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# Pocket Safety Guide for Dams and Impoundments

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**Inside Front Cover**

# Pocket Safety Guide for Dams and Impoundments

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# Contents

## Introduction

This "Pocket Safety Guide for Dams and Impoundments" was developed for dam owners and other people as a quick reference when assessing low hazard dams and impoundments. For indepth discussion, please refer to the U.S. Fish and Wildlife Service "Low Hazard Dams—Standing Operating Procedures" or FEMA 145, "Dam Safety: An Owner's Guidance Manual."

**Dam—**Any artificial barrier, including appurtenant works, that impounds or diverts water on a temporary or long-term basis. For the purposes of this guide, when we refer to dams, we also are referring to impoundments.

**Hazard potential classification—**A system that categorizes dams according to the degree of adverse incremental consequences from their failure or misoperation, that does not reflect in any way on their current condition (their safety, structural integrity, or flood routing capacity), and that includes the following categories:

- **High hazard potential—**loss of one human life is likely if the dam fails.
- **Significant hazard potential—**possible loss of human life and likely significant property or environmental destruction.
- **Low hazard potential—**no probable loss of human life and low economic and/or environmental losses.

Various Federal and State agencies may have different definitions for the dams over which they have jurisdiction. Please refer to your agency or State dam regulatory requirements for direction.

## Responsibilities and Liability

The two types of dam structures on national forests are:

- Operated and owned by the Forest Service
- Operated and owned by the holder of a Special Use Authorization

The owner is responsible for the operation and maintenance of a safe dam. Maintaining a dam safely is a key element in preventing failure and limiting the liability that an owner could face. The extent of an owner's liability varies from State to State and depends on statutes and case law precedents.

Owners can be liable for any failure of a dam and all damages resulting from its failure. Any uncontrolled release of the reservoir resulting from a dam failure can have a devastating effect on persons and property downstream.

This guide is designed for a wide audience. The recommended action taken by individuals will be determined by their expertise with dam maintenance. Inexperienced individuals should photograph suspected problem(s) and report to the owner who is responsible for the dam.

When you become aware of any unusual conditions that seem critical or dangerous to a dam, report them immediately to the appropriate Federal or State agency official. You may need to contact a professional engineer in dam safety to address the conditions.

## Dam Diagram

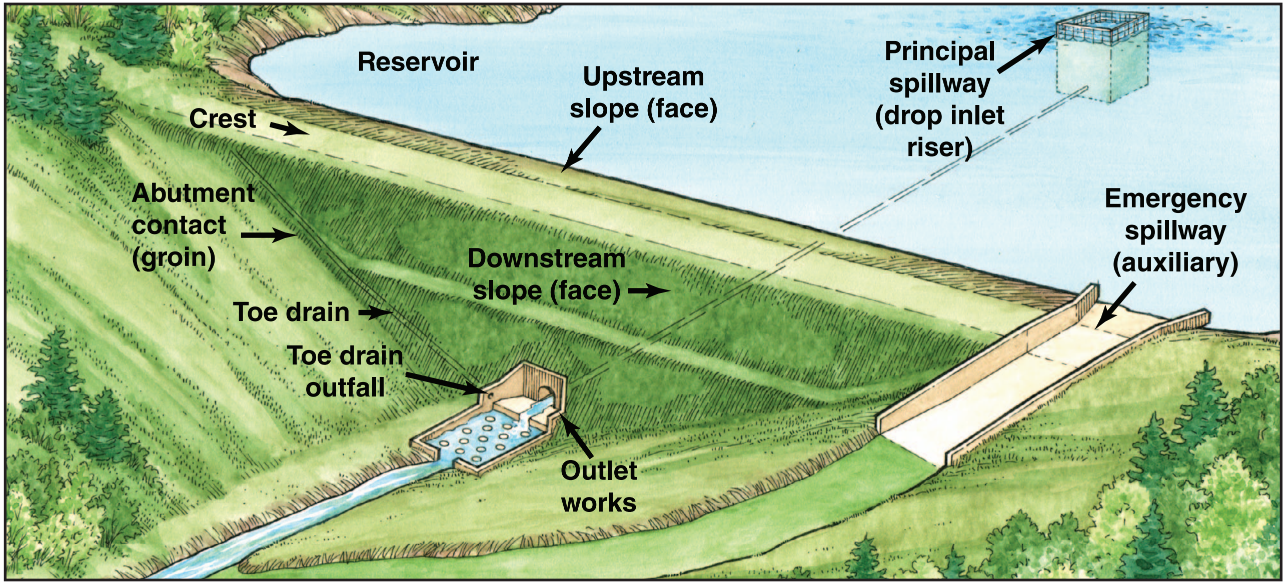


Figure 1—Typical dam diagram showing common terms.

## Possible Dam Failures

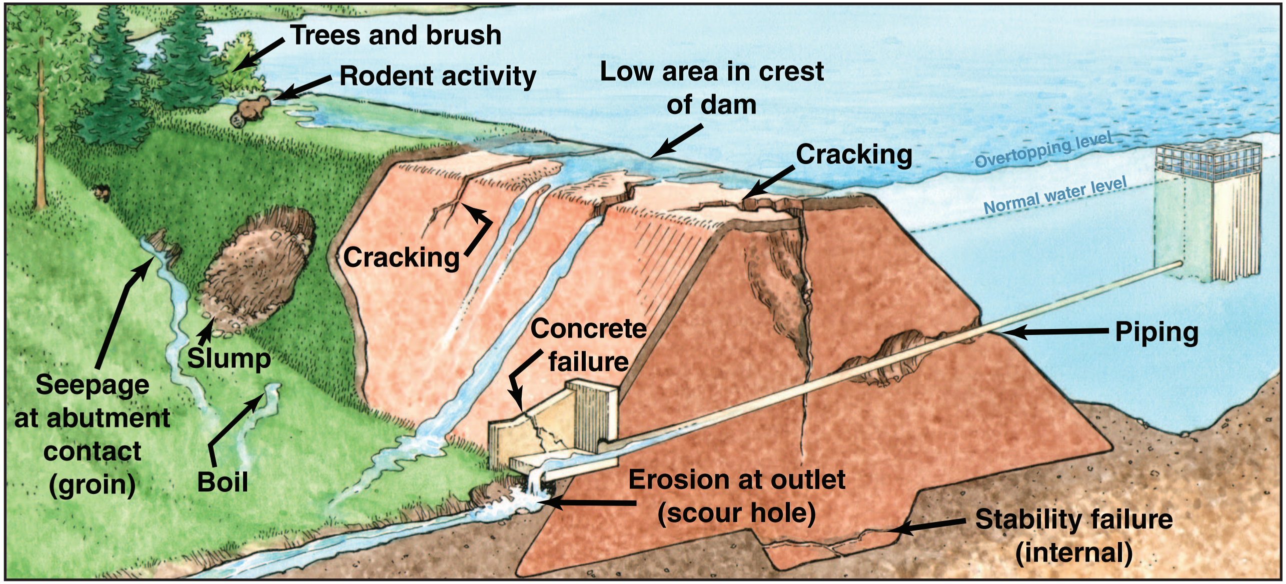


Figure 2—Some causes of dam failures.

