D.3. Mine Safety and Health Administration
30 CFR § 56.20010
Retaining dams.

If failure of a water or silt retaining dam will create a hazard, it shall be of substantial construction and inspected at regular intervals.
DEPARTMENT OF LABOR
Mine Safety and Health Administration

30 CFR Parts 56 and 57

RIN 1219-AB70

Metal and Nonmetal Dams

AGENCY: Mine Safety and Health Administration, Labor.

ACTION: Advance Notice of Proposed Rulemaking (ANPRM).

SUMMARY: Dam failures at metal and nonmetal mines have exposed miners to life-threatening hazards. The Mine Safety and Health Administration (MSHA) is reviewing its existing metal and nonmetal standards for dams. The Agency is concerned that some dams pose hazards because they are not designed, constructed, operated, and maintained to accepted dam safety practices. MSHA is considering approaches to better protect miners from the hazards of dam failures and is soliciting information to help determine how best to proceed.

DATES: Comments must be received by midnight Eastern Daylight Saving Time on October 12, 2010.

ADDRESSES: Comments must be identified with “RIN 1219-AB70” and may be sent to MSHA by any of the following methods:


2. Electronic mail: zzMSHA-Comments@dol.gov. Include “RIN 1219-AB70” in the subject line of the message.


MSHA will post all comments on the Internet without change, including any personal information provided. Comments can be accessed electronically at http://www.msha.gov under the “Rules and Regs” link. Comments may also be reviewed in person at the Office of Standards, Regulations, and Variances, 1100 Wilson Boulevard, Room 2350, Arlington, Virginia. Sign in at the receptionist's desk on the 21st floor.

MSHA maintains a list that enables subscribers to receive e-mail notification when the Agency publishes rulemaking documents in the Federal Register. To subscribe, go to http://www.msha.gov/subscriptions/subscribe.aspx.

FOR FURTHER INFORMATION CONTACT: Patricia W. Silvey, Director, Office of Standards, Regulations, and Variances, MSHA, at silvey.patricia@dol.gov (E-mail), 202-693-9440 (Voice), or 202-693-9441 (Fax).

SUPPLEMENTARY INFORMATION:

I. Background

MSHA's database contains information on nearly 2000 dams at metal and nonmetal mines. Mine operators have constructed these structures for various purposes, such as disposing of tailings or mine waste, processing minerals, treating or supplying water, and controlling run-off and sediment. Although many of these dams are designed, constructed, operated, and maintained according to accepted dam safety practices, others are not and dam failures and near failures continue to occur.

Since 1990 to the present, MSHA investigated dam failures at metal and nonmetal mines in virtually every region of the country and at small and large operations. Failures or near failures have occurred at copper, phosphate, sand and gravel, trona, gypsum, and limestone mines, among others. Failures have damaged property and equipment, but no deaths or serious injuries have occurred. Examples of dam failures include:

- A 1990 failure of a 100-foot high dam at a limestone mine in Puerto Rico released over 10 million gallons of water and tailings. The failure flooded eight lanes of a major highway, depositing tailings up to eight feet thick. The dam failed about 2 a.m. when no miners were present. The mine operator did not use an engineer to design the dam; several design and construction deficiencies, such as poor compaction, steep slopes, and absence of internal drains, contributed to the failure.

- A 70-foot high tailings dam failed at an andesite quarry in Wisconsin in 1992, tearing apart a railroad track and leveling a power line at the mine. The dam failed at 3 a.m. when no miners were present. The dam was not designed by an engineer. After a
The existing requirements for dams at metal and nonmetal mines, 30 CFR 56.20010 and 57.20010, are derived from the Metal and Nonmetal Mine Safety Act of 1966. The standards state: “If failure of a water or silt retaining dam will create a hazard, it shall be of substantial construction and inspected at regular intervals.” The standards promulgated for coal mines under the Federal Coal Mine Health and Safety Act of 1969 were similar, but specified that the mine operator inspect the dams at least once per week and record the inspection findings.

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The requirements for coal mines were revised in 1975 after the Buffalo Creek dam failure. For dams which can present a hazard or are of a certain size, the existing standards require a coal mine operator to:

- Have a registered professional engineer certify the dam's design;
- Develop plans for the design, construction, maintenance, and abandonment of the dam and have the plans approved by MSHA;
- Have a qualified person inspect the dam weekly;
- Have instrumentation monitored weekly;
- Correct any hazardous conditions and make required notifications; and
- Submit an annual report with a registered, professional engineer's certification that construction, operation, and maintenance of the dam have been in accordance with approved plans.

11. Key Issues on Which Comment Is Requested

MSHA is asking interested parties to comment on measures to assure that mine operators design, construct, operate and maintain dams to protect miners against the hazards of a dam failure.

MSHA seeks comments on the questions below. If a commenter refers to a particular dam as an example, please identify the mine, or provide the number of miners and the mine's commodity. Also, include the dam's storage capacity, height, and hazard potential and characterize its complexity. Provide enough detail with the comments that the Agency can understand the issues raised and give them the fullest consideration. Comments should include alternatives, rationales, benefits to miners, technological and economic feasibility, impact on small mines, and supporting data. Please include any information that supports your conclusions and
recommendations: Experiences, data, analyses, studies and articles, and standard professional practices.

General Questions

1. MSHA is seeking information concerning current dam safety practices at metal and nonmetal mines. What measures do mine operators currently take to design, construct, operate, and maintain safe and effective dams? What measures do mine operators currently take to safely abandon their dams? For mine operators with dams, please provide your experiences.

2. MSHA is required to inspect every mine in its entirety, which includes dams of all sizes and hazard potential. A common approach for dam safety is to have tiered requirements based on a dam's size and hazard potential. How should MSHA determine safety requirements based on a dam's size and hazard potential? Please include specific recommendations and explain your reasoning.

3. What non-Federal authority regulates the safety of dams at metal and nonmetal mines in your state, territory, or local jurisdiction? Please discuss the specific requirements, including the principles that they address. If possible, please provide information about relevant non-Federal dam safety requirements through a hyperlink or other means.

4. What records should be kept of activities related to the safety of dams? Please be specific and include your rationale. What records should be provided to miners if hazardous conditions are found?

Design and Construction of Dams

MSHA's existing standards do not include specific requirements for design of dams. MSHA found that inadequate design contributed to some of the metal and nonmetal dam failures. In responding to the following questions, please discuss how any requirements should vary according to the size or hazard potential of a dam, and why.

5. How should mine operators assure that dams are safely and effectively designed? Please suggest requirements that MSHA should consider for safe design of dams. Please be specific and include your rationale.

6. Please suggest requirements for review of dam designs by mine operators and MSHA and include your rationale for specific recommendations and alternatives.

7. With new standards, operators may need to evaluate and upgrade existing dams. Please elaborate on how the safety of existing dams should be addressed.

8. MSHA's existing standards for dams at metal and nonmetal mines do not address whether a dam is constructed as designed. What measures are necessary to ensure that mine operators construct dams as designed?

9. How should MSHA verify that dams have been constructed as designed? Please explain your rationale.

Operation and Maintenance of Dams

MSHA's existing standards do not contain specific requirements addressing the operation and maintenance of dams.

10. What should a mine operator do to operate and maintain a safe dam? How should MSHA verify that dams are safely operated and maintained? Please be specific.

MSHA's existing standards require dams to be inspected at regular intervals if failure would create a hazard. Inspections can identify hazardous conditions, allowing a mine operator to take corrective action to prevent a failure. The Agency will be referring to two types of inspections in this document, "routine" and "detailed." Mine operators should perform frequent, routine dam inspections, which may include monitoring instrumentation, to identify unusual conditions and signs of instability. Personnel with more specialized knowledge of dam safety should conduct detailed inspections to identify less obvious problems and evaluate the safety of the dam. Detailed inspections, occurring less often, would include an examination of the dam and a review of the routine inspections and monitoring data. The Guidelines recommend that inspection personnel be qualified for their level of responsibility and trained in inspection procedures.

11. What measures should mine operators take to assure that dams are adequately inspected for unusual conditions and signs of instability?

12. How often are routine inspections of dams conducted? How often should they be conducted? What determines the frequency? Who conducts the routine inspections? Please be specific and include your rationale.

13. Instruments, such as weirs, provide information on the performance of a dam. How frequently should mine operators monitor dam instrumentation? Please provide your rationale.

14. What information should be documented during routine dam inspections? Please provide your rationale.

15. Does a competent engineer inspect your mine's dam? If so, at what frequency? Please explain the rationale for these
inspections and what is evaluated.

16. How often should detailed inspections be conducted? Please include your rationale.

17. What information and findings should be documented during detailed dam inspections? Please be specific and include your rationale.

18. How should MSHA verify that mine operators conduct routine and detailed inspections? Please explain how your suggestion would work.

Qualifications of Personnel

A mine operator is responsible for the design, construction, operation, and maintenance of dams. For an effective dam safety program, an operator must use personnel who are knowledgeable about dam safety.

19. What qualifications do mine operators currently require of persons who design, inspect, operate, and manage dams? In what capacities are engineers used? Please be specific in your response.

20. The Guidelines recommend that dams be designed by competent engineers. What specific qualifications or credentials should persons who design dams possess? Please include your rationale.

21. The Guidelines recommend that a dam be constructed under the general supervision of a competent engineer knowledgeable about dam construction. What specific qualifications or credentials should a person have who verifies that a dam is being constructed as designed? Please provide your rationale.

22. What training should personnel receive who perform frequent, routine inspections and who monitor instrumentation at dams? In your response, please suggest course content and the frequency of the training, including the rationale for your recommendations.

23. What qualifications or credentials should be required of persons who perform detailed inspections to evaluate the safety of a dam? Please be specific and include your rationale.

Abandonment of Dams

24. Some regulatory authorities require that dam owners obtain approval of a plan to cap, breach, or otherwise safely abandon dams. What actions should mine operators take to safely abandon dams? Please include specific suggestions and rationale.

25. How can MSHA verify that a mine operator has safely abandoned a dam?

Economic Impact

MSHA seeks information to assist the Agency in deriving the costs and benefits of any regulatory changes for dams at metal and nonmetal mines. In answering the following questions, please indicate the dam's storage capacity, height, and hazard potential and characterize the complexity of each dam referenced. Also, please include the state where each dam is located, and the number of employees at the mine.

26. What are the costs of designing a new dam? Please provide details such as hours, rates of pay, job titles, and any contractual services necessary. How often is the design of an existing dam changed? What are the costs of a redesign?

27. What are the costs of constructing a dam? Please provide details based on: Size of dam; labor costs, including hours, rates of pay, job titles; costs of equipment and materials; and any contractual services necessary.

28. Please describe the oversight you provide during dam construction to assure it complies with the design plan. How much does it cost per year per dam for oversight and quality control? What special knowledge, qualifications, or credentials do you require of those who provide oversight?

29. How often do you add height to an existing dam or modify it in some other way? Who supervises the design and construction of these modifications, for example, a professional engineer, competent engineer, contractor, etc? Please be specific and provide rationale for your answer. How much does it cost? Please provide details such as labor costs, including hours, rates of pay, job titles, and costs of equipment and materials and any contractual services necessary.

30. How much does it cost per year per dam for routine inspections? If you incur separate costs for monitoring instrumentation, how much is that cost? How often do you have a detailed inspection conducted? How much does it cost per year for these inspections?

31. Does the state or local jurisdiction in which you operate require you to use a professional engineer? If so, when is a professional engineer specifically required? (If you have dams in more than one state please identify which states require a professional engineer and which do not).
32. What are the costs associated with training personnel who conduct frequent, routine inspections and monitor instrumentation at dams?

33. What costs are involved in capping, breaching, or otherwise properly abandoning a dam? Please provide details of your experience and what was involved when you properly abandoned a dam. Describe any impact of a properly abandoned dam.

34. What are the costs to a mine operator if a dam fails? Please characterize other impacts such as loss of life, environmental damage, etc.

35. Do you have insurance against a dam failure? If so, please specify cost and coverage. Does the insurance carrier require the use of a professional engineer for specific dam activities? If a professional engineer is not required, does the insurance carrier give a discount if one is used? Does your insurance company have any other requirements related to dam safety?

36. What quantifiable and non-quantifiable costs and benefits for the downstream community are involved when a dam is properly designed and constructed? In addition, MSHA welcomes comments on other relevant indirect costs and benefits.

Dated: August 9, 2010.

Joseph A. Main,
Assistant Secretary of Labor for Mine Safety and Health.

[FR Doc. 2010-19960 Filed 8-12-10; 8:45 am]
BILLING CODE 4510-43-P
D.4. National Park Service
This guideline provides an outline of responsibilities for NPS personnel in the planning, design, preservation, rehabilitation/construction, maintenance and operation, inspection, acquisition or disposal of dams under NPS management. Instructions on recommended coordination with local officials and non-NPS dam owners are given also: It is not intended as a technical manual but as a management guideline. A list of recommended technical references is provided in Appendix B.

Application of the guideline by NPS personnel should be commensurate with each dam's size, complexity, operational importance, hazard potential classification, and ownership. Inquires about the application of the guideline may be made to the park, regional, or Washington Office NPS Maintenance, Operation, and Safety of Dams (MOSD) Program coordinators.
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CHAPTER ONE
INTRODUCTION

A. General

Dams and their appurtenant works represent a valuable resource to the National Park System and require careful management. The purpose of this guideline is to outline management responsibilities for the preservation/maintenance, operation, and safety of dams under NPS jurisdiction as respectively required by Statute 16 U.S.C. 1 and Departmental Manual Part 758.

These responsibilities include, but are not limited to, planning, design, preservation, rehabilitation/construction, maintenance and operation, inspection, acquisition or disposal of dams under NPS management, and coordination with local officials.

The guideline is not intended as a standard for technology of dams. Current references dealing with the technology of dams and appurtenant works are provided in Appendix B. The guideline may be used, as appropriate, when coordinating with non-NPS dam owners.

Application of this guideline by Regional Directors, Superintendents, and Manager, Denver Service Center (DSC), should be commensurate with each dam's size, complexity, operational importance, hazard potential, and ownership.

Non-NPS dams also will be monitored carefully and information about them kept within the NPS inventory data base management system. These are dams and appurtenant works for which NPS managers have no direct operational responsibility; but where their failure or misoperation could have a definite effect on park safety or operations. Regional Directors and Superintendents will request observer status during inspections and in the preparation and review of emergency action plans at non-NPS dams that significantly affect park areas. A list of such dams is available in the most current NPS Inventory of Dams, Appendix A.

The NPS Park Facility Management Division has overall responsibility for the coordination of the Maintenance, Operation, and Safety of Dams (MOSD) Program; however, there are many NPS programs—land acquisition, cultural resources management, design, construction, law enforcement, security, and public safety that are closely interrelated and should be properly coordinated. A qualified engineer should be assigned by each Regional Director to assure the implementation of all appropriate portions of this guideline when a major action is undertaken in the acquisition, advance planning; preservation/design/construction formal inspection, or disposal of either high (1) or significant (2) hazard potential dams under NPS management. Low (3) hazard potential dams will still receive periodic inspections to assess any changes in their hazard potential, to evaluate maintenance and repair needs, and to determine if they are still essential to park operations. Non-essential dams and appurtenant works should be dewatered and removed in an environmentally sound manner.

Regional Directors and Superintendents will provide, as appropriate for each type and size dam, documentation and reporting as indicated in Chapter Two, section F.

B. Management Objectives

The following objectives are given for the Maintenance, Operation, and Safety of Dams (MOSD) Program:

- Establishment of MOSD Program within WASO and Regional Park Facility Management Divisions with designated program coordinators and/or project engineers;
- Assure management control of technical activities;
  
  Maintain inventory data base on any size, type, owner, or status dam that will affect or is affecting park operations or safety,
  Conduct proper planning, design, construction management, or periodic inspection of all dams under NPS management,
  Perform corrective action or disposal of deficient dams under NPS management,
- Provide sufficient funding and personnel to support these responsibilities;
- Integrate MOSD Program into other NPS activities, funding sources, and programs;
  
  Routine Maintenance (park facility and maintenance staff),
  Cyclic Maintenance (park facility and maintenance staff ),
  Repair and Rehabilitation (park facility and maintenance staff ),
Cyclic Maintenance of Cultural Resources (cultural resources and facility/maintenance staff),

Cultural Resources Preservation Fund (cultural resources staff),

Construction and Major Rehabilitation (park facility/maintenance and Denver Service Center staff),

Risk Management (occupational and public type safety at dam as pertains to heights/depths, dangerous flows and equipment),

Visitor Services Division (guard against vandalism and coordinate emergency action plans at certain NPS and non-NPS dams),

Land and Structures Acquisition (purchase of dams and appurtenant works).

This is not an all-inclusive list. NPS managers should be constantly alert to what impact both NPS and non-NPS dams have on park safety and operations.

C. Applicability

Regional Directors and Superintendents will be responsible for the upkeep of the NPS inventory data base system (Appendix A) for any size, type, owner, or status dam (planned acquisition or disposal) that affects park maintenance, operations, resource, or safety. Where projects do not have any purpose, they should be dewatered and removed under the supervision of qualified personnel and project areas restored. For those dams that are used for park management and operations, NPS managers will annually schedule, as appropriate, funding and personnel to assure that their structures are properly planned, designed, rehabilitated, constructed, maintained, operated and periodically inspected. MOSD program personnel should be contacted immediately when a dam is planned for acquisition or disposal. They will be responsible for the evaluation and inventory of the structure into the MOSD program. A formal safety report including cost estimates to correct identified deficiencies should precede the appraisal of a dam site. The condition of the dam may have a bearing on the fair market value of the property.

D. Definitions

1. General. The following definitions apply to this guideline. More detailed definitions are provided in the explanation of terms used in the NPS inventory of dams database management system as given in Appendix A.

2. Dam or Project. Any artificial or natural barrier including appurtenant works (spillways, inlet and outlet works, tunnels, pipelines, penstocks, power stations, diversions, penstocks, canals, gates, conduits, navigation locks, instrumentation, or mechanical and electrical equipment) that impounds, controls, stores, or diverts streamflow and affects park maintenance, operation, resource, or safety. In some cases these structures will include embankments used for trails, roads, or railroads and during heavy runoff would act as dams and thus pose a possible hazard potential. Also landslides and ice formations need to be evaluated as a possible dam. For the management of NPS dams, there is no limitation to size, type, or status (proposed acquisition or disposal) in regard to these criteria. Dams not essential for environmental preservation, management, or operation of parks should be dewatered and breached under the supervision of qualified personnel and the project area restored. In some cases, the impoundment areas have become filled with sediment or covered by vegetation such that removal or restoration is too expensive or damaging to park resource. In these cases, the dam will still need to be maintained to prevent the impounded sediment or any other material from being discharged downstream if the dam were to fail. This guideline applies with equal force whether the dam has a permanent reservoir or is a detention dam for temporary storage of floodwaters.

In addition to conventional structures, this definition of "dam" specifically includes "tailing dams," embankments built by waste products disposal and retaining a disposal pond.

3. Hazard Potential. Potential loss of life or property or resource damage downstream of a dam from floodwaters released at the dam, or water released by partial or complete failure of the dam, and upstream of the dam from effects of rim slides or upstream dam failure. Also the effect of a failure, partial failure, or other incident should be considered for highways, roads, or trails crossing over the dam. A hazard potential is considered significant if there is a potential to cause loss of life or major damage to permanent structures, utilities, or transportation facilities. A detailed description of hazard potential is provided below. It is not an indicator of structural, maintenance, operational or safety condition.

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<th>HAZARD POTENTIAL CLASSIFICATION</th>
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<tr>
<td>CATEGORY</td>
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<td>5=Deactivated</td>
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4. Occupational and Public Type Safety. See Chapter 6, section B, 2. The following features or conditions may exist at a structurally sound dam but still pose a hazard potential to NPS personnel or public safety:

a. Waterways
   (1) Spillways
   (2) Sluices
   (3) Intake and release structures
   (4) Submerged objects

b. Structural Heights
   (1) Embankments
   (2) Walls
   (3) Cat Walks

c. Mechanical or electrical equipment at dam

5. Dam Failure. Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters which adversely affects a dam’s primary function of impounding water is properly considered a failure. They are, however, normally amenable to corrective action.

6. Maintenance. Maintaining structures and equipment in intended operating condition; equipment repair and minor structure repair.

7. Listed are some of the essential National Park Service Operations for dams.

   a. Irrigation
   b. Hydroelectric Power Generation
   c. Flood Control
   d. Navigational Lockage
   e. Water Supply
   f. Recreation
      (1) Camping, Sunbathing, or Sightseeing
      (2) Swimming and Bathing
   g. Conservation of Natural Habitat and Cultural Resources
   h. As Bridges, Roadways, and Hiking Trails

8. Rehabilitation or Improvement. Repair of structural deterioration to restore original condition; alteration of structures to improve dam stability; enlarge reservoir capacity, or increase spillway and outlet works capacity; replacement of equipment.

9. Emergency Action Plan. Formal plan of procedures to alleviate dangers during construction of or after completion of a dam to reduce loss of life or damages if conditions develop in which dam failure or misoperation is likely or unpreventable.

Note 1: Annual Informal Inspection required. See Chapter 6, section C, 2, a.

Note 2: Formal Inspection required every five years. Intermediate Inspection required every two years. See Chapter 6; section C, 2, b and c.

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<th>deactivated projects</th>
<th>4 = Unknown</th>
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<td></td>
<td>3 = Low</td>
<td>None expected (No permanent facilities, campsites, or other visitor use areas)</td>
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<tr>
<td></td>
<td>2 = Significant</td>
<td>Few (No urban developments and no more than a small number of inhabitable facilities, or visitor use areas)</td>
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Note 2: Formal Inspection required every five years. Intermediate Inspection required every two years. See Chapter 6; section C, 2, b and c.
CHAPTER TWO
ORGANIZATIONAL MANAGEMENT

A. Authorities

1. 16 U.S.C. 1. General legislative authority for the management and operation of park areas. It includes the maintenance and rehabilitation of those facilities as designated an integral part of the park operation.


4. Executive Memorandum, October 4, 1979, Implements Federal Guidelines for Dam Safety as appropriate for each agency.

5. Departmental Manual Part 753 – Specific implementation of DOI program

   a. Each agency has responsibility of operating own program.

   b. Bureau of Reclamation coordination and advice on DOI agency programs.

   c. Important objectives:

      (1) Complete an accurate inventory,

      (2) Initiate periodic inspections and necessary corrective action,

      (3) Develop emergency action plans at appropriate dams.

6. NPS Management Policies, sections 1.5, External Threats and Opportunities; 8.2.5.2, Emergency Preparedness and Emergency Operations; and 9.5 Dams and Reservoirs

B. Management Responsibilities

1. General. The Director is responsible for the development and implementation of policy, resources, and procedures for the maintenance, operation, safety, or else deactivation (non-essential) of each dam under his control. The Associate Director of Park Planning, Facilities, and Lands, with her/his park facility management staff, assists the Director in discharging this responsibility and shares in it. The Maintenance, Operation, and Safety of Dams Program is established as a component of the Park Facility Management Division. The field directorate is responsible for obtaining compliance with this guideline and assuring that procedures are carried out.

   Regional Directors, Superintendents, and Manager, Denver Service Center, will establish a Maintenance, Operation, and Safety of Dams Coordinator within their respective organizations as appropriate. See Appendix C for listing. The coordinator will be responsible for ensuring that every effort is made to enhance the maintenance, operation, and safety of dams under NPS control, and to coordinate with non-NPS dam owners about the condition of their structures if they affect park safety, operations, or resource.

   Refer to Appendix G for an example letter for coordinating with non-NPS dam project owners and/or regulators. Duties of the office will include surveillance and evaluation of administrative, technical, and regulatory practices related to the acquisition, design, preservation/rehabilitation/ construction, maintenance and operations, inspection of dams, and upkeep of the NPS inventory for both NPS and non-NPS dams that affect park safety and operations. The coordinator will represent NPS in the field of dam structures, ownership, reconstruction, management, ecology and cultural significance. The coordinator will be a key spokesperson in resolving interagency water and related land resources conflicts as pertains to dams and appurtenant works.

2. Design Responsibility. The design function can never be considered finished as long as the dam remains in place; design involvement should continue throughout construction and operation of the project. Regional Directors should establish appropriate programs for on-site construction and operational inspections for review by appropriate design personnel and technical specialists. The program will include frequent and mandatory inspections during construction to confirm that site conditions conform to those assumed for design or to determine if design changes may be required to suit the actual conditions.

   The design function includes responsibility for planning any dam instrumentation to be installed during construction and/or operation to monitor conditions that could potentially threaten dam safety.

   An initial reservoir filling and surveillance plan will be prepared by the design staff.
3. Construction Responsibility. The responsibility for administering construction and supply contracts, for understanding the design and contract intent, for maintaining technical coordination between design and construction engineers, and for managing the construction staff to assure compliance with specifications should be vested in an identified engineer at the construction project for important dams. Important dams are those classified as high (1) or significant (2) hazard potential, those whose failure would significantly impact park operations or resources, or involving substantial investment. The project engineer should have the administrative and technical control of all resources necessary to accomplish safe construction of the dam. Construction personnel should understand the conditions upon which the design is based and the relationship between these conditions and the design features. When unanticipated conditions are encountered, design personnel should be involved in determining their effect.

4. Maintenance and Operation. The responsibility for project maintenance and operation is assigned to the facility/maintenance or engineering staff. They will handle any requirements for coordination with the Denver Service Center Regional Team or an engineering firm. They will be responsible for preparing annual informal inspection reports for all dams and appurtenant works under NPS management and assure that periodic formal and intermediate type inspection reports are prepared by qualified and licensed engineers for high (1) and significant (2) hazard potential dams under NPS management responsibility.

5. Technical Coordination. A project engineer should be assigned technical coordination responsibility for each dam under NPS management that has either a high (1) or significant (2) hazard potential classification. He should handle necessary technical coordination within the agency and with private and public organizations.

6. Emergency Action Planning. An emergency plan should be formulated by the appropriate Park Manager and his maintenance and law enforcement staff for each NPS dam that has either a high (1) or significant (2) hazard potential. The plan should be in the detail warranted by the size and location of the dam and reservoir. It should evaluate inundation areas resulting from floods or dam failure, and upstream conditions that might result from major land displacements or increased flood flows, including the effects from failure of upstream dams. Regional Directors and Superintendents will coordinate with non–NPS dam owners when applicable to assure that appropriate emergency action plans are implemented for areas within park boundaries.

Where applicable, the plan should include inundation maps for the flows resulting from design floods and from possible failure of the dam. The complete emergency plan should be transmitted to appropriate local, state and Federal governmental bodies. The plan should be periodically reviewed and kept up to date, and periodically publicized to maintain awareness of its existence. In addition to the emergency plan for the complete dam, a similar plan should be prepared for the construction period, including area facilities that may remain during the period and floods that may be anticipated.

7. Risk–Based Analysis During Floodplain Evaluations. NPS managers should evaluate potential losses due to failure or misoperation, particularly when considering non–structural alternatives in correcting dam deficiencies. Although the value of potential property losses can be estimated, it is recognized that potential loss of lives can only be quantified, but not evaluated. On new dams, potential losses can be used in study of project alternatives and in assessment of additional safety incorporated into the dam facilities. On existing dams, a risk–based analysis should be considered in establishing priorities for examining and rehabilitating the dams for improving their safety or for the disposal of the dam.

C. Inventory Data Base Management  (Reference Appendix A)

In compliance with Public Law 107-310 and Departmental Manual Part 753, the National Park Service has developed an inventory of dams based upon information from the U.S. Army Corps of Engineers National Inventory of Dams (NID), Bureau of Reclamation Inspections, and NPS field reports. See Appendix A. This inventory lists both NPS and non–NPS dams that are located within or immediately adjacent to park boundaries and affect safety, operations, property, or resource. Dams are sorted in the following sequence:

1. Regional codes in alphabetical order;
2. Park Codes in alphabetical order;
3. Hazard Potential classification
4. Size Classification;
5. Structural height in feet;
6. Maximum impounding capacity in acre feet.

