Best Practices in Dam and Levee Safety Risk Analysis

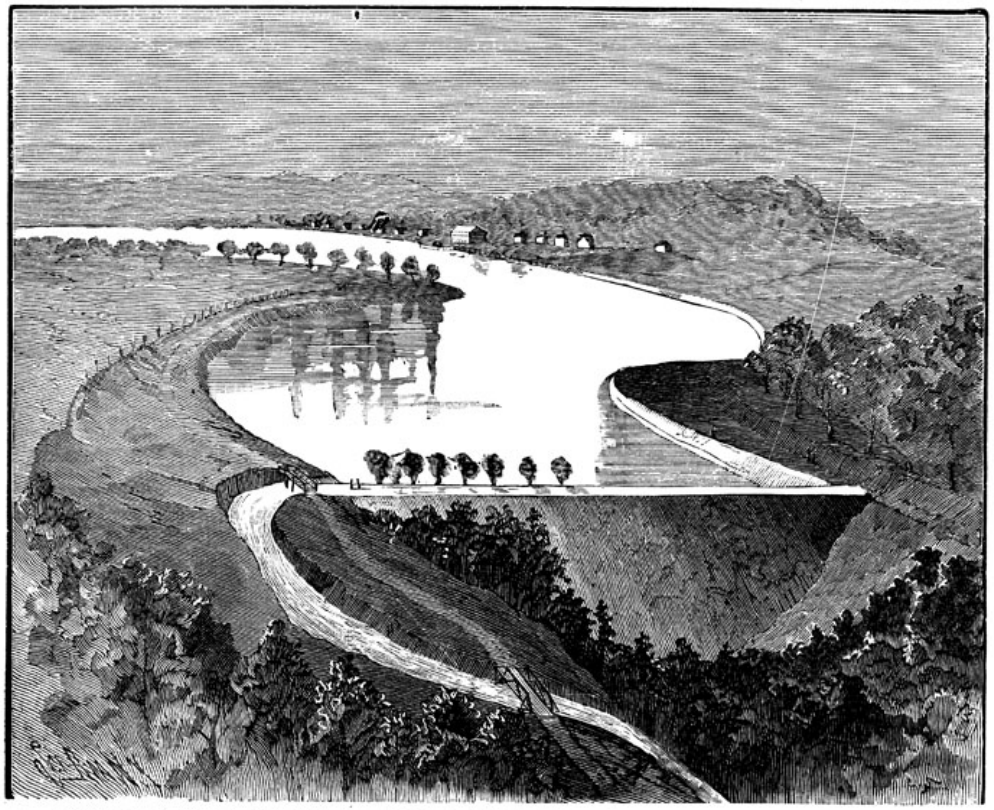
VIII-1. Operational Risks

19 March 2015

RECLAMATION
Managing Water in the West

US Army Corps of Engineers
BUILDING STRONG®

Etching of South Fork Dam and Spillway



SOUTH FORK LAKE BEFORE THE DESTRUCTION OF THE DAM.

- U/S of Johnstown, PA
- Owned by fishing club
- 72 feet high by 918 long
- Originally constructed of rolled earth (1840-1852)
  - Low level outlet through stone culvert
  - Puddled core material

South Fork Dam

- Failed in 1862 due to collapse of stone outlet conduit, reconstructed but outlet filled in
- Spillway:
  - Ungated overflow
  - 99 feet wide
  - Bridge across spillway with supports at 6-1/2 foot spacing
  - Iron Screens were placed across the spillway to prevent fish from escaping reduced spillway capacity by 40%
- Dam crest lowered to widen roadway so that carriages could pass
- No camber, center portion of dam crest lower

South Fork Dam

- Heavy rains in May of 1889
- Inflow greater than spillway capacity <u>and</u> fish screens became plugged with debris
- Dam overtopped and failed

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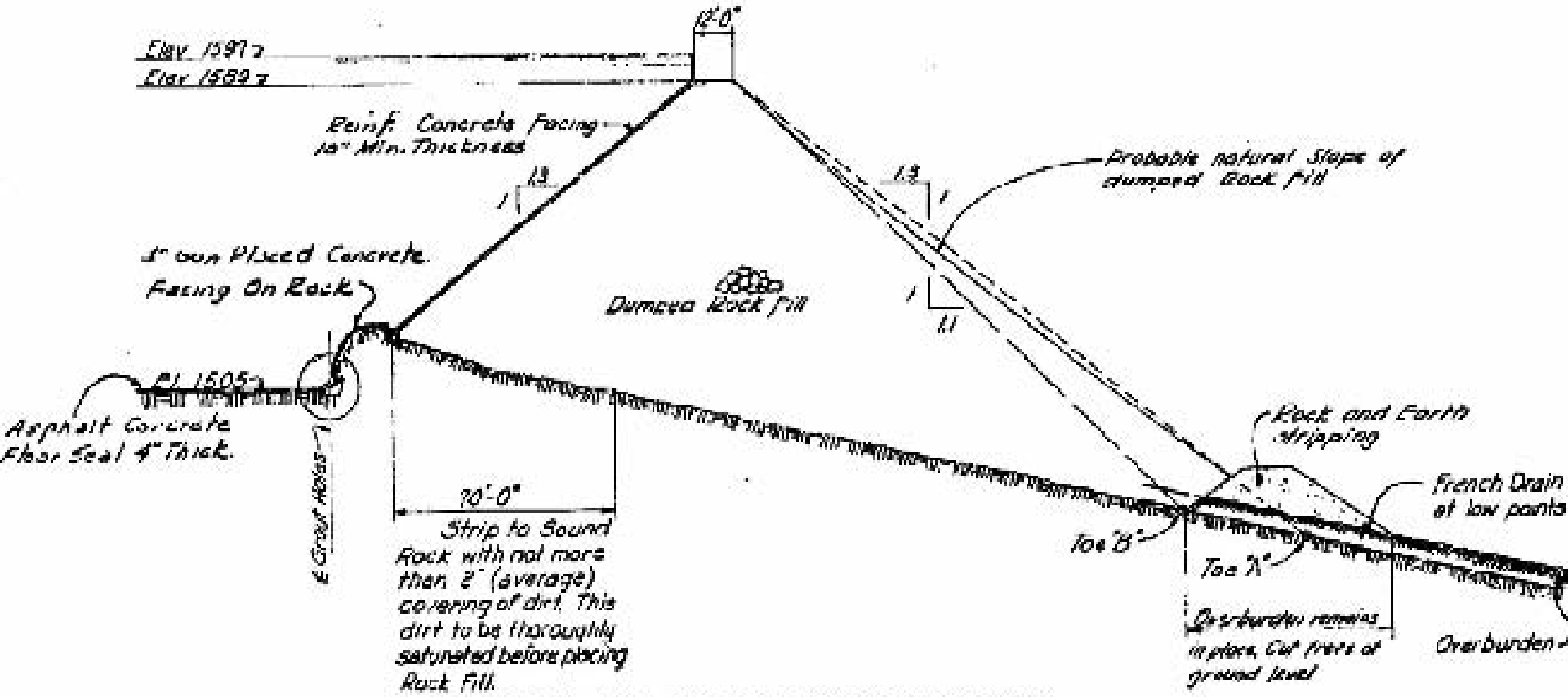
P.R.R.

