Lessons Learned From Dam Failures
A Look at the Past and a Look Forward

Gannett Fleming

Maryland
Department of
the Environment

Some of us learn from other people's mistakes, and the rest of us have to be the other people.

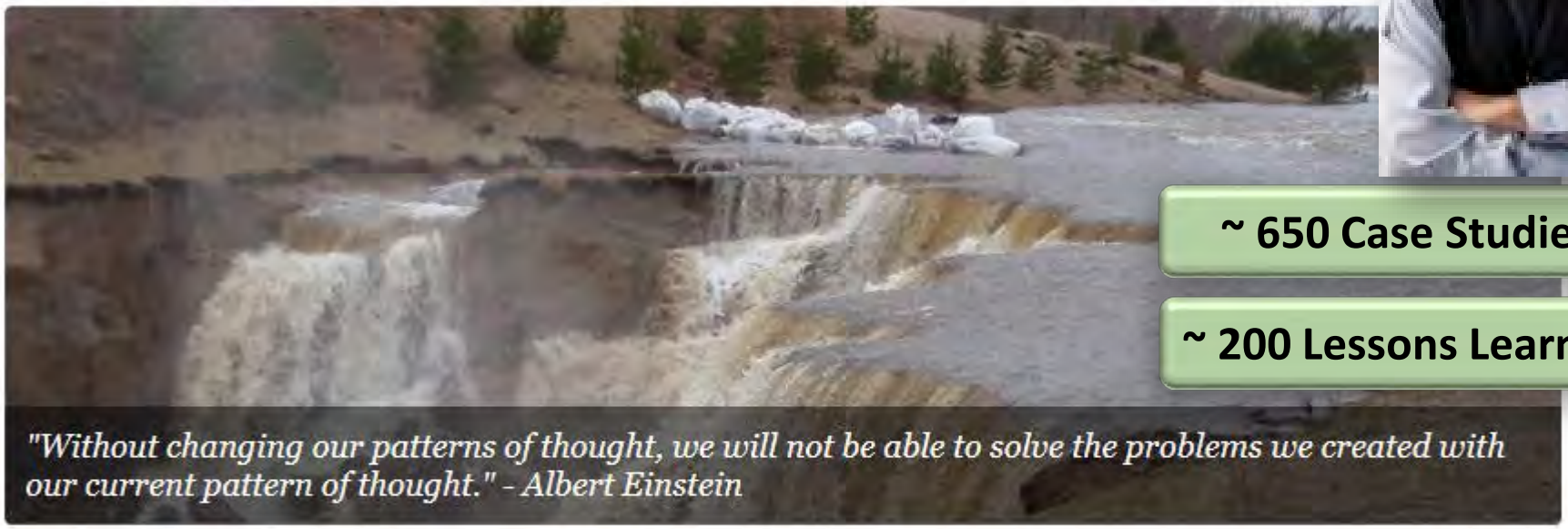
Zig Ziglar

Lessons Learned

From Dam Incidents and Failures

http://damfailures.org

Home | Lessons Learned | Case Studies | Resources | About



~ 650 Case Studies

~ 200 Lessons Learned

Lessons Learned

See the lessons learned from dam incidents and failures.

Learn More

Case Studies

Learn more about historic dam incident and failure case studies.

Explore

About

Find out more about this website and how you can contribute.

About this Site

Education & Research Tool

Lessons Learned from Dam Incidents and Failures

Learning from past incidents and failures is a key component of dam safety education. In late 2013, James Demby, Jr., P.E. and the Federal Emergency Management Agency (FEMA) authorized a Gannett Fleming project team to research past dam failures and incidents and select the most appropriate information to include in a compendium of lessons learned supported by case histories. The primary goal of this project was to convey educational information relating to and resulting from dam failures and incidents in an innovative, user-friendly manner that is appealing to contemporary users. As a result, this Lessons Learned from Dam Incidents and Failures website was created. The site is currently hosted and maintained by the Association of State Dam Safety Officials (ASDSO) with oversight and ongoing contributions by the ASDSO Dam Failures and Incidents Committee.

Presented within this website are links to individual case studies as well as lessons learned pages that summarize historical dam incidents and failures and the valuable information gleaned from them. Each page contains a background and description, photographs, videos, best practices, and other resources related to the case study or lessons learned being addressed. The contents of this webpage encompass a range of failure modes, dam types, and dam safety topics including best practices regarding engineering and design practices, human factors, emergency planning and response, operation and maintenance, and regulatory issues. Dam safety engineers, dam operators, dam owners, regulators, emergency managers, academia, and students are encouraged to use the material presented herein.

Visit: www.Damfailures.org

Need to Convey Lessons Learned

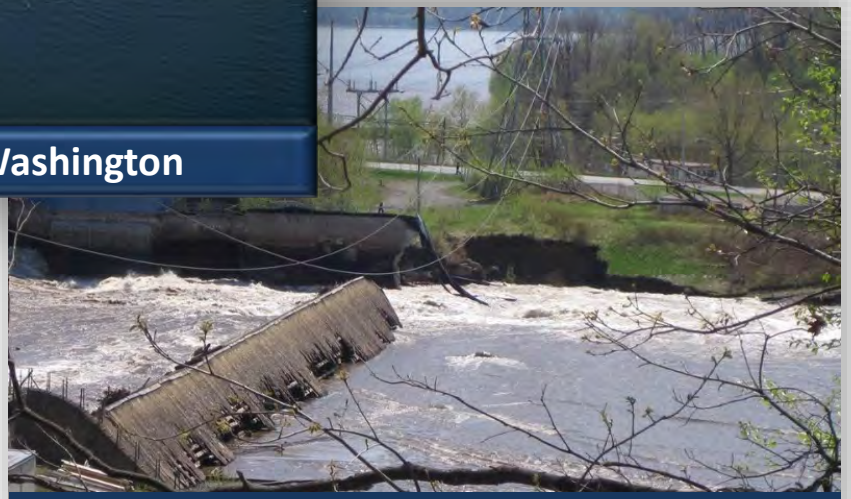
Recent *Dam Incidents* .....

Mt. Polley Tailings Dam – Canada

Ivanovo Dam – Bulgaria (8 fatalities)

Wanapum Dam – Washington

King No. 1 Dam – Wyoming



Donnaconna Dam – Quebec

Constructed 2004 ….

Tampa Bay Reservoir, FL (2007)

Rehabilitated 2001 ….

Silver Lake Dam Failure, MI (2003)

Rehabilitated 2005 ….

Lake Hadlock Dam, NY (2005)

Kingstowne Park Dam, DC (2010)

Hope Mills Dam , NC (2010)


Camara Dam, Brazil (2004)
7 Fatalities

Floods, rain expose SC's flawed dam safety program

HIGHLIGHTS

Six Richland County dams broke, causing death and destruction in floods

In **October 2015,** South Carolina received record amounts of rainfall which caused a 1000-year flood throughout much of the state. During this flood event, emergency orders were issued to many dams throughout the state, and ~~**36**~~ **>52 dams have been reported to have failed**, 4 of which were unregulated.

