Senior Leaders Dam Safety Seminar

Understand Risks

"Quality (risk) analysis could both facilitate two-way communication between top management and individuals with substantial knowledge about each of the relevant aspects of utility operations and provide a clear understanding of all the information available to make a key risk management decision."

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

Leadership

"The critical common element is an unwavering commitment to safety at the top of an organization: the CEO and board of directors must create the culture and establish the conditions under which everyone in a company shares responsibility for maintaining a relentless focus on preventing accidents."

(The accidents they are talking about are not OSHA accidents)

National Commission on the BP Deepwater Horizon Oil Spill (2011)

Leadership

"Likewise, for the entire industry, leadership needs to come from the CEOs collectively, who can apply pressure on their peers to enhance performance."

National Commission on the BP Deepwater Horizon Oil Spill (2011)

Outline

How Dams Fail – A Historical Perspective

Consequences of Dam Failures

Organizational and System Failures

What Dam Safety is Not

What Dam Safety is Not

A Compliance Exercise

What Dam Safety Is

What Dam Safety Is

A Legal, Ethical, & Moral Responsibility

Each licensee hereunder shall be liable for all damages occasioned to the property of others by the construction, maintenance, or operation of the project works or of the works appurtenant or accessory thereto, constructed under the license and in no event shall the United States be liable therefore."

Federal Power Act

H.R. 3753

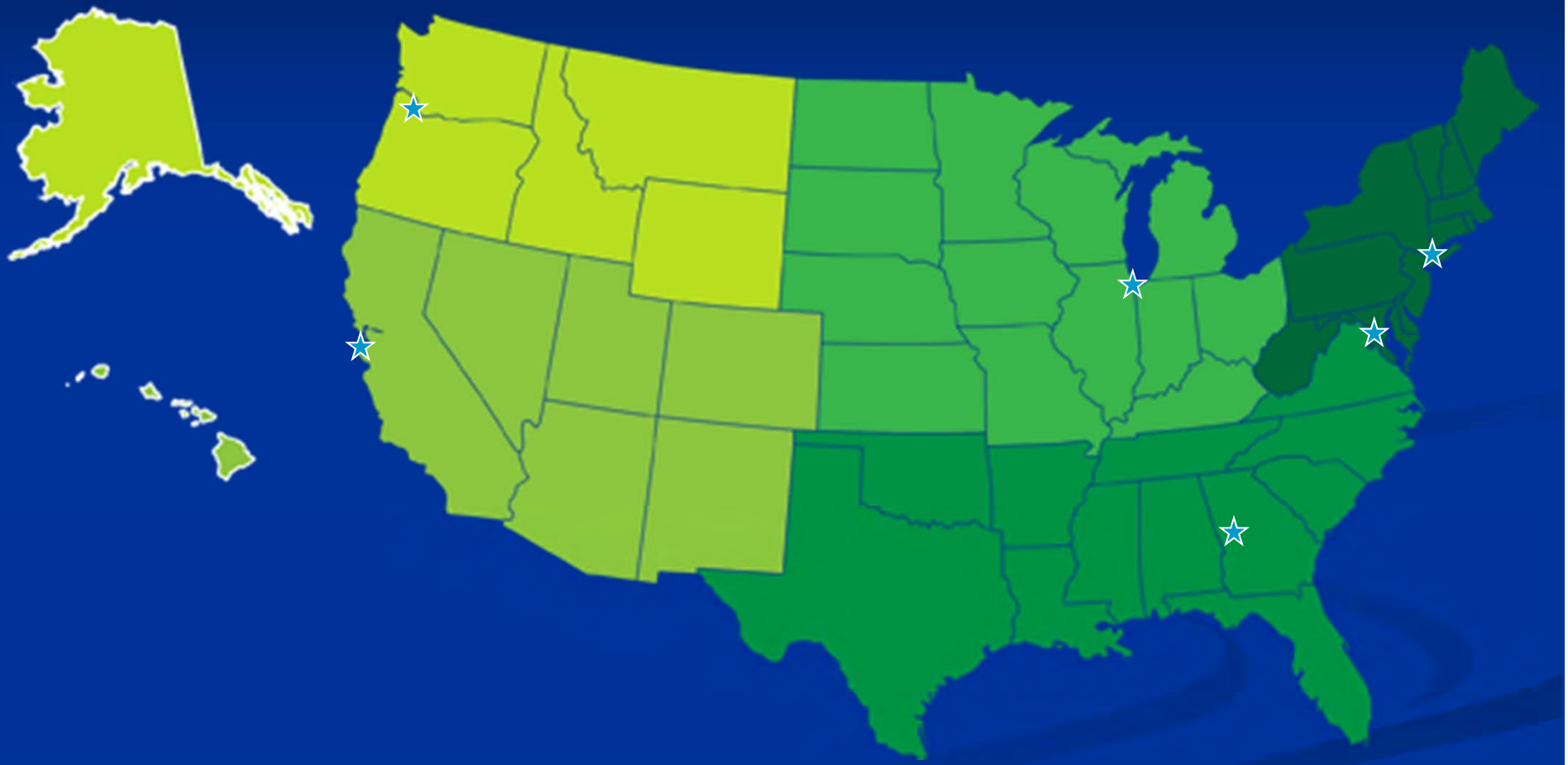
SECTION 1. FINDINGS.

- The Congress finds that actions by the Federal Energy Regulatory Commission (`FERC') leading to the acceptance and approval of the surrender of a hydroelectric license for Project No. XXXX, including, but not limited to, the **FERC's failure to ensure, during the effective period of the issued hydroelectric license, that the project's facilities were adequately maintained, rendered the project unfit for operation and thereby wasting the hydraulic potential of waters of the United States.**

"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."

FERC Dam Safety Program

Regional Organization

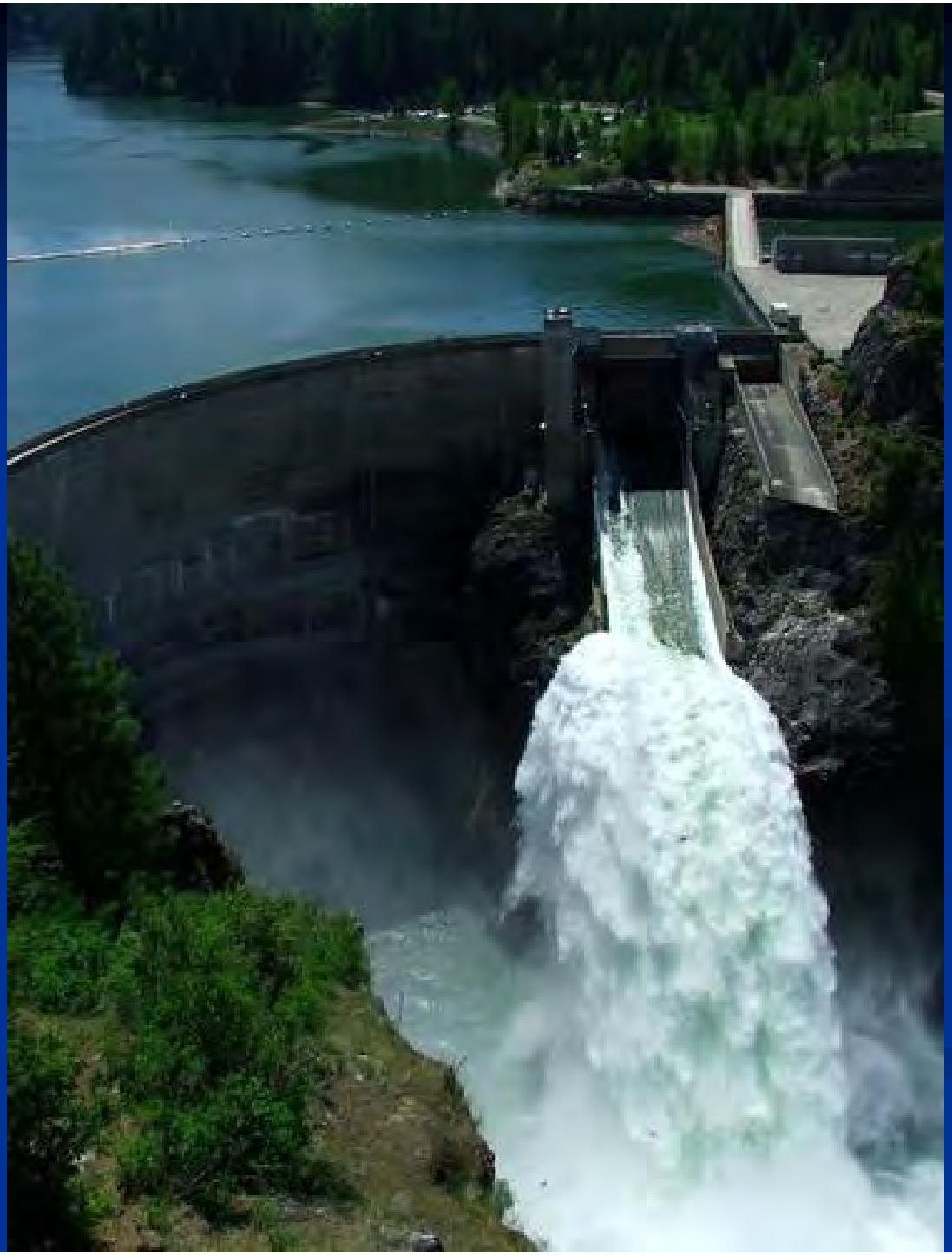


Breadth

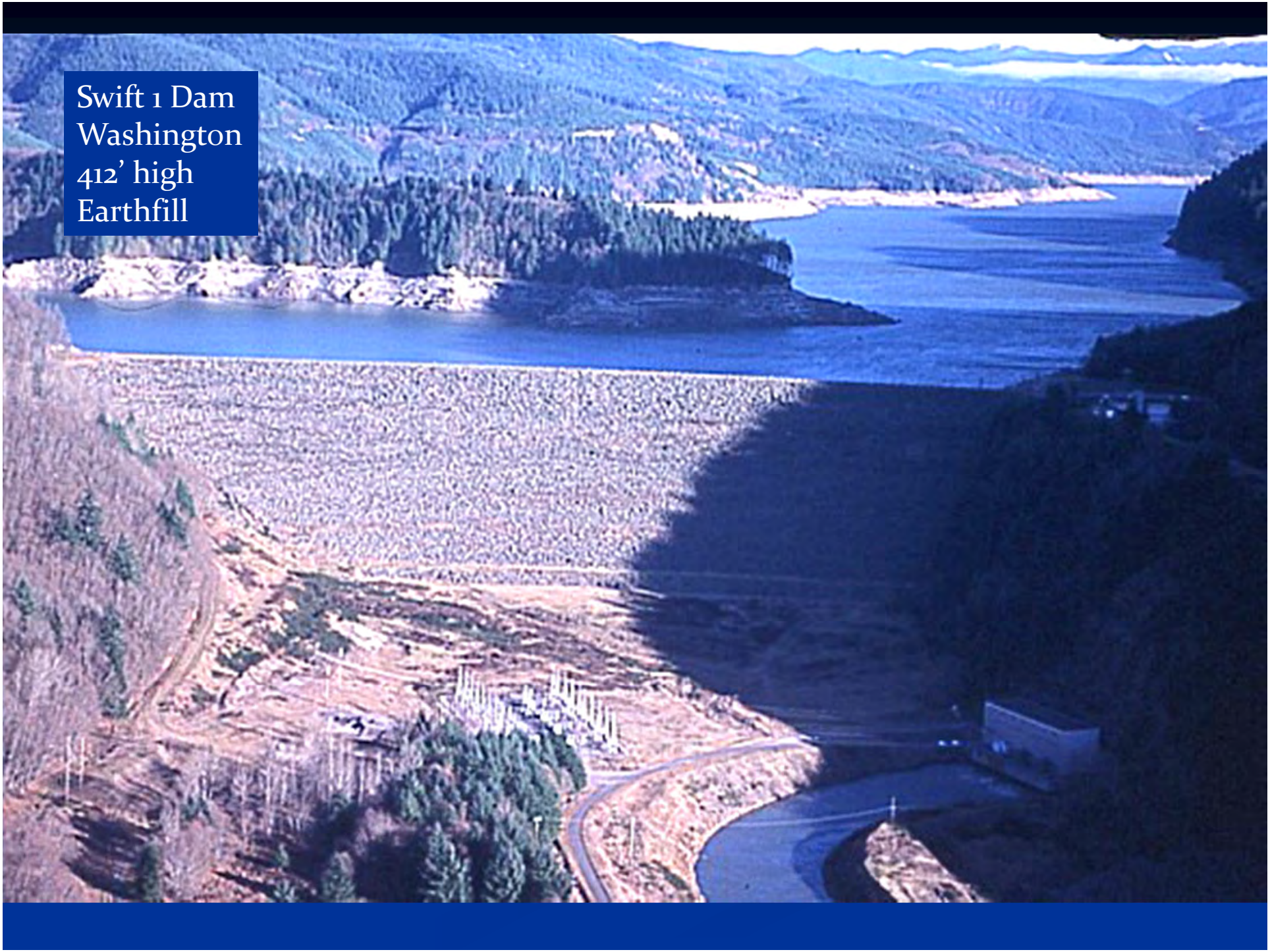
- Over 2900 jurisdictional dams
- 800 High Hazard Potential Dams (likely to cause loss of life in a failure)
- 200 Significant Hazard Potential Dams (likely to cause significant economic and/or environmental consequences)
- Heights from 0.5 feet to 770 feet


Oroville Dam
California
770’ high
Earthfill

Boundary Dam
Washington
340’ high
Concrete Gravity-Arch

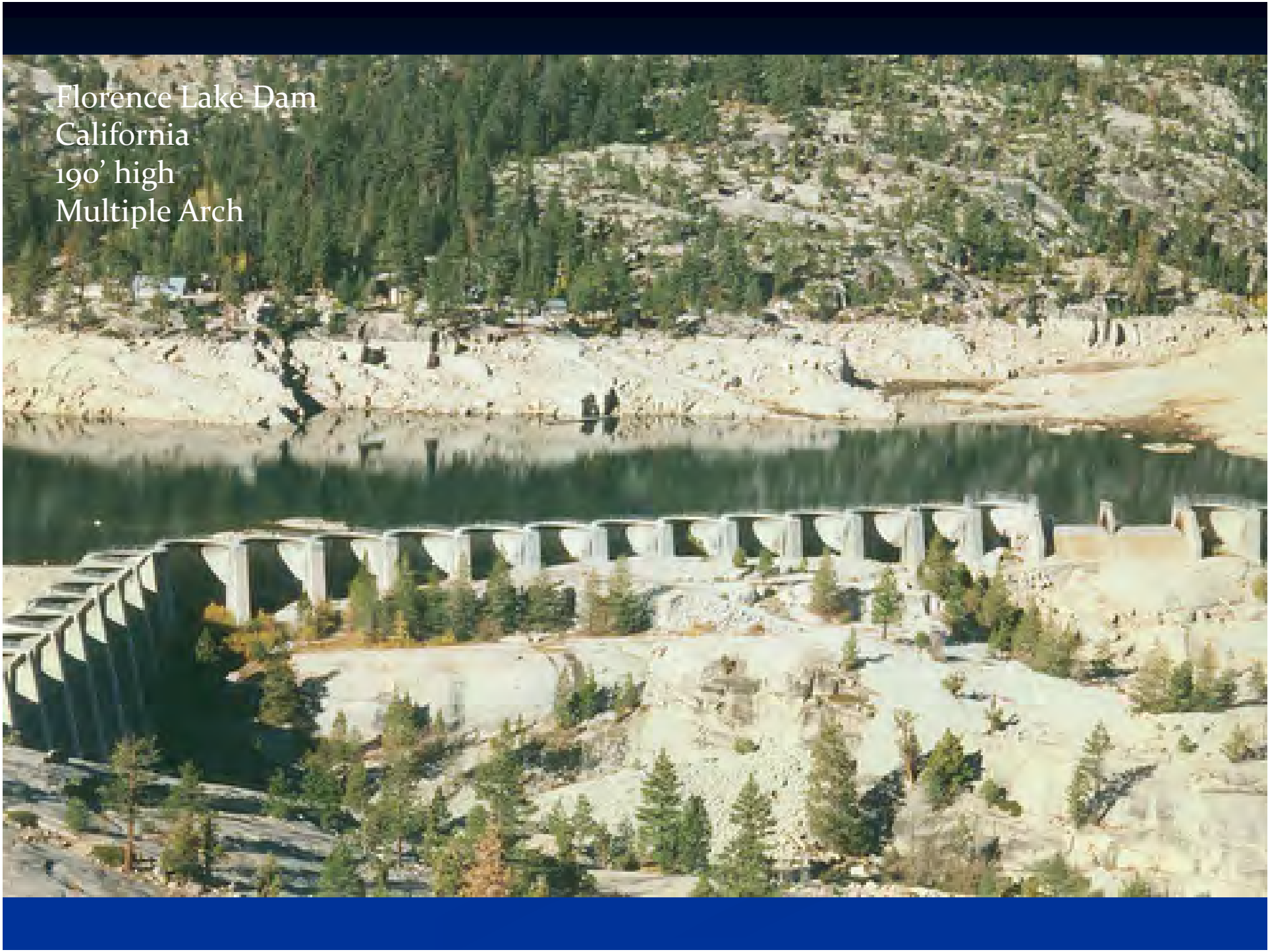


Shoshone Diversion
Idaho
1.5’ high
Concrete Gravity


Swift 1 Dam
Washington
412’ high
Earthfill


Wishon Dam
California
260’ High
CFR


Hells Canyon Dam
Idaho
323’ high
Concrete Gravity Dam


Florence Lake Dam
California
190’ high
Multiple Arch

Principal Elements of Program

- Owner's Dam Safety Program
- Inspections
  - Owner's
  - FERC
  - Independent Consultant (Part 12D)
- Potential Failure Mode Analysis/ Risk Assessment
- Surveillance and Monitoring Plans and Reports
- Emergency Action Plans
- Analysis
- Security Assessments
- Public Safety Programs