Failure Consequences, Johnstown, PA

- 2,209 Deaths
- 99 entire families died, including 396 children
- The greatest loss of life due to failure of a man-made structure for a single event in the history of the United States until 9/11.

Taum Sauk

- Concrete-faced earthfill “ring-dike” structure
- Upper reservoir of pumped-storage project
- Water routinely stored on 10-foot high parapet



TYPICAL DIKE SECTION ON SOUND ROCK

Scale 1"=30'-0"

Taum Sauk

- Membrane liner installed in 2004
- Reservoir level instrumentation could not be reinstalled properly due to liner warranty issues
- Instruments were loose and not reading reservoir level properly
- Resetting of reservoir sensors did not account for settlement of embankment
- Alarms wired so high level and high-high level sensors both needed to trigger for alarm
- Over-pumping was not detected and dam overtopped and failed

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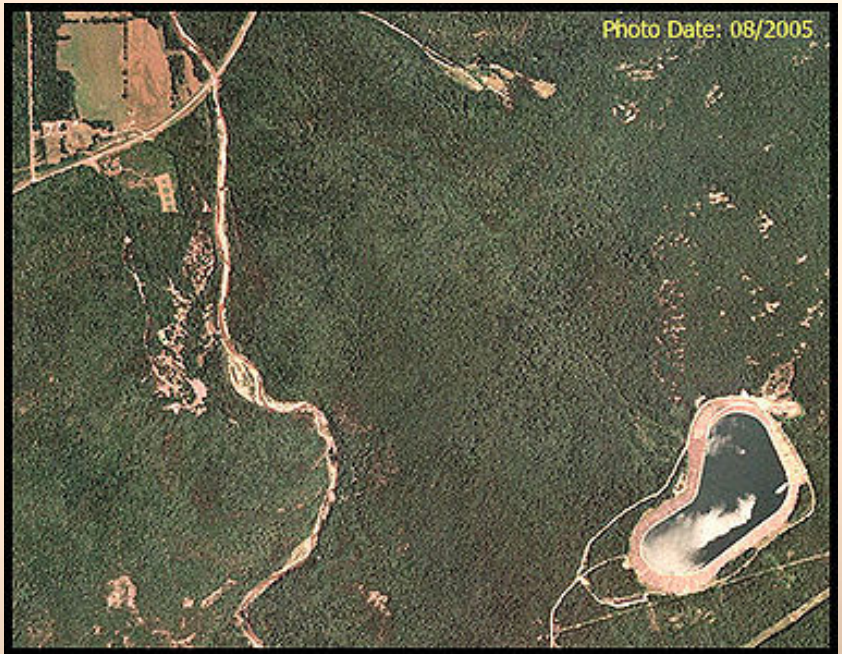
Taum Sauk

- 5 people in Ranger's house were miraculously thrown out of the way when the flood hit
- No one died



Taum Sauk

- Winter – campground not occupied
- No one died

Key Concepts

- Operational failure can include:
  - Debris plugs spillway (perhaps with log boom failure), dam overtops
  - Gates fail to open (hoists, chains, binding, electrical, remote communications), dam overtops
  - Gates open inadvertently – life-threatening flows
  - Communication breakdown – no warning d/s, control system doesn't work
  - Loss of access to operate gates, dam overtops
  - Loss of release capacity (e.g. turbine), dam overtops
  - Overfilling off-stream reservoir, dam overtops
  - Reluctance to open gates and flood people out
  - Operational changes adversely affect equipment needed to pass floods

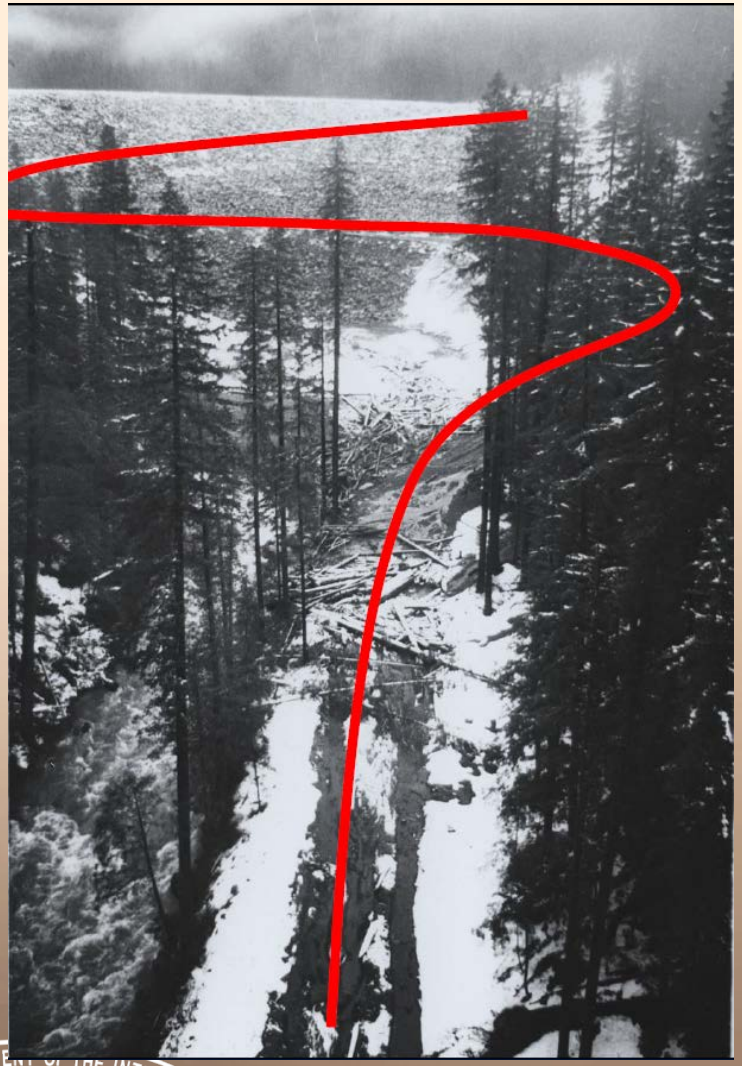
Data on Spillway (Lack of) Release Incidents