Class action lawsuit filed against Department of Water Resources

By: Josh Copitch

Posted: Aug 11, 2017 11:25 AM PDT

Updated: Aug 11, 2017 11:25 AM PDT

2017

$1 Billion Worth Of Claims For Oroville Dam Damages Filed With The State Of California

Ben Adler

Friday, August 4, 2017 | Sacramento, CA | Permalink

'Get out now!' Public warned as Harvey strains Houston's dams and levees

2017

Rescue worker Adam Caballero carries CaroLine Kirkpatrick through an Omni Hotel as mandatory evacuation orders went into effect after the Addicks Reservoir overflowed. (Robert Gauthier / Los Angeles Times)

- 100,000 homes damaged
- 15,000 totally submerged
- 70 fatalities

Government faces suit over Addicks and Barker dam releases

Class action lawsuit in Washington, D.C. says Army Corps of Engineers flooded after Harvey passed

By Gabrielle Banks Updated 4:32 pm, Wednesday, September 6, 2017

Published on Saturday, September 23, 2017 by Common Dreams

Tens of Thousands Flee for Safety as Guajataca Dam Fails in Puerto Rico

Swelled with rains following Hurricane Maria, failed dam sends torrent of water into downstream communities

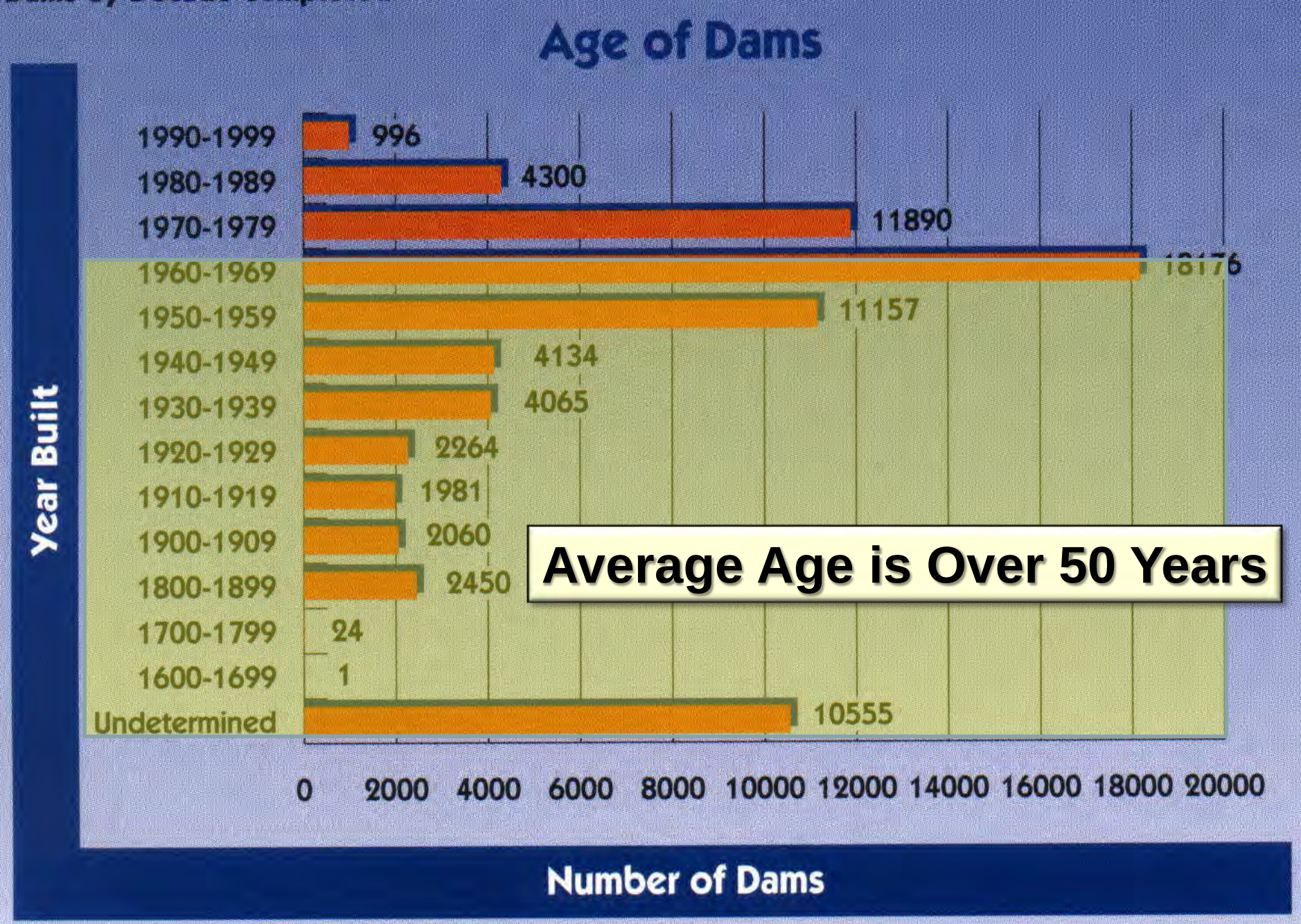
by Common Dreams staff

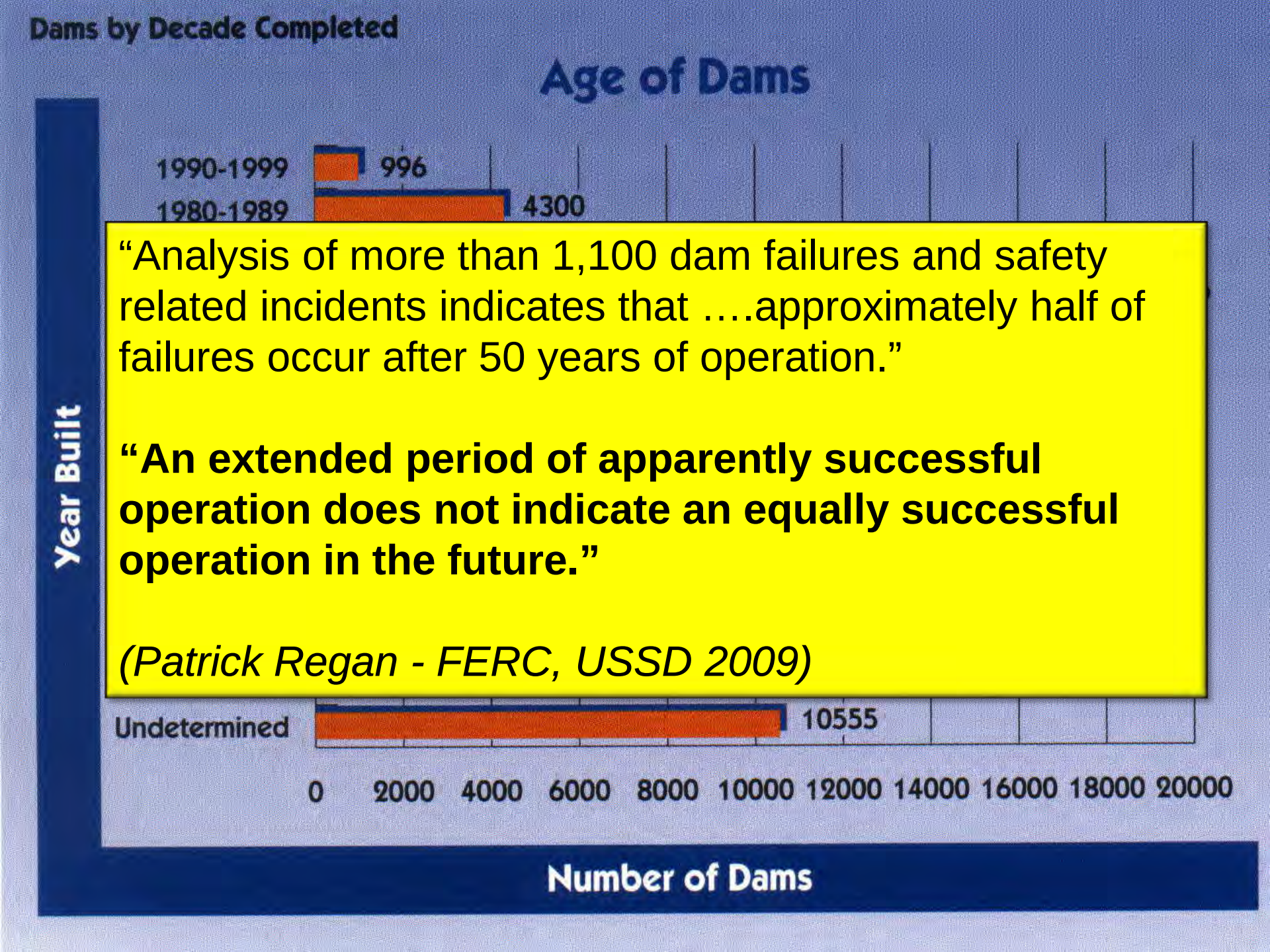
2017

44 Comments

Fears had grown overnight and evacuations had begun and footage showed the dam, located in northwest city of Guajataca, failing and waters rushing downstream. (Screenshot: Video footage/BBC)

Dams by Decade Completed





"Analysis of more than 1,100 dam failures and safety related incidents indicates that ….approximately half of failures occur after 50 years of operation."

"An extended period of apparently successful operation does not indicate an equally successful operation in the future."

