

Session 4: Operation, Maintenance, and Safety Inspection of Dams



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What Will Be Covered in Session 4? Maintenance Problems & Solutions

- Excessive Vegetation
- Animal Damage
- Debris
- Erosion
- Slope Failures
- Concrete Problems
- Seepage
- Drains
- Material Deterioration
- Miscellaneous



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O&M Pays Off

- Proper operation, maintenance, and inspection of a dam is like that of an older vehicle in need of extensive repair:
 - If left un-maintained, repair is expensive.
 - If maintenance and repair are performed as needed, costs are minimized.

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Excessive Vegetation



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Tree and Brush Removal

- Keep Entire Dam and Spillways Clear of Trees and Brush

Reasons:

- Heavy brush makes inspection difficult
- Heavy brush makes it difficult to see problems as they develop
- Roots may increase seepage risks as they decay
- Root systems can lift and displace concrete structures
- Trees and brush prevent growth of desirable vegetation
- Brush encourages and hides borrowing animals
- Roots can clog embankment drains and penetrate conduits
- Uprooted trees produce large voids reducing stability, decreasing seepage paths and reducing freeboard

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Maintenance Of Vegetation

- Periodic Mowing is Essential
- Follow Recommendations in O & M Manual
- Mow to Minimum Height of 3 inches
- Remove Vegetation from Riprap Areas by Hand
- Good Reference:

Technical Manual for Dam Owners

Impacts of Plants on Earthen Dams

FEMA 534 – September 2005

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Poorly Maintained Embankment



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Trees and Brush On Upstream Slope



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Woody Vegetation



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Poorly Maintained Spillway



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Root Penetration



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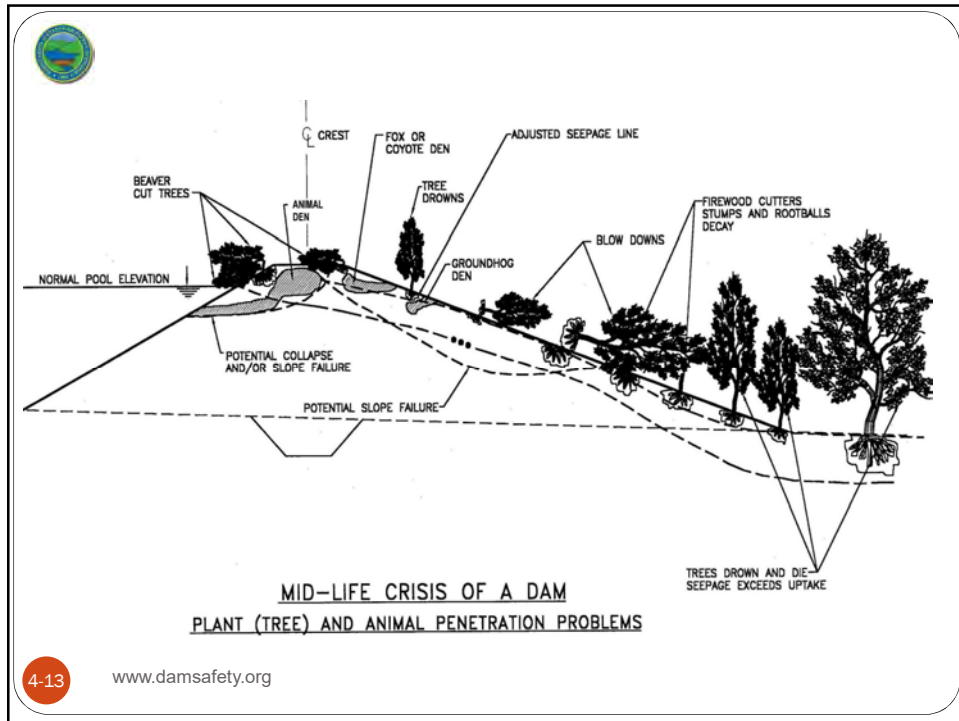
Excellent Vegetation Management



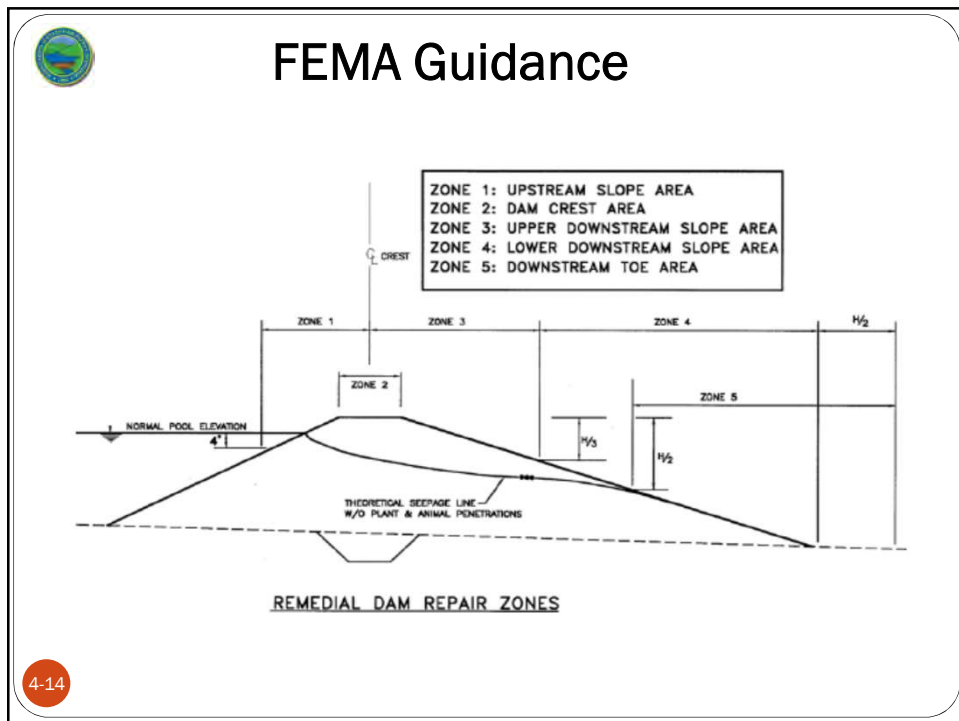
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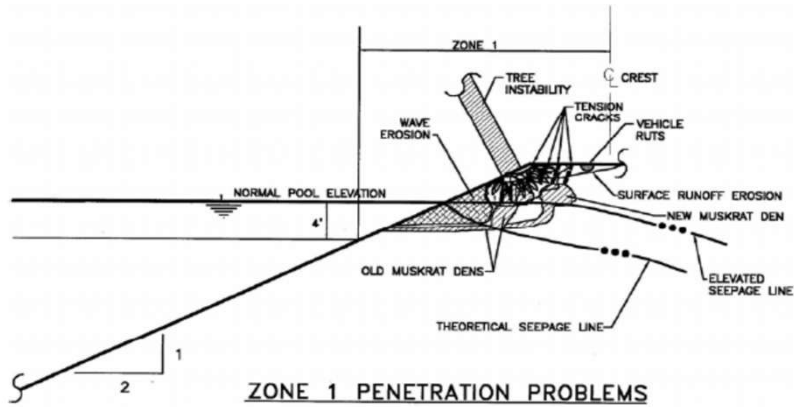
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FEMA Guidance