# Outlet Structures

## *Gate Valve*

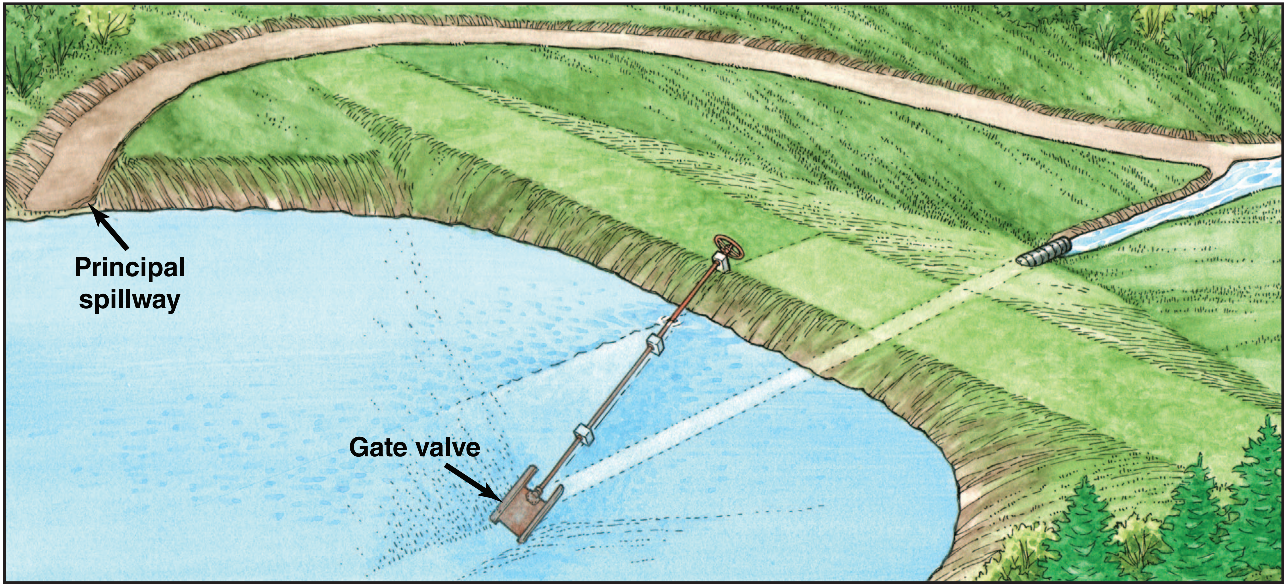


Figure 3—Typical gate valve used with a principal spillway to control water level.

## *Drop Inlet Riser*

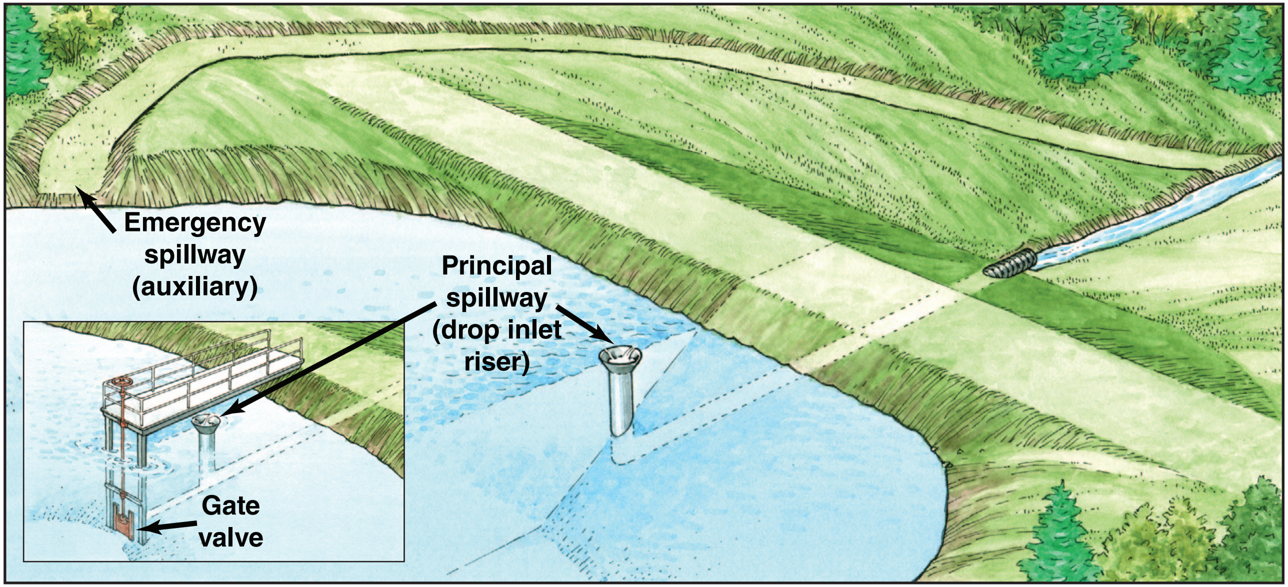


Figure 4—Typical drop inlet riser serving as a principal spillway to control water level.

# Dam Problems

## *Sinkholes*

### Probable Causes and Possible Consequences

- Internal erosion of embankment materials or the foundation (piping) can cause a sinkhole.
- An eroded cavern (cave-in) can result in a sinkhole.
- A small hole in the wall of an outlet pipe can develop into a sinkhole.
- Water with sediment at the exit indicates erosion of the dam.
- Piping can empty a reservoir through a small hole in the wall. It also can lead to dam failure as soil pipes develop and erode through the foundation or a pervious part of the dam.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Inspect other parts of the dam that may be susceptible to seepage or more sinkholes.
- Check seepage and leakage outflows for muddy water.
- Have a qualified engineer inspect the conditions, identify the exact cause of sinkholes, and recommend further actions.
- Depending on the location of the sinkhole in the embankment, have the reservoir drawn down as necessary.

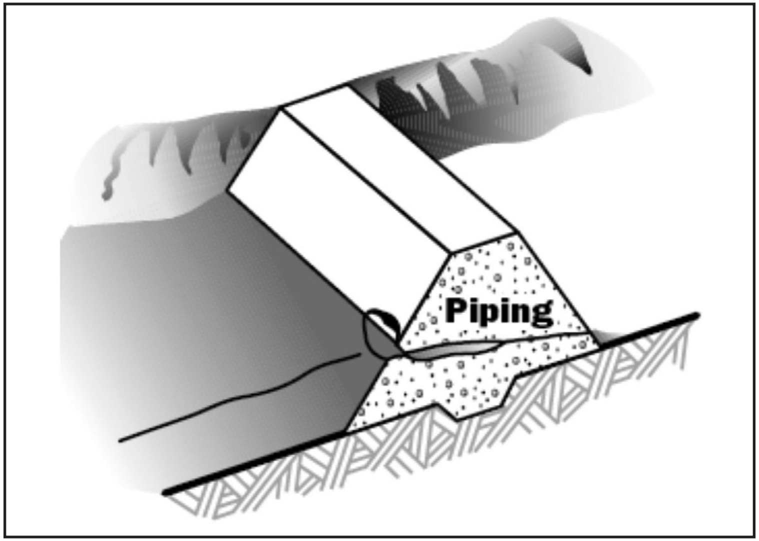


Figure 5—Sinkholes.

Figure 6—Whirlpool action is an indication of advanced piping.