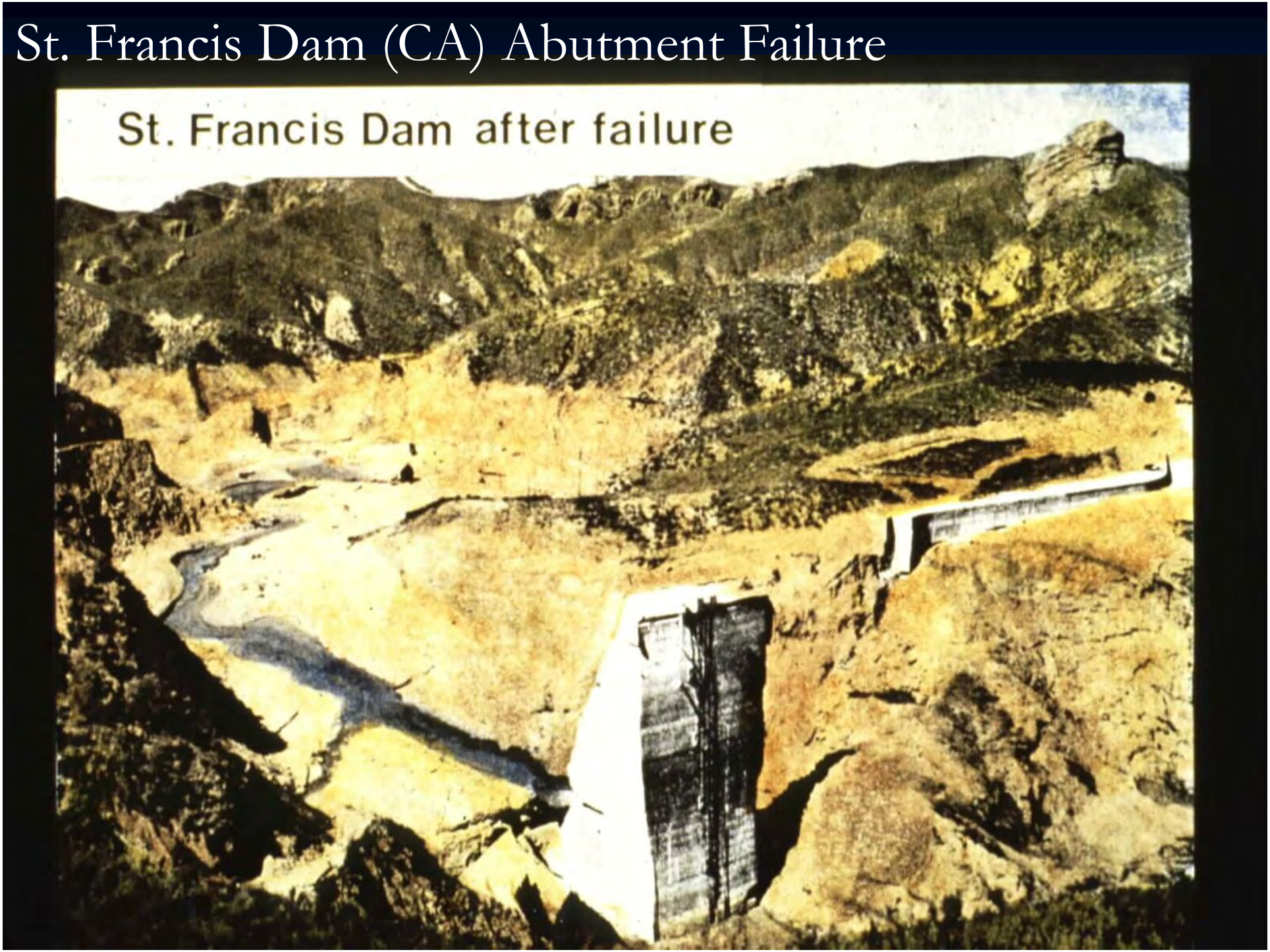
How Dams Fail

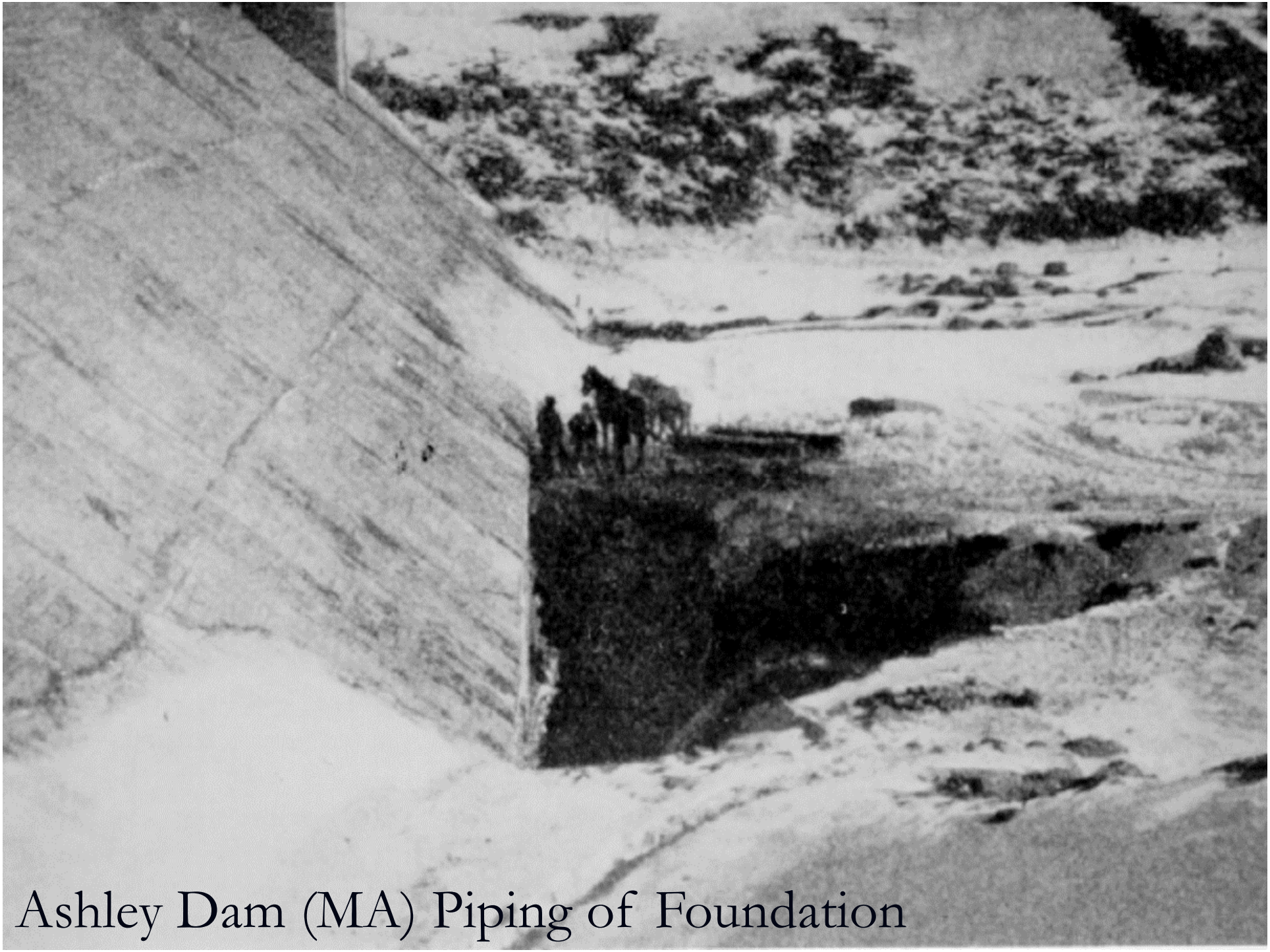
A Historical Perspective

Concrete Gravity Dams

Austin Dam (PA) – Sliding on Foundation

St. Francis Dam (CA) Abutment Failure





Ashley Dam (MA) Piping of Foundation

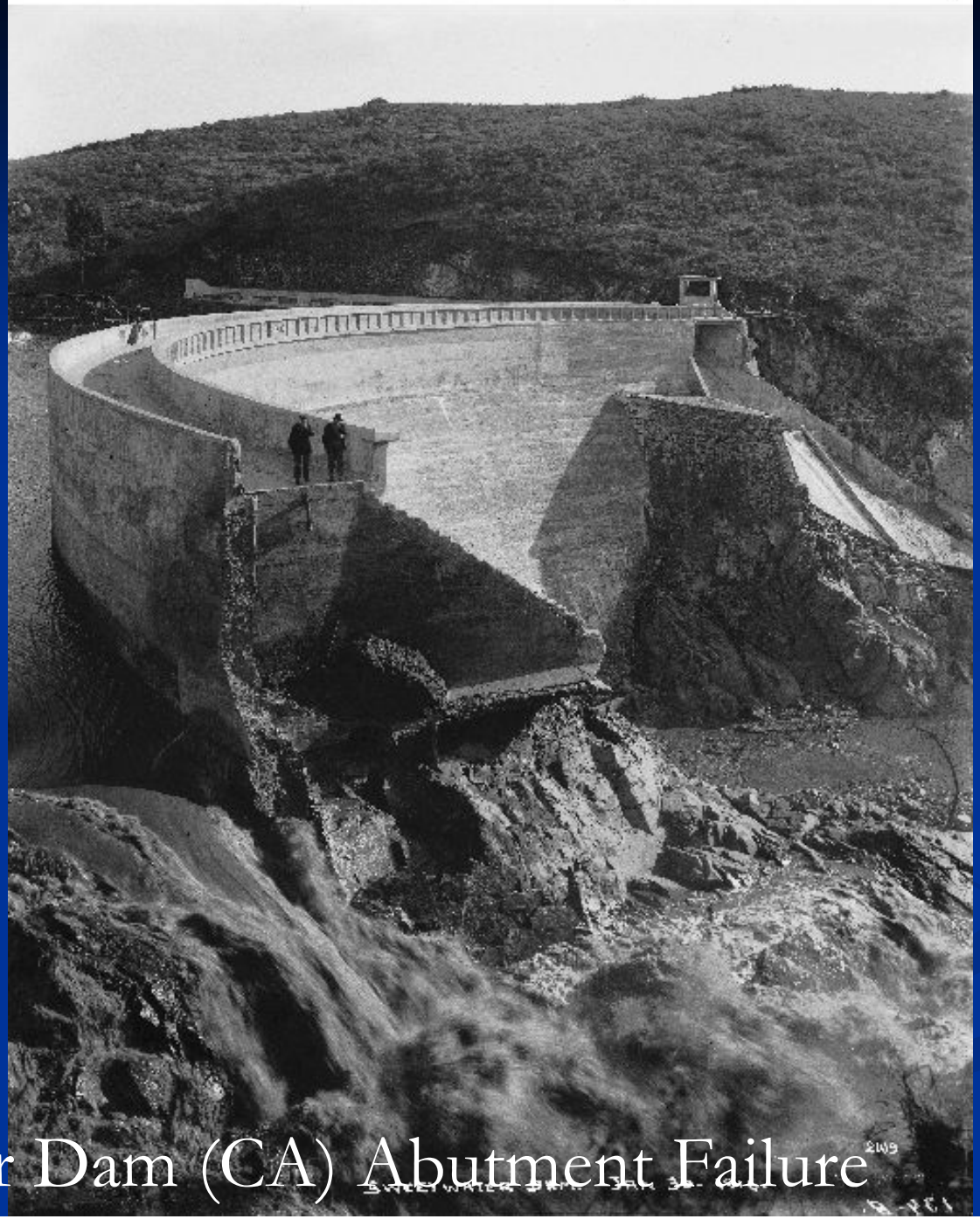
Concrete Arch Dams


Gleno Dam (Italy) Overtopping and Sliding

Vaiont Dam (Italy) Landslide into Reservoir


Mt.Toc
Erto
Casera Ferrera
nine
Castello Lavazzo
Longarone

San Diego Historical Society

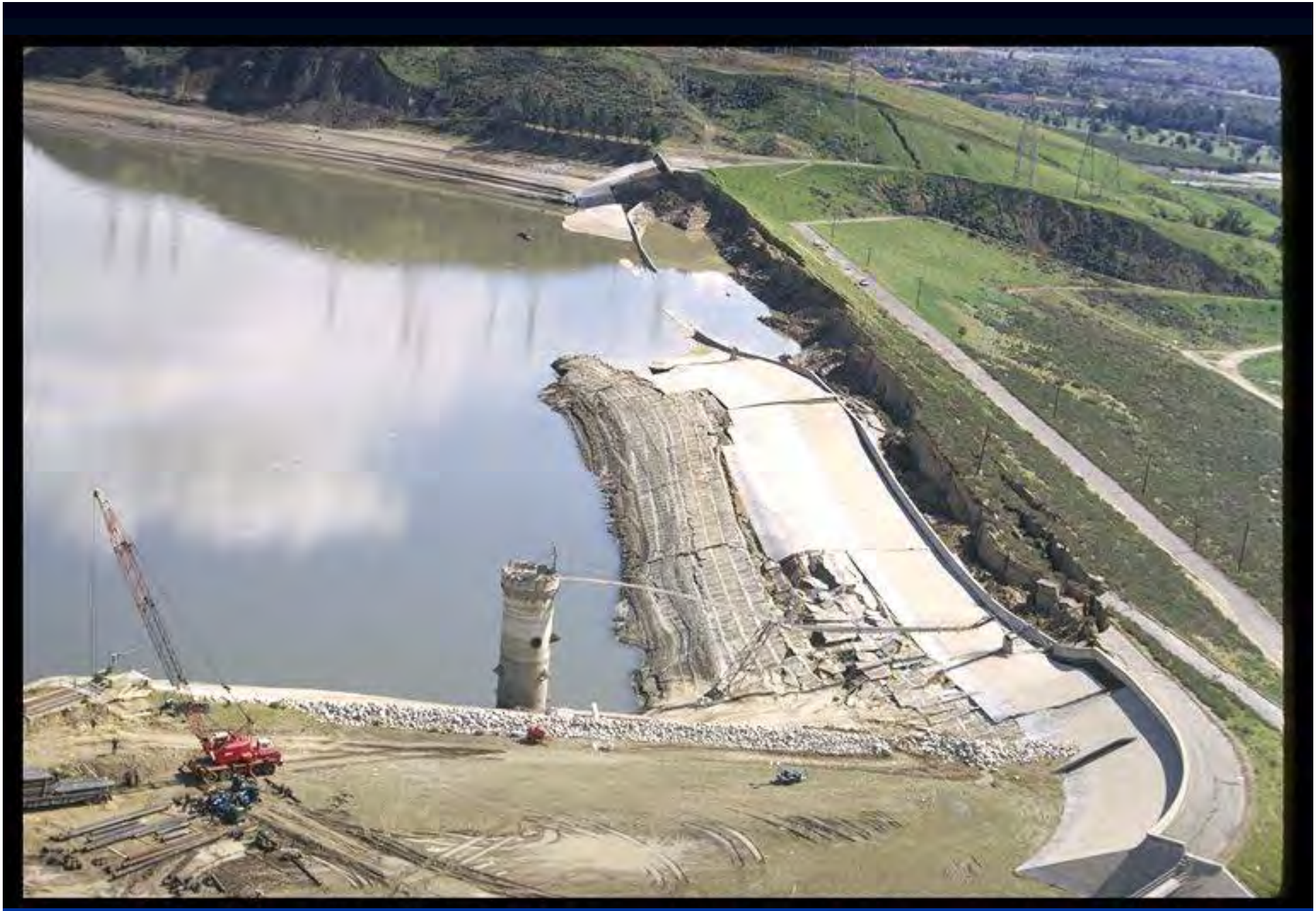


Sweetwater Dam (CA) Abutment Failure

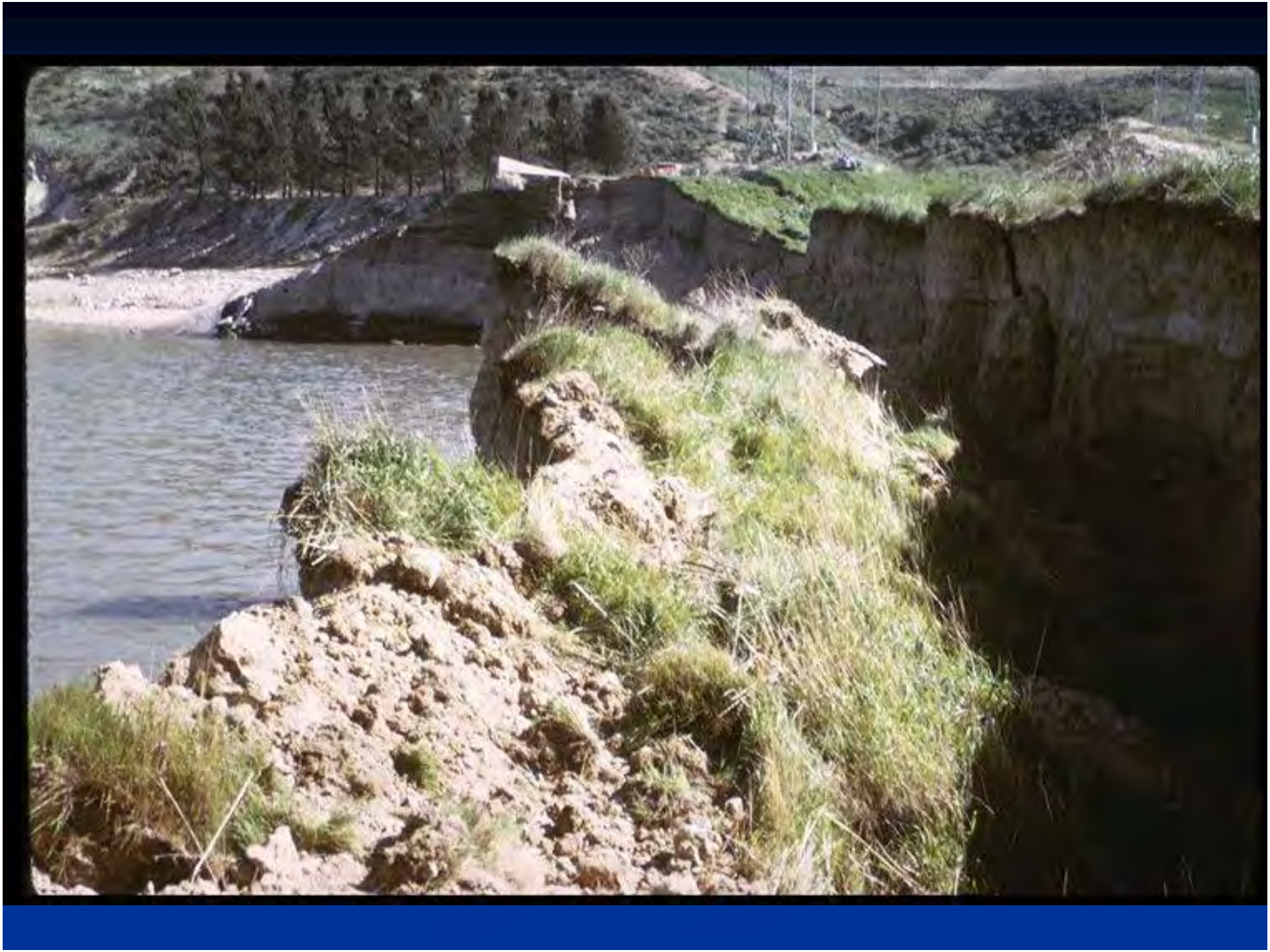
Earthfill Dams

Noppikoski Dam (Sweden) Overtopping

Teton (ID) Piping



Lower San Fernando (CA) Liquefaction



Banquiao (China) Overtopping

Southfork (PA) Overtopping

Rockfill Dams

Taum Sauk (MO) Overtopping

Dam Failure Statistics

The average annual probability of a given dam having a failure is about 1×10^{-4} per year

McCann and Hatem 1986

For dams built in the United States before 1959, on the average one in fifty failed.