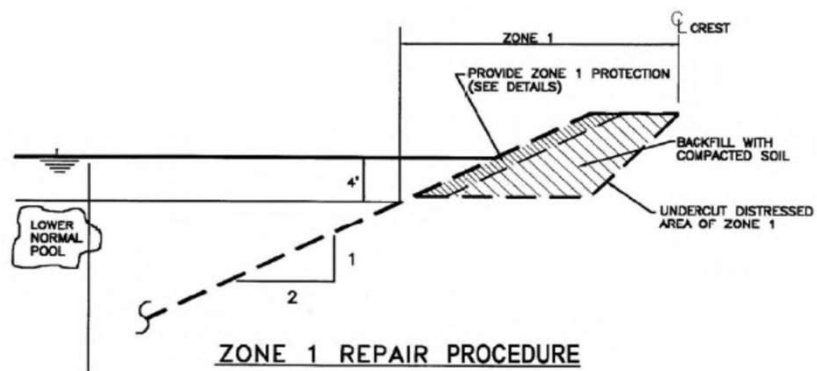


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FEMA Guidance



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FEMA Guidance

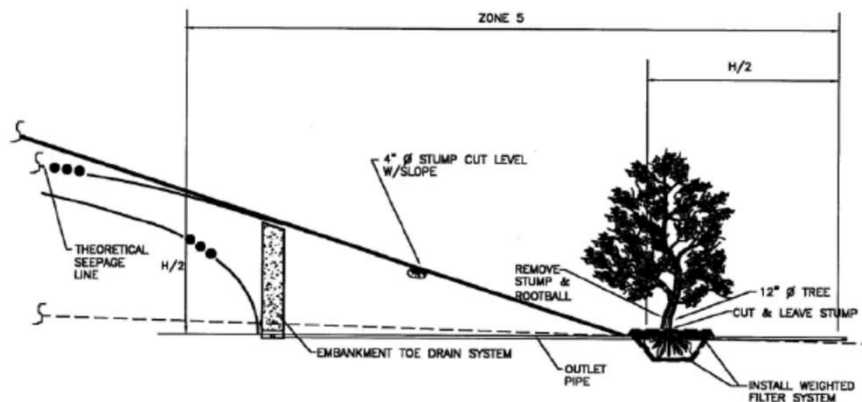


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FEMA Guidance



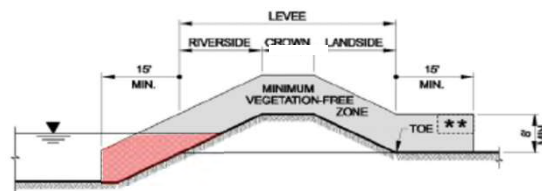
- Stumps >4-in. Removed and Backfilled with Compacted Fill if Toe Drain System Provided
- Otherwise Backfill with Filter Drain

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Army Corps of Engineer Guidance



★★ IN THIS 4' X 7' TRANSITION ZONE, TEMPORARY OBSTRUCTION BY LIMBS AND CROWN IS ALLOWED DURING DEVELOPMENT OF NEW PLANTINGS, FOR UP TO 10 YEARS

▼ WATER SURFACE ELEVATION AT ORDINARY HIGH WATER MARK

VEGETATION-FREE ZONE BELOW THE ORDINARY HIGH WATER MARK

- Removal of Vegetation and Stumps Below the Waterline Requires Permitting Under Section 404 of the Clean Water Act.
- Simple Clearing of Vegetation Using Hand Tools and Lifting Equipment to Remove Trunks and Large Limbs Generally Does Not Require Section 404 Permitting.

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Army Corps of Engineer Guidance

- Removal of Non-Compliant Vegetation
 - Excavated Removal of Stump and All Roots Greater than ½-inch in diameter.
 - Backfill Stump Void to Match Adjacent Soils
 - Must Consider Impoundment Levels, Seepage Conditions, Structural Impacts and Other Considerations
 - Consult with an Experienced Engineer to Identify Potential Concerns and Develop and Appropriate Plan

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Guidance on Vegetative Clearing

- Natural Resources Conservation Service
 - **TR-60 : Earth Dams and Reservoirs** (July 2005)
- Bureau of Reclamation
 - **Design of Small Dams** (November 1987)
- Army Corps of Engineers
 - **ETL 1110-2-571 : Guidelines for Landscape Planting and Vegetative Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures** (April 2009)
- Federal Emergency Management Agency
 - **FEMA 534 : Technical Manual for Dam Owners; Impacts of Plants on Earthen Dams** (September 2005)
 - Development Undertaken by Association of State Dam Safety Officials
 - **Technical Manual on the Effects of Tree and Woody Vegetation Root Penetrations on the Safety of Earthen Dams** (December 2002)

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Animal Damage

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Animal Impacts on Dams

- Destroy Vegetation
- Dig Burrows
- Block Spillways
- Plug Drains
- Paths and Trails

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Animal Impact on Dams

- **Beavers:** Block spillways and burrow into the Dam
- **Muskrats:** Dig large burrows on upstream slope
- **Groundhogs:** Dig large burrows on downstream slope
- **Livestock:** Trample vegetation and create erosion paths

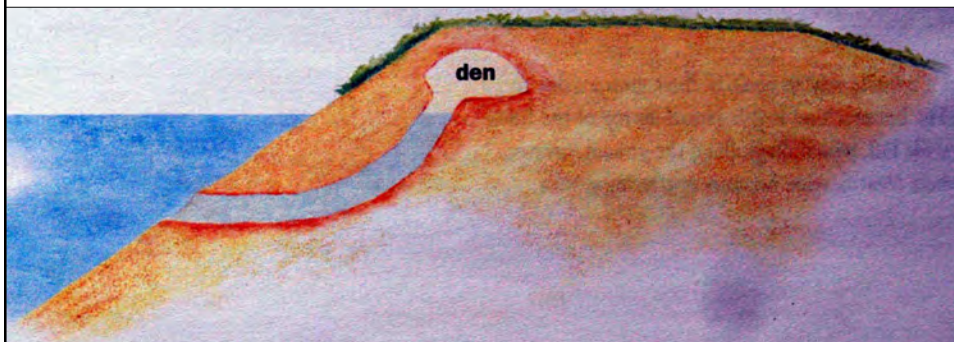
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Beaver Den



Entrance of a Beaver Den is Often Just Below the Water Line

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Source: FEMA Technical Manual 473

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Beaver Impact on Spillways



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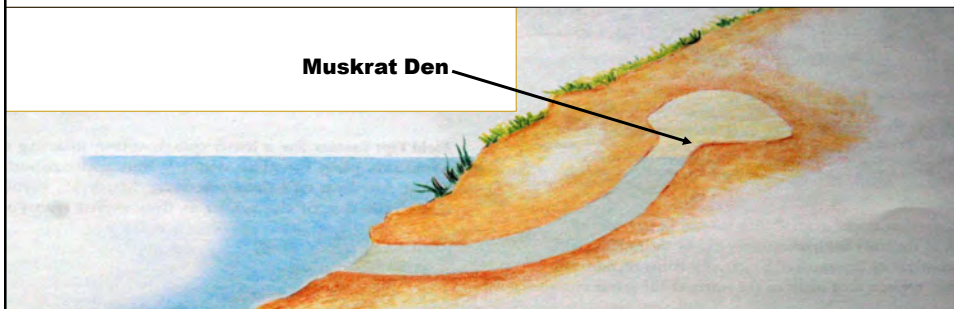
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Muskrat Den

Muskrat Den



**Musk rats Dig their Dens on the Upstream Slope with Entrance
Below Water Crest is 6 to 18 inches Below Water**

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Source: FEMA Technical Manual 473

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Muskrat Holes – Upstream Face



Muskrat Holes Found along
Upstream Face of Dam when
Lake was Lowered

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Muskrat Holes – Upstream Face



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Muskrat Burrow Entrance



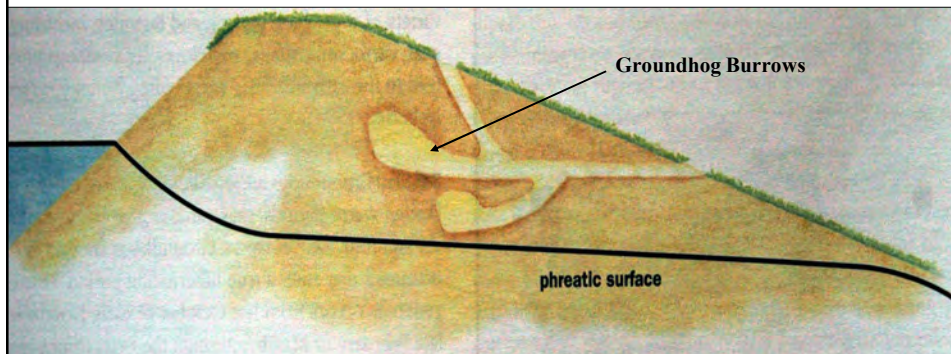
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Groundhog Burrows



Groundhog Burrows are Extensive and Irregular in Pattern

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Source: FEMA Technical Manual 473

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Groundhog Holes – Downstream Face



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Vegetation Management

Vegetation Obscures Dam
& Encourages Animal
Activity



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Dangerously Close Burrows

muskrat burrow

dam crest

water level

groundhog burrow

phreatic surface

dangerously close burrows

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Source: FEMA Technical Manual 473

