the relative risk (likelihood and consequences) of potentially immanent failure modes; and

2. To reduce the risk of each failure mode through a) management actions (e.g. reservoir operating restrictions, emergency repairs); b) improved detection of worsened conditions that could lead to failure; c) contingency planning covering all aspects of the owner's responsibilities, including the decision and notification steps that lead to initiating a downstream evacuation; and d) coordination of contingency planning with the local authorities who are responsible for evacuation.

It must be stressed that the use of risk assessment in support of short term decisions must not delay taking immediate emergency action, when such action is prudent and necessary. However, we believe that, even when immediate action has been taken, risk assessment can be used to help guide the on-going decision process. Benefits of this use of risk assessment in this short term context include the following:

1. Understanding of the development of event sequences which might lead to immanent failure.

2. Assessment of the need for additional instrumentation to identify changed conditions.

3. Identification of critical values of performance parameters for initiating additional investigation or emergency action.

4. Assessment of the benefits of various short term actions such as reducing reservoir levels, or improving response times for making emergency releases.

5. Assessment of the adequacy of warning time and ways to increase warning time and its reliability.

10 CONCLUSIONS

We have stated that the true nature of dam safety management is intrinsically a problem in risk management and decision making under uncertainty. In a world in which regulations are becoming less prescriptive, dams are being moved from public to private responsibility, there is growing competition for financial resources, and the pubic is becoming more risk averse and wants to be more involved in decisions which affect their well being, the continuous risk management framework can provide a valuable approach to meeting these challenges. The risk management approach should treat dams as integral structures whose safety should be managed in a holistic manner. It should also take into account the uncertainties which exist as a result of the current limitations in our capabilities to predict and monitor dam performance.

Risk assessment is a component of the risk management approach. It provides the opportunity for engineering inputs to be considered along side the many other factors that owners and others must consider when making dam safety decisions. In our experience it is important to clearly define the decision process that will be used. Adopting a "decision driven" approach to risk assessment will provide a basis for appropriate and justifiable limits on the level and detail of risk assessment efforts with the goal of reaching a quality, well communicated and highly defensible dam safety decision.

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In some situations the funds needed to meet extreme event standards simply do not exist. In many other cases reliance on a purely standards based approach does not provide adequate justification to convince lay decision makers of the need to meet these standards and a "stalemate" has resulted. We do not argue with the desirability, and even the necessity, of meeting extreme event standards in many cases. However, we observe so many cases in different countries, in which no risk reduction has been accomplished even though it is well recognized that standards are not being met. We suggest that in many cases the focus should be on identifying and justifying the next most cost effective risk reduction steps rather than waiting to meet an extreme event standard. In addition, correcting for all state-of-the-art "deficiencies" is often impracticable and must be addressed by risk management rather than structural approaches. The irony is that even when expensive works are completed to meet standards, a dam may remain much more at risk to the malfunctioning of gate systems, to inadequately trained operators, or to the absence of a properly maintained early warning system, than it was to undercapacity of a spillway, for example. Of course each case must be individually evaluated, and as we have sought to emphasize, in some cases standards based solutions will be justified. When properly implemented, risk assessment can serve as a valuable tool within a comprehensive risk management framework for effective dam safety management. We further suggest that such a comprehensive and systematic approach is necessary for the proper exercise of duty of care of a dam owner and to assist in meeting due diligence.

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Guidelines for Cooperation
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Appendix J

Example of a Simple Decision Matrix

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Table

a) Factors Affecting Survivability

Geomembrane Type	Available Thickness (mils)	TENSILE PROPERTIES*		Test Method	Data Source
		Strength (psi)	Elongation (%)		
HDPE	30-120	3800	600	ASTM D 638	National Seal Company product literature
VLDPE	20-100	3500-3700	1000	ASTM D 638	Poly-America, Inc. product literature
CSPE**	36-60	5400-5700	17	FTMS 191-5102	Koerner(1990), Seaman Corporation product literature
PVC	20-60	2300	350	ASTM D 882	Watersaver Co., Inc. product literature
URETHANE**	33	6700	20 (est.)***	FTMS 191-5102	Cooley, Inc. product literature
XR-5**	30-40	13000	20	FTMS 191-5102	Seaman Corporation product literature
SHELT. 8218**	18	7800	20 (est.)***	FTMS 191-5102	Seaman Corporation product literature

* Tensile properties measured at break.
** Scrim reinforced.
*** Elongation not reported, but estimated value is typical of scrim reinforced geomembranes.

NOTES: 1) Test data are from narrow strip tensile tests. Results may vary for other sample geometries.
2) Reported property values are affected to a degree by the test method used to measure them. Since test methods are not consistent from one manufacturer to another, caution should be used in comparing test results.

b) Survivability Rating

Geomembrane Type	Thickness		Tensile Strength		Elongation		TOTAL SCORE		RATING
	Score	Weight	Score	Weight	Score	Weight	Unweighted	Weighted	
HDPE	1.00	2	0.29	2	0.60	1	1.89	3.18	1
VLDPE	0.83	2	0.28	2	1.00	1	2.12	3.24	1
CSPE	0.50	2	0.44	2	0.02	1	0.96	1.89	3
PVC	0.50	2	0.18	2	0.35	1	1.03	1.70	3
URETHANE	0.28	2	0.52	2	0.02	1	0.81	1.60	3
XR-5	0.33	2	1.00	2	0.02	1	1.35	2.69	2
SHELT. 8218	0.15	2	0.60	2	0.02	1	0.77	1.52	3

NOTES: 1) Score for each category was obtained by dividing the maximum property value for the individual geomembrane by the maximum property value for all geomembranes.
2) Weighting factors are based on a subjective evaluation of the relative importance of the various properties. Other justifiable weighting factors could result in different ratings.