The current inventory provides information about inspection results, corrective action, emergency action plans (EAP’s) and financial information. This data base will be reviewed periodically by NPS field management for completeness and accuracy and any changes submitted annually by September 30 to the Washington Office of the Park Facility Management Division. More frequent updating should be performed whenever any formal inspection reports or corrective actions are completed on either high (1) or significant (2) hazard potential dams.

Dams in this inventory are classified primarily by their hazard potential which is an indicator of risk and not structural condition. Dams are classified as high (1) or significant (2) hazard potential when their failure or misoperation would jeopardize life or damage significant park resources or facilities. Low (3) hazard potential dams normally would not.
NPS structures will receive annual informal inspections to evaluate operational reliability, maintenance, and any changes in hazard potential classification. Inspection and other evaluation results will be used to update the NPS inventory of dams.

Information requests from, and coordination with, non-NPS dam owners should be well documented.

D. Staffing

1. Technical and Support. NPS managers should assure adequate and competent technical staffing or consultants from other agencies or engineering firms are available to perform the essential functions in planning, design, construction, operation and maintenance, acquisition, or disposal of dams under NPS management. These personnel should be well supported by administrative, clerical, and other elements to ensure that technical staff is not diverted from technical work.

Construction inspection staffing should assure quality as well as quantity inspection coverage. Staffing should be reviewed by higher authority than the local construction office.

The operating personnel must be qualified to perform the many functions required in the operation, including the recognition of conditions possibly detrimental to dam safety. Operation and maintenance staffing requires careful attention to personnel responsible for operating inspections, and to personnel who participate in the periodic inspection program. It is essential that support personnel and equipment are provided to accomplish needed maintenance activities.

2. Professional Advancement. NPS managers should maintain a positive program for advancement of technical personnel in recognition of acquired experience, training and education, and increased competence. It is essential that technical as well as the managerial expertise be required for safe, effective dam design, construction, and operating programs. Professional registration and active membership in professional and technical societies should be given due consideration in assessing qualifications for higher technical positions. Provision should be made for the establishment of procedures to screen and disseminate information on technical advances relating to dam design, construction, and maintenance and operation. Programs for continuing professional training should be oriented toward keeping the technical staff abreast of improved technology.

3. Training. To supplement technical staffing, NPS managers should provide internal personnel training. Provisions should be made for technical personnel to observe and participate in decision-making meetings and to make site visits with more experienced staff. Staff members should be allowed to attend consultants meetings in order to gain valuable experience.

Technically qualified maintenance personnel should be trained in problem detection and evaluation, and application of appropriate remedial (emergency and non-emergency) measures.

Personnel involved in inspections should be trained for the requirements of these duties. The training should cover the types of information needed to prepare for the inspections, critical features that should be observed, inspection techniques, and preparation of inspection reports.

MOSD coordinators, maintenance personnel, and park emergency action plan (EAP) coordinators should complete training every two years to assure they stay abreast of developments in the maintenance, operation and safety of dams. Training for the inspection of dams is normally provided by the Bureau of Reclamation (USBR) on an annual basis. These courses are geared to persons not familiar with engineering or geology but who are responsible for the safety and maintenance of small dams. Contact Inspections and Emergency Management Group, Bureau of Reclamation, 303-445-2740 for further details.

Designated park emergency operations plan coordinators should attend training in the preparation, exercising, or use of EAPs and ensure their integration into the park’s overall emergency operations plan.

E. Funding and Personnel Resources

1. General. Continuity and adequacy of funding and personnel are essential to carry out the MOSD program objectives. The NPS budget formulation and execution system offers an opportunity for managers to identify funding priority for those activities, programs, staff levels, or other operating requirements to assure a sound MOSD program. Long-term programming objectives should be developed and adhered to in order to establish a systematic program. To meet these objectives, the following activities should be properly staffed, funded and scheduled by Regional Directors and Superintendents:

<table>
<thead>
<tr>
<th>Period</th>
<th>Activity/Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>As necessary</td>
<td>Staff</td>
</tr>
<tr>
<td>Every two years</td>
<td>Training</td>
</tr>
<tr>
<td>Annually</td>
<td>Update NPS Inventory of Dams</td>
</tr>
</tbody>
</table>
A base level program will be established in each applicable region, park, and DSC to assure that routine and recurring activities are properly funded and staffed. To assure cost effective management of NPS dams, the above sequence should be followed as closely as possible, particularly the periodic inspections which give a comprehensive evaluation of the dam's purpose and condition in relationship to park objectives.

2. Sources. The primary funding and personnel source for this program is the maintenance, repair/rehabilitation, or construction programs. Although Servicewide funding for the MOSD program has been made available out of the Washington Office Park Facility Management Division, it is now the responsibility of Regional Directors, Superintendents, and Manager, Denver Service Center, to assure adequate funding and personnel to meet: MOSD program objectives. There are several other funded programs which are interrelated to the maintenance, operation and safety of dams. The following list is provided to alert NPS managers as to the need for well coordinated and funded programs to prevent overlap and duplication of funding and personnel:

- Cultural Resources Cyclic Maintenance
- Preservation, Design and Construction
- Risk Management Division (occupational and public type safety)
- Law enforcement and ranger Activities (evacuation during imminent disasters)
- Land Acquisition (acquire existing dams during land purchases).

3. Methods. There are several methods of requesting funding and personnel to assure the maintenance and safety of NPS dams. Reprogramming of funds/personnel is only for extremely, urgent action within the current fiscal year. This type of programmatic change would occur only when an NPS dam is found to be seriously deficient and poses an imminent threat to life and significant property, and immediate corrective action is necessary. Supplemental budget requests may be used during the current budget year to provide urgently needed funds or personnel, but some delay is allowable in performing corrective action. The regular budget formulation and execution process is used to program funds for routine but yet necessary activities. The NPS Operating Financial System (OFS) is used for preparing requests of annual operating type funding or personnel increases. Activities that would be programmed with this form are as follows:

- Staff
- Inventory Data Base Management – Training
- Travel
- Periodic Inspections
- Routine Maintenance, Repairs, and Operation
- Develop and Update Emergency Action Plans

The NPS Project Management Information System (PMIS) is normally used for multi-year funding for substantial development projects involving major rehabilitation, reconstruction, or acquisition. In developing these funding and personnel resources, close coordination should be made with the budget officer.

4. Cost Accounting. Cost accounting should be used to assure cost effective management of funds and manpower utilized in the
maintenance, operation, and safety of dams.

F. Documentation

1. General. Throughout project acquisition, development, and operation, all data, computations, engineering and management decisions should be documented for planning, site investigation, design, construction, initial reservoir filling, maintenance and operations, or disposal of dams under NPS management. The amount of documentation should vary with the level of hazard potential or operational importance of the structure. Dams under NPS management that have either a high (1) or significant (2) hazard potential classification will receive full documentation.

2. Design/Construction. Written documentation should be maintained in standardized format on all designs for the project. All phases of the construction should be documented, including reporting of routine and special activities. Changes in construction plans and departures from expected site conditions should be documented, with any consequent design changes. As-built drawings should be prepared as facilities are completed, and should be made available to operation and maintenance personnel and to the dam inspection staff. An initial reservoir filling and surveillance plan should be prepared by the design staff. Initial filling should be well documented, including a record of reservoir elevations and controlled water releases during the filling.

3. Operation and Maintenance Log. Operation and maintenance should be fully documented, including the routine activities and systematic inspection processes, and complete information on project maintenance, rehabilitation, and improvements. In addition to records on the actual operations, the operating record should include data on reservoir levels, inflow and outflow, drainage system discharge and structural behavior.

If there are maintenance problems that require continuing remedial work, a thorough record of the work should be maintained, and a final report made after complete remedy of the problem.

4. Data Books. Data Books will be prepared by the Bureau of Reclamation (USBR) or other inspecting organization for all NPS high (1) or significant (2) hazard potential dams which are scheduled for formal inspection. Appendix E is a checklist of the types of existing data which will be valuable for evaluating the safety, maintenance, and operation of these dams. Existing information for these Data Books should be prepared and distributed by Regional Directors or Superintendents to USBR or other inspecting organization two months prior to the actual on-site examination.

5. Required Reports. At the indicated times, Regional Directors and Manager, DSC, will submit the following reports or documents to the Director, Attention: Park Facility Management Division:

   a. Immediately, report any partial or total dam or appurtenant works failure, misoperation, or uncontrolled release of reservoir affecting park resources, operations, or safety.

   b. Immediately, report any injury, death, or significant property or resource loss because of dam failure, misoperation, or uncontrolled release of reservoir. Items wand b should be combined if appropriate.

   c. Immediately, report any dam in seriously deficient condition, as so determined from a formal inspection, and whose failure or misoperation would affect park safety or operations. State what corrective action is being taken and when it will be completed.

   d. Inventory update at least annually by September 30, on any size, type, owner or status dam (planned acquisition or disposal) that affects park resources, operations, or safety.

   e. Report annually, by September 30, on any planned or actual major preservation, rehabilitation, construction, acquisition, or disposal of dams that affect park safety or operations.

   f. Submit annually, by September 30, list of personnel responsible for coordination of maintenance, operation, and safety of dams program and any training that has been attended.

   g. Submit annually, by September 30, a brief financial summary of funding, either programmed or spent by fiscal year, for this program. Items e and g should be combined if appropriate.

   h. Distribute annually, by September 30, copies of completed and approved NPS Annual Informal Inspection (AII) reports.

   i. Report annually, by September 30, on the status of park emergency operations plans (EOP’s) in which are integrated emergency action plans for any High or Significant hazard potential dams affecting the park. Also for NPS affected areas, an Early Flood Warning, Search/Rescue, Evacuation, and Recovery Plan (ESEP) should be integrated in the park’s EOP.

G. Technical Reviews
1. Extent. All factors affecting the safety of high (1) or significant (2) hazard potential dams under NPS management will be reviewed during design, construction, and operation on a systematic basis. Reviews include those internal to the agency and those external to the agency by individuals or boards (consultants) with recognized expertise in dams.

2. Internal. Provision should be made for automatic internal review of all design and construction decisions, methods, and procedures related to dam safety. Reviews should be at levels of authority above the design section or designer–supervisor relation.

3. External. An appropriate level of independent review by a qualified engineering firm or other Federal agency (i.e., Bureau of Reclamation) with safety of dams expertise should be performed during design or construction of dams under NPS management.
CHAPTER THREE
NPS PLANNING AND ENVIRONMENTAL EVALUATION PROCESS
FOR PROPOSED OR EXISTING DAMS

A. General

Considerable information has been compiled in Appendix A about dams that affect park maintenance, operations and safety. Information on these facilities is updated periodically in the NPS inventory of dam data base which is discussed in Chapter Two, section C, and is readily available upon request. These dams should be appropriately considered during the NPS planning and environmental evaluation process in the following sequence of activities to assure their systematic management:

- Inventory of any size, type, owner, or status (proposed acquisition or disposal) dams that affect park maintenance, operations, or safety; - Periodic inspection of any of the above dams under NPS management, including dams proposed for acquisition. If possible, estimates of funding and personnel should be included for corrective action or disposal;

- Acquisition of dams. A formal safety report including cost estimates to correct identified deficiencies should precede the appraisal of a dam site. The condition of the dam may have a bearing on the fair value of the property.

- Qualified NPS project engineer or coordinator assigned to any high (1) or significant (2) hazard potential dam undergoing detailed investigation to assure coordination with guideline;

- Preparation of design, plans, and specifications for major preservation, rehabilitation, or construction;

- Independent review of design, plans, and specifications of high (1) or significant (2) hazard potential dams;

- Performing preservation, major repair or rehabilitation, reconstruction, or construction;

- Independent review of preservation, major repair or rehabilitation, reconstruction, or construction on any high (1) or significant (2) hazard potential dams;

- Maintenance and operations;

- Emergency action plans at either high (1) or significant (2) hazard potential dams; and

- Disposal (sale or removal and restoration of drained impoundment).

B. Acquisition, Holding, or Disposal

During the acquisition, holding, or disposal of dams at NPS administered areas, proper planning should be undertaken to assure compliance with the National Environmental Protection Act (NEPA) of 1969, Public Law 91–190, as amended; various Executive orders on floodplains, wetlands, and safety of dams; and the Section 404 Permit Program by the U.S. Army Corps of Engineers. The objectives of these regulatory requirements are to help provide a safe, ecologically and culturally complementary, and favorable benefit/cost ratio project. This guideline on the maintenance, operation and safety of dams should be properly integrated into the NPS planning and environmental evaluation process. Any dam, regardless of owner, that has a high (1) or significant (2) hazard potential or is/will be important to park management should be discussed in the General Management Plan and its associated environmental document in regard to its purpose and required care. Dams that are not essential to park management and operation should be properly disposed. Information should be requested from non-NPS dam owners during the NPS planning and environmental evaluation process to determine the safety and operational significance of their structures on NPS floodplain management and the need for any emergency action plans. Refer to Appendix G for an example letter for coordinating with non-NPS dam project owners and/or regulators. The Corps will assist in providing information about non-NPS dams and hydrologic and hydraulic analyses in determining the 100 and 500-year floodplains. When possible, the floodplain and emergency action plan inundation mapping should be combined. Flood profiles should be presented with the mapping. A current list of these dams by region and hazard potential is also given in Appendix A.

C. Floodplain Management and Wetland Protection

The NPS floodplain/wetland protection guidance should be carefully reviewed with proper consideration as to the effects of dam safety and operation on floodplains in NPS administered areas. Any dam having a high (1) or significant (2) hazard potential that is located upstream, at, or downstream of a particular floodplain study reach under NPS investigation will be evaluated as part of the environmental assessment process and reported in the "Statement of Finding" as to its safety and operational effects on floodplain
development. The Regional Dams Coordinator will provide the necessary evaluation. Many of the older high (1) or significant (2) hazard potential dams in or adjacent to park boundaries were not designed or maintained to safely operate during the 100 and 500-year base floods which are used for park planning in floodplains. Consequently, because the probable failure of these older dams would produce significant flooding above the natural 100 or 500-year floods, it is paramount that these types of structures receive periodic inspection and appropriate corrective action. For non-NPS dams whose operational safety cannot be ascertained, conservative design and operational procedures in park administered areas should be utilized to compensate for this condition. Inhabitable facilities, utilities or transportation systems will not be built or operated in floodplains subject to the effects of dams in seriously deficient conditions, and there are no active and funded programs for corrective action.

D. U.S. Army Corps of Engineers Section 404 Permit Program

The protection of wetlands is interrelated to the U.S. Army Corps of Engineers Section 404 Permit Program for dredging (digging) or filling in or near any significant stream, river, lake, or harbor. This dredging or filling permit requirement is applicable for new dams or existing dams proposed for modification or disposal. Requirements are based upon volume of material and other considerations. Local U.S. Army Corps of Engineer Districts will provide advice on the applicability of the Section 404 Permit Program for dams and appurtenant works under NPS management.
CHAPTER FOUR
MANAGEMENT OF TECHNICAL ACTIVITIES - SITE INVESTIGATION
AND DESIGN FOR PROPOSED OR EXISTING DAMS

A. General

This section of the guideline outlines the site investigation and design technical activities that Regional Directors, Superintendents, and Manager, Denver Service Center, should ensure are undertaken to obtain safe design or evaluation of dams. It is recognized that the extent of application of this guideline will vary depending on the size, function, and hazard potential classification of the dam.

B. Hydrology

1. Hazard Evaluation. Areas impacted by dam construction and existing dams should be examined for potential hazards to present and future developments in the event of major flooding by controlled flood discharges or flooding induced by dam failure or misoperation. This hazard evaluation is the basis for selection of the performance standards to be used in design or evaluation of existing dams. See Chapter 1, Section D, 3.

2. Flood Development. Hypothetical floods, generally of severe magnitude, should be developed for use in design or evaluation of major dam and reservoir features, including development of appropriate floods for the construction period.

3. Flood Selection for Design (or Evaluation). The selection of the design flood should be based on an evaluation of the relative risks and consequences of flooding, under both present and future conditions. Higher risks may have to be accepted for some existing structures because of irreconcilable conditions. Reference should be made to U.S. Army Corps of Engineers Publication, ER 1110-2-106, National Program for Inspection of Non-Federal Dams, Washington, D.C., September 26, 1979, page D-11, for assistance in making the determination.

When flooding could cause significant hazards to life or major property damage, the flood selected for design should have virtually no chance of being exceeded. If lesser hazards are involved, a smaller flood may be selected for design. Ideally, spillway operation should be evaluated in such a way that dam failure resulting from overtopping would not significantly increase the hazard to loss of downstream life or property from that flooding condition which would exist just before overtopping failure.

To reduce hydrologic and hydraulic engineering costs, systematized computer programs like HEC-1 Dam Break by U.S. Army Corps of Engineers could be utilized effectively for many small National Park Service dams. This computer program will generate an inflow design flood, route the flood through and/or over the dam (including outflow from any defined hypothetical dam failure), and then route the flood wave to a downstream damage reach for evaluation, all in a single operation. This systematic method allows for a rapid optimization of spillway requirement to adequately protect existing and any anticipated downstream development.

4. Hydrologic Design of Reservoir. In addition to selection of a design flood, the hydrologic design of a new reservoir or the evaluation of an existing project involves consideration of discharge and storage capacities, reservoir regulation plans including constraints, land requirements, and wind/wave effects.

Reservoir regulation plans should be developed in the planning of projects so that realistic release rates will be used in routing the design flood. Regulation plans should include the construction period.

The reservoir regulation plans; water control management plan, and data. Information systems should be periodically reviewed for deficiencies and potential for misoperation during both severe flood events and normal conditions. Necessary corrections should be made as soon as practicable.

5. Downstream Effects. Safety design includes studies to ascertain areas that would be flooded during occurrence of the design flood and in the event of dam failure. The areas downstream from the project should be evaluated to determine the need for land acquisition, flood plain management, Flood Insurance Program or other methods to prevent major damage. Information should be developed and documented suitable for releasing to downstream interests regarding remaining risks of flooding.

6. Warning Systems. Safety design should include an emergency flood warning system and action plan that would effectively notify all concerned in ample time for appropriate action.

C. Earthquake Investigation and Design

1. Investigation Factors. The following factors should be considered in selection of design earthquakes.

   a. Geologic and tectonic setting of the site area by analysis of the lithology, stratigraphy, structural geology, and tectonic history.

   b. Historic earthquake record to include the size, location, and other seismological characteristics as available, and the relationship, if possible, with the tectonic setting of the area—in which the earthquakes have occurred.
c. Influence of the properties of the surficial materials on the determination of the size of historical earthquakes.

d. Influence of faulting or other tectonic features on the estimate of the occurrence, size and location of possible future earthquakes.

2. Selection of Design Earthquakes. From the above factors, earthquakes should be selected that have sufficient potential of occurring to require consideration in the dam design. Earthquake description should include estimates to the extent practical of the size, location, depth, focal mechanism, and frequency of occurrence.

3. Engineering Seismology. Determination should be made of the characteristics of ground motion that would be expected from the design earthquakes, to the extent possible, to include amplitude (displacement, velocity and acceleration), frequency content, and duration.

4. Need for Earthquake Analysis. The probable effects of earthquakes on the dam and its appurtenant structures should be evaluated to determine the need for inclusion of earthquake forces in the structures analyses. Evaluation includes consideration of factors such as the project stage, hazard and risk factors, the size of the dam and reservoir, the potential ground motion at the site, site geology, and type of structure. Where determination is made that no earthquake forces are required in analysis, the determination should be justified.

5. Seismic and Geologic Studies.

a. Earthquake Sources. The essential first step is determination of the design seismic events (usually the maximum credible earthquakes) and an estimate of the ground motion: at the site due to these events. From a study of the regional tectonics and seismicity, and both regional and local geology, potential sources for seismic events are identified, and the maximum credible earthquake magnitudes postulated.

b. Design Events. A maximum credible earthquake (MCE) is defined herein as the hypothetical earthquake from a given source that could produce the severest vibratory ground motion at the dam. Time histories of the estimated rock motion (accelerograms) at the dam for the various seismic events are selected to characterize the severity of the strong motions by their peak accelerations, frequency content, and duration.

6. Design for Earthquake Forces.

a. Safety Concerns. All earthquake–related safety concerns should be identified. Potential safety concerns include but should not be limited to dam foundation integrity stability, unacceptable stress levels, fault displacements; abutments stability; effects of dam overtopping; dam stability; susceptibility of embankment dams to embankment or foundation liquefaction, cracking or excessive deformation.

b. Analysis Method. Determination of appropriate earthquake analysis methods for evaluation of safety concerns may be, as appropriate, by qualitative evaluations, pseudostatic analysis, and dynamic analysis. The methods selected should be appropriate to the identified safety concerns in accordance with good engineering practice and with currently available technology.

c. Structural Adequacy. Structural adequacy assessments should be made of all safety–related components and concerns identified. These assessments should incorporate all applicable data and analysis.

D. Geotechnics

1. General.

a. Site specifics. After a site is selected, a program for the geotechnical exploration, design, and analysis of that specific site is required. No checklist can be made which would cover all eventualities at all sites, or at any one site, and attempts to formulate such a list would be counterproductive to the intent to ensure dam safety. The best insurance for adequate geotechnical work is a well–trained and experienced staff actively involved in field inspections throughout all phases of the development of the site.

b. Documentation. Because many evaluations are possible for a given set of geotechnical conditions, it is important that full documentation be made of the reasoning process involved in geotechnical decisions. General guidelines for documentation are given in Chapter Two, section F.

c. Management of Diverse Technical Expertise. Geotechnical work encompasses the expertise of geologists, geophysicists, and engineers—all with diverse experience, training, and technical terminology. The administrative and technical supervision
of these experts should be structured to optimize coordination and cooperation. Management should encourage intellectual curiosity and an inquisitive approach to all geotechnical work. Since the field of geotechniques is rapidly expanding, Regional Directors and Manager, Denver Service Center, should assure that those persons associated with site exploration and development, maintain currency with the state of the art.

2. Exploration and Identification of Geotechnical Problems. The exploration program needs to be site specific, flexible, and executed so as to obtain the maximum data from each part of the program. Regional Directors and Manager, Denver Service Center, should ensure sufficient funding for an orderly development of the exploration program in order to reduce uncertainties and to make adequate provisions for required corrective measures.

3. Geotechnical Design. Geotechnical design considerations for the dam foundation and reservoir area are essentially defined after the geologic conditions of the site, the type of dam, and the magnitude of the stresses imposed on the foundation by the dam and reservoir have been determined.

4. Foundation Treatment.
   a. General. The preparation of the foundation, including the abutment, is one of the most important phases of construction. The primary purposes of foundation treatment are to provide stability, obtain positive control of seepage, and minimize adverse deformation. The geology, foundation conditions, foundation treatment, and proposed structure should be considered together.
   b. Stability. Surfaces should be prepared to provide a satisfactory contact between the foundation and the overlying structure by removal of unsuitable materials. Deficiencies in the foundation which are not removed should either be treated by modification of the structure or by appropriate foundation treatment tailored to handle the conditions encountered.
   c. Positive Control of Seepage. Highly permeable foundations should be treated by such measures as cutting off the pervious material, grouting, increasing the seepage path by upstream blankets, or controlling the seepage with drainage systems. Where appropriate, surficial cavities should be traced, cleaned out, and backfilled with material satisfying the design requirements. When cavities exist at depth, measures should be taken to ensure against the migration of cavity material.
   d. Control of Piping. Silts and fine sands in the foundation, which are susceptible to piping, should be removed if practical, cut off near the downstream limits of the dam, covered with impervious material, or provided with filtered drainage systems. If pipable material is used in the dam, the foundation surface treatment should prevent migration of dam material into the foundation.
   e. Deformation. Foundations subject to differential settlement or foundations having highly compressible anomalies can cause stress concentrations or cracking in dams. The foundation excavation should be shaped to remove abrupt changes in elevation to preclude excessive differential settlement or stress concentrations. Low shear strength material in a foundation can cause shear failure. Excavation and replacement of low strength material is a positive method for treating a foundation that has either or both of these unfavorable conditions.

5. Instrumentation. Although a well conceived foundation instrumentation program serves to monitor the foundation and give an indication of distress, it cannot of itself certify the safety of the foundation. The expertise of the engineer/geologist to analyze, design and prepare a foundation that will safely carry the loads and water pressure imposed by the dam and the reservoir is fundamental to the design adequacy of the foundation. The purposes of foundation instrumentation are fourfold: to (1) provide data to validate design assumptions; (2) provide information on the continuing behavior of the foundation; (3) observe the performance of critical known features; and (4) advance the state of the art of foundation engineering.

6. Inspection and Continuing Evaluation During Construction. Those responsible for the investigation and design of the foundation should make on-site evaluations to confirm that actual conditions conform to those assumed in the design and to review documentation of site conditions.

7. Reevaluation at Existing Structures. Older dams under NPS jurisdiction may not have been designed to standards equal to current criteria. Also, a substantial portion of safety–related dam incidents are associated with foundation problems which develop in a time–dependent fashion after construction. For these reasons, systematic reevaluations of existing dams should be made for appropriate structures.

E. Hydraulic Appurtenances

1. General.
   a. Protective Measures. All hydraulic appurtenances used for releasing water should be designed to preclude jeopardy to the damming provisions.
   b. Blockage. Allowances for or preclusion of blockage of hydraulic facilities should be incorporated in the design.
c. Reliability. When operational failure of a gated passage would jeopardize the damming provisions, alternate capacity should be provided. When operation of a gated passage is essential to safety, reliable manpower, communications and accessibility should be assured.

d. Hydraulics and Hydrology. Hydraulics and hydrologic design considerations should be correlated with Chapter 4, B.

2. Design Flood Releases.

a. Spillway and Outlets. Gated spillways are the usual hydraulic appurtenances for control of all, or the major portion of, the design flood and major emergency releases. Outlets (sluiceways, conduits and tunnels) may be used alone or in conjunction with spillways to control flood discharges.

b. Selection of Type. Spillways and outlets should be selected to meet the site specific purposes of the project. For a drainage area with short concentration time combined with reservoir storage capacity that is small relative to the flood volume, especially for embankment dams, (1) the spillway should usually be uncontrolled, and (2) outlets should not normally be used for sole or part control of the design flood except in special cases where the outlet can be uncontrolled.

3. Other Water Releases. Other water release hydraulic appurtenances such as navigation facilities, locks, fish facilities, ice sluices, trash sluices, and water quality facilities should conform to the requirements of section E.1.

4. Reservoir Evacuation. Where practicable, reservoir release facilities should be provided to lower the pool to a safe level adequate to correct conditions that might threaten the integrity of the dam.

5. Control of Flows During Construction. The provisions of section E.1 also apply generally to the design of hydraulic appurtenances used during construction. The capacity of these appurtenances should be sufficient to satisfy the discharge requirements of the regulation plan for control of water during construction.

6. Design Criteria and Guidance. If existing design criteria and guidance from past projects and experience are used for design of the hydraulic appurtenances, their sufficiency should be documented.

F. Concrete Dams and Concrete Elements of Embankment Dams

1. Site Specific Design. Because all dam sites are unique, the type of dam and its appurtenances should be specifically matched to site conditions and project requirements. It is essential when reviewing the safety of existing dams to consider conditions which may have changed physically, new concepts resulting from new technology, and additional project information since construction, i.e., foundation deterioration, increased flood hydrographs, or larger design earthquakes.