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Maintain Animal Guards

Animal Guard

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Missing Guard

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Keep Animal Guards In Place

Nest Inside an Embankment Drain



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Livestock Damage



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Controlling Livestock Damage



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Burrowing Animal Control

- Owner Responsible for Control of Nuisance Wildlife
- Owner Must Abide by Applicable Federal/State Regs
- Applicable Federal Regulations:
 - Endangered Species Act
 - Migratory Bird Treaty Act
 - Federal Insecticide, Fungicide and Rodenticide Act
- State Regulations:
 - Some species protected by State even if not by Federal
 - Know your State Regulations

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Reference: FEMA Technical Manual 473

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Animal Control Methods

- **Habitat Modification**

Remove aquatic vegetation that grows along face of the dam

- **Trapping**

Trapping and relocation should be coordinated with the appropriate state agency since permit may be required

- **Use Of Fumigants and Toxicants**

Coordinate with appropriate wildlife agency in your state regarding legality and restrictions on application

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Minor Repair of Burrows

- Excavate and Remove Debris from Large Dens

- Fill Material Should be:

- Well graded
- Fine grained
- Free from vegetation, organic material & rocks
- Placed in 8-inch to 12-inch thickness to compact
- Be moist but not wet when compacted

- Re-Vegetate as Recommended by:

- State Dam Safety Office
- Soil Conservation District
- NRCS

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Minor Repair of Burrows

- Optional Fill Material – Mud Packing:
 - Mixture of soil and cement
 - Can be made into a slurry
 - Fill burrow with tremie methods

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Debris/Trash Racks

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Areas To Check For Debris

- Primary Spillway Inlets
- Primary Spillway Conduits
- Secondary Spillway Inlets/Channels
- Reservoir

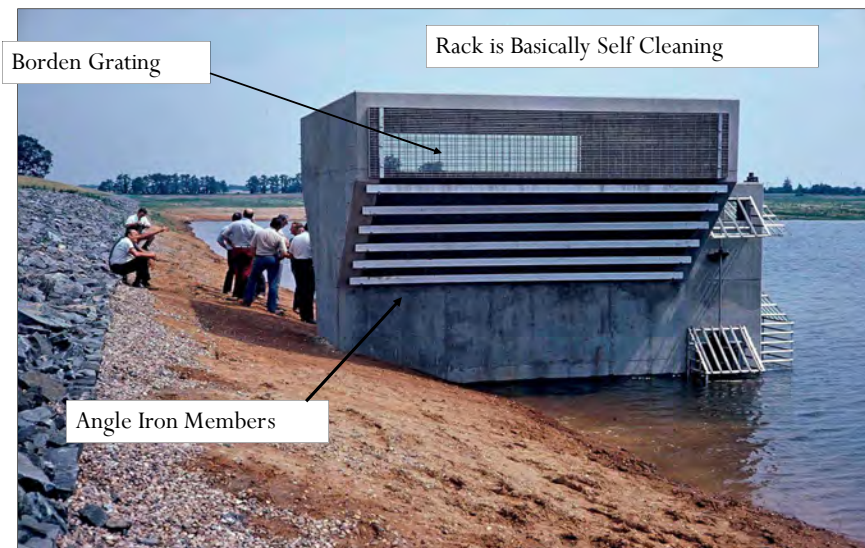
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Properly Designed Trash Racks



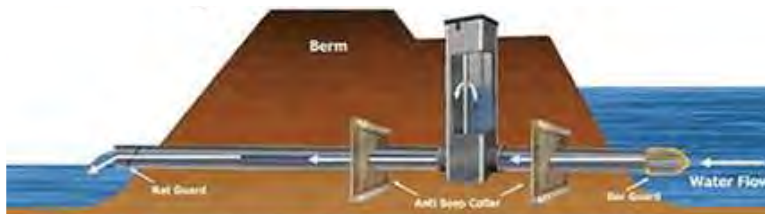
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Beaver Control Agri Drain



Typical Installation and Recommended Component Items--

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How To Control Damage

VERMONT AGENCY OF NATURAL RESOURCES
FISH & WILDLIFE DEPARTMENT

Best Management Practices for Handling Human-Beaver Conflicts



- <https://dec.vermont.gov/sites/dec/files/BMP-BEAVER-CONFLICTS-BROCHURE.pdf>

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Modified Trash Rack



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Debris Accumulation



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Poorly “Designed” Trash Rack



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Debris In Conduit



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Brush & Debris In Spillway



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Spacing Smaller Than Necessary



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Debris Removal

If riser/trash rack becomes so clogged with debris that the riser becomes submerged, removal may require first lowering the lake by pumping or siphoning



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Debris In Reservoir



Heavy Debris in the impoundment can block the spillway during a flood



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Corrective Actions – Trash Racks

- Remove Debris Regularly
- Clean and Paint if Required
- Replace Missing Members/Bolts
- Consider Effectiveness
 - Rack dimensions
 - Opening size

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Corrective Actions – Trash Racks

Design Considerations:

- Maximum Velocity 2.5 fps
- Bar Spacing –
 - $\frac{1}{3}$ to $\frac{1}{2}$ Pipe/Orifice Diameter
 - Not so small that they trap debris that would easily pass through the conduit
- Seek Engineering Assistance

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Corrective Actions

- Conduits/Risers
 - Remove debris
 - Keep entrance sections clear
 - Check joint alignment/displacement
- Gated / Ungated Spillways
 - Remove debris
 - Keep entrance sections clear
- Reservoir
 - Remove floating debris (natural & manmade)
 - Consider a floating debris barrier

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Erosion

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Areas To Check

- Embankment Crest and Slopes
- Groin (embankment to abutment contact)
- Earth Spillway
- Shoreline
- Conduit Outlets
- Outlet Channel
- Structural Spillway Outlets/Sidewalls

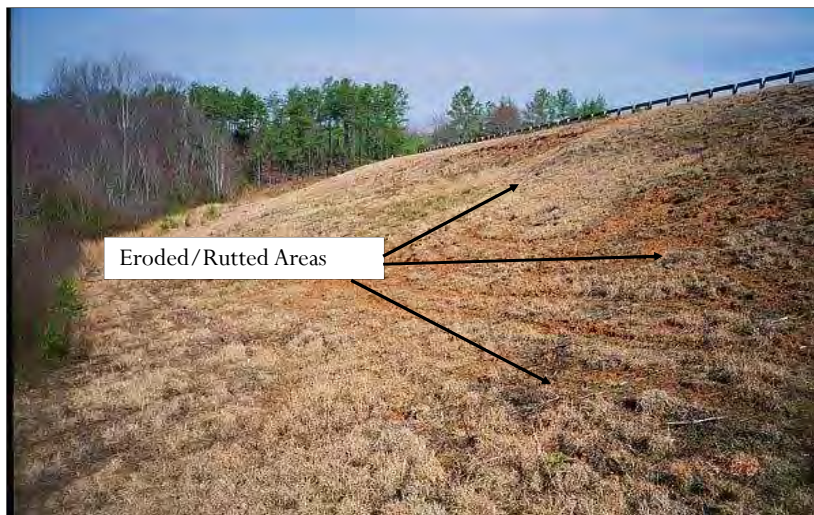
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Surface Erosion and Ruts



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Corrective Action – Minor Erosion/Ruts

- Often Caused by Concentrated Surface Runoff from Crest and/or Sparse Vegetation on Slope
- Corrective Action
 - Control surface runoff at crest
 - Fill deep rutted areas with fine grain well graded compacted soil
 - Re-grade slope
 - Re-vegetate sparse and disturbed area as recommended by State Dam Safety Office/SCD/NRCS

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Ruts And Depressions on Dam Crest



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Corrective Action – Crest

- Crown Crest to Have Uniform Sheet Flow to Slopes
- Consider Use of Topsoil to Establish Good Growth
- Vegetate as Recommended by State Dam Safety Office/SCD/NRCS
- Restrict Vehicle Traffic to Maintenance Equipment
- If Heavy Traffic Cannot be Avoided Protect with Gravel

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Secondary Spillway Outlet Channel



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Spillway Side Slopes



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Corrective Action – Earth Spillways

- Determine Cause of Sparse Vegetation
 - Was spillway designed as bare earth
 - Is it weathered rock and designed as such
 - Is there vehicle, foot or animal traffic causing ruts/erosion
 - Is there seepage keeping the spillway wet restricting growth
- Correct Problem Based on Cause
 - If designed as earth or rock, no action required
 - Restrict vehicle, foot and animal traffic if the cause
 - Control seepage with drainage if necessary
 - Re-grade and seed as recommended by State Dam Safety Office/SCD/NRCS