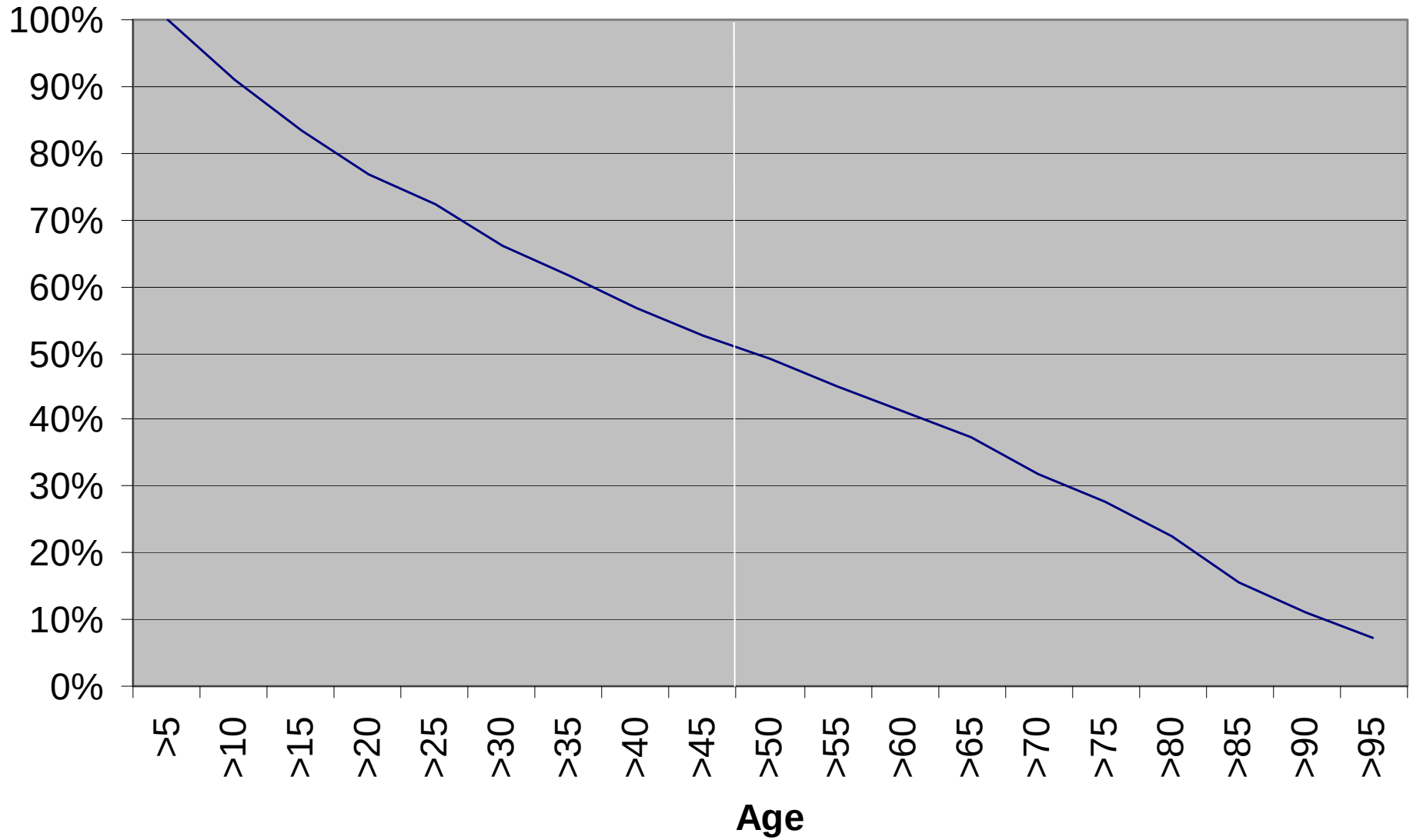
Levy and Salvadori (1992)

Annual Probability of a Dam Failure in a Portfolio of Dams

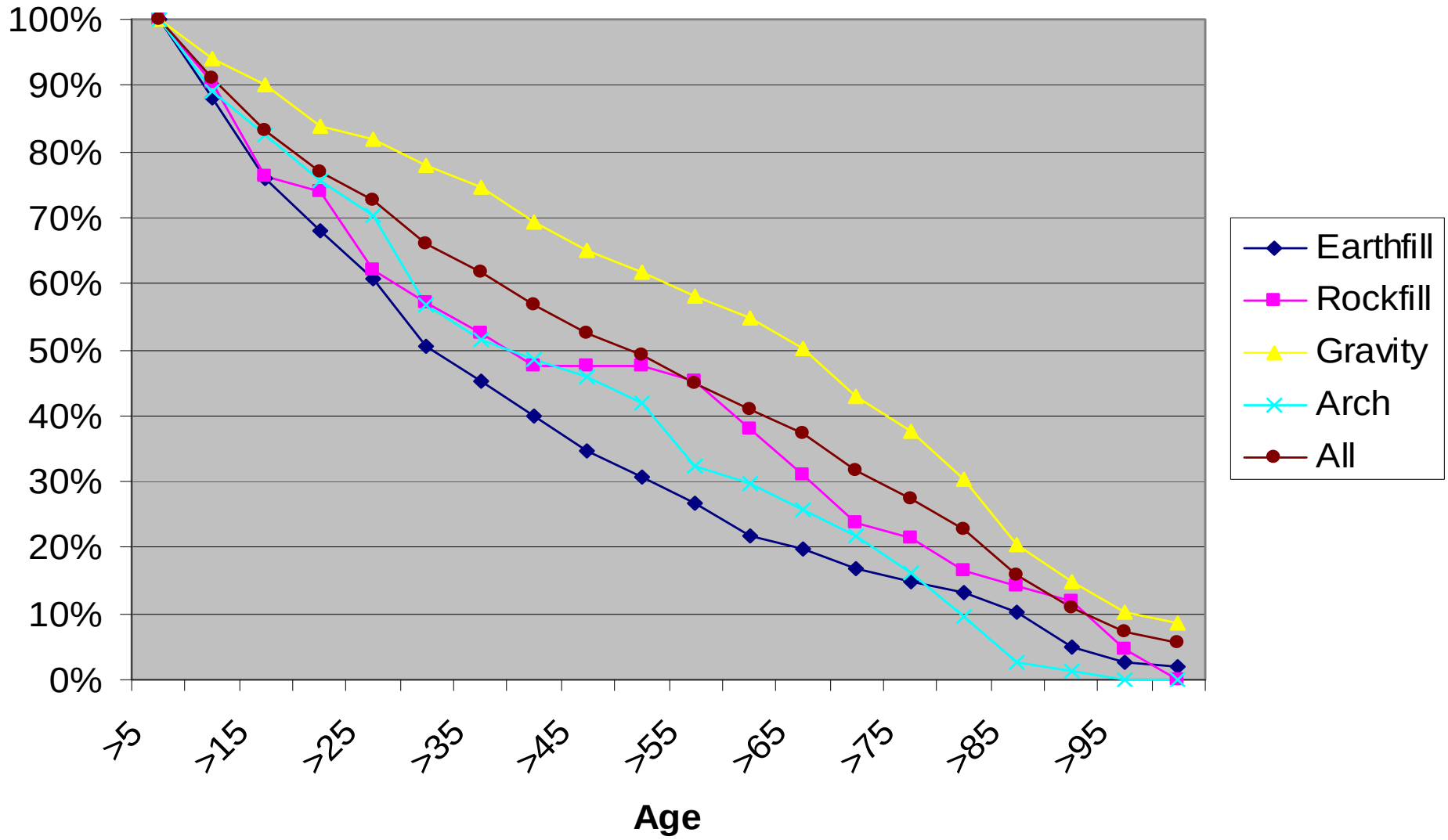
Depending on how many dams you own the annual probability of a having a dam failure varies widely.

1 dam	1 in 10,000
10 dams	1 in 1,000
50 dams	1 in 200
100 dams	1 in 100

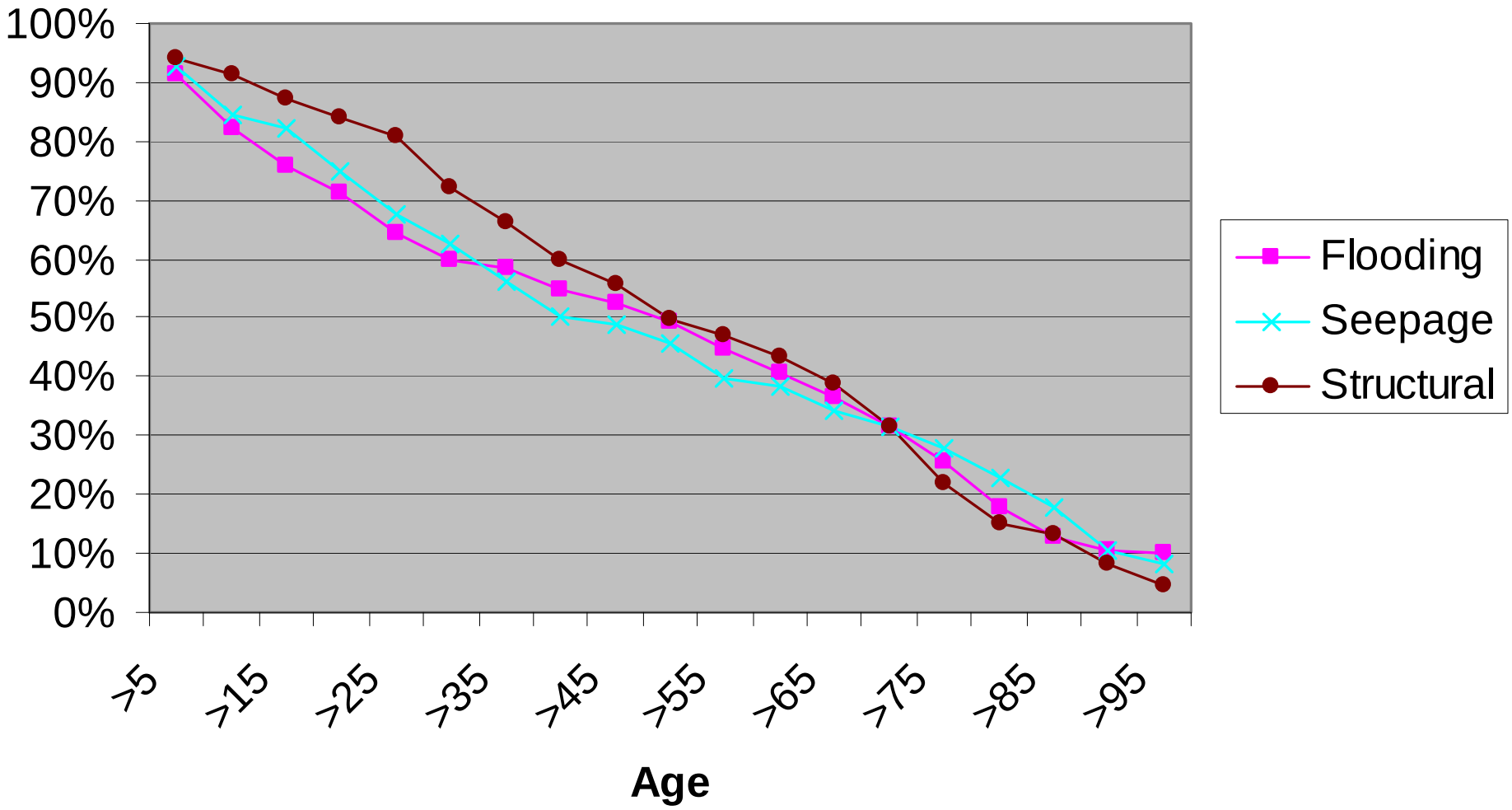
% of Incidents that Occur at an Age Greater Than
All Dams that Survive their 1st Five Years



% of Incidents That Occur At An Age Greater Than By Type of Dam



% of Incidents that Occur at an Age Greater Than by Failure Mode After 1st 5 Years of Operation



Dam Safety Evaluation (Traditional)

- Is the dam here today? (check static stability)
- Will the dam be here after a big storm? (check spillway capacity)
- Will the dam be here after a big earthquake? (Check seismic stability/potential for liquefaction)

Current State of Practice

- Standards
  - Broadly Drawn – can't recognize uniqueness of each dam
  - Generally don't address issues that can't be analyzed (Operational issues, Human Factors)
  - Singular – can't address combination of events
  - May work against ALARP principle

Current State of Practice

- Risk-Informed (as generally practiced)
  - Linear
    - doesn't address parallel events
    - doesn't address interactions of "separate" systems
  - Subjective – Rely on expert elicitation
    - Good News – we don't have a lot of failures
    - Bad News - Don't have a lot of data to make informed estimates of probabilities

FAA

- The Federal Aviation Administration has a requirement that “no single failure ***or probable combination of failures*** during any one flight shall jeopardize the continued safe flight and landing of the aircraft”.

- In the dam safety community we do the first part, examining a single failure, fairly well.
- In few instances do we adequately address the combination of failures – the system failures.
  - An example is the thought that we don't need to simultaneously consider earthquake and flood loading. What we often overlook is the fact that if an earthquake severely damages a critical component such as a spillway, we only have until the onset of the next rainy season to repair the damage without endangering the dam and the population at risk.

What Are We Seeing Today?

Operational and Organizational Failure Modes

Taum Sauk Upper Reservoir Dam: A Systems Failure

Patrick J. Regan, P.E.
Federal Energy Regulatory Commission

MIT Systems Engineering Workshop
April, 18, 2012

Project Description

- The Taum Sauk Project is located on the East Fork of the Black River approximately 90 miles southwest of St. Louis, Missouri.
- Taum Sauk is a pumped storage project owned by AmerenUE. It was the first large pumped-storage project to begin operation in the U. S.
- The project includes an upper reservoir, a shaft/tunnel water conduit, a 450-MW PH with two pump-turbine units, and a lower reservoir.

Taum Sauk

- Dam Type: Concrete-faced rockfill
- Dam Height: 84’
- Reservoir Capacity: 4350 ac-ft
- Spillway Capacity: N/A
- Pumping Capacity: 5258 cfs
- Flood of Record: N/A


N

Construction

- The dike was topped with a 12’ layer of rock placed in 4’ lifts and compacted with a vibratory roller. The crest was 12’ wide.
- The 10’ high parapet wall was cast in place on top of this layer.
- The shotcrete face slab had a design thickness of 10 inches with No. 7 bars at 12 inches both ways.
- The face slab was placed in 60’ wide panels.
- Expansion joints used 3/4-in asphaltic expansion joint material and U-shaped copper water stops.
- A reinforced concrete plinth was placed at the toe of the concrete face.


N

Settlement

- Settlement of the rockfill varied between 1 and 2 feet with the lowest area at Panel 72, where the top of the parapet wall was 1596.99. (Original top of wall was El 1599)
- Several other panel areas ranged in elevations from El 1597 to 1598. (November 6, 2004 survey data)

Leakage/Seepage

- Leakage from the Upper Reservoir was a problem, beginning in September 1963, only a few months after first filling
- Seepage suddenly increased to 103 cfs requiring emergency repairs including; excavation, grouting, a concrete cutoff, joint repairs and plugging two holes in the floor with concrete at panels 91 and 92.
- Three days later additional leakage caused another shut-down and repair. The repair consisted of excavating a 230' long by 4' wide trench excavated to "rock" and backfilled with concrete at Panels 90 to 93 and 95.

