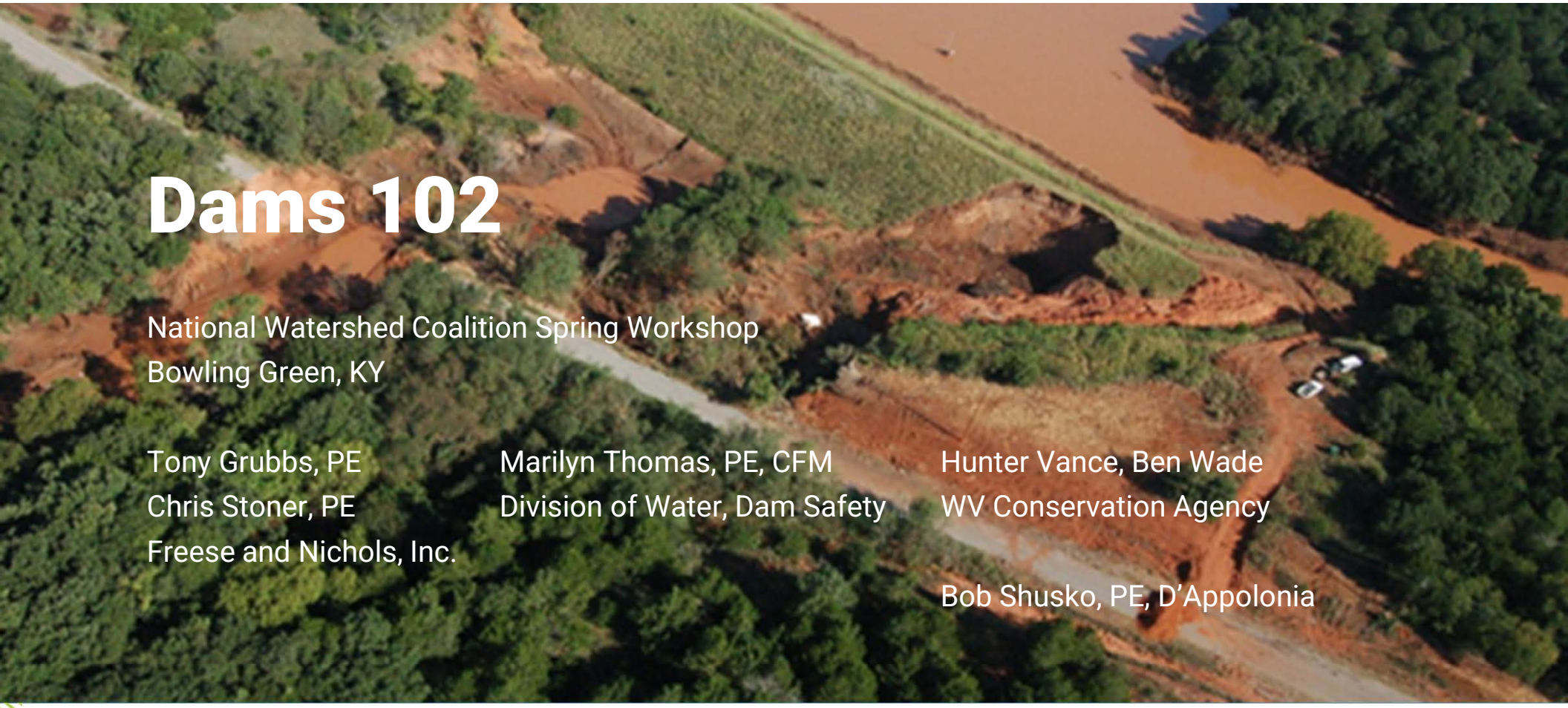


# Dams 102

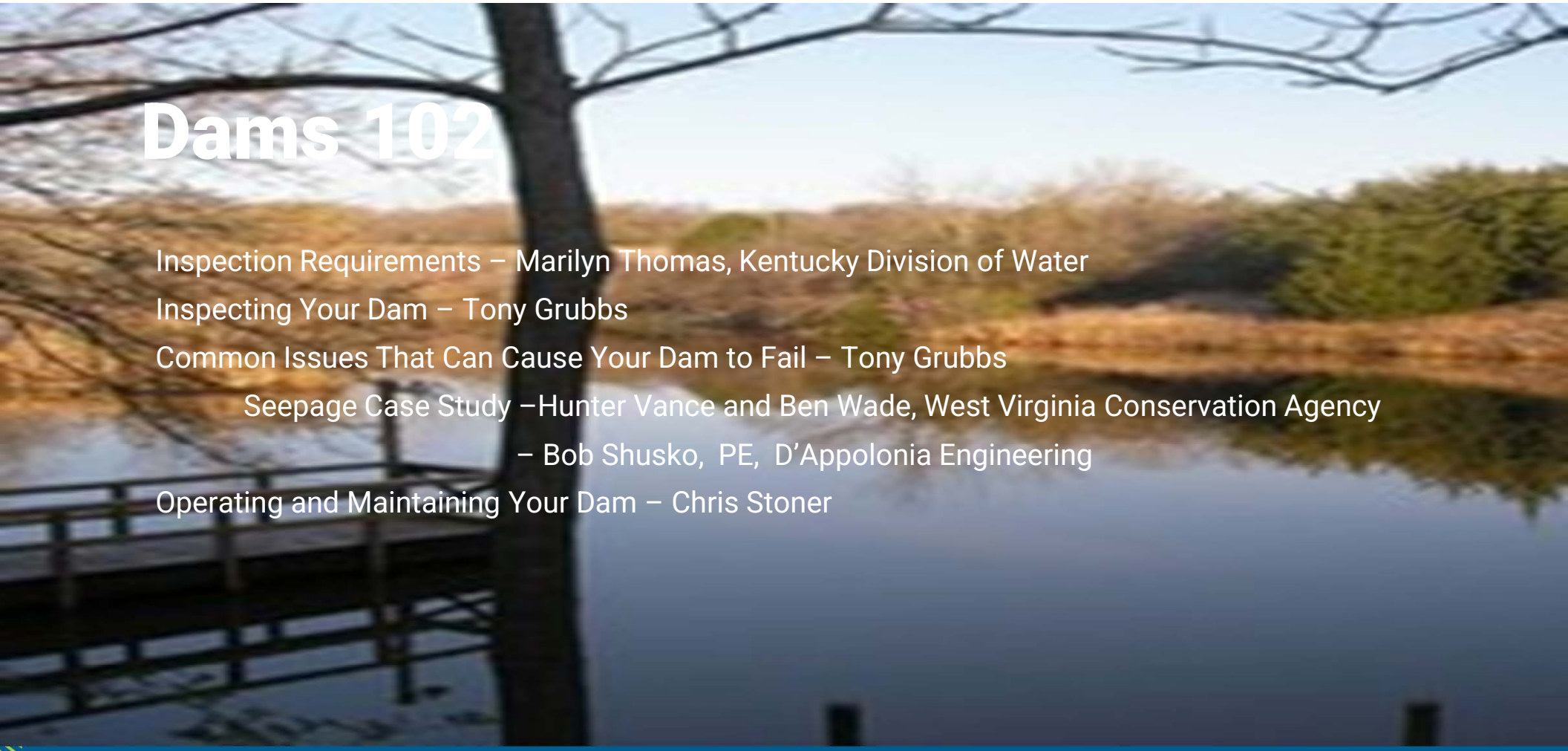
National Watershed Coalition Spring Workshop
Bowling Green, KY


Tony Grubbs, PE
Chris Stoner, PE
Freese and Nichols, Inc.