## *Slide, Slump, or Slip*

### Probable Causes and Possible Consequences

- Foundation movement or a too steep slope can cause earth or rocks to move along a slip plane which can lead to a slump of the embankment.
- Slide movements in the reservoir basin can lead to inlet obstruction or dam failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Evaluate the extent of the slide.
- Monitor the slide.
- Draw down the reservoir level if the safety of the dam is threatened.
- Have a qualified engineer inspect the conditions and recommend further actions.

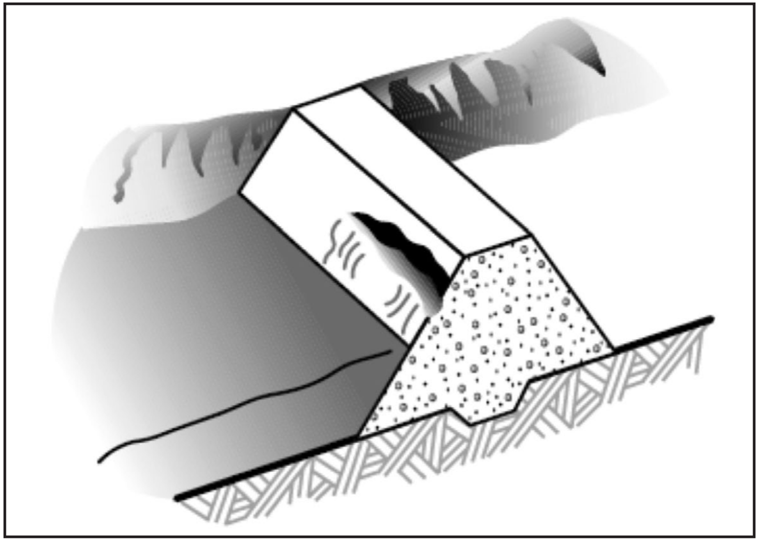

Figure 7—Slide, slump, or slip.

Figure 8—Slumping on the downstream face of a dam.

## *Broken Down or Missing Riprap*

### Probable Causes and Possible Consequences

- Poor-quality riprap deteriorates and does not protect the slope.
- Wave or ice action can displace riprap allowing erosion of the bank.
- Similar-sized round rocks may roll downhill and expose the slope.
- Wave action against these unprotected areas decreases the embankment width.

### Recommended Action

- Reestablish the normal slope.
- Place bedding material and properly sized riprap to protect against wave action.

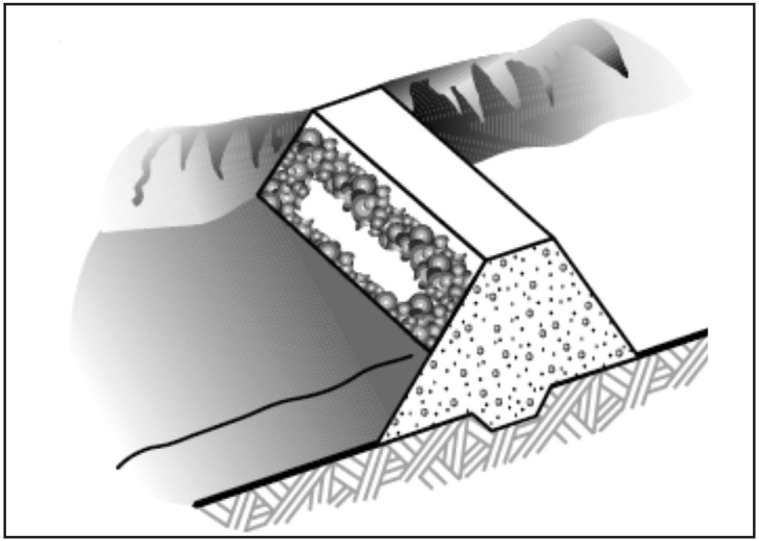

Figure 9—Broken down or missing riprap.

Figure 10—Wave erosion on the unprotected face of a dam.

# *Erosion*

## Probable Causes and Possible Consequences

- Water from intense rainstorms or snowmelt carries surface materials down the slope and results in continuous troughs, which can be hazardous if allowed to continue.
- Erosion can lead to deterioration of the downstream slope and failure of the structure.

## Recommended Action

- If erosion is detected early, add protective grasses that may resolve the problem.
- Protect eroded areas; add rock or riprap, which is the preferred method.

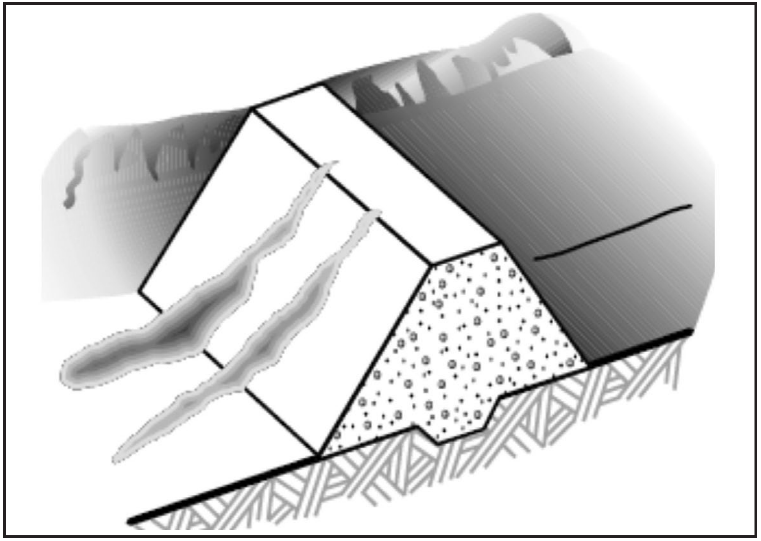

Figure 11—Erosion.

Figure 12—Erosion on the downstream face of a dam.

## *Trees or Obscuring Vegetation*

### Probable Causes and Possible Consequences

- Natural vegetation (bushes) obscures visual inspection and harbors rodents.
- Large tree roots can create seepage paths.
- Large trees can blow over during a storm and damage the dam, which may cause a breach.

### Recommended Action

- Control vegetation that obscures visual inspection of the embankment.
- Remove all large, deep-rooted trees and shrubs on or near the embankment.
- Backfill voids properly.
- Remove trees at the toe of the dam to provide a 25-foot buffer.

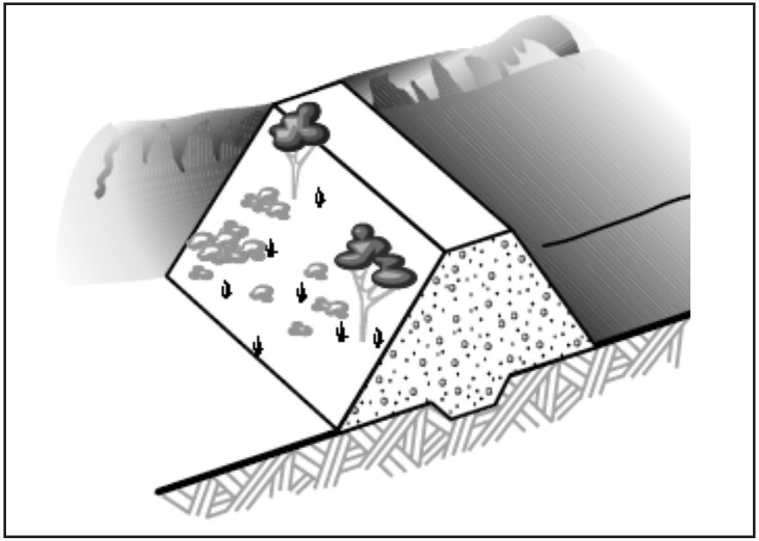

Figure 13—Trees or obscuring vegetation.