TAUM SAUK UPPER RESERVOIR
CREST SURVEY DATA

POINT	NORTHING	EASTING	ELEV	DESCRIPTION
1276	619315.868	727999.450	1598.26	TOP_P_33
1276	619315.334	727999.173	1598.26	TOP_P_34
1278	619280.452	727981.344	1598.29	TOP_P_34
1280	619280.213	727960.741	1598.25	TOP_P_35
1282	619244.863	727912.535	1598.60	TOP_P_35
1284	619244.898	727911.780	1598.61	TOP_P_36
1286	619286.385	727783.644	1598.61	TOP_P_36
1288	619228.176	727783.120	1598.55	TOP_P_37
1290	619173.563	727714.416	1598.47	TOP_P_37
1292	619173.402	727714.261	1598.48	TOP_P_38
1294	619138.327	727688.118	1598.40	TOP_P_38
1296	619138.199	727685.886	1598.41	TOP_P_39
1298	619133.281	727677.119	1598.31	TOP_P_39
1300	619132.749	727676.848	1598.30	TOP_P_40
1302	619087.364	727588.787	1598.11	TOP_P_40
1304	619087.150	727588.535	1598.10	TOP_P_41
1306	619032.235	727519.340	1597.85	TOP_P_41
1308	619032.036	727519.050	1597.84	TOP_P_42
1310	619001.082	727488.879	1597.70	TOP_P_42
1312	619000.171	726947.215	1598.15	TOP_P_88
1314	619347.662	726946.575	1598.34	TOP_P_88
1316	619348.891	726946.571	1598.32	TOP_P_01
1318	619405.357	726884.119	1598.38	TOP_P_01
1320	619405.814	726884.273	1598.35	TOP_P_02
1322	619461.323	726887.823	1598.33	TOP_P_02
1324	619461.308	726888.006	1598.34	TOP_P_03
1326	619512.119	726730.887	1598.21	TOP_P_03
1328	619512.534	726731.274	1598.21	TOP_P_04
1330	619556.234	726761.868	1598.11	TOP_P_04
1332	619556.482	726762.048	1598.12	TOP_P_05
1334	619582.675	726809.557	1598.13	TOP_P_05
1336	619583.146	726809.901	1598.18	TOP_P_06
1338	619624.726	726863.385	1598.24	TOP_P_06
1340	619624.998	726863.681	1598.25	TOP_P_07
1342	619655.834	726912.494	1598.24	TOP_P_07
1344	619656.157	726912.745	1598.24	TOP_P_08
1346	619686.656	726964.176	1598.29	TOP_P_08

NORTH SIDE OF BREACH

APPROXIMATE LOCATION OF THE SOUTH SIDE OF BREACH

NO ACCESS PERMITTED

SEE NOTE 4

UPPER RESERVOIR

MINIMAL TO NO DISPLACEMENT
MODERATE TO SIGNIFICANT DISPLACEMENT
BREACH

NOTES

1. UPPER RESERVOIR DRAWING DIGITIZED FROM PDF FILE(S) SENT TO KUHLMANN DESIGN GROUP FROM AMEREN U.E. ON DECEMBER 15, 2005
2. APPROXIMATE LOCATION OF BREACH:
   -NORTH SIDE HAS BEEN LOCATED
   -SOUTH SIDE IS ASSUMED (DUE TO NO ACCESS)
3. DATUM BASED ON - NAD(83) HORIZONTAL
   NAVD(27) VERTICAL

   BENCHMARK - TOP OF COPPER BOLT SET IN TOP OF GRANITE BOULDER PAINTED ORANGE AND YELLOW, 21'7" +/- NORTH FROM CENTERLINE OF GATE AT BASE OF NORTH RAMP.

   ELEVATION = 1488.476' (CONTRACTOR)
   NORTHING = 621467.668
   EASTING = 728333.261
4. ELEVATIONS IN PARENTHESIS ON PANELS 69 THRU 75 WERE SURVEYED BY AMEREN ON 11/6/04.

SCALE: 1" = 100'

NO	DATE	REVISION
0	12/27/05	INITIAL ISSUE
1	12/27/05	AMEREN ADDED COLOR CODING
2	12/27/05	AMEREN ADDED ELEV. PANELS 69-75

PROJECT NO.	CONTRACT NO.
060150	0028
DRAWN	CHECKED
JPB	RGB
DATE	DECEMBER 30, 2005

S1

EXHIBIT

KdG
85 Progress Parkway
Maryland Heights,
Missouri 63043-3706
(314) 621-0883

Leakage/Seepage

- Additional repairs were made in subsequent years, mostly on leakage through the horizontal and vertical joints in the concrete facing.
- Particular emphasis was on the joints between the concrete facing and bedrock, the joint at the toe of the parapet section, and the joint between the concrete facing and plinth.
- Leakage increased significantly (40 to 100 cfs) after an extended outage in 1999 due, in part, to more frequent cycling of the facility.
- To reduce seepage, a geomembrane liner was installed in 2004, significantly reducing the leakage to about 5 cfs.

Typical Project Operation
Prior to Deregulation

- The Taum Sauk facility was operated about 100 days a year prior to deregulation of electric power markets in the 1990's.
- Pumping generally occurred only on weekends.
- Only one pump was used for pump-back.

Typical Project Operation
After Deregulation

- The change in the market made it profitable to run the facility around 300 days a year.
- The pump/turbine units were upgraded in 1999, a decision likely influenced by deregulation, increasing the efficiency and profitability.
- The new pump/turbine runners had a maximum pumping flow of 3,000 cfs per unit compared to 2,450 cfs per unit for the original runners.
- Two pumps were used for pump-back.
- In total the probability of over-pumping increased 15 times

Typical Project Operation
After Deregulation

- A typical daily cycle in the summer was to generate in the morning, pump back in the afternoon, generate in the evening, and pump back again in the early morning.
- Generation and pump-start and duration was determined by system needs and controlled from Ameren's Osage Plant.

Other Changes in Plant Operation

- In the 1967 safety report, J.B. Cooke recommended visual oversight of all pumping operations. UE implemented the recommendation.
- Between 1968 and 2005 UE ended visual oversight of pumping.

Remediation

- In 2001 Ameren prepared plans to install an 80-mil reservoir liner in order to reduce leakage.
- The liner was anchored about 1 ft below the top of the parapet wall and near the top of the upstream plinth.
- As part of the “project improvement” the old reservoir control systems were replaced by a new system in November of 2004.

Remediation

- The original reservoir monitoring system consisted of:
  - (1) three Warrick conductivity sensors at elevations 1591.00, 1596.0 and 1598.0,
  - (2) a float riding on a cable guided roller assembly in a pipe to monitor upper reservoir levels for normal shutdown of the units, and
  - (3) a set of mercury switches tied to a float in a stilling well for High and High-High backup pump shutoff.
- The system components were anchored to the dam.

Remediation

- In 1994, a differential pressure transducer was added to provide secondary level indication.
- In 2000, the original skate system, encoder, and chart recorder were replaced with a differential pressure level transducer, PLC, and a digital level indicator at the upper reservoir.
- A staff gage attached to the parapet wall allowed calibration of the instrumentation.
- Because the staff gage was fixed to the parapet wall, it settled along with the wall. Ameren believes that, due to settlement, the upper reservoir was actually operating at El 1595 instead of El 1596.

Remediation

- The over-pumping protection systems were replaced during installation of the liner in 2004.
- Four 4-inch-diameter High Density Polyethylene (HDPE) pipes, to house the pressure sensors, were placed down the upstream slope of the dike at parapet wall panel 50.
- The new system was not anchored to the concrete face because it was decided that the new liner should not be penetrated by anchor bolt holes.

Remediation

- Stability of the HDPE pipes was provided by a system of unistrut sections, steel bolts, turnbuckles, jam nuts, eyebolts and U-shaped cable lock bolts tied to two stainless steel cables.
- The cables were anchored only at the plinth and at the base of the parapet wall.
- Down slope movement of the HDPE pipe assembly was limited by clamps placed on the cable just below the eyebolt connection to the pipe assembly.
- No restraint to upslope movement was included.

Remediation

- At the time of the failure, the upper reservoir control system consisted of two sets of sensors sending signals through three independent PLCs.
  - One set of sensors were two Druck pressure transducers used to monitor reservoir levels
  - The second set of sensors consisted of four Warrick conductivity sensors.
    - Two of the Warrick sensors (HIGH and HIGH-HIGH) were to determine if water levels in the upper reservoir were too high.
    - The other two Warrick sensors were to determine if water levels in the upper reservoir were too low.
    - Activating these sensors would start a hard shutdown of the generator/pump units.

Remediation

- At the time of the breach the elevations of the Warrick sensors were 1597.4 (HI) and 1597.66 (HI-HI), respectively.
- The staff gage was removed.
- Due to several “false” shut-downs, the Warrick sensors were rewired in parallel rather than series, thereby requiring both sensors to activate prior to initiating a pump shut-down.

Prior Overtopping

- On September 25, 2005 Ameren employees observed water pouring over the parapet wall along the northwest portion of the reservoir, describing the incident as resembling “Niagara Falls.”
- The operators manually shut down the pumps and turned on the generating units to lower the reservoir.

Prior Overtopping

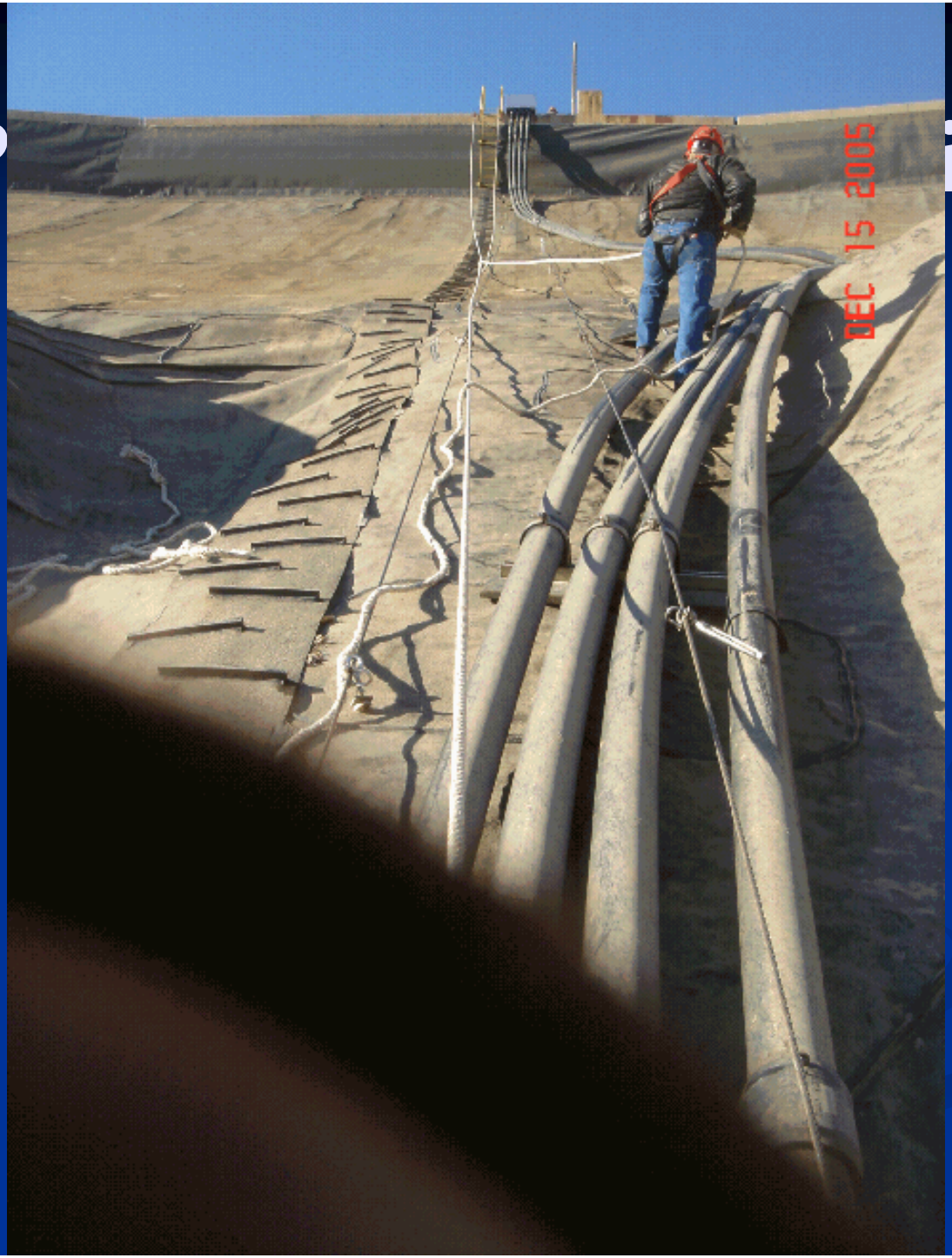
- The plant operator sent an e-mail to his supervisors on Sept. 27th warning them about continued overtopping of the upper reservoir after the second overtopping incident.
- *"Overflowing the upper reservoir is obviously an absolute 'NO-NO,'" "The dam would severely erode and cause eventual failure of the dam..." and "If water continued to spill over the top of the wall, it could cause a section to collapse and then it would be all down hill from there — literally."*

Remediation

- After installation of the liner and new reservoir level measuring instruments in 2004, but before October 2005, the 1st pump off and 2nd pump off were set at El 1594 and 1596, respectively.
- In October, 2005 Ameren noticed movements of the HDPE pipes housing the pressure sensors.
- After October 2005, the first pump off was set at El of 1592 and the 2nd pump off at El 1594.
- At El 1594.2, shutdown for both pumps was to be initiated if they were not shutdown already.
- Unfortunately, Ameren did not know with certainty how much the sensors had moved.


DEC 15 2005

P it



Failure – Just the Facts

The Upper Reservoir of the Taum Sauk Pumped Storage Project was overtopped during the final minutes of the pumping cycle on the morning of Dec. 14, 2005. Data indicate that pumping stopped at 5:15 AM with the initial breach forming at about the same time. Once overtopping began, erosion started at the downstream toe of the 10' high parapet wall. Erosion progressed below the parapet wall, likely causing instability and resulting in the initial loss of one or two parapet wall sections.

Failure – Just the Facts

Subsequent erosion and breach of the rockfill embankment formed a breach about 656’ wide at the top of the rockfill dam and 496’ at the base of the dam. The peak discharge from breach was about 273,000 cfs which occurred within 10 minutes of the initial breach. The complete evacuation of the reservoir occurred within 25 minutes.

Consequences

- Downstream of the breach was Johnson Shut-Ins State Park, a popular recreation area that draws nearly 250,000 visitors annually.
- The flood wave swept down Proffit mountain causing extensive erosion and environmental damage.
- The flood wave passed into the Black River causing inundation and extensive damage to the State Park.

Consequences

- The consequences from the failure could have been far worse had it occurred at a different time of year.
- The failure occurred around 5:15 AM with flood waters quickly reaching the park.
- Fortunately, the campground was empty during the middle of December, resulting in no deaths.
- Hundreds of sleeping campers may have perished in the state park campground had the failure occurred on a busy summer weekend.

A Systems Perspective of the Failure

Contributors to Failure
Design

- Large pumped storage was new technology
- Dumped Rockfill
- Steep slopes
- Didn't take advantage of new state-of-practice
- Water stored on 10' high parapet wall
- No spillway
- Reliance on control system to prevent over-pumping
- Control system placed near intake/outlet

Contributors to Failure
Construction

- Fines were left in the fill – especially at the closure section
- Failure to remove all substandard material from beneath dam footprint
- Outer shell of the dike contained more sandy and pebble sized materials in the closure section

Contributors to Failure
Performance History

- Excessive settlement, lowest point 2’ lower than design
- Large (4-5 inches) offset of parapet wall sections – torn waterstops?
- Excessive seepage
- Joint opening

Contributions to Failure
Operation History

- Deregulation
- Change from 100 days/yr to 300 days/yr
- Change from 1 pump cycle/wk to 2-3 cycles/day
- Change from 1 pump to 2 pumps
- Upgrade pumps from 2,450 cfs to 3,000 (20% increase)
- Visual surveillance of pumping to none
- Failure to take action after earlier over-pumping events

Contributions to Failure Remediation

- Design of revised water level control system didn't consider settlement of parapet walls or the affects of the inlet/outlet vortex
- Sensor pipes not fastened to dam
- Staff gage removed
- Changed winter operation from -2 feet to normal full pool
- Misplacement of emergency shut-off sensors (above lowest point on wall)
- Wiring Warrick sensors in parallel.
- Uncertainty in sensor movement

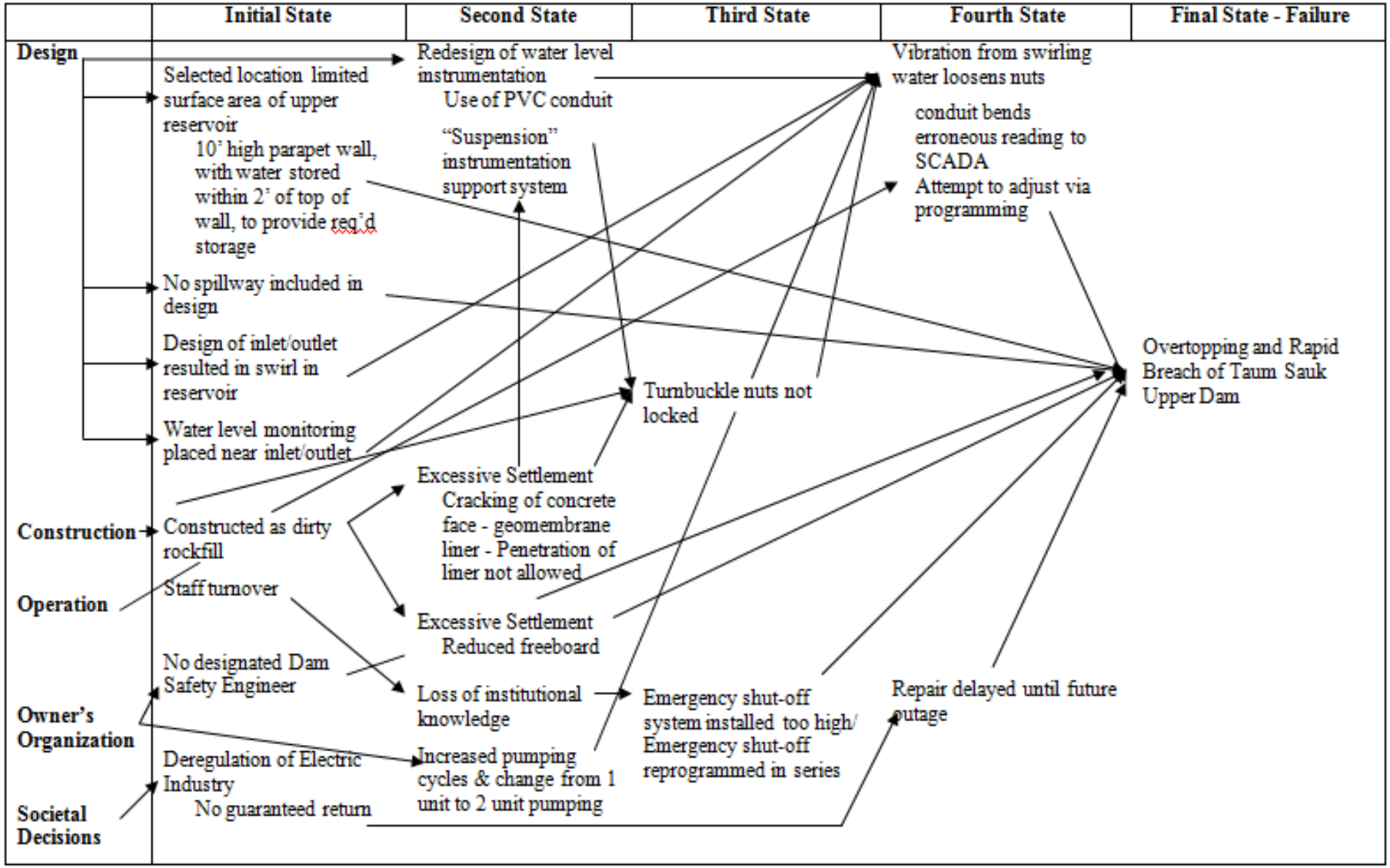


Figure 2 – Interaction Flow Chart – Taum Sauk Upper Dam Failure

Operational Failure Modes

- Can you get there?
- Will it Work?
- Stuff Happens – Just don't let it happen to you!