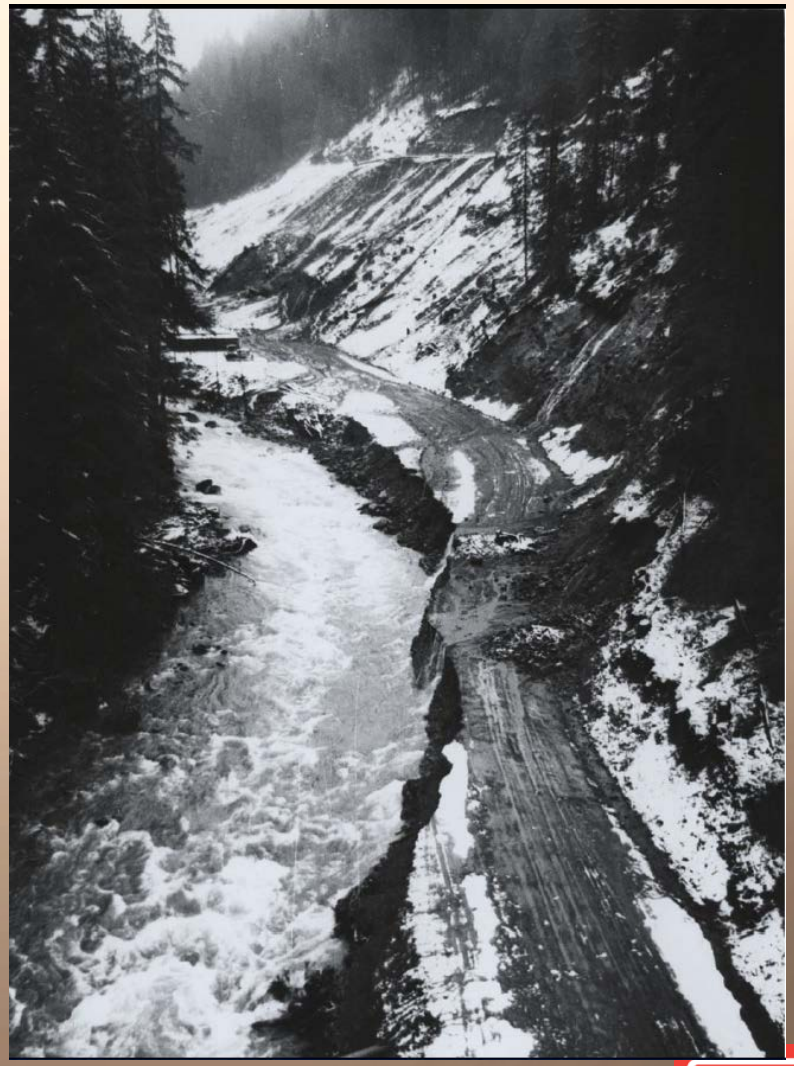
- National Performance of Dams Database
  - 24 incidents related to debris plugging
  - 19 incidents related to structural failure
  - 25 incidents related to mis-operation
- FERC Incident database
  - 6 incidents related to debris plugging

