Forest Service Handbook
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Forest Service Handbook 7509.11 – Dams Management Handbook
Chapter 30 - Operation and Maintenance Inspections

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Superseded Directive: 1, August 8, 1990; Entire Handbook issued, December 1986

Approved by: F. Dale Robertson, Chief

Date approved:

Responsible Staff:

Explanation of changes: Following is an explanation of the changes throughout the directive by section.

Posting Instructions: Amendments are numbered consecutively by Handbook number and calendar year. Post document in numerical order of chapters (1109.12, sec. 4.32, ex. 01). Remove entire national text of the Handbook and replace with this amendment. DO NOT REMOVE SUPPLEMENTS OR INTERIM DIRECTIVES. Retain this transmittal as the first page of this document.

Revises and updates entire Handbook. Significant changes in direction are as follows:

05: Moves select definitions from FSM 7500. Modifies definitions to agree with Glossary of Terms for Dam Safety, prepared by the Interagency Committee for Dam Safety (ICODS), and Federal Emergency Management Agency (FEMA).

08: Updates reference list and adds names and addresses of agencies, associations, and groups publishing reference materials related to dams and dam safety.

10: Changes chapter title from Project Files to Records and Files.

40: Changes chapter title from Safety Evaluation/Hazard Potential to Safety Inspections and Hazard Assessments. Replaces the term "safety evaluation" with "safety inspection" throughout.

42: Replaces the term "Hazard - Potential Evaluations "with" Hazard Assessment."

42.3: Adds hazard classification examples.

53: Adds direction on location of copies of emergency action plans.

54: Adds direction on testing emergency action plans.

62: Revises direction to exclude Regional dam or water resources engineer from serving on a dam failure investigation team in cases of potential or apparent conflict of interest.

70: Changes title from Dam Inventory to Management of Special Use and Other Non-Forest Service Projects. Previous direction contained in this chapter is moved to FSM 7514; moves direction from previous chapter 80 to chapter 70.

80: Changes title from Management of Special-Use and Other Non-Forest Service Projects to Planning and Design.

Completes previously reserved FSM 7520 and incorporates it into
FSH 7509.11.

81: Provides guidance and definitions for four phases in the design schedule.

82: Provides guidance for planning and designing channel layout.

83: Provides guidance for assigning hazard classification.

This Handbook is now available electronically in the National Information Center in the same format as the paper copy. Henceforth, amendments to this Handbook will be issued to Forest Service units electronically on a document basis.

Table of Contents

Operation and maintenance inspections are an integral part of the Forest Service dam safety program. These inspections provide the information needed to determine whether a dam is receiving adequate operation and maintenance attention and whether any repairs or modification of procedures are needed. This chapter provides guides for performing these inspections.

30.2 - Objective

To ensure safe dams through periodic inspections performed by qualified personnel. See FSM 7502 for additional objectives governing dams management.

31 - Operation Inspections

Conduct periodic inspections of dams and maintain records of inspections and followup activities; take actions necessary to document inspections and document actions taken to correct deficiencies.

31.1 - Inspection Items

Items that should be examined during an operation inspection are as follows:

1. Determine whether the dam is being operated as the designer intended. For example, if the designer intended the spillway entrance to be unobstructed, the entrance should be checked for the use of unauthorized flashboards.

2. If administrative limitations have been placed on the dam operation, such as maximum reservoir elevation, check for evidence that the operator is in compliance.

3. Check to ensure instrumentation and recording devices function properly and that data are being collected. Also, determine whether the data are being evaluated by a qualified person.

4. If an emergency action plan is required (FSM 7517), ensure the plan is available to key personnel listed in the plan. Review the plan for completeness and make sure it has up-to-date required information, names, and the phone numbers. Also determine whether the key personnel listed are familiar with the plan and their individual responsibilities.

5. Discuss the functioning of the dam with the operator to determine whether any unusual events related to the dam have been observed. Based on this discussion, make a general assessment of the adequacy of the operator's knowledge of the project.

31.2 - Frequency of Inspections

Conduct operation inspections at least as often as maintenance inspections. If administrative limitations have been placed on the operation of a dam or if there are special operating

agreements, operation inspections may need to be made more frequently. Criteria for determining the frequency of the inspections are given in FSM 7516.21.

31.3 - Inspection Reports

While a separate formal report is not required each time an operation inspection is made, make a record of the inspection. The report may be combined with the maintenance inspection report. If the inspector finds no problem with the operation, only a brief note is necessary stating the date an inspection was made and that no problems were found.

32 - Maintenance Inspections

The purpose of a maintenance inspection is to determine whether a dam is receiving adequate maintenance for the anticipated operating conditions and whether any conditions have developed or are developing that could significantly affect the structure's ability to function safely. Periodic maintenance inspections for Class A, B, C, and high-hazard Class D dams must be performed by a qualified engineer (FSM 7505 and 7516.2).