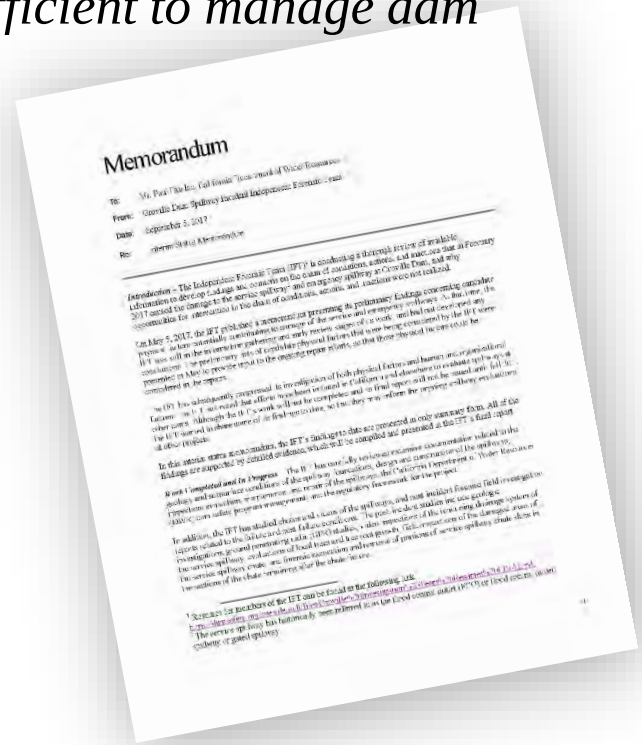
(Patrick Regan - FERC, USSD 2009)

Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones.

Donald Rumsfeld, Feb. 12 2012

*"… **Lessons to be Learned** –At this time, the IFT shares three higher-level lessons that have been identified so far:*

1. ***Physical inspections**, while necessary, are not sufficient to identify risks and manage safety. At Oroville Dam, more frequent physical inspections would not likely have uncovered the issues which led to the spillway incident.*
2. ***Comprehensive periodic reviews** of original design and construction, taking into account comparison with the current state of the practice, are needed for all components of dam projects.*
3. ***Compliance with regulatory requirements** is not sufficient to manage dam owners' and public risk…"*


Memorandum

US Deaths From Dam Failures

Dam Failure	Lives Lost
South Fork, PA (1889).	2,209
New Orleans Levees (2005)	1,833
St. Francis, CA (1928)	450
Walnut Grove, AZ (1890)	150
Mill River, MA (1874)	143
Buffalo Creek, WV (1972)	125
Austin, PA (1911).	80
Laurel Run, PA (1977)	40
Kelly Barnes, GA (1977)	39
Canyon Lake, SD (1972)	33
Lower Otay, CA (1916)	30
Teton, ID (1976)	14
Swift, MT (1964)	19
Ka Loko, HI (2006)	8
Baldwin Hills, CA (1963)	5

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Causes of Dam Incidents

Fundamental Causes	Percentage

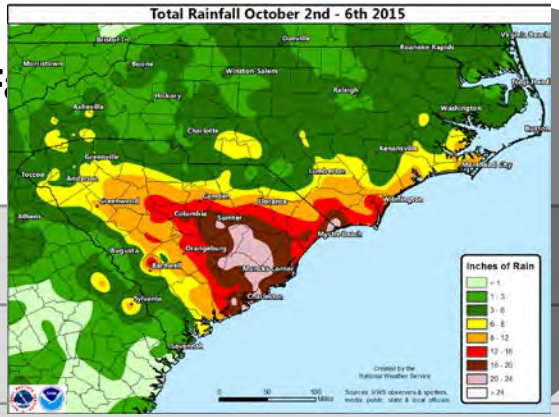
Causes of Dam Incidents

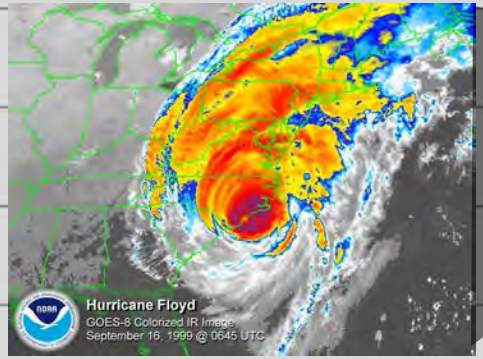
Fundamental Causes	Percentage
Sabotage	0
Earthquake Instability	1
Faulty Construction	2
Gate Failure	2
Sliding	10
Deformation	11
Spillway Erosion/Breach	14
Overtopping	25
Seepage/Piping	35

75%

Source: NRC, Safety of Existing Dams, 1983

No. U.S. Dam F
(through





ASDSO; M. Ogden
www.damsafety.org

Lessons Learned from Dam Overtopping and Breach Failures

Lessons Learned from Embankment Dam Seepage Failures

Lunch Time (12:00-12:45 AM)

