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d. History of previous failures or deficiencies and pending remedial measures for correcting known deficiencies and the schedule for accomplishing remedial measures should be indicated.

10. *Earthquake History* including a summary of the seismic data of significant recorded earthquakes in the vicinity of the dam and information on major damage in the vicinity of the dam from both recorded and unrecorded earthquakes. Regional geologic maps and other documents showing fault locations should be collected.

11. *Inspection History* including the results of the last safety inspection, the organization that performed the inspection, the date inspection performed and the authority for conducting the inspection.

12. *Principal Design Assumptions and Analyses.*

a. *Hydrologic and Hydraulic Determinations.*

(1) Quantity, time and area distribution, and reference source of depth-area-duration data of spillway design storm precipitation (point precipitation if applicable).

(2) Maximum design flood inflow hydrograph including loss rates (initial and average for design flood conditions) and time of runoff concentration of reservoir watershed (peak inflow only when applicable).

(3) Maximum design flood outflow hydrograph (maximum outflow only when applicable).

(4) Discharge-frequency relationship, preferably at damsite, including estimated frequency of spillway design flood for small dams, when appropriate.

(5) Reservoir area and storage capacity versus water surface elevation (table or curves).

(6) Rating curves (free flow and partial gate openings) for all discharge facilities contributing to the maximum design flood outflow hydrograph. Also a composite-rating of all contributing facilities, if appropriate.

(7) Tailwater rating curve immediately below damsite including elevation corresponding to maximum design flood discharge and approximate nondamaging channel capacity.

(8) Hydrologic map of watershed above damsite including reservoir area, watercourse, elevation contours, and principal stream-flow and precipitation gaging stations.

b. *Stability and Stress Analysis* of the dam, spillway and appurtenant structures and features including the assumed properties of materials and all pertinent applied loads.

c. *Seepage and Settlement Analyses.* The determination of distribution, direction and magnitude of seepage forces and the design and construction measures for their control. Settlement estimates and steps adopted to compensate for total settlement and to minimize differential settlements.

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APPENDIX II TO APP. D TO § 222.6—INSPECTION ITEMS

This appendix provides guidance for performing field inspections and may serve as the basis for developing a detailed checklist for each dam.

1. *Concrete Structures in General.*

a. *Concrete Surfaces.* The condition of the concrete surfaces should be examined to evaluate the deterioration and continuing serviceability of the concrete. Descriptions of concrete conditions should conform with the appendix to "Guide for Making a Condition Survey of Concrete in Service," American Concrete Institute (ACI) Journal, Proceedings Vol. 65, No. 11, November 1968, page 905-918.

b. *Structural Cracking.* Concrete structures should be examined for structural cracking resulting from overstress due to applied loads, shrinkage and temperature effects or differential movements.

c. *Movement—Horizontal and Vertical Alignment.* Concrete structures should be examined for evidence of any abnormal settlements, heaving, deflections, or lateral movements.

d. *Junctions.* The conditions at the junctions of the structure with abutments or embankments should be determined.

e. *Drains—Foundation, Joint, Face.* All drains should be examined to determine that they are capable of performing their design function.

f. *Water Passages.* All water passages and other concrete surfaces subject to running water should be examined for erosion, cavitation, obstructions, leakage or significant structural cracks.

g. *Seepage or Leakage.* The faces, abutments and toes of the concrete structures should be examined for evidence of seepage or abnormal leakage, and records of flow of downstream springs reviewed for variation with reservoir pool level. The sources of seepage should be determined if possible.

h. *Monolith Joints—Construction Joints.* All monolith and construction joints should be examined to determine the condition of the joint and filler material, any movement of joints, or any indication of distress or leakage.

i. *Foundation.* Foundation should be examined for damage or possible undermining of the downstream toe.

j. *Abutments.* The abutments should be examined for sign of instability or excessive weathering.

2. *Embankment Structures.*

a. *Settlement.* The embankments and downstream toe areas should be examined for any evidence of localized or overall settlement, depressions or sink holes.

b. *Slope Stability.* Embankment slopes should be examined for irregularities in

alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.

c. *Seepage.* The downstream face of abutments, embankment slopes and toes, embankment—structure contacts, and the downstream valley areas should be examined for evidence of existing or past seepage. The sources of seepage should be investigated to determine cause and potential severity to dam safety under all operating conditions. The presence of animal burrows and tree growth on slopes which might cause detrimental seepage should be examined.

d. *Drainage Systems.* All drainage systems should be examined to determine whether the systems can freely pass discharge and that the discharge water is not carrying embankment or foundation material. Systems used to monitor drainage should be examined to assure they are operational and functioning properly.

e. *Slope Protection.* The slope protection should be examined for erosion-formed gullies and wave-formed notches and benches that have reduced the embankment cross-section or exposed less wave resistant materials. The adequacy of slope protection against waves, currents, and surface runoff that may occur at the site should be evaluated. The condition of vegetative cover should be evaluated where pertinent.