See chapter 70 for guidance on the administration of inspection requirements for dams not owned by the Forest Service.

32.1 - Frequency of Inspections

Determine the frequency of maintenance inspections by considering the size of the dam, its hazard rating, and its condition. Develop an inspection schedule as directed in FSM 7516.21. Inspect high-hazard structures annually and following earthquakes, major storms, and periods of unusually heavy runoff. Over a period of several years make inspections under varied reservoir conditions if possible; for example, in a year when the reservoir is full and the next year when it is almost empty.

32.2 - Inspection Aids

1. Prior to making the field examination, the inspector should review the following information for the dam:

    a. Final drawings showing the "as-constructed" condition.

    b. Operation and maintenance plans.

    c. Emergency action plan.

    d. Photographs and site map showing camera points from which photographs were taken.

e. Prior inspection reports.

2. Determine what equipment may be needed during the inspection. The following is a list of equipment that may be useful:

a. Camera and film (use a combination of a normal and telephoto lens for the most accurate photo record).

b. Tape measure (steel or cloth).

c. Hand level.

d. Access and operating key, handwheel, or other tools.

e. Ladder.

f. Shovel.

g. Axe.

h. Flashlight or handheld spotlight.

i. Sheet of plastic or canvas for collecting and concentrating flows so they can be more easily measured.

j. Volume measuring device, small weir, or bucket of known volume.

k. Stopwatch.

l. Probe rod.

m. Rock pick.

n. Hand mirror (for inspecting small outlets).

o. Vernier caliper and ruler for inside, outside, and depth measurements.

p. High boots or waders.

q. Flagging and survey stakes.

r. Clear measured volume vessel (such as a one-quart glass jar) for measuring leaks and examining sediments in flows.

33 - Field Examination

Deduce the condition of a dam's interior by observing and evaluating the condition of its surfaces and the immediate surrounding area, checking the operation of its mechanical equipment, measuring seepage from the structure; and collecting and evaluating data from installed instruments.

33.1 - Embankments

33.11 - Structural Deformation

Check for signs of structural deformation by looking for features such as depressions, loss of freeboard, differential settlement along zone interfaces where they are visible on the crest; subsidence as indicated by sinkholes on embankment surfaces; zones of settlement as indicated by transverse cracks across the crest and slopes, especially near the center and ends of the dam; and cracks and spreading in concrete or timber facings on rockfill embankments. Probe cracks and measure for depth and width, and record and photograph the locations.

33.12 - Stability

Detect instability by looking for evidence of cracks, displacements, sloughs, slides, bulges, and escarpments on the embankment surfaces and on the natural terrain adjacent to the dam. Any significant variance from a smooth or uniform embankment surface may be an indication of instability. Bulges, seeps, or depressions in the ground surface below the downstream toe may also indicate an unstable condition. Instability can be caused by a saturated embankment resulting from water infiltrating into the embankment from the reservoir, snowmelt, or rainfall. Dated photographs of the staked outline of a saturated area provide good references for future monitoring.

33.13 - Seepage

Detect seepage by checking the downstream face and hillsides adjacent to the abutments and the downstream area for emerging flows, hydrophilic vegetation, boils, pressure spurts, depressions, sinkholes, or saturation patterns. Observe the seepage for color, algae, turbidity, and suspended solids. Measure or estimate the flow rate. Examine and measure flows from toe and internal drains. Record the level of the reservoir surface when observations about seepage and drain flows are recorded.

33.14 - Erosion

Examine slopes for loss, displacement, and deterioration of riprap; settlement or loss of the finer grained materials underlying the riprap; and beaching of the upstream face. Examine slopes exposed to surface runoff for erosion channels, gullies, and animal, human, and vehicle traffic damage. Dispersive soils in an embankment can allow very serious erosion tunnels and

channels to develop. If an area is known to have dispersive soils, take extra care when checking an embankment for erosion. Measurements and photographs of erosion channels are valuable for determining the rate of erosion development.

33.15 - Vegetation and Animals

Inspect embankments for:

1. Brush and trees with large root systems that could cause breaching if blown over.

2. Dead root systems that have the potential for creating water passages.

3. Obscuring and impenetrable vegetation.

4. Evidence of burrowing animals.

Remove heavy growth of brush or small trees on a dam to facilitate inspection of the embankment and to remove habitat for burrowing animals.

33.2 - Concrete and Masonry Structures

33.21 - Structural Deformation

Detect undue stress and strain by looking for cracks, crushing, displacements, or offsets in concrete monoliths, buttresses, face slabs, and arch barrels. This may occur on exterior surfaces and in galleries, valve chambers, operating chambers, and conduits on interior surfaces. Check for stress and temperature cracking patterns in buttresses, pilasters, diaphragms, and arch barrels; the loss of tension in anchorages and tendons; and displaced or torn waterstops.