Figure 14—Trees growing on the crest and the faces of a dam.

## *Rodent Activity and Animal Impact*

### Probable Causes and Possible Consequences

- Cattail-filled areas and areas where trees are close to the reservoir provide ideal habitat and foraging areas for animals.
- An overabundance of rodents increases the chance of animal burrowing, which creates holes, tunnels, and caverns.
- Tunnels may reduce the required length of the seepage path, which could cause a piping problem.
- Tunnels can lead to the collapse of the dam crest and may cause dam failure.

### Recommended Action

- Start a rodent control program to reduce the population and prevent future damage to the dam.
- Determine the exact location and extent of tunneling.
- Backfill existing rodent holes with suitable well-compacted material to repair damages.

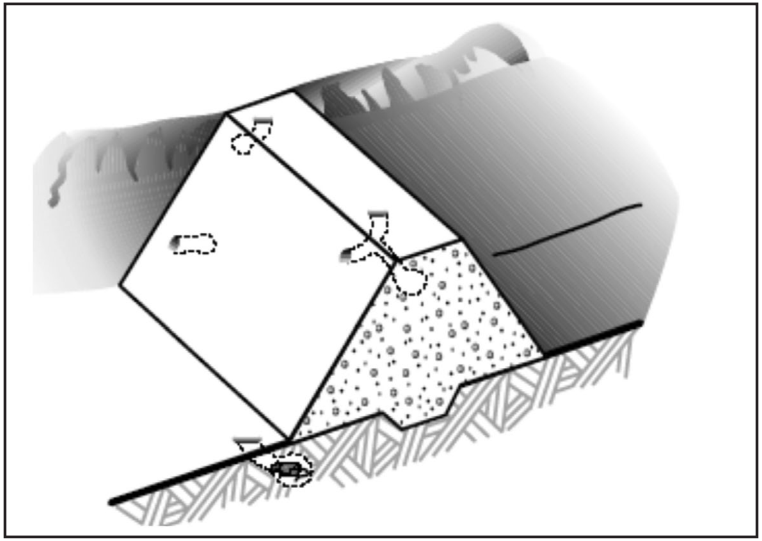

Figure 15—Rodent activity

Figure 16—Rodent holes in the dam face can cause dam failure.

## *Livestock and Cattle Traffic*

### Probable Causes and Possible Consequences

- Livestock paths and activities on the downstream dam face can damage slopes, especially when wet.
- Livestock activities may reduce erosion protection and cause erosion channels.
- Bare areas may allow water to stand and be susceptible to drying cracks.

### Recommended Action

- Fence the embankment area to keep out livestock.
- Repair erosion protection by reestablishing grasses or by placing riprap.

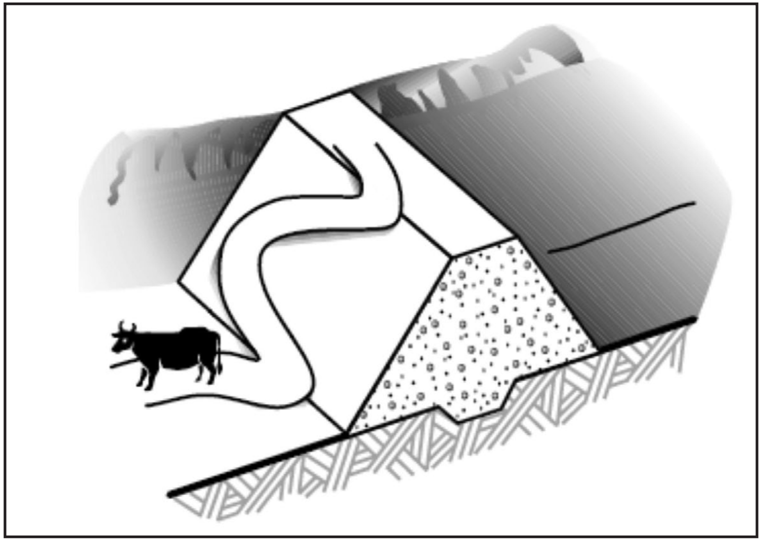

Figure 17—Livestock and cattle traffic.

Figure 18—Livestock paths on dam faces can lead to dam erosion.

## *Transverse Cracking*

### Probable Causes and Possible Consequences

- Uneven movement between adjacent segments of the embankment may cause transverse cracking.
- Deformation caused by structural stress or instability may provide a path for seepage through the embankment cross section.
- If not corrected, cracking creates an area of low strength within the embankment that may lead to future structural movement, deformation, or failure.
- Cracks create a point for water to enter the embankment. Saturation of the adjacent embankment area may occur and could lead to localized failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Inspect the crack and carefully record its location, length, depth, width, and other pertinent physical features. Stake out the crack limits.
- Have a qualified engineer determine the cause of cracking and supervise all steps necessary to reduce danger to the dam and correct the condition.
- Excavate the crest along the crack to a point below the bottom of the crack. Backfill the excavation using suitable material and correct construction techniques. This seals the cracks at the crest surface to prevent surface water infiltration. Monitor the crest routinely for evidence of future cracking.

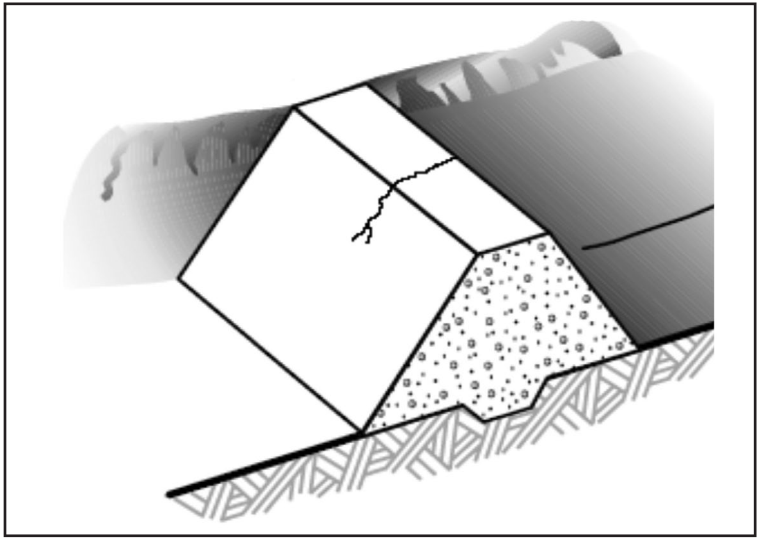

Figure 19—Transverse cracking.

Figure 20—Transverse cracks can be an indication of dam instability.