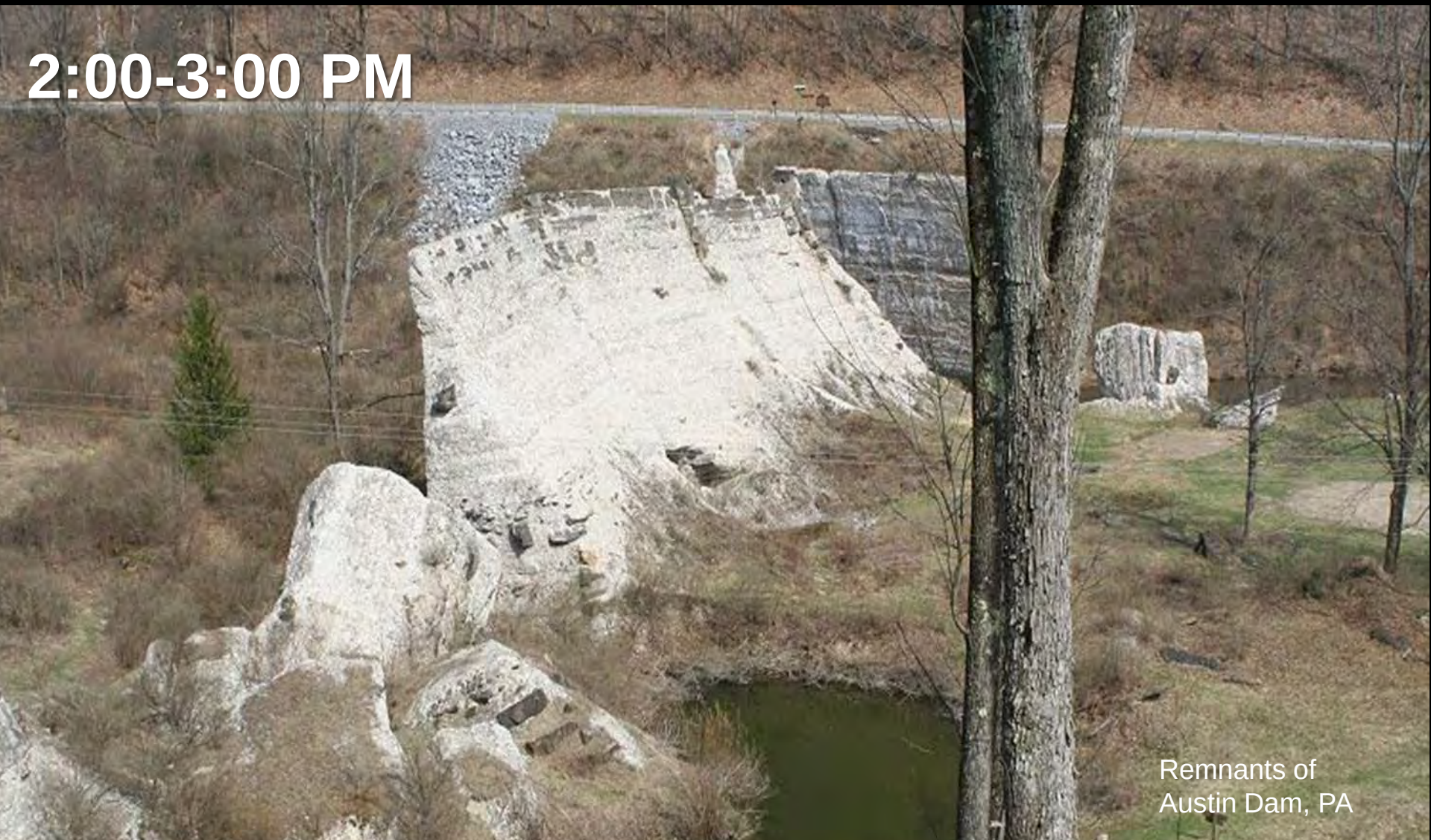
Unleased Terror – Dam Breaks

2006 Kaloko Dam Failure

Over, Under Gone,
The Killer in our Midst

Lessons Learned from Spillway Erosion Failures

Lessons Learned from Concrete Dam Failures

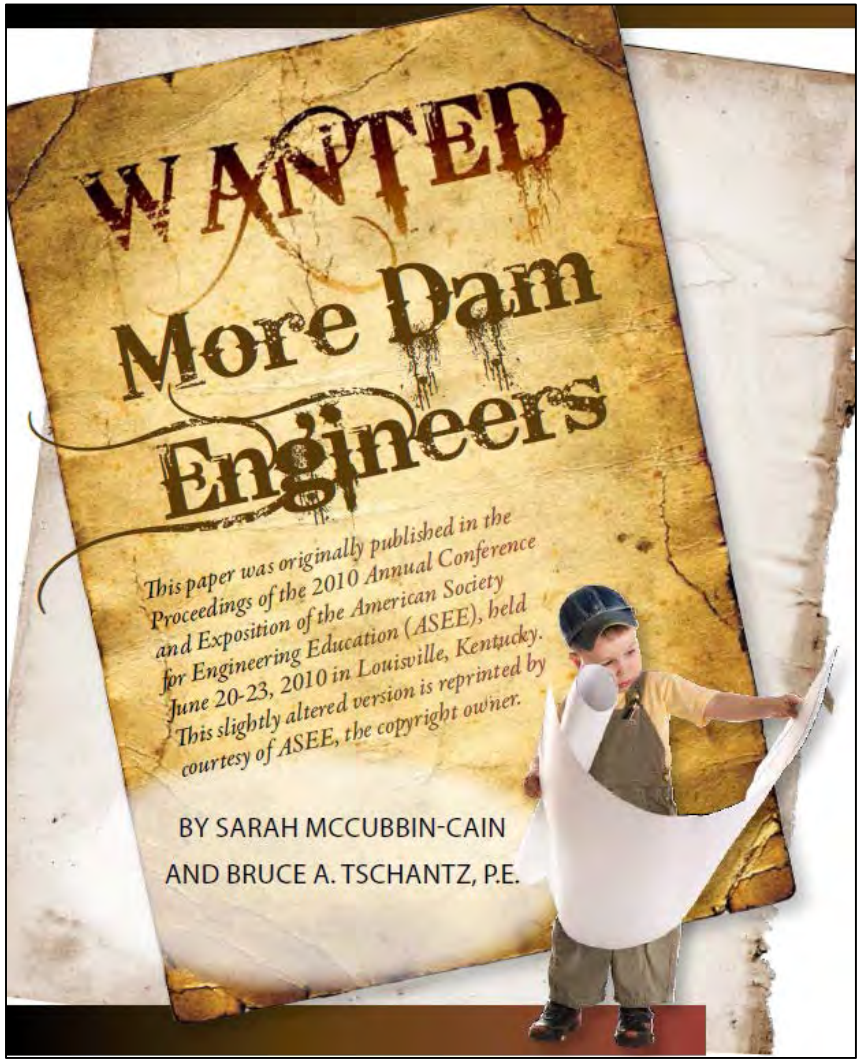


Remnants of
Austin Dam, PA

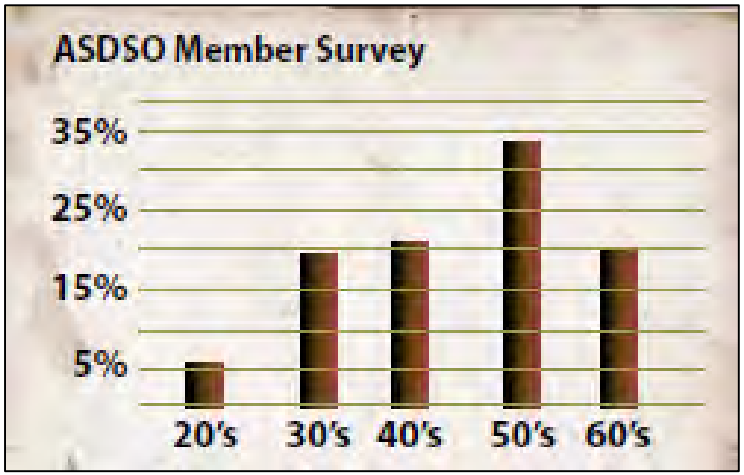
Public Safety Around Dams – An Emerging Crisis

Need to Convey Lessons Learned

Train New Engineers



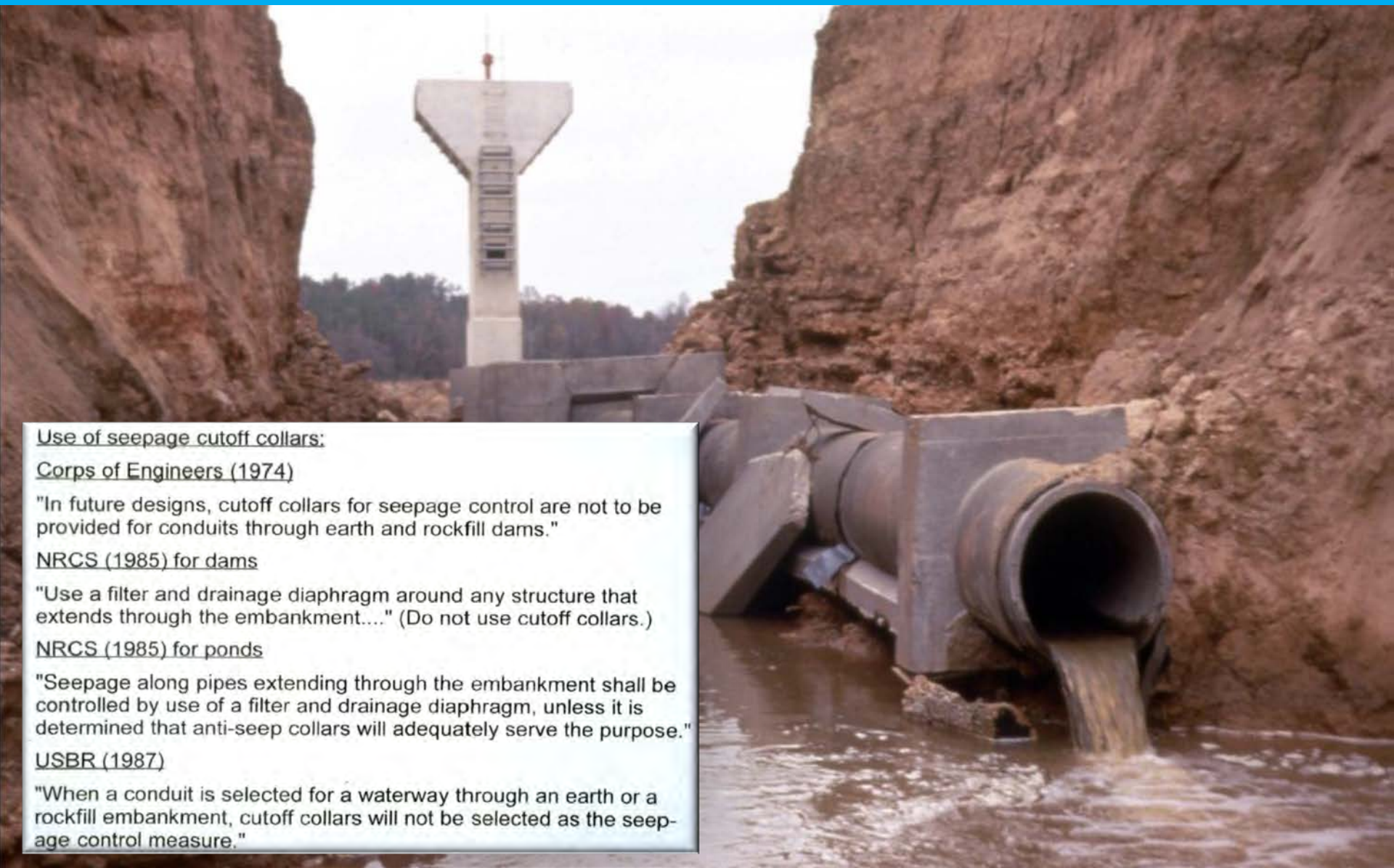
"Dam safety-related employers indicated a short-term need for almost 260 engineers and estimated a need for about 760 engineers for dam safety work over the next ten years as a result of projected attrition in the profession."