2. Materials. Concrete for the structures requires competent investigation of material sources and adequacy of supply testing of materials properties in accordance with accepted standards, and proper proportioning of concrete mixes (including additives) for strength, durability, control of thermal properties, and economy.

3. Design of Structures. There are three components of a dam which must be considered for safety; the foundation, the dam, and its appurtenant structures.

   a. Foundation. Proper design of a concrete dam requires information on the foundation geological conditions and material properties to assure its capabilities to support the loads of the dam and reservoir, in its natural state or as improved by foundation treatment.

   b. Dam. Concrete dams should be designed to be safe against overturning and sliding without exceeding allowable stresses of the foundation and the concrete for all loading conditions imposed on the dam. The shape and/or curvature of a dam and its contact with the foundation are extremely important in providing stability and favorable stress conditions. Proper consideration should be given to ensure the dam's safety in the event of overtopping.

   c. Appurtenances. Safety-related appurtenances such as outlet works structures, spillways, penstocks, powerhouses, and navigation locks should be designed with the same degree of safety as the main dam. If the project has a powerhouse as an integral part of the dam, it should be designed for the same safety requirements as the dam.

4. Definition of Loads. The dam and appurtenances should be designed or evaluated for all static and dynamic loads to which they will be subjected.

5. Design Methods. The methods required for design of the several types of concrete dams and their appurtenances vary from simple to complex, depending on the type and size of the structure, the hazard potential, the site, the kinds of loading, and foundation conditions. The design process involves judgment and analytical expertise to select appropriate methods to analyze...
a structure whether it requires a simple or complex analysis and to determine design input that is representative of the range and variation of foundation and structural material properties. The selection of input parameters is just as important as the mechanics of the analysis used.

6. Design Evaluation. Technically qualified supervisory personnel should assure that structures are designed to meet the requirements for safety. This includes confirmation of design input parameters, design methods, and utilization of allowable factors of safety against overturning, sliding, and stressing appropriate to the probability of the loading conditions.

7. Instrumentation. Knowledge of the behavior of structures and their foundations may be given by studying the service action of the structures using observations on embedded and other internal instrumentation and external measurements.

8. Construction and Operational Follow-up. It is necessary that the designers should be involved in the construction and operation processes to confirm that the design intent is carried out, and to allow changes and modifications resulting from redesign necessitated by differences between assumptions and actual field or operating conditions.

G. Embankment Dams

Section F contains general dam considerations. The following additional considerations are applicable to embankment dams:

1. Site Specific Design. Embankment design should be developed for specific site conditions and based on adequate exploration and testing to determine all pertinent geologic and material factors with particular emphasis on shear strength and stability, permeability and control of seepage, and consolidation and settlement.

2. Materials. Embankments can generally be designed to utilize locally available construction materials; investigation of materials characteristics is required and problem materials should be either discarded or protected by defensive design. There is often a need for importing special materials for slope protection, filters, and drainage systems. Any embankment zoning should consider the properties and quantities of available materials and the effect of their characteristics on the construction process.

3. Design Constructibility. Embankment designs should be constructible with regard to such items as location of borrow areas with respect to flooding, in situ moisture conditions, climatic effects on construction schedules, width of zoning, and needs for special material processing. Design should include protection of critical features from overtopping by floods during construction.

4. Embankment Design. The safety of an embankment is dependent on its continued stability without excessive deformation under all conditions of environment and operation, and on control of seepage to preclude adverse effects on stability and prevent migration of soil materials. Design considerations given below are specific to embankment dams.

   a. Seismic. Where earthquake design is necessary, consideration should be given to earthquake–related concerns of soil liquefaction and cracking potential, stability and excessive deformation, abutment stability, overtopping effects, and required defensive measures.

   b. Stability. Embankment stability should be analyzed for all pertinent static and dynamic loading conditions without exceeding allowable shearing stresses in the embankment or foundation.

   c. Settlement and Cracking. The potential for transverse cracking of the embankment caused by differential settlement, tension zones, and possible hydraulic fracturing should be minimized by careful consideration of abutments, foundation and cutoff trenches, and their geometry and treatment.

   d. Seepage. The design should attempt to prevent or minimize seepage through the embankment and its foundation and abutments; however, the designer should recognize that seepage usually occurs and that protective control measures must be provided. Filtering transition zones and foundation and abutment treatment to seal openings should be provided wherever necessary to preclude migration of soil materials into or out of all embankment element contacts both upstream and downstream. Filters, drainage blankets, and transitions should be of a quality and size to conservatively control and safely discharge seepage for all conditions for the life of the project. Particular attention should be given to contacts with foundation, abutments, embedded structures, and the end slope of closure sections to ensure adequate compaction and bonding to control seepage.

   e. Zoning. Embankment zoning when used should ensure adequate stability for all pertinent conditions, and should control seepage through the embankment and provide filter action to prevent migration of material.

   f. Erosion. Upstream and downstream slopes and foundation and abutment contacts should be protected against erosion from surface runoff, wave action, and impinging currents. Spillways and outlet works should be located and designed so that discharges do not erode the embankment or its foundation.
5. Instrumentation. Embankment design and prediction of embankment performance are based on an imprecise combination of theory and empirical procedure; consequently, performance during construction and operation should be monitored by a design system of external measurements and/or installed instrumentation.

6. Construction and Operational Follow–up: Stability should be evaluated during and after construction using strength parameters from as–placed materials and observations of pore pressure and seepage if and when condition, warrant. Designers should inspect and review performance of embankments during and after reservoir impoundment to detect and provide prompt remedial treatment for problems. While major emphasis is placed on initial impoundment the surveillance should continue for the life of the project

CHAPTER FIVE
MANAGEMENT OF TECHNICAL ACTIVITIES – CONSTRUCTION OR REHABILITATION OF DAMS

A. Introduction

This section of the guideline outlines the construction technical activities that Regional Directors, Superintendents, and Manager, Denver Service Center, should ensure are undertaken to obtain safe construction of dams. The principles and guideline are prepared in a broad sense to ensure that construction of a safe structure is the prime requisite. It is recognized that the extent of application of this guideline will vary depending upon the size, function, and hazard potential.

1. Construction Contracts. Construction contracts should be based on site conditions as interpreted at the time of contract award. All anticipated work on foundation cleanup, preparation, and treatment should be included as specified items of the work. Contract provisions should require the contractor to submit to the construction engineer advance notice of significant shift change to enable adequate inspection coverage of multi-shift operation.

2. Construction/Design Interface. Many aspects of construction directly overlap in design considerations. Reference is made below to numbered paragraphs in Chapter 4, Management of Technical Activities – Site Investigation and Design, which concern such common interests:

a. Geotechnics
   (1) General
      (i) Site Specifics
   (2) Exploration and Identification of Geotechnical Problems
   (3) Geotechnical Design
   (4) Foundation Treatment
   (5) Instrumentation
   (6) Inspection and Continuing Evaluation During Construction
b. Hydraulic Appurtenances
   (1) Control of Flows During Construction
c. Concrete Dams and Concrete Elements of Embankment Dams
   (1) Site Specific Design
   (2) Materials
   (3) Design of Structures
      (i) Foundation
   (4) Instrumentation
   (5) Construction and Operational Follow–up
d. Embankment Dams
   (1) Site Specific Design
   (2) Materials
   (3) Design Constructibility
   (4) Embankment Design
      (i) Settlement and Cracking
         (ii) Seepage
   (5) Instrumentation
   (6) Construction and Operational Follow–up

B. Evaluation During Construction. Field personnel must be highly trained and experienced in the design principles and site
conditions are to be understood and a safe structure is to be constructed.

When differing site conditions (different from those anticipated) are encountered construction supervisory forces must have authority to suspend any or all portion of the work affected until the design engineers, with assistance as needed, can evaluate the condition and determine if design modification is required.

Construction milestones should be identified when the design engineers will inspect the work and concur with the progress of construction.

C. Orientation of Construction Engineers and Field Inspectors. Construction engineers need to be aware of design philosophies and assumptions as to site conditions and function of project structures, and must understand the designers' intent concerning technical provisions in the specifications.

Construction specifications, supplemental reports, and conferences to orient field personnel to the particular site, the features of the dam, and the designers' intent for construction should, as applicable, include the following:

1. Design Related
   a. Design concepts. An explanation should be given of philosophies and assumptions and the reasons for special requirements in the specifications to assure accomplishment of design intent.
   b. Construction sequence. Identification and explanation of the dates to which construction progress must conform to satisfy project requirements, and the special sequences for construction activities that are required by design.
   c. Instrumentation systems. Description should be given of the instrument types, their purpose, the procedures for installation of each instrument type, the method and time interval for reading each instrument, and the importance of prompt data transmission for analysis and feedback.
   d. Care and diversion of water. Description of the design features included to prevent and/or control flooding and turbidity and accomplish diversion and closure of the dam. This should also contain the design requirement for controlling normal flows through the work area to assure that construction is always accomplished under dry conditions. Critical aspects of the construction schedule related to flood problems should be emphasized.

2. Foundation
   a. Description. Discussion of the type of foundation conditions expected to exist, i.e., overburden, general rock description, formation weaknesses (such as joints, shears and faults), and acceptable foundation conditions.
   b. Excavation. Discussion of the depth and nature of materials expected to be encountered, the controls for dewatering and blasting, identification of critical areas, quantity estimates, and an acceptable foundation.
   c. Preparation. Review of the methods of rock foundation preparations such as: cleaning; the use of wire mesh, mortar, shotcrete, or cock bolts; grouting, and treatment of faults, shears and joints; as well as subsequent exploration to assure desired results. Review of methods of earth foundation preparation.

3. Materials
   a. Materials from required excavation. Definition should be given of acceptable and unacceptable properties of materials, the usage and the processing required if used, and identification of waste area locations.
   b. Other excavated materials. Identification of the location and amount of useable material, “based on current test data,” available from all designated areas, including borrow pits. Review of the blasting methods that are expected to produce the desired rock quality and sizes. Discussion should be given of the expected amounts of waste and the areas where borderline material may be used in lieu of wasting, such as in berms or certain zones of the downstream shell of an earthfill dam.
   c. Embankment. Description should be given of both acceptable and unacceptable material properties, placement, and compaction procedures for each zone. Review of required procedures for areas adjacent to abutment, around instruments, and at interfaces between zones and/or structures.
   d. Concrete and concrete materials. Identification should be given of acceptable aggregate sources and review of mix designs, joint and surface treatment, finish requirements, form tolerances, and placement procedures. Cooling as well as hot and cold weather protection requirements should be defined.

4. Construction General
a. Field control. Discussion of the quality assurance procedures required to control all phases of construction. Acceptable placement standards should be established for concrete, earth and rock materials, and embankments.

b. Structural. Discussion should be given of structural steel installation, reinforcing steel placement, and anticipated problem areas and specified treatment for such areas.

c. Mechanical–electrical. Description of equipment installation requirements, special procedures, performance tests, protective coatings, and protection devices such as ground fault indicators.

d. Environmental. Identification of those construction controls required to minimize environmental damage, comply with environmental regulations, and assure public involvement.

D. Construction Assurance

1. Construction Procedures. Criteria must assure that acceptable methods and procedures are specified and utilized to accomplish design requirements. At the time, the design and construction organizations must maintain the flexibility necessary to modify design, material requirements, and construction specifications as conditions dictate without altering the basic design intent.

2. Construction Materials Testing. A materials laboratory must be established at the field construction office that is adequately staffed and equipped to accomplish the on–site testing requirements set forth in the engineering considerations and instructions to field inspection personnel.

3. Quality Assurance. It is mandatory that adequate construction quality assurance systems and procedures be established to assure safe dam construction. The quality assurance system must guarantee, by direct inspection and testing, that construction is accomplished in compliance with the contract plans and specifications. Daily inspector's reports, laboratory test data records, and photographs are the minimum mandatory methods of documentation. General guidelines for documentation are given in Chapter two, section F.

As part of the quality assurance program, the contractor should normally be required to submit various plans for approval not limited to, but including, the following:

- Construction Schedule
- Safety Program
- Care and Diversion of Water (including pollution control)
- Fire Protection
- Plant layout (including haulroads)
- Environmental measures
- Equipment Inventory
- Dewatering Foundations and Borrow Areas
- Excavation Sequence of Foundations and Borrow Areas
- Drilling and Blasting Procedures
- Concrete Placement
- Restoration of Construction Area

CHAPTER SIX
MANAGEMENT OF TECHNICAL ACTIVITIES – OPERATION AND MAINTENANCE
FOR PROPOSED OR EXISTING DAMS AND APPURTRANENT WORKS

A. General

This section of the guideline outlines the management responsibilities for operation and maintenance, periodic inspection program, and emergency action planning that Regional Directors, Superintendents, and the Manager, Denver Service Center, should ensure are undertaken to obtain the safe and economic operation of dams under their jurisdiction. It is recognized that the extent of application of this guideline will vary depending on the size, function, and hazard potential classification of the dam.

B. Operation and Maintenance

1. General. All features of NPS dams and appurtenant works should receive maintenance or operation as recommended from

inspection reports—annual informal, intermediate, or formal. These reports should be prepared by trained and experienced engineers familiar with the maintenance and operation of small dams.

Unless it is an extenuating condition, extensive maintenance or testing of dam equipment should only be performed because of recommendations in an inspection report. These recommendations should be performed by personnel familiar with the maintenance and operation of small dams.

Serious maintenance, operational, or safety problems that are discovered during maintenance or operation work should be reported immediately to the Park Superintendent and personnel responsible for inspections as to the proper action to be taken. Maintenance and operations should be scheduled far enough in advance to take advantage of good weather periods, terrain conditions, and manpower and equipment availability to assure safe and economic work.

A log of maintenance and any required operation will be maintained and filed with the previous Annual Informal Inspection. The log will list the crew supervisor's name, date, activity accomplished or attempted, if incomplete, and total cost (overhead, materials, and labor, if readily available). Information about failures (partial or total), misoperation, accidents, flooding, or instrumentation readings should also be kept in the log.

2. Operating Procedures. Operations consist of the periodic testing of gates or any other type equipment to assure reliable use, establishing instrumentation as required, or reviewing any operating manuals or emergency action plans for completeness and accuracy. When appropriate, written operating instructions should be prepared for the dam and its associated structures and equipment. The instructions should cover the functions of the dam and reservoir and describe procedures to follow during flood conditions to ensure dam safety.

If appropriate for more critical NPS dams, reservoir operating rule curves should be available for each normal mode of operation and for emergency conditions.

An auxiliary power system, such as a gasoline, crane or diesel-operated generator, is essential if the outlet and spillway gates and other dam facilities are electrically operated.

All spillway and outlet gates should be tested on a regular schedule. The tests should include use of both the primary and the auxiliary power systems.

Project security is a matter of concern at important dams and appurtenant works. This includes preventing structural damage by vandals or saboteurs and unauthorized operation of outlet or spillway gates. In some cases restricting public access is essential and security patrols may be necessary.

Occupational and public type safety is of paramount importance at certain dams and reservoirs. Specifically, this type safety at the dam, appurtenant works, on and around reservoirs, and below the dam should be considered, particularly in recreational areas. Safety measures should include identification of high watermarks to indicate past or probable reservoir levels and streamflows, posting of safety instructions at highly visible and key locations, and providing audible safety warnings upstream of and below outlets as appropriate.

When applicable, occupational and public safety should be evaluated by personnel from the Safety Division. They should accompany the engineering team for the dam inspection to evaluate hazard potentials to personnel and visitors such as heights, depths, dangerous flows, mechanical and electrical equipment, and supplies. Their recommendations should be referenced in the inspection report.

Communication should be maintained among affected governmental bodies and with the public to enhance the safety aspects of the operation of the dam, if warranted. Communication alternatives include written communications, radio, telephone, television, and newspapers.

In the following sections, outlets or outlet gates refer to gates or valves on any outlets such as sluices, conduits or tunnels, pumps, generating units, and infrequently operated plant intake and discharge gates. If the project has a navigation lock, emergency closure and other infrequently operated equipment should also be included.

3. Maintenance. Maintenance is normally the preserving of structures, appurtenant works and equipment in intended operating condition by the proper control of vegetation, removal of debris and trash, equipment repair, and minor structural repair. It is not the repair of structural deterioration to restore original condition, improvements for dam safety, enlarging reservoir capacity, increased spillway and outlet capacity, or the replacement of equipment. Such major rehabilitation of construction should be carried out with the assistance of NPS, Denver Service Center (DSC), and Bureau of Reclamation (USBR).

The following list of typical maintenance work is provided:

- harmful vegetation, debris, and trash should be removed from the dam, appurtenant works, immediate upstream and
downstream areas, and access roads to assure structural integrity, reliable operation, visual observation, and accessibility. Undesirable material should be removed and properly disposed of so as to prevent problems during high water, winds, fire, or vandalism; -vegetation maintenance for erosion control and esthetics;

- large vegetation which has become an integral part of the dam or appurtenant works needs to be carefully evaluated to determine if removal is warranted;

- lubrication of equipment;

- painting;

- maintaining internal drainage systems; -minor mechanical and structural repairs;

- correcting minor deterioration of concrete and embankment surfaces;

- taking measurements from instrumentation;

- placement of signs warning of heights/depths, dangerous flows, and equipment, when applicable;

- placement of barriers to prevent unauthorized access;

- all maintenance work is to be performed in a safe manner. The use of personal–protective and safety devices is required when so determined by the supervisor or the Superintendent in consultation with the area safety officer or Regional Safety Manager.

C. Periodic Inspection Program

1. General. The purpose of the NPS periodic inspection program is to verify throughout the operating life of the project the structural integrity of the dam and appurtenant structures and assure the protection of human life and property.

All NPS dams will receive some level of evaluation based on current technical guidelines and criteria prior to any significant repairs, rehabilitation, or construction. New dams added to the inspection program should be planned, designed, and constructed in accordance with current technical criteria. Improvements in dam technology require that dams and appurtenant structures be reassessed to assure dam safety for more stringent design and materials criteria.

Regional Directors and Superintendents are responsible for assuring that the existing dams for which they are responsible are periodically inspected, and that new dams are inspected initially upon completion of construction and periodically thereafter.

2. Types and Frequencies of Inspections. The inspection types and intervals herein recommended are for guidance in developing inspection programs for all dams under NPS management. This guideline does not preclude other inspections or more frequent inspections if deemed necessary, depending on project history and importance of the facility.

Inspection personnel should be selected carefully, have qualifications commensurate with their assigned levels of responsibility, and receive training in the inspection procedures. Qualifications and training required for inspection personnel may vary with the complexity of the facility and with the level of the inspection.

a. Annual Informal Inspection. All dams and appurtenant works under NPS management will receive this type of inspection. Inspection is performed annually by NPS or contract personnel to evaluate hazard potential classification, maintenance, structural and mechanical integrity for operational reliability, visitor safety on or around the dam and updating or completing the NPS inventory of dams data base management system. Immediately after any unusual event such as large floods, earthquakes, suspected sabotage, vandalism, or structural or operational failure, an inspection will be performed by NPS personnel. Particular attention should be given to detecting evidence of (or changes in) leakage, erosion, -sinkholes, boils, seepage, slope instability, undue settlement, displacement, tilting, cracking, deterioration, and improper function of drains and relief wells.

The checklist given in Appendix C of Safety Evaluation of Existing Dams, USBR, 1980, or equivalent form, should be used to assure thoroughness. Previous inspection reports should be reviewed to see what earlier corrective action recommendations were or were not performed. - A brief explanation should be written as to why previously recommended maintenance or operations were not performed.
The annual informal inspection report package should consist of the following items:

- Map;
- Any photographs or drawings;
- Completed checklist of dam and appurtenant features
- Very brief memorandum with recommended corrective action for use by maintenance and operations personnel;
- Operational and maintenance condition code specified;
- Updated inventory listings or forms;

The following codes should be used to describe the operational and maintenance condition of structures and related equipment, and reported into the NPS Inventory:

1. Will fulfill intended purpose and required annual maintenance or operations are performed;
2. Will fulfill intended purpose but required maintenance, operations, or minor repairs is needed;
3. May not fulfill intended purpose and maintenance or major repair is needed;
4. Will not fulfill intended purpose and major repair or rehabilitation is needed.

Reports should receive review and be given signature approval, and the following distribution made:

1. Director (Park Facility Management Division)
1. Regional Director (Park Facility Management Division)
1. Park Superintendent

b. Intermediate Inspections. This type inspection is required of dams under NPS management that have either a high (1) or significant (2) hazard potential. For low hazard potential dams, intermediate inspections are not required. Intermediate inspections should include a thorough field inspection of the dam and appurtenant structures, and a review of the records of inspections made at, and following, the last formal inspection.

If unusual conditions are observed that are outside the expertise of these inspectors, arrangements should be made for inspections to be conducted by specialists.

(1) Frequency of intermediate inspections. Intermediate inspections, should be performed every three years where there is a high probability that dam failure or misoperation could result in loss of life or significant property damage.

(2) Qualifications of personnel for intermediate inspections. Intermediate inspections should be performed by technically qualified engineers, experienced in the operation and maintenance of dams and trained to recognize abnormal conditions. The inspectors should have access to and be familiar with all pertinent histories for the dam, and should be directly responsible for and intimately familiar with the operating characteristics of the dam. The dam tender or operator should be a participant in these inspections.

(3) Currently this type of inspection will be performed by USBR personnel as deemed necessary.

c. Formal and Special Inspections. This type inspection is required of dams under NPS management that have either a high (1) or significant hazard (2) potential. Formal inspections will not be performed for dams under NPS jurisdiction and classified as low hazard potential. A formal inspection is required periodically to verify the safety and integrity of the dam and appurtenant structures. Formal inspections should include a review to determine if the structures meet current accepted design criteria and practices. The inspection should include a review of all pertinent documents including instrumentation, operation, and maintenance and, to the degree necessary, documentation of investigation, design, and construction. In making the detailed inspection of the dam, appurtenant structures and equipment, diving inspections of underwater structures affecting the integrity of the dam should be included. All formal inspections should be conducted by a team of highly trained specialists. To assure that a dam and its appurtenant facilities are thoroughly inspected, checklists should be prepared to cover the condition of structural, electrical, and mechanical features. This inspection should also verify that operating instructions are available and understood, instrumentation is adequate and data assessed to...
assure structures are performing as designed, and there are emergency provisions for access to and communication with all project operating facilities.

(1) Frequency of formal inspections. Formal inspections should be made periodically at intervals not to exceed 6 years. Depending on past experience or the project history, some dams may require more frequent formal inspections.

(2) Frequency of special inspections. Special inspections should be performed immediately after the dam has passed unusually large floods and after the occurrence of significant earthquakes, sabotage, or other unusual events reported by operating personnel.

(3) Qualifications of personnel for formal and special inspections. Formal and special inspections should be conducted under the direction of licensed professional engineers experienced in the investigation, design, construction, and operation of dams. The inspection team should be chosen on a site-specific basis considering the nature and type of the dam. The inspection team should be comprised of individuals having appropriate specialized knowledge in structural, mechanical, electrical, hydraulic, and embankment design; geology; concrete materials; and construction procedures. They must be capable of interpreting structural performance and relating conditions found to current criteria and safety aspects. It is imperative that the inspection team adequately prepare for the inspections by reviewing and discussing all documents relative to the safety of the dam.

(4) The Bureau of Reclamation (USBR) is the preferred organization to perform both formal and intermediate inspections and any special studies or emergency services for NPS, particularly on either the high or significant hazard potential dams. However, NPS managers may, at their discretion, utilize other qualified agencies or contractor services when USBR would not be able to respond in sufficient time. NPS personnel will accompany the team and act as observers during this inspection.

(5) Data Books will be prepared by USBR or other inspecting organization for all NPS high (1) or significant (2) hazard potential dams which are scheduled for formal inspection. Appendix E is a checklist of the types of existing data which will be valuable for evaluating the safety, maintenance, and operation of NPS dams. Existing information for these Data Books should be prepared and distributed by Regional Directors or Superintendents to USBR or other inspecting organization two (2) months prior to the actual on-site examination.

(6) The following classification system will be used to describe safety of dam conditions. One of these classifications is assigned to a dam following an on-site examination and evaluation using available data and current state-of-the-art knowledge:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S–Satisfactory</td>
<td>No existing or potential dam safety deficiencies are recognized. All essential elements can be expected to function under all conditions, including such events as the maximum probable flood (MPF) or maximum creditable earthquake (MCE), which have only a remote chance of occurring;</td>
</tr>
<tr>
<td>F–Fair</td>
<td>No existing or potential dam safety deficiencies are recognized for normal operating conditions. All essential elements can be expected to function under normal operating conditions. Remotely occurring events of magnitudes approaching a MPF or MCE will likely cause a dam safety deficiency;</td>
</tr>
<tr>
<td>P–Poor</td>
<td>A potential dam safety deficiency for normal operating conditions is recognized. Major damage has occurred at one or more of the essential elements or may be anticipated to occur during normal operating conditions. Immediate corrective actions to resolve the deficiency(s) are recommended and reservoir or other project restrictions may be necessary until problem is resolved;</td>
</tr>
<tr>
<td>U–Unsatisfactory</td>
<td>A dam safety deficiency is recognized for normal operating conditions. One or more essential elements will not operate adequately under normal operating conditions. Problem resolution requires immediate action.</td>
</tr>
</tbody>
</table>

In association with any classification term, maintenance work to correct an existing condition of one or more essential elements, or installation of additional equipment to enhance dam safety and/or to monitor performance, may be advised. It is expected that adequate maintenance can prevent many dam safety deficiencies from occurring.

3. Instrumentation. Instrumentation or performance observation devices are used to supplement visual inspections in evaluating the performance and safety of dams. Careful examination of instrumentation data on a continuing basis may reveal a possible critical condition. Conversely, instrumentation may be a means of assuring that an observed condition is not serious and does not require immediate remedial measures.

a. Adequacy of Instrumentation. Instrumentation to monitor structural and functional performance should be installed in dams
where complex or unusual site conditions have been encountered or where there is a high probability that failure could result in loss of life or extensive property damages.

b. Observation of Monitoring Devices. The instrumentation data should be collected by personnel trained specifically for the purpose, including training to recognize and immediately report to those responsible for inspections any anomalies in the readings or measurements. Performance observation data should be properly established for record purposes. The frequency of instrument readings should be established at the time the instrumentation system is designed in order to give a timely warning of possible adverse conditions.

c. Data Analysis. It is essential that instrumentation data be processed, reviewed and assessed in a timely manner by a specialist familiar with the design, construction, and operation of the project. Operation manuals and design information should be referred to and evaluated of possible adverse threats.

4. Correction of Deficiencies. The inspection program could reveal those deficiencies or potential deficiencies which, if uncorrected, could eventually lead to failure or misoperation of the dam. Deficiencies may vary from emergency type items where immediate action is required to non-emergency type items which must be corrected in a timely manner but do not present an immediate danger to the safety of the structure. In all cases, corrective action should be made under the supervision of qualified personnel. Emergency action plans to be implemented when failure has already occurred or is imminent are discussed in Emergency Action Planning.

   a. High Priority Corrective Action. High priority corrective action is required for deficiencies which could result in failure of the dam within a short period of time. The Director will be notified immediately by the appropriate Regional Director of any dams (NPS or non-NPS) that are in this condition, and what action is being taken to remove the threat to park safety or operations.

   b. Non-emergency Corrective Action. Non-emergency corrective action is action taken when there is no immediate threat to the safety or operation of the dam, or any threat to life or property downstream. The Director will be notified immediately by the Regional Director of any dams (NPS and non-NPS) that are in this condition. The corrective action should be scheduled in advance of the fiscal year in which the work is to be done to allow time for planning, funding through the normal budgeting process, and arranging for special reservoir operations when required. Some of these deficiencies may be corrected through the regular operation and maintenance program discussed in operations and maintenance.

   c. Follow-up Action. Periodic inspection reports should continue to list identified deficiencies along with any newly discovered deficiencies and show the status of corrective action. Appropriate inspection personnel should make frequent field examinations, as long as the problem exists, to see that all corrective measures are being completed. When deficiencies are not corrected in a reasonable length of time, an investigation should be made to determine the reason for delay, and the Director should be notified of the findings.