Operations Potential Failure Modes

- In extreme events such as floods or earthquakes access to a dam may be cut off and power lines, microwave reflectors, radio towers may be knocked out.

- Example
  - Gates are local operation only.
  - Access to dam is prevented during floods due to inundation of access road

SCADA Issues

- Supervision Control And Data Acquisition (SCADA) systems are becoming more common as owners react to cost pressures by reducing staff, remotely operating units and automating data acquisition.
- License and grid conditions often require owners to more accurately control their units.
- SCADA system failures have contributed to several incidents and failures including Taum Sauk Dam.

SCADA Failures

- Failure to Open on Demand
- Failure to Close on Demand
- Closure without Demand
- Open without Demand


Lower Elevation
Looking Southeast

Events Leading up to Incident

- During high flows the Cowlitz Falls project is required to flush sediment through low level outlets to prevent flooding upstream
- The design of the dam has the low level outlets beneath the radial gates
- The control system is designed to NOT allow the sluice gates to open while the spill gates are open due to excessive vibration in the sluice gates

Events Leading up to Incident

- In 2003, the Cowlitz Falls project was undergoing a SCADA upgrade.
- An early storm had Cowlitz Falls spilling
- Without operator intervention, the sluice gate opened, bypassing both the intent of the SCADA system and a PLC designed to lockout the sluice when the spill gate was open

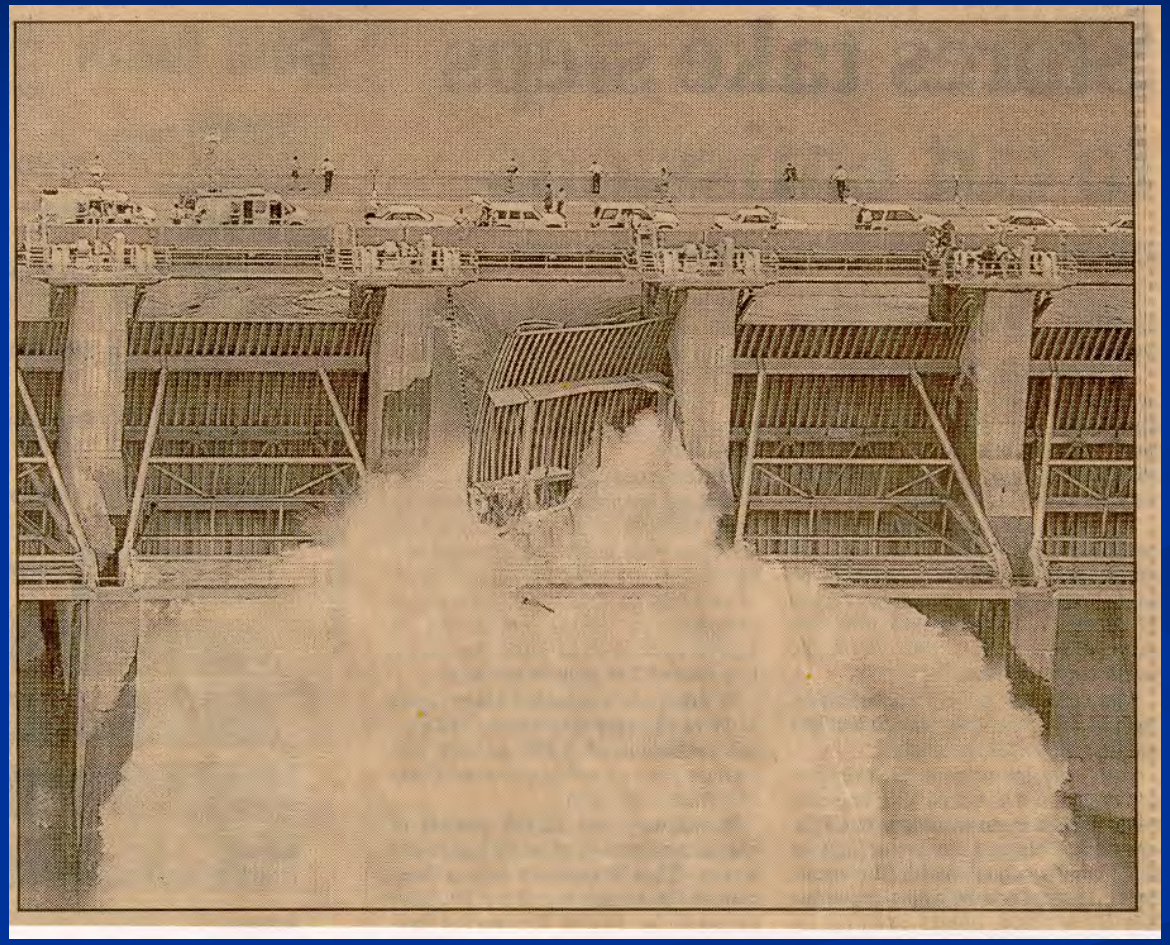
Lessons Learned

- Automated supervision, control and data acquisition (SCADA) systems pose some serious dam safety issues
- Need for careful and thorough testing
- Can't test all possibilities – only test what you can think of
- Need for keeping documentation current
- Need for operator training after initial installation and subsequent updates

Operations Potential Failure Modes

- Change in gate operations from a few times a year to daily (for fish passage)
- Lubrication schedule remained the same.
- Gearbox stripped, gate dropped on one side

Folsom Dam Gate Failure



Static Failure Modes
Contributing Factors

- Lack of Gate Maintenance
- Gate Binding
- Concrete Deterioration in Crest Structure or Chute
- Improper Construction

Lack of Gate Maintenance

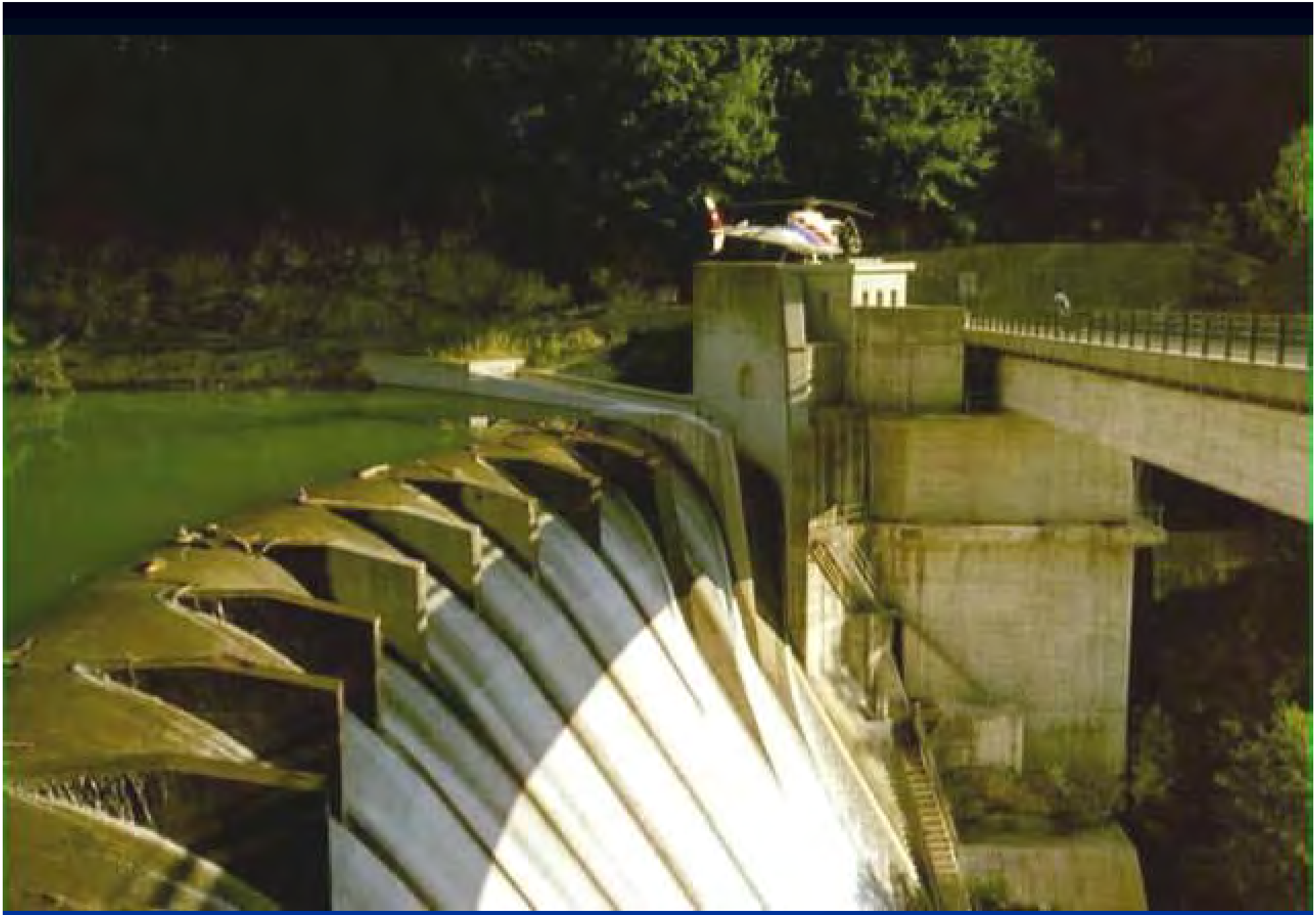
- Corrosion of key gate members or components, reducing member capacity
- Reduced reliability of back-up power supplies
- System problems not identified by regular exercising of gates


06/06/2005


Rivet heads
deteriorated

Consequences

- The spillway at Palagnedra Dam was completely blocked with debris.
- Water spilled over the main concrete dam and through a low spot upstream on the right bank.
- 50,000 cu meters of glacial moraine material was washed out from the downstream side of a 40 m high diaphragm wall upstream on the right side of the reservoir nearly causing failure of the wall.



Logbooms

- Logbooms may not be adequately strong to withstand large rafts of debris
  - Forces on anchorage is very large
  - Connections are often weak link
- Failure of a logboom may make things worse by allowing debris to knit together rather than passing singly over dam


LOGBOOM

Lessons Learned

- Spillway blockage due to debris is NOT an uncommon problem
- Narrow spillway openings can be a critical failure mode
- Logbooms are not necessarily the answer and can make things worse

Can You Get There?

Heading west

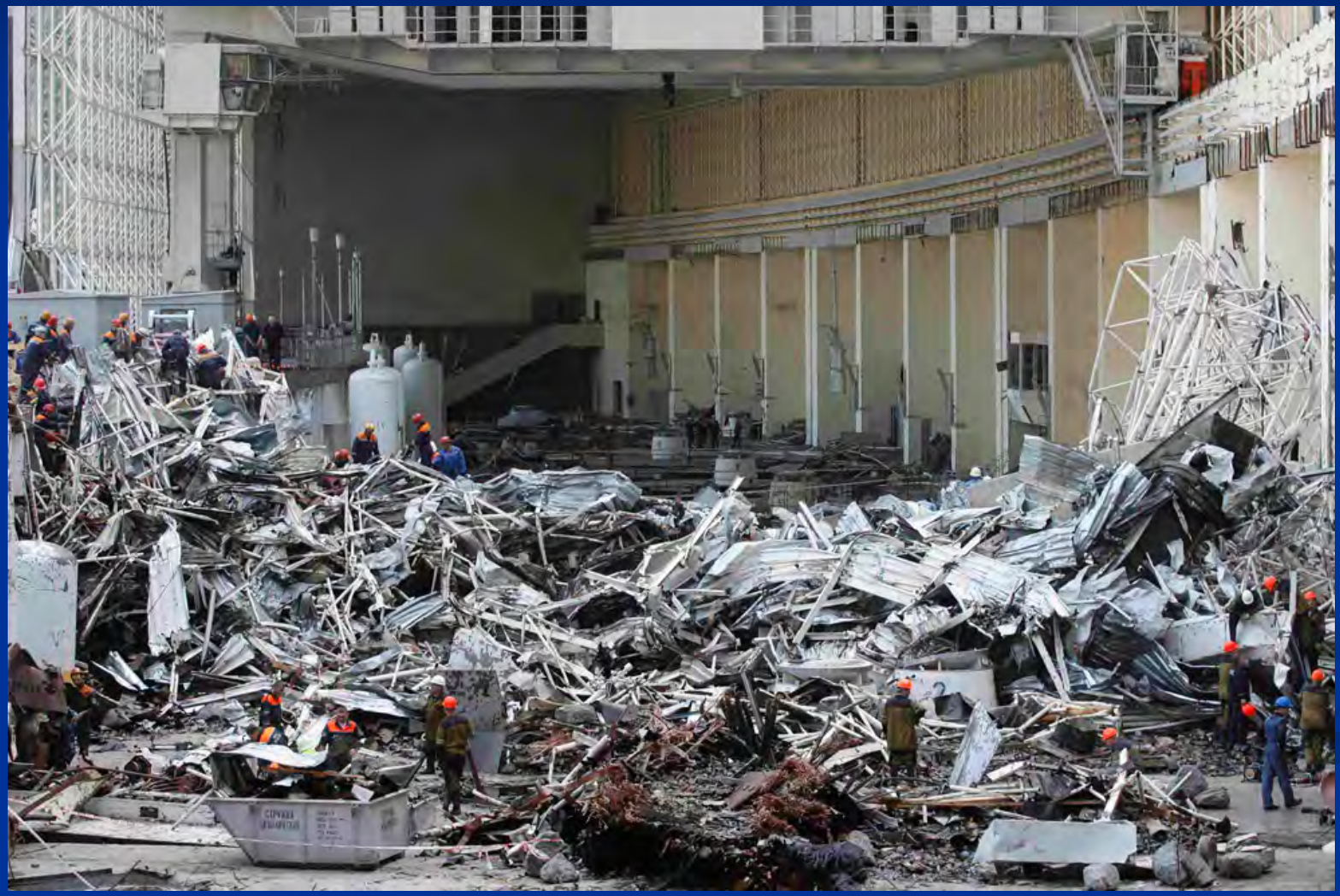

JAN 1 '97

Two Rivers slide across Hwy. 70/89


JAN. 4 1997

Can a Problem in a PH Cause a Dam Failure at a Remote Project?