33.22 - Stability

Check for marginal stability and sliding resistance by looking for excessive or uneven uplift pressures in piezometers; pressure spurts from foundation drain holes, construction joints, and cracks; differential movements between adjacent monoliths, buttresses, arch barrels, and face slabs; discontinuities near the juncture of arches and thrust blocks; and movement along construction joints. Pressure seeps at the downstream face and in galleries can be caused by excessive uplift on horizontal construction lift surfaces.

33.23 - Seepage

(Sec. 33.13.)

33.24 - Concrete Deterioration

Examine concrete for deterioration caused by alkali-aggregate reaction, freezing-thawing cycles, leaching, and erosion.

33.25 - Vegetation

Examine structures for vegetation in joints and cracks, and behind walls.

33.3 - Foundation

Assess foundation conditions by observing the reaction of any instruments that have been installed in the foundation and by checking for leakage and seepage patterns emerging downstream or in galleries, drain holes, and drain line systems. Inspect grouting and drainage tunnels. Look for depressions and sinkholes in the dam and surrounding area. Foundation consolidation and solution cavities may be revealed by settling and tilting of supported structures.

33.4 - Spillways and Outlet Works

Spillway components and arrangements vary widely depending on the purpose, constraints, and characteristics of the dam. The inspector must keep these needs and constraints in mind while examining each spillway component. If possible, performance of the spillway and outlet works should be observed during heavy runoff or flooding conditions.

33.41 - Approach Channel

Examine the approach channel for serviceability by noting whether there are obstructions to the flow, such as trash, debris, ice, rock and soil deposits, beaver dams, or large vegetation. Also look for indications of potential slides and slumps in the side slopes of channels.

33.42 - Log Booms

Examine log booms for serviceability and potential obstruction to flow by checking for sinking or missing sections, lodged drifts, parting, loss of anchorage, misalignment, and improper slack.

33.43 - Open Channels

Check open channels for obstructions such as vegetation or debris. Examine structural walls and channel inverts for excessive loadings, which are indicated by deflections and differential movements at joints. Check drain systems for serviceability and flow patterns. Examine unlined channels for excessive erosion. Observe flow through the channels to determine whether there are dangerous hydraulic flow patterns, such as formation of large cross-waves, inadequate wall freeboard, water wall climb, uneven water depth distribution, water ride-up at

horizontal curves, or negative pressures (cavitation) at vertical curves. If none are directly observable, look for evidence of these conditions after discharges have receded.

33.44 - Hydraulic Control Structures

Examine gravity structures, weirs, piers, slabs, and buttresses for indications of stress, strain, instability, foundation erosion, and undercutting in a manner similar to that for concrete structures (sec. 33.2). Examine spillway entrances and other control structures for obstructions that would dangerously raise the storage level or decrease the outlet capacity. Check serviceability of trash control devices. Examine hoods, vent openings, and water passages of siphon spillways for freedom from obstruction and correct elevation settings. Check air passages and splitters for nappe aeration for clear openings and secure anchorages.

Examine the serviceability and performance of mechanical and electrical equipment by having the operator run the equipment through its operating range while checking for binding, vibration, oil pressure retention, leaks, adequate power, and unusual noises. Check the dependability of the basic power supply and auxiliary power sources. Examine the equipment for broken, missing, and worn parts. Check that equipment operating instructions are posted nearby and that operating cranks and portable drive motors are present. Determine the serviceability and availability of authorized flashboards, supports, access walkways, and hoists.

Also determine whether mechanical and electrical equipment is adequately protected against unauthorized operation.

33.45 - Spillway Bridges

Include spillway bridges in the Forest Bridge Inventory and ensure regular inspection by a qualified bridge inspector. Ensure that the bridge has been analyzed to determine that it is capable of supporting heavy equipment needed in an emergency.

33.46 - Terminal Structures

Examine spillway terminal structures for evidence of poor or dangerous hydraulic performance; erosion damage to the spillway, its foundation, the dam, or other critical structures; and indications of structural weakness.

33.47 - Closed Conduits and Tunnels

Inspect conduits and tunnels internally for obstructions, corrosion, and wear; evidence of excessive external loads indicated by pressure jets; distorted cross sections, cracks, displacements, and movements of joints; and undue leakage at joints. During operation look for air injection or expulsion and for indications of hydraulic jump formation within the conduit.

Also examine the exterior of a conduit or tunnel for seepage and piping at the point where it emerges from the embankment.

