Training
Aids for
Dam
Safety

MODULE:

IDENTIFICATION OF VISUAL DAM SAFETY DEFICIENCIES

TADS

A video presentation accompanies this workbook.

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PREFACE

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

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

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

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

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

ACKNOWLEDGMENTS

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IDENTIFICATION OF VISUAL DAM SAFETY DEFICIENCIES

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IDENTIFICATION OF VISUAL DAM SAFETY DEFICIENCIES

OVERVIEW

INTRODUCTION

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

YOUR ROLE IN MAINTAINING DAM SAFETY

You can play an important role in the dam safety process because, as an owner, operator, or maintenance worker, your frequent visits or attendance at the site place you in a unique position to observe developing adverse conditions at the dam. You can contribute to dam safety in two ways:

- By properly operating and maintaining the dam according to the Standing Operating Procedures (SOP) and established dam safety regulations, and

- By taking the time to be observant about the condition of the dam and its components, recording your observations, and informing a facility engineer, dam safety inspection personnel, the owner, or other appropriate authorities of conditions that could indicate potential dam safety problems.

A deficiency is anything that may affect the safety of the dam, either in the near term or in the future. Many deficiencies can be found as you go about your regular duties. You may wish to carry a small notepad and pencil with you to write down what you find. Include details in your description such as location, size, amount, and anything else that will help describe the conditions.

Other items that are useful for spotting or defining deficiencies are . . .

- Binoculars for viewing areas that are difficult to reach by foot,

- A measuring tape for measuring the dimensions of cracks and other deficiencies and their distance to a reference point, and

- A small, clear container for checking the clarity of seeps or leakage.

ABOUT THIS MODULE

This module is designed to provide guidelines to dam owners, operators, and maintenance personnel for the visual detection of dam safety deficiencies. If you have been given the responsibility for performing dam safety inspections, refer to the Safety Inspection Of Dams Modules, which provide more indepth information on dam safety inspection.

There are two parts to this module: a videotape presentation and a booklet. Unlike other TADS modules where the text portion is the primary source of information and instruction, the videotape presentation for this module illustrates the many types of deficiencies you may encounter at a dam, and the booklet merely summarizes the key points made in the videotape.

ABOUT THIS MODULE (Continued)

The videotape presentation describes deficiencies that may be found on the . . .

- Crest and slopes of embankment dams
- Crest, faces, and galleries of concrete dams
- Spillways and outlet works
- Mechanical equipment
- Abutments and reservoir rim
- Area downstream from the dam

This booklet summarizes the types of deficiencies described in the videotape presentation.

A hardhat symbol appears next to any deficiency you should report **immediately** to a qualified engineer or other appropriate authority.

☞ **You should watch the videotape presentation now. After watching the videotape presentation, review the remainder of this booklet.**

METHODS FOR SPOTTING DEFICIENCIES

HOW TO SPOT DEFICIENCIES

There are a number of methods or techniques that will enhance your ability to spot deficiencies at the dam.

On the crest of either an embankment or concrete dam . . .

- If you usually drive across the crest to get from one point to another, you might want to occasionally walk across, systematically looking for deficiencies that would otherwise go unnoticed.

- Misalignment may be detected by sighting along a linearity, such as guard rails, pavement stripes, parapet walls, or handrails.

Many of the deficiencies that may be found on the slopes of embankment dams are also found on the abutments and the area downstream. They may be detected . . .

- By walking the slopes, abutments, and area downstream in a systematic manner, keeping in mind sight distance limitations. If you are mowing grass on these areas, this is the perfect opportunity to look for deficiencies.

- By using binoculars to look at portions of embankments or abutments that are inaccessible (such as areas that are too steep to walk along safely).

Deficiencies on the faces of concrete dams may be detected . . .

- By viewing from the crest, the abutments, or from the area downstream. Binoculars will help you get a closer look.

- From a boat. If you have an opportunity to be on the reservoir or tailwater in a boat, glide along the upstream or downstream faces of the dam to get a closer look.