Marilyn Thomas, PE, CFM
Division of Water, Dam Safety

Hunter Vance, Ben Wade
WV Conservation Agency

Bob Shusko, PE, D'Appolonia



# Dams 102

Inspection Requirements – Marilyn Thomas, Kentucky Division of Water

Inspecting Your Dam – Tony Grubbs

Common Issues That Can Cause Your Dam to Fail – Tony Grubbs

Seepage Case Study –Hunter Vance and Ben Wade, West Virginia Conservation Agency

– Bob Shusko, PE, D'Appolonia Engineering

Operating and Maintaining Your Dam – Chris Stoner

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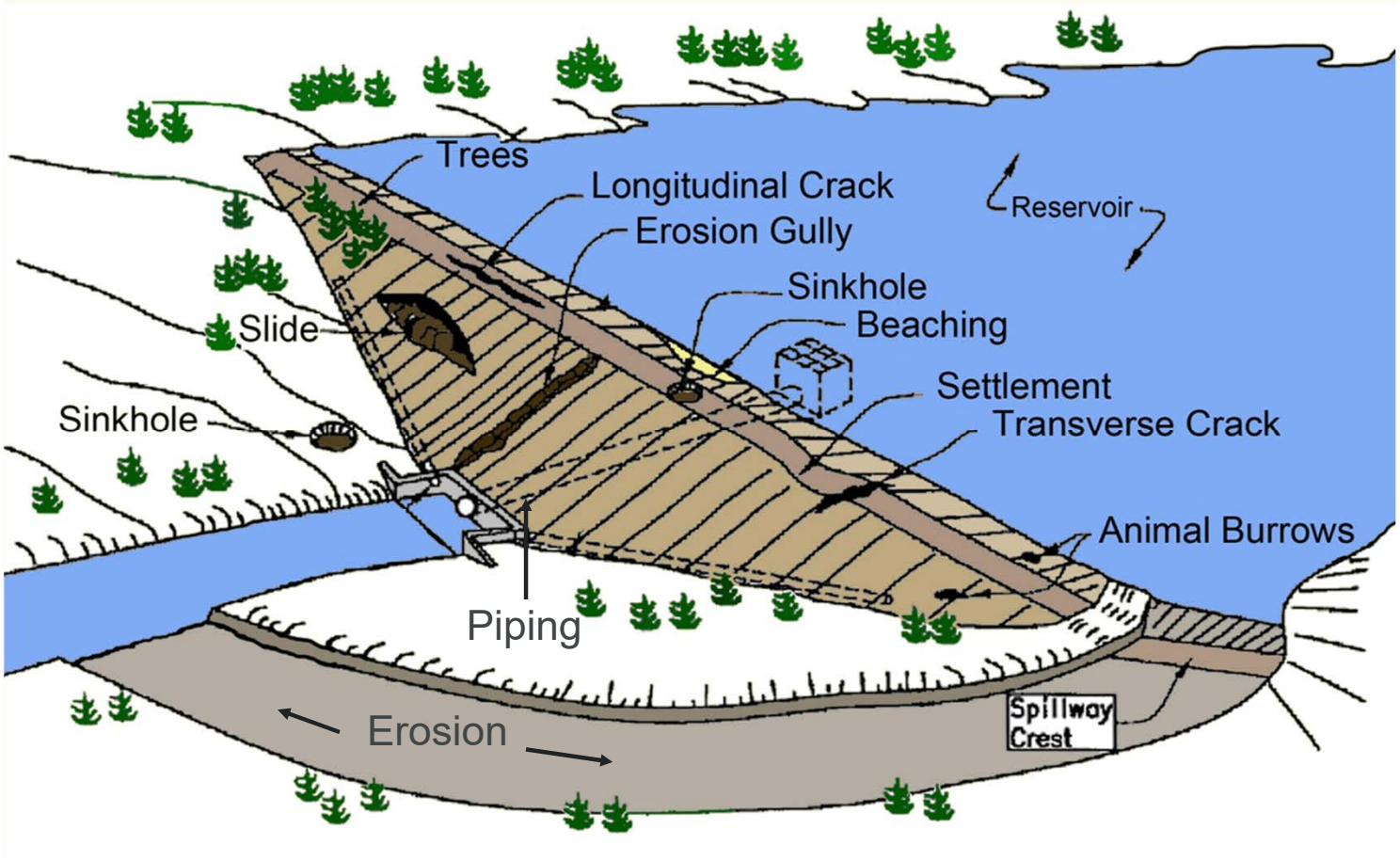
# Kentucky Inspection Requirements

# Causes of Dam Failures

- Natural events – floods and earthquakes
- Design flaw(s)
- Construction defects/inferior construction materials
- Age/lack of maintenance
- Unstable foundation/abutment
- Seepage/leakage
- Mechanical equipment failure (gates, valves)
- Misoperation of equipment (gates, valves)

# Common Defects in Earth Dams



# Main Areas to Inspect

Upstream Slope

Crest

Downstream Slope

Groins and Downstream Toe

All Spillway Inlets and Outlets

# Inspections

Annual

Following Storms

Following Earthquakes

Hazard Classification Reviews

Formal Inspections of HHP Dams

| Type | Frequency | Scope |
|---|---|---|
| **Annual** | **366 days** | • **Performed by registered P.E.**<br>• **Thorough site inspection**<br>• **Verify structural integrity**<br>• **Review documentation**<br>• **Evaluation of changes in performance**<br>• **Conduct supplementary analyses**<br>• **Develop recommendations for repairs** |
| **Special** | **Immediately after unusual event** | |
| **Monthly** | **31 days** | • **Weekly/monthly inspections coordinated with facility management, and performed by owner personnel**<br>• **Limited site inspection, with focus on any problem areas**<br>• **Identify any emerging condition** |
| **Weekly** | **7 days** | |
| **After Storms** | **After Storm** | |

# Annual Inspections

- Typically, independent P.E. experienced in dams/levees, may be supported by a team of specialists (e.g., civil engineer, geologist, structural engineer, mechanical engineer, hydrologist)
- Thorough review of existing documentation (find any inherent weaknesses in the dam)
- Review performance since the last inspection
- Review instrumentation and pipe inspections
- Conduct supplementary analyses of any emerging issues
- Reaches consensus on repairs/remedial measures
- Documents inspection with report and photos
- Diving inspection may be considered for underwater structures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# Monthly/Weekly/After Storms

- Should be conducted by Owner staff
- Review recent inspection documents and communications on changing conditions
- Be Safe

# Special Inspections

- Safety of the dam and protection of downstream population from immediate threat
- Unusual event
- Significant Rain Event
- Earthquake
- Emergency Event

# Importance of Inspecting Under Varying Conditions

- Perform inspections under different water levels to observe differences in the dam's performance, or to observe normally unobserved features.
  - Higher Pool Levels: May detect seepage conditions that may not have been present during lower pools
  - Lower Pool Levels: May be able to inspect features that are normally underwater (upstream riprap, trashracks, intake structures)
- May require adjusting the date of a scheduled inspection or performing an unscheduled inspection.