Sayano-Shushenskaya



Sayano-Shushenskaya

- Dam Type: Gravity Arch
- Dam Height 242 meters / 794 ft
- Reservoir Capacity: 31.3 km^3 / 25.4M ac-ft
- Spillway Capacity: 12,800 m^3/s / 455K cfs
- Powerhouse Capacity: 3,500 m^3/s / 124K cfs
- Flood of Record: 24,300 m^3/s

Sayano-Shushenskaya

- No low-level outlet – maximum draft 45 m
- Est. storage volume in top 45 m – 18.1 cu km
- No TSV on the penstocks
- Reservoir filled as dam was raised
- Upstream monoliths raised first

Sayano-Shushenskaya

- Certification for Operation in 2000 noted need for additional spillway capacity
- Construction of additional spillway capacity delayed due to lack of funding

Sayano-Shushenskaya

- Turbine has large area of rough operation
  - Need for new design recognized in 2000
  - Plant control system does not take into account area of rough operation
- Operates in Unified Electric System – Siberia
- Constructed under Russian state ownership
- Privatized in 1993

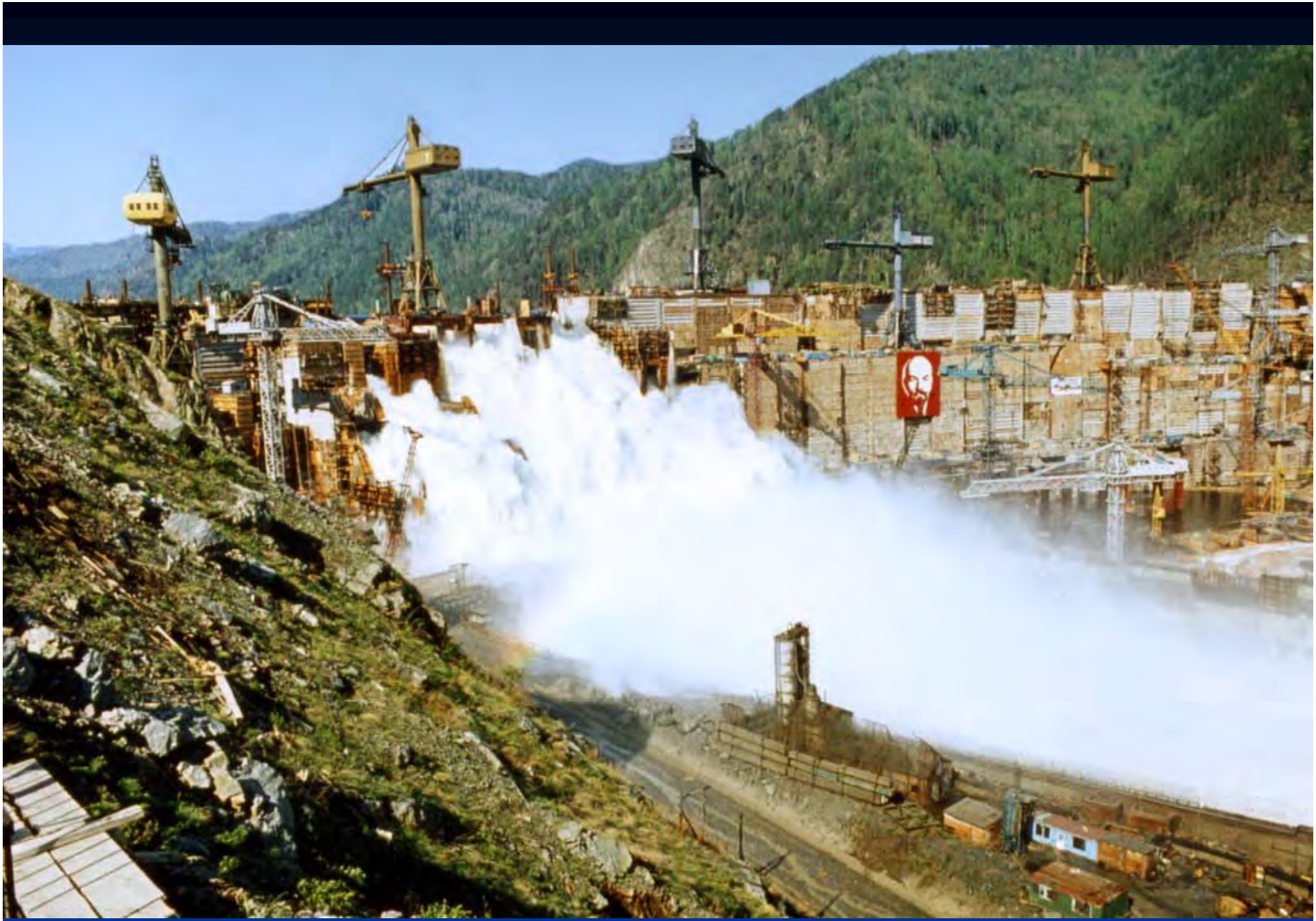
Can a Problem in a PH Cause a Dam Failure at a Remote Project?

Background Information

- During construction the spillway was used to pass water
- During construction a flood resulted in 4500 m^3/s being discharged through the spillway
- The spillway stilling basin was severely damaged while passing 4500 m^3/s - 7m of the foundation was eroded
- The flood also overtopped the partially constructed dam cracking the dam-foundation interface and some concrete monoliths
- The damage to the spillway was repaired

Background Information

- The foundation and monoliths were grouted (under 200 meters of head)
- In 1988 a flood of 4400 m^3/s damaged the stilling basin again
- Again, the stilling basin was repaired
- A new tunnel spillway is being constructed




17.07.86

How Could a Dam Failure Occur? Part 1 - Reality

1) Under Normal Operation
2) A fire at a remote power plant causes the system dispatcher to transfer load-following responsibility to SSH hydro plant
3) SSH staff start Unit 2 and place in load following mode
4) Operation of Unit 2 over the course of 30 years causes partial to complete fatigue failure of the bolts holding down the turbine head cover

How Could a Dam Failure Occur? Part 1 - Reality

5) In load following mode Unit 2 transitions through the rough operating region on several occasions
6) The fatigue failure of the head cover bolts reaches a critical state
7) The turbine head cover tears loose ejecting the turbine through the generator

How Could a Dam Failure Occur? Part 1 - Reality

8) The open head cover allows water to flood into the powerhouse
9) The flooding water knocks out station power cutting power to the penstock intake gates
10) Water flows for half an hour until the gates can be closed using manual operators
11) The flooding damages the powerhouse to the extent that all 10 units are forced off line and only two units will be available to help pass flow in the coming runoff season

How Could a Dam Failure Occur? Part 1 - Reality

12) Damage to the powerhouse results in the majority of inflow passing through the spillway for an extended period
13) Operation through the winter results in icing over the spillway and collapse of a crane used to access the stilling basin for repair

How Could a Dam Failure Occur? Part 2 - Hypothetical

14) Higher than normal snowfall in the watershed may lead to larger than normal runoff (assume flood of record)
15) The high runoff requires the spillway to run full
16) The excess inflow rapidly fills the reservoir
    - 19 days if one tunnel spillway and two units are available
    - 12 days if only two units are available
    - 7 days if the service spillway becomes inoperable
17) The excess inflow overtops the dam reinitiating the crack at the dam foundation interface
18) High spillway flows destroys the stilling basin bottom and begins to undercut the dam toe
19) Undercutting continues as the spillway passes flow.

How Could a Dam Failure Occur? Part 2 - Hypothetical

20) Cracking of the dam-foundation interface leads to increased uplift under the dam
21) The combination of continued toe undercutting and increasing uplift under the dam leads to a sliding failure of the dam

How Big a Problem is This?

- Everything except the last 2 slides is a reality
- Over one million people live downstream of the dam
- There is an embankment dam 12 miles downstream that would fail if overtopped


Hoover Dam
Height – 726.4’
Crest Length – 1244’
Res. – 28.5M ac-ft


Sayano-Shushenskaya
Height – 794’
Crest Length – 3524’
Res. – 25.4M ac-ft


How Big is Big?

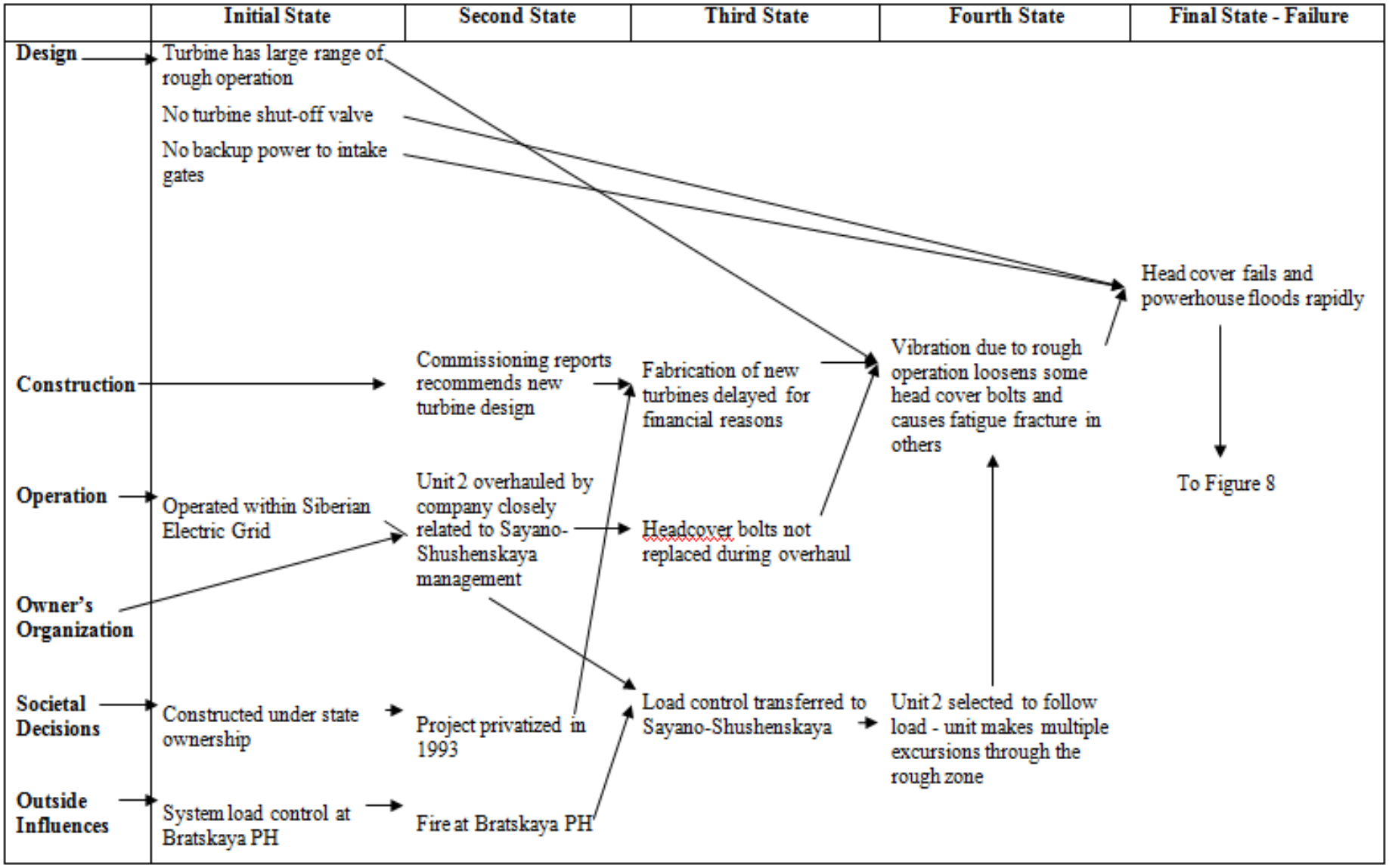


Figure 5 – Interaction Flow Chart – Failure of Sayano-Shushenskaya Powerhouse Turbine Headcover

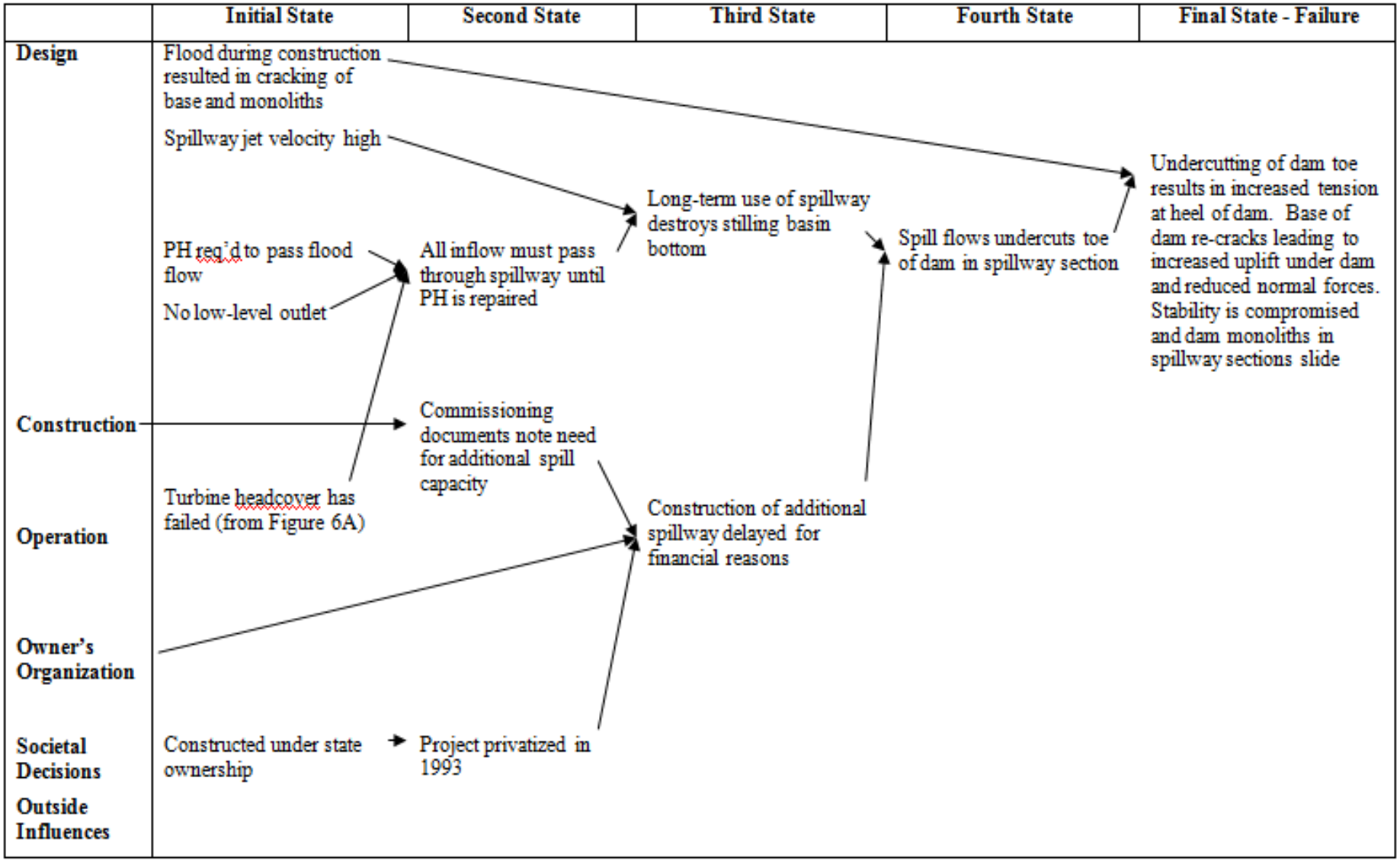


Figure 8 – Interaction Flow Chart – Potential Failure Mode Sayano-Shushenskaya Dam

Things to Consider

- Impacts of Deregulation
  - Profit Driven Environment vs. Guaranteed Rate of Return
- Operational or Physical Modifications for Environmental or Other Reasons
  - Spillway gate operation
  - Low level outlet operation
  - Lake level restrictions
  - etc
- Impacts of Increasing Use of SCADA Systems
  - What happens if you lose communication link
- Impacts of Increasing Use of Remote Operation
  - Can you get to a site in inclement weather or emergency