Picture of Palagendra Dam with Debris

Picture of Kerckhoff Dam w/ Debris

Project Access





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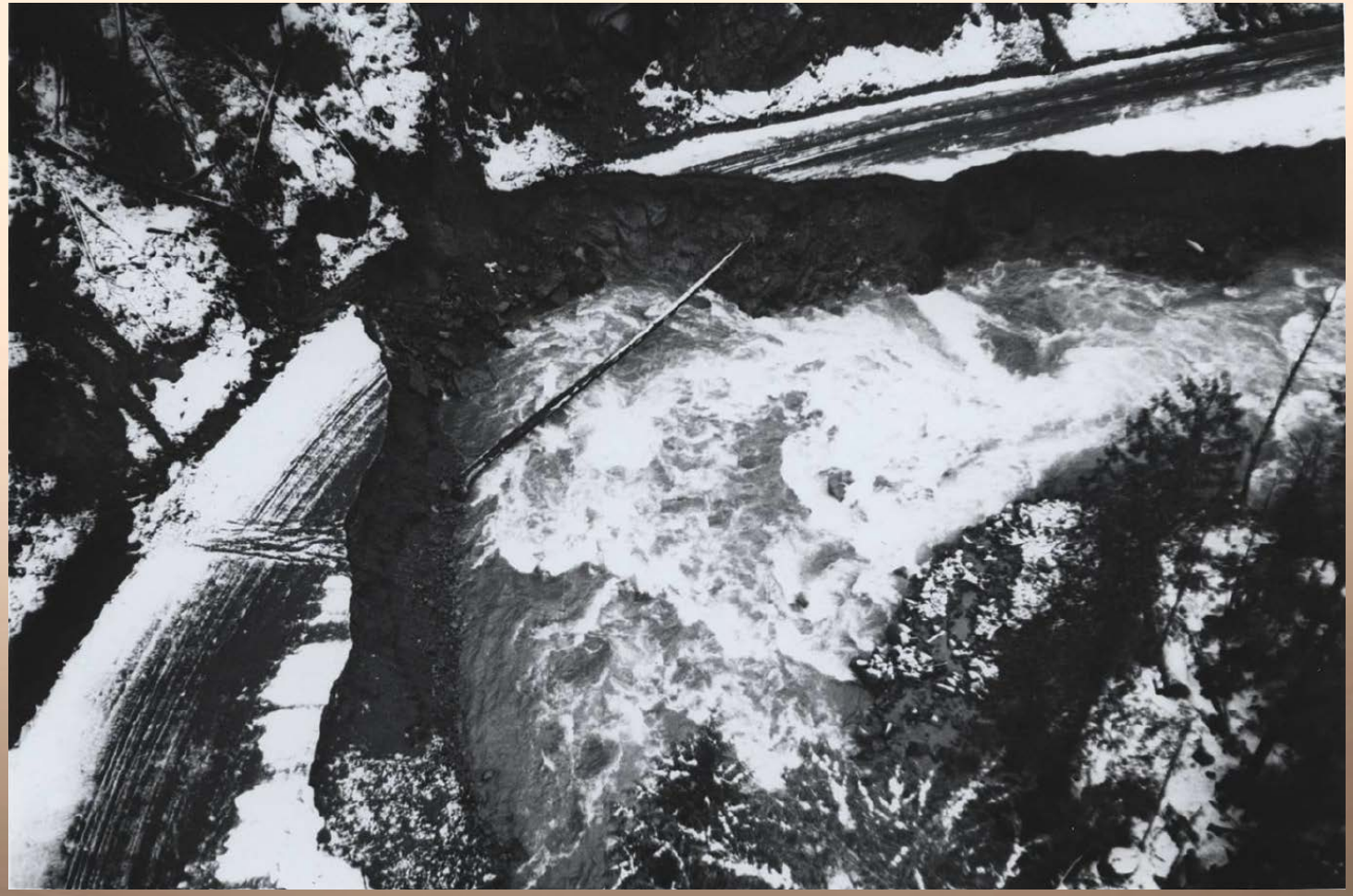
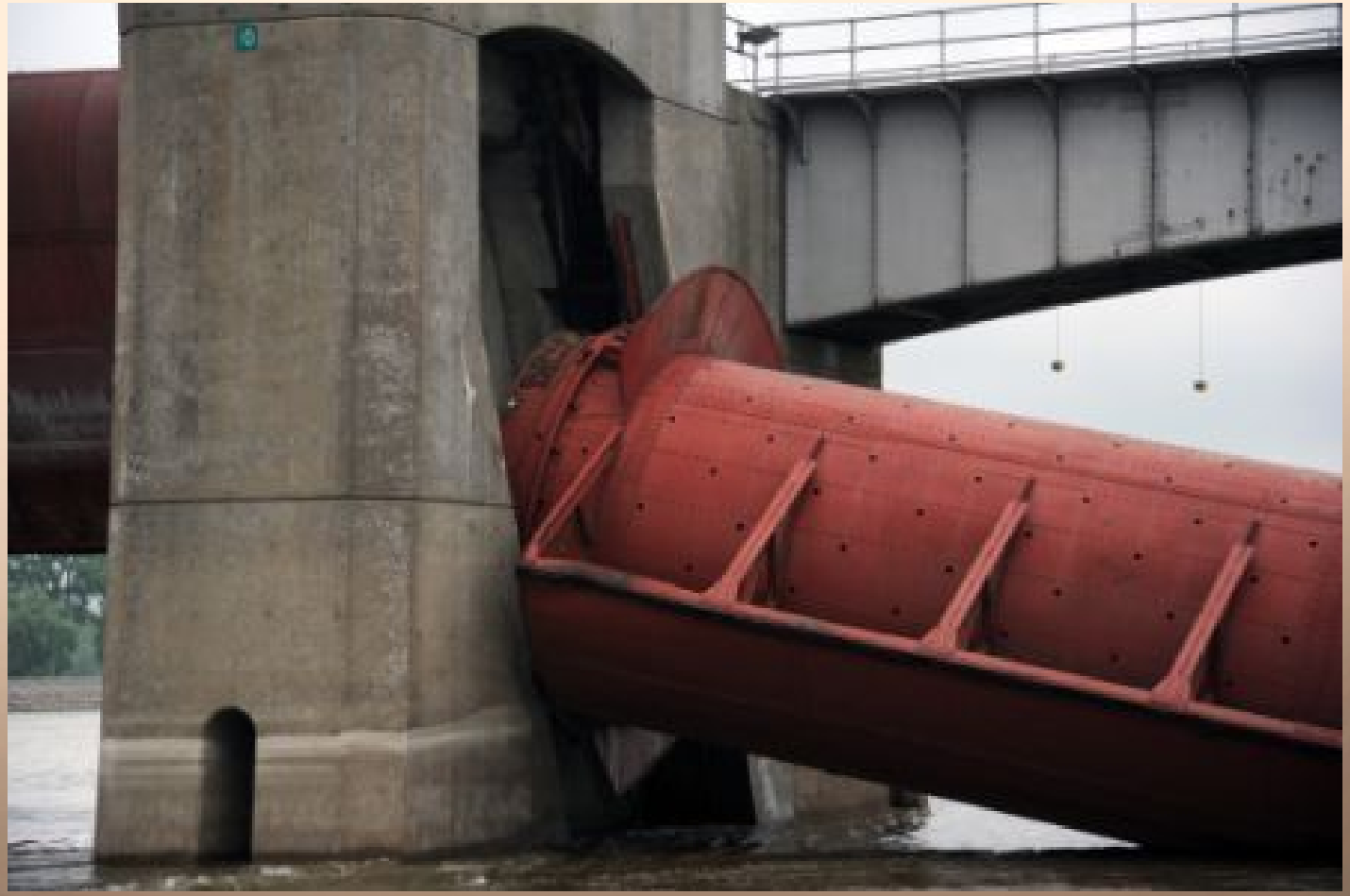
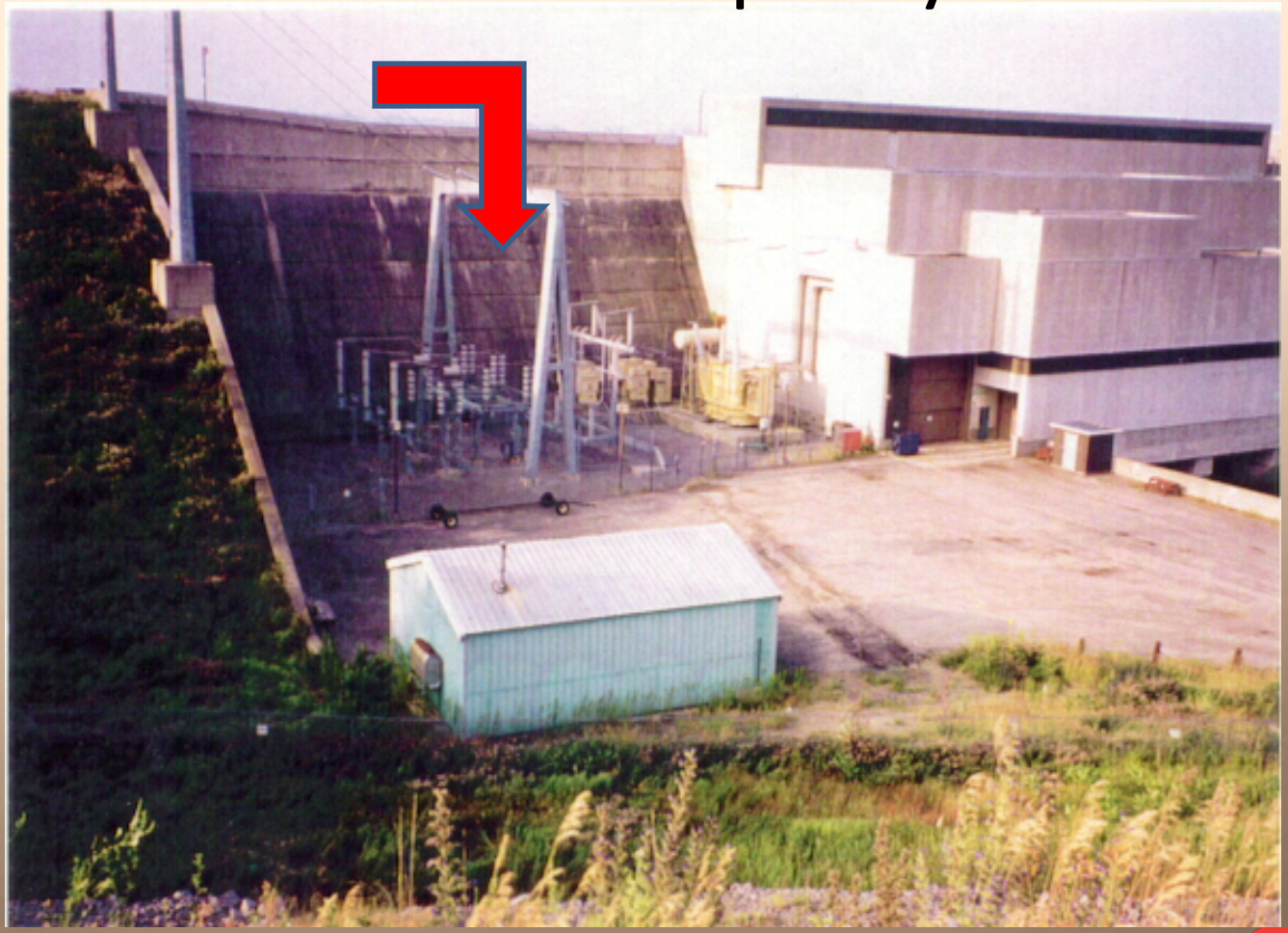