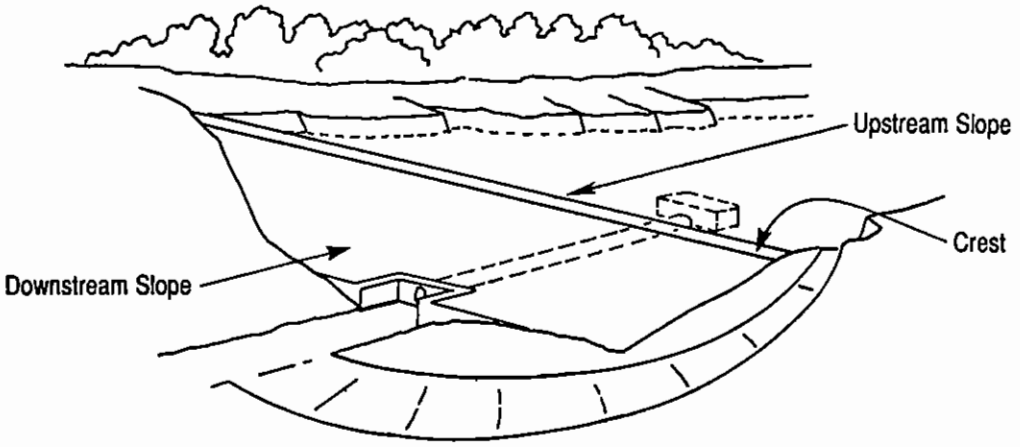
Depending on its size, the reservoir rim can be checked by using binoculars or viewing from a boat.

Spillways and outlet works can be examined by walking along or through them. Binoculars, again, are useful for observing distant features.

Scheduled operational testing of mechanical equipment, such as gates and valves, offers a good opportunity to look for deficiencies. You can check them visually, looking for missing, loose, or broken parts, and then operate the equipment to listen for signs of trouble such as straining motors or rough operation.

☞ Keep in mind that the level of the reservoir will have an effect on some deficiencies, such as seepage and leakage, and the performance of gates and valves. Note the level of the reservoir when you record a concern.

CHECKING AN EMBANKMENT DAM CREST AND SLOPES



On the crest of an embankment dam, look for . . .

- ✓ Misalignment
- ✓ Cracks

  If there are cracks . . .

  - Are any of these cracks new?
  - Have any old cracks increased in size?
  - Have any cracks led to erosion, gullies, or instability?
- ✓ Settlement
- ✓ Excessive or deep-rooted vegetation
- ✓ Animal burrows
- ✓ Damage to or displacement of survey markers or other instrumentation on or near the crest

On the slopes of an embankment dam, look for . . .

- ✓ Seepage or signs of seepage, such as lush vegetation

  If there is seepage . . .

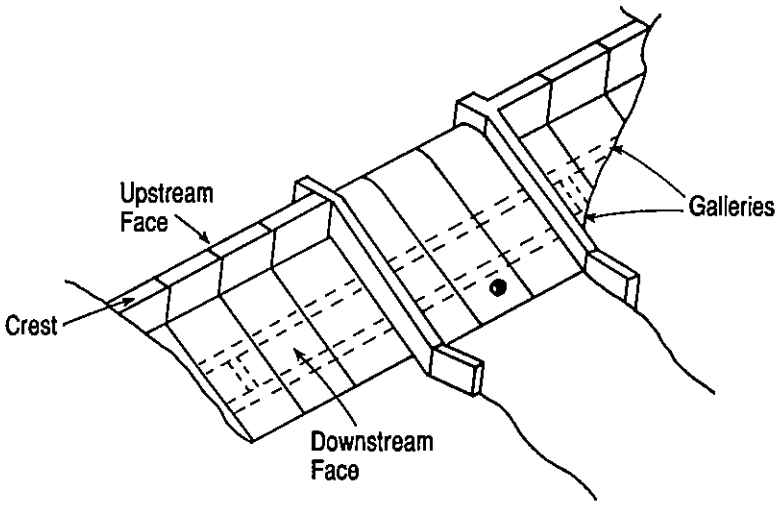
  - Is there new or increased flow?
  - Is the seepage cloudy (which may indicate that piping is taking place)?
- ✓ Slides, or signs of slides such as cracks, scarps, and/or bulges
- ✓ Bald spots or places where grass is sparse
- ✓ Excessive or deep-rooted vegetation
- ✓ Animal burrows
- ✓ Erosion gullies

Continued . . .