# Importance of Inspecting Under Similar Conditions

- Inspect at similar water levels to determine if performance of the dam changes over time under the same loading conditions (phreatic surface, seepage gradient, wave loading)
  - Ex: Increase in toe drain seepage flow under similar pool levels
  - Ex: Increase in water levels in piezometers under similar pool levels
  - Ex: Increase in upstream slope erosion

# Other Critical Times to Inspect or to Increase Frequency of Inspections

- When there has been a significant change in historic inspection observations
  - New (or increase in) seepage or water-loving vegetation
  - New/enlarged crack or sloughing
  - New/enlarged depression or sinkhole
- After unusual events (floods, earthquakes, nearby construction, etc.)

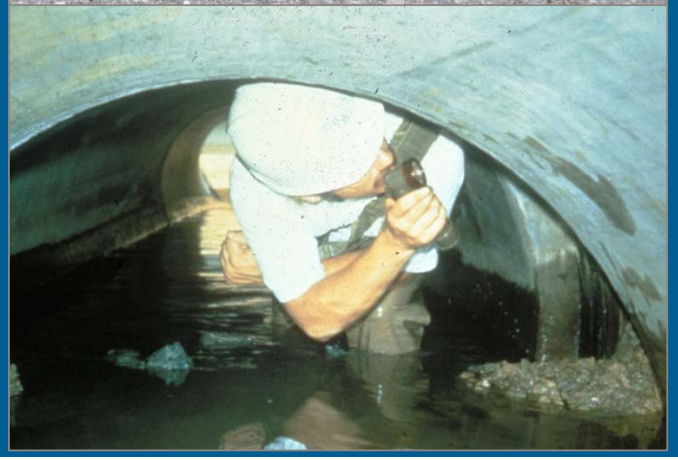
# Site Preparation

## Before

## After

# Health and Safety

- What are the hazards?
- What PPE is needed?
- Special concerns for specific types of inspections:
  - Confined Space
    - Outlet works, pipes, valve housings, manholes, etc. **Confined space entry should NOT be performed during routine inspections**
  - Water hazards, boat inspections, underwater inspections, swift water – **NOT** part of a routine inspection



# Causes of Dam Failures

www.damsafety.org

# Minnesota's Rapidan Dam at risk of 'failure' amid severe flooding

The Rapidan Dam, built in 1910, is located on the Blue Earth River in Minnesota.

By Leah Sarnoff
June 25, 2024, 5:47 PM



# Final report says Edenville Dam failure was preventable, casts broad blame

By: Ryan Jeltema May 5, 2022 Updated May 19, 2023 0

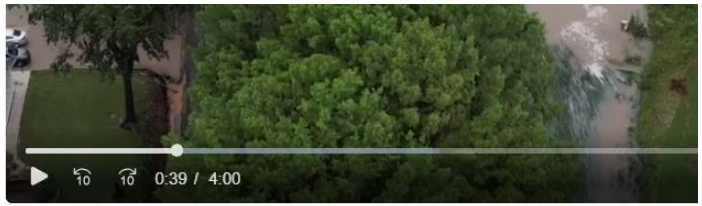
4 of 11

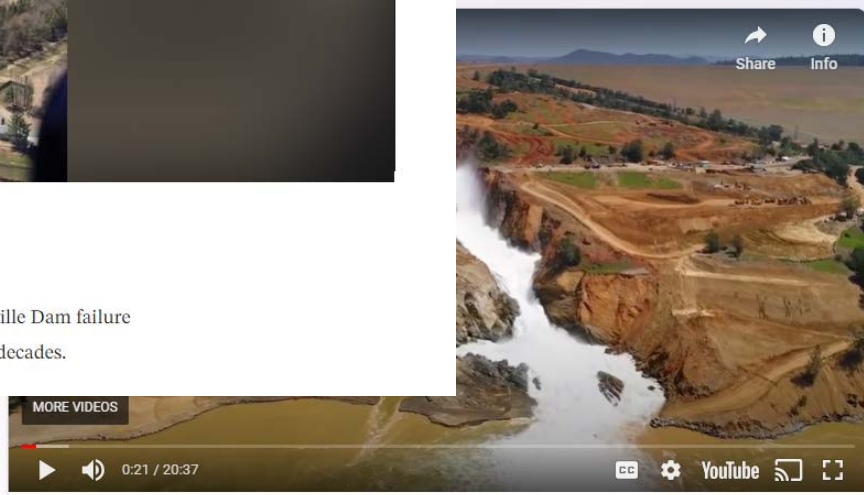
The Edenville Dam failed on May 19, 2020.

MID-MICHIGAN (WJRT) - The final report on what caused the Edenville Dam failure nearly two years ago casts wide blame for the catastrophe dating back decades.