33.48 - Control Gates and Valves

Inspect control gates, valves, and all other mechanical devices used to control the water level for reliable access during both routine and emergency situations; serviceability of lubrication systems, air vents, drainage, and sump pump facilities; and security against unauthorized operation. Check gates and valves for freedom of movement, corrosion binding of seals, leaking seals, and dangerous or unsuitable operator positions or operational directions.

33.49 - Cavitation

Detect the occurrence of cavitation in waterways at liner plates, gate leaves and seats, and valve leaves and seats by checking these features for surface pitting when they are unwatered and by listening for the sound of implosions when they are in service.

33.5 - Project Environs

Briefly examine the area surrounding a dam for conditions and events that may be related to the safety of the project. This generally involves checking for major changes in the character of the area since the last safety evaluation, or since the structure was designed, if there has not been a safety evaluation.

1. Examine the reservoir surface for vortices that indicate flow around, beneath, or through the dam. When the reservoir level is down, look for depressions and sinkholes. Measure and record silt levels on the reservoir bottom at specified locations; measure silt levels at the same locations for each inspection.

2. Inspect the downstream flood plain to assess the hazard potential. Give specific attention to the proximity and extent of residential, recreational, and commercial developments as well as transportation routes, and utility routes. Keep informed about development plans in or near the flood plain on both National Forest System lands and other lands.

3. Examine land forms and the stream channel near the downstream toe of the dam for reservoir-connected "springs," dangerous seepage or piping regardless of source, stream channel obstructions that interfere with the flow from the outlet and spillway, and stream headcutting that could progress upstream to the dam.

4. Examine the watershed for major changes in land use or cover, such as that caused by urbanization, fire, or timber harvest, that could significantly increase flood runoff.

34 - Common Deficiencies and Failure Modes

Deficiencies that can occur in existing dams range from major defects which could result in catastrophic failure, to relatively minor deterioration which may or may not necessitate remedial work. Some common modes of failure or defects and some of their typical causes are shown in Exhibit 01.

34 - Exhibit 01

Deficiencies and Failure Modes in Existing Dams

Failure Mode or Defect	Causes
Overtopping	- Insufficient spillway capacity. - Obstruction in the spillway. - Erosion or settlement of the crest.
Embankment and Foundation Piping	- Improper selection or absence of filter materials around drains. - Poor embankment compaction, especially around the outlet conduit. - Cracking in the outlet conduit. - Erosion of dispersive soils. - Animal burrows. - Differential settlement. - Removal of soluble materials. - Decomposition of organic materials. - Presence of an object that has reduced the cross-sectional width of the dam, such as a tree that has blown over and removed part of the embankment.
Embankment and Foundation Slides	- Defective or inferior materials. - Improper design. - Improper construction. - Excessive pore pressures (often caused by too rapid drawdown of the reservoir, a plugged filter, or leaking outlet conduit). Excessive strain and pore pressure buildup due to an earthquake or earthquakes.
Embankment Cracking	- Differential settlement. - Shrinkage (desiccation cracking). - Excessive strain due to an earthquake.
Deterioration of Slope Protection	- Inadequate thickness of slope protection. - Defective or inferior slope protection materials. - Inadequate size of riprap. - Uniform gradation of riprap.

Failure Mode or Defect	Causes
Crest Slumping	- Excessive strain due to earthquake - Inadequate embankment compaction. - Traffic wear. - Foundation consolidation.
Reservoir Slides and Leakage	- High permeability. - Saturation of slopes. - Inherent weakness of natural soil and rock formations. - Earthquakes. - Removal of soluble material from soil and rock in the reservoir basin. - Rapid reservoir drawdown. - Wave undercutting of steep slopes. - Removal of impervious soil from the reservoir basin to construct the dam.
Spillway Failure	- Inadequate capacity. - Broken linings. - Faulty gates and hoists. - Obstructions. - Improper design. - Erosion of the foundation.
Outlet Failure	- Improper gate position or location. - Faulty gates and hoists. - Broken conduits. - Silt accumulations. - Obstructions. - Improper design or operation. - Piping along the outlet conduit. - Cavitation.
Concrete Dam Instability	- High uplift or unanticipated uplift distribution. - Differential displacements and deflections. - Overstressing. - Scouring of alluvial foundations.
Concrete Deterioration	- Alkali-aggregate reaction. - Freezing and thawing. - Leaching. - Erosion.

35 - Inspection Reports

After completing the field investigation, the inspector must prepare a brief, written report for future reference and for consideration by the responsible line officer. The report should discuss the general condition of the dam, significant changes since the last inspection, seepage and drain flow rates, reservoir stage, and recommendations for remedial work or changes in procedures. Classify needed maintenance as Priority 1, Priority 2, or Routine (FSM 7515.33).

Place a copy of the report in the project file and send copies to other interested parties such as the Forest Staff Officer for engineering activities and the Regional Office through appropriate channels.