3. *Spillway Structures.* Examination should be made of the structures and features including bulkheads, flashboards, and fuse plugs of all service and auxiliary spillways which serve as principal or emergency spillways for any condition which may impose operational constraints on the functioning of the spillway.

a. *Control Gates and Operating Machinery.* The structural members, connections, hoists, cables and operating machinery and the adequacy of normal and emergency power supplies should be examined and tested to determine the structural integrity and verify the operational adequacy of the equipment. Where cranes are intended to be used for handling gates and bulkheads, the availability, capacity and condition of the cranes and lifting beams should be investigated. Operation of control systems and protective and alarm devices such as limit switches, sump high water alarms and drainage pumps should be investigated.

b. *Unlined Saddle Spillways.* Unlined saddle spillways should be examined for evidence of erosion and any conditions which may impose constraints on the functioning of the spillway. The ability of the spillway to resist erosion due to operation and the potential hazard to the safety of the dam from such operation should be determined.

c. *Approach and Outlet Channels.* The approach and outlet channels should be exam-

ined for any conditions which may impose constraints on the functioning of the spillway and present a potential hazard to the safety of the dam.

d. *Stilling Basin (Energy Dissipators).* Stilling basins including baffles, flip buckets or other energy dissipators should be examined for any conditions which may pose constraints on the ability of the stilling basin to prevent downstream scour or erosion which may create or present a potential hazard to the safety of the dam. The existing condition of the channel downstream of the stilling basin should be determined.

4. *Outlet Works.* The outlet works examination should include all structures and features designed to release reservoir water below the spillway crest through or around the dam.

a. *Intake Structure.* The structure and all features should be examined for any conditions which may impose operational constraints on the outlet works. Entrances to intake structure should be examined for conditions such as silt or debris accumulation which may reduce the discharge capabilities of the outlet works.

b. *Operating and Emergency Control Gates.* The structural members, connections, guides, hoists, cables and operating machinery including the adequacy of normal and emergency power supplies should be examined and tested to determine the structural integrity and verify the operational adequacy of the operating and emergency gates, valves, bulkheads, and other equipment.

c. *Conduits, Sluices, Water Passages, Etc.* The interior surfaces of conduits should be examined for erosion, corrosion, cavitation, cracks, joint separation and leakage at cracks or joints.

d. *Stilling Basin (Energy Dissipator).* The stilling basin or other energy dissipator should be examined for conditions which may impose any constraints on the ability of the stilling basin to prevent downstream scour or erosion which may create or present a potential hazard to the safety of the dam. The existing condition of the channel downstream of the stilling basin should be determined by soundings.

e. *Approach and Outlet Channels.* The approach and outlet channels should be examined for any conditions which may impose constraints on the functioning of the discharge facilities of the outlet works, or present a hazard to the safety of the dam.

f. *Drawdown Facilities.* Facilities provided for drawdown of the reservoir to avert impending failure of the dam or to facilitate repairs in the event of stability or foundation problems should be examined for any conditions which may impose constraints on their functioning as planned.

5. *Safety and Performance Instrumentation.* Instruments which have been installed to measure behavior of the structures should be

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examined for proper functioning. The available records and readings of installed instruments should be reviewed to detect any unusual performance of the instruments or evidence of unusual performance or distress of the structure. The adequacy of the installed instrumentation to measure the performance and safety of the dam should be determined.

a. *Headwater and Tailwater Gages.* The existing records of the headwater and tailwater gages should be examined to determine the relationship between other instrumentation measurements such as stream flow, uplift pressures, alignment, and drainage system discharge with the upper and lower water surface elevations.

b. *Horizontal and Vertical Alignment Instrumentation (Concrete Structures).* The existing records of alignment and elevation surveys and measurements from inclinometers, inverted plumb bobs, gage points across cracks and joints, or other devices should be examined to determine any change from the original position of the structures.

c. *Horizontal and Vertical Movement, Consolidation, and Pore-Water Pressure Instrumentation (Embankment Structures).* The existing records of measurements from settlement plates or gages, surface reference marks, slope indicators and other devices should be examined to determine the movement history of the embankment. Existing piezometer measurements should be examined to determine if the pore-water pressures in the embankment and foundation would under given conditions impair the safety of the dam.

d. *Uplift Instrumentation.* The existing records of uplift measurements should be examined to determine if the uplift pressures for the maximum pool would impair the safety of the dam.

e. *Drainage System Instrumentation.* The existing records of measurements of the drainage system flow should be examined to establish the normal relationship between pool elevations and discharge quantities and any changes that have occurred in this relationship during the history of the project.

f. *Seismic Instrumentation.* The existing records of seismic instrumentation should be examined to determine the seismic activity in the area and the response of the structures of past earthquakes.

6. *Reservoir.* The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

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a. *Shore line.* The land forms around the reservoir should be examined for indications of major active or inactive landslide areas and to determine susceptibility of bedrock stratigraphy to massive landslides of sufficient magnitude to significantly reduce reservoir capacity or create waves that might overtop the dam.

b. *Sedimentation.* The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin which could cause a sudden increase in sediment load thereby reducing the reservoir capacity with attendant increase in maximum outflow and maximum pool elevation.

c. *Potential Upstream Hazard Areas.* The reservoir area should be examined for features subject to potential backwater flooding resulting in loss of human life or property at reservoir levels up to the maximum water storage capacity including any surcharge storage.

d. *Watershed Runoff Potential.* The drainage basin should be examined for any extensive alterations to the surface of the drainage basin such as changed agriculture practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics. Upstream projects that could have impact on the safety of the dam should be identified.

7. *Downstream Channel.* The channel immediately downstream of the dam should be examined for conditions which might impose any constraints on the operation of the dam or present any hazards to the safety of the dam. Development of the potential flooded area downstream of the dam should be assessed for compatibility with the hazard classification.

8. *Operation and Maintenance Features.*

a. *Reservoir Regulation Plan.* The actual practices in regulating the reservoir and discharges under normal and emergency conditions should be examined to determine if they comply with the designed reservoir regulation plan and to assure that they do not constitute a danger to the safety of the dam or to human life or property.

b. *Maintenance.* The maintenance of the operating facilities and features that pertain to the safety of the dam should be examined to determine the adequacy and quality of the maintenance procedures followed in maintaining the dam and facilities in safe operating condition.

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