Spencer Dam Destroyed by Flood Waters - Historic Flooding in N

YouTube | KRVN Video | 13K views | Mar 17, 2019



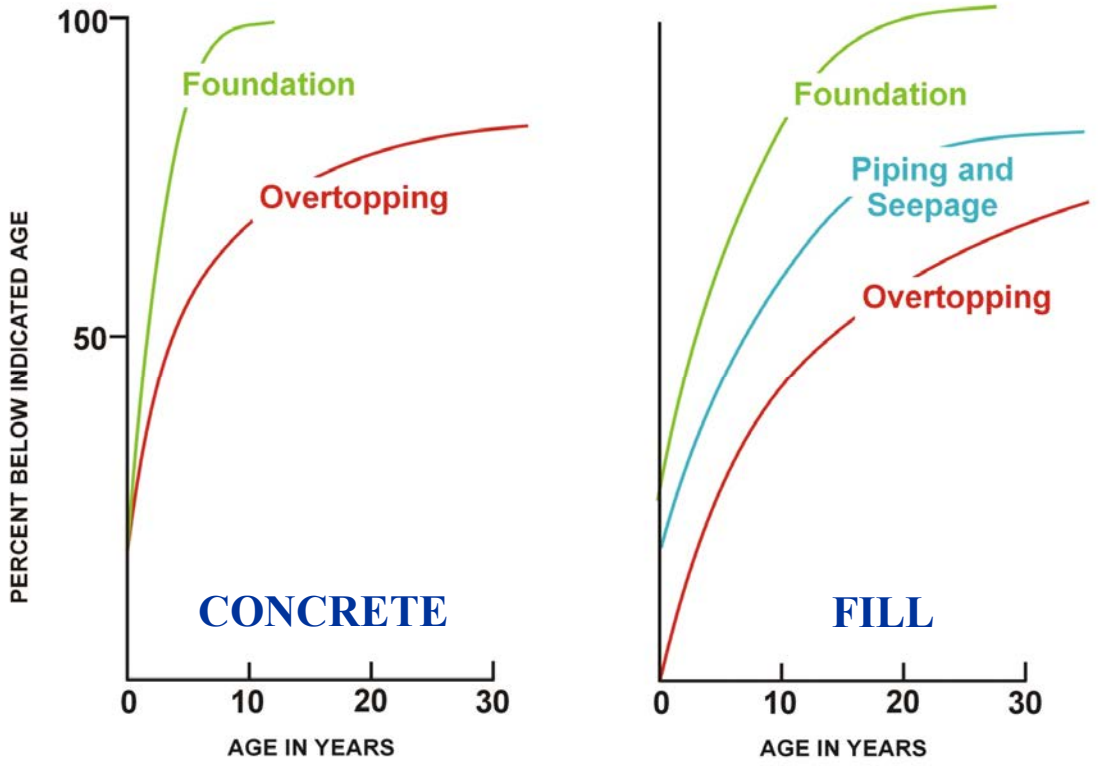

Rebuilding the Oroville Dam Spillways

YouTube | Practical Engineering | 2.6M views | Dec 21, 2021

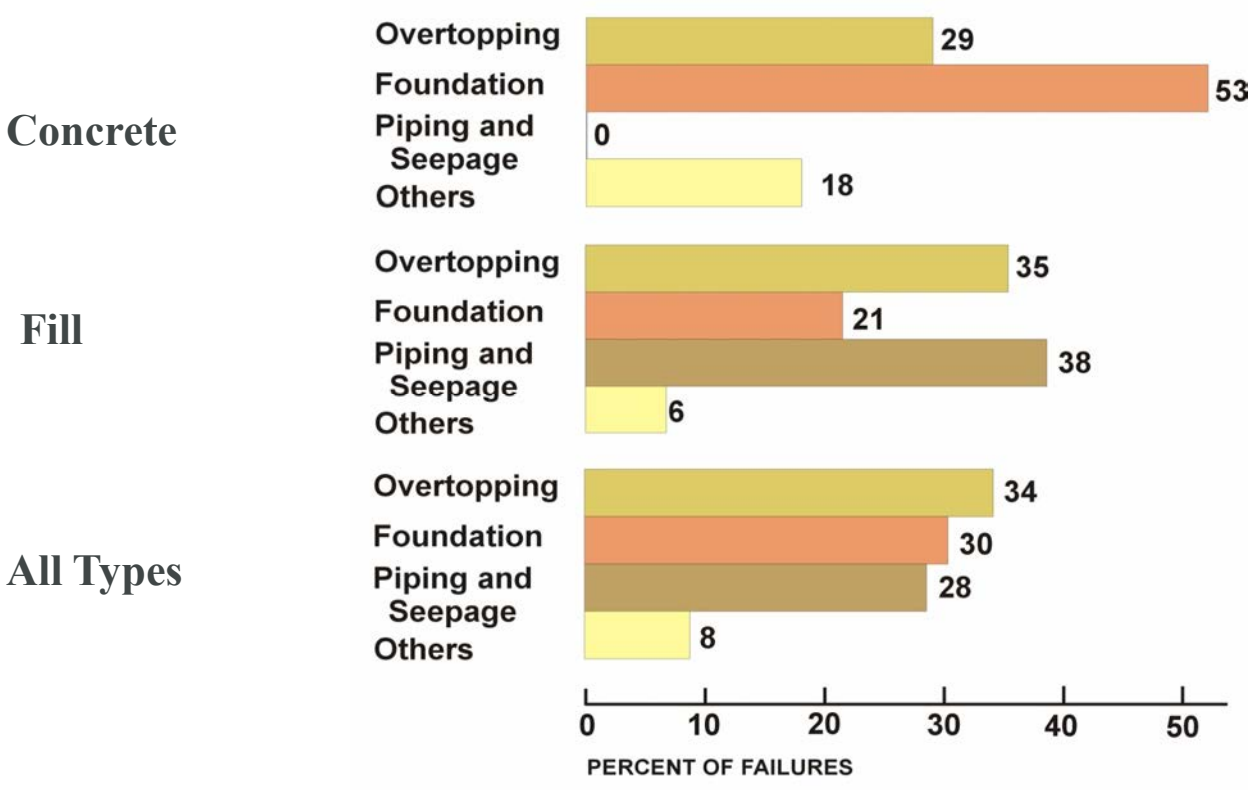
# Statistics On Dam Failures

# Dam Failures by Age of Dam

Over 15 m height



# Dam Failures by Type of Dam



# Causes Of Dam Failures

- Extreme Natural Events
- Inadequate Design
- Poor Operation and/or Maintenance
- Vandalism
- *Construction Defects*

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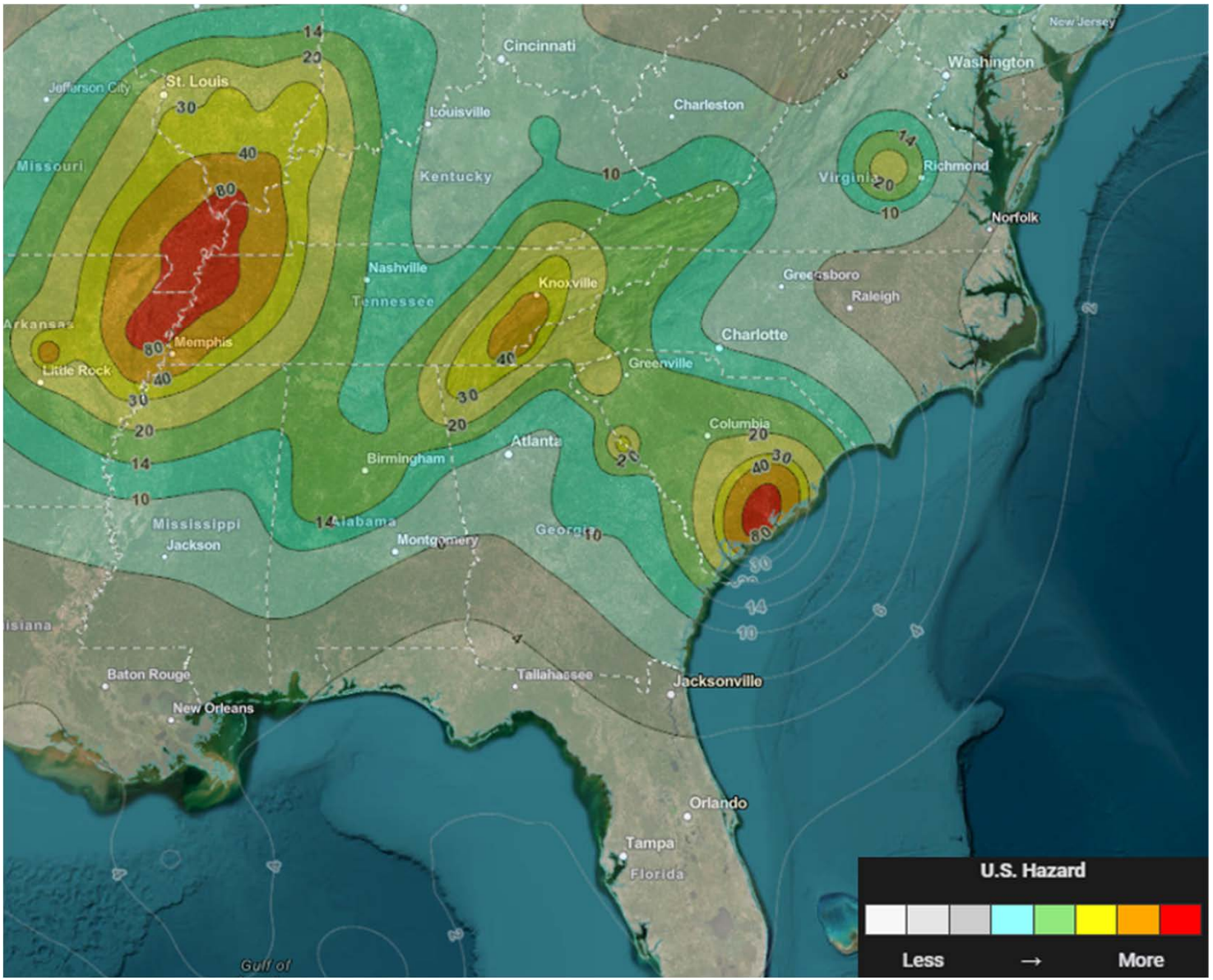
# Extreme Natural Events

