

ABSTRACT

MAINTENANCE & OPERATION OF DAMS TO PREVENT FAILURE

BY

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The authors have developed a presentation with the objective of passing on to Dam owners our experience as to how to operate and maintain a Dam in a safe manner. Our approach is to relate the causes of Dam failures and costly distress to operation and maintenance procedures. Topics to be covered include:

- Typical Dam Types including Earth, Concrete Gravity, Ambursen, and Timber Crib are covered. A brief description of each is provided with photographs.
- Various Dam failure modes are presented associated with each type of Dam.
- Discussions of several significant Dam failures complete with photographs.
- Specific examples of operation and maintenance deficiencies that can lead to failure of a Dam;
- What to look for during an inspection which could indicate potential problems.
- Summary of recommended operation and maintenance procedures for Dams.

Maintenance & Operation of Dams to Prevent Failure

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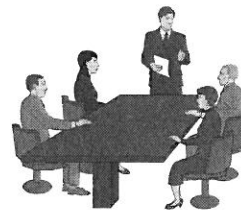
November 16, 1998



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Objective

Pass on to owners of dams
our experience as to how to
operate and maintain a dam
in a safe manner



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Approach

Relate causes of dam failures
and costly distress to
operation and maintenance
procedures



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Recommended References

- ***Operation, Maintenance and Inspection Manual for Dams, Dikes and Levees***
 - by George Mills, ODNR
- ***Fact Sheets published by ODNR***
 - WEB Site www.dnr.state.oh.us
- ***Dam Failure Incidents NPDP***
 - WEB Site www.npdp.stanford.edu



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Typical Dam Types

- **Earth Fill**
 - Most Common, Very Vulnerable**
- **Concrete Gravity**
 - Less Common, Less Vulnerable
- **Ambursen**
 - Least Common, Very Vulnerable
- **Timber Crib**
 - Less Common, Highly Vulnerable



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Typical Earth Dam



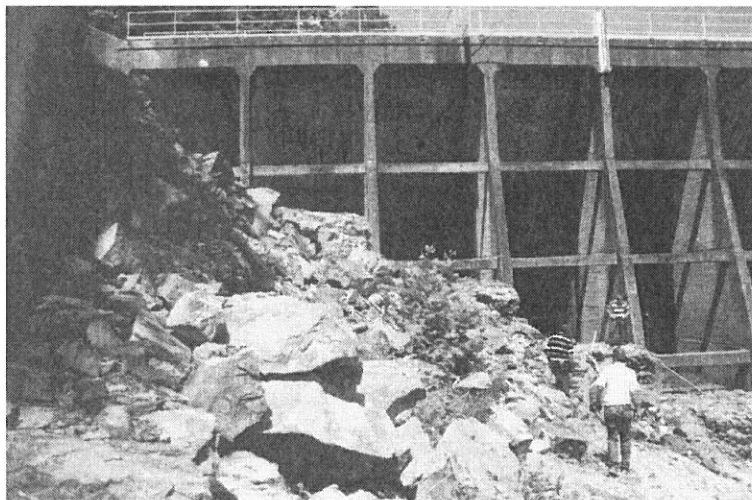
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Typical Concrete Gravity Dam



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Typical Ambursen Dam



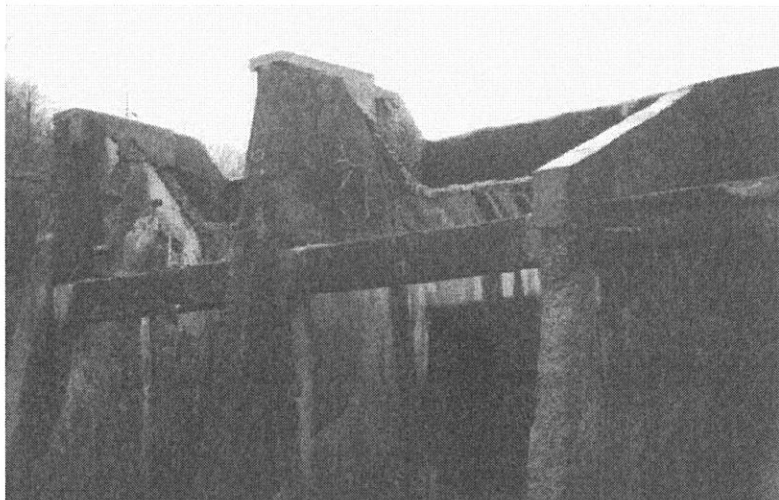
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Typical Ambursen Dam