Information and images courtesy of Sarah McCubbin-Cain and Bruce Tschantz

Need to Convey Lessons Learned

Educate Practicing Engineers & Regulators



Use of seepage cutoff collars:

Corps of Engineers (1974)

"In future designs, cutoff collars for seepage control are not to be provided for conduits through earth and rockfill dams."

NRCS (1985) for dams

"Use a filter and drainage diaphragm around any structure that extends through the embankment...." (Do not use cutoff collars.)

NRCS (1985) for ponds

"Seepage along pipes extending through the embankment shall be controlled by use of a filter and drainage diaphragm, unless it is determined that anti-seep collars will adequately serve the purpose."

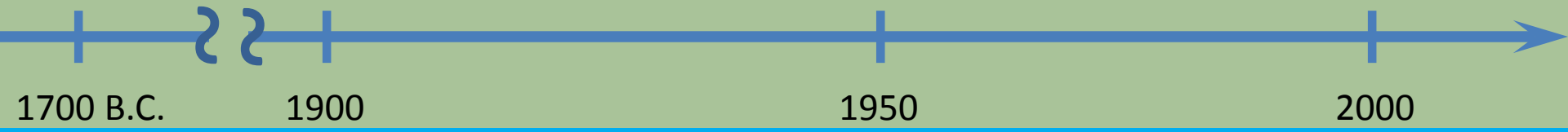
USBR (1987)

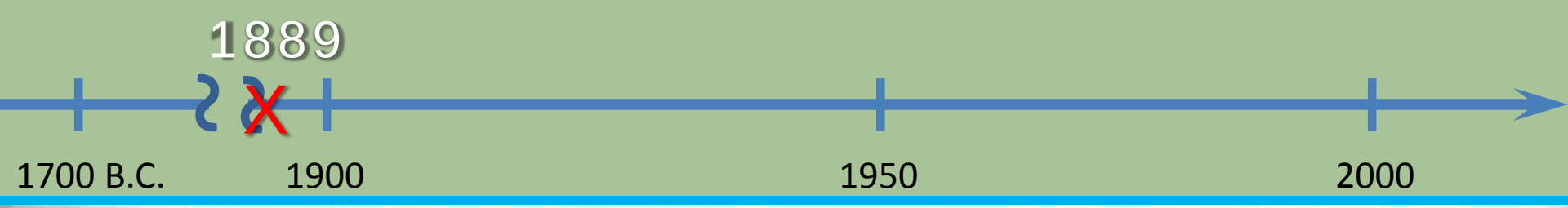
"When a conduit is selected for a waterway through an earth or a rockfill embankment, cutoff collars will not be selected as the seepage control measure."

Need to Convey Lessons Learned

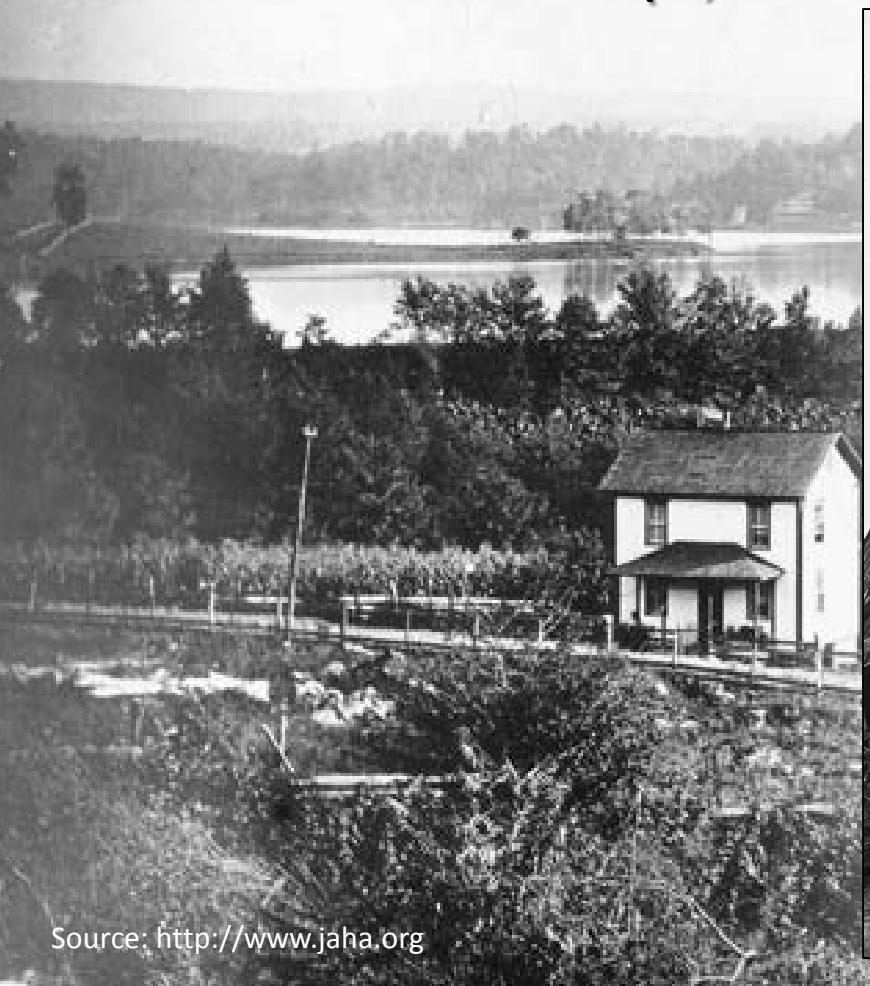
Share Performance Information

King No. 1 Dam – Wyoming – July 2014

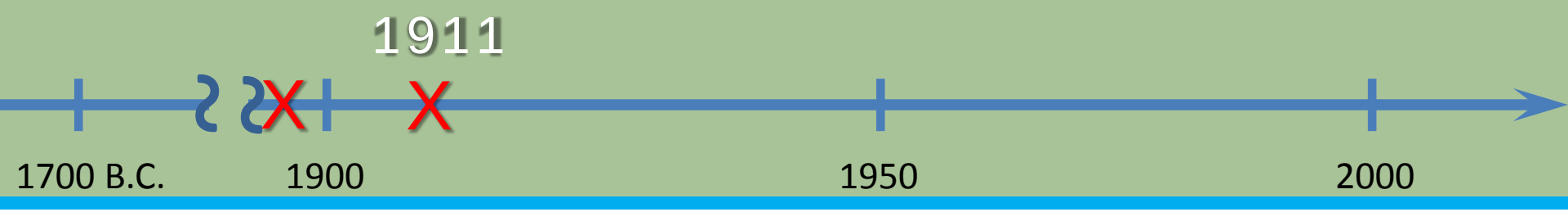

1700 B.C.
1900
1950
2000



South Fork Dam, Johnstown, PA (2,209 lives lost)