5. Documentation. Proper documentation of the dam’s current and past performance is necessary to assess the adequacy of operation, maintenance, surveillance, and proposed corrective actions. A complete record or history of the investigation, design, construction, operation, maintenance, surveillance, periodic inspections, modifications, repair, and remedial work should be established and maintained so that relevant data relating to the dam is preserved and readily available for reference. This documentation should commence with the initial site investigation for the dam and continue through the life of the structure. This information will be collected by NPS personnel and delivered to the USBR to develop Data Books on high (1) and significant (2) hazard potential dams. See Chapter Six, section C.2. The data base management system for NPS dams will be maintained to keep current all data elements.

   a. Instrumentation. All instrumentation observation data and evaluation thereof should be properly tabulated and documented for record purposes.

   b. Inspections. All inspection observations, especially as related to the safety of the dam, should be documented. The extent and nature of inspection reports required for the annual informal, intermediate formal, and special inspections, will vary in proportion to the intensity of the inspection and the nature of the findings. Informal inspection reports may range from memoranda to brief reports. Intermediate inspection reports may vary from memoranda or trip reports to more formal reports containing substantial records, detail, and recommendations. Formal and special inspections require complete, formal technical reports of all findings, corrective actions and recommendations for permanent record and reference purposes in order to form a basis for major remedial work when required. All reports should be in a self-explanatory form that permits their retention as permanent records and should carefully document times of inspections, inspection personnel, and findings of the inspection.

   c. Correction of Deficiencies. All deficiencies corrected as a result of the recommendations contained in periodic inspection reports should be fully documented in report form and made a part of the permanent project record. Alterations made to the facility as a result of changes in criteria to meet current practices or changes in dam technology should be fully documented, including as-constructed drawings. Promptly perform corrective action on deficient dams. Dams listed as SERIOUSLY DEFICIENT should be corrected immediately. A dam is SERIOUSLY DEFICIENT if:

1 An official inspection report classifies the dam safety condition as:
a **POOR**—this classification is applied when major damage has occurred, or may be anticipated to occur, at one or more of the essential elements during normal operating conditions. Immediate corrective actions to resolve the deficiency(s) are recommended and reservoir or other restrictions may be necessary until problems are resolved; or

b **UNSATISFACTORY**—this classification is applied when one or more essential elements will not operate adequately under normal conditions. Problem resolution requires immediate corrective action; and/or

2 If the maintenance condition is rated:

a “3”, which indicates it may not fulfill intended purpose and maintenance or major repair is needed) or;

b “4”, which indicates it will not fulfill intended purpose and major repair or rehabilitation is needed.

6. NPS Observer Status at non-NPS Dams. Refer to Appendix G for an example letter for coordinating with non-NPS dam project owners and/or regulators.

a. General. Dams that NPS has no jurisdiction over, but are located immediately adjacent to or within park boundaries and affect safety or operations, will be carefully monitored. Regional Directors, Superintendents, and Manager, DSC, will report and maintain information about these non-NPS dams in our inventory data base system. Regional Directors should request the presence of NPS observers during the inspection of non-NPS dams located within or immediately adjacent to park boundaries and that are in the high (1) or significant (2) hazard potential classification. Such coordination will assure NPS awareness of their condition.

b. U.S. Army Corps of Engineers Safety Condition Codes. The following dam safety assessment codes are from the U.S. Army Corps of Engineers’ National Inventory of Dams (NID) data base management system, circa 1981. These safety of dams condition classification are referenced here for non-NPS dams located either within or immediately adjacent to park boundaries.

- For non-NPS dams or appurtenant works may have been assessed as “Unsafe,” if deficiencies are assessed to be of such a nature that, if not corrected, they could result in the failure or misoperation of the project with subsequent loss of life and/or substantial property damage. This classification is analogous to the National Park Service and Bureau of Reclamation safety of dams condition classification of Poor (Chapter 6, section C, 2, c, (6)).

- If the probable failure of an “Unsafe” dam or appurtenant works is judged to be an imminent threat to life or substantial property and immediate action is required to reduce or eliminate the deficiencies, the "Unsafe" condition of the dam should be considered an "emergency." This classification is analogous to the National Park Service and Bureau of Reclamation safety of dams condition classification of Unsatisfactory (Chapter 6, section C, 2, c, (6)). If the probable failure is judged not to be imminent, the "Unsafe" condition should be considered a "non-emergency."

D. Emergency Action Planning

1. General. It is intended that this guideline will minimize the risk of future dam failures. Nevertheless, it is recognized that despite the adequacy of this guideline and its implementation, the possibility of dam failures still exists. Even though the probability of such failures is small, preplanning is required to identify conditions which could lead to failure, in order to initiate emergency measures to prevent such failures as a first priority, and, if this is not possible, to minimize the extent and effects of such failure. This guideline provides operating and mobilization procedures to be followed upon indication of an impending or possible dam failure or a major flood. Project information and inspection results will be used to keep the NPS inventory data base system current.

Emergency Action Plans (EAP) are required for all high (1) or significant (2) hazard potential dams under Federal regulation or jurisdiction: The purpose of an EAP is to provide early warning and evacuation in the event of either a possible or actual dam failure or misoperation. An example EAP is provided in Appendix F for use by the parks. Superintendents should designate an EAP Coordinator, along with other individuals as given in Appendix F, at appropriate parks, with either NPS or non–NPS dams within the specified hazard potential category (see inventory in Appendix A). EAP coordinators should initiate EAP's for appropriate NPS dams or coordinate with non–NPS dams owners in the implementation of their EAP within park boundaries. Refer to Appendix G for an example letter for coordinating with non-NPS dam project owners and/or regulators.

Pertinent information about EAP’s should be recorded into the NPS Inventory of Dams. Since coordination is needed with state and local officials in implementing EAP’s, a list of state dam safety officers has been, provided in Appendix G.

2. Coordination with non–NPS Dam Owners. In those regions where high or significant hazard potential non–NPS dams exist within or immediately adjacent to park boundaries, Superintendents will request from those owners coordination in the preparation and implementation of any Emergency Action Plans as appropriate for park areas.
3. Evaluation of Emergency Potential. Prior to development of an emergency action plan, consideration must be given to the extent of land areas, and types of development within the areas, that would be inundated as a result of dam failure or flood, and the time available for emergency response.

a. Determination of Mode of Dam Failure. There are many potential causes and modes of dam failure, depending upon the type of structure and its foundation characteristics. Similarly, there are degrees of "failure" and, often, progressive stages of failure. Many dam failures can be prevented from reaching a final catastrophic stage by recognition of early indicators or precursor conditions, and by prompt, effective emergency actions. While emergency planning should emphasize preventive actions, recognition must be given to the catastrophic condition, and hazard potential should be evaluated in that light. Analysis should be made to determine the most likely mode of dam failure under the most adverse condition and the resulting peak water outflow following the failure. Where there is a series of dams on the stream, analyses should include consideration of the potential for progressive "domino" failure of the dams.

b. Inundation Maps. To evaluate the effects of dam failure, maps should be prepared delineating the area which would be inundated in the event of failure. Land uses and significant development or improvements within the area of inundation should be indicated. The maps should be equivalent to or more detailed than the United States Geological Survey (USGS) quadrangle maps, 7-1/2 minute series, or of sufficient scale and detail to identify clearly the area that should be evacuated if there is evident danger of failure of the dams. Since detailed inundation maps may not be readily available or easily used at a disaster area, a concise and clear word description should also be prepared for easy word-of-mouth communication. The word description would tell potential evacuees how high they should elevate themselves above the river or by horizontal distance to an area known to be safe from inundation. Copies of the maps should be distributed to local government officials for use in the development of an evacuation plan.

c. Classification of Inundation Areas. To assist in the evaluation of hazard potential, areas delineated on inundation maps should be classified in accordance with the degree of occupancy and hazard potential. The potential for loss of life is affected by many factors, including, but not limited to, the capacity and number of exit roads to higher ground and available transportation.

d. Time Available for Response. Analyses should be made to evaluate the structural, foundation, and other characteristics of the dam and determine those conditions which could be expected to result in slow, rapid or practically instantaneous dam failure.

4. Actions to Prevent Failure or Minimize Effects of Failure.

a. Development of Emergency Action Plan. An emergency action plan should be developed for each dam that constitutes a hazard to life or property, incorporating preplanned emergency measures to be taken prior to and following assumed dam failure. The plan should be coordinated with local governmental and other authorities involved in public safety and approved by the Regional Director for NPS dams. To the extent possible, the emergency action plan should define emergency situations that require immediate notification of local officials. The emergency action plan should include notification plans, which are discussed below in section b. A procedure should be established for review and revision, as necessary, of the emergency action plan, including notification plans and evacuation plans, at least once every year.

b. Notification Plans. Plans for notification of key personnel and the public are an integral part of the emergency action plan and should be prepared for slowly developing, rapidly developing, and instantaneous dam failure conditions. Notification plans should include a list of names and position titles, addresses, office and home telephone numbers, and radio communication frequencies and call signals, if available, for Regional Director, Superintendents, and Managers, or non-NPS dam owner personnel, public officials, and other personnel and alternates who should be notified as soon as emergency situations develop. A procedure should be developed to keep the list current.

Each type of notification plan should contain the order in which key agency or owner supervisory personnel or alternates should be notified. At least one—key supervisory level or job position should be designated to be manned, or the responsible person should be immediately available by telephone or radio 24 hours a day. A copy of each notification plan must be posted in a prominent place at the project site near a telephone and/or radio transmitter.

Where dams located upstream from the dam for which the plan is being prepared could be operated to reduce inflow or where the operation of downstream dams would be affected by failure of the dam, operators of those dams should be kept informed of the current and expected conditions of the dam as the information becomes available.

Civil defense officials having jurisdiction over all or part of the area subject to inundation should receive early notification. Local law enforcement officials and, when possible, local government officials and public safety officials should receive early notification.
The capabilities of the Civil Defense Preparedness Agency's National Warning System (NAWAS) should be determined for the project and utilized as appropriate. Information can be obtained from State or local civil defense organizations.

When it is determined that a dam may be in danger of failing, the public officials responsible for the decision to implement the evacuation plan should be kept informed of the developing emergency conditions.

The news media, including radio, television, and newspapers, should be utilized to the extent available and appropriate. Notification plans should define emergency situations for which each medium will be utilized and should include an example of a news release that would be the most effective for each possible emergency.

Notification of recreation users is frequently difficult because the individuals are often alone and away from any means of ready communication. Consideration should be given to the use of standard emergency warning devices, such as sirens, at the dam site. Consideration should be given to the use of helicopters with bullhorns for areas further downstream. Vehicles equipped with public address systems and helicopters with bullhorns are capable of covering large areas effectively.

c. Evacuation Plans. Evacuation plans should be prepared and implemented by the local jurisdiction controlling inundation areas. This would normally not be the dam agency or owner. Evacuation plans should conform to local needs and vary in complexity in accordance with the type and degree of occupancy of the potentially affected area. The plans may include delineation of area to be evacuated; routes to be used; traffic control measures; shelter; methods of providing emergency transportation; special procedures for the evacuation and care of people from institutions such as hospitals, nursing homes, and prisons; procedures for securing the perimeter and for interior security of the area; procedures for the lifting of the evacuation order and reentry to the area; and details indicating which organizations are responsible for specific functions and for furnishing the materials, equipment, and personnel resources required.

The assistance of local civil defense personnel, if available, should be requested in preparation of the evacuation plan. State and local law enforcement agencies usually will be responsible for the execution of much of the plan and should be represented in the planning effort. State and local laws and ordinances may require that other State, county, and local government agencies have a role in the preparation, review, approval, or execution of the plan. Before finalization, a copy of the plan should be furnished to the dam agency or owner for information and comment.

d. Stockpiling Repair Materials. Suitable construction materials should be stockpiled for emergency use. The amounts and types of construction materials needed for emergency repairs should be determined based on the structural, foundation, and other characteristics of the dam; design and construction history; and history of prior problems.

e. Locating Local Repair Forces. Arrangements should be made with, and a current list maintained of, local entities, including contractors, and Federal, State and local construction departments, for possible emergency use of equipment and labor.

f. Training Operating Personnel. Technically qualified project personnel should be trained in problem detection, evaluation, and appropriate remedial (emergency and non-emergency) measures.

g. Increasing Inspection Frequency. Frequency of appropriate surveillance activities should be increased when the reservoir level exceeds, a predetermined elevation. Piezometers, water level gages, and other instruments should be read frequently and on schedule. The project structures should be inspected as often as necessary to monitor conditions related to known problems and to detect indications of change or new problems that could arise. Hourly or continuous surveillance may be mandated in some instances. Any change in conditions should be reported promptly to the supervisor for further evaluation.

The supervisor should issue additional instructions, as necessary and alert repair crews and contractors for necessary repair work if developing conditions indicate that emergency repairs or other remedial measures may be required.

5. Actions Upon Discovery of a Potentially Unsafe (Seriously Deficient) Condition. Action to be taken will depend on the nature of the problem and the time estimated to be available for remedial or mitigating measures. As time permits, one or more of the following actions will be required.

a. Notification of Supervisory Personnel. This is essential, if time permits, since development of failure could vary in some or many respects from previous forecasts or assumptions, and advice may be needed.

b. Initiation of Predetermined Remedial Action. It is imperative that at least one technically qualified individual, previously trained in problem detection, evaluation, and remedial action, be at the project or on call at all times. Depending on the nature and seriousness of the problem and the time available, emergency actions can be limited, such as lowering the reservoir and holding water in upstream reservoirs. Other actions to be taken include notifying appropriate highway and traffic control officials promptly of any rim slides or other reservoir embankment failures which may endanger public highways.

c. Determination of Need for Public Notification. To the extent possible, emergency situations that will require immediate notification of public officials in time to allow evacuation of the potentially affected areas should be predefined for the use of management and project personnel. If sufficient time is available, the decision to notify public officials that the dam can be
expected to fail will be made at a predetermined supervisory level within the agency or owner organization. If failure is imminent or has already occurred, project personnel at the dam site would be responsible for direct notification of the public officials. The urgency of the situation should be made clear so that public officials will take positive action immediately.
APPENDIX A
NPS NATIONAL INVENTORY OF DAMS ON-LINE DATABASE ACCESS

Access to database is only available to personnel listed in the NPS email directory.

The URL is: http://pfmd2.nps.gov/PRP/Dams/dams/index.cfm

APPENDIX B
RECOMMENDED REFERENCES FOR MAINTENANCE, OPERATION, AND SAFETY OF DAMS


NOTE: ASCE publications may be obtained by contacting:
American Society of Civil Engineers
Attention: Publications
[New address needed]


NOTE: Reinhold publication may be obtained by contacting:
Van Nostrand Reinhold Co.
7625 Empire Drive
Florence, Kentucky 41042
Telephone: 606–525–6600


NOTE: Trans Tech publication may be obtained by contacting:
Trans Tech Publications


NOTE: Soil Conservation Service publications may be obtained by request from SCS field offices or by contacting:
Records and Communications Branch
Administration Services Division
Soil Conservation Service
P.O. Box 2890
Washington, D.C. 20013
Telephone: 202–447–3907


NOTE: Army publications may be obtained by contacting:
Office of the Chief of Engineers Publications Depot
890 South Pickett Street
Alexandria, Virginia 22304
Telephone: 202–272–7772


NOTE: Reclamation publications may be obtained by contacting:
Bureau of Reclamation
Attention: Publications, Code 922
P.O. Box 25007
Denver, Colorado 80225
Telephone: 303–234–3000
### NATIONAL PARK SERVICE NATIONWIDE 24-HOUR COMMUNICATIONS

<table>
<thead>
<tr>
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<th>(H) Home</th>
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<tbody>
<tr>
<td>Dispatch Office</td>
<td>Shenandoah National Park</td>
<td>(O) 540-999-3422</td>
<td></td>
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<tr>
<td>(They have 24-hour emergency numbers for all National Park System parks and offices)</td>
<td>3655 US Highway 211 East</td>
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<tr>
<td>Luray, VA 22835-9051</td>
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### BUREAU OF RECLAMATION CONTACTS

<table>
<thead>
<tr>
<th>Coordinator for Overall NPS Assistance</th>
<th>Bureau of Reclamation</th>
<th>Telephones</th>
<th>(O) Office</th>
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<tr>
<td>Civil Engineer, Betty Dinneen 1/</td>
<td>Technical Service Center</td>
<td>(O) 303-445-3029 1/ *</td>
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<tr>
<td>Alternate: Sue Thompson 2/</td>
<td>Attention: Client and Support Sevs, code 8010</td>
<td>(O) 303-445-2610 2/ *</td>
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<tr>
<td></td>
<td>P.O. Box 25007</td>
<td>(fax) 303-445-6356</td>
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<td></td>
<td>Bldg. 67, Denver Federal Center</td>
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<td></td>
<td>Denver, Colorado 80225-0007</td>
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### Dam Safety Program

<table>
<thead>
<tr>
<th>Chief, Bruce Muller 1/</th>
<th>Dam Safety Office, code D-1440</th>
<th>Telephones</th>
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<tr>
<td>Alternate: Civil Engineer, Rob Rocklin 2/</td>
<td></td>
<td>(O) 303-445-2765 1/ *</td>
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<td></td>
<td>(H) 303-978-9534 1/</td>
<td>(O) 303-445-2770 2/</td>
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<td></td>
<td>fax 303-445-6463</td>
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### Coordinator for Examinations, Civil Engineer, Chris Danley 1/ Alternate: Civil Engineer, Chris Veesaert 2/ | Inspections and Emergency Mgmt. Group code D-8470 | Telephones | (O) Office | (H) Home |
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<td>fax 303-445-6381</td>
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* Work hours vary; however, one of these individuals will be available from 7:00 a.m. to 4:00 p.m. (Rocky Mountain Time), Monday through Friday.

### NATIONAL PARK SERVICE WASHINGTON AND FIELD OFFICE

#### COORDINATORS AND CONTACTS

<table>
<thead>
<tr>
<th>Name</th>
<th>Mailing Address</th>
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<tbody>
<tr>
<td>Chief Ranger, Robert Gray 1/</td>
<td>National Park Service</td>
<td>(O) 202-513-7022 1/</td>
<td></td>
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<tr>
<td>Alternate: Mark Hartsoe 2/</td>
<td>Park Facility Management</td>
<td>(O) 202-513-7001 1/</td>
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<tr>
<td></td>
<td>Division, Org. Code 2420</td>
<td>(H) 703-493-8050 1/</td>
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<td></td>
<td>Maintenance, Operation, Safety of Dams Program</td>
<td>(O) 202-513-7025 2/</td>
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<tr>
<td></td>
<td>1201 I (Eye) Street, N.W., 10th Floor, space 41</td>
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<td>Washington, D.C. 20005-5905</td>
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| Civil Engineer, Bill Heubner 1/          | Alaska Support Office                         | (O) 907-644-3384 1/ |            |          |
| Alternate: Facility Manager, Tim Hudson 2/| Alaska Region                                  | (O) 907-644-3381 2/ |            |          |
|                                           | Planning, Design and Maintenance Division     |             |            |          |
|                                           | 240 West Fifth Avenue                         |             |            |          |
|                                           | Anchorage, Alaska 99501-2327                  |             |            |          |

### LIST OF NATIONAL AND REGIONAL COORDINATORS AND CONTACTS

FOR THE NATIONAL PARK SERVICE (NPS) MAINTENANCE, OPERATION, AND SAFETY OF DAMS (MOSD) PROGRAM

U.S. DEPARTMENT OF THE INTERIOR

FOR ALL DAMS AND IMPOUNDMENTS AFFECTING THE NATIONAL PARK SYSTEM

### NATIONAL PARK SERVICE WASHINGTON AND FIELD OFFICE COORDINATORS AND CONTACTS, continued

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<tr>
<td>Chief Ranger, Robert Gray 1/</td>
<td>National Park Service</td>
<td>(O) 304-535-6171 1/</td>
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<tr>
<td>Alternate: Park Manager, Pam Underhill 2/</td>
<td>Appalachian National Scenic Trail Park Office</td>
<td>(H) 304-258-5637 1/</td>
<td>(O) 304-535-6278 2/</td>
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</table>
LIST OF NATIONAL AND REGIONAL COORDINATORS AND CONTACTS
FOR THE NATIONAL PARK SERVICE (NPS) MAINTENANCE, OPERATION, AND SAFETY OF DAMS (MOSD) PROGRAM
U.S. DEPARTMENT OF THE INTERIOR
FOR ALL DAMS AND IMPOUNDMENTS AFFECTING THE NATIONAL PARK SYSTEM

NATIONAL PARK SERVICE WASHINGTON AND FIELD OFFICE
COORDINATORS AND CONTACTS, continued

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<tr>
<td>Civil Engineer, Mark Spadea 1/</td>
<td>Northeast Region, Philadelphia Office</td>
<td>(O) 215-597-0043 1/</td>
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<tr>
<td></td>
<td>U.S. Custom House, Room 350</td>
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<td>Civil Engineer, David Price 1/</td>
<td>Northeast Region, Boston Office</td>
<td>(O) 617-223-5096 1/</td>
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<tr>
<td>Alternate: Fred Bentley 2/</td>
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<td>Steve Butterworth 1/</td>
<td>Columbia Cascade Support Office</td>
<td>(O) 206-220-4277 1/</td>
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<tr>
<td>Alternate: Geoff Swan 2/</td>
<td>Pacific West Region</td>
<td>(O) 206-220-4275 2/</td>
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<td>Design and Engineering</td>
<td>(H) 425-643-7739 1/</td>
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</table>
Facility Management Chief, Jack Williams 1/  
Steven Bosiljevac, Civil Engineer 2/  
Pacific Great Basin Support Office  
Pacific West Region  
1111 Jackson Street, Suite 700  
Oakland, CA  94607

Civil Engineer, Gregory Robinson 1/  
Alternate-1: Chief of Engineering, Fred Shott 2/  
Alternate-2: Civil Engineer, John Gopaul 3/  
Emergency Incidents: Chief Ranger, Judy Forte 4/  
Southeast Support Office  
Southeast Region  
100 Alabama Street, S.W.  
Atlanta, Georgia 30303

Structural/Seismic Engineer, Rich Silva 1/  
Alternate: Chief, Facility Design, Bruce Warneke, 2/  
National Park Service  
Denver Service Center  
12795 West Alameda Parkway  
P.O. Box 25287  
Denver, Colorado 80225-0287

Federal Interagency Committee on Dam Safety (ICODS) National Dam Safety Program  
Chris Doyle 1/  
Alternate: Eugene Zeizel 2/  
Alternate: Rita Henry 3/  
Federal Emergency Management Agency  
Federal Dam Safety Program  
500 C Street, S.W., room 416  
Washington, DC 20472

National Design Engineer, William Irwin  
Alternate: Ronald Marlow 2/  
U.S. Department of Agriculture, Natural Resources Conservation Service  
National Dam Safety Program  
P.O. Box 2890, Room 6136S  
Washington, DC 20013-2890

Executive Director, Lori Spragens  
Association of State Dam Safety Officials  
(859-257-5140)
APPENDIX D
DATA BOOK LISTING

I. TYPICAL DATA RECORDS

A. Typical Types of Records - The following outline represents information needed by the Bureau of Reclamation or other inspecting organization in the MOSD program to adequately prepare a Technical Data Book. The data book will be used to evaluate the safety, maintenance, and operation of a dam. Information should be presented to inspection teams 2 months prior to on-site inspection.

1. Document verifying NPS ownership or dam safety responsibility
2. Copy of any contractual agreements between NPS and lessee of NPS dams therein relating to acquisition, planning, safety inspections, design, maintenance, operation, construction, financial arrangements, disposal, or any other activity significantly affecting park safety, maintenance, or operations
3. Most current information from any type inventory of NPS dams
4. Aerial photographs of damsite and reservoir area
5. Design criteria and technical records
6. Construction reports
7. Project history
8. Correspondence
9. Previous Safety of Dams report
10. Emergency Preparedness Plan
11. Pertinent photographs
12. Hydrology studies (most recent inflow design flood, other floods considered at the time of design, and flood routings)
13. Instrumentation monitoring records
14. Operation and Maintenance Reports
15. Reservoir operation record
16. SOP (Standard Operating Procedures)
17. DOC (Designers' Operating Criteria)
18. Statistics of dam, powerplant (if applicable), and reservoir
19. Design and as-built drawings
20. Reservoir area and capacity curves
21. Discharge curves for all water control structures and conduits
22. Monthly maximum and minimum reservoir elevations since first filling
23. Average daily inflow to reservoir (include the source of the information and the period of record used)
24. Any current operating restrictions (maximum water surface elevation, maximum discharge of spillway(s) and outlet works, etc.)
25. Records of any known problems experienced in operating and maintaining the dam, spillway, and outlet works (seepage, sinkholes, sloughing of slopes, offsets, displacements, cracking, erosion, mechanical equipment failure, debris, etc.)

B. Geology

1. Topographic maps, USGS quadrangle maps
2. Geologic reports (general regional, specific data on damsite and reservoir, geologic profile along axis of dam, landslide surveillance data, and geologic interpretation)
3. Seismicity [shear and fault zone data, seismic risk zone, MCE (maximum credible earthquake), and seismic considerations in design]
4. Geologic and seismic maps and drawings
5. Liquefaction studies
6. Geophysical data
7. Volcanic activity in area
8. Local petrochemical activity

C. Concrete Dams
1. Drawings: section through crown cantilever including lines of centers for an arch dam, plan view of dam, profile of dam-foundation contact, and surface contour map (most detailed USGS map of damsite)
2. Tailwater data
3. Most recent reservoir silt survey data (including density of silt)
4. Maximum and minimum reservoir temperatures - relative to depth in reservoir
5. Most recent concrete tests and properties to include data on compressive, tensile and shear stresses, density, modulus of elasticity, Poisson's ratio, and diffusivity
6. Contraction joint grout closure temperatures
7. Depth of ice in reservoir at dam
8. Location and monitoring data for major cracks in dam
9. Design and measured uplift pressures

D. Embankment Dams

1. Type of dam (homogeneous, zoned, etc.)
2. Gradation of construction materials
3. Surface and internal drainage features
4. Upstream and downstream slope protection
5. Freeboard
6. Crest details (including camber)
7. Placement densities and moisture content
8. Materials testing (laboratory and field tests performed)
9. Filter design criteria
10. Toe drain system
11. Soil parameters (including strength, permeability, void ratio, etc.)
12. Foundation and abutment conditions
13. Stability, settlement, and seepage measurements and analyses
14. Preconstruction and postconstruction investigations (test pits, drill holes, etc.)
15. History of reservoir filling and drawdown rates
16. Piezometer data

E. Mechanical Equipment

1. Descriptions
2. Design data on gates, valves, etc.
3. Installation-related problems
4. Air venting system (including test results available)
5. Emergency gate closure report
6. Manual or automatic operation of equipment
7. Remote control
8. Auxiliary power
9. Steel pipe and its drainage system
10. Trashracks
11. Special operating conditions and restrictions
12. Control equipment
13. Corrosion protection
14. Additional equipment needed to pass the design flood or to evacuate the reservoir
15. History of gate or valve operation and associated problems

II. TYPICAL LOCATIONS OF RECORDS

Suggested locations for obtaining the engineering-related records are:

A. Washington, D.C. office
B. Regional office
C. District office
D. Subdistrict office
E. Area office
F. Agency office
G. Project office

Suggested locations of obtaining geologic records are:

1. U.S. Geological Survey
2. State Geological Survey
4. State Bureau of Mines
5. State and local university libraries
6. State, city and other local libraries
7. Consulting geologists
APPENDIX E
EXAMPLE EMERGENCY ACTION PLAN

The purpose of the EAP is to facilitate the early warning and, if necessary, evacuation of persons in areas that would be affected by possible dam or appurtenant works failure or misoperation. Superintendents should develop an appropriate EAP for either high (1) or significant (2) hazard potential dams under their jurisdiction or coordinate with non-NPS dam owners to assure implementation of their EAP in affected park areas. Personnel designations, mapping, and local government contacts should have been made by September 30, 1982, and recorded into the NPS Inventory of Dams.