Limit Switch Failure



Switchyard Floods – Loss of Power Release Capacity



Spillway Operating Deck and Generator Floods

Emergency generator room same elevation as catwalk.

Catwalk almost inundated during flood – gates must be operated from catwalk

Rock Slide Damages Spillway Gates

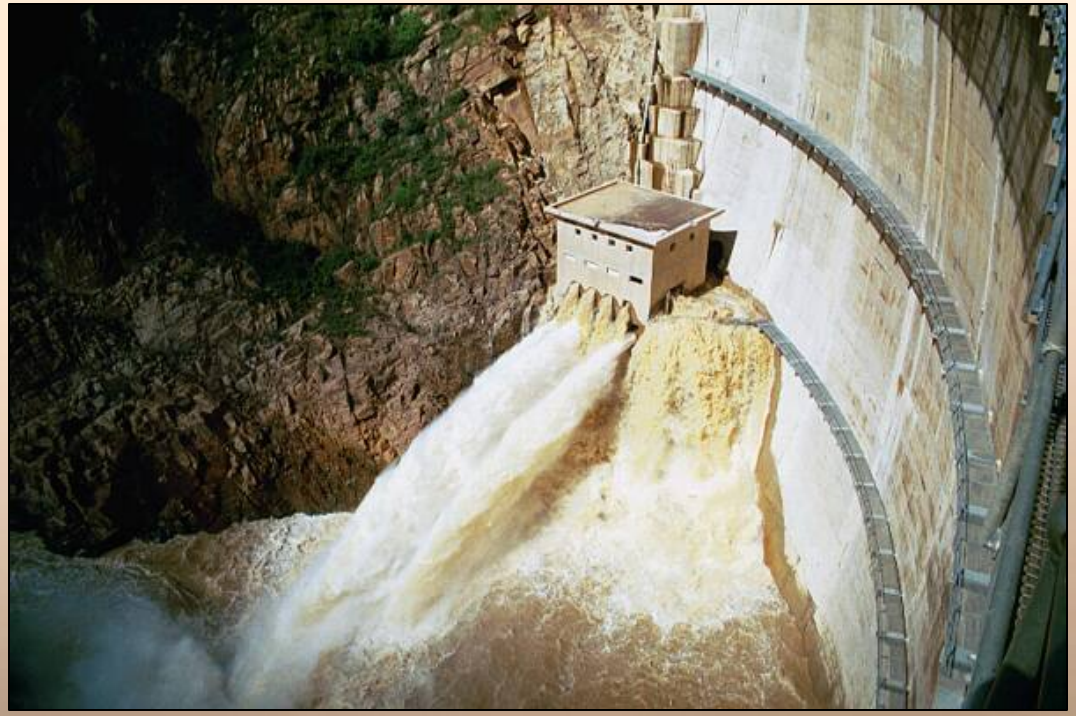
Insufficient Pump Capacity Inundates Leveed Area