## *Longitudinal Cracking*

### Probable Causes and Possible Consequences

- Uneven settlement between adjacent sections or zones within the embankment may cause longitudinal cracking.
- Foundation failure causes loss of embankment support, which can result in embankment slide.
- Settlement creates an area of low strength within an embankment, which may lead to future structural movement, deformation, or failure.
- Cracks create a point for water to enter the embankment. Saturation of the adjacent embankment area may occur and could lead to localized failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Inspect the crack and carefully record the location, length, depth, width, alignment, and other pertinent physical features. Immediately stake out the crack limits and monitor frequently.
- Have a qualified engineer determine the cause of cracking and supervise the steps necessary to reduce danger to the dam and correct the condition.
- Effectively seal the cracks at the crest surface to prevent surface water infiltration.
- Monitor the crest routinely for evidence of further cracking.

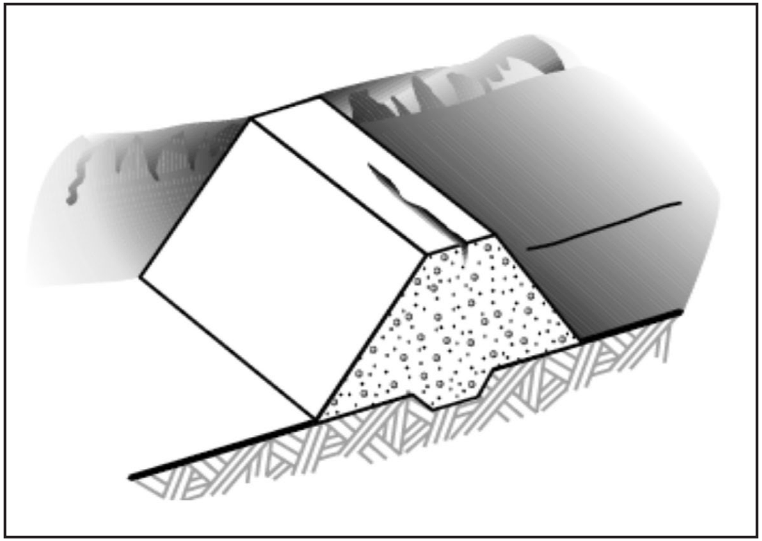

Figure 21—Longitudinal crack.

Figure 22—Longitudinal cracks can be an indication of dam instability.

# *Low Area in the Crest of a Dam*

## Probable Causes and Possible Consequences

- Excessive settlement of the embankment or internal erosion of embankment material may cause a depression on the top of a dam.
- Foundation spreading upstream and/or downstream, prolonged wind erosion, or improper final grading following construction may cause a low area in the crest of a dam.
- Low areas can reduce the freeboard available to pass flood flows safely through the spillway.

## Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Establish survey monuments along the length of the crest to determine the exact amount, location, and extent of settlement in the crest.
- Have a qualified engineer determine the cause of the low area and supervise all necessary steps to reduce any threat to the dam and correct the condition.
- Use proper construction techniques to fill in the low area and reestablish a uniform elevation over the length of the crest.
- Reestablish and routinely monitor survey monuments to detect any settlement across the crest of the dam.

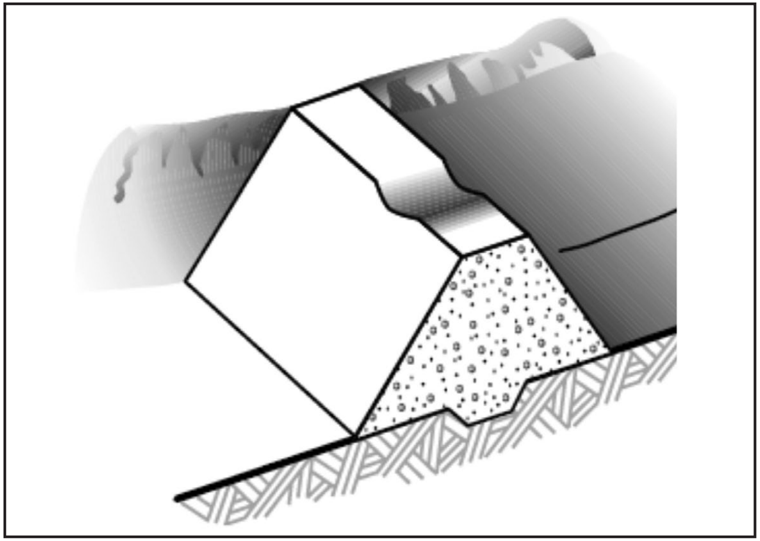

Figure 23—Low area in the crest of a dam.

Figure 24—Low areas in the crest of a dam reduce the freeboard.

## Excessive Quantity and/or Muddy Water Exiting From a Point

### Probable Causes and Possible Consequences

- Water has created an open pathway, channel, or pipe through the dam. The water is eroding and carrying embankment material.
- Surface agitation of water and embankment materials exiting at one point may cause muddy water.
- Rodents, frost action, or poor construction may allow water to create an open pathway or pipe through the embankment.
- Continued flows can saturate parts of the embankment and lead to slides in the area.
- Continued flows can further erode embankment materials and lead to dam failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Begin measuring outflow quantity. Determine whether water is getting muddier, staying the same, or clearing up.
- Have a qualified engineer inspect the condition and recommend further actions.
- If the quantity of flow is increasing, lower the water level in the reservoir until the flow stabilizes or stops.
- Search for an opening on the upstream side of the dam. Plug it if possible.

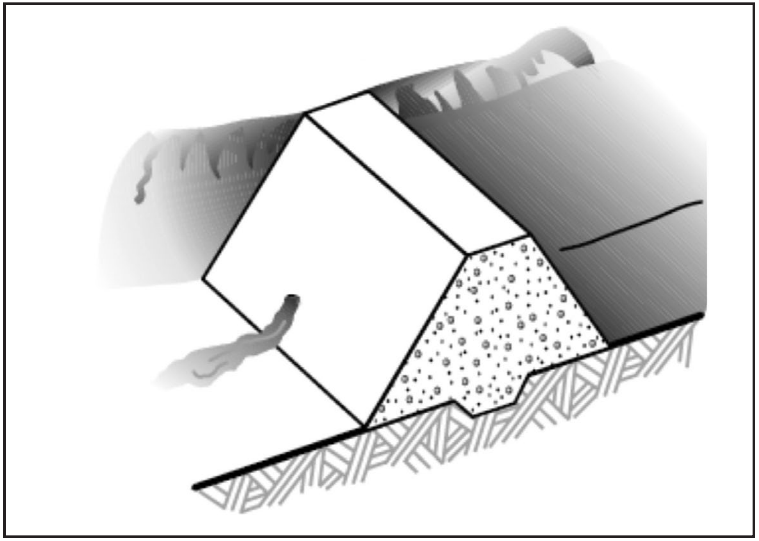

Figure 25—Excessive quantity and/or muddy water exiting from a point.

Figure 26—Excessive water piping through the dam at the toe of the embankment.

## *Seepage Water Exiting as a Boil in the Foundation*

### Probable Causes and Possible Consequences

- Some part of the foundation material is supplying a flow path. This could be caused by a sand or gravel layer in the foundation.
- Increased flows can lead to erosion of the foundation and dam failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Examine the boil to see if foundation materials are being transported.
- Have a qualified engineer inspect the condition and recommend further actions.
- If soil particles are moving downstream, use sandbags or earth to create a dike around the boil. The pressures created by the water level may control flow velocities and temporarily prevent further erosion.
- If erosion is increasing, the reservoir level should be lowered.