- Excessive Rainfall
  - Overtopping
  - Erosion
- Earthquake
  - Slope Failure
  - Liquefaction
  - Structural Failure

# Overtopping

# Earthquakes



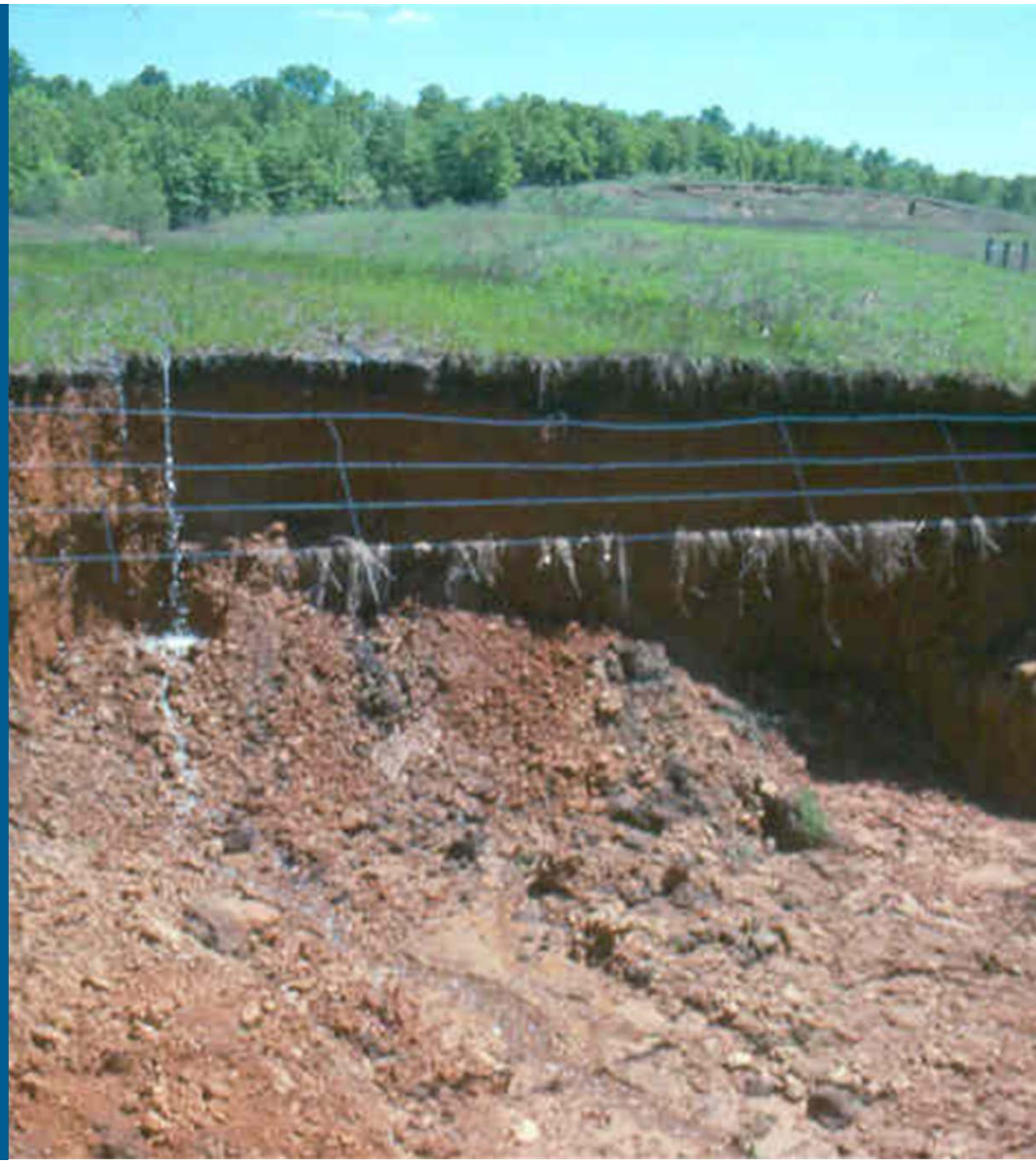
# Slope Failure


# Structural Failure

# Inadequate Design

- Overtopping
- Spillway Failure (Erosion)
- Slope Failure
- Uncontrolled Seepage (Piping)
- Structural Failure
- Differential Settlement