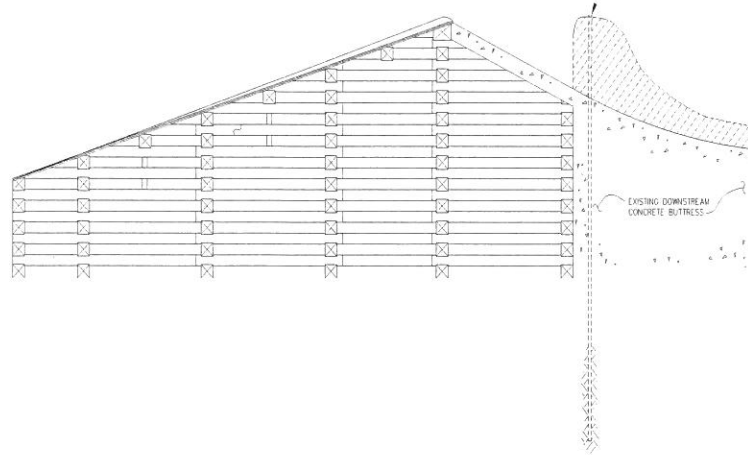
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Typical Ambursen Dam



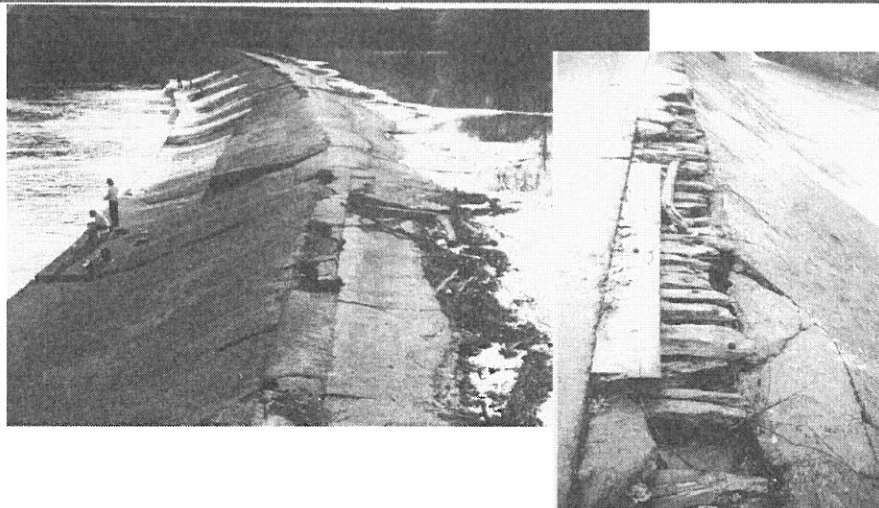
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Typical Timber Crib Dam



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Typical Timber Crib Dam



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Earth Dam Failures

- **Overtopping**
- **Piping**
- **Liquefaction (unlikely in Ohio)**
- **Slope Vegetation**
- **Rodents**
- **Drains & Outlet Works**



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Concrete Gravity Dam Failures

- **Overtopping**
- **Severe Foundation Leakage**
- **Deteriorated Concrete**



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Ambursen Dam Failures

- **Deteriorated Concrete**
- **Overtopping**
- **Severe Foundation Leakage**



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Timber Crib Dam Failures

- **Deteriorated Concrete**
- **Overtopping**
- **Deteriorated Timbers**
- **Excessive Foundation Leakage**



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Overtopping Failures

- **Basic inadequate capacity for storage & discharge**
 - Spillway is too small
 - Spillway receiving area is inadequate
 - Inadequate crest elevation for storage
- **Deformed crest**
- **Poorly maintained crest**



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Overtopping Failures

Vincent No. 2

- June 9, 1995 Colorado
- Overtopping occurred during a spring snowmelt flood. Spillway was obstructed by snow. Crest was overtopped at 5 locations, with the first one immediately over the outlet pipe. Failure was slow because of the superior erosion resistance of the clay section.



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View of the Breach from Downstream Toe



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Aerial View of the Breach



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Downstream Slope at North Overtopped Area



BACK & DOWNCUTTING



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Overtopping Failures

Lake Pauline

- June 28, 1994 South Carolina
- 5.5 inches/24 hours plus two upstream dam failures cause overtopping
- Road closed and property damage



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Lake Pauline Breach



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Lake Pauline Breach



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Example of Well-Maintained Crest



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Well-maintained Crest U/S Slope Wave Protection



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Example of Poorly-maintained Crest



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Example of Poorly-maintained Crest



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Piping Failure

Erosion of the soil by a seep on the downstream slope that progresses back toward the impoundment until a direct path or “pipe” is formed



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Piping Failure

Evidence or “Clues”