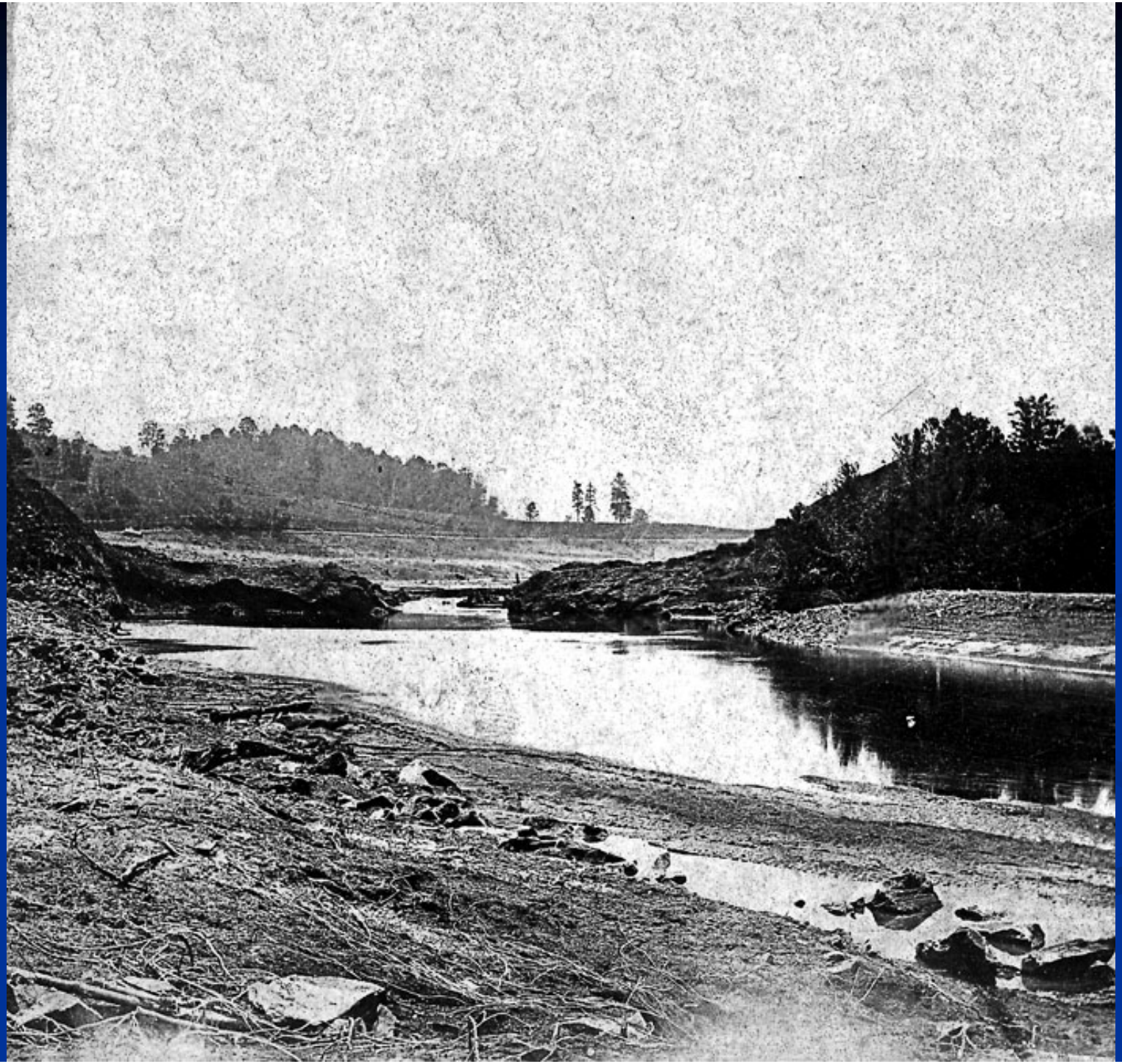
Things to Consider

- Human Factors
- Organizational Factors

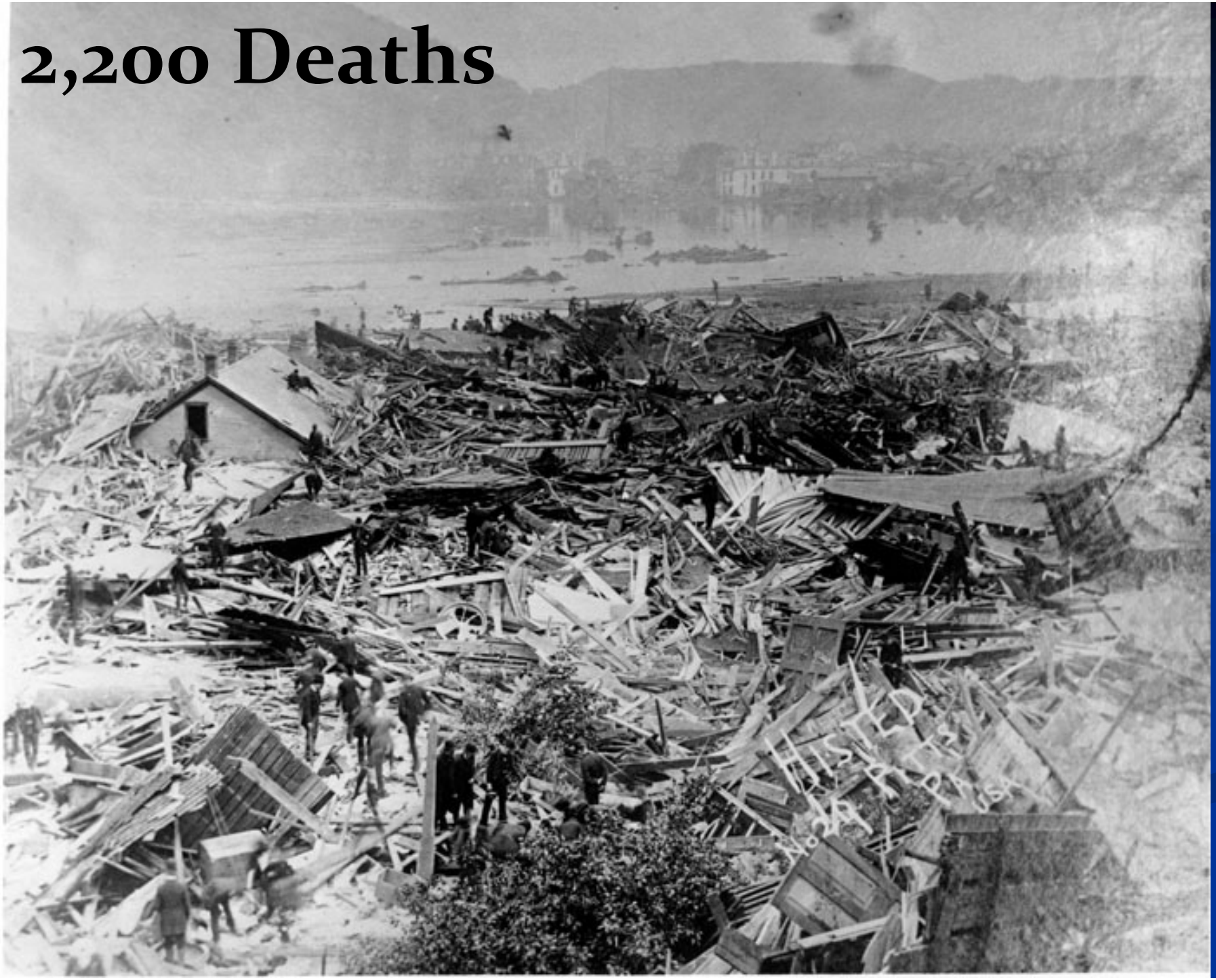
Consequences of Dam Failure

Stored Energy in Oroville Reservoir

Approximately 128 times the energy in the atomic bomb dropped on Hiroshima

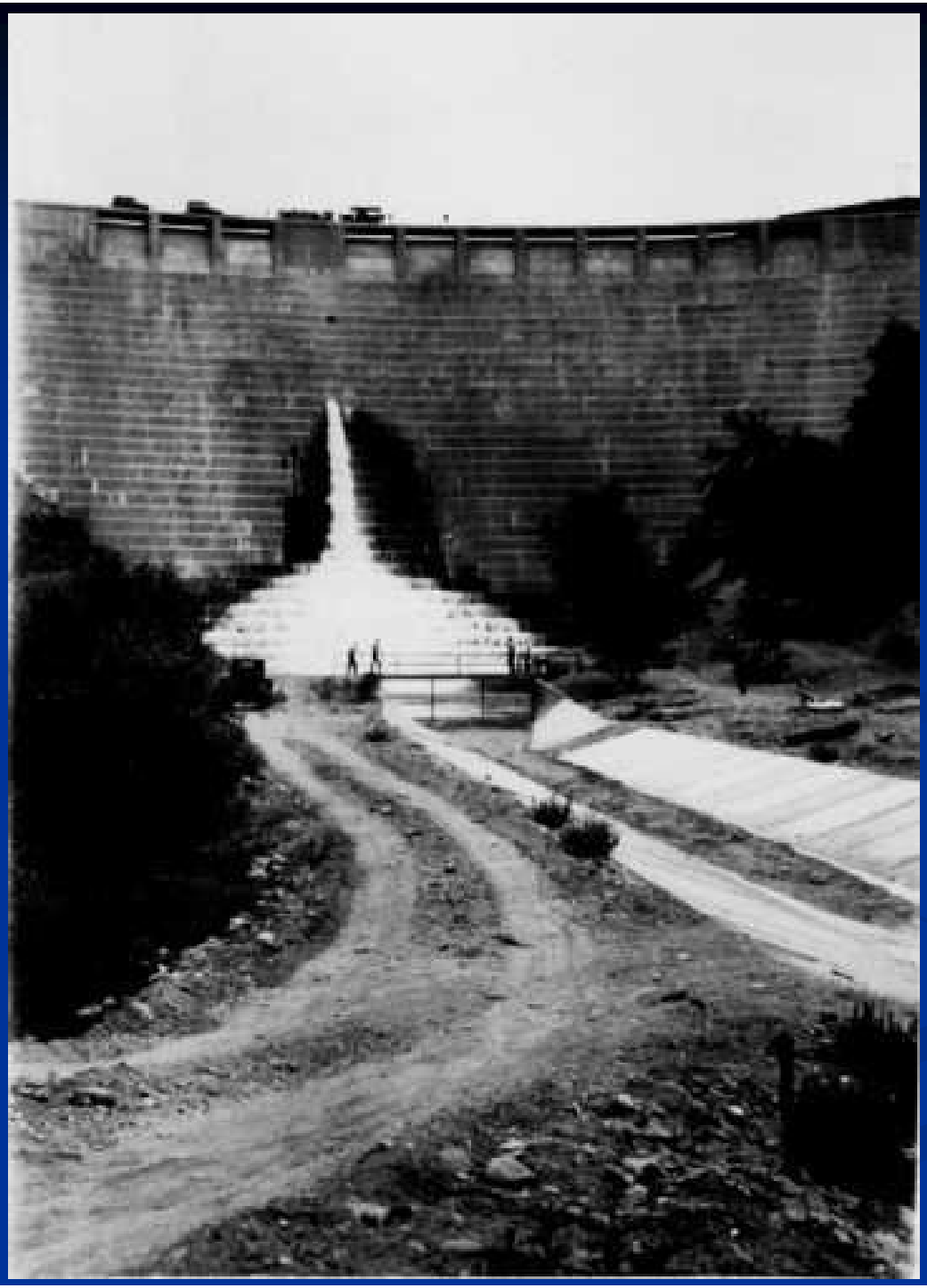


2,200 Deaths



The Monument to the Unknown Dead, 1892. It still stands in Johnstown's Grandview Cemetery.


11 Deaths




>500 Deaths


2500 Deaths

The Taum Sauk failure cost Ameren between

$1.5 and $3 Billion

in direct and indirect costs.

Code of Hammurabi

53. If any one be too lazy to keep his dam in proper condition, and does not so keep it; if then the dam break and all the fields be flooded, then shall he in whose dam the break occurred be sold for money, and the money shall replace the corn which he has caused to be ruined.

54. If he be not able to replace the corn, then he and his possessions shall be divided among the farmers whose corn he has flooded.

English Common Law

John Rylands (1801-1888), owner of the Ainsworth Mills, Lancashire, UK, whose impoundment flooded his neighbor's mine, giving rise to the concepts of dangerous accumulations, escape of same, and liability without fault.

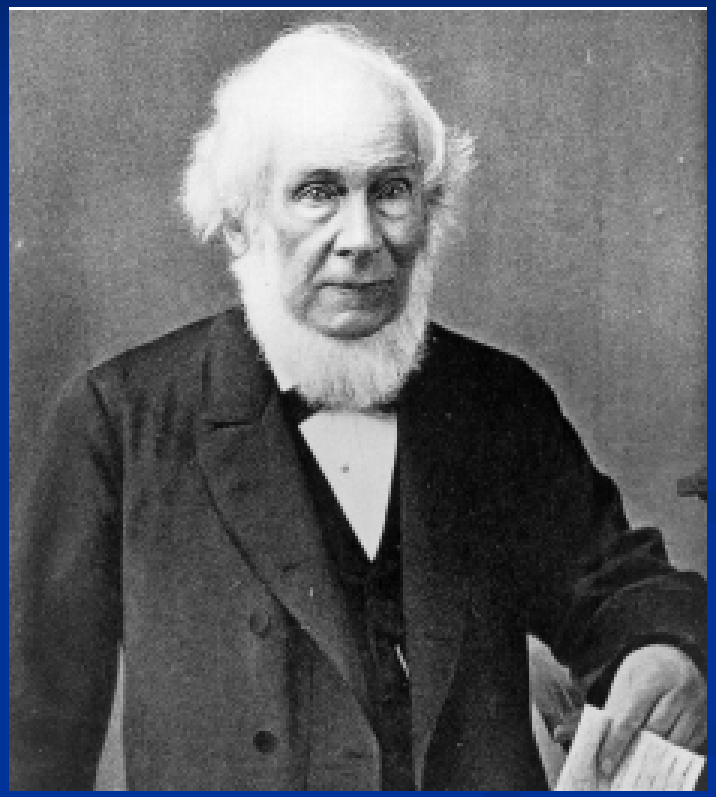


Image credit: John Rylands University Library, Manchester, UK

Importance of a Robust Owner's Dam Safety Program

18CFR12

- Volume 18 of the Code of Federal Regulations Part 12 contains the FERC regulations related to Dam Safety
- These regulations should be viewed as a minimum. They do **NOT** define an appropriate owners' dam safety program.

Why Does the FERC Require a Written ODSP

- Every Dam is unique – we cannot write guidelines that cover every possible failure mode.
- Dams are not just a combination of individual components.
- Dams are a complex system operating within a larger system; the power grid.

Why Does the FERC Require a Written ODSP

- Dam failures are generally NOT caused by a single factor such as earthquakes or extreme floods.
- Many, if not most, failures are due to some form of mis-operation or other human or organizational factors.
- Taum Sauk

Stewardship

“the careful and responsible management of something entrusted to one’s care”

Merriam Webster Dictionary


Taum Sauk Dam


Kingston Dam

BP Deepwater Drilling Platform


San Bruno
Gas Pipeline

Common Causes of Organizational Accidents

Organizations that are often complacent about safety due to the low frequency of adverse events, arrogant about the probability of an adverse event happening to them and ignorant of the real risks inherent in their operations

Regan, P., 2012, Call to Stewardship, USSD

Common Causes of Organizational Accidents

Organizations focused on meeting the letter of regulatory requirements but ignoring the underlying spirit and purpose of the regulations

Regan, P., 2012, Call to Stewardship, USSD

Common Causes of Organizational Accidents

Organizational safety programs focused on personal safety rather than system safety

Regan, P., 2012, Call to Stewardship, USSD

Common Causes of Organizational Accidents

Organizations being driven by financial performance resulting in decisions being made to operate systems near the boundaries of safety

Regan, P., 2012, Call to Stewardship, USSD

Common Causes of Organizational Accidents

A tendency to fixing symptoms of problems rather than determining the underlying causes and fixing the fundamental problems

Regan, P., 2012, Call to Stewardship, USSD

Common Causes of Organizational Accidents

Poor communication within, and outside, of organizations

Regan, P., 2012, Call to Stewardship, USSD

Common Causes of Organizational Accidents

A lack of corporate safety culture in many organizations (System safety not personal safety)

Regan, P., 2012, Call to Stewardship, USSD

Complacency, Arrogance & Ignorance

Complacency

"It won't happen because It's been fine for a long time."

Arrogance

"It might happen, but not to me."

Ignorance

"What is It?"

Complacency

"Believing that past non-events predict future non-events (forgetting to be afraid)"

James Reason, Author of Managing the Risks of Organizational Accidents

Complacency
(Related to Focus on Financial Performance)

"Absent major crises, and given the remarkable financial returns available from deepwater reserves, the business culture succumbed to a false sense of security. The *Deepwater Horizon* disaster exhibits the costs of a culture of complacency."

National Commission on the BP Deepwater Horizon Oil Spill (2011)

Complacency
(Related to Focus on Personal Safety)

"Awards for slip and fall reduction promote complacency. . . They create the illusion of protection in workplaces where process safety management hasn't been properly implemented. The safety plaques are paper shields, easily immolated in explosions, along with the workers they beguiled."

Gerard, L.W., Safety Awards that Endanger Workers' Lives, May, 2010

Arrogance

"... an August 2005 incident in Pennsylvania during which 100 million gallons of fly ash spilled into the Delaware River through a breached plug in an ash settling pond did not prompt any response or study within TVA of TVA's own potential ash pond risks."

McKenna Long & Aldridge LLP, et.al, 2009, A Report to the Board of Directors of the Tennessee Valley Authority Regarding Kingston Factual Findings

Arrogance

"Incidentally, Mr. Jack Shepley of the F.P.C. Washington Office called Mr. Vencill recently and asked for some information about the upper reservoir level detection and pump shutdown which I sent him. . . . ***I told him there would be no structural damage if the pumps failed to shut down***, but there would be some washing of the roadway surface." (emphasis added)

Letter from Raymond Weldy
to Barry Cooke, August 1968


Taum Sauk (MO)

Ignorance

"There is no evidence top management has taken the steps necessary to be well-informed about the key aspects of decisions selected to manage major risks that concern PG&E."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Ignorance
(Related to Focus on Financial Performance)

"The ignorance of technical risks is a byproduct of PG&E's overall focus on financial performance ..."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Focus on Regulatory Requirements

PG&E

The Panel noted that while PG&E was "targeting efforts to comply" in reality;

"PG&E was skirting the requirements of the integrity management regulations through use of an 'exception' process, whereby critical repairs and other activities were delayed."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

PG&E

". . .we seriously question whether PG&E has embraced the spirit of the pipeline integrity regulations."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Focus on Personal Safety Not System Safety

Focus on Personal Safety

"Disasters don't happen because someone drops a pipe on his foot or bumps his head. They result from flawed ways of doing business that permit risks to accumulate."

Elkind, P., et.al., BP: 'An accident waiting to happen', Fortune Magazine, January 24, 2011

BP

"Consider this: BP had strict guidelines barring employees from carrying a cup of coffee without a lid - but no standard procedure for how to conduct a 'negative-pressure test', a critical last step in avoiding a well blowout. If done properly, that test might have saved the *Deepwater Horizon*."

Elkind, P., et.al., BP: 'An accident waiting to happen', Fortune Magazine, January 24, 2011

PG&E

"Management's focus in recent times appears to have been on the occupational safety of its employees and lacking an equivalent focus on the public safety aspects of its system."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Focus on Financial Performance

Focus on Financial Performance

"... it should not be forgotten that commercial success in a competitive environment implies exploitation of the benefit from operating at the fringes of the usual, accepted, practice."

Rasmussen, J., Risk Management in a Dynamic Society: A Modelling Problem, 1997

Focus on Financial Performance

"Closing in on and exploring the boundaries of the normal and functionally acceptable boundaries of established practice during critical situations necessarily implies the risk of crossing the limits of safe practice."

Rasmussen, J., Risk Management in a Dynamic Society: A Modelling Problem, 1997

Ameren

"Divers were summoned and they ascertained that the new sensor conduits had become detached from their mountings along the sloping concrete face of the reservoir. . . . Unfortunately, permanent repairs were postponed until regularly-scheduled maintenance the following spring to avoid an additional shutdown of the facility."

Rogers, J.D., Overview of the Taum Sauk Pumped Storage Power Plant Upper Reservior, 2008

Fixing Symptoms not Problems

"Symptomatic solutions are usually easier, faster, and cheaper to implement than long-term fundamental solutions."

Marais, K., et.al., Archetypes for Organizational Safety, September 2003

"Initially, positive results to symptomatic solutions are seen immediately, as the visible symptoms are eliminated. Once a symptomatic solution has been successfully applied, the pressure to find and implement a fundamental solution tends to decrease."

Marais, K., et.al., Archetypes for Organizational Safety, September 2003

“The underlying problem remains.”

Marais, K., et.al., Archetypes for Organizational Safety, September 2003

TVA

"In 2003 and 2006, seeps along the west side of the Kingston dredge cells were discovered. The 'fixes' put in place to remedy these seeps were limited to patching the specific leaks."

McKenna Long & Aldridge LLP, et.al, 2009, A Report to the Board of Directors of the Tennessee Valley Authority Regarding Kingston Factual Findings

TVA

"As evidenced by its limited corrective actions, TVA focused on the earlier incidents as the problem, rather than as a symptom of a larger trouble."