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Erosion In Groin Area



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Corrective Action – Groin Area

- Erosion in Groin Area is Usually the Result of Concentrated Runoff or Seepage from the Abutment at the Contact
- Corrective Action:
 - Control surface runoff
 - Control seepage with drainage system
 - Apply structural measure if necessary
 - *Riprap*
 - *Concrete gutter*

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Shoreline Erosion



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Shoreline Erosion – Loss of Riprap



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Corrective Action – Shoreline Erosion

- Shoreline Erosion is Generally Caused by Wave Action or Foot Traffic (fishermen or animals)
- Loss of Riprap by Being Undersize or Vandalism
- Corrective Action:
 - Have engineer design riprap protection based on fetch length, wind velocity by NRCS/Corps procedures
 - Restrict foot traffic or protect with riprap
 - Restrict animal traffic (livestock trying to get water)
 - For vandalism partially grout or make large

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Properly Designed Riprap



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Erosion at Conduit Outlet



Outfall set too high with no protection

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Corrective Action – Conduit Outlet

- Usual Causes
 - High outlet velocity
 - Outlet set too high
 - Unstable channel downstream (head cutting)
- Corrective Action
 - Have engineer design outlet protection
 - Plunge Pool/Riprap/Structural
 - Stabilize downstream channel

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Outlet Channel Erosion



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Corrective Action – Outlet Channel

- Usual Causes
 - No/inadequate energy dissipation on structural spillway
 - Outlet channel inherently steep and unstable
 - Outlet conduit set too high
- Corrective Action
 - Have engineer design structural energy dissipation measure
 - Have engineer design channel stabilization measure

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Erosion Along Spillway Side Wall



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Corrective Action – Spillway Sidewalls

- Usual Causes
 - Surface runoff adjacent to wall
 - Seepage along sidewall
 - Foot or animal traffic
- Corrective Action
 - Re-grade area at top of slope to control runoff
 - Provide slope protection (riprap)
 - Provide seepage control or drainage along sidewall

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Slides/Sloughs/Cracking

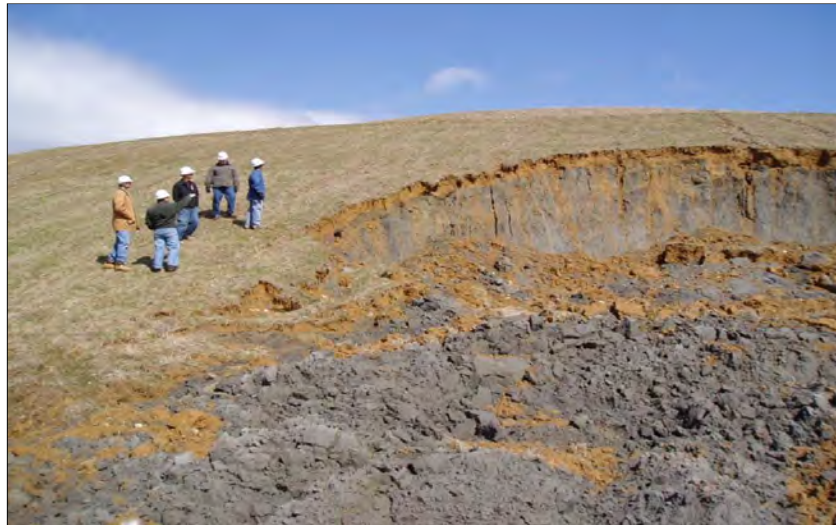
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Deep Seated Slope Failure



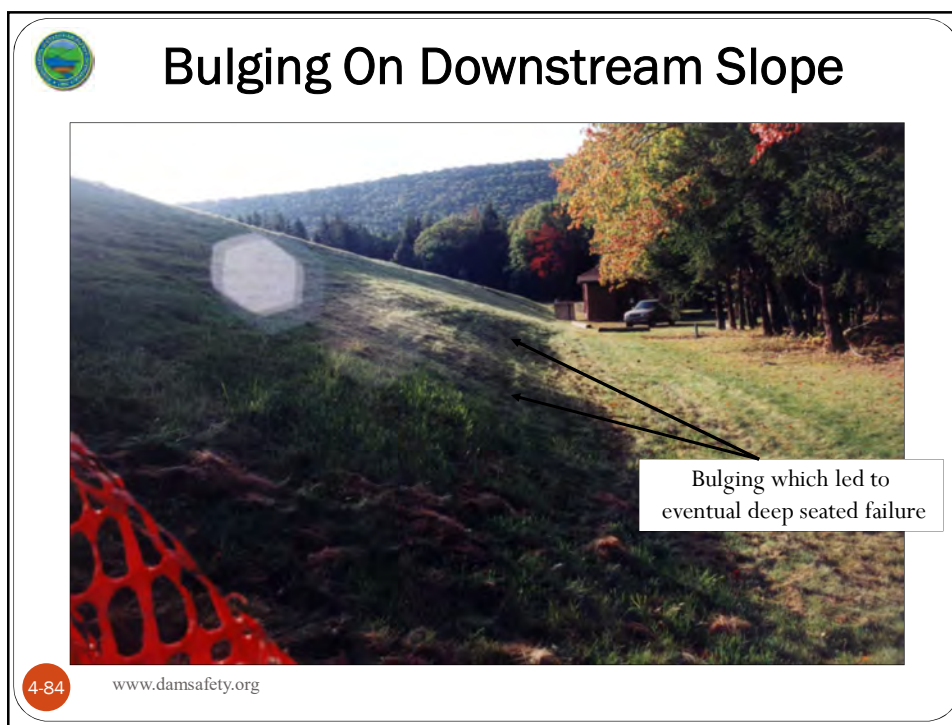
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Surface Cracks In Crest



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Corrective Actions – Deep Slides

- Deep Slides are a Serious Problem that Can Lead to a Rapid Dam Failure
- Lower or Prepare to Lower the Lake
- Follow EAP Procedures (if you have one)
- Repair Under Direction of an Engineer

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Corrective Actions – Shallow Slides

- Usually Not as Serious as Deep Seated Slides
- Cause Must be Determined
- Investigation Should be by Engineer
- Repair Under Direction of Engineer

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Corrective Action – Bulging

- Usually Not an Immediate Problem
- Cause Must be Determined
- Investigation by Engineer
- Repair Under Direction of Engineer

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Corrective Action – Surface Cracks

- Surface Cracks Can be an Indication of a Serious Problem in the Dam Foundation or Can Just be the Result of Desiccation
- Monitor Crack for Expansion or Growth
- Cause Should be Determined by Engineer
- Repairs Should be Made Under Direction of Engineer

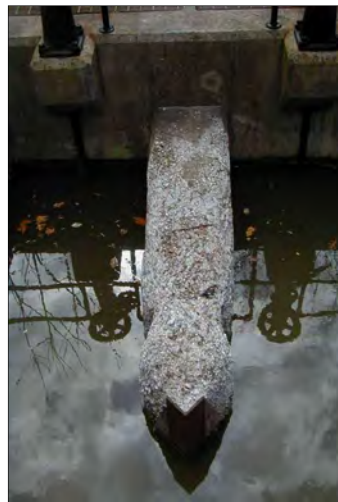
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Concrete Spalling



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Concrete Spalls and Cracks



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Concrete Spalls



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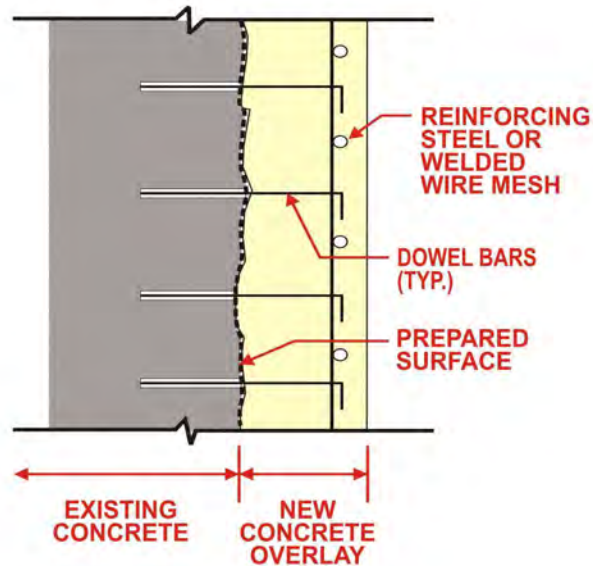
Corrective Action – Spalling