# Spillway Erosion



# Uncontrolled Seepage and Piping

# Spillway Undermining/Scour

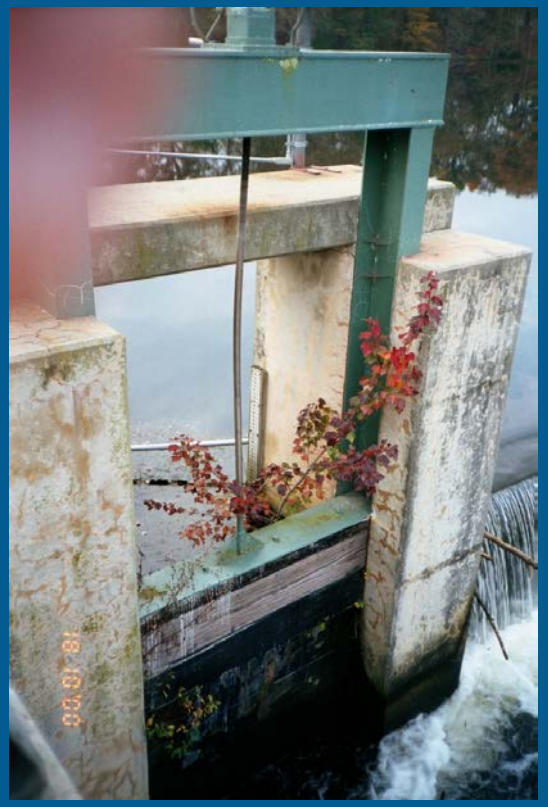
# Cracks Due to Differential Settlement

# Poor Operation and Maintenance

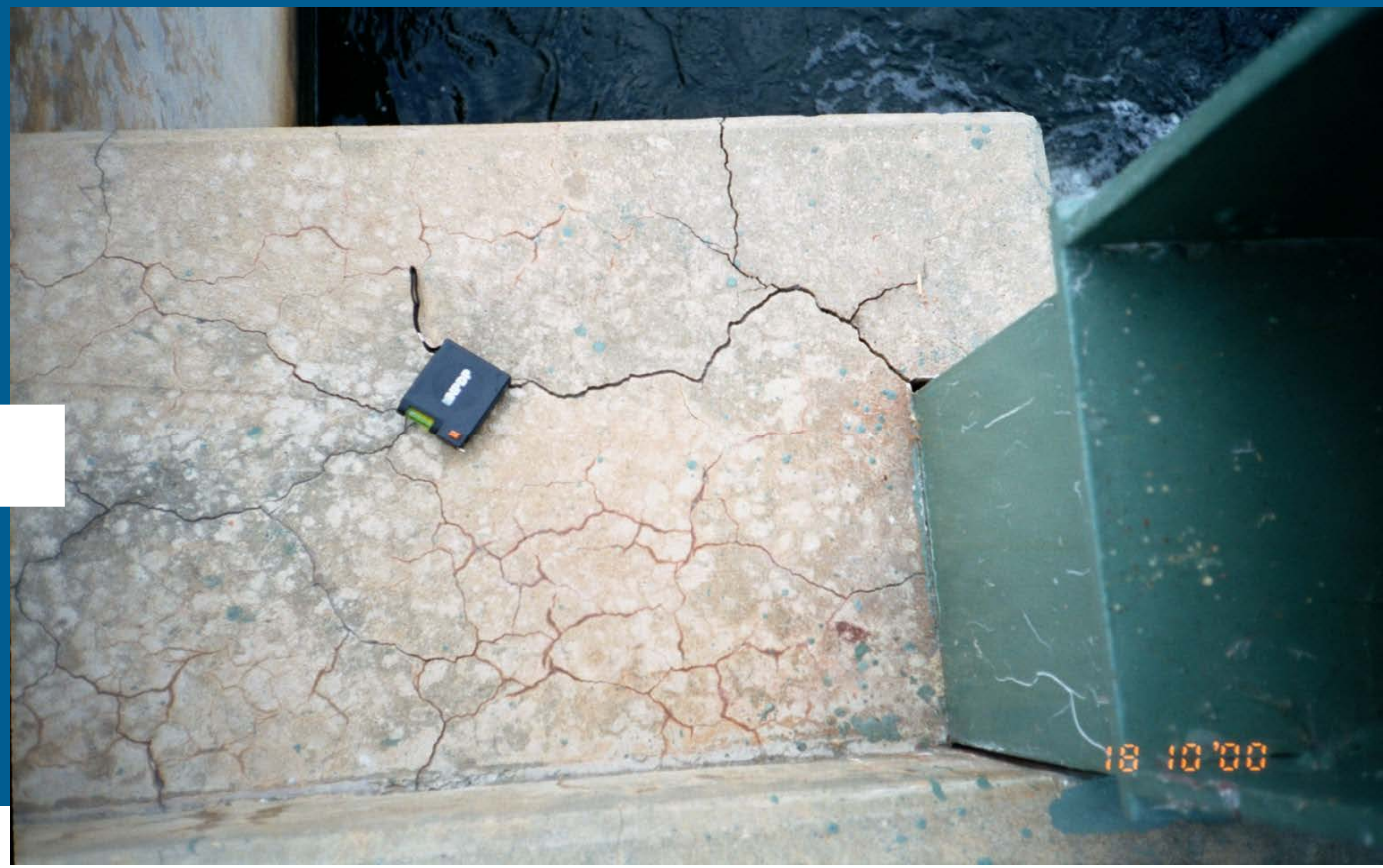
- Inoperable Gates
- Concrete Deterioration
- Conduit Deterioration/Seepage
- Blocked Spillways
- Plugged Embankment Drains
- Inadequate Vegetation Control
- Animal Activity
- Unapproved Modifications