Sugar Tree Bottom Levee System

Backflow Through Interior Drainage Culvert Due to Failure to Close Gate

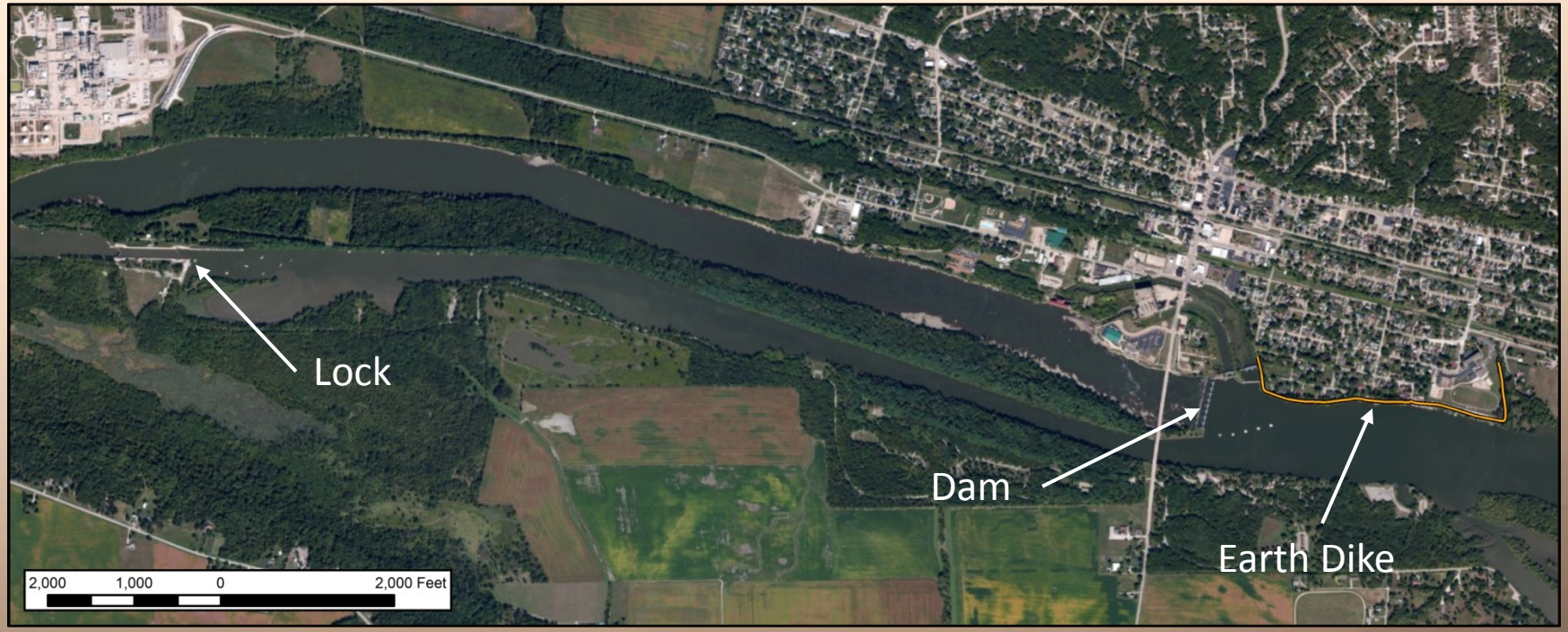
Brookport Levee System

Valve Failure

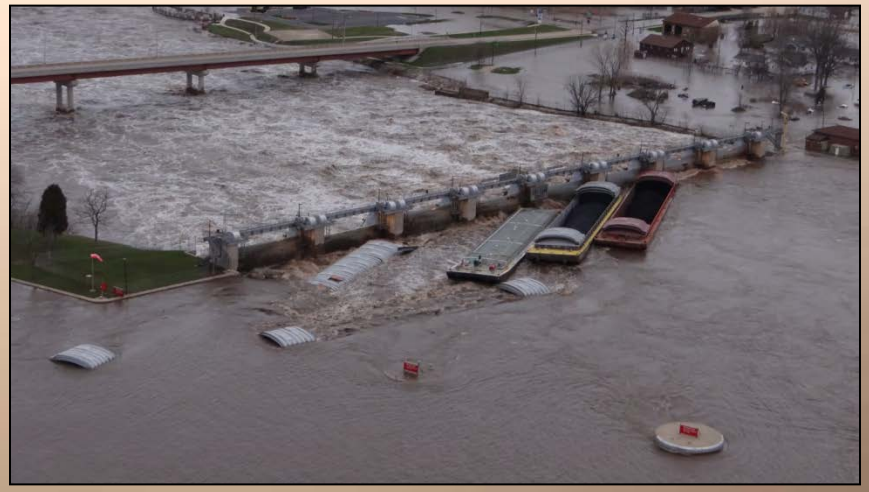


- Low flow bypass valve vibration caused cracks in weld around valve flange and blow out.
- Valve failure caused release of water from the reservoir and major damage to structure.
- What if other critical controls are in the building?

Marseilles Lock and Dam, IL
Site Plan



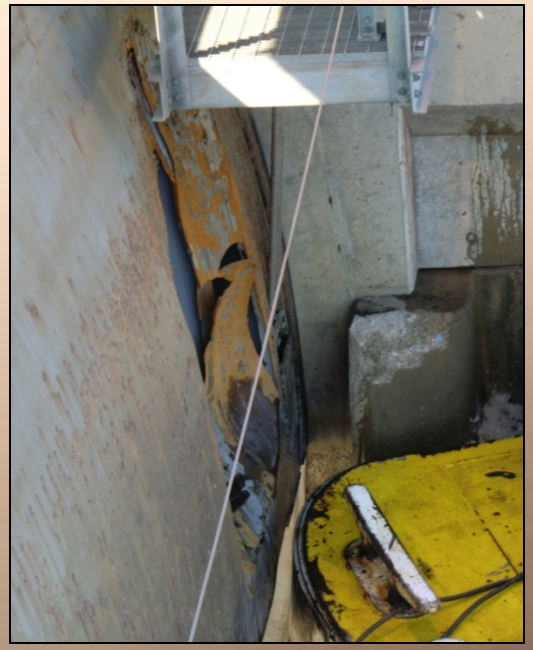
Marseilles L&D, IL
Incident 18-19 April, 2013



Marseilles Damage Summary

- Main Dam
  - Six barges break free and three sink.
  - Gates 2 through 6 impacted by barges leaving Gates 2 and 3 inoperable
  - Pier 2 trunnion anchorage destroyed
  - Decreased spillway capacity led to erosion at dam around boiler house
- Earth Dike (Note: this structure is upstream of the main dam)
  - Erosion of earth section
  - Widespread residential flooding