CHECKING AN EMBANKMENT DAM CREST AND SLOPES

- ✓ Riprap that is improperly sized (riprap that is too small for protection, that either has broken down or was too small to begin with)
- ✓ Areas of missing or damaged riprap
- ✓ Beaching
- ✓ Debris from slides blocking intake/outlet structures or damaging appurtenances
- ✓ Damage to or displacement of instrumentation such as survey markers, piezometer or inclinometer casings, weirs and flumes, etc.
- ✓ Cracks
- ✓ Depressions
- ✓ Sinkholes

CHECKING THE CREST, FACES, AND GALLERIES OF CONCRETE DAMS



On the crest of a concrete dam, look for . . .

- ✓ Cracks

  If there are cracks . . .

  - Are any of these cracks new?
  - Have any old cracks increased or decreased in size?

- ✓ Displacement along cracks or joints
- ✓ Cracks in the concrete around handrails or other embedded metalwork that may also indicate displacement
- ✓ Concrete deterioration, such as disintegration, spalling (slivers or slabs of concrete breaking away from the surface), popouts (small indentations left when portions of concrete break away from the surface), pitting (tiny cavities in the concrete), or scaling (flaking or peeling of the concrete or mortar)

On the faces of a concrete dam, look for . . .

- ✓ Leakage, or signs of leakage, such as water running from joints and/or cracks and/or lift lines, wetness, staining, vegetation, or efflorescence (the formation of whitish calcium deposits on the surface of the concrete as leakage evaporates)

  If there is leakage . . .

  - Is leakage occurring at new locations?
  - Is there an increase/decrease in the amount of flow in previous leakage areas?

- ✓ Cracks
- ✓ Concrete deterioration

Continued . . .

CHECKING THE CREST, FACES, AND GALLERIES OF CONCRETE DAMS

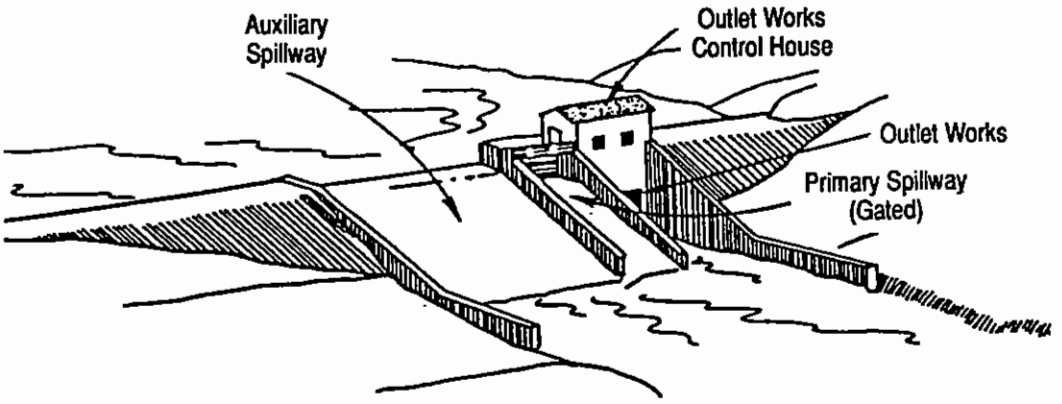
In the galleries of a concrete dam, look for . . .

- ✓ Cracks
- ✓ Concrete deterioration
- ✓ Leakage through cracks or joints
- ✓ Clogged drains

At a masonry dam, also look for . . .

- ✓ Deterioration of the mortar that joins the stone, brick, rock, or cement blocks
- ✓ Loosening and movement of the blocks
- ✓ Leakage along joints or between blocks

CHECKING THE SPILLWAYS AND OUTLET WORKS



The construction materials and configuration of spillways and outlet works may differ considerably from one dam to the next.

On earthen-lined channels (grass, riprap, or rock), look for . . .

- ✓ Erosion damage or bare spots in grass or riprap lining that expose the channel to erosion
- ✓ Deterioration or displacement of the riprap
- ✓ Slides or signs of slides that have, or could, block the channel
- ✓ Depressions
- ✓ Rock falls

On concrete spillways and outlet works, look for . . .

- ✓ Concrete deterioration
- ✓ Cavitation and erosion

Check wall and conduit joints for signs of . . .

- ✓ Displacement
- ✓ Separation
- ✓ Compression

Look behind channel walls for . . .

- ✓ Depressions
- ✓ Sinkholes

Check weepholes and drains to see if they have become clogged.

Continued . . .