- Chip Away Any Loose Material
- If Section Loss is Not Significant, Apply a Concrete Sealer/Protective Coating
- If Section Loss is Significant, Construct a Structural Overlay with Dowels and Reinforcing (requires engineering)

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Structural Overlay



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Concrete Cracking



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Concrete Cracking



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Corrective Action – Cracking

- Severe Crack through the Section will Require Removal and Replacement with Dowels and Reinforced Concrete
- Structural Crack Repair Requires Epoxy Injection



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Corrective Action – Cracking

- Non-Structural Crack may be Repaired with a Polyurethane Resin Injection or Caulk



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Exposed Aggregate



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Exposed Aggregate



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Exposed Aggregate – After



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Corrective Action – Exposed Aggregate

- Due Wetting/Drying and Freeze/Thaw Cycles
- Due to Hydraulic Abrasion/Erosion
- Surface Mortar (sand, cement, and water) is Removed
- Repair with:
 - Sealer/protective coating
 - Concrete repair mortar (re-profiling mortar)
 - Epoxy mortar

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Alkali-Silica Reaction / Alkali-Aggregate Reaction



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Corrective Action – ASR / AAR

- Water and Air Promote the Reaction, so Sealing the Concrete Surfaces to Minimize Water/Air Infiltration Helps to Slow Down Process
- Eventually the Structural Integrity will be Compromised, Structure Will Have to be Replaced

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Vegetation in Joints



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Corrective Action – Vegetation

- Should be Removed Immediately, Including Stalk and Roots
- Cutting or Pulling
- Application of Herbicide

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Leaking Joints



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Corrective Action – Leaking Joints

- You Need to Understand Original Design of the Joint:
 - Was dam constructed with water-stops
 - Is there a continuous drain behind joint
 - Are there fines being removed
- Inject Water Reactive Hydrophobic Polyurethane Resin That Remains Flexible
- Flush Out Drain
- Reconstruct Joint and Drain

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Joint Failure



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Corrective Action – Joint Failure

- Vegetation in Joints and Leaking Joints Can Lead to Joint Failure
- Joint Failure is When the Joint Separates Enough to Allow Spillway Discharge to Erode the Underlying Soils
- The Concrete Slabs then Can Be Lifted or Collapse into the Underlying Void
- Reconstruction of the Spillway is Required

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Seepage Problems

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Seepage Thru Embankment



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Seepage Thru Abutment



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Seepage Thru Foundation



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Seepage / Piping

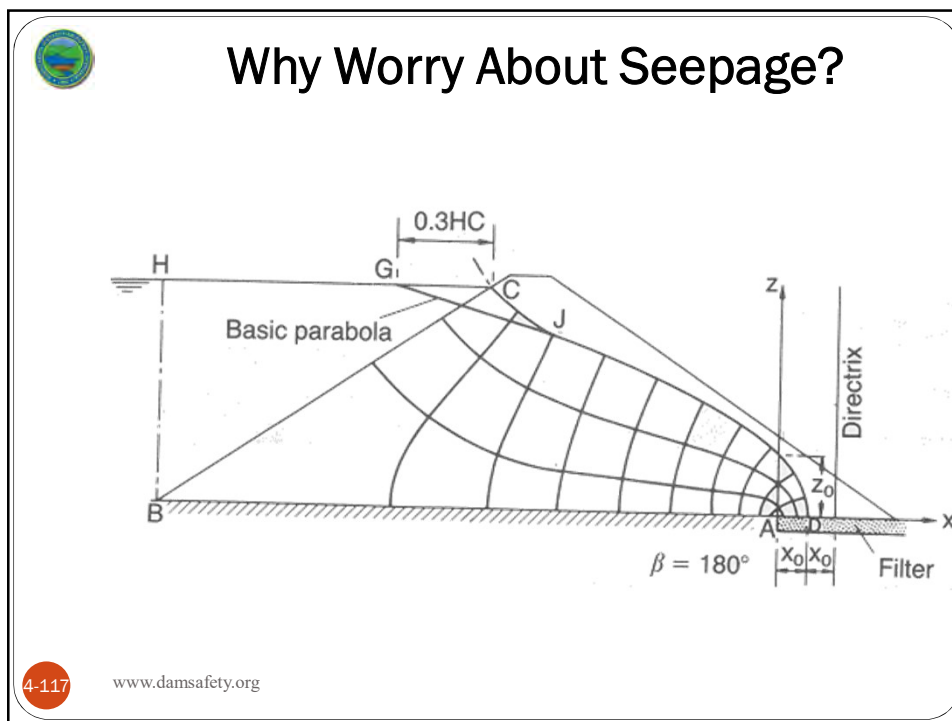


Embankment Seepage - Boil

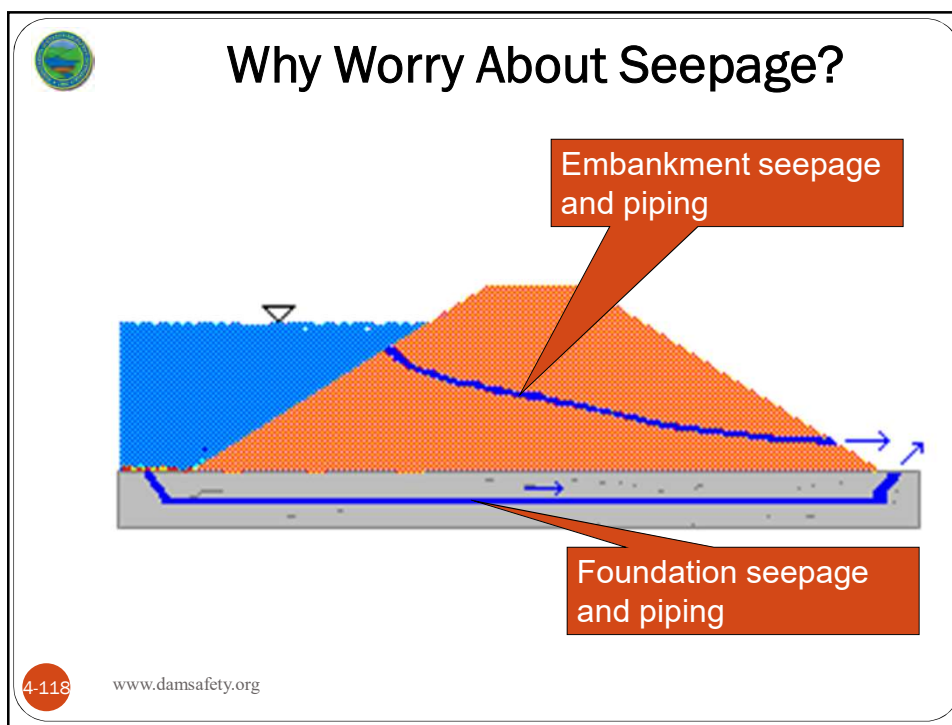
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Upstream Vortex



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Corrective Action - Seepage

- All Dams Leak or Seep
- Seepage Alone is Not Necessarily a Problem, But it Should be Monitored Visually and the Quantity Measured on a Regular Basis
- Seepage Can Lead to “Piping” Erosion and Embankment Instability
- If the Seepage is Muddy, There is a PROBLEM
- A Seep Exiting at the Toe can be Repaired with a Reverse Graded Filter
- Seepage through the Embankment can be Collected and Controlled by Filter Drain Installation

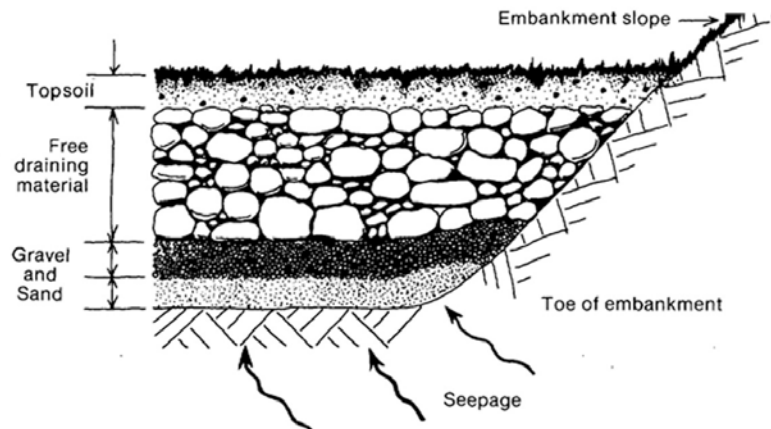
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Reverse Weighted Filter