BASIC SYSTEM ELEMENTS

An effective Emergency Action Plan incorporates several essential elements. These are:

1. Dependable and responsible rainfall and staff gage observers. Their duties are to report to the Dam Operator the rainfall accumulation over a given period of time and the elevation of the reservoir pool or flow in the emergency spillway, if any. One of these observers should also give the dam a brief visual inspection at each gage reading to see if it is in danger of failing from reasons other than overtopping. The equipment needed to make these measurements can be a simple plastic rain gage and some sort of pole or staff in the reservoir or spillway area with elevations indicated clearly on it. There are more elaborate instruments available such as automatic rain and water level gages, but at a respectively higher cost. Their use is optional, but not essential.

2. Reliable and rapid local communications system with an emergency backup. This system is used to communicate the data gathered by the gage observers to the Dam Operator and by the Dam Operator in notifying the proper authorities of the need to initiate the warning plan and the evacuation plan. It can be by telephone, ham radio, CB radio, or police, fire, and other emergency radio systems. It is important that any system chosen have an emergency backup.

3. Dam Operator and Alternate. These persons' duties are to interpret the rainfall, streamflow, and spillway flow data given to them by the observers and other available weather information and, when necessary, notify the park EAP Coordinator or other authorities of the need to initiate the warning and evacuation plan.

4. Dam Hydraulic and Hydrologic Data. This information developed by a qualified engineer or gathered from other competent sources is used to establish the various trigger points (rainfall measurements, pool or spillway flow elevations, or other pertinent facts) at which the several progressive phases of the emergency warning system are initiated. This information is obtained from an engineer study which compares various rainfalls on the watershed with the spillway discharges they create and reservoir elevations. The Bureau of Reclamation is developing some of this type of information during their assessments of NPS Dams classified as high or significant hazard potential.

5. A Warning Dissemination Plan. This basically consists of a list of people to be notified if the conditions dictate. This should include the local government Emergency Services Coordinator or other designated local government officials who will in turn notify the people directly affected by flooding outside the park and carry out the Evacuation Plan, if that becomes necessary.

6. The Evacuation Plan. This consists of a list of homes, businesses, campsites, stream crossings, recreation activities, highways and roads, with their locations clearly identified on an inundation map, that are to be evacuated if necessary, and a means of transporting the people to a designated emergency shelter. Mapping should be of sufficient detail and scale to show where possible homes, businesses, campsites, stream crossings, highway and roads, and recreational activities are located in relationship to the dam and estimated flooding. Access routes should be clearly marked. Since detailed inundation maps may not be readily available or easily used at a disaster area, a concise and clear word description should also be prepared for easy word-of-mouth communication. Time word description would tell potential evacuees how high they should elevate themselves above the river or by horizontal distance to an area known to be safe from inundation. The EAP with the map should be filed with the park EAP Coordinator and the local Emergency Services Coordinator or other local government officials. The plan should also provide for the protection of the evacuated area until the residents can return to their areas. The local Emergency Services Coordinator or other local government officials are responsible for preparing and carrying out the Evacuation Plan if located outside the park. Proper coordination should be assured with these officials.
EXAMPLE EMERGENCY WARNING SYSTEM

The following is a fictitious example of a well-organized Emergency Action Plan for a city and is based on one prepared by the Tennessee Valley Authority for the City of Norton, Virginia. This is not necessarily the type of system that will be best suited to your situation, but it should give you a general idea of how one is set up.

STAGE I

1. Rain measuring equipment will be inspected and measurements begun initially upon notice of a flood watch or warning. This warning would come from the National Weather Service.

2. Rainfall measured by the gage observer will be compared by the Dam Operator with the rainfall of other weather observers such as local government Emergency Service officials during flood watches and warnings.

3. Rainfall will be monitored around the clock and reported to the Dam Operator on a 24-hour basis by the rainfall gage observer.

4. Upon receiving notice that two (2) inches of rain in any 24-hour period has fallen, the Dam Operator will initiate State II by notifying the EAP Coordinator who will notify the:
   A. Superintendent
   B. Park Ranger,
   C. Administrative Manager

STAGE II

1. Every four hours after Stage II is affected, the staff gage observer will personally read the gage at the spillway and record the reading and report it to the Dam Operator.

2. When a depth of two (2) feet in the spillway exists, the frequency of the readings will be increased every two hours, or will be made even more frequently if desired by the Dam Operator.

3. In the event the spillway readings reach three (3) feet, Stage III will be put into effect by the Dam Operator. The Dam Operator will notify the EAP Coordinator of Stage III, who will in turn notify the:
   A. Superintendent
   B. Park Ranger
   C. Administrative Manager
   D. Local Government Emergency Official

Stage III

1. The Emergency Action Plan Coordinator will initiate the Evacuation Plan.

2. The Evaluation Plan will be implemented by the Ranger Division under the direction of the Park Ranger, with assistance from all available Fire, Rescue, and other appropriate personnel.

3. Necessary transportation from the affected area will be provided by a school bus or other means as determined by the EAP Coordinator.

4. Evacuated persons will be sheltered as designated in the evacuation notice.

5. Once the area is evacuated, persons designed by the Park Ranger will secure the area from access except for official business.

6. Readings of the spillway level will continue to be, read by the gage observer and be reported hourly to the EAP Coordinator during Stage III until water recedes to one foot or less over the spillway.

CONCLUSION

The local government Emergency Services Coordinator in your city or county should be notified, if appropriate, of your plans to establish the EAP, and its development must be closely coordinated with him so that he will be completely familiar with it. Once the plan is established it should be reviewed annually and updated if the conditions downstream have changed enough, to dictate it.

The Warning Dissemination and Evacuation Plans can also be used if the dam is failing from reasons other than flooding and overtopping. On new or rehabilitated structures this Emergency Action Plan should be established prior to the beginning of
impoundment so that an evacuation can be carried out—if a failure prone situation develops. Hopefully you will never need to use it, but if the need ever arises, such a system will greatly reduce the chance of any loss of life.

APPENDIX F
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APPENDIX G
Example Letter To Non–NPS Dam Owner or Regulatory Agency (Preferably)

Certified Mail, Receipt Requested
Ms. Francis Doe, Chief, Engineering Division
South Lakes, Inc.
176 Water Street
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Subject: Back River Dam

Dear Ms. Doe:

As discussed during our telephone conversation on July 15, 1982, certain information about your dam, which affects Waterway National Park, is needed.

As you can well understand, we need this information so that appropriate steps can be taken to assure that park visitors and resources are protected in those areas for which we have warning, rescue and evacuation responsibilities, in the event of spillway releases, possible dam failure, or accidents at the dam or reservoir.

Please send the following items to this park periodically and by certified mail:

1. A copy of your most current formal safety of dams inspection report, and if the dam has any serious deficiencies, an explanation of how and when corrective action will be performed. Please review and revise the attached NPS Inventory of Dams Report listing for your dam based upon this report. To be able to assign a safety of dams condition code [data element 27], this report will need to include a recent stability analysis including the use of criteria for the Maximum Probable Flood (MPF) and Maximum Credible Earthquake (MCE). If the project is proposed for construction or reconstruction, the National Park Service would appreciate the opportunity to review and comment on your design and construction documents.

2. Permission granting NPS observer status during your next formal safety of dams inspection.

3. Please incorporate the park into your Emergency Action Plan (EAP) and send us a copy. This EAP contains early warning, flood mapping, and evacuation procedures and is given to those jurisdictions that would be affected by spillway releases, possible dam failure, misoperation, or even an accident at the dam or reservoir. Your Notification Directory or Call-up List should state that the park is immediately affected and should be contacted directly by the dam operator/tender. Based upon these documents, the park will include your EAP into the park’s Early Flood Warning, Search/Rescue, Evacuation, and Recovery Plan (ESEP) for those areas which it has warning, rescue, and evacuation responsibility. Your EAP and the park’s ESEP will become part of the park’s Emergency Operations Plan. This responsibility is described in the U.S. Department of the Interior, National Park Service Reference Manual -40, Dams and Appurtenant Works, Chapter 6, Section D, and is in accordance with the Federal Guidelines for Dam Safety, pages 10 and 36.

If you have any questions or comments about this request, please contact (Park Official) at 999-999-9999.

Sincerely,

Regional Director/Superintendent

cc: NPS Regional Maintenance, Operations, and Safety of Dams Program Coordinator
NPS Washington Office, Park Facility Management Division, code 2420
APPENDIX H
List of Official Technical Supplements to Director’s Order #40 and Reference Manual (RM)-40

for the National Park Service (NPS) Maintenance, Operation, and Safety of Dams (MOSD) Program


<table>
<thead>
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Appendix H

continued, List of Official Technical Supplements to Director’s Order #40 and Reference Manual (RM)-40

INVENTORYING
2, Section
NPS Inventory of Dams on-line database Servicewide C and Appendix A
National Park Service, Park Facility
Management Division, Washington, D.C., 2005

HAZARD POTENTIAL
1, Section
Downstream Hazard Classification WASO A7615(610) D, 3. Guideline for
determining down-
Guidelines, ACER Technical Memorandum Regionwide sification at and
tactical potential clas-
No. 11, Bureau of Reclamation, Regionwide not a classification of
downstream of dam-
Assistant Commissioner, Denver, maintenance,
Colorado, 1988 (Revised) not a classification of
safety structural, or public
condition.

STRUCTURAL AND MAINTENANCE EXAMINATION
6, Section
examining earth memo, February 12, and concrete dams.
Bureau of Reclamation, memo, May 17, 1990, stream hazard (risk)
Dam Safety Division, Regionwide sification at and
Denver, Colorado, 1983 (Revised) not a classification of
subsequent releases,
Regionwide structural, or public

PUBLIC SAFETY EXAMINATION
6, Section B
Public Safety Around Dams and WASO A7615(610), Manual for examining
public safety memo, June 12, 1992, around dams and
Reservoirs, Interim Working Regionwide
reservoirs.
Guideline, Dam Safety Inspection
Section, Bureau of Reclamation,
Denver, Colorado, June 1992

Appendix H
October 9, 1987

Special Directive 87-4

To: Directorate, Field Directorate, Washington Office (WASO)
Division Chiefs, and All Superintendents

From: Acting Director

Subject: Dams and Appurtenant Works - Desk Reference Manual for Maintenance, Operation, and Safety

This Directive replaces and updates Staff Directive 86-2 of the same subject. It provides a brief explanation of the National Park Service (NPS) Maintenance, Operation, and Safety of Dams (MOSD) program responsibilities.

Complete management responsibilities are outlined in more detail in NPS-40, Dams and Appurtenant Works, Chapter 2. The key action responsibilities are as follows:

° Prepare, review, and update annually Emergency Action Plans (EAP's) for any NPS dams that are classified as Downstream HIGH or SIGNIFICANT Hazard Potential. Use NPS-40, Chapter 2, Section B, paragraph 6 and Chapter 6, Section D.

° Prepare, review, and update annually Emergency Action Plans for park areas that are affected by non-NPS dams. Information about contacting State dam safety officials regarding private dams that affect park areas is provided in NPS-40, Appendix F and attachment 2 of this Directive.

° Prepare or obtain official inspection reports for all NPS and non-NPS dams and incorporate findings into the Inventory of Dams. Use NPS-40, Chapter 6, Section C and Dam Inventory Users Guide, Revised February 1985.

° Promptly perform corrective action on deficient dams. Dams listed as SERIOUSLY DEFICIENT should be corrected immediately. A dam is SERIOUSLY DEFICIENT if an official inspection report classifies the safety condition as POOR or UNSATISFACTORY or the maintenance condition as 3, 4, or 5. Use the current Inventory of Dams and NPS-40, Chapter 3, Section C and Chapter 6, Section C, paragraph 4.

° Maintain accurately the NPS Inventory of Dams for any size, type, or owner (NPS or non-NPS) of dams that affect park resources, safety, maintenance, or operations. Dams that are proposed, existing, or deactivated and either within, adjacent to, or upstream of park areas will be included. Use NPS-40, Chapter 2, Section C and Dams Inventory Users Guide, revised February 1985.
* Dams and appurtenant works including adjacent areas out to 15 feet will be kept free of any woody vegetation, trees, roots, bushes, debris, or any other material which interferes with the access, visibility, inspection, operation, or maintenance of the facility. Grass will be mowed at prescribed intervals, particularly before inspections. Complete inspections cannot be performed when access or visibility is impared by vegetation or debris. Spillways and other water control devices should be kept clear of obstructions and debris and seepage monitored on a regular basis. Use NPS-40, Chapter 6, Section B and the Operations and Maintenance Guidelines for Small Dams.

* Maintain operations and maintenance logs for NPS dams. Use NPS-40, Chapter 6, Section B and the Operations and Maintenance Guidelines for Small Dams, page 13 and Appendix B.

* Retain only essential dams. Dams, appurtenant works, and impoundments unauthorized by legislation or not approved in a General Management Plan should be deactivated, particularly if they are deficient. Deficient dams should not be acquired. Use NPS-40, Chapter 1, Section C and Chapter 3.

A list of official guidelines, an example letter for initiating contact with a non-NPS dam owner, and a list of NPS and Bureau of Reclamation engineers for special assistance, particularly during emergencies, are provided in attachments 1, 2, and 3 respectively.

For additional information, contact your Regional Dams Coordinator or Mr. Charles Karpowicz, NPS Dams Officer, at 202-565-1249 if you have any questions.

Attachments (3)

cc: Commissioner, Bureau of Reclamation
List of Official Guidelines and Manuals for the National Park Service (NPS)
Maintenance, Operation, and Safety of Dams (MOSD) Program

<table>
<thead>
<tr>
<th>Title of Guideline or Manual</th>
<th>NPS ID</th>
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Technical Supplements to NPS-40 Management Guideline

|----------------------------|-----------------------------------------------|------------------------------------------------|

List of Official Guidelines and Manuals Attachment 1-1, continued
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<tr>
<td>INVENTORYING</td>
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<td>Reference NPS-40, Chapter 2, Section C. A users guide for NPS Dams and Related Flood Plain Inventory Report printouts.</td>
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<td>Downstream Hazard Classification</td>
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<td>Guidelines, ACER Technical Memorandum No. 11, Bureau of Reclamation, Assistant Commissioner, Denver, Colorado, 1988 (Revised)</td>
<td>WASO A7615(610)</td>
<td>memo, June 12, 1992, Regionwide</td>
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<td>Safety Evaluation of Existing Dams, Bureau of Reclamation, Dam Safety Division, Denver, Colorado, 1983 (Revised)</td>
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<td>memo, June 12, 1992, Regionwide</td>
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<tr>
<td>PUBLIC SAFETY EXAMINATION</td>
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<td>Reference NPS-40, Chapter 6, Section B Manual for examining public safety around dams and reservoirs.</td>
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<td>FINANCE</td>
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<td>Reference NPS-40, Chapter 2, Section E. Example financial work sheet for formulating budgets and tracking expenses in the management or monitoring of all dams.</td>
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<td>Financial Work Sheet, SMOD Form I</td>
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Attachment 2, Example Letter
Example Letter To Non-NPS Dam Owner or Regulatory Agency (Preferably)

Certified Mail, Receipt Requested
South Lakes, Inc.
Attention: Ms. Francis Doe, Chief of Engineering Division
176 Water Street
Riverton, Texas 99999

Subject: Back River Dam

Dear Madam:

As discussed during our telephone conversation on July 15, 1982, certain information about your dam which affects Waterway National Park is needed.

You can well understand our need for this information so that appropriate steps can be taken to assure that park visitors and resources are protected in those areas for which we have warning, rescue, and evacuation responsibilities in the event of spillway releases, possible dam failure, or accidents at the dam or reservoir.

Please place this park on your mailing list to receive periodically and by certified mail the following items:

1. A copy of your most current formal safety of dams inspection report, and if the dam has any serious deficiencies, an explanation of how and when corrective action will be performed. Please review and revise the attached NPS Inventory of Dams Report listing for your dam based upon this report. To be able to assign a safety of dams condition code [data element 27], this report will need to include a recent stability analysis including the use of criteria for the Maximum Probable Flood (MPF) and Maximum Credible Earthquake (MCE). If the project is proposed for construction or reconstruction, the National Park Service would appreciate the opportunity to review and comment on your design and construction documents.

2. Permission granting NPS observer status during your next formal safety of dams inspection.

3. Incorporation of the park into and a copy of your Emergency Action Plan (EAP). This EAP has early warning, flood mapping, and evacuation procedures and is given to those jurisdictions who would be affected by spillway releases, possible dam failure, misoperation, or even an accident at the dam or reservoir. Your Notification Directory or Call-up List should state that the park is immediately affected and contacted directly by the dam operator/tender. Based upon these documents the park will prepare its own EAP for those areas which it has warning, rescue; and evacuation responsibility. The NPS prepared EAP is part of the park's Emergency Operations Plan. This responsibility is described in the U.S. Department of the Interior, National Park Service management guideline, NPS-40, Dams and Appurtenant Works..., Chapter 6, Section D, and is in accordance with the Federal Guidelines For Dam Safety, pages 10 and 36.

If you have any questions or comments about this request, please contact (Park Official) at commercial telephone 999-999-9999.

Sincerely,

Regional Director/Superintendent

cc: WASO Engineering and Safety Services Division, Code 610
**LIST OF CONTACTS AND COORDINATORS FOR THE NATIONAL PARK SERVICE (NPS) MAINTENANCE, OPERATION, AND SAFETY OF DAMS PROGRAM**

**12/13/99, D:\document\dams13.99**

**BUreau of Reclamation Contacts**

<table>
<thead>
<tr>
<th>Name</th>
<th>Mailing Address</th>
<th>Telephones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator for Overall NPS Assistance Civil Engineer, Betty Dinneen</td>
<td>Bureau of Reclamation Technical Service Center Attention: Client Business Svcs, D-8010 P.O. Box 25007 Bldg. 67, Denver Federal Center Denver, Colorado 80225-0007</td>
<td>(O) 303-445-3029 (O) 303-445-2594</td>
</tr>
<tr>
<td>Alternate: Tom Luebke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternate: Dave Eubank 2/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordinator for Examinations, Civil Engineer, Leon Faris</td>
<td>Inspections and Emergency Mgmt. Group D-8470</td>
<td>(O) 303-445-2747</td>
</tr>
<tr>
<td>Alternate: Civil Engineer, Chris Veeseart</td>
<td></td>
<td>(O) 303-445-2742* fax 303-445-6381</td>
</tr>
</tbody>
</table>

* Work hours vary; however, one of these individuals will be available from 7:00 a.m. to 4:00 p.m. (Rocky Mountain Time), Monday through Friday.

**National Park Service Washington and Field Office Coordinators**

| NPS Dams Program Officer, Charles Karpowicz 1/ | National Park Service Park Facility Management Division, Org. Code 2420 1640 C Street, N.W. room M18 7252 Washington, D.C. 20240 | (O) 202-565-1249 1/ |
| Alternate: Mark Hartsoe 2/ | | (O) 202-565-1244 |
| Civil Engineer, Bill Keubner 1/ | Alaska SO (Support Office) Alaska Region Planning, Design and Maintenance Division 2525 Gamble Street, Room 107 Anchorage, Alaska 99503-2892 | (O) 907-257-2675 1/ |
| Alternate: Supervisory General Engineer Bruce Sherwood 2/ | (H) 907-257-2878 2/ |
| Chief Ranger, Robert Gray | National Park Service Appalachian National Scenic Trail Park Office C/O NPS Harpers Ferry Center Harpers Ferry, West Virginia 25425 | (O) 304-535-6278 |
| Alternate: Park Manager, Pam Underhill | | (H) 304-258-5637 fax 304-535-6270 |
| Civil Engineer: Phil Ayers 1/ | Denver SO Intermountain Region Facility Management, Design, and Engineering Branch 12795 West Alameda Parkway P.O. Box 25287 Denver, Colorado 80225-0287 | (O) 303-969-2606 1/ |
| Alternate: Roger Maxwell, 2/ | | (H) 303-215-0979 2/ |
| Tim Windle 3/ | (O) 303-969-2659 2/ |
| Civil Engineer, Joe Bruno 1/ | Southwest SO Intermountain Region Maintenance, Design, and Engineering Office P.O. Box 728 Santa Fe, New Mexico 87504-0728 | (O) 505-988-6036 1/ |
| Alternate: Program Leader, Maintenance, Design, and Engineering, Richard Niemeyer 2/ | | (H) 505-471-0132 2/ |
| Alternate: Civil Engineer, Allen Bengtson | | (O) 505-988-6035 2/ |
| Environmental Engineer, Dick Fisher 1/ | Midwest SO Midwest Region Maintenance and Engineering 1709 Jackson Street Omaha, Nebraska 68102-2571 | (O) 402-221-3945 1/ |
| Alternate: Civil Engineer, Wayne Vander Tuin 2/ | | (H) 402-332-2519 2/ |
| | | (O) 402-221-3691 2/ fax 402-221-3665 |

List of Contacts and Coordinators Attachment 1 of 3 continued
### NATIONAL PARK SERVICE WASHINGTON AND FIELD OFFICE COORDINATORS, continued

<table>
<thead>
<tr>
<th>Name</th>
<th>Mailing Address</th>
<th>Telephones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Engineer, Stan Tolman 1/</td>
<td>National Capital SO</td>
<td>(O) 202-619-7270 2/</td>
</tr>
<tr>
<td>Alternate-1: Don Filsoof 2/</td>
<td>National Capital Region</td>
<td>(O) 202-619-7270 2/</td>
</tr>
<tr>
<td>Alternate-2: Dave Hammers 3/</td>
<td>Maintenance and Design</td>
<td>(O) 202-619-7270 2/</td>
</tr>
<tr>
<td></td>
<td>Room 358</td>
<td>(O) 202-619-7270 2/</td>
</tr>
<tr>
<td></td>
<td>1100 Ohio Drive, S.W.</td>
<td>(O) 202-619-7270 2/</td>
</tr>
<tr>
<td></td>
<td>Washington, D.C. 20242</td>
<td>(O) 215-597-0043</td>
</tr>
<tr>
<td>Civil Engineer, Mark Spadea</td>
<td>Philadelphia SO</td>
<td></td>
</tr>
<tr>
<td>Alternate: Facility Manager, Ross Flanagan</td>
<td>Northeast Region</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance, Design, and Engineering U.S. Custom House, Room 306</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200 Chestnut Street</td>
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</tr>
<tr>
<td></td>
<td>Philadelphia, Pennsylvania 19106</td>
<td></td>
</tr>
<tr>
<td>Civil Engineer, David Price 1/</td>
<td>Boston SO</td>
<td>(O) 617-223-5096 1/</td>
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<tr>
<td>Alternate: Fred Bentley 2/</td>
<td>Northeast Region</td>
<td>(O) 617-223-5260 1/</td>
</tr>
<tr>
<td></td>
<td>Engineering and Facility Management 15 State Street</td>
<td>(O) 617-223-5260 1/</td>
</tr>
<tr>
<td></td>
<td>Boston, Massachusetts 02109-3572</td>
<td></td>
</tr>
<tr>
<td>Environmental Engineer, Noby Ikeda, 1/</td>
<td>Pacific Great Basin SO</td>
<td>(O) 415-427-1377 1/</td>
</tr>
<tr>
<td>Alternate: Facility Management Chief,</td>
<td>Pacific West Region</td>
<td>(O) 415-408-1402 1/</td>
</tr>
<tr>
<td>Jack Williams, 2/</td>
<td>Facility Management</td>
<td>(O) 415-427-1384 2/</td>
</tr>
<tr>
<td></td>
<td>600 Harrison Street, Suite 600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>San Francisco, CA 94107-1372</td>
<td></td>
</tr>
<tr>
<td>Civil Engineer, Richard Engle 1/</td>
<td>Columbia Cascade SO</td>
<td>(O) 206-220-4274 1/</td>
</tr>
<tr>
<td>Alternate: Jeff Swan 2/</td>
<td>Pacific West Region</td>
<td>(O) 206-220-4274 2/</td>
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<td></td>
<td>Design and Engineering</td>
<td>(H) 206-842-6153 1/</td>
</tr>
<tr>
<td></td>
<td>909 First Avenue</td>
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</tr>
<tr>
<td></td>
<td>Seattle, Washington 98104-1060</td>
<td></td>
</tr>
<tr>
<td>Civil Engineer, Simon Tran-M-Trung 1/</td>
<td>Southeast SO</td>
<td>(O) 404-562-3108 1/</td>
</tr>
<tr>
<td>Alternate-1: Dan Cockrum 2/</td>
<td>Southeast Region</td>
<td>(O) 404-562-3257 1/</td>
</tr>
<tr>
<td>Alternate-2: Leon Folsom 3/</td>
<td>Education and Visitor Services</td>
<td>(O) 404-562-3124 2/</td>
</tr>
<tr>
<td></td>
<td>Maintenance and Engineering Division</td>
<td>(O) 404-562-3124 3/</td>
</tr>
<tr>
<td></td>
<td>100 Alabama Street, S.W.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atlanta, Georgia 30303</td>
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</tr>
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### NATIONAL PARK SERVICE DENVER SERVICE CENTER

<table>
<thead>
<tr>
<th>Name</th>
<th>Mailing Address</th>
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<tbody>
<tr>
<td>Geotechnical Engineer, Mike Casias 1/</td>
<td>National Park Service</td>
<td>(O) 303-969-2302 1/</td>
</tr>
<tr>
<td>Alternate: Chief, Engineering Services,</td>
<td>Denver Service Center</td>
<td>(O) 303-969-2140 2/</td>
</tr>
<tr>
<td>Terry Wong, 2/</td>
<td>Engineering Services, DSC-EM</td>
<td>(O) 303-969-2930</td>
</tr>
<tr>
<td></td>
<td>12795 West Alameda Parkway</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P.O. Box 25287</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Denver, Colorado 80225-0287</td>
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*List of Contacts and Coordinators
Attachment 2 of 3 continued*
## OTHER CONTACTS

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<tr>
<td><strong>FEDERAL HIGHWAY ADMINISTRATION</strong></td>
<td></td>
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<tr>
<td>Program Manager, Arthur E. Hamilton</td>
<td>Federal Lands Highway Program Federal Highway Administration, Room 4136 400 7th Street, S.W. Washington, D.C. 20590</td>
<td>(O) 202-366-9494</td>
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<tr>
<td><strong>FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)</strong></td>
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<tr>
<td>Alternate: Rita Henry 2/</td>
<td></td>
<td></td>
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<tr>
<td><strong>ASSOCIATION OF STATE DAM SAFETY OFFICIALS (ASDSO)</strong></td>
<td></td>
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<tr>
<td>Executive Director, Lori Spragens Conference Coordinator, Susan Sorrell Administrative Assistant, Carrie Wright</td>
<td>Association of State Dam Safety Officials 450 Old Vine Street, Second Floor Lexington, KY 40507</td>
<td>(O) 606-257-5140 fax 606-333-1988</td>
</tr>
</tbody>
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D.5. Natural Resources Conservation Service
Preface

This Technical Release (TR) describes design procedures and provides minimum requirements for planning and designing earth dams and associated spillways. This TR was developed to provide uniform criteria for earth dams and reservoirs. NRCS plans, designs, and constructs complex dams under widely varying conditions. It is essential that these dams be constructed with uniform criteria to ensure consistent performance. As new experience, materials, and knowledge become available, this document will be revised.