CHECKING THE SPILLWAYS AND OUTLET WORKS

Look for obstructions in the flow path, specifically . . .

- ✓ Bushes, trees, or other vegetation
- ✓ Material from slides or rock falls or other debris
- ✓ Sediment

Look at trashracks if unwatered for . . .

- ✓ Debris blockage
- ✓ Damaged metalwork

Look at trash booms for . . .

- ✓ Waterlogged members
- ✓ Broken or missing parts
- ✓ Separated line

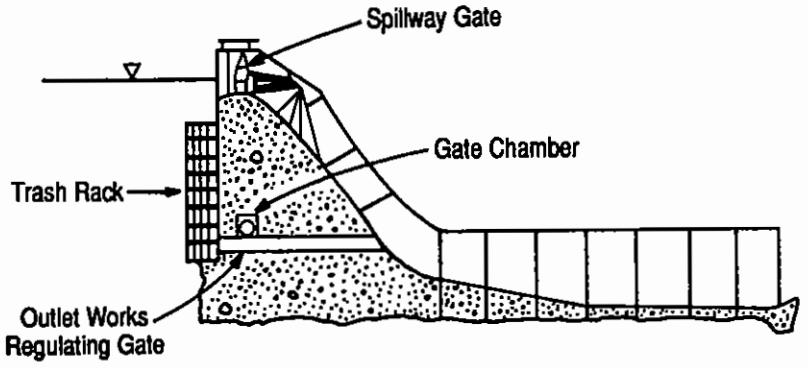
Examine metal components for . . .

- ✓ Corrosion
- ✓ Cavitation and erosion
- ✓ Scaling and flaking
- ✓ Loss of protective coatings
- ✓ Pitting

Check for seepage along conduits, especially at the downstream end.

Check for seepage flowing into the conduit, especially if it carries sediment.

CHECKING THE MECHANICAL EQUIPMENT



On gates and valves, look for surface damage, including . . .

- ✓ Cracks
- ✓ Broken welds
- ✓ Missing, broken, or loose parts
- ✓ Loss of protective coatings
- ✓ Corrosion and rusting of metal
- ✓ Cavitation

On the housing and frame, look for . . .

- ✓ Damage
- ✓ Bent members
- ✓ Misalignment
- ✓ Signs of deterioration of the seals
- ✓ Signs of binding on the seal plates (scrapes and gouges)

Check the operating systems for . . .

- ✓ Missing, broken, or loose parts
- ✓ Corrosion damage at hoisting connections
- ✓ Damaged stems and stem guides
- ✓ Oil leakage around stems
- ✓ Inadequate fluid levels or leakage of operating fluids

Continued . . .

CHECKING THE MECHANICAL EQUIPMENT

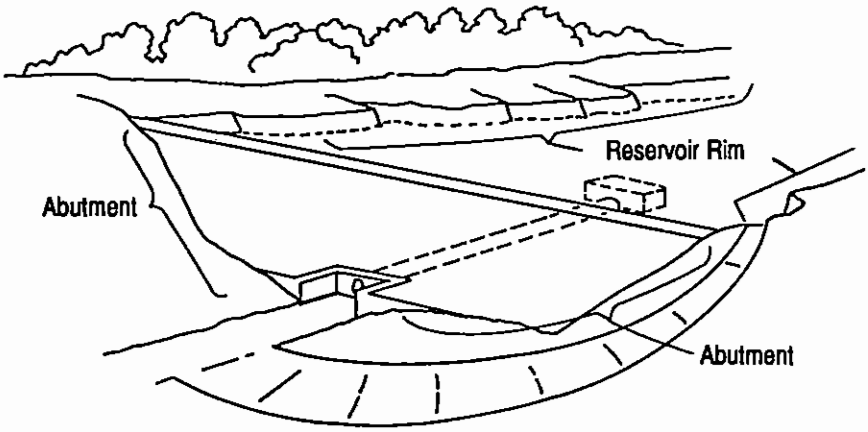
When operating gates and valves . . .

- ✓ Listen for signs of trouble, such as straining, unusual humming, or squealing motors
- ✓ Touch the motor to see if it is hot--a sign of overloading
- ✓ Look for rough or jerky operation, excessive vibration, or binding

Auxiliary power systems to be used in the event that primary power is lost should be test operated on a routine schedule according to the Standing Operating Procedures. The test operation should be conducted under both normal and simulated adverse conditions. When checking auxiliary power systems . . .