# Inoperable Gates

Bent Stem, Trash and Woody Vegetation Makes Gate Inoperable During Emergency



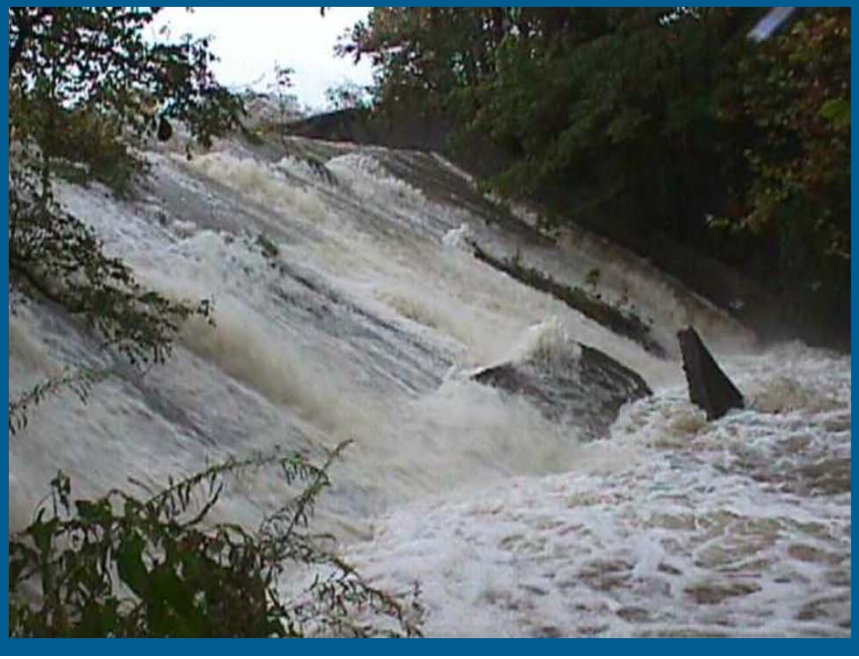
# Concrete Deterioration




Concrete Deterioration That Could Result In Structural Failure

# Concrete Deterioration

Deteriorated Concrete Spillway Can Lead To Failure During Flow

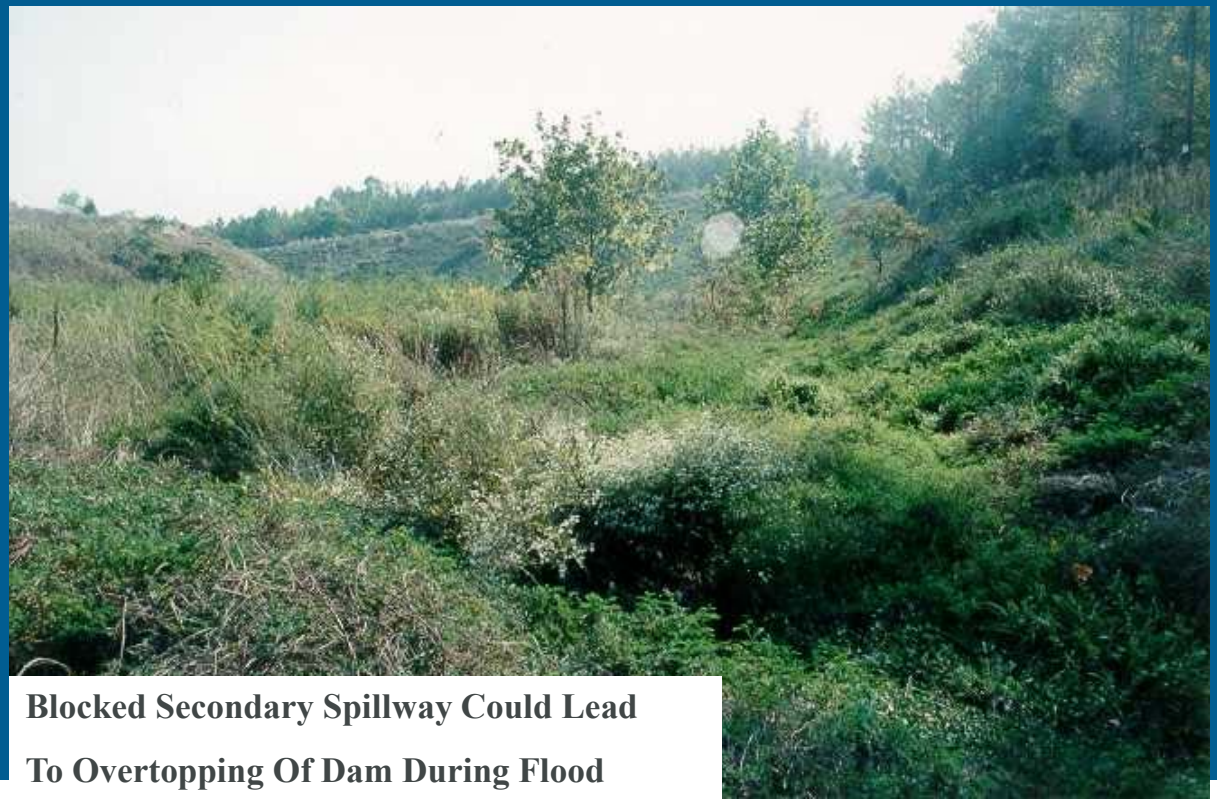


# Conduit Leakage

**Seepage Into the Conduit Could Lead To Piping a Failure Of The Embankment**

# Blocked Outlet Works

# Blocked Secondary Spillway



Blocked Secondary Spillway Could Lead To Overtopping Of Dam During Flood

# Secondary/Auxiliary Spillways are designed to flow!

# Minor discontinuities can cause major problems:

# Even small trees can cause big problems

# Plugged Drains

# Inadequate Vegetation Control

**Inadequate Vegetation Control Leads To Animal Borrows, Root Development and Poor Inspection - All Of Which Could Lead To Dam Deterioration and Failure**

# Remove Small Trees and Brush from Dam & Spillway

# Trees & Brush

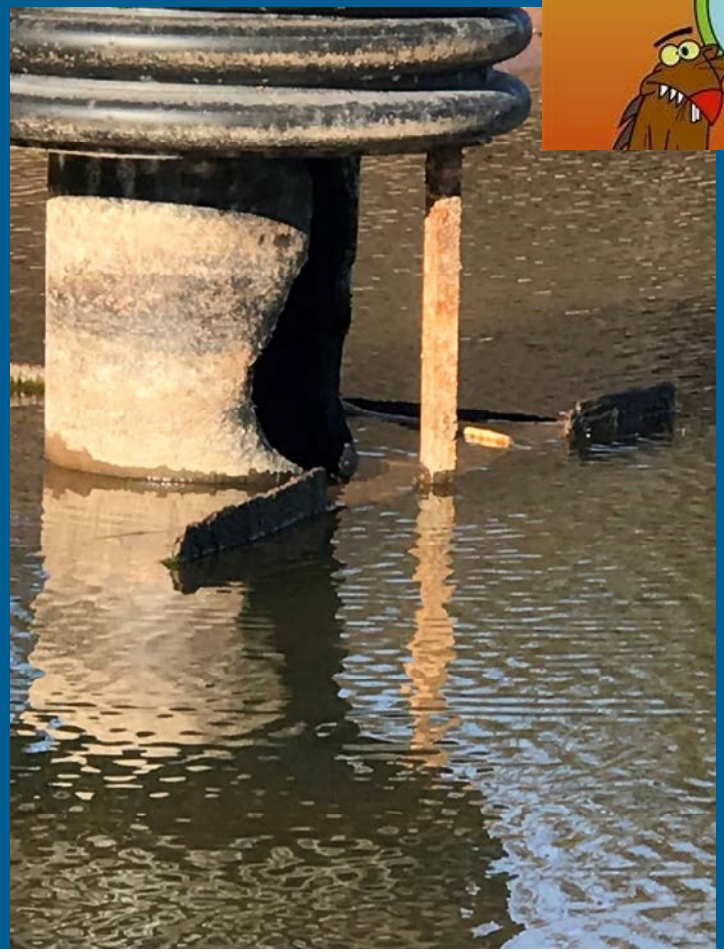
- Contrary to what some like to say, tree roots do not hold the dam together.
- Roots die and can leave a void for water to pass through.
- Trees can uproot and fall during a storm leaving a big hole in the dam.

# Inadequate Vegetation ~~Control~~

# Avoid Overgrazing of the Dam and Spillway

**(Please do not feed hay in the spillway)**

# Animal Activity

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Wildlife control is provided by permitted operators and is not a free service. The Kentucky Department of Fish & Wildlife does not give preference to any specific operators. Please use your own judgment when selecting an operator.
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# Unapproved Modifications

# Unapproved Modifications

**Road Access Added Over Crest Of Dam Resulted In Lowering Of Crest In That Area That Could Lead To Overtopping**

# Unapproved Modifications

# Seepage - Piping

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# Seepage

- Major cause of failure of dams
- Increase in seepage rate under similar pool level
  - Indicator of development of concentrated seepage paths and piping
- Decrease in seepage rate under similar pool level
  - Indicator of plugged drains (look for seepage in new areas)

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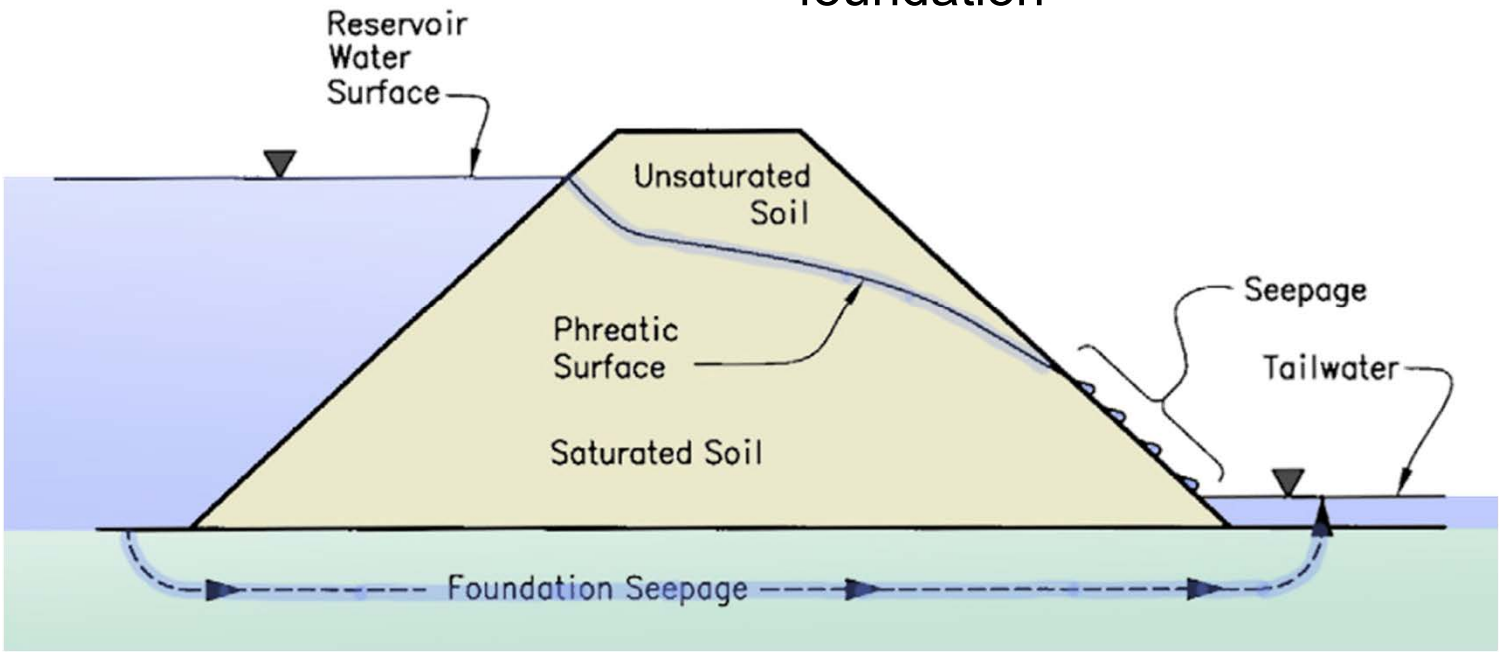
# Seepage