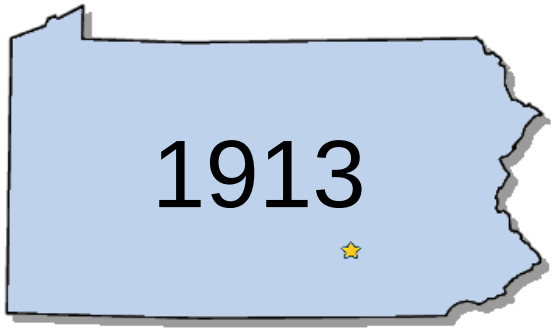


Source: http://www.jaha.org

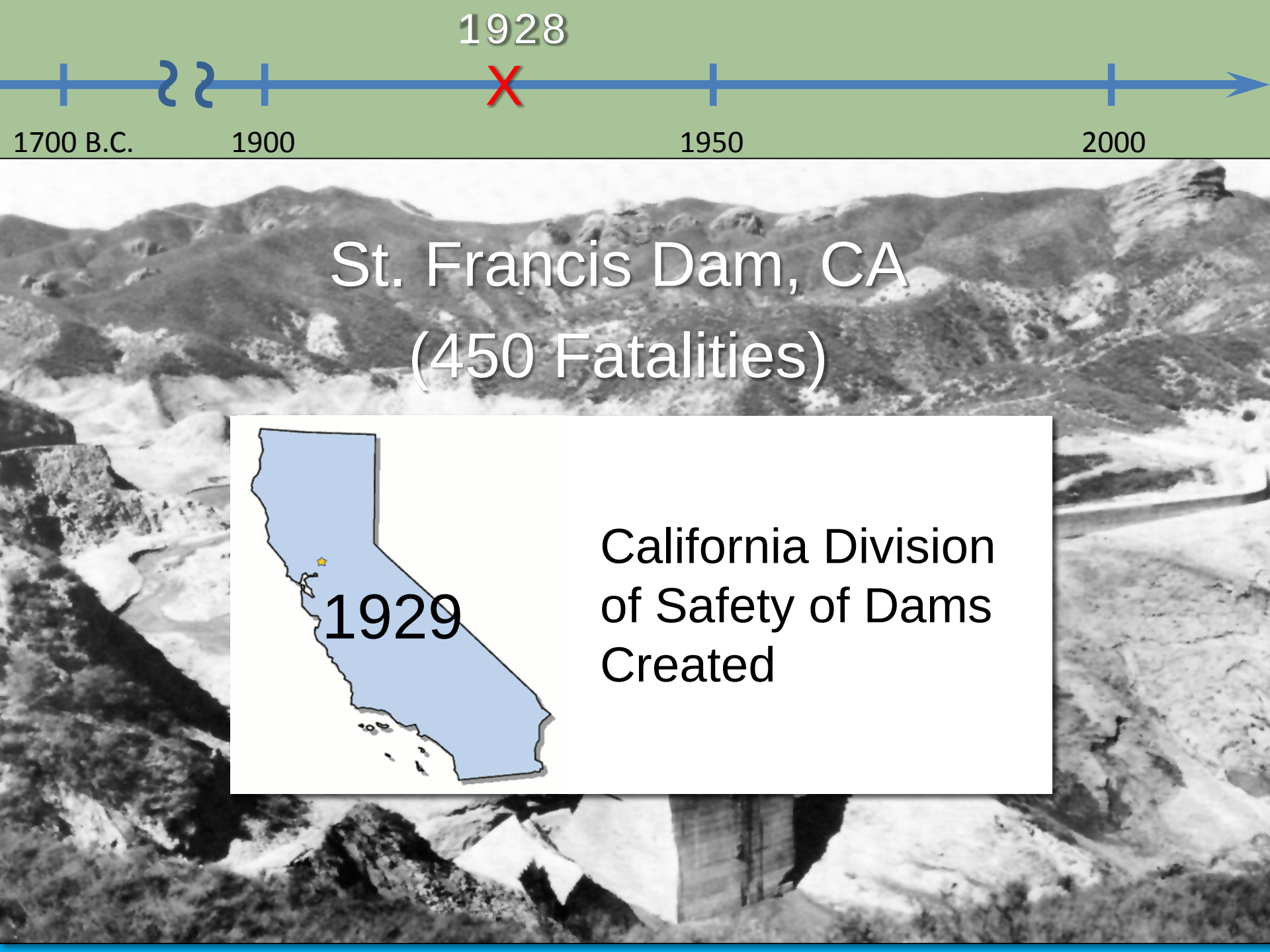


Austin Dam, Austin, PA

(79 Fatalities)



Pennsylvania first state to enact dam safety legislation

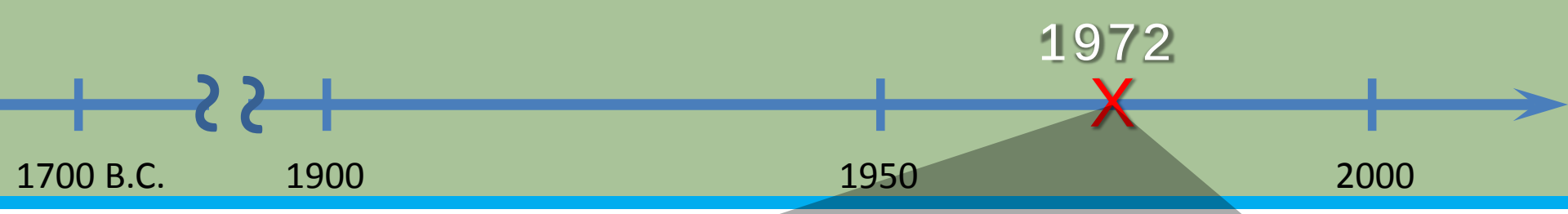

1928
1700 B.C.
1900
1950
2000
St. Francis Dam, CA
(450 Fatalities)
1929
California Division
of Safety of Dams
Created