- **An increase in flow rate through an “old” seep**
- **Muddy or discolored seepage**
- **Sinkholes**
- **Whirlpool eddy currents in the impoundment**



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Piping Failure

- **Once developed, very difficult to control**
 - Evacuation is in order
 - Immediately Lower Impoundment
- **If not fully developed,**
 - Control it!!!
 - Efforts to stop it will probably fail!
 - Rapidly place coarse sand and gravel
 - Balance Water Pressure



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Example Seepage with “Clues”



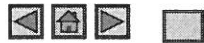
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Example Showing Control “Fix”

SEEP



SEEP



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Example Showing Control “Fix”



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Example Showing Monitoring Weir



V-NOTCH WEIR



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Piping Failure

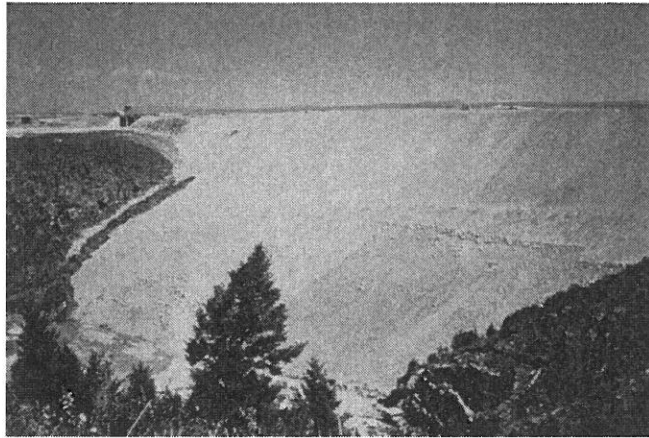
Teton Dam

- June 5, 1976
- 11 Fatalities
- 25,000 homeless
- \$400 million damages
- Warnings prevented more loss of life
- Occurred during initial filling



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Teton Dam Failure Photograph 1/5



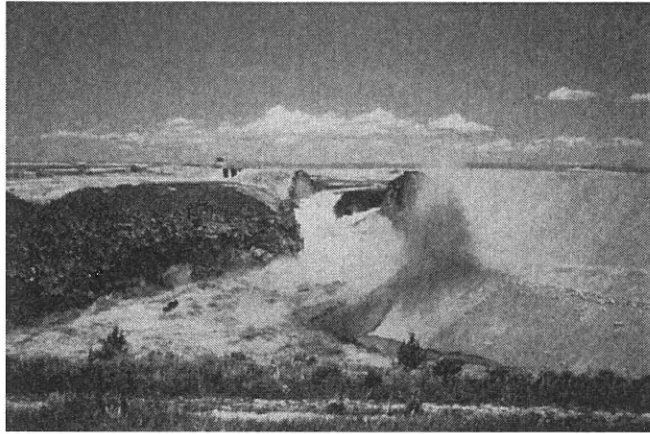
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Teton Dam Failure Photograph 2/5



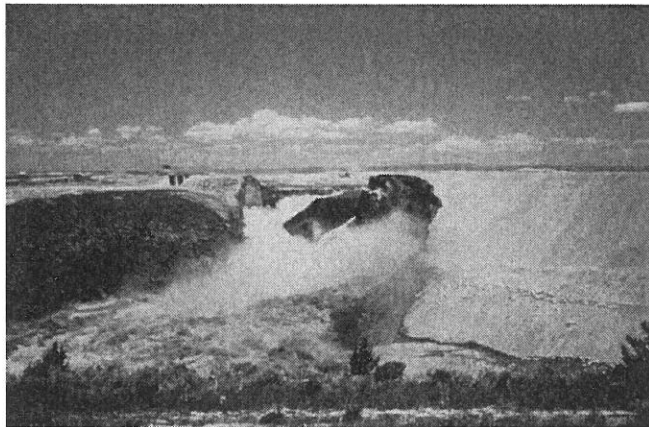
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Teton Dam Failure Photograph 3/5



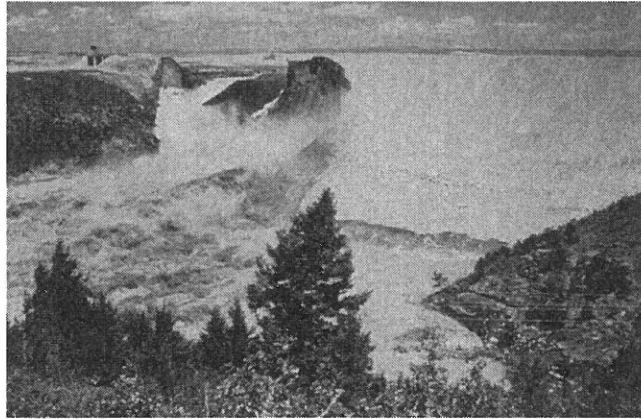
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Teton Dam Failure Photograph 4/5