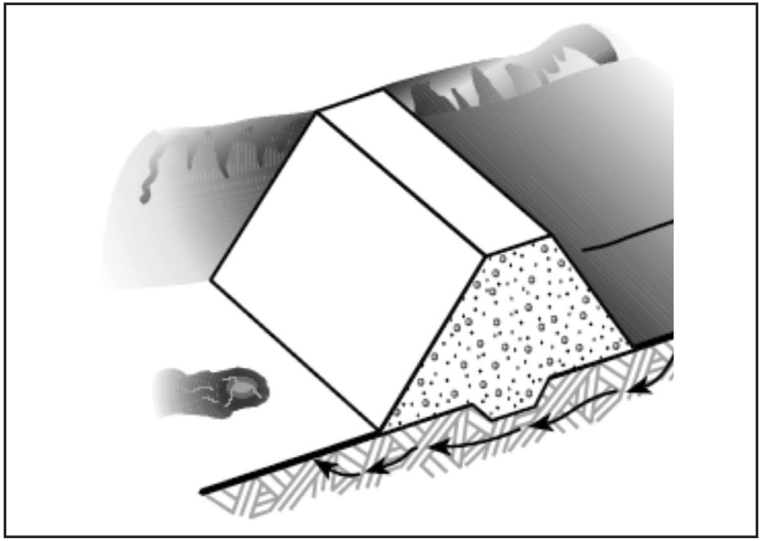

Figure 27—Seepage water exiting as a boil in the foundation.

Figure 28— Sandbags surrounding a boil on the downstream side of the dam.

## Seepage Water Exiting at the Abutment Contact

### Probable Causes and Possible Consequences

- Water flowing through pathways in the abutment or through the embankment can cause seepage.
- Seepage can lead to erosion of the embankment material and dam failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Study the leakage area to determine the quantity of flow and extent of saturation.
- Inspect for developing slides daily.
- Have a qualified engineer inspect the condition and recommend further actions.
- To ensure embankment safety, water level in the reservoir may need to be lowered.

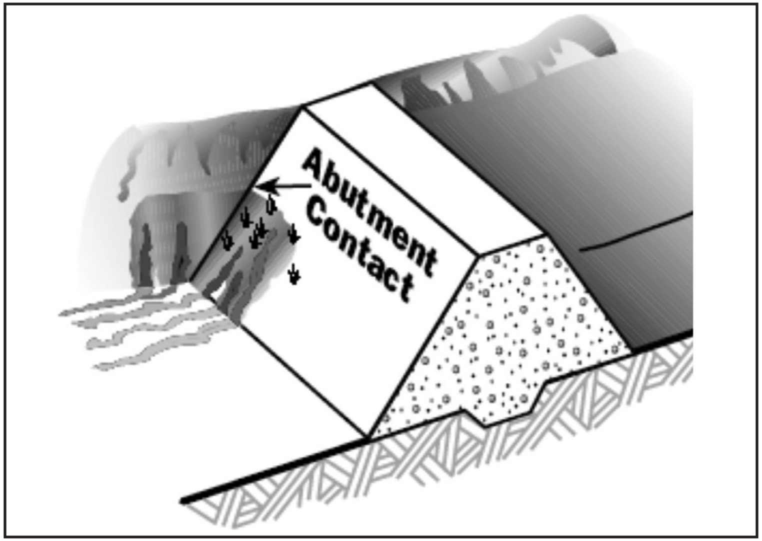


Figure 29—Seepage exiting at the abutment contact (groin).


Figure 30—Seepage at the abutment contact (groin) can lead to dam failure.

## *Seepage Water Exiting From a Point Adjacent to the Outlet Pipe*

### Probable Causes and Possible Consequences

- A break or hole in the outlet pipe or poor compaction around the pipe allows water to flow and creates a pathway along the outside of the outlet pipe.
- Continued flows can lead to embankment material erosion and dam failure.

### Recommended Action

*Report the suspected problem to the appropriate Federal or State agency official immediately.*

- Thoroughly investigate the area by probing and/or shoveling to determine cause.
- Determine if seepage is carrying soil particles (muddy water).
- Determine quantity of flow.
- Have a qualified engineer inspect the condition and recommend further actions.
- If flow increases or is carrying embankment material, the reservoir level should be lowered until leakage stops.
- Investigate the embankment along the alignment of the spillway pipe if there are any signs of settlement or sinkholes.

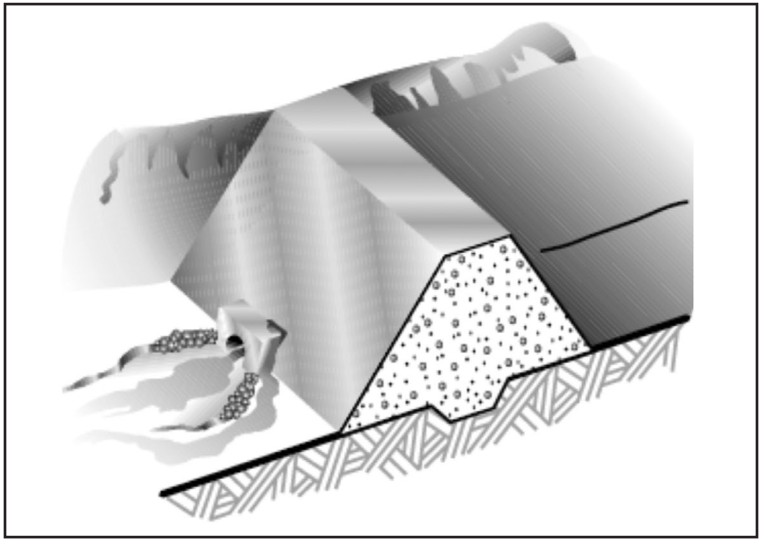

Figure 31—Seepage water exiting from a point adjacent to the outlet pipe.

Figure 32—Piping of water alongside an outlet pipe.

## *Failure of Concrete or Rock Outfall Structures*

### Probable Causes and Possible Consequences

- Excessive side pressures on a nonreinforced concrete structure or poor concrete quality can cause failure of the outfall structure.
- Too steep of a slope can cause rocks to roll down the hill and partially block the outlet.
- The embankment may be exposed to erosion by outlet releases because of loss of an outfall structure.

### Recommended Action

- Monitor a typical dimension (such as “D” shown in figure 33) to check for progressive failure.
- Repair by patching cracks and supplying drainage around the concrete structure. The entire outfall structure may need to be replaced.
- Repair the slopes and place riprap to stabilize them.

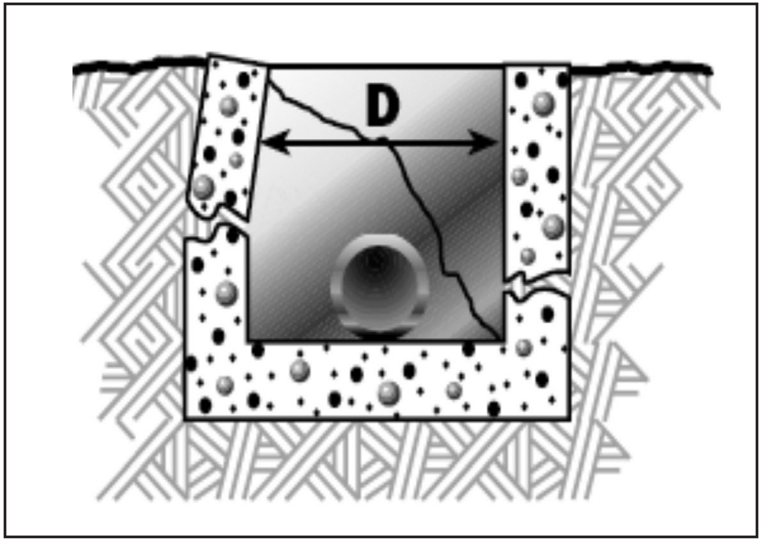


Figure 33—Failure of a concrete outfall structure.