Seepage paths through embankment and foundation



# Seepage

## Sand Boil

## Cloudy Discharge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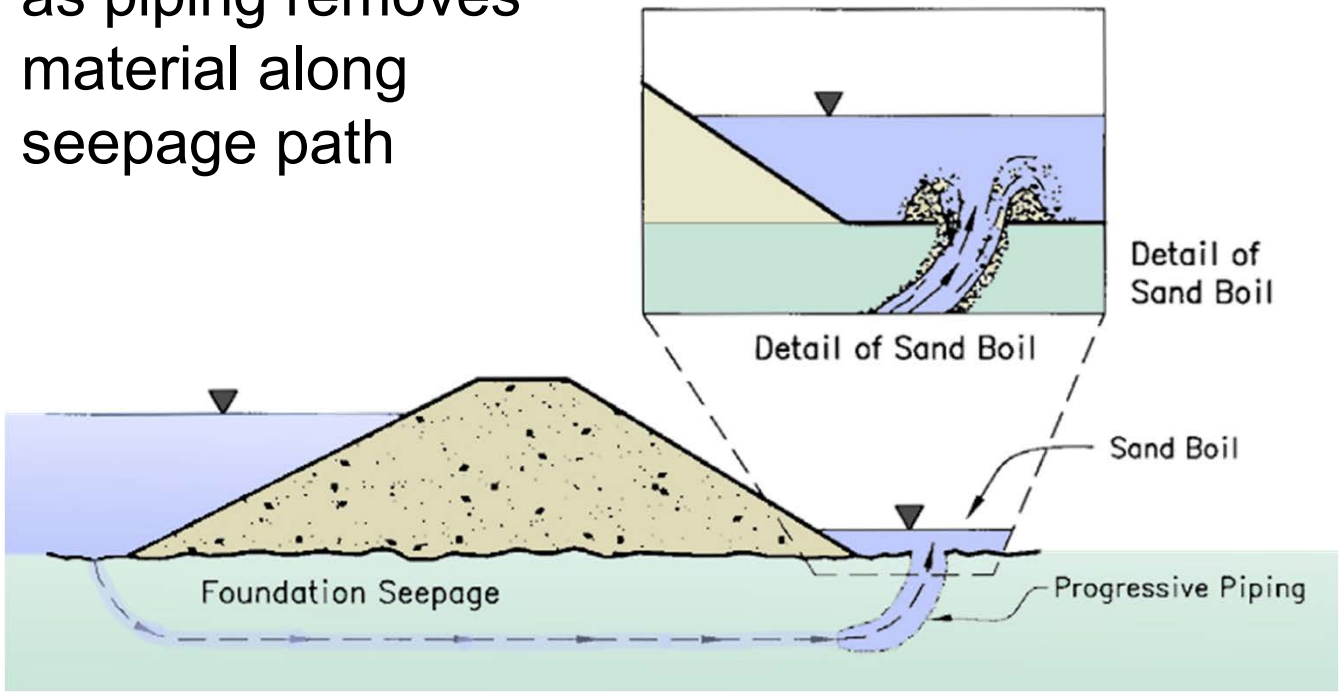
# Sand Boils

Sandboils develop as piping removes material along seepage path



# Sand Boils

- Bubbling up or “boiling action” caused by high seepage exit velocities usually in fine sandy soil
- Sand boils may indicate piping; look for:
  - Cloudy discharge
  - Cone of sand around seepage exit point
- Take immediate action:
  - Record pool level and elevation/location of boil
  - Photograph
  - Record seepage flow
  - **Contact management**

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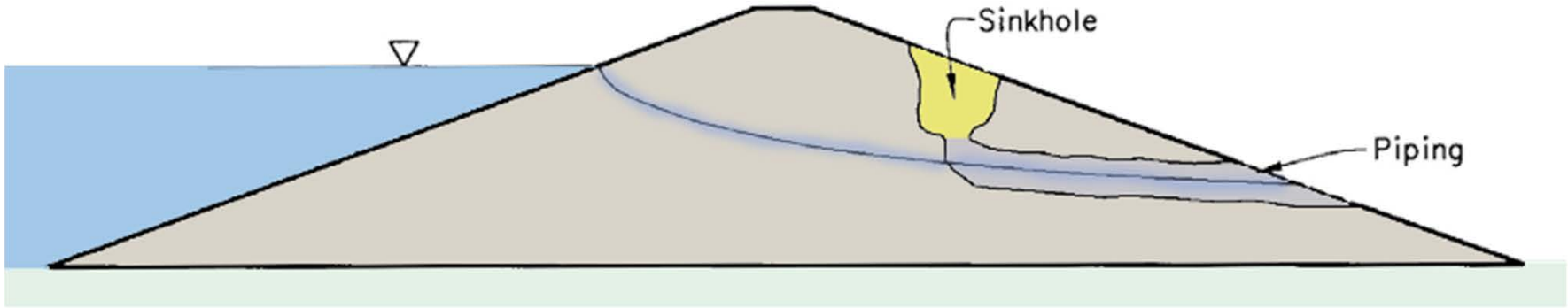
# Downstream Slope – Sinkholes




- Sinkholes are caused by loss of embankment or foundation material, causing surface collapse
- Typically have steep sides
- May indicate piping or internal erosion (e.g., along outlet works conduit)
- Can be caused by animal burrows or decomposition of organic matter
- Check for sandboils and cloudy seepage downstream

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# Downstream Slope – Sinkhole

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# Seepage Inspection Tips

Most common seepage locations:

- Downstream slope
- Abutment groins
- Penetrations through embankment (outlets and drains)

Look for:

- Areas of green, lush/wetland vegetation
- Abrupt changes or horizontal lines of greener vegetation
- Flowing water
- Turbid or cloudy water

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# Seepage Inspection Tips

If seepage is observed, record:

1. Location of seepage
2. Flow rate:  use weir, flume, or bucket and stopwatch

   Note: Typical garden hose flow varies from 9-12 gpm
3. Pool level
4. Flowing clear/cloudy
5. Photograph
6. Compare flow with previous readings with similar pool level

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# Summary

**CONTACT APPROPRIATE PERSONNEL IMMEDIATELY IF YOU OBSERVE:**

- Sand boils or turbid seepage.
- Seepage that has increased since the last inspection (consider changing basin level).
- Cracks that extend below the pool level or potential pool level.
- Transverse and longitudinal large cracking in the embankment.
- Deep-seated slides or bulging associated with slides.
- Sinkholes or other large depressions.

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# Seepage Case History

www.damsafety.org

# Operation and Maintenance

What you can (and should) do as a dam owner.

# Dams can overtop…

# Trails - Do Not Allow Paths to Develop on the Dam or in the Spillway


**Structures in Auxiliary Spillway**


# Structures in Auxiliary Spillway

# Seepage

# Plugged Drains

# Uncontrolled Seepage

**Plugged Embankment Drains Could Lead To Excessive Seepage and Boils That Could Lead To Embankment Failure**

# Encroachment


# Encroachment

Drill Pads & Locations


Flood Pool

# Energy Exploration

# Wind Energy

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Malcolm Baldrige National Quality Award Recipient **2010** & **2024**

# Thank you


www.watershed coalition.org

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