McKenna Long & Aldridge LLP, et.al, 2009, A Report to the Board of Directors of the Tennessee Valley Authority Regarding Kingston Factual Findings

TVA

"Investigating the cause of incidents beyond the specific physical occurrences into the functioning of systems is fundamental to a robust safety program."

McKenna Long & Aldridge LLP, et.al, 2009, A Report to the Board of Directors of the Tennessee Valley Authority Regarding Kingston Factual Findings

Poor Communication

TVA

"Employees tended to use the concept of 'silos' to refer to two related, but yet distinct, phenomena - (1) the more common use of the term indicating a lack of collaboration among various business units across TVA or within a particular department and (2) the tendency within TVA not to readily share information with one's superiors."

McKenna Long & Aldridge LLP, et.al, 2009, A Report to the Board of Directors of the Tennessee Valley Authority Regarding Kingston Factual Findings

PG&E

"Frequently, employees cited poor communication and abundance of organizational silos that have impeded their ability to understand what work was being undertaken and hence the quality of the work."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Lack of Corporate Safety Culture

Corporate Safety Culture

“the way safety is perceived, valued and prioritized in an organization. It reflects the real commitment to safety at all levels in the organization. It has also been described as how an organization behaves when no one is watching."

SKYbrary, EUROCONTROL

Corporate Safety Culture

"A number of concerns surfaced in the course of our investigation that go to this issue of whether PG&E has a high functioning organization, capable of fulfilling its mandate for safe and reliable gas service."

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

Corporate Safety Culture

"We think this failing is a product of the culture of the company – a culture whose rhetoric does not match its practices."

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

Corporate Safety Culture

"Whether it is the regulated entity or the regulator, the issue of organizational culture is an aspect the Panel felt could not be ignored."

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

Corporate Safety Culture

"Both organizations failed to understand the critical technical and managerial nature of the pipeline integrity mandate and neither created an environment in which excellence was demanded."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Corporate Safety Culture

"The Panel believes both of these institutions must confront and change elements of their respective cultures to assure the citizens of California that public safety is the foremost priority."

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Key Elements of a Safety Culture

- an ***informed culture***
- a ***reporting culture***
- a ***just culture***
- a ***flexible culture***
- a ***learning culture***

Reason, J., 1997, *Managing the Risks of Organizational Accidents*

Key Elements of a Safety Culture

Informed Culture - one in which those who manage and operate the system have current knowledge about the human, technical, organizational and environmental factors that determine the safety of the system as a whole.

Reason, J., 1997, *Managing the Risks of Organizational Accidents*

Key Elements of a Safety Culture

Reporting Culture - a culture in which people are willing to report errors and near misses

Reason, J., 1997, *Managing the Risks of Organizational Accidents*

Key Elements of a Safety Culture

Just Culture - a culture of 'no blame' where an atmosphere of trust is present and people are encouraged or even rewarded for providing essential safety-related information, but where there is also a clear line between acceptable and unacceptable behaviour

Reason, J., 1997, *Managing the Risks of Organizational Accidents*

Key Elements of a Safety Culture

Flexible Culture which can take different forms but is characterized as shifting from the conventional hierarchical mode to a flatter professional structure, and,

Reason, J., 1997, *Managing the Risks of Organizational Accidents*

Key Elements of a Safety Culture

Learning Culture - the willingness and the competence to draw the right conclusions from its safety information system, and the will to implement major reforms when the need is indicated.

Reason, J., 1997, *Managing the Risks of Organizational Accidents*

BP

This disaster was preventable if existing progressive guidelines and practices been followed—the Best Available and Safest Technology. BP's organizations and operating teams did not possess a functional Safety Culture. Their system was not propelled toward the goal of maximum safety in all of its manifestations but was rather geared toward a trip-and-fall compliance mentality rather than being focused on the Big-Picture.

Deepwater Horizon Study Group
Investigation of the Macondo Well Blowout Disaster

BP

It has been observed that BP's system "forgot to be afraid." The system was not reflective of one having well-informed, reporting, or just cultures. The system showed little evidence of being a high-reliability organization possessing a rapid learning culture that had the willingness and competence to draw the right conclusions from the system's safety signals.

Deepwater Horizon Study Group
Investigation of the Macondo Well Blowout Disaster

BP

The Macondo well disaster was an organizational accident whose roots were deeply embedded in gross imbalances between the system's provisions for production and those for protection.

Deepwater Horizon Study Group
Investigation of the Macondo Well Blowout Disaster

BP

This disaster also has eerie similarities to the BP Texas City refinery disaster. These similarities include:

a) multiple system operator malfunctions during a critical period in operations,

b) not following required or accepted operations guidelines ("casual compliance"),

c) neglected maintenance,

BP

d) instrumentation that either did not work properly or whose data interpretation gave false positives,

e) inappropriate assessment and management of operations risks,

d) multiple operations conducted at critical times with unanticipated interactions,

BP

g) inadequate communications between members of the operations groups,

h) unawareness of risks,

i) diversion of attention at critical times,

j) a culture with incentives that provided increases in productivity without commensurate increases in protection,

Deepwater Horizon Study Group
Investigation of the Macondo Well Blowout Disaster

BP

k) inappropriate cost and corner cutting,

l) lack of appropriate selection and training of personnel, and

m) improper management of change.

BP

In both cases—the BP Texas City and the BP Macondo well disasters—meetings were held with operations personnel at the same time and place the initial failures were developing. These meetings were intended to congratulate the operating crews and organizations for their excellent records for worker safety.

Deepwater Horizon Study Group
Investigation of the Macondo Well Blowout Disaster

BP

Both of these disasters have served—as many others have served—to clearly show there are important differences between worker safety and system safety. One does not assure the other.

Alternatively

Shell Oil

Shell Oil has a corporate policy, Goal Zero, that encourages workers to call for work to stop when they suspect that something is proceeding improperly.

Shell gives awards to what they term 'Goal Zero Heroes'. So, rather than just recognizing worker safety, Shell also recognizes those who have taken action to prevent system failures.

http://www.shell.com/home/content/environment_society/safety/culture

Colonial Pipeline

"All employees have the right and responsibility to shut down, in an orderly fashion, any system that they believe to be endangering the public, environment, themselves or co-workers."

Colonial Pipeline, Operating Philosophy, 2008

Where Do We Go From Here?

“I think we have to be frank with ourselves, not just about what it will cost to upgrade our infrastructure, but what it will cost if we fail to do so.”

Liveris, A., "Make it in America: The Case for Re-Inventing the Economy"

Leadership

"The critical common element is an unwavering commitment to safety at the top of an organization: the CEO and board of directors must create the culture and establish the conditions under which everyone in a company shares responsibility for maintaining a relentless focus on preventing accidents."

(The accidents they are talking about are not OSHA accidents)

National Commission on the BP Deepwater Horizon Oil Spill (2011)

Leadership

"Likewise, for the entire industry, leadership needs to come from the CEOs collectively, who can apply pressure on their peers to enhance performance."

National Commission on the BP Deepwater Horizon Oil Spill (2011)

Acknowledge Ownership and Responsibility

The Independent Review Panel on the San Bruno explosion recommended the CPUC require:

"certification by senior management of the operator that parallels the certifications now required of corporate financial statements pursuant to Sarbanes-Oxley."

(The Sarbanes-Oxley Act, enacted after the financial collapse of ENRON, requires financial audits of companies address the risks to a company's financial well being.)

Report of the Independent Review Panel, San Bruno Explosion, June 2011

Solve Problems not Symptoms


DEC 15 2005


12/15/2005

Communicate

"To meet the challenge of addressing the complexities inherent in risk management, the leadership of the organization needs to establish and promote a thorough and honest company-wide communication system."

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

Keep Learning

"It should not be necessary for each generation to rediscover principles of process safety which the generation before discovered. We must learn from the experience of others rather than learn the hard way. We must pass on to the next generation a record of what we have learned."

Jesse C. Ducommun – ex Vice President Amoco

Quoted by Baker, J.A, et al, The Report of the BP U.S. Refineries Independent Safety Review Panel, January 2007

Keep Learning

"Large organizations, either in the private sector or public sector, always have a churning of staff. . . . The result is that when something bad happens, or even if something good happens, few people know those solutions which have proven to work in the past and those that have failed miserably."

Shamah, J., How soon they forget: Organizational memory and effective policies, May 2009

Understand Risks

"Quality (risk) analysis could both facilitate two-way communication between top management and individuals with substantial knowledge about each of the relevant aspects of utility operations and provide a clear understanding of all the information available to make a key risk management decision."

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

Understand Risks

". . . it is the job of the CEO and senior management to assess and manage the company's exposure to risk."

"The audit committee should discuss the company's major financial risk exposures and the steps management has taken to monitor and control such exposures."

NYSE Listing Standards Part 7d

Understand Risks

An organization's risk maturity is gauged by the priority, proactive thought, and serious effort allocated to manage the most significant risks facing an organization. Collectively, risk management and risk culture are the foundations that influence how well decisions about risk are made.

Understand Risks

Quality risk analysis to support strategic and policy risk management decisions at PG&E does not exist. There is no evidence top management has taken the steps necessary to be well- informed about the key aspects of decisions selected to manage major risks that concern PG&E, such as its top ten catastrophic risks.

Report of the Independent Review Panel,
San Bruno Explosion, June 2011

PG&E Risk Factors 2010

- operating limitations that may be imposed by environmental laws or regulations, including those relating to GHG, or other regulatory requirements;
- imposition of stricter operational performance standards by agencies with regulatory oversight of the Utility's facilities;
- environmental accidents, including the release of hazardous or toxic substances into the air or water, urban wildfires, and other events caused by operation of the Utility's facilities or equipment failure;
- fuel supply interruptions;
- equipment failure;
- failure or intentional disruption of the Utility's information systems, including those relating to operations, such as the advanced metering infrastructure being deployed by the Utility, or financial information, such as customer billing;
- labor disputes, workforce shortage, and availability of qualified personnel;
- weather, storms, earthquakes, wildland and other fires, floods or other natural disasters, war, pandemic, and other catastrophic events;
- **explosions**, accidents, **dam failure**, mechanical breakdowns, and terrorist activities; and
- other events or hazards.

PG&E Risk Factors 2011

- the release of hazardous or toxic substances into the air or water;
- fuel supply interruptions or the lack of available fuel which reduces or eliminates the Utility's ability to provide electricity and/or natural gas service;
- **the failure of a large dam or other major hydroelectric facility**;
- the breakdown or failure of equipment, electric transmission or distribution lines, or **natural gas transmission and distribution pipelines**, that can cause explosions, fires, or other catastrophic events;
- the failure of new generation facilities to perform at expected or at contracted levels of output or efficiency;
- use of new or unproven technologies;
- the failure to take expeditious or sufficient action to mitigate operating conditions, facilities, or equipment, that the Utility has identified, or reasonably should have identified, as unsafe, which failure then leads to a catastrophic event;
- operator or other human error;
- cyber-attack;
- severe weather events such as storms, tornadoes, floods, drought, earthquakes, tsunamis, wildland and other fires, pandemics, solar events, electromagnetic events, or other natural disasters; and
- acts of terrorism, vandalism, or war.

Ethics

"Any profession, be it law or medicine, or engineering, empowers the individual with special talents that benefit the public, and the wise use of these talents for the public good is expected. To do otherwise is to be professionally immoral."

Vesilind, P., "Responsibility", Bucknell University

"Never sacrifice safety for cost, no matter how urgent your client may become. He does not recognize the danger and you should. If you cannot agree with him, resign your engagement, for sooner or later the reckoning will come."

Hatton, C., New England Water Works Association, 1912


RESCUERS. BRINGING OUT A VICTIM. AUSTIN, PA. '14.

Do onto others ……..

Would you live with your family below your dam?

Future Initiatives

Initiatives

- Owner's Dam Safety Programs
- Risk-Informed Decision-Making
- Time Sensitive EAPs

Redlands Dam and the Grand Canyon Flood

The Sensation

- On August 17, 2008 the Redlands Dam on a tributary stream to the Colorado River failed leading to wide spread reporting of flooding, stranded hikers and helicopter rescues.
- The event was even reported on BBC World News.

The Sensation

- A Google search of “Redlands Dam” returned 542,000 hits
- A Google search of “Redlands Dam Grand Canyon” returned 230,000 hits

The Headlines

- "Grand Canyon Flood Caused By Redlands Dam Breach"
- "Dam breaks near Grand Canyon; hundreds evacuate"
- "Grand Canyon rescue as dam bursts"
- "Redlands Dam Breaks, Evacuating Grand Canyon"

The Stories

- Heavy rains caused the Redlands Dam near the Grand Canyon to fail, causing some flooding in the small village of Supai, Ariz. on Aug. 17, 2008.
- Hundreds of people are evacuated from the Grand Canyon after an earthen dam broke
- Grand Canyon National Park spokeswoman Maureen Oltrogge said water from the Redlands Dam had caused flooding in a side canyon

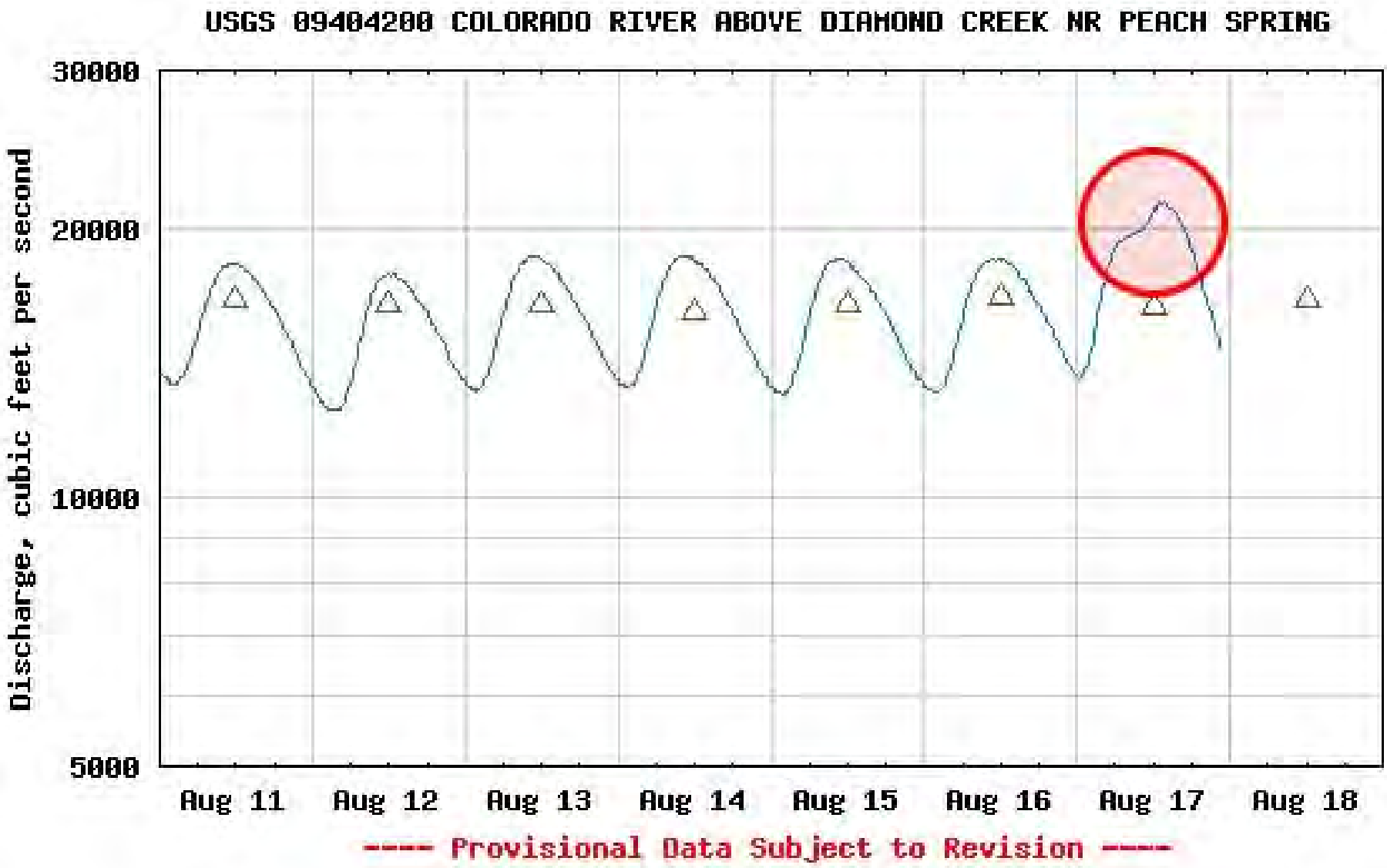
The Stories

- "Authorities have found all 11 people who were unaccounted for after a dam burst, causing major flooding in Supai Canyon"
- "Redlands Earthen Dam was breached about 45 miles upstream from Supai, flooding parts of the canyon and nearly washing away rafters, park officials said"

The Reality

- Redlands Dam was a ranch stock pond.
- It was too small to be listed on the National Inventory of Dams
- The flooding for the most part was the result of extreme rains that caused even the Colorado River hydrograph to spike


Redlands Dam Aerial
112°26'0"W
112°25'30"W
35°48'30"N
35°48'0"N
Dam breach here
Reservoir about
800' x 500'
N
Feet
0
500
1,000



The Diamond Creek Gage is at mile 226 on the Colorado River. Havasu Creek dumps into the Colorado at mile 157. The Redlands Dam is at least 55 miles up Havasu/Cataract Creek. That is more than 120 miles that the water would have to travel in just 8 hours (15 miles an hour). However, the flash flooding was reported in the Havasu campground between 1 AM and 3 AM Sunday. So, the dam break didn't cause the jump in the Diamond Creek gage on Sunday afternoon. It was the large area of heavy rain that fell between the Redlands Dam and Supai Village.

The Message

- Any dam failure may get more attention than you can possibly imagine
- Dam breaks affect all of us due to public perception. How many people really understand that the dam break had essentially nothing to do with the flooding in the Grand Canyon?
- **All DAMS MATTER!**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