1700 B.C. 1900 1950 1972 2000

Near PMP Rainfalls

PA, NY & SD

Canyon Lake Dam, SD
July 12, 1972

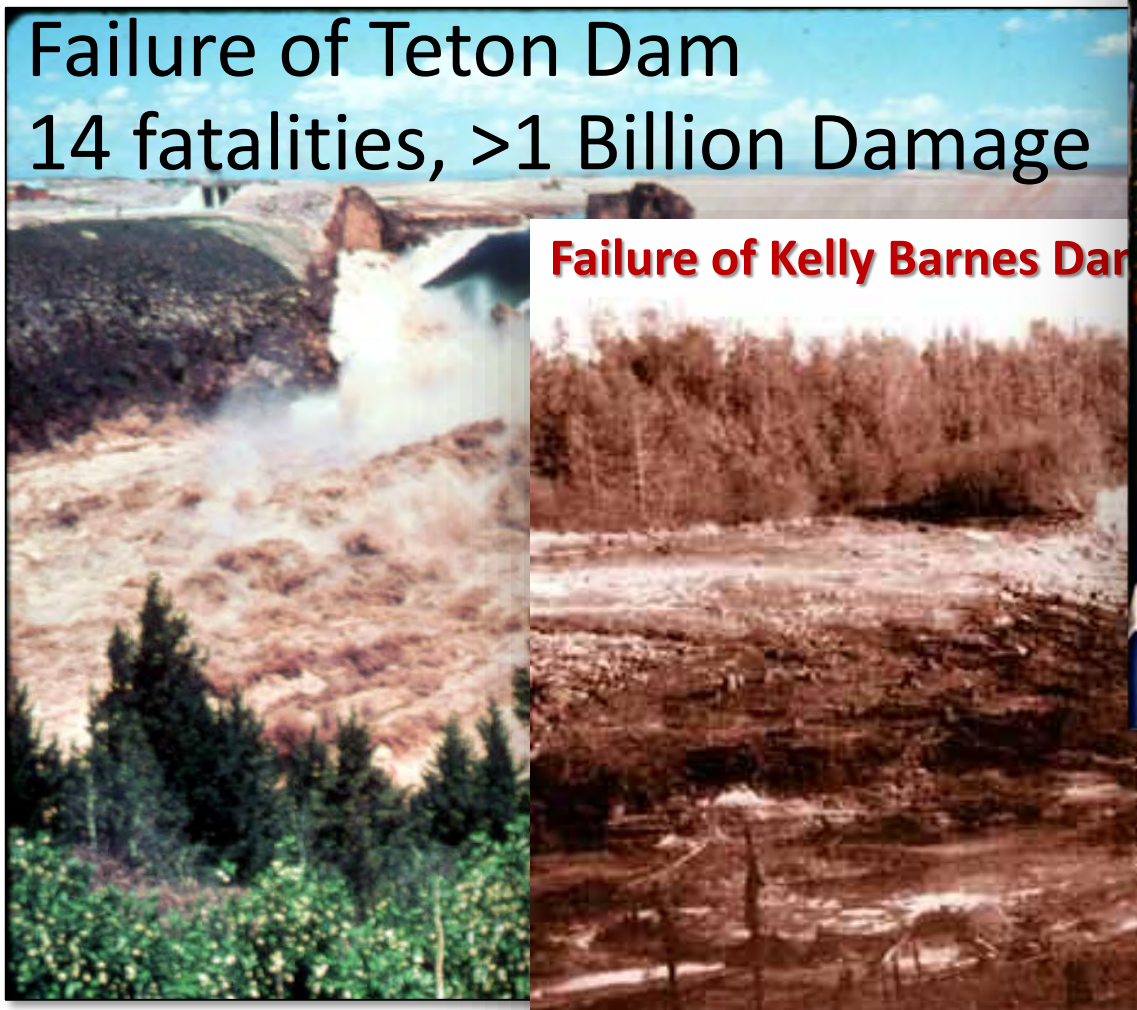


National Dam Safety Inspection Act, PL 92-367

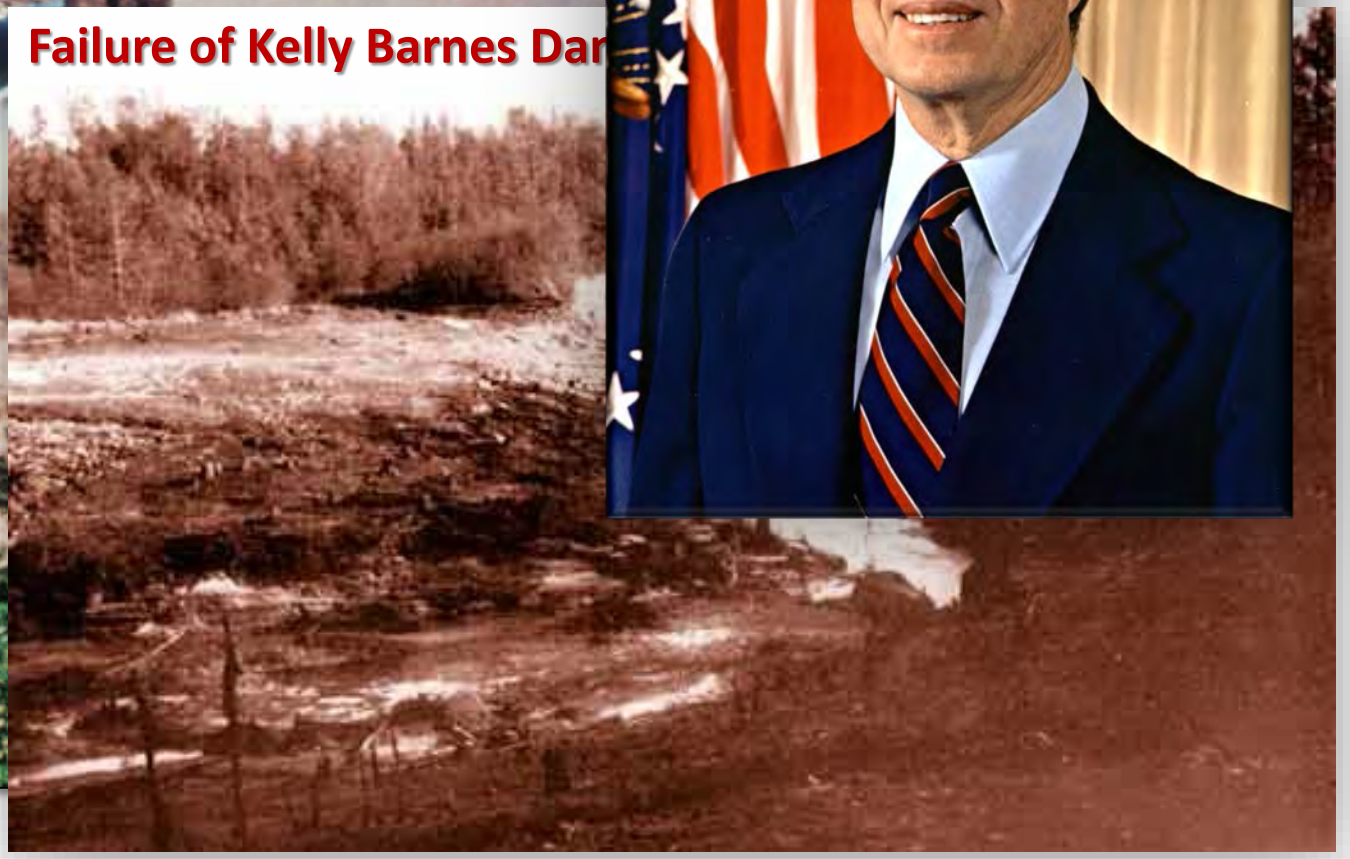
- Dams >25’ high or impounded more than 50-acre-feet
- Dams < 6’ high or storing < 15 acre-feet were excluded
- Congress charged USACE
  - Inventory all dams
  - Review inspections
  - Recommend comprehensive national program