This TR applies to all Low Hazard Class dams with a product of storage times the effective height of the dam of 3,000 acre-feet$^2$ or more, those more than 35 feet in effective height, and all Significant and High Hazard Class dams. Requirements are stated as maximum or minimum limits and may not be satisfactory design criteria for all sites. In some cases, problems may arise where proven solutions are not available or alternate procedures may need to be evaluated before the best solutions can be developed and selected. Experience, state laws and regulations, investigations, analysis, expected maintenance, environmental considerations, or safety laws may dictate more conservative criteria to ensure satisfactory performance.

This edition of the TR incorporates all previously issued revisions and amendments, as well as significant changes in chapters 2 (24-hour Design Storms), 5 (Slope Stability Analysis), and 7 (New Earth Spillway Breach Model) that were widely distributed and reviewed. This edition also makes numerous editorial corrections, including SCS to NRCS; emergency spillway to auxiliary spillway; and Class a, b, c to Low, Significant, High Hazard Class, respectively.
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<td>Stability design (auxiliary spillway) and freeboard hydrographs</td>
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### Part 3

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General

Dam classification

In determining dam classification, a number of factors must be considered. Consideration must be given to the damage that might occur to existing and future developments should the dam suddenly release large quantities of water downstream due to a breach, failure, or landslide into the reservoir. The effect of failure on public confidence is an important factor. State and local regulations and the responsibility of the involved public agencies must be recognized. The stability of the spillway materials, the physical characteristics of the site and the valley downstream, and the relationship of the site to industrial and residential areas including controls of future development all have a bearing on the amount of potential damage in the event of a failure.

Dam classification is determined by the above conditions. It is not determined by the criteria selected for design. The policy on classification is in 210-V-NEM (National Engineering Manual), Part 520, Subpart C, DAMS.

Classes of dams

The following classes of dams have been established by policy and repeated here for convenience of the user.

- Low Hazard Class—dams located in rural or agricultural areas where failure may damage farm buildings, agricultural land, or township and country roads.
- Significant Hazard Class—dams located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways or minor railroads, or cause interruption of use or service of relatively important public utilities.
- High Hazard Class—dams located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

Peak breach discharge criteria

Breach routings are used to help delineate the area potentially impacted by inundation should a dam fail and can be used to aid dam classification.

Stream routings made of the breach hydrograph will be based upon topographic data and hydraulic methodologies mutually consistent in their accuracy and commensurate with the risk being evaluated.

The minimum peak discharge of the breach hydrograph, regardless of the technique used to analyze the downstream inundation area, is:

1. For depth of water at the dam at the time of failure where \( H_w \geq 103 \text{ ft} \)
   \[
   Q_{\text{max}} = (65) H_w^{1.85}
   \]

2. For depth of water at the dam at the time of failure where \( H_w < 103 \text{ ft} \)
   \[
   Q_{\text{max}} = (1,100)B_r^{1.35} \quad \text{where } B_r = \frac{(V_s)(H_w)}{A}
   \]
   but not less than \( Q_{\text{max}} = (3.2)H_w^{2.5} \) nor more than \( Q_{\text{max}} = (65)H_w^{1.85} \)

3. When the width of the valley, \( L \), at the water surface elevation corresponding to the depth, \( H_w \), is less than,
   \[
   T = \frac{(65)H_w^{0.35}}{0.416}
   \]
   replace the equation, \( Q_{\text{max}} = (65)H_w^{1.85} \), in 1 and 2 above with,
   \[
   Q_{\text{max}} = (0.416)(L)H_w^{1.5}
   \]
   where:
   \( Q_{\text{max}} \) = the peak breach discharge, \( \text{ft}^3/\text{sec} \)
   \( B_r \) = breach factor, acre
   \( V_s \) = reservoir storage at the time of failure, acre-ft
   \( H_w \) = depth of water at the dam at the time of failure; however, if the dam is overtopped, depth is set equal to the height of dam, ft
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\[ A = \text{cross-sectional area of embankment at the assumed location of breach, usually the template section (normal to the dam longitudinal axis) at the general flood plain location, ft}^2 \]

\[ T = \text{theoretical breach width at the water surface elevation corresponding to the depth, } H_w, \text{ for the equation, } Q_{\text{max}} = (65)H_w^{1.85}, \text{ ft} \]

\[ L = \text{width of the valley at the water surface elevation corresponding to the depth, } H_w, \text{ ft} \]

The peak discharge value determined by using principles of erosion, hydraulics, and sediment transport may be used in lieu of the peak discharge computed using the above equations.

**Utility cables and pipelines**

Existing pipelines, cables, and conduits of a wide variety of sizes, materials, and functions are frequently encountered at dam sites. These conduits are usually located at shallow depths in the flood plain. They constitute a hazard to the safety of the dam and must be either relocated away from the site or reconstructed or modified to provide the durability, strength, and flexibility equal in all aspects to the principal spillway designed for the site, in accordance with service criteria and procedures. Overhead cables or power lines must be relocated or raised as necessary to prevent damage or hazard to the public.

Every reasonable effort should be made to have such conduits, cables, and pipelines removed from the site. Most utilities and industries will want their facility removed from the site for easy maintenance. Only as a last resort and under the limitations imposed below are conduits permitted to remain under an earth dam embankment.

Conduits permitted to remain under any part of the embankment below the crest of the auxiliary spillway are to be:

- provided with seepage control against potential piping;
- properly articulated on all yielding foundations;
- encased in concrete or otherwise treated to ensure durability and strength equal to that of the principal spillway; and
- made watertight against leaking either into or out of the pipe.

Enclosure of the conduit cable or pipeline within another conduit that meets the requirements of this section and is positively sealed at the upstream end to prevent seepage into the enclosing conduit is acceptable. Such an enclosing conduit must extend the full distance through which the conduit, cable, or pipeline being enclosed is beneath the embankment.

**Cut slope stability**

Natural and excavation cut slopes must be planned and formed in a stable and safe manner. Spillways, inlet and outlet channels, borrow pits, reservoir edges, abutment areas, and foundation excavations are all locations where these considerations are needed. Field investigations, methods of analysis, design and construction requirements, and resultant specifications must recognize and provide for safe functional performance.

**Joint use of reservoir capacity**

A reservoir site may be used more efficiently where hydrologic conditions permit joint use of storage capacity by flood water and conservation storage. The following requirements must be met for joint use storage dams.

- There is reasonable assurance that water will be available to meet objectives.
- Flood protection objectives of the project are satisfied.
- Spillway conditions are such that the dam will perform safely.

Special hydrologic studies must be made to show that the requirements can be met. This may include hydro-meteorologic instrumentation and analysis.

Hydraulic features must include an ungated spillway outlet at the top of the joint use pool. A gated opening must be provided at the bottom of the joint use pool adequate for use of the conservation storage and evacuation of the joint use pool.

Provisions must be made for operation of the joint use pool to ensure functioning of the dam as designed. These must include a competent operating and maintaining organization and a specific operation and maintenance plan. These requirements must be a part of the planning process and agreed to by the sponsors or owner.
Visual resource design

The public generally prefers lake or waterscape scenery. Therefore, when permanent pools are created by dam construction, they can enhance the visual resource if the water views are emphasized. A visual design objective must focus public views toward the permanent pool and reduce the visual focal effects of the structural elements.

Visual focus on the lake is achieved by locating roads and walkways so that the entering or first perceptions of the site are of the waterscape scenery. In most landscapes, the lake will automatically predominate if other elements are visually designed to be subordinate.

Borrow areas must be shaped to blend with the surrounding topography. These areas must be revegetated with herbaceous and woody plants to visually fit the existing surrounding vegetation. Fences must be constructed parallel to the contour as much as possible, be located behind existing vegetation, as seen from the major viewpoints, and be placed low in the landscape. Dams must be shaped to blend with the natural topography to the extent feasible.

Safety and protection

Many dams are hazardous to the public. Features designed for recreation or fish and wildlife are especially attractive to the public since they provide an opportunity to use the water. All dams must be designed to avoid hazardous conditions where possible. Open-top risers, steep-walled channels and chutes, plunge pools, and stilling basins are hazardous and require special attention. All dams must be provided with safety fences, guard rails, or other safeguards as necessary to protect the public and operation and maintenance personnel.

The embankment and spillways must be fenced where necessary to protect the dam from livestock and foot and vehicular traffic.

Water supply pipes

Water supply pipes or conduits for other purposes installed under any part of the embankment below the crest of the auxiliary spillway are to:

- provide durability, strength, and flexibility equivalent to the principal spillway;
- be watertight against anticipated pressures;
- be adequate for their intended use; and
- be provided with seepage control against potential piping.

Streamflow diversion during construction

Streamflow past the dam site, unless controlled, occurs at a somewhat random time with variable frequency and magnitudes. A hazard exists during dam construction beginning when the embankment, cofferdam, or other ancillary structures obstruct the natural streamflow. During construction, a greater risk usually exists for some time than after the dam is completed. The risk is different for each dam because of the varying factors of construction time, climate, watershed size, and diversion capacity. An evaluation should be made of the risk from embankment failure by overtopping and other similar hazards during construction. The risk involved in overtopping during construction increases with the following factors:

- dams of higher hazard class
- greater volume of reservoir storage
- dams with larger watersheds
- longer critical construction time periods
- smaller diversion “release” rates (less unit discharge per unit watershed area)

The consequence of overtopping during construction may vary from a slight amount of erosion on a homogeneous clay dam to a breach of an embankment including loss of a temporary diversion cofferdam. The erosion or breach causes increased inundation and sedimentation of downstream areas.

The risk may be evaluated based upon experience of comparable dams constructed in the same hydrologic setting. An evaluation may also be made using available streamflow records to obtain stage-duration-frequency information for a range of diversion rates. Streamflow data should be used when available; otherwise, an evaluation may be made using climatological record data for generation of synthetic hydrographs to develop stage duration-frequency information for a range of diversion rates.

The size of diversion must be designed to provide an acceptable level of risk. The probability required to protect against overtopping varies from 20 percent to 5 percent chance in any one year. A 10 percent chance probability is frequently used when the critical con-
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Construction period is limited to one construction season. An alternative to a larger diversion capacity is to provide protection against erosion to the embankment surface (reinforcement) up to the desired elevation of acceptable risk.

**Reservoir conservation storage**

Reservoirs with water stored for conservation purposes must be analyzed using a water budget to determine a dependable water supply.

For most purposes, a dependable water supply is defined as one that is available at least 8 out of 10 years or has a probability of 80 percent chance in any one year. A purpose such as municipal and industrial water may require a 95 percent chance probability of existing in any one year. Other purposes, such as recreation, require an analysis of the reservoir surface elevation fluctuation to evaluate the acceptable percent chance of occurrence.
Hydrology

This section describes hydrologic criteria for determining spillway discharges and floodwater storage volumes. Detailed procedures for developing principal spillway, auxiliary spillway, and freeboard hydrographs are found in the NRCS National Engineering Handbook, chapter 21, section 4, Hydrology (NEH-4). Methods of flood routing hydrographs through reservoirs and spillway systems are contained in chapter 17, NEH-4. Special studies, as used in this text, refer to all site-specific studies with prior concurrence of selected procedures.

Precipitation and runoff amounts

Principal spillway
Precipitation data must be obtained from the most recent National Weather Service (NWS) reference which is applicable to the area under study. References that contain precipitation data for return periods up to 100 years and for durations up to 10 days are listed in sections A and B of table 2-1.

The return period for design precipitation amounts is dependent on the dam classification, purpose, size, location, and type of auxiliary spillway. Table 2-2 shows minimum return period. The minimum allowable areal adjustment ratios for 1- and 10-day precipitation amounts are tabulated in table 2-3 (a).

A storm duration of not less than 10 days must be used for sizing the principal spillway. The procedure in chapter 21, NEH-4 for developing the storm distribution uses both the 1-day and 10-day runoff volumes.

The procedure for estimating runoff volumes must be selected based on which one requires the higher auxiliary spillway crest elevation when the principal spillway hydrograph is routed through the structure. Procedures to be used to estimate runoff volumes include:

- The runoff curve number (CN) procedure described in NEH-4. Use average antecedent runoff conditions (ARC II) or greater unless a special study shows that a different condition is justified. The CN adjustment for 10-day storm is estimated from table 2-3(b).
- Runoff volumes, based on stream gage studies which also account for snow melt, from figures 2-1(a) and (b) or 2-2(a) and (b).

A special study may show that local streamflow records can be used directly or regionalized to develop design runoff volumes.

Transmission losses reducing the runoff volume in arid and semiarid climatic areas may be used if the climatic index, as defined in chapter 21, NEH-4, is less than one. If transmission losses appear to be significant even though the climatic index is one or more, such as in cavernous areas, special studies are required.

Obtain quick return flow from the map, figure 2-1(c), or table 2-4, as appropriate.

Auxiliary spillway and freeboard
The most recent NWS references applicable to the location of the dam site shall be used to determine precipitation amounts, spatial distributions, and temporal distributions. Table 2-1 provides references current as of date of this publication. See the NWS Web site, http://www.nws.noaa.gov/oh/hdsc/index.html, for the most current references.

Minimum precipitation amounts shall be in accordance with table 2-5.

The discharge capacity, stability (surface erosion potential), and integrity (breaching potential) of the auxiliary spillway shall be evaluated as follows:

- Both a short duration (6 hour or longer) and a long duration (24 hour or longer) storm shall be analyzed and the most critical results used to check the discharge capacity and the integrity of the auxiliary spillway.
- Only the short duration storm shall be used to check the stability of the auxiliary spillway.
- For locations where NWS references provide estimates of local storm and general storm values, both storms shall be analyzed. For other locations, at least a 6-hour and a 24-hour duration storm shall be analyzed.

In areas without applicable NWS references for spatial distribution, minimum areal adjustment ratios shown in figure 2-3 may be used. Spatial adjustments shall not be applied for drainage areas less than 10 square miles.

In areas without applicable NWS reference for temporal distribution, the dimensionless auxiliary and freeboard storm distribution shown in figure 2-4 may be used. Alternately, the 24-hour storm can be constructed by critically stacking incremental rainfall amounts of successive 6-, 12-, and 24-hour durations as described in Hydrometeorological Report 52 (HMR52).
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<table>
<thead>
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<tr>
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<td>Technical Paper 42.  Puerto Rico and Virgin Islands (1961)</td>
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<tr>
<td>Technical Paper 43.  Hawaii (1962)</td>
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<td>Technical Paper 47.  Alaska (1963)</td>
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<td>Technical Paper 51.  Hawaii (1965)</td>
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<th>C. Durations from 5 minutes to 60 days and return periods to 100 years</th>
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<td>Hydrometeorological Report 51.  For 37 contiguous states east of the 105rd meridian (1978)</td>
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<tr>
<td>Hydrometeorological Report 53.  Seasonal variation of 10 square-mile PMP estimates, states east of the 105th meridian (1980)</td>
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<td>Hydrometeorological Report 54.  PMP and snowmelt criteria for southeast Alaska (1983)</td>
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<td>Hydrometeorological Report 55A.  Between the Continental Divide and the 103rd meridian (1988)</td>
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1/ National Weather Service, National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce
Table 2-2  Minimum principal spillway hydrologic criteria

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<tr>
<th>Class of dam</th>
<th>Purpose of dam</th>
<th>Product of storage X effective height</th>
<th>Existing or planned upstream dams</th>
<th>Precipitation data for maximum frequency of use of auxiliary spillway types: $\frac{1}{2}$</th>
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<td>less than 30,000</td>
<td>none</td>
<td>$1/2$ design life</td>
</tr>
<tr>
<td></td>
<td>only $\frac{2}{3}$</td>
<td></td>
<td></td>
<td>$3/4$ design life</td>
</tr>
<tr>
<td></td>
<td>greater than 30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>single or multiple</td>
<td>less than 30,000</td>
<td>none</td>
<td>$P_{50}$</td>
</tr>
<tr>
<td></td>
<td>$\frac{1}{2}$</td>
<td></td>
<td></td>
<td>$1/2 (P_{50} + P_{100})$</td>
</tr>
<tr>
<td></td>
<td>greater than 30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>all</td>
<td>any $\frac{2}{3}$</td>
<td></td>
<td>$P_{100}$</td>
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<td>Significant</td>
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<td>all</td>
<td>none or any</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>single or multiple</td>
<td>all</td>
<td>none or any</td>
<td>$P_{100}$</td>
</tr>
</tbody>
</table>

$^1$ Precipitation amounts by return period in years. In some areas, direct runoff amounts determined by figure 2-1 and 2-2 or procedures in chapter 21, NEH-4 should be used in lieu of precipitation data.

$^2$ Applies to irrigation dams on ephemeral streams in areas where the annual rainfall is less the 25 inches.

$^3$ The minimum criteria are to be increased from $P_{25}$ to $P_{100}$ for a ramp spillway.

$^4$ Low Hazard Class dams involving industrial or municipal water are to be designed with a minimum criteria equivalent to that of Significant Hazard Class.

$^5$ Applies when the upstream dam is located so that its failure could endanger the lower dam.
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The maximum 6-hour rainfall should occur in the second 6-hour quadrant. The next highest 6-hour incremental rainfall should occur in the third 6-hour quadrant, the next highest in the first, etc.

The NRCS runoff curve number procedure defined in NEH-630 and NEH-4 shall be used to determine runoff volumes. Antecedent runoff condition (ARC) II or greater shall be assumed. The same curve number shall apply throughout the entire storm.

Special probable maximum precipitation (PMP) studies can be considered and may be conducted by NWS or other hydrometeorologists with experience in such work. Useful special studies may have been conducted by federal or state agencies or major dam owners. Special studies should be considered especially for large drainage areas, areas of significant variation in elevation, or areas located at the boundary of two studies where discontinuities occur.

Methods in the Federal Guidelines for Dam Safety – Inflow Design Floods, FEMA 94, may alternately be used to proportion the embankment and auxiliary spillway, provided downstream land use controls exist to prevent voiding incremental risk assumptions after the dam is completed.

Design hydrographs

Principal spillway hydrographs
Procedures in chapters 16 and 21, NEH-4 and applicable national computer programs shall be used to develop the principal spillway hydrograph using precipitation and runoff amounts as described in the preceding section.

When the area above a proposed dam is hydrologically complex, the area should be divided into two or more hydrologically homogeneous sub-basins for developing the design hydrograph.

Streamflow records may be used to develop the principal spillway hydrograph where a special study shows they are adequate for this purpose.

Stability design (auxiliary spillway) and freeboard hydrographs
Procedures in chapters 16 and 21, NEH-4 and applicable national computer programs shall be used to develop stability design (auxiliary spillway) and freeboard hydrographs using precipitation and runoff amounts and sub-basins, if necessary, as described in the preceding sections.

Dams in series

Upper dam
The hydrologic criteria and procedures for the design of an upper dam in a system of dams in series must be the same as, or more conservative than, those for dams downstream if failure of the upper dam could contribute to failure of the lower dam. The dam breach criteria described earlier will be used to develop the breach hydrograph peak discharge.

Lower dam
For the design of a lower dam, hydrographs shall be developed for the areas controlled by the upper dams based on the same hydrologic criteria as the lower dam. The hydrographs are routed through the spillways of the upstream dams and the outflows routed to the lower dam where they are combined with the hydrograph from the intermediate uncontrolled drainage area. The combined principal spillway hydrograph is used to determine the capacity of the principal spillway and the floodwater retarding storage requirement for the lower site. The combined stability design (auxiliary spillway) hydrograph is used to evaluate the stability (erosion resistance) of any vegetated or earth spillway at the lower site. The combined freeboard hydrograph is used to determine the height of dam and to evaluate the integrity of any vegetated or earth spillway at the lower site.

If upon routing a hydrograph through the upper dam, the dam is overtopped, or its safety is questionable, it is considered breached. For design of the lower dam, the breach hydrograph must be routed downstream to the lower dam and combined with the uncontrolled area hydrograph.

In design of the lower dam, the time of concentration \( T_c \) of the watershed above an upper dam is used to develop the hydrographs for the upper dam. The \( T_c \) of the uncontrolled area above the lower site is used to develop the uncontrolled area hydrographs. If the \( T_c \) for the total area exceeds the storm duration, the precipitation amounts for the stability design (auxiliary spillway) and freeboard hydrographs must be increased by the values in the applicable NWS references (Table 2-1).

The minimum precipitation amounts for each of the required hydrographs may be reduced by the areal reduction factor for the total drainage area of the dam system.
Large drainage areas

When the area above a proposed dam approaches 50 square miles, it is desirable to divide the area into hydrologically homogeneous sub-basins for developing the design hydrographs. Generally, the drainage area for a sub-basin should not exceed 20 square miles. Watershed modeling computer programs, such as the NRCS Technical Release (TR) 20 – Project Formulation-Hydrology or NRCS SITES – Water Resources Site Analysis, may be used for inflow hydrograph development. This software can be downloaded from http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models.html.

If the $T_c$ for the entire drainage area is greater than 24 hours, storm durations longer than the $T_c$ should be tested to determine the duration that gives the maximum reservoir stage for the routed stability design (auxiliary spillway) and freeboard hydrographs.

Precipitation amounts may exhibit marked variation in a large watershed. This variation is based upon topographical and meteorological parameters such as aspect, orientation, mean elevation of sub-basin, and storm orientation. Consideration shall be given to having the NWS make a special PMP study for large watersheds with drainage areas more than 100 square miles. Individual watershed PMP studies can take into account orographic features that are smoothed in the generalized precipitation studies. A special study also may be warranted in areas where significant snowmelt can occur during the design storms.

Studies to make use of available stream flow records are encouraged for purposes such as unit hydrograph development, watershed storage and timing effects, and calibration of watershed models.

<table>
<thead>
<tr>
<th>Table 2-3</th>
<th>Principal spillway volume adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>--Area/point ratio--</td>
</tr>
<tr>
<td>(m²)</td>
<td>1 day</td>
</tr>
<tr>
<td>10</td>
<td>1.000</td>
</tr>
<tr>
<td>15</td>
<td>0.977</td>
</tr>
<tr>
<td>20</td>
<td>0.969</td>
</tr>
<tr>
<td>25</td>
<td>0.965</td>
</tr>
<tr>
<td>30</td>
<td>0.961</td>
</tr>
<tr>
<td>35</td>
<td>0.957</td>
</tr>
<tr>
<td>40</td>
<td>0.954</td>
</tr>
</tbody>
</table>

* If area is greater than 100 square miles, request PMP from Conservation Engineering Division (CED).

<table>
<thead>
<tr>
<th>(b)</th>
<th>Runoff curve numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>10 days</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>99</td>
<td>98</td>
</tr>
<tr>
<td>98</td>
<td>96</td>
</tr>
<tr>
<td>97</td>
<td>94</td>
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<tr>
<td>96</td>
<td>92</td>
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<td>90</td>
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<tr>
<td>94</td>
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<tr>
<td>93</td>
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<td>91</td>
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<td>84</td>
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<td>83</td>
<td>69</td>
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<tr>
<td>82</td>
<td>68</td>
</tr>
<tr>
<td>81</td>
<td>66</td>
</tr>
</tbody>
</table>

* This table is used only if the 100-year frequency 10-day point rainfall is 6 or more inches. If it is less, the 10-day CN is the same as that for the 1-day CN.
Earth Dams and Reservoirs

Table 2-4  Minimum quick return flow for principal spill-way hydrographs

<table>
<thead>
<tr>
<th>Ci</th>
<th>QRF</th>
<th>Ci</th>
<th>QRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>in/d</td>
<td>ft³/sec/mi²</td>
<td>in/d</td>
<td>ft³/sec/mi²</td>
</tr>
<tr>
<td>1.00</td>
<td>0</td>
<td>1.50</td>
<td>0.233</td>
</tr>
<tr>
<td>1.02</td>
<td>0.011</td>
<td>0.30</td>
<td>1.52</td>
</tr>
<tr>
<td>1.04</td>
<td>0.022</td>
<td>0.60</td>
<td>1.54</td>
</tr>
<tr>
<td>1.06</td>
<td>0.033</td>
<td>0.90</td>
<td>1.56</td>
</tr>
<tr>
<td>1.08</td>
<td>0.045</td>
<td>1.20</td>
<td>1.58</td>
</tr>
<tr>
<td>1.10</td>
<td>0.056</td>
<td>1/50</td>
<td>1.60</td>
</tr>
<tr>
<td>1.12</td>
<td>0.067</td>
<td>1.80</td>
<td>1.65</td>
</tr>
<tr>
<td>1.14</td>
<td>0.078</td>
<td>2.10</td>
<td>1.70</td>
</tr>
<tr>
<td>1.16</td>
<td>0.089</td>
<td>2.40</td>
<td>1.75</td>
</tr>
<tr>
<td>1.18</td>
<td>0.100</td>
<td>2.70</td>
<td>1.80</td>
</tr>
<tr>
<td>1.20</td>
<td>0.112</td>
<td>3.00</td>
<td>1.85</td>
</tr>
<tr>
<td>1.22</td>
<td>0.122</td>
<td>3.29</td>
<td>1.90</td>
</tr>
<tr>
<td>1.24</td>
<td>0.133</td>
<td>3.58</td>
<td>1.95</td>
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<tr>
<td>1.26</td>
<td>0.144</td>
<td>3.86</td>
<td>2.00</td>
</tr>
<tr>
<td>1.28</td>
<td>0.153</td>
<td>4.12</td>
<td>2.05</td>
</tr>
<tr>
<td>1.30</td>
<td>0.163</td>
<td>4.37</td>
<td>2.10</td>
</tr>
<tr>
<td>1.32</td>
<td>0.171</td>
<td>4.61</td>
<td>2.20</td>
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<tr>
<td>1.34</td>
<td>0.180</td>
<td>4.83</td>
<td>2.30</td>
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<tr>
<td>1.36</td>
<td>0.188</td>
<td>5.05</td>
<td>2.40</td>
</tr>
<tr>
<td>1.38</td>
<td>0.195</td>
<td>5.25</td>
<td>2.50</td>
</tr>
<tr>
<td>1.40</td>
<td>0.202</td>
<td>5.44</td>
<td>2.60</td>
</tr>
<tr>
<td>1.42</td>
<td>0.209</td>
<td>5.63</td>
<td>2.70</td>
</tr>
<tr>
<td>1.44</td>
<td>0.216</td>
<td>5.80</td>
<td>2.80</td>
</tr>
<tr>
<td>1.46</td>
<td>0.222</td>
<td>5.97</td>
<td>2.90</td>
</tr>
<tr>
<td>1.48</td>
<td>0.228</td>
<td>6.13</td>
<td>3.00**</td>
</tr>
</tbody>
</table>

* Change in tabulation interval
**For Ci greater than 3, use:
QRF (ft³/sec/mi²) = 9(Ci-1)⁰.⁵
or
QRF (in/d) = 0.03719 [QRF (ft³/sec/mi²)]

where:
QRF = quick return flow
Ci = climatic index
in/d = inches per day
### Table 2-5  Minimum auxiliary spillway hydrologic criteria

<table>
<thead>
<tr>
<th>Class of Dam</th>
<th>Product of storage X effective height</th>
<th>Existing or planned upstream dams</th>
<th>Precipitation data for 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Auxillary spillway hydrograph</td>
</tr>
<tr>
<td>Low 2</td>
<td>less than 30,000</td>
<td>none</td>
<td>P100</td>
</tr>
<tr>
<td></td>
<td>greater than 30,000</td>
<td>any 3</td>
<td>P100 + 0.06(PMP − P100)</td>
</tr>
<tr>
<td></td>
<td>all</td>
<td>any 3</td>
<td>P100 + 0.12(PMP − P100)</td>
</tr>
<tr>
<td>Significant</td>
<td>all</td>
<td>none or any</td>
<td>P100 + 0.12(PMP − P100)</td>
</tr>
<tr>
<td>High</td>
<td>all</td>
<td>none or any</td>
<td>P100 + 0.26(PMP − P100)</td>
</tr>
</tbody>
</table>

1 P100 = Precipitation for 100-year return period. PMP = Probable maximum precipitation  
2 Dams involving industrial or municipal water are to use minimum criteria equivalent to that of Significant Hazard Class.  
3 Applies when the upstream dam is located so that its failure could endanger the lower dam

---

**Figure 2-1**  Principal spillway runoff volumes in north-central and southeastern states

(a) 100-year, 10-day runoff (inches), principal spillway hydrograph  

100-year 10-day runoff volumes (inches)  
for developing the principal spillway hydrograph

![Map showing runoff volumes](image)

**Ratios for 50- and 25 year 10-day runoff volumes**

<table>
<thead>
<tr>
<th>To obtain:</th>
<th>Multiply map values by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-year 10-day runoff</td>
<td>Area 1 0.85 Area 2 0.90 Area 3 0.92</td>
</tr>
<tr>
<td>25-year 10-day runoff</td>
<td>Area 1 0.70 Area 2 0.80 Area 3 0.90</td>
</tr>
</tbody>
</table>
Figure 2-1  Principal spillway runoff volumes in north-central and southeastern states–continued

(b) Ratios of volumes of runoff (A1/Q10), principal spillway hydrograph

Ratios of volumes runoff ($Q_1/Q_{10}$)
for developing the principal spillway hydrograph

Legend

$Q_1$ – 1-day volume runoff
$Q_{10}$ – 10-day volume runoff
Figure 2-1  Principal spillway runoff volumes in north-central and southeastern states—continued

(c) Quick return flow

NOTE:

For Wisconsin, Michigan, and eastern Iowa use csm values shown in circles.
Figure 2-2  Principal spillway runoff volumes in snowmelt producing flood areas

(a) 100-year, 10-day runoff (inches)
Figure 2-2  Principal spillway runoff volumes in snowmelt producing flood areas—continued

(b) Ratios of volumes of runoff \( \frac{Q_1}{Q_{10}} \)
Earth Dams and Reservoirs

Figure 2-3 Areal adjustment, auxiliary spillway and freeboard

Areal precipitation adjustments for drainage areas 10 to 100 square miles

Figure 2-4 Dimensionless design storm distribution, auxiliary spillway and freeboard
Sedimentation

Reservoirs used to store or retard water from surface runoff will trap and store a large portion of the sediment in the runoff water. Therefore, allocate storage capacity for the calculated sediment accumulation during the design life of the reservoir. Criteria and general procedures needed to determine the volume required for sediment accumulation and its allocation in the reservoir are contained in NEH-3, Sedimentation. The latter also includes procedures for determining:

- sediment yield for present conditions and for the future after planned land treatment and other measures are applied in the drainage area of the dam;

- trap efficiency of the reservoir;
- distribution and types of sediment expected to accumulate;
- proportion of the sediment that will be continuously submerged vs. that aerated; and
- densities to which the sediment will become compacted.