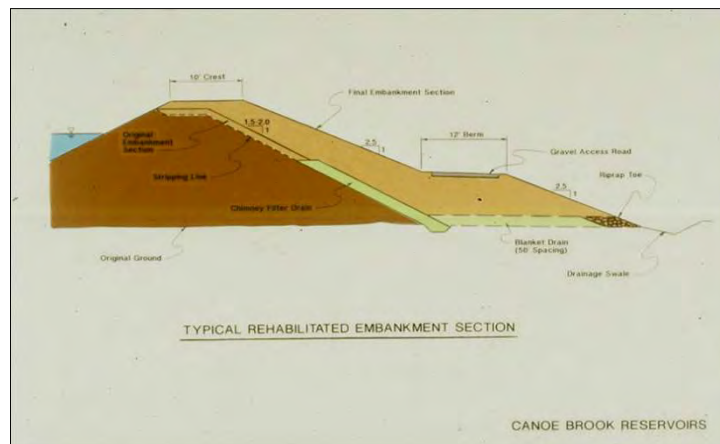
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Chimney & Blanket Drains Rehabilitation



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Embankment Drains

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Clogged Drains & Conduits



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Clogged Drains & Conduits



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Clogged Drains & Conduits



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Material Deterioration

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Material Deterioration



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Material Deterioration



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Material Deterioration

- Corrugated Metal Pipe Products
 - Large number dams with CMP products designed and constructed under the Soil Conservation Service (now NRCS) in 1960s - 1980s.
 - Dams used for irrigation, wildlife, recreation
 - CMP used for principal spillway risers, outlet barrels, low-level outlet, toe drains, etc.
 - Design life of CMP 50 years +/- . In harsh soil and water chemistry conditions, products have lasted less time.
 - In most applications, nearing or at end of design life, in poor condition, require replacement.

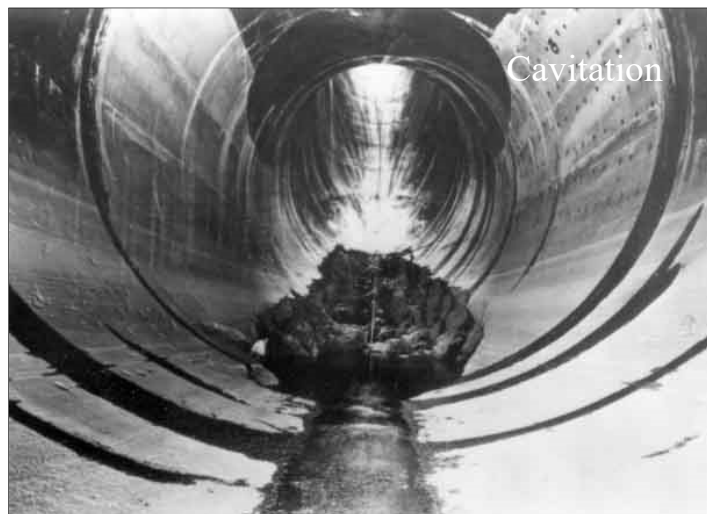
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Material Deterioration



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Material Deterioration



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Material Deterioration



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Corrective Action – Material Deterioration

- Corrosion – Periodic Painting with Corrosion Inhibiting Paint or Sealer, may Require Sand Blasting First
- Corrosion – Do Not Use Corrugated Metal Pipe
- Cavitation – Repair Damage with Concrete or Welded Steel Liner and Aerate Flows (See next slide)
- Worn or Damaged Parts – Periodic Inspections and Performance Monitoring

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Corrective Action – Cavitation

Aerate flows
with aeration slot



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Miscellaneous

- Fish Screens
- Gates, Stems and Operators
- Flashboards
- Aquatic Vegetation
- Access Roads
- Sediment
- Design Modifications
- Maintenance Equipment and Materials

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Traveling Fish Screen



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Gate Operator



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Gate & Stem



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Gate & Stem



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Weirboards-Stoplogs



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Corrective Action – Gates/Weirboards-Stoplogs

- Gates Should be Lubricated Periodically According to Manufacturers Recommendations
- Gates Operator Should be Cleaned and Painted as Needed
- Gates Should Never be Forced Opened or Closed, Can Bend Stem and Disengage Disc from Frame – If Stuck Determine Reason
- Gates Should be Cycled Open and Closed in 25% Increments

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Corrective Action – Gates/Stoplogs

- Stoplogs Should Not be Forced into Place
- Replace Timber Planks as Needed, Dimensioned Just Smaller than Slot Dimensions
- Contact Edges Should be Chamfered
- If Leaking Badly, Plastic Sheet can be Placed Up Against Upstream Face
- Design Stoplogs with Nesting Lifting Eye Bolts

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Access Road



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Corrective Action – Access Roads

- If Access Road is Across Dam Crest, Make Sure Minimum Crest Elevation is Maintained
 - Add fill or crushed stone as necessary
- Make Sure Access Road is Clear of any Obstacles or Debris such as Fallen Trees
- Repair any Ruts or Erosion with Fill or Crushed Stone

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Sediment

- Sediment Accumulation in:
 - Reservoir
 - Outlet conduit
 - Drains

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Sediment – Reservoir



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Sediment – Reservoir



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Sediment – Conduit/Drains



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Design Modifications

- Modifications to the Dam Should Not be Undertaken without Input from a Licensed Engineer and a Permit from the State Dam Safety Office

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Design Modifications - Examples

- Raising Normal Pool by Adding Flashboards to Spillway
 - Adds hydrostatic load to dam
 - Reduces freeboard
 - Increases flooding levels upstream
- Lowering Crest of Dam
 - Reduces freeboard
- Placing Obstructions in Spillway Channels
 - Fences, stockpile materials, park equipment and vehicles – all reduce channel capacity

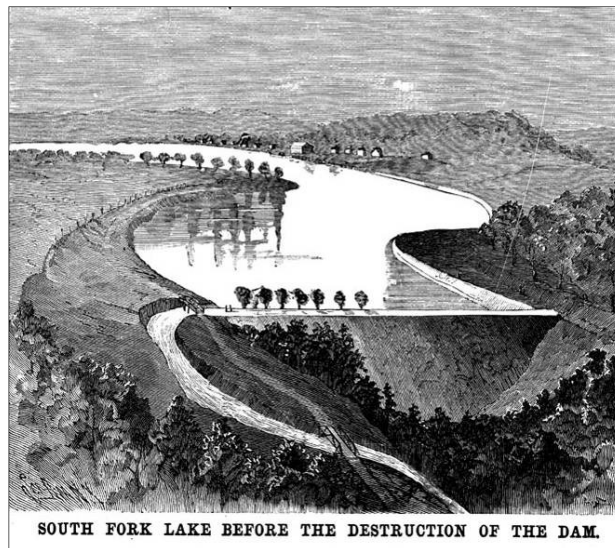
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Design Modifications



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Design Modifications



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Design Modifications



Fish Screens

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Design Modifications



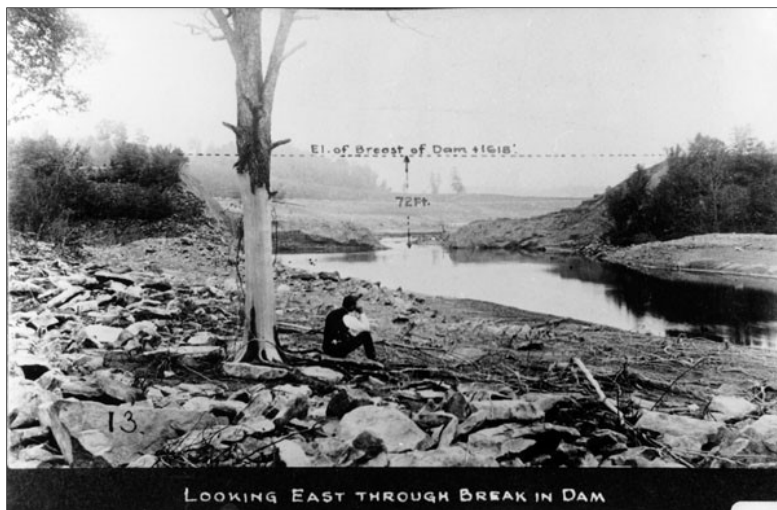
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Design Modifications