Figure 34—Rock failure around an outlet pipe.

## Outlet Releases Eroding the Toe of the Dam

### Probable Causes and Possible Consequences

- The outlet pipe may be too short and cause a scour hole.
- No energy-dissipating pool or structure at the downstream end of the conduit can cause a scour hole.
- Erosion of the toe of the dam makes the downstream slope too steep and causes progressive sloughing.

### Recommended Action

- Extend the outlet pipe beyond the toe (use the same size of pipe and material). Form a watertight connection to the existing conduit.
- Stabilize the slope.
- Use riprap over suitable bedding to protect the embankment.

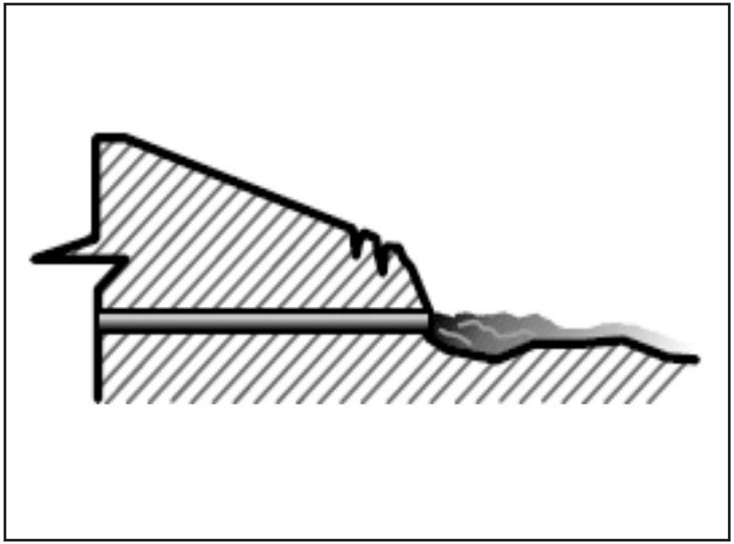

Figure 35—Outlet releases erode the toe of the dam.

Figure 36—A scour hole at an outlet erodes the toe of the slope.

## *Excessive Vegetation or Debris in the Spillway Channel or Around the Inlet*

### Probable Causes and Possible Consequences

- An accumulation of slide materials, dead trees, excessive vegetative growth, etc., in the spillway channel can reduce waterway capacity.
- Reduced discharge capacity may cause the spillway to overflow and the dam to overtop. Prolonged overtopping can cause dam failure.

### Recommended Action

- Clean out debris periodically and control vegetative growth in the spillway channel.
- Install a log boom in front of the spillway entrance to intercept debris.

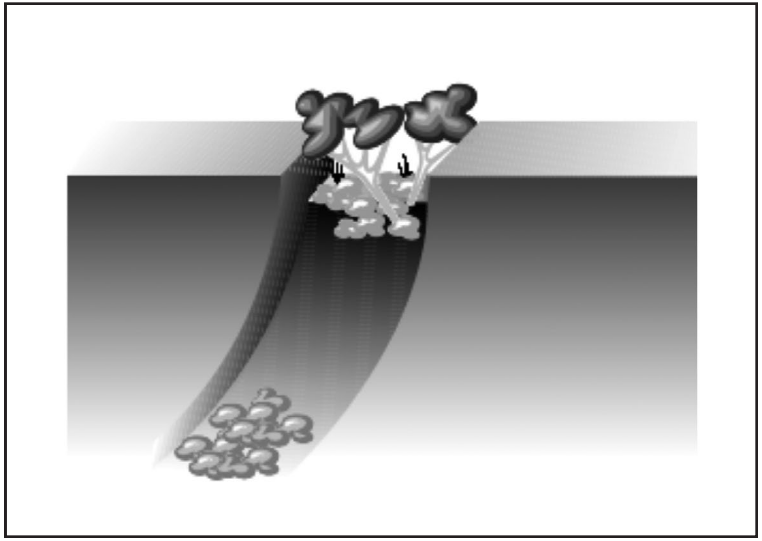

Figure 37—Excessive vegetation or debris in a spillway channel.

Figure 38—A blocked spillway channel may cause overtopping of the dam.

## *Erosion of Spillway Channels*

### Probable Causes and Possible Consequences

- Surface runoff from intense rainstorms or flow from the spillway carries surface material down the spillway causing continuous troughs.
- Livestock traffic creates gullies where runoff flow can concentrate.
- Unabated erosion can lead to slides, slumps, or slips, which can result in reduced spillway capacity. Inadequate spillway capacity can lead to embankment overtopping and result in dam failure.

### Recommended Action

- Photograph the condition and bring it to the attention of the engineer.
- Replace eroded material with compacted fill to repair damaged areas.
- Revegetate the areas if appropriate.
- Install suitable rock riprap to protect against future erosion.

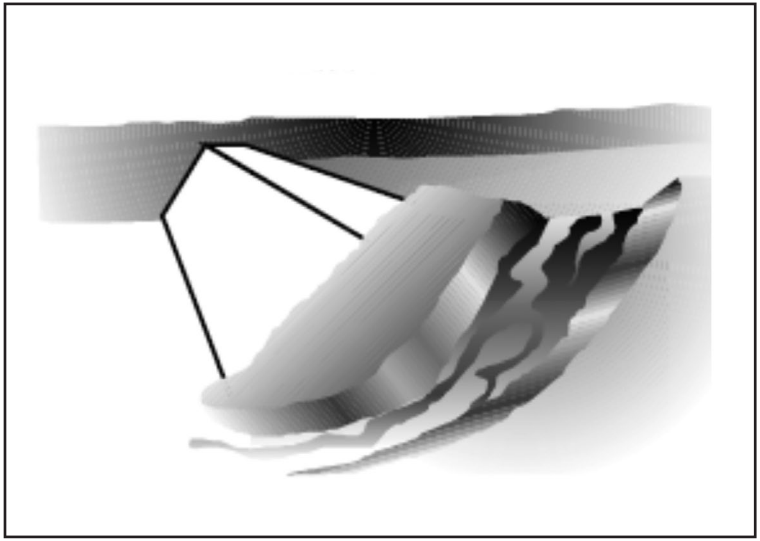

Figure 39—Erosion channels.

Figure 40—Erosion of the spillway channel may lead to slumps or slides of the spillway sides.

## Resources

Dam Operation, Maintenance, and Inspection Manual, 1985, revised 2007. North Carolina Department of Environmental and Natural Resources, Division of Land Resources, Land Quality Section.

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Safety Evaluation of Existing Dams: A Manual for the Safety Evaluation of Embankment and Concrete Dams,1992. U.S. Department of the Interior, Bureau of Reclamation (BOR). Denver, CO.