- ✓ See that the equipment that may need to be run on the backup system is operated, including a representative gate or valve on each appurtenance so equipped.
- ✓ If hand operation is considered the backup to primary power, verify the capability to open critical gates and valves in a timely manner.

CHECKING THE ABUTMENTS AND RESERVOIR RIM



On the abutments, look for . . .

- ✓ Seepage, or signs of seepage, such as lush vegetation or staining of rock

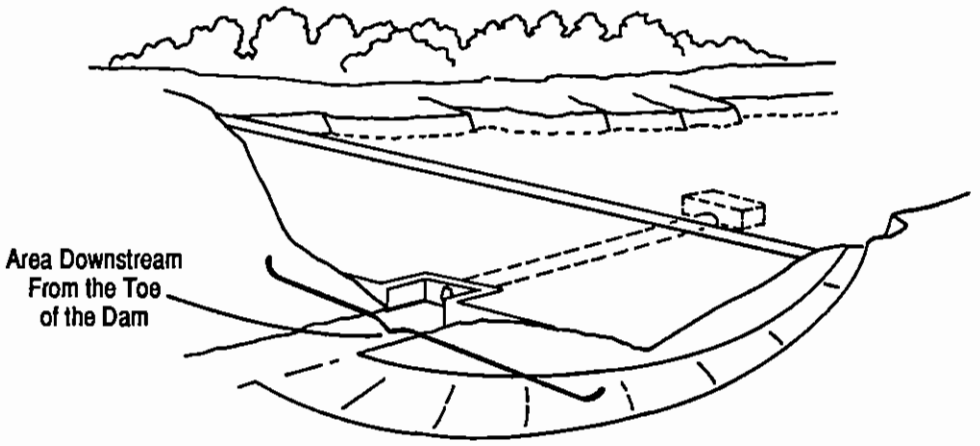
  If there is seepage . . .

  - Is seepage occurring at new locations?
  - Are there increases or decreases in the amount of flow in previous seepage areas?
  - Is the seepage cloudy (which may indicate that piping is taking place)?

On the abutments and reservoir rim, look for . . .

- ✓ Slides, or signs of slides, such as cracks, scarps, bulges, or leaning or pistol-handled trees
- ✓ Debris from slides entering the reservoir with the potential for blocking intakes of appurtenant structures or damaging appurtenances
- ✓ Depressions
- ✓ Sinkholes
- ✓ Deep-rooted vegetation near the dam
- ✓ Animal burrows near the dam
- ✓ Whirlpools

CHECKING THE AREA DOWNSTREAM FROM THE DAM



Along the area downstream from the toe of the dam, look for . . .

- ✓ New or increased seepage, or signs of seepage such as lush or water-loving vegetation (particularly in areas of sparse or no vegetation), or water flows

  If there is new or increased seepage . . .

  - Is the seepage cloudy (which may indicate that piping is taking place)?
  - Are there sand boils?

- ✓ Changes in controlled seepage (toe drains, relief wells)

  If there are changes in controlled seepage . . .

  - Is there an increase at the same reservoir level?
  - Is the seepage cloudy?

- ✓ Damage to or problems with seepage measurement devices, specifically . . .
  - ✓ Illegible staff gauges
  - ✓ Damage to or movement of staff gauges
  - ✓ Water bypassing the device
  - ✓ Debris blocking the flow of water
  - ✓ Sediment in the weir box
  - ✓ Weir edges that need to be cleaned
- ✓ Damage to instrumentation, such as piezometers and inclinometers

SUMMARY

REMEMBER . . .

You can play an important role in the dam safety process by . . .

- Properly operating and maintaining the dam according to Standing Operating Procedures and established dam safety regulations, and
- Taking the time to . . .
  - Observe conditions that are unusual or changing
  - Record your observations
  - Inform a facility engineer, dam safety inspection personnel, the owner, or other appropriate authorities of conditions that could indicate potential dam safety problems

GLOSSARY

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

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

CAVITATION - A process that damages concrete or metal by the formation of bubbles in a water flow, created when offsets or irregularities exist on a flow surface exposed to high velocities.

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

CONTROL EQUIPMENT - A general term for the system of gates and valves with which flows through an outlet works are regulated.

CREST - The top surface of the dam or high point of the spillway control section.