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Hazard Re-Classification

Likely loss of
life upon
failure of
Dam



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Maintenance Equipment

- Power Equipment
 - Dump truck, backhoe
 - Stump grinder, mulcher
 - Mower, tractor
- Hand Equipment
 - Chain saw
 - Weed whackers, trimmers, clippers
 - Wheelbarrow, rakes, shovels
 - Hand tools

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Slope Mowers



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Slope Mowers



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Slope Mowers



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Slope Mowers



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Maintenance Materials

- Stockpiled Material
 - Rip rap
 - Crushed stone (#57)
 - Sand and sand bags
 - Random earthfill
 - Topsoil
- Geotextile, Geogrids, Erosion Control Matting
- Fertilizer, Lime, Grass Seed, Mulch
- Sealant, Caulk, Mortar Mix
- Paint, Lubricant, Grease

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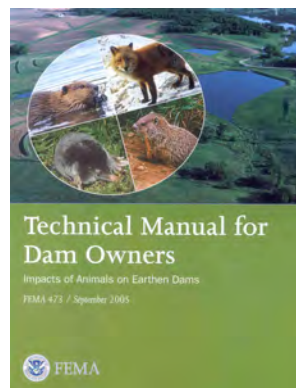
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OM&I Information Resources

on <https://damsafety.org/dam-owners>

- *OM&I Manual* (Ohio Dam Safety Program)
- *Dam Safety: An Owner's Manual* (FEMA)
- SEED Manual (US Bureau of Reclamation)
- Impacts of Animals on Earthen Dams (FEMA)
- Impacts of Plants on Earthen Dams (FEMA)



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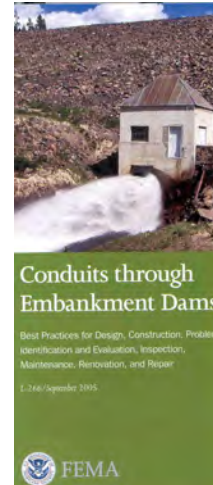
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OM&I Information Resources

on <https://damsafety.org/dam-owners>

- Conduits Through Embankment Dams (FEMA)
- *Internal Erosion of Earth Dams*
- *Ohio Dam Safety Fact Sheets* (Ohio Dam Safety Program)
- Piezometer monitoring software



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PREVIOUS SLIDE PRESENTATION

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Session 4: Operation, Maintenance, and Safety Inspection of Dams



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What Will Be Covered in Session 4

- Dam operations
- Maintenance issues & activities
- Inspection issues & activities

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What Will Be Covered (continued)

- Problems with:
 - Earth dams
 - Spillway systems
 - Outlet works
 - Concrete dams

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*The responsibility for proper operation,
maintenance, and inspection of dams
falls upon dam owners.*

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Proper Dam Operations

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Dam Operations

- Recordkeeping
- Periodic Inspection
- Emergency action plan (EAP)
 - EAP recommended updates on an annual basis
 - Downstream development is typically a potential concern that can drastically affect EAP contents

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Dam Operations (Cont.)

- Public safety
 - Public access must be controlled
 - Includes proper warning signs, fencing, etc.

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Public Safety



Refer to Session 6 for more on public safety.

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Dam Operations (Cont.)

- Operation of bottom drain, siphon systems, and gates/flashboards
 - Bottom drains, siphon systems, pool control gates, flashboards, and other outlet control works must be operated at least annually.
 - If systems are deteriorated and have not been operated in many years, they must be inspected by a qualified engineer.

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Operating a control gatewheel crank



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Dam Operations (cont.)

- Monitoring fluctuation of pool elevation
- Removal of floating debris
- Monitoring instrumentation systems
- Monitoring alarm/warning systems
- Wildlife damage control

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Monitoring outlet control works



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Monitoring Instrumentation



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Dam Maintenance

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Dam Maintenance Factors

- Type of dam
- Function of dam
- Watershed characteristics
- Spillway system characteristics
- Prevailing climatic conditions

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Dam Maintenance Activities

- Nurturing and mowing grassed areas
- Removal of trees and brush
- Removal of floating debris from outlet works
- Repair of eroded/scoured areas
- Control and repair of damage caused by wildlife

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Nurturing and Mowing Grassed Areas and Removal of Trees and Brush

- Tall grass and brush make inspections more difficult
- Tall grass provides a haven for borrowing animals
- Trees can blow over in high winds and severely damage the embankment.
- Tree roots penetrate the embankment and alter its structural integrity.
- Tree roots can become pathways for seepage.

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Nurturing and Mowing Grass Areas



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Removal of Trees and Woody Vegetation



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Removal of Floating Debris from Outlet Works



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Debris at Flood Control Inlet



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Repair of Eroded/Scoured Areas



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Identify Wildlife Activity



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Beaver Activity

- Beaver dams can block emergency spillways



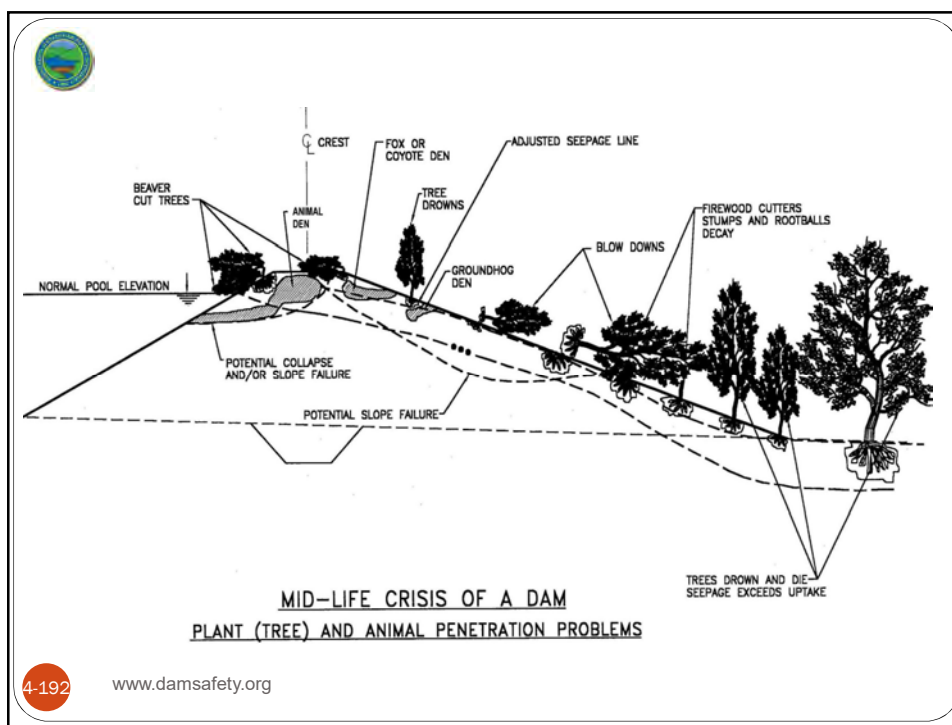
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Dam Maintenance Activities (Cont.)

- Opening and closing of outlet & spillway gates to ensure operability
- Painting and repair of metal components
- Grouting and sealing concrete joints/cracks
- Removal and protection of spalling concrete
- Repair of embankment surface erosion

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Opening and Closing of Lake Drains to Ensure Operability



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Painting and Repairing of Metal Components



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Grouting/Sealing of Concrete Joints/Cracks



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Repair Spalling Concrete



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Repair Embankment Surface Erosion



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Restoring Embankment



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Dam Maintenance Activities (Cont.)

- Maintenance and stabilization of outlet channels
- Maintenance or repair and replacement of warning signs
- Maintenance of instrumentation/monitoring systems
- Maintenance of upstream slope wave erosion protection

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Dam Maintenance Activities (Cont.)

- Maintenance and stabilization of outlet channels



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Dam Maintenance Activities (Cont.)

- Maintenance of Upstream Slope Wave Erosion Protection



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Dam Maintenance Activities (Cont.)