Training Aids for Dam Safety, Module: Evaluation of Seepage Conditions, 1990. David E. Wright, John M. Cyganiewicz, Charles H. McElroy, and Robert L. James. U.S. Department of the Interior, Bureau of Reclamation. Denver, CO.

## Web Sites

Association of State Dam Safety Officials

<http://www.damsafety.org/>

Bureau of Reclamation Training

<http://www.usbr.gov/ssle/damsafety/traininglinks.html>

Federal Emergency Management Agency

<http://www.fema.gov/plan/prevent/damfailure/publications.shtm>

FEMA Training Aids for Dam Safety (TADS): A Self-Instructional Study Course in Dam Safety Practices

<http://www.fema.gov/library/viewRecord.do?id=3308>

Technical Service Center Resources for Dam Safety Programs

<http://www.usbr.gov/pmts/tech_services/damsafety/index.html>

## Useful Terms

**Abutment—**That part of the valley side against which the dam is constructed. An artificial abutment is sometimes constructed, as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment. The left and right abutments of dams are defined with the observer viewing the dam looking in the downstream direction, unless otherwise indicated.

**Appurtenant structure—**Ancillary features of a dam, such as outlets, spillways, powerplants, tunnels, etc.

**Berm—**A nearly horizontal step in the sloping profile of an embankment dam. Also a step in a rock or earth cut.

**Breach—**An opening through a dam that allows the uncontrolled draining of a reservoir. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening caused by discharge from the reservoir. A breach is generally associated with the partial or total failure of the dam.

**Channel—**A general term for any natural or artificial facility for conveying water.

**Conduit—**A closed channel to convey water through, around, or under a dam.

**Core wall—**A wall built of relatively impervious material, usually of concrete or asphaltic concrete, in the body of an embankment dam to prevent seepage.

**Crest length—**The measured length of the dam along the crest or top of dam.

**Crest of dam**—See "Top of dam."

**Cross section**—An elevation view of a dam formed by passing a plane through the dam perpendicular to the axis.

**Cutoff wall**—A wall of impervious material usually of concrete, asphaltic concrete, or steel sheet piling constructed in the foundation and abutments to reduce seepage beneath and adjacent to the dam.

**Dam**—Any artificial barrier, including appurtenant works, that impounds or diverts water either temporarily or long term.

**Dam failure**—Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water or the likelihood of uncontrolled release. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water is properly considered a failure. These lesser degrees of failure can progressively lead to or heighten the risk of a catastrophic failure. They are, however, normally amenable to corrective action.

**Drain, toe**—A system of pipe and/or pervious material along the downstream toe of a dam used to collect seepage from the foundation and embankment and convey it to a free outlet.

**Drainage area**—The area that drains to a particular point on a river or stream.

**Embankment dam**—Any dam constructed of excavated natural materials, such as both earthfill and rockfill dams, or of industrial waste materials, such as a tailings dam.

**Face**—The external surface of a structure (e.g., the surface of a wall of a dam).

**Filter (filter zone)**—One or more layers of granular material graded (either naturally or by selection) to allow seepage through or within the layers while preventing the migration of material from adjacent zones.

**Flashboards**—Structural members of timber, concrete, or steel placed in channels or on the crest of a spillway to raise the reservoir water level but intended to be quickly removed, tripped, or fail in the event of a flood.

**Flood**—A temporary rise in water surface elevation resulting in inundation of areas not normally covered by water. Hypothetical floods may be expressed in terms of average probability of exceedance per year, such as one-percent-chance-flood, or expressed as a fraction of the probable maximum flood or other reference flood.

**Foundation**—The portion of the valley floor that underlies and supports the dam structure.

**Freeboard**—Vertical distance between a specified stillwater (or other) reservoir surface elevation and the top of dam, without camber.

**Gate**—A movable water barrier for the control of water.

> **Crest gate (spillway gate)**—A gate on the crest of a spillway to control the discharge or reservoir water level.
>
> **Outlet gate**—A gate controlling the flow of water through a reservoir outlet.

**Height, hydraulic—**The vertical difference between the maximum design water level and the lowest point in the original streambed.

**Height, structural—**The vertical distance between the lowest point of the excavated foundation to the top of the dam.

**Intake—**Placed at the beginning of an outlet-works waterway (power conduit, water supply conduit), the intake establishes the ultimate drawdown level of the reservoir by the position and size of its opening(s) to the outlet works. The intake may be vertical or inclined towers; drop inlets; or submerged, box-shaped structures. Intake elevations are determined by the head needed for discharge capacity, storage reservation to allow for siltation, the required amount and rate of withdrawal, and the desired extreme drawdown level.

**Leakage—**Uncontrolled loss of water by flow through a hole or crack.

**Length of dam—**The length along the top of the dam. This also includes the spillway, powerplant, navigation lock, fish pass, etc., where these form part of the length of the dam. If detached from the dam, these structures should not be included.

**Outlet—**An opening through which water can be freely discharged from a reservoir to the river for a particular purpose.

**Phreatic surface—**The free surface of water seeping at atmospheric pressure through soil or rock.

**Piping—**The progressive development of internal erosion by seepage.

**Reservoir—**A body of water impounded by a dam and in which water can be stored.

**Reservoir surface area—**The area covered by a reservoir when filled to a specified level.

**Riprap—**A layer of large uncoursed stone, precast blocks, bags of cement, or other suitable material, generally placed on the slope of an embankment or along a watercourse as protection against wave action, erosion, or scour. Riprap is usually placed by dumping or other mechanical methods, and in some cases is hand placed. It consists of pieces of relatively large size, as distinguished from a gravel blanket.

**Seepage—**The internal movement of water that may take place through the dam, the foundation, or the abutments.

**Slope—**Inclination from the horizontal. Sometimes referred to as batter when measured from vertical.

**Slope protection—**The protection of a slope against wave action or erosion. See “Riprap.”

**Spillway—**A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means, such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

**Spillway channel—**An open channel or closed conduit conveying water from the spillway inlet downstream.

**Spillway chute—**A steeply sloping spillway channel that conveys discharges at super-critical velocities.

**Spillway crest—**The lowest level at which water can flow over or through the spillway.

**Storage—**The retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas, as in the progression of a flood wave through a natural stream channel.

**Toe of the dam—**The junction of the downstream slope or face of a dam with the ground surface; also referred to as the downstream toe. The junction of the upstream slope with ground surface is called the heal or the upstream toe.

**Top of dam—**The elevation of the uppermost surface of a dam, usually a road or walkway, excluding any parapet wall, railings, etc.

**Trashrack—**A device located at an intake to prevent floating or submerged debris from entering the intake.

**Valve—**A device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway to control or stop the flow.

## About the Author

**James Scott Groenier** began working for MTDC in November 2003 as a civil engineering project leader. Groenier earned a bachelor's degree from the University of Wisconsin at Madison and a master's degree from Montana State University. He worked for Wisconsin and Illinois State Departments of Transportation before starting his career with the Forest Service. He has worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests.

## Library Card

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This pocket safety guide was developed as a quick reference to help dam owners and others assess low hazard dams and impoundments. Uncontrolled release of a reservoir resulting from a dam failure can have a devastating effect on people and property downstream. Safely maintaining a dam is a key element in preventing dam failure and limiting the liability a dam owner could face.

**Keywords:** dam failure, dams, erosion, impoundments, low hazard dams, reservoirs, riprap, safety at work, spillways

## Notes

## Notes

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