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

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

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

DIFFERENTIAL MOVEMENT - Localized movement of one section of a structure relative to adjacent sections.

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

DOWNSTREAM SLOPE - The inclined surface of an embankment dam that faces away from the reservoir.

EFFLORESCENCE - A deposit of salts that is leached from within the concrete and deposited on the surface.

EMBANKMENT DAM - Any dam constructed of excavated natural materials (includes both earthfill and rockfill dams).

ENTRANCE CHANNEL - A structure that conveys water to the control section of the spillway or to the intake structure of the outlet works.

GLOSSARY

FLUME - A constricted channel of specific dimensions in which water is accelerated for the purpose of measuring water flow.

GALLERY - A passageway in the body of a dam used for inspection, operation, foundation grouting, and/or drainage. Galleries may run longitudinally or transversely, horizontally or on a slope.

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

INCLINOMETER (INCLOMETER) - An instrument usually consisting of a metal or plastic tube inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within the tube. This monitor measures (at different points) the tube's inclination to the vertical. The device may be used to measure slope or settlement.

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

JOINTS - (1) **CONSTRUCTION JOINT** - The interface between two successive placings of concrete where bond is intended. (2) **CONTRACTION JOINT** - Joints between concrete blocks that are designed to prevent the formation of tension cracks as the structure undergoes volumetric shrinkage due to temperature drop. Contraction joints are vertical and run transversely through the dam, from the foundation to the crest. (3) **EXPANSION JOINTS** - Joints placed in a concrete structure primarily to accommodate volumetric expansion due to temperature rise.

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

MASONRY DAM - A dam constructed mainly of stone, brick, or concrete jointed with mortar.

MISALIGNMENT - The movement of a structure from its design location.

OUTLET - An opening through which water can be discharged.

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

PIEZOMETER - An instrument used for measuring water pressure within soil, rock, or concrete.

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

GLOSSARY

PITTING - Development of relatively small cavities in the concrete surface.

POPOUT - A small portion of concrete surface that breaks away, due to internal pressure, leaving a shallow, conical depression.

RESERVOIR - The body of water impounded by a dam.

RESERVOIR RIM - The boundary of the reservoir including all areas along the valley sides above and below the water surface.

RETURN CHANNEL - A structure that conveys spillway and outlet works discharges to the natural stream channel downstream of the dam structure.

RIPRAP - (1) Broken rock or boulders placed on upstream and downstream slopes of embankment dams to provide protection from erosion. (2) Broken rock or boulders placed on floors and slopes of channels and pools to provide protection from erosion.

SAND BOIL - A condition resulting from the upward flow of seepage under pressure and characterized by a boiling action of the surface seepage. Often accompanied by a cone of material around the boil which develops from the deposition of foundation or embankment material carried by the seepage.

SCALING - Flaking or peeling away of the surface of concrete or mortar.

SCARP - An over-steepened surface on a slope resulting from instability or erosion. A scarp consists of a relatively flat area with a steep back slope.

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

SETTLEMENT - The vertical downward movement of a structure.

SINKHOLE - A depression resulting from loss of material underlying the surface.

SLIDE - The unplanned descent of a mass of earth or rock down a slope.

SPALLING - The loss of chunks of concrete from a surface, usually because of compression, impact, or abrasion.

SPILLWAY - A structure that passes normal and/or flood flows in a manner that protects the structural integrity of the dam.

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

TOE DRAIN - A seepage control drain located along or beneath the toe that carries internal seepage water away from the dam.

GLOSSARY

TOE OF DAM - The junction of the downstream slope of a dam with the ground surface; also referred to as the **downstream toe.** For an embankment dam, the junction of the upstream face with the ground surface is called the **upstream toe.**

TRASH BOOM - A floating structure that provides a barrier to catch debris and prevent it from entering a spillway.

TRASHRACK - A structure of metal or reinforced concrete bars located at the intake of a waterway to prevent entrance of floating or submerged debris above a certain size.

UPSTREAM FACE - The vertical or near-vertical surface of a concrete dam that is in contact with the reservoir.

UPSTREAM SLOPE - The vertical or near-vertical surface of an embankment dam that is in contact with the reservoir.

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

WEEPHOLE - A drain embedded in a concrete or masonry structure to pass moisture from the foundation material to the surface of the structure.

WEIR - A structure of given shape and dimensions built across a stream or channel to control or measure flow quantities.