Marseilles L&D, IL
Tainter Gate Damage



Marseilles L&D, IL
Dam Erosion Damage

Marseilles L&D, IL
Earth Dike Damage

Example Assessment

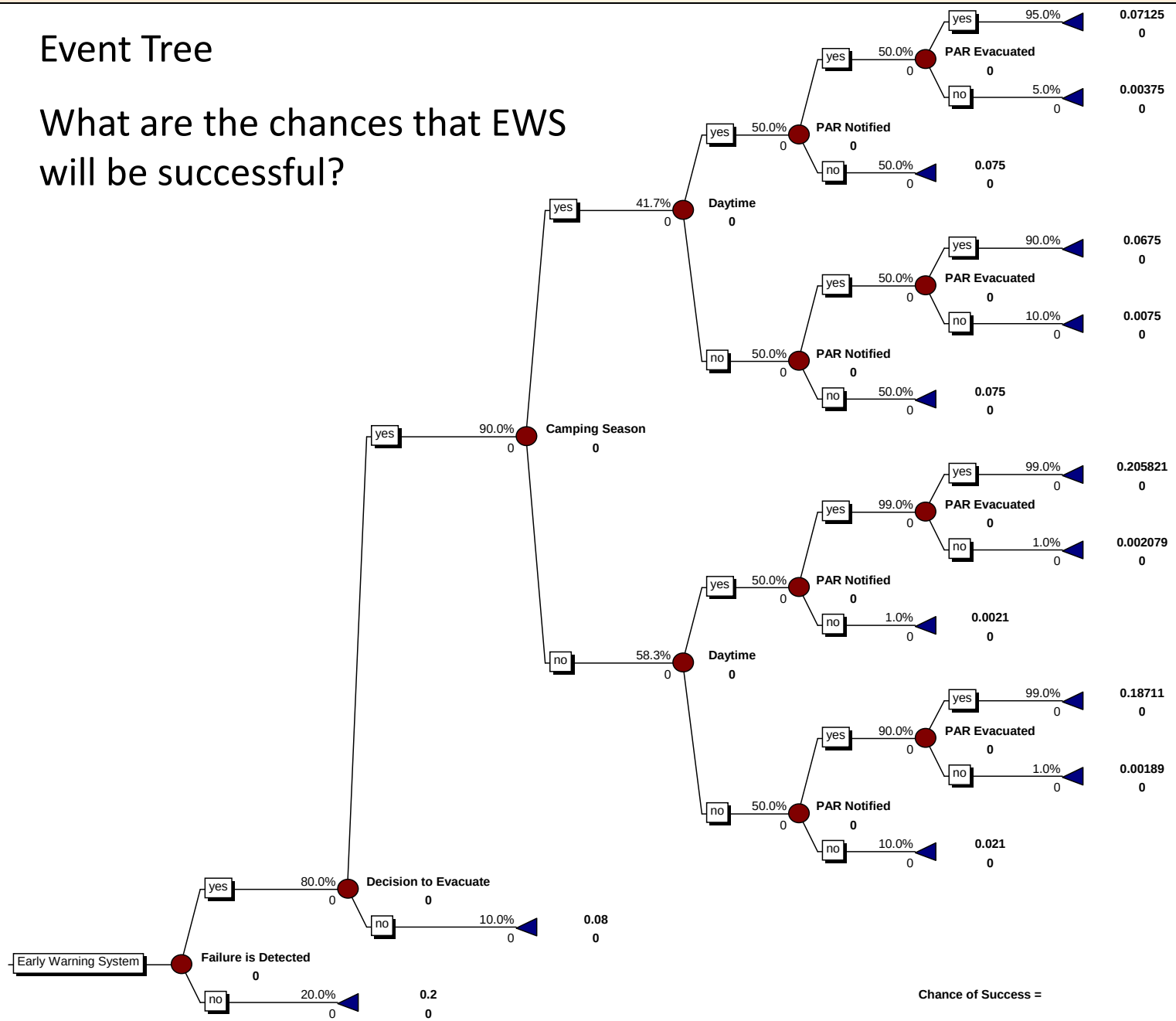
- Concrete arch dam
- Concerns about sliding of block in left abut
- Remote location – interim EWS
- Two large camp-grounds and 3 small towns along river d/s
- 1 hour flood wave travel time to first campground

Early Warning System

- Transmitted via satellite every 15 minutes:
  - Reservoir level gage and d/s flow gage
  - 2 float triggers on river bank d/s
  - 2 in-place inclinometers and 2 shear strips across shear
  - 1 extensometer across dam contraction joint near shear
- Strong motion accelerograph (left abutment)
  - Set to trigger at 0.05g
  - Ground motions transmitted via radio repeater
- All data goes to 24/7 control center, alarms programmed for various combinations
- Operators would alert sheriff and Forest Service Office near campgrounds

Event Tree

What are the chances that EWS will be successful?



Able to Detect Failure

- 3 independent platforms to collect and transmit data
- Numerous independent instruments
- System programmed with verification alarm combinations
- False alarm (with no secondary alarm verification) resulted in modifications to system
- High likelihood of success (80%), although not 100% because there is a small chance all communications could be wiped out by a large earthquake, which may not be interpreted as dam failure even if it occurred

Decision Made to Evacuate

- Table-top exercise has been conducted – operators know what to do
- Operating personnel given authority to initiate evacuation
- High chance decision would be made (0.9), but not 100% because decision would need to be made without visual confirmation

PAR Notified

- More Likely
  - Sheriff's office available 24/7
  - Reliable phone service (prior to flood wave)
  - People in towns concentrated, easy to reach
- Less Likely
  - Forest Service Office business hours only
  - Sheriff's office opposite side of county
  - Recreationists spread out, especially during day
- High likelihood of success (0.9) non-camping season due to concentrated population
- Uncertain (0.5) camping season, spread out during the day, and may be no-one to warn at night

Population Evacuates

- Most could leave on paved road
- Obvious which way to climb to safety
- Given warning, it is likely (0.9) that everyone would evacuate, but not 100% since there may be a traffic jam if everyone tried to leave at once and notification may not be in time

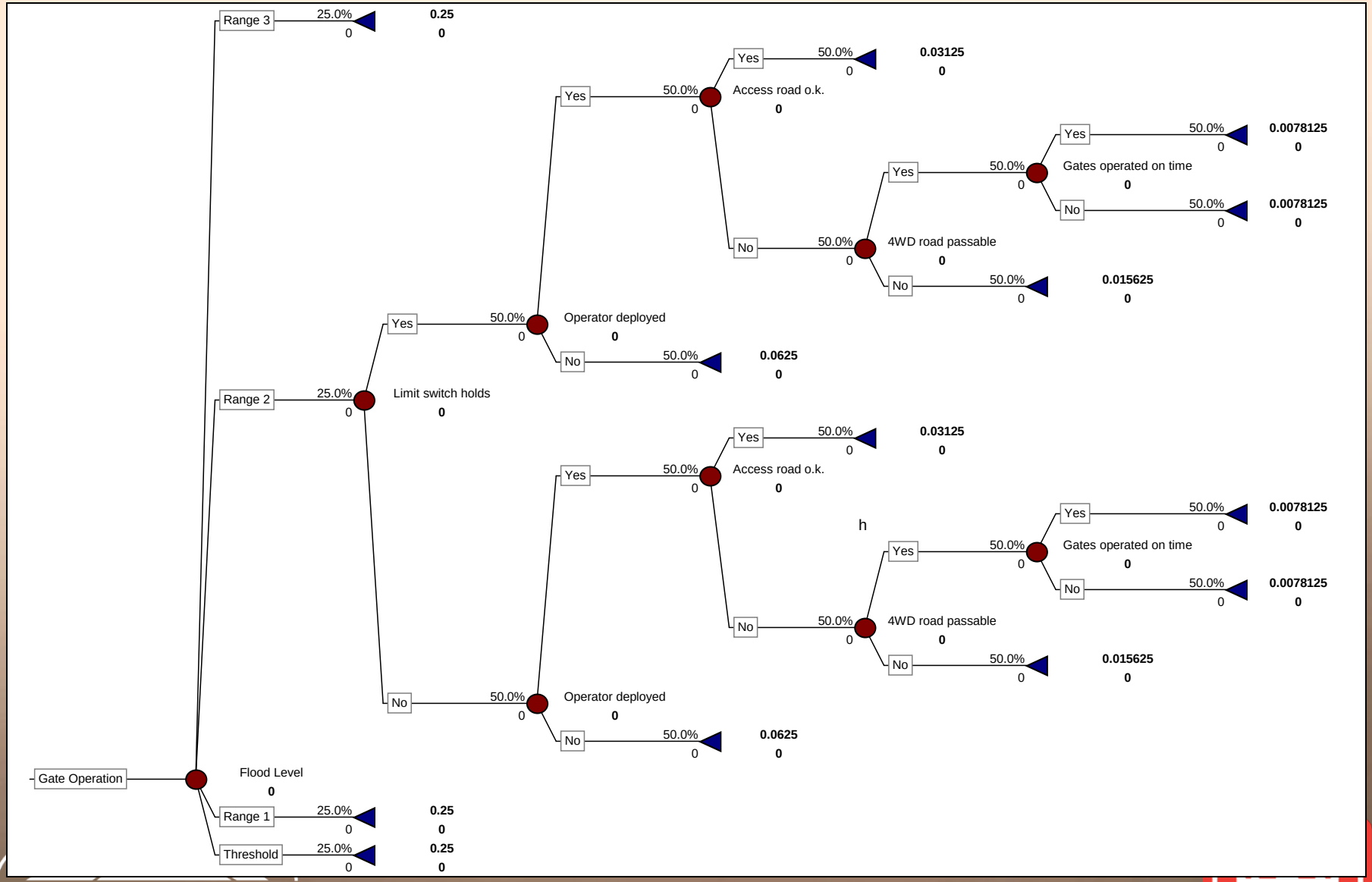
- Chance of EWS success ~ 50%
- Learned a lot about EWS and how to improve