If the amount of sediment accumulation calculated exceeds two watershed inches in 50 years for the uncontrolled drainage area of the dam, reevaluate the entire watershed to determine if more economical methods of reducing sediment yield or trapping sediment may be feasible and applicable.
**Geologic investigations**

The intensity and detail of geologic site investigations shall be consistent with the class of dam, complexity of site geology, and the data needed for design. General requirements, procedures, and criteria are set forth in the NEM-531 and NEH-8.

Following are the geologic conditions that require special consideration beyond the minimum investigations spelled out in the above reference.

**Seismic assessment**

Dams in zones 3 and 4, Alaska, Puerto Rico, and the Virgin Islands, and High Hazard Class dams in zone 2 (fig. 4-1) require special investigations to determine liquefaction potential of noncohesive strata, including very thin layers, and the presence at the site of any faults active in Holocene time. As part of this investigation, a map must be prepared showing the location and intensity of magnitude of all intensity V or magnitude 4 or greater earthquakes of record, and any historically active faults, within a 100-kilometer (62-mile) radius of the site. (Obtain earthquake information for this map from NOAA at www.ngdc.noaa.gov/seg/hazard/int_srch.shtml and USGS at www.neic.cr.usgs.gov.) The report should also summarize other possible earthquake hazards such as ground compaction, landslides, excessive shaking of unconsolidated soils, seiches, and in coastal areas, tsunamis.

**Auxiliary spillways**

Large dams with auxiliary spillways in soft rock or cemented soil materials that cannot be classified as soil as defined in NEH-628, chapter 52 or as rock, as generally defined for engineering purposes, and spillways in rocks with extraordinary defects require a special individual evaluation.

**Mass movements**

Evaluate landslides and landslide potential at dam and reservoir sites, especially those in shales and where unfavorable dip-slope or other adverse rock attitudes occur. Summarize the history of mass movement in the project area. Auxiliary spillway cuts and reservoir effects must be given careful consideration.

**Karstic areas**

Limestone and gypsum in reservoirs and at dam sites require special investigational methods and careful evaluation of subsidence, leakage hazards, and construction costs. Multipurpose structures in these areas are especially critical.

**Multipurpose dams**

Investigate the ground water regime and hydraulic characteristics of the entire reservoir area of water storage dams and evaluate for leakage. Use the water budgets to determine the need for reservoir sealing.

**Subsidence**

Investigate the potential for surface subsidence due to past or future solid, liquid (including ground water) or gaseous mineral extraction. NEM-531, subpart B sets forth criteria for these evaluations.

Evaluate the impact of the preemption of mineral deposits, including sand and gravel, by dams and reservoirs.

In arid and semiarid areas and in eolian deposits, determine the potential of moisture deficient soil materials to collapse upon saturation or wetting. If the potential exists, make extensive and intensive site investigations to provide quantitative information for design and construction.

**Other**

Special studies and evaluations may be necessary where compaction shales; some types of siliceous, calcareous or pyritic shales; rebound joints; dispersed soils; or artesian waters occur at a site.
Figure 4-1  Seismic zone map

Minimum Seismic Coefficients

<table>
<thead>
<tr>
<th>Zone</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
</tr>
<tr>
<td>3 and 4</td>
<td>Base on seismic assessment</td>
</tr>
</tbody>
</table>

Seismic Zone Map
Contiguous States
Figure 4-1  Seismic zone map—continued

Minum Seismic Coeficients

<table>
<thead>
<tr>
<th>Zone</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
</tr>
<tr>
<td>3 and 4</td>
<td>Base on seismic assessment</td>
</tr>
</tbody>
</table>

Seismic Zone Map
Hawaii
Earth embankments and foundations

Earth embankments constructed of soil and rock are the principal means of impounding water. The earth embankment and its foundation must withstand the anticipated loads without movements leading to failure. Measures must be provided for adequate seepage control.

Height

The design height of an earth embankment must be sufficient to prevent overtopping during passage of either the freeboard hydrograph or stability design hydrograph plus the freeboard required for frost conditions or wave action, whichever is larger. The design height must also meet the requirements for minimum auxiliary spillway depth. The design height of the dam must be increased by the amount needed to compensate for settlement.

Top width

The minimum top width of embankment is shown in table 5-1.

<table>
<thead>
<tr>
<th>Total height of embankment, H, (ft)</th>
<th>All dams</th>
<th>Single purpose</th>
<th>Multipurpose or other purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 or less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–19</td>
<td>8</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>20–24</td>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>25–34</td>
<td>12</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>35–95</td>
<td>N/A</td>
<td>14</td>
<td>(H+35)/5</td>
</tr>
<tr>
<td>Over 95</td>
<td>N/A</td>
<td>16</td>
<td>26</td>
</tr>
</tbody>
</table>

The width may need to be greater than the above minimums to:
- meet state and local standards;
- accommodate embankment zoning;
- provide roadway access and traffic safety; and
- provide structural stability.

An increase in top width is a major design feature in preventing breaching after embankment slumping caused by earthquake ground motion.

When the embankment top is used as a public roadway, the minimum width shall be 16 feet for one-way and 26 feet for two-way traffic. Guardrails or other safety measures shall be used and must meet the requirements of the responsible road authority.

Embankment slope stability

Analyze the stability of embankment slopes using generally accepted methods based on sound engineering principles. Document all analyses including assumptions regarding shear strength parameters for each zone of the embankment and each soil type or horizon in the foundation. Documentation should include methods used for analyses and a summary of results. Design features necessary to provide required safety factors should be noted.
Use the appropriate degree of conservatism in the analysis that is consistent with the adequacy of the site investigation and the soil-testing program. Consider the complexity of the site and consequences of failure in determining the level of detail in the analyses. Minimum required safety factors are summarized in table 5-2 for each condition analyzed.

Evaluate the effect of seismicity on each site. Determine whether the site is in a seismically active area, its proximity to active faults, and the predicted ground motion intensity at the site. If the site is located in zone 3 or 4 shown in figure 4-1, perform special seismic studies. Otherwise, use the horizontal acceleration factors shown in figure 4-1 in a pseudo-static stability calculation using conditions summarized in table 5-2.

Analyze embankment stability for each of the following conditions in the design life of the structure that are appropriate to the site. If a condition is not analyzed, clearly document the reasons. Document any correlated shear strength parameters, including correlations to field performance, used to justify a lack of detailed analyses of a particular condition.

End of construction
This case should be analyzed when either embankment or foundation soils (or both) are predicted to develop significant pore pressures during embankment construction. Factors determining the likelihood of this occurring include the height of the planned embankment, the speed of construction, the saturated consistency of foundation soils, and others. Perform appropriate shear tests to model placement conditions of embankment soils, as summarized in table 5-2. Consider the highest likely placement water content of embankment soils in the shear-testing program. Either field vane shear tests or laboratory tests should determine the unconsolidated/undrained strength of slowly permeable foundation soils. The undrained strength of foundation clays should be corrected for plasticity index when field vane shear tests are used for measurement.

Rapid drawdown
Analyze the stability of the upstream embankment slope for the condition created by a rapid drawdown of the water level in the reservoir from the reservoir level from which a phreatic line is likely to develop. Ordinarily, assume a phreatic line has developed from the normal full reservoir elevation. Then, assume the water in the reservoir is rapidly lowered to the elevation of the lowest gated or ungated outlet and analyze the stability of the embankment following this drawdown. For rare situations, the upstream drawdown condition should be analyzed assuming that soils are saturated from temporary pool storage to the elevation of the auxiliary spillway. This condition should be analyzed if it is possible that in the future the riser could become plugged or other circumstances could cause the temporary impoundment to this higher elevation. For this condition, assume a zone of saturated soils in the embankment occurs based on transient flow nets that determine the portion of the embankment likely to become saturated during the temporary storage. Transient flow nets may be used to examine the temporary saturation of the portion of the embankment above permanent normal pool. Select shear parameters for the analyses according to table 5-2, as illustrated in figure 5-1.

Use infinite slope equations and appropriate safety factors in analyzing the stability of zones in the exterior slope of the embankment with soils having zero effective cohesion parameters, when the critical failure is wholly within soils of this character. If cohesionless zones occur with other soil types in a cross section being analyzed, circular arc or wedge-shaped surfaces should also be explored that intersect the soil zones with cohesion to locate the minimum safety factor. Note that different safety factors are considered adequate for infinite slope analyses than for failure surfaces that are deeper within the profile. See table 5-2 for details.

**Figure 5-1** Mohr-Coulomb Envelope for upstream drawdown
Table 5-2  Slope stability criteria

<table>
<thead>
<tr>
<th>Design condition</th>
<th>Primary assumption</th>
<th>Remarks</th>
<th>Shear strength to be used</th>
<th>Minimum safety factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. End of construction (upstream or downstream slope)</td>
<td>Zones of the embankment or layers of the foundation are expected to develop significant pore pressures during construction</td>
<td>Embankment soils that are slowly permeable should be tested at water contents that are as wet as likely during construction (usually wet of optimum) Saturated slowly permeable foundation soils that are not predicted to fully consolidate during construction Permeable embankment zones and/or foundation strata</td>
<td>UU – includes triaxial UU tests, unconfined compression (qu) tests, and field vane shear tests</td>
<td>1.4 for failure surfaces extending into foundation layers 1.3 for embankments on stronger foundations where the failure surface is located entirely in the embankment</td>
</tr>
<tr>
<td>2. Rapid drawdown (upstream slope)</td>
<td>Drawdown from the highest normal pool to the lowest ungated outlet</td>
<td>Consider failure surfaces both within the embankment and extending into the foundation</td>
<td>Lowest shear strength from a composite envelope of CU and CD envelopes (fig. 5-1)</td>
<td>1.2 1.1 for infinite slope analysis</td>
</tr>
<tr>
<td>3. Steady seepage without seismic forces (downstream slope)</td>
<td>Phreatic line developed from pool at the principal spillway crest Uplift pressure simulated by phreatic line developed from auxiliary spillway crest applied to saturated embankment and foundation soils</td>
<td>Consider failure surfaces both within the embankment and extending into the foundation</td>
<td>Lowest shear strength from a composite envelope of CU and (CU+CD)/2 envelopes (fig. 5-2)</td>
<td>1.5 1.1 for infinite slope analysis</td>
</tr>
<tr>
<td>4. Steady seepage with seismic forces (downstream slope)</td>
<td>Phreatic line developed from principal spillway crest with no uplift</td>
<td>Consider failure surfaces both within the embankment and extending into the foundation</td>
<td>Lowest shear strength from a composite envelope of CU and (CU+CD)/2 envelopes (fig. 5-2)</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Earth Dams and Reservoirs

Steady seepage without seismic forces
Using shear parameters, as specified in table 5-2 and illustrated in figure 5-2, analyze the downstream slope considering a phreatic line developed from the reservoir at the principal spillway crest. Subject saturated soils below the phreatic line to an uplift force simulated by a phreatic surface developed from the auxiliary spillway crest. Phreatic surfaces for the analyses may be developed using flow nets or Casagrande procedures.

Use infinite slope equations and appropriate safety factors as under Rapid Drawdown condition.

Steady seepage with seismic forces
Using shear parameters, as specified in table 5-2, analyze the downstream slope considering a phreatic line developed from a pool at the principal spillway crest. Apply a horizontal acceleration constant appropriate to the seismic zone in which the site is located, as specified in figure 4-1. Do not use uplift forces due to a reservoir stage at the auxiliary spillway because the likelihood of a simultaneous occurrence of an earthquake and an auxiliary spillway flow event is extremely remote.

Use infinite slope equations and appropriate safety factors in analyzing the stability of zones in the exterior slope of the embankment with soils having zero effective cohesion parameters. The equations should incorporate the horizontal acceleration constant specified in figure 4-1.

Consider following additional guidance in analyzing slope stability.

- Only effective stress (CD) parameters are appropriate for soils that will consolidate as rapidly as load is applied. These parameters are applicable for all conditions of stability analyzed for these soil types.
- The end of construction condition is usually the one that controls the design of embankments when it is applicable. Special designs including staged construction or monitoring pore pressures during construction may be required to achieve objectives for some site conditions such as soft clay foundation soil horizons.
- Total stress parameters used in the construction of composite shear strength envelopes should not consider large negative pore pressures that may develop during shear testing. Either maximum deviator stress or maximum principal effective stress ratio failure criteria should usually be used to define total stress parameters. Total stress parameters interpreted from maximum arbitrary strain criteria should be used only when other criteria are less limiting.
- Infinite slope equations should model the predicted seepage pattern in the slope being analyzed. The three equations used are for no seepage, for horizontal seepage paths, and for seepage paths parallel to the slope face.
- Residual effective stress parameters should be used for modeling slope stability analyses involving fissured clays or shales if pre-existing movements have occurred. These parameters are based on drained shear strength tests where stresses are determined at high strain values beyond the peak strength. Residual parameters may also be considered for designing against shallow slope failures in desiccated clay embankments.

Seepage
To the extent needed, an analysis shall be made of anticipated seepage rates and pressures through the embankment, foundation, abutments, and reservoir perimeter (when storage is desired). Controls and treatment should be adequate to:

- accomplish the intended reservoir function;
- provide a safely operating structure; and
- prevent damage to downstream property.
**Zoning**

Embankment zoning can be used when needed to:

- obtain a stable structure with the most economical use of available materials;
- control seepage in a safe manner; or
- reduce to a minimum the uncertainties of material strengths and resultant stability.

Embankment zones should be a minimum of 10 feet wide except for filters and drains with specified and controlled gradation. Drains and filters should meet the requirements contained in Soil Mechanics Notes.

Soil materials which exhibit significant shrinkage, swell or dispersion should be used only with extreme care. If possible, they should not be used for embankment construction. When there is no economical alternative to their use, they must be:

- treated to improve their performance;
- placed in zones where effects will not be detrimental; or
- protected by use of filters and drains or self-healing transition zones.

**Surface protection**

Embankment surfaces must be protected against surface erosion. Protection may be vegetative, gravel, rock riprap, soil cement, structural, or similar treatment of durable quality and proven satisfactory performance.

**Vegetative protection**

Vegetative protection may be used on surfaces where the following conditions can be met:

- inundation of the surfaces is of such frequency that vegetative growth will not be inhibited;
- vigorous growth can be sustained under average climatic conditions by normal maintenance without irrigation; and
- stable protection can be designed according to the procedures in TR-56.

**Structural protection**

Protection against wave erosion by riprap or other structural measures shall be provided for:

- multiple purpose dams; and
- dams with fluctuating normal water levels.

Protection must extend from the lowest drawdown elevation that presents an erosion hazard, to a few feet above the crest of the lowest ungated spillway. The upper limit shall be based on an analysis of anticipated wave height and run up.

Quality of riprap and other structural protection must be consistent with the anticipated life of the dam and designed to be structurally stable.
**Principal spillways**

The structural design and detailing of principal spillways must conform to the recommendations of NEH-6, Structural Design, and NRCS standard drawings. All component parts of principal spillways except easily replaceable parts such as gates and trash racks shall be equally durable.

**Capacity of principal spillway**

The required capacity of the principal spillway depends on the:

- purpose of the dam;
- amount of storage provided by the retarding pool;
- kind of auxiliary spillway;
- stream channel capacity and stability downstream;
- potential damage from prolonged storage in the retarding pool;
- potential damage downstream from prolonged high outflow rates;
- possibility of substantial runoff from two or more storms in the time required to empty the retarding pool;
- limitations imposed by water rights or other legal requirements;
- environmental concerns;
- planned or potential alterations of the channel downstream; and
- necessity to pass base and flood flows during construction.

The principal spillway may be single-stage, having an ungated inlet at only one elevation, or multiple-stage, having inlets at two or more elevations. In the case of multiple-stage spillways, the lower stage or stages usually perform the primary flood control function, and the high stage has the capacity needed to prevent the auxiliary spillway from functioning more frequently than permissible.

The principal spillway capacity should be adequate to empty the retarding pool in 10 days or less. This requirement is considered met if 15 percent or less of the maximum volume of retarding storage remains after 10 days. Where low release rates are required to meet the objectives of the project, a longer period than 10 days may be needed. For these situations, additional storage is required to minimize the opportunity for increased frequency of auxiliary spillway flow due to recurring storms.

Compute the 10-day drawdown from the time the maximum water surface elevation is attained during the passage of the principal spillway hydrograph. The entire design inflow hydrograph including quick return flow, upstream releases, and outflow must be considered in determining the evacuation time of the retarding storage. The inflow from storm runoff must be considered for the entire evacuation time.

For dams where more than 15 percent of the retarding storage volume remains after 10 days, the elevation of the crest of the auxiliary spillway must raised. The raised crest elevation is determined by adding the remaining retarding storage volume to the initial retarding storage volume.

**Elevation of principal spillways**

**Single-purpose floodwater retarding dams**

The crest of the principal spillway or of the low stage inlet of a two-stage principal spillway shall be set at the submerged sediment pool elevation. For dry dams, the elevation of the principal spillway inlet shall be placed as described above and provisions made to drain the reservoir in a reasonable time and, thus, satisfy the functional or legal requirements of the dam.

**Other dams**

When conservation storage will be provided, the elevation of the crest of the lowest ungated inlet of the principal spillway is determined by the volume, area, or depth of water required for the planned purpose or purposes and the required sediment storage. The lowest crest may be the crest of the low-stage inlet, single-stage inlet, or an open spillway.

**Routing of principal spillway hydrographs**

Reservoir flood routing used to proportion dams and associated spillways shall be based on the assumption that all sedimentation expected in the reservoir during its design life has occurred. The reservoir stage-storage curve used for routing should reflect the anticipated accumulation of sediment. The initial reservoir stage for principal spillway hydrograph routing shall be at the crest of the lowest ungated inlet or (if not subtracted from the stage-storage curve) the anticipat-
ed elevation of the sediment storage, whichever is higher, except as provided below:

- For dams with significant base flow, principal spillway hydrograph routings must start not lower than the elevation of the water surface associated with the base flow. Significant base flow is average annual or seasonal flow that would produce at least 0.5 feet of head over the lowest principal spillway inlet immediately prior to a flood or occupy more than 10 percent of the floodwater storage capacity.

- For dams with joint use storage capacity, when one of the uses is floodwater detention, routing of the principal spillway hydrograph may begin at the lowest anticipated elevation of the joint use pool in accordance with the operation plan.

- Single purpose, low hazard class irrigation dams with gated outlets and earth or vegetated auxiliary spillways, which are located on ephemeral streams in areas where the average annual precipitation is less than 25 inches, may be considered to have discharged up to 70 percent of the storage, exclusive of sediment storage in determining the elevation to start routing.

**Design of principal spillways**

**Hydraulics**

The principal spillway must be designed to carry the planned flow for expected head and tailwater conditions. TR-29, Design Note No. 8, NEH-5, the Engineering Field Handbook for Conservation Practices and other appropriate references shall be used for hydraulic design.

**Risers**

Risers for drop inlet spillways must be designed to maintain the reservoir pool level at or near the inlet crest elevation during low flow periods, to establish full pipe flow at as low a head over the crest as practical, and to operate without excessive surging, noise, vibration, or vortex action at any reservoir stage. This requires the riser to have a larger cross-sectional area than the conduit. Standard risers have an inside width equal to the width (diameter) D, of the conduit and an inside length equal to three times the width (diameter) of the conduit (D x 3D cross section).

Risers shall be designed to exclude trash too large to pass freely through the spillways, including the outlet structure, and to facilitate the passage of smaller trash. Standard D x 3D risers tend to line up longer pieces of trash and facilitate their passage into and through the conduit. Covered risers with standard skirted or baffle inlets should be used in most cases because they are most effective in excluding trash without becoming clogged. Skirted inlets, having a cover with skirts extending below the weir crest elevation, are applicable where backfill or settlement levels will be at least two times the conduit width (diameter) below the crest. Baffle inlets are applicable for risers that will be backfilled to the crest elevation or where sediment is expected to build up to the crest elevation.

Risers shall be designed structurally to withstand all water, earth, ice, and earthquake loads to which they may be subjected. Articulation must be provided to allow movement of the riser with respect to the conduit.

Risers with low-stage inlets at or near the bottom must be provided with concrete aprons to prevent erosion of soil and undermining of the riser footing by high velocity flow approaching the inlet.

Standard risers must be used where applicable for low hazard class dams with an effective height of more than 35 feet and for all significant and high hazard class dams. Prefabricated pipe risers are permissible, where hydraulically and structurally adequate, for low hazard class dams not more than 35 feet in effective height. The riser pipe must be of the same material as the conduit and at least one standard pipe size larger than the conduit pipe.

Special riser designs are required for spillways having maximum conduit velocities more then 30 feet per second and for spillways having conduits larger then 48 inches in width (diameter). Generally, these should be similar to standard risers, but a special elbow and transition is required at the junction of the riser and conduit, and special design of the inlet may be necessary. Hydraulic model testing should be considered if the maximum total head on the spillway is more than 75 feet or the conduit velocity exceeds 50 feet per second.

**Conduit**

The conduit should be straight in alignment when viewed in plan. Changes from straight alignment, if required, must be accomplished by watertight angle changes at joints or by special elbows having a radius equal to or greater than the diameter or width of the conduit. Thrust blocks of adequate strength must be provided if special pipe elbows are used. They must be designed to distribute the thrust due to change in direction for the maximum possible discharge. Drop inlet
conduits shall be installed with enough slope to ensure free drainage to the outlet of all parts of the conduit (including camber) at the time of construction and under the maximum anticipated settlement.

All conduits under earth embankments must support the external loads with an adequate factor of safety. They must withstand the internal hydraulic pressures without leakage under full external load and settlement. They must convey water at the design velocity without damage to the interior surface of the conduit.

Principal spillway conduits under earth dams may be designed to support fill heights greater than the original constructed height if there is a reasonable possibility that the embankment height may be raised later to incorporate additional storage for some approved beneficial use.

Rigid principal spillway conduits shall be designed as positive projecting conduits in accordance with the principles and procedures given in TR-5.

Principal spillway conduits must be of reinforced concrete pressure pipe or cast-in-place reinforced concrete, unless corrugated steel or welded steel pipe is used.

Cast-in-place rectangular reinforced concrete conduits must be designed in accordance with principles and procedures in TR-42, TR-45 or other appropriate design aids.

For Reinforced Concrete Water Pipe—Steel Cylinder Type, Prestressed, meeting specification AWWA Standard C301, the 3-edge bearing strength at the first 0.001-inch crack shall be used with a safety factor of at least one.

For Reinforced Concrete Water Pipe—Steel Cylinder Type, Not Prestressed, meeting specification AWWA Standard C300; for Reinforced Concrete Water Pipe Noncylinder Type, Not Prestressed, meeting specification AWWA Standard C302, and for other types of reinforced concrete pipe, the 3-edge bearing strength at the first 0.01-inch crack shall be used with a safety factor of at least 1.33.

Elliptical or other systems of reinforcement requiring special orientation of pipe sections are not permitted in spillway conduits.

Reinforced concrete pipe must be designed to support at least 12 feet of earth fill above the pipe at all points along the conduit.

- **Reinforced Concrete Pipe**
  - Minimum inside diameters on yielding foundations
    
    Low hazard class dams: The minimum diameter of the principal spillway conduit must be 30 inches, unless a joint extension safety margin of at least 1.5 inches is used, in which case, the minimum diameter shall be 18 inches for maximum fill heights up to 50 feet at the centerline of the dam and 24 inches for greater fill heights.

    Significant hazard class dams: The minimum diameter of the principal spillway conduit must be 30 inches, unless a joint extension safety margin of 1.5 inches is used, in which case, the minimum diameter shall be 24 inches.

    High hazard class dams: The minimum diameter of the principal spillway conduit must be 30 inches.

  - Minimum inside diameters on nonyielding foundations: The minimum diameter of the principal spillway conduit for low hazard class dams must be 18 inches for heights up to 50 feet at the centerline of the dam and 24 inches for heights greater than 50 feet, and 24 inches for all significant and high hazard class dams. The conduit and cradle or bedding must rest directly on firm bedrock thick enough so that there is essentially no foundation consolidation under the conduit. Under these conditions, the cradle or bedding under the conduit need not be articulated.

- **Corrugated steel pipe or welded steel pipe**

Principal spillways of corrugated steel or welded steel pipe may be used for single purpose low hazard class dams with the product of storage times effective height of dam less than 10,000. While installation costs of steel pipes may be less, concrete may compare favorably with steel when replacement costs and associated problems are considered.