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Teton Dam Failure Photograph 5/5



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Piping Failure

Eureka Wastewater Holding Pond Dike

- July 8, 1995 --After a major storm
- 30 foot deep gullies on private property
- No fatalities
- Environmental Damage



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Eureka Pond Dike Failure View of Breached Embankment



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Eureka Pond Dike Failure View of Eroded Embankment



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Trees & Man-made Features

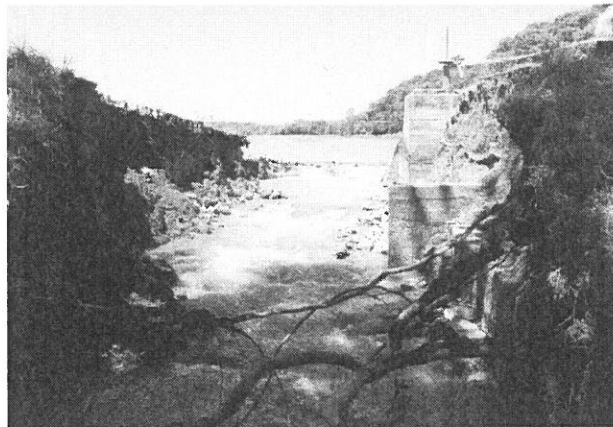
Trees

- Roots can cause piping
- Overturned trees can result in overtopping
- Brush prevents inspection and early detection of seepage & piping



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Tree Roots Can Cause Piping



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Overturned Trees Can Lead to Overtopping



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Trees & Man-made Features

Man-made features

- **Conduits & Drains can cause piping**
- **Slabs & Docks prevent inspection**
- **Pilings can cause piping**
- **Excavations for man-made features can lead to overtopping & stability failure**



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Drains Can Lead to Piping Failure



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Slabs Can Inhibit Inspection and Lead to Overtopping



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Rodents & Burrows

Groundhogs

- Burrows are above phreatic surface
- Tunnel network
- Evidence is mounds of fresh dirt in the spring
- Burrows can lead to seepage, then piping
- Controlled by fumigants or shooting
- Mowed vegetation



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Rodents & Burrows

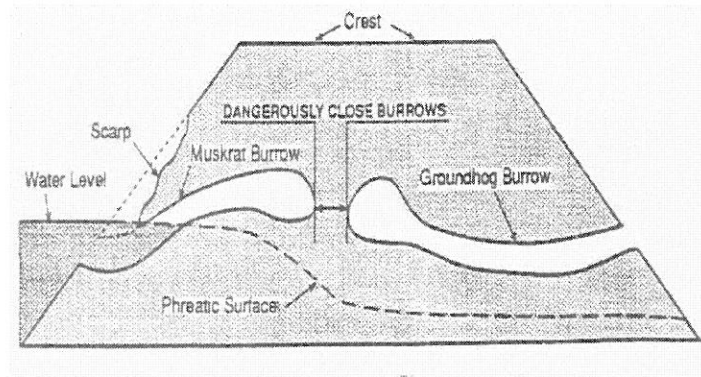
Muskrats

- Burrows begin 12 to 18 inches below water level and tunnel upward above water table
- Tunnels can be over 15 ft long
- Tunnels lead to seepage, then rapid piping
- Controlled with filters and riprap
- Eliminate vegetation below water level
- Controlled by trapping



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Rodent Burrow Damage



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Other Rodent Problems

Beavers

- Plug spillways & outlets, reduce capacity
- General nuisance
- Controllable by trapping (regulated)
- Controllable by removing cuttings



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Recommendations

Know your spilling & storage capacities

- Translate into “easy to understand” terms
- Emergency Action Plan
- Upgrade Program if deficient



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Recommendations

Seepage & Leakage

- Monitoring Program with weirs & piezometers
- Read & Record
 - Monthly, Quarterly, Semi-Annual
- Turbidity Measurements



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Recommendations

- **Keep the dam crest and slopes free of trees and brush**
- **Prohibit man-made structures on the crest and slopes**
- **Mow the crest and downstream stream slope**
- **Keep the spillway and outlet obstruction-free**



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Recommendations

- **Inspect the dam bi-annually**
 - **Rodents**
 - **Seepage**
 - **Slumping**
 - **Vegetation**
 - **Spillway and Outlets**
- **Hire an Expert Inspector Every 5 Years**



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