Exercise (Dams)

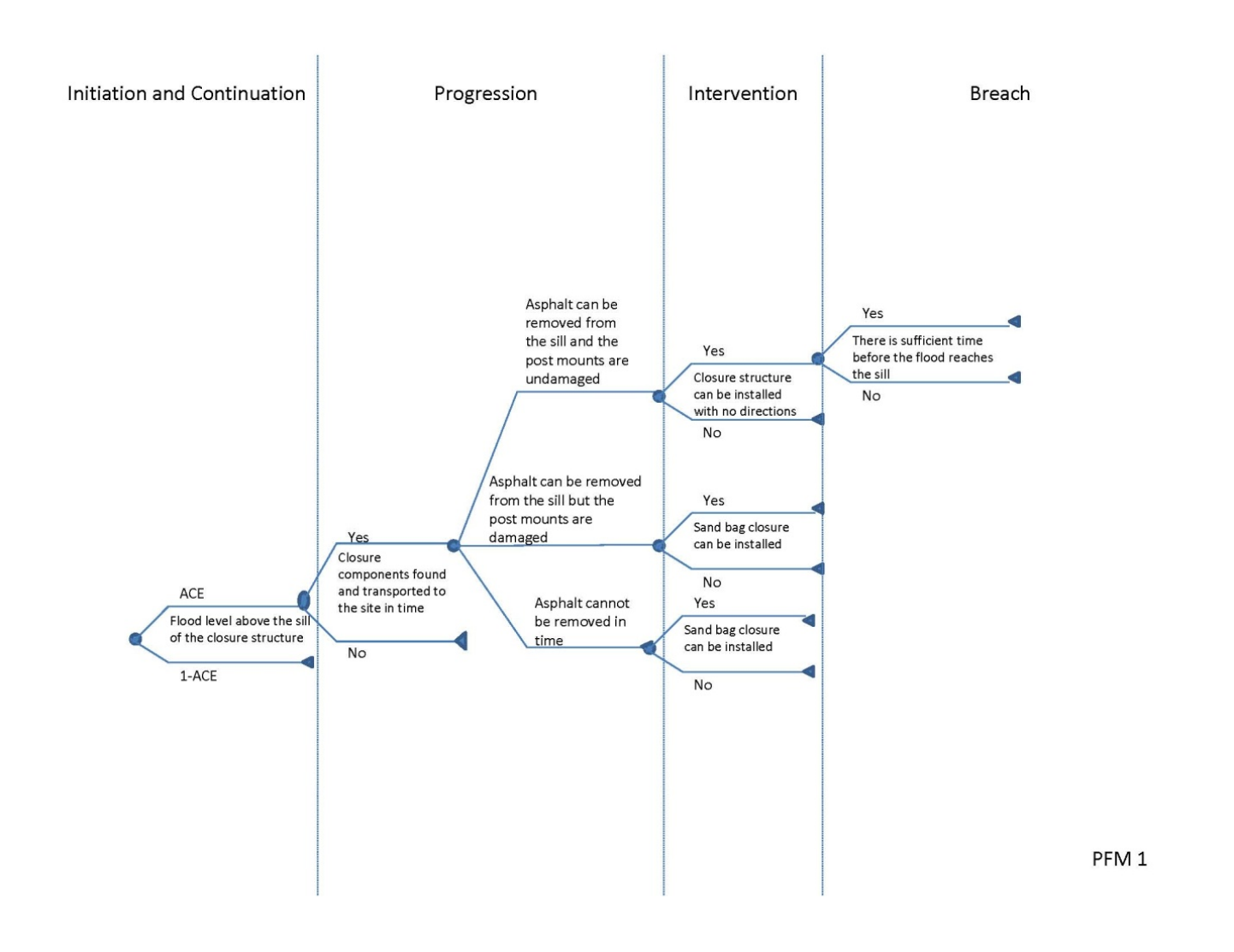
- Given the following potential failure mode description, develop an event tree to evaluate dam overtopping as a result of operational failure.

- During a large flood, releases in excess of those that can be passed through the automated gate are required. The automated gate is opened to buy some time until an operator can get to the site. The limit switch on the automated gate fails (as it did in 1994) due to a loss in communications and the gate opens fully wiping out the main access road. An operator is deployed to the site, but cannot make it to the gate operating controls before the main access road is wiped out. The operator next must attempt to make it to the site through the back road, but due to bad road conditions does not make it to the dam in time to operate the gates, and the dam breaches by overtopping erosion.

Exercise Possible Solution (Dams)



Exercise (Levees)

- Given the following potential failure mode description develop an event tree to evaluate inundation as a result of operational failure.
- During a large rainfall event related to a severe thunderstorm, the creek experiences a rapid rise in water level in excess of those that can be passed without the installation of a closure along Park Avenue. Post and beam closure structure components are located in a shed in the maintenance yard on the far side of town about a 15 minute drive away. It has been twenty years since the structure was installed and there are no directions stored with the parts. The concrete sill for the closure structure was paved over by the highway department two years ago to smooth the roadway for truckers and improve drainage from the road. The gap between the ends of the floodwall where the closure structure should be installed is 70 feet wide, and flood waters are expected to crest 6 feet above the road surface. There is insufficient time to chip the asphalt, and transport and install the closure structure. The residents under the direction of the fire chief and the public works manager attempt to sand bag the opening. All efforts to close the opening fail and the floodwaters enter the town along Park Avenue.

Exercise Possible Solution (Levees)