In each case, the following limitations apply:

- diameter of pipe not less than 18 inches;
- height of fill over the pipe not more than 25 feet;
- provision for replacement if the materials will not last for the design life of the structure;
- pipe structurally strong enough to withstand outside loads and hydraulic pressure; and
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- pipe watertight.

Corrugated steel pipe shall be polymer-coated with watertight connecting bands. The minimum gage must be designed for 35 feet of fill over the pipe.

Welded steel pipe conduits must be structurally designed as rigid pipe. A joint extension safety margin of 1.5 inches shall be provided for conduits on yielding foundation. Welded steel pipe must be protected by a Class A exterior coating as defined in Conservation Practice Standard 430-FF, Irrigation Water Conveyance, Pipeline, Steel, or by an exterior coating of coal tar-epoxy paint conforming to Paint grade and backfill materials to be adjacent to the conduit shall be made. The resistivity measurements are made on saturated samples.

Joints between lengths of corrugated steel or welded steel pipe, other than welded joints, are to be electrically bridged on the outside of the pipe with insulated copper wire, #6 AWG or larger, securely attached to the uncoated pipe metal at both sides of the joint. This requirement applies whether or not the cathodic protection is completed by the installation of anodes, etc. The wire should have a tough, waterproof insulation designed for direct burial, with a rating of at least 600 volts. Bare wire and exposed pipe metal at the points of connection are to be thoroughly coated with a coating equivalent to the original pipe coating to prevent the entry of moisture.

Soil investigations for resistivity and pH of the subgrade and backfill materials to be adjacent to the conduit shall be made. The resistivity measurements are made on saturated samples.

Cathodic protection must be provided for welded steel pipe conduits according to the criteria in Conservation Practice Standard 432-FF in the National Handbook of Conservation Practices (NHCP).

Cathodic protection meeting the above requirements must be provided for corrugated steel pipe in soil whose resistivity in a saturated condition is less than 4000 ohms cm or whose pH is lower than 5.0.

If cathodic protection is not required according to the above criteria and anodes are not installed during construction of the dam, pipe-to-soil potentials must be measured within the first 2 years after construction or after the water level has stabilized and when the soil around the conduit is estimated to be at its normal post-construction moisture content. Cathodic protection must be installed at this time if such measurements indicate it is needed.

Joints

Conduit joints shall be designed and constructed to remain watertight under maximum anticipated hydrostatic head and maximum probable joint opening as computed from Standard Drawing ES-146 and related procedures of TR-18, including the effects of joint rotation and the required margin of safety. The required joint extensibility is equal to the unit horizontal strain in the earth adjacent to the conduit multiplied by the length (in inches) of the section of conduit between joints plus the extension (in inches) due to calculated joint rotation plus a margin of safety.

A margin of safety of not less than 0.5 inch shall be used. The required joint extensibility plus the maximum permissible joint gap equals the required joint length. The required joint extensibility depends on the maximum potential foundation consolidation under the spillway barrel. For significant and high hazard class dams, the consolidation must be estimated from adequate foundation borings and samples, soil mechanics laboratory tests, and engineering analysis. For low hazard class dams where undisturbed foundation samples are not taken for other purposes, approximate procedures based on soil classification and experience may be used for estimating foundation consolidation.

Only joints incorporating a round rubber gasket set in a positive groove which will prevent its displacement from either internal or external pressure under the required joint extensibility shall be used on precast concrete pipe conduits. Concrete pipe must have steel joint rings providing rubber to steel contact in the joint.

Articulation of the conduit (freedom for required rotation) shall be provided at each joint in the conduit, at the junction of the conduit with the riser and any outlet structure. Concrete bedding for pipe conduits need not be articulated. Cradles must be articulated if on yielding foundations. Welded steel pipe conduits need not be articulated if the pipe and bedding rest directly on firm bedrock.

Piping and seepage control—Use a filter and drainage diaphragm around any structure that extends through the embankment to the downstream slope. Design the diaphragm with single or multiple zones to meet the requirements of NEH-633, chapter 23.

Locate the diaphragm aligned approximately parallel to the centerline of the dam or approximately perpendicular to the direction of seepage flow. Extend the diaphragm horizontally and vertically into the adjacent
embankment and foundation to intercept potential cracks, poorly compacted soil zones or other discontinuities associated with the structure or its installation.

Design the diaphragms to extend the following minimum distances from the surface of rigid conduits:

- horizontally and vertical upward 3 times the outside diameter of circular conduits or the vertical dimension of rectangular box conduits except that:
  - vertical extension need be no higher than the crest of the auxiliary spillway, or higher than 2 feet below the embankment surface, and
  - horizontal extension need be no further than 5 feet beyond the sides and slopes of any excavation made to install the conduit.
- vertically downward:
  - for conduit settlement ratios ($\delta$) of 0.7 and greater (reference NRCS Technical Release No. 5), the greater of (1) 2 feet or (2) 1 foot beyond the bottom of the trench excavation made to install the conduit. Terminate the diaphragm at the surface of bedrock when it occurs within this distance. Additional control of general seepage through an upper zone of weathered bedrock may be needed.
  - 1.5 times the outside diameter of circular conduits or the outside vertical dimension of box conduits for conduit settlement ratios ($\delta$) less than 0.7.

Design the diaphragms to extend in all directions a minimum of two times the outside diameter from the surface of flexible conduits, except that the diaphragm need not extend beyond the limits in the above or beyond a bedrock surface beneath the conduit.

Provide minimum diaphragm thickness of 3 feet and minimum thickness of 1 foot for any zone of a multi-zone system. Use larger thickness when needed for capacity, tying into embankment or foundation drainage systems, accommodating construction methods, or other reasons.

For homogeneous dams, locate the diaphragm in the downstream section of the dam such that it is:

- downstream of the cutoff trench;
- downstream of the centerline of the dam when no cutoff trench is used; and
- upstream of a point where the embankment cover (upstream face of the diaphragm to the downstream face of the dam) is at least one-half of the difference in elevation between the top of the diaphragm and the maximum potential reservoir water level.

For zoned embankments, locate the diaphragm downstream of the core zone and/or cutoff trench, maintaining the minimum cover as indicated for homogeneous dams. When the downstream shell is more pervious than the diaphragm material, locate the diaphragm at the downstream face of the core zone.

It is good practice to tie these diaphragms into the other drainage systems in the embankment or foundation. Foundation trench drains and/or embankment chimney drains that meet the minimum size and location limits are sufficient and no separate diaphragm is needed.

Design the minimum capacity of outlets for diaphragms not connected to other drains by assuming the coefficient of permeability ($k$) in the zone upstream of the diaphragm is 100 times the coefficient of permeability in the compacted embankment material. Assume this zone has a cross-sectional area equal to the diaphragm area and the seepage path distance equal to that from the embankment upstream toe to the diaphragm. This higher permeability simulates a sealed filter face at the diaphragm with partially filled cracks and openings in the upstream zone.

For channels, chutes or other open structures, seepage and piping control can be accomplished in conjunction with drainage for reduction of uplift and water loads. The drain, properly designed to filter the base soils, is to intercept areas of potential cracking caused by shrinkage, differential settlement, or heave and frost action. These structures usually require the use of footings, keywalls and counterforts, and drainage is properly located immediately downstream of these features. This drainage when properly designed can control piping and provide significant economies due to the effect on soil loads, uplift pressures, overturning forces and sliding stability.

**Outlets**

The choice of outlet is to be based on a careful consideration of all site and flow conditions that may affect operation and energy dissipation.

- Cantilever outlet and plunge pools may be
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installed where their use:
- does not create a piping hazard in the foundation of the structure.
- is compatible with other conditions at the site.

Plunge pools shall be designed to dissipate the energy and be stable. Unless the pool is to be in bedrock or very erosion resistant materials, riprap will be necessary to insure stability. Design Note 6, Armored Scour Hole for Cantilever Outlet, shall be used for design.

Cantilever outlets shall be supported on bents or piers and must extend a minimum of 8 feet beyond the bents or piers. The bents must be located downstream from the intersection of the downstream slope of the earth embankment with the grade line of the channel below the dam. They must extend below the lowest elevation anticipated in the plunge pool. The invert of the cantilever outlet must be at least 1 foot above the tailwater elevation at maximum discharge.

- SAF basins may be used when there is adequate control of tailwater. Use TR-54 for structural design and NEH-14 for hydraulic design.
- Impact basins may be used where positive measures are taken to prevent large debris from entering the conduit. TR-49 is to be used for hydraulic design.

**Trash racks**

Trash racks shall be designed to provide positive protection against clogging of the spillway under any operating level. The average velocity of flow through a clean trash rack must not exceed 2.5 feet per second under the full range of stage and discharge. Velocity must be computed on the basis of the net area of opening through the rack.

If a reservoir outlet with a trash rack or a ported concrete riser is used to keep the sediment pool drained, the trash rack or riser must extend above the anticipated sediment elevation at the riser to provide for full design flow through the outlet during the design life of the dam. The velocity through the net area of the trash rack above the maximum sediment elevation must not exceed 2 feet per second when the water surface in the reservoir is 5 feet above the top of the trash rack or riser inlet.

**Antivortex device**

All closed conduit spillways designed for pressure flow must have adequate antivortex devices.

**High sulfate areas**

Under certain conditions, concrete is susceptible to deterioration from sulfate ions, especially those derived from sodium and magnesium sulfates. In areas where experience or soil tests indicate the potential for problems, the following shall be used for design purposes.

<table>
<thead>
<tr>
<th>Sulfate concentration (^1) (parts per million)</th>
<th>Hazard</th>
<th>Corrective measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 150</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>150 – 1,000</td>
<td>Moderate</td>
<td>Use Type II Cement. (ASTM C-150). Adjust mix to protect against sulfate action.</td>
</tr>
<tr>
<td>1,000 – 2,000</td>
<td>High</td>
<td>Use Type V Cement (ASTM C-150). Adjust mix to protect against sulfate action. Use soils in contact with concrete surfaces that are low in sulfates.</td>
</tr>
<tr>
<td>2,000 – UP</td>
<td></td>
<td>Do not use concrete materials unless measures are taken to protect concrete surfaces from sulfates. Product manufacturers should be consulted.</td>
</tr>
</tbody>
</table>

\(^{1}\) Sulfate concentration is for soil water at the concrete surface.
**Auxiliary spillways**

Auxiliary spillways are provided to convey excess water through, over, or around a dam. They are usually open channels excavated in natural earth, earthfill, rock, or constructed of reinforced concrete.

**Closed type spillways**

An open channel auxiliary spillway must be provided for each dam except as provided below:

- Low hazard class dams with a product of storage times the effective height of the dam of less than 10,000 – a closed conduit principal spillway having a conduit with a cross-sectional area of 12 square feet or more, an inlet which will not clog, an elbow designed to facilitate the passage of trash, and large enough to pass the routed freeboard hydrograph is the minimum acceptable design without an open channel auxiliary spillway.

- Dams with drainage areas of 10 square miles or less (except those covered by item 1) – a closed conduit principal spillway having a conduit with a cross-sectional area of 20 square feet or more, an inlet which will not clog, an elbow designed to facilitate the passage of trash and large enough to pass the routed freeboard hydrograph peak discharge without overtopping the dam is the minimum acceptable design without an open channel auxiliary spillway.

- Dams with drainage areas greater than 10 square miles (except those covered by item 1) – a closed type primary auxiliary spillway may be used in lieu of an open channel auxiliary spillway. Drop inlet spillways with a standard two-way covered top inlet must have a minimum unobstructed cross-sectional area of each opening of the conduit of 40 square feet. All other closed type primary auxiliary spillways must have a minimum unobstructed cross-sectional area of each opening of 80 square feet. The ratio of width to height in both cases is must be between 0.75 and 1.33. The spillways must be large enough to pass the routed freeboard hydrograph peak discharge without overtopping the dam.

**Spillway requirements**

**Capacity of auxiliary spillways**

Auxiliary spillways must be proportioned so they will pass the stability design hydrograph at the safe velocity determined for the site. They must have sufficient capacity to pass the freeboard hydrograph with the water surface in the reservoir at or below the elevation of the design top of the dam. In no case is the capacity of the auxiliary spillway to be less than 200 ft$^3$/sec or $237 \text{ DA}^{0.493}$. The minimum difference in elevation between the crest of the auxiliary spillway and the settled top of the dam is 3 feet. State law may establish minimum capacity or depth greater than those given above.

**Elevation of the crest of the auxiliary spillway**

Table 2-2 gives the maximum allowable frequency of use of earth and vegetated auxiliary spillways. The minimum retarding storage volume and the associated principal spillway discharge must be such that the discharge through the auxiliary spillway will not occur during the routing of the principal spillway hydrograph and the 10-day drawdown requirement is met or the crest elevation of the auxiliary spillway is raised as noted under Capacity of Principal Spillway.

For earth spillways, it refers to sites where peak flows of short duration may be expected and where erosion resistant soils and moderate slopes exist. When vegetated spillways are used, the sites must have these same characteristics, and in addition, conditions must be such that vigorous vegetation can be maintained without irrigation. When conditions are less favorable, auxiliary spillways shall be designed for less frequent use. This may be done by raising the crest elevation, increasing the capacity of the principal spillway, adding a structural primary auxiliary spillway, or a combination of the above.

The maintenance required for the auxiliary spillway will be increased as the frequency and duration of flow increase. Good design requires balancing the spillway maintenance cost against the increased cost of modifying the other elements of the dam to reduce the flow frequency.

**Auxiliary spillway routings**

The stability design and the freeboard hydrographs must be routed through the reservoir starting with the water surface at the elevation of the lowest ungated principal spillway inlet, the anticipated elevation of the sediment storage, the elevation of the water surface associated with significant base flow or the pool elevation after 10 days of drawdown from the maximum...
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Stage attained when routing the principal spillway hydrograph, whichever is higher, except as provided in the following:

- dams with gated spillways and joint use storage capacity – stability design and freeboard hydrograph routings are to be started at or above the elevation of the lowest ungated outlet or at the elevation of the water surface associated with the average annual base flow, whichever is higher.

- single purpose, low hazard class irrigation dams – stability design and freeboard hydrograph routings are to be started at or above the water surface elevation of the irrigation storage.

Hydraulic design

The relationship between the water surface elevation in the reservoir and the discharge through the auxiliary spillway shall be evaluated by computing the head losses in the inlet channel upstream of the control section or, if a control section is not used, by computing the water surface profile through the full length of the spillway. Bernoulli’s equation and Manning’s formula shall be used to evaluate friction losses, compute water surface profiles and determine velocities. Policy on the selection of flow resistance values is given in the discussion of the various types of auxiliary spillways.

Structural stability

The spillway must be investigated, analyzed, designed and constructed adequately to establish and maintain stability during the passage of design flows without blockage or breaching. Excavated open cut spillways must have cut and fill slopes in earth and rock which are stable against sliding. Cut slope stability must be evaluated for the long-term weathered, natural moisture condition and for adverse moisture conditions associated with rapid drawdown from the auxiliary spillway design discharge.

Vegetated and earth auxiliary spillways

Vegetated and earth auxiliary spillways are open channels and usually consist of an inlet channel, a control section, and an exit channel. Subcritical flow exists in the inlet channel and the flow is usually supercritical in the exit channel.

Vegetated auxiliary spillways are usually trapezoidal in cross-section and are protected from damaging erosion by a grass cover. They are adapted to sites where a vigorous grass growth can be sustained by normal maintenance without irrigation.

Earth spillways are used in those areas where vegetative growth cannot be maintained. They are similar to vegetated spillways, but are designed for lower velocities, lower stresses, and less frequent use. Normally, they require more maintenance after a flow occurs.

Earth and vegetated auxiliary spillways are designed on the basis that some erosion or scour will occur during passage of infrequent storms, but the spillway will not breach during passage of the freeboard storm.

Hydraulic data in TR-39 Hydraulics of Broad Crested Spillways can be used in the design of vegetated or earth auxiliary spillways. A minimum vegetal retardance curve index of 5.6 as defined in Agriculture Handbook 667 (AH-667) Stability Design of Grass-Lined Open Channels shall be used to determine hydraulic capacity and vegetal stress in vegetated spillways. A minimum Manning’s $n$ of 0.02 shall be used for earth spillways. Actual hydraulic capacity of the spillway will be based on an appraisal of the roughness condition at the site.

Layout

Guidance on the layout of auxiliary spillways is provided in NEH-628.50, Earth Spillway Design. Spillways must be located away from the dam whenever possible. The layout and profile of vegetated or earth spillways should provide safety against breaching of the spillway during the passage of the freeboard hydrograph. Both extending the length and flattening the grade of the exit channel to delay or prevent headcut formation, and maximizing the bulk of material to contain any headcut advancement should be considered.

The inlet channel must be level for a minimum distance of 30 feet upstream from the exit channel. This level part of the inlet channel (control section) must be the same width as the exit channel, and its centerline must be straight and coincident with the centerline of the exit channel. A curved centerline is permissible in the inlet channel upstream from the level part, but it must be tangent to the centerline of the level part. Any curved inlet channel should be depressed below the level part to reduce velocities.

The exit channel must be straight and perpendicular to the level part of the inlet channel for a distance equal to at least one-half of the maximum base width of the dam. Curvature may be introduced below this point if it is certain that the flowing water will not impinge on the dam should the channel fail at the curve.
When the upstream edge of the exit channel is considered as a control section for hydraulic calculations, the exit channel grade shall be sufficient to ensure supercritical flow for all discharges equal to or greater than 25 percent of the maximum discharge through the spillway during the passage of the freeboard hydrograph. However, the slope in the exit channel need not exceed 4 percent \((s = 0.04 \text{ ft/ft})\) to meet this requirement.

The exit channel can be terminated at some point above the maximum tailwater elevation, or can be extended to the principal spillway outlet or natural stream channel below the dam. The exit channel can contain several different grades. In either layout, erosion will occur wherever allowable stresses are exceeded and maintenance is required to protect the integrity of the spillway. Land rights must be considered in making the decision on how to handle the return flow to the natural or constructed stream channel downstream from the dam, and where eroded materials will be deposited.

**Stability design of earth and vegetated earth spillways**

Limitations during routing of the stability design (auxiliary spillway) hydrograph – the maximum stress limitations given below for vegetated or earth spillways apply to the exit channel. They must not be exceeded in the reach where an exit channel failure might cause the flow to impinge on the toe of the dam. The stress limitations are based on the maximum discharge in routing the stability design (auxiliary spillway) hydrograph and the assumption that uniform flow conditions exist in the exit channel.

When the anticipated average use of an earth or vegetated spillway is more frequent than once in 50 years, the allowable stress will be determined in accordance with AH-667. The allowable values may be increased 20 percent when the anticipated average use is once in 50 years, or 50 percent when the anticipated average use is once in 100 years. The allowable stress shall be determined for the actual vegetal cover conditions that can be reasonably expected to exist at the time of the flow. Values for grasses or mixtures not included in AH-667 shall be determined by comparing their characteristics with those that are described. Where special studies or investigations have been made to determine the allowable stress for a species, soil, and condition, those values may be used in lieu of those shown in the handbook.

Ramp spillways are not generally favored by the dam engineering profession, but may be used where alternate solutions are not practical. Ramp spillways shall not be steeper than 10 per cent. Ramp spillways must be constructed with the same compaction procedures and quality control as the earth embankment. The upper one foot of vegetated ramp spillways should be topsoil.

**Integrity design of earth and vegetated earth spillways**

The spillway shall be evaluated for headcut development and advancement during passage of the freeboard storm using the procedures in NEH-628.51, Earth Spillway Erosion Model, and NEH-628.52, Field Procedures Guide for the Headcut Erodibility Index. The spillway design must be such that the spillway will not breach (i.e., headcut will not advance beyond the upstream edge of the level part of the inlet channel) during passage of the freeboard storm.

Special precautions for high hazard class dams—Special consideration must be given to the layout of spillways on high hazard class dams to assure the spillway will not breach under the most extreme conditions of flow. The length of the exit channel is to be increased to the maximum extent possible so that the area most susceptible to erosion is at a considerable distance from the dam. Within the limitations of the site, the profile of the spillway is to be such that a maximum bulk of material is provided.

It is preferable that the flow be confined without the use of levees, but when they are necessary they are to be high enough to contain the peak flow of the routed freeboard hydrograph. Levees must be constructed of erosion resistant materials and compacted to the degree necessary to develop this resistance. They must have a top width not less than 12 feet and, if not protected with riprap, have side slopes not steeper than 3 horizontal to 1 vertical on the side where water flows. When constructed on a foundation subject to piping or undermining, they must be keyed into the foundation with a compacted core having a bottom width not less than the top width of the levee and of sufficient depth to reach sound material, or to a depth equal to the height of the levee, whichever is less.

Crest control structures shall be provided to maintain a uniform surface where the soils are highly erodible from on-site runoff and very low flows through the spillway. The effective bulk length may be increased by installing barriers that will effectively stop a gully advancing through the spillway. Consideration should be given to the reduction of the duration and volume...
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of flow through the auxiliary spillway by raising the elevation of the crest of the spillway, thereby increasing the volume of storage in the retarding pool. An alternate or complementary procedure is to increase the capacity of the principal spillway by means of a two stage inlet of sufficient size to carry an appreciable amount of the outflow hydrograph.

**Rock auxiliary spillway**

Some of the principles used for the layout of earth auxiliary spillways are applicable to rock auxiliary spillways. Allowable average frequency of use and permissible velocities must be ascertained for the specific site based on knowledge of the hardness, condition, durability, attitude, weathering characteristics, and structure of the rock formation. An individual appraisal is necessary to determine the proper roughness coefficient, \( n \). The design is to be such that the auxiliary spillway will not breach during passage of the freeboard storm.

**Structural auxiliary spillways**

Structural spillways shall be designed so that the passage of the freeboard hydrograph will not cause serious damage to the embankment or the structures themselves. The configuration of a structural spillway must be compatible with the foundation conditions at the site, the channel stability downstream from the spillway, the possible range of tailwater depth, and the proximity of the spillway to the embankment. The inlet portion of a chute spillway shall consist of a straight inlet, a box drop inlet, an ogee crest, or other appropriate hydraulic structure which will produce critical flow at the crest and result in a determinate stage-discharge relationship.

The hydraulic design of structural auxiliary spillways shall be in accordance with the principles set forth in NEH-5, Hydraulics; NEH-11, Drop Spillways; NEH-14, Chute Spillways; and U.S. Department of Interior, Bureau of Reclamation publications, or based on model studies, with consideration given to the effects of air entrainment by water traveling at supercritical velocities.

The design discharge for hydraulic proportioning of structural auxiliary spillway must not be less than two-thirds of the planned structure capacity during passage of the routed freeboard hydrograph, except that all headwalls and sidewalls shall be designed to prevent overtopping during passage of the full maximum freeboard discharge. When the magnitude of a structural auxiliary spillway exceeds that of structures commonly designed by NRCS, model studies or other special studies shall be made.

The outlet section of concrete chute spillways must consist of a hydraulic jump basin, such as a SAF, deflector bucket, roller bucket, or other appropriate hydraulic structure which will dissipate the energy of the high velocity discharge.

Structural auxiliary spillways must be designed to withstand lateral earth pressures, uplift, seepage and other hydrostatic and hydrodynamic pressures. They must be structurally designed for the full maximum freeboard discharge with uplift and sliding safety factors of not less than 1.0 and in accordance with the principles set forth in NEH-6, Structural Design; NEH-11, Drop Spillways and NEH-14, Chute Spillways, utilizing TR-50, TR-54; and other appropriate and available design working aids.
Glossary

Auxiliary spillway. The spillway designed to convey excess water through, over, or around a dam.

Auxiliary spillway system. A single auxiliary or combination of auxiliary spillways designed to work together.

Base flow. The sustained or fair-weather discharge which persists after storm runoff and associated quick return flow have been depleted. It is usually derived from groundwater discharge or gradual snow or ice melt over extended periods of time, but need not be continuous flow. (It can be based on annual or seasonal periods, depending upon when major floods usually occur.)

Breach hydrograph. The outflow hydrograph attributed to the sudden release of water in reservoir storage due to a dam breach.

Conservation storage. Water impounded for consumptive uses such as municipal, industrial and irrigation and nonconsumptive uses such as recreation and fish and wildlife.

Control section. In an open channel spillway, it is that section where accelerated flow passes through critical depth.

Dam. An artificial barrier together with any associated spillways and appurtenant works that do or may impound or divert water.

Design life. A period of time during which a dam is designed to perform its assigned functions satisfactorily.

Dry dam. A dam that has an ungated outlet positioned so that essentially all stored water will be drained from the reservoir by gravity. The reservoir will normally be dry.

Earth dam. A dam in which the principal barrier is an embankment of earth or rock fill or combination of earth and rock fill.

Earth spillway. An open channel spillway in earth materials without vegetation.

Economic life. The period of time during which economic benefits accrue to a dam.

Effective height of dam. The difference in elevation in feet between the lowest open channel auxiliary spillway crest and the lowest point in the original cross section on the centerline of the dam. If there is no open channel auxiliary spillway, the top of the dam becomes the upper limit.

Exit channel of an open channel spillway. The portion downstream from the control section which conveys the flow to a point where it may be released without jeopardizing the dam.

Freeboard hydrograph. Used to evaluate the total spillway flow capacity of the dam and, consequently, establish the minimum settled elevation of the top of the dam. It is also used to evaluate the integrity (breaching resistance) of a vegetated or earth auxiliary spillway.

Inlet channel of an open channel spillway. The portion upstream from the control section.

Joint extensibility. The amount of a pipe joint that can be extended from the fully engaged position without losing strength or watertightness. In case of rubber gasket joints, it is measured from the center of the gasket to the point of flare of the bell ring or collar when the joint is fully closed.

Joint gap. The longitudinal dimension between the end face of the spigot end of a pipe joint and the corresponding face of the bell end of the connecting pipe. It does not include the beveled portion designed for seal ing compounds.

Joint use pool. The portion of a reservoir which serves two or more purposes; for instance, conservation storage and floodwater storage.

Primary auxiliary spillway. The spillway with the lowest crest elevation in an auxiliary spillway system.

Principal spillway. The lowest ungated spillway designed to convey water from the reservoir at predetermined release rates.

Principal spillway hydrograph. The hydrograph used to determine the minimum crest elevation of the auxiliary spillway. It is used to establish the principal spillway capacity and determine the associated minimum floodwater retarding storage.
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**Quick return flow.** The diminishing discharge directly associated with a specific storm that occurs after surface runoff has reached its maximum. It includes base flow, prompt subsurface discharge (commonly called interflow), and delayed surface runoff.

**Ramp spillway.** A vegetated spillway constructed over an earth dam in a manner such that the spillway is a part of the embankment.

**Retarding pool.** The portion of the reservoir allotted to the temporary impoundment of floodwater. Its upper limit is the elevation of the crest of the auxiliary spillway.

**Retarding storage.** The volume in the retarding pool.

**Rock spillway.** An open channel spillway through competent, nonerodible, natural rock materials.

**Sediment pool.** The portion of the reservoir allotted to the accumulation of submerged sediment during the design life of the dam.

**Sediment pool elevation.** The elevation of the surface of the anticipated submerged sediment accumulation at the dam.

**Sediment storage.** The reservoir capacity allocated to total sediment (submerged and aerated) accumulation during the life of the dam.

**Spillway.** An open or closed channel, conduit or drop structure used to convey water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of water.

**Stability design hydrograph.** The hydrograph used to establish the dimensions of the auxiliary spillway.

**Storage.** The capacity of the reservoir below the elevation of the crest of the auxiliary spillway.

**Vegetated spillway.** A vegetated open-channel spillway in earth materials.

**Visual focal.** An element in the landscape upon which the eyes automatically focus because the element's size, form, color, or texture contrasts clearly with its surroundings.