- Removal of sediment deposits at inlet
- Removal of diseased trees on lake rim
- Control and removal of aquatic growth
- Maintenance of emergency access routes



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Dam Safety Inspection Activities

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Dam Safety Inspection Activities



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Purpose of Inspections

- Identify O & M needs
- Monitor instrumentation
- Identify early warning signs of potential problems or failure

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Inspections: What to Look For

- Stability of Embankment & Structures
- Erosion - Embankment Upstream & Downstream Slopes, Abutment Juncture, Spillways & Outlets
- Seepage - Through Dam, Abutment, Foundation, Around Structures
- Vegetal Cover - Type & Condition
- Wildlife Damage
- Deterioration/Cracking of Concrete Surfaces & Structures

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Dam Inspection Activities



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Dam Inspection Activities: Embankments/Earthen Dams

- Embankment slope stability
- Wave erosion
- Embankment seepage
- Abutment seepage
- Foundation seepage
- Woody vegetation growth

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Deep-Seated Slope Failure



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Shallow Slope Failure



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Wave Erosion



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Embankment Seepage



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Abutment Seepage



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Piping or Boil



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Woody Vegetation



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Dam Inspection Activities: Embankments/Earthen Dams (Cont.)

- Wildlife damage
- Sinkholes, depressions, or dropouts
- Embankment cracking
- Sparse vegetation areas
- Surface erosion and vehicular ruts

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Wildlife Damage (Groundhog Hole)



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Sinkhole/Dropout



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Embankment Cracking



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Sparse Vegetation Areas



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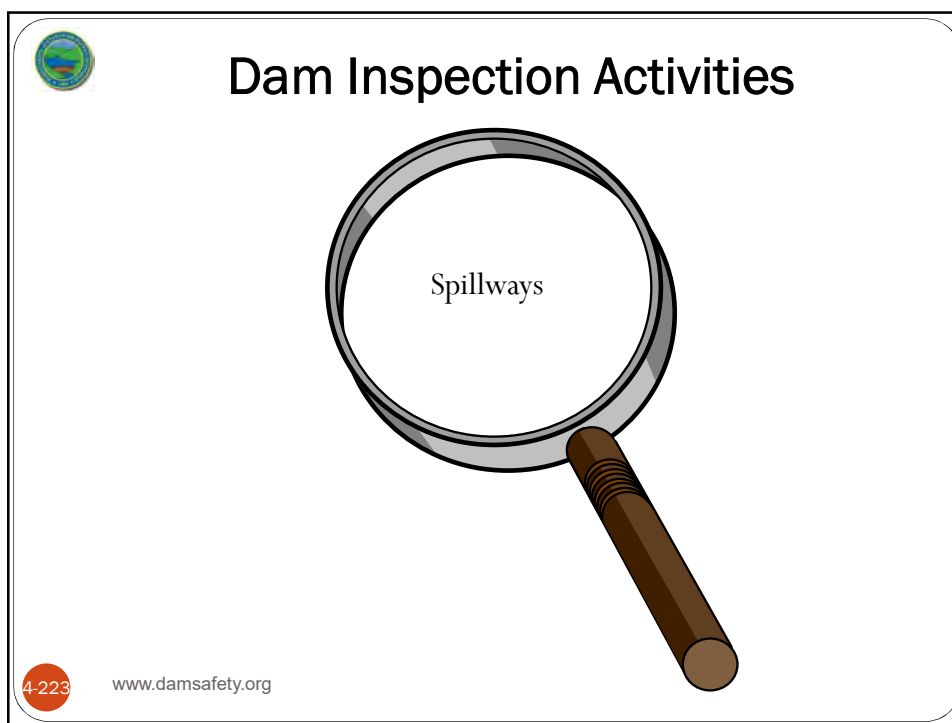
Vehicular Ruts (and woody vegetation)



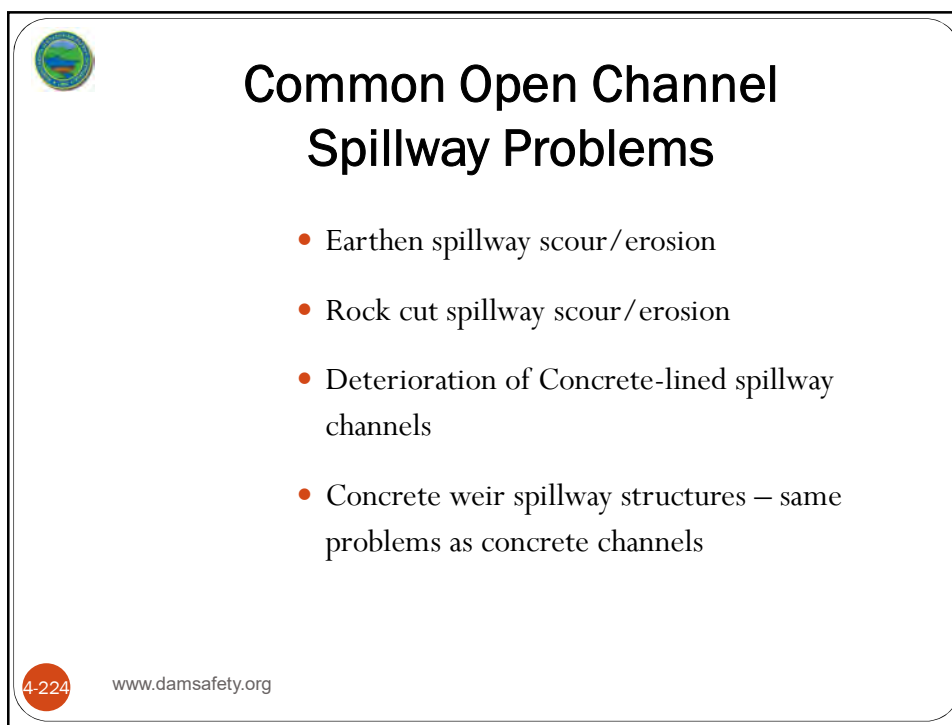
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Earthen Spillway Scour/Erosion



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Earthen Spillway Scour/Erosion



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Slope Instability of Rock Cut Channel



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Deterioration of Concrete and Joints



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Undermining of Concrete Slabs



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Common Spillway Conduit & Outlet Problems

- Undermining of conduit outlet
- Seepage along spillway conduit
- Joint deterioration and/or separation
- Differential settlement along conduit
- Misalignment of spillway conduit
- Spillway conduit deterioration

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Concrete Outlet



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Undermining of Outlet Conduit



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Joint Separation of Outlet Pipe



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Differential Settlement along Conduit and Misalignment of Outlet Conduit



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Outlet Conduit Deterioration



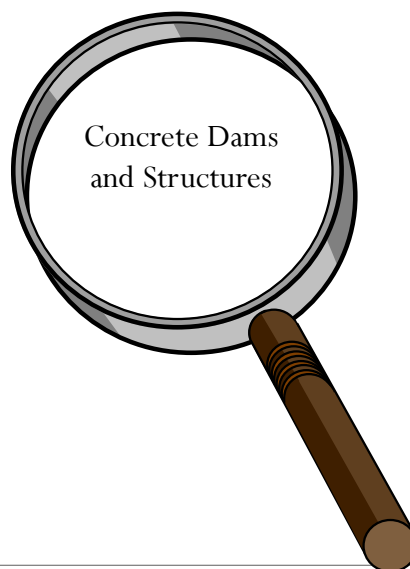
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Dam Inspection Activities



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Inspection of Concrete Structures

- Concrete deterioration
- Structural movements
- Leakage

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Concrete Deterioration - Cracking



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Concrete Cracking



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Displaced Wall



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Concrete Spalling



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Concrete Efflorescence



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Structural Movements - Lateral Movement



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Leakage



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Gate Leakage



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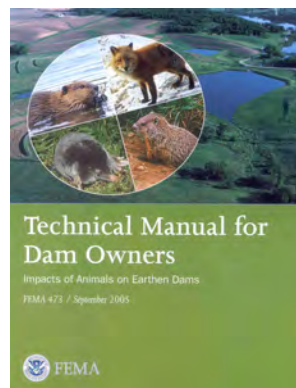
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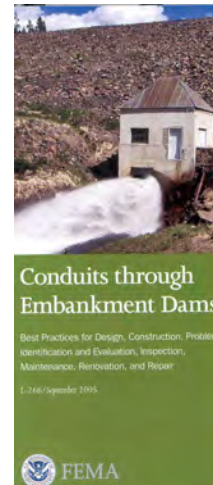
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