1700 B.C. 1900 1950 1976 1977

Failure of Teton Dam
14 fatalities, >1 Billion Damage



Failure of Kelly Barnes Dam



1700 B.C. 1900 1950 1972 2000 *2012*

National Dam Safety Act

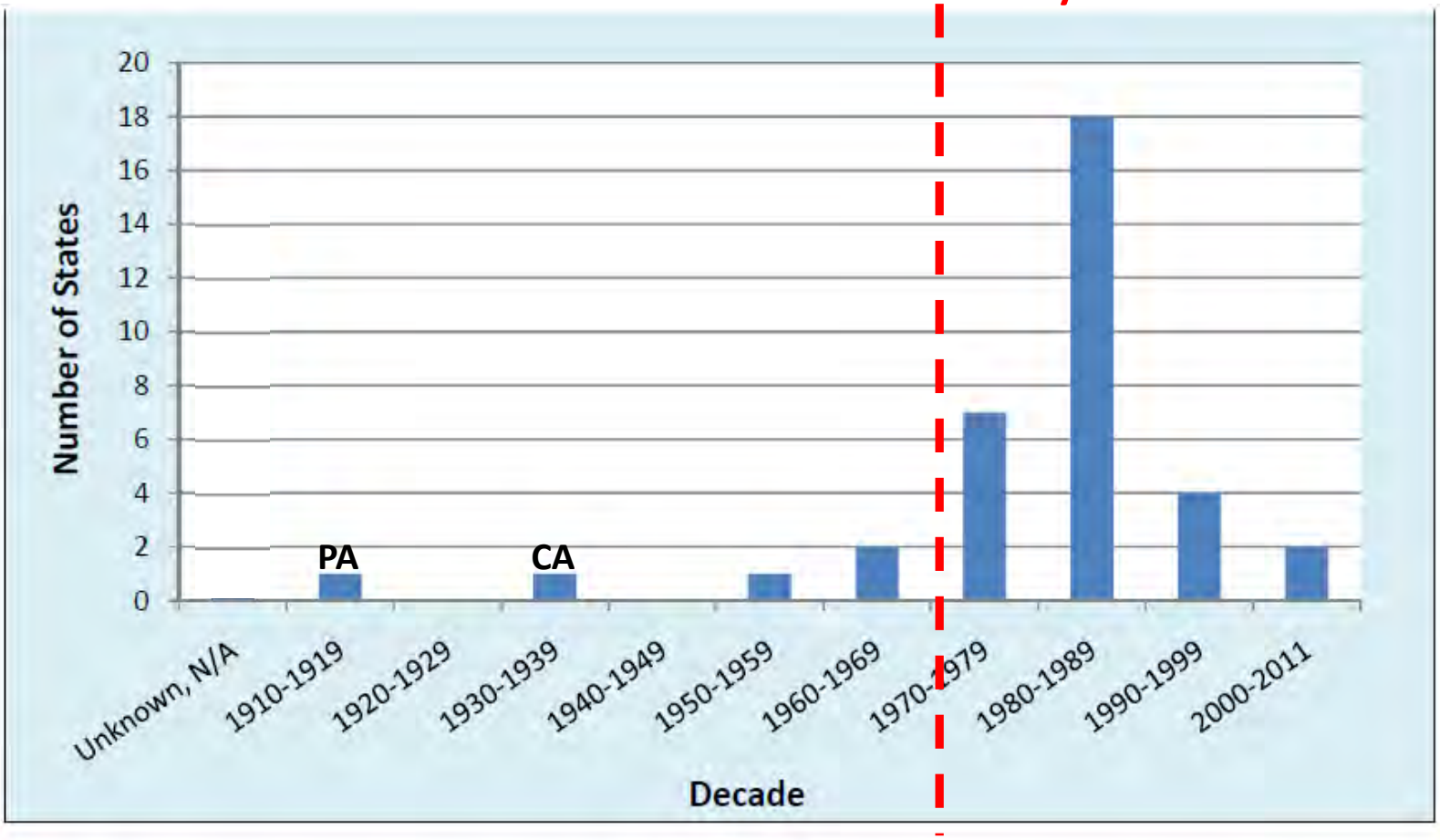
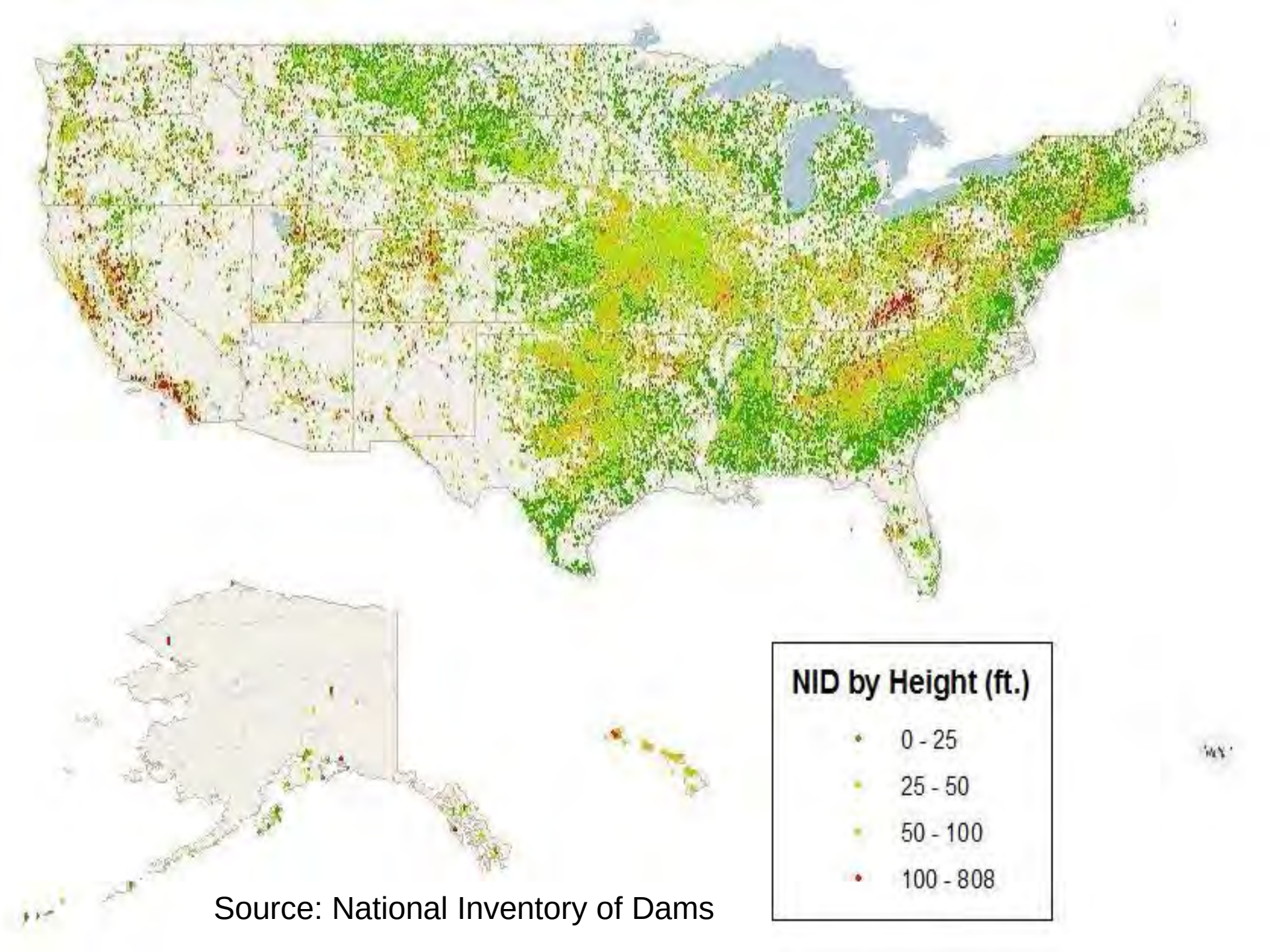
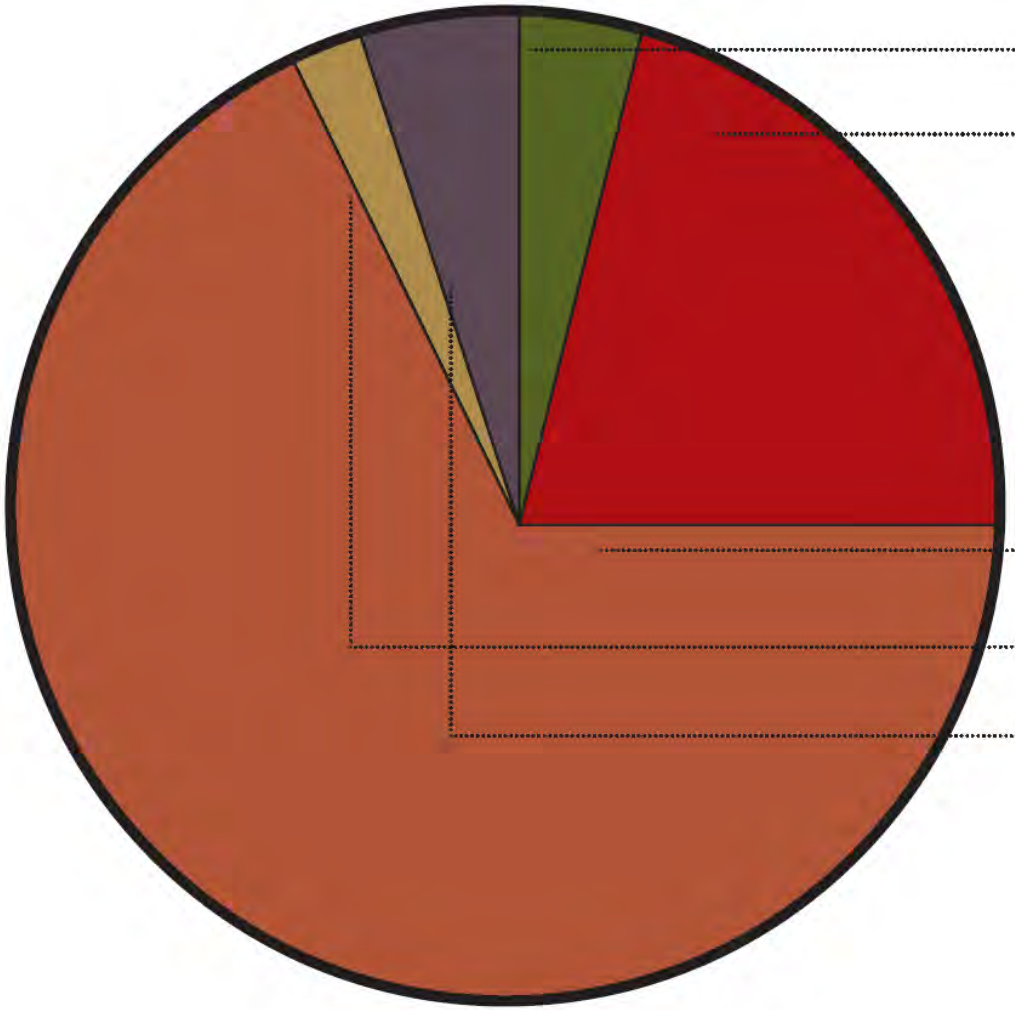


Figure 9.1 State Adoption of Spillway Design Flood Criteria by Decade



Source: National Inventory of Dams

Ownership of Dams



Federal	4%
Local Government	21%
Private	68%
Public Utility	2%
State	5%

Source: National Inventory of Dams, U.S. Army Corps Engineers, January 2005.

Federally Owned ~~or Regulated Dams~~

~~27,252 Dams (11,900 NID)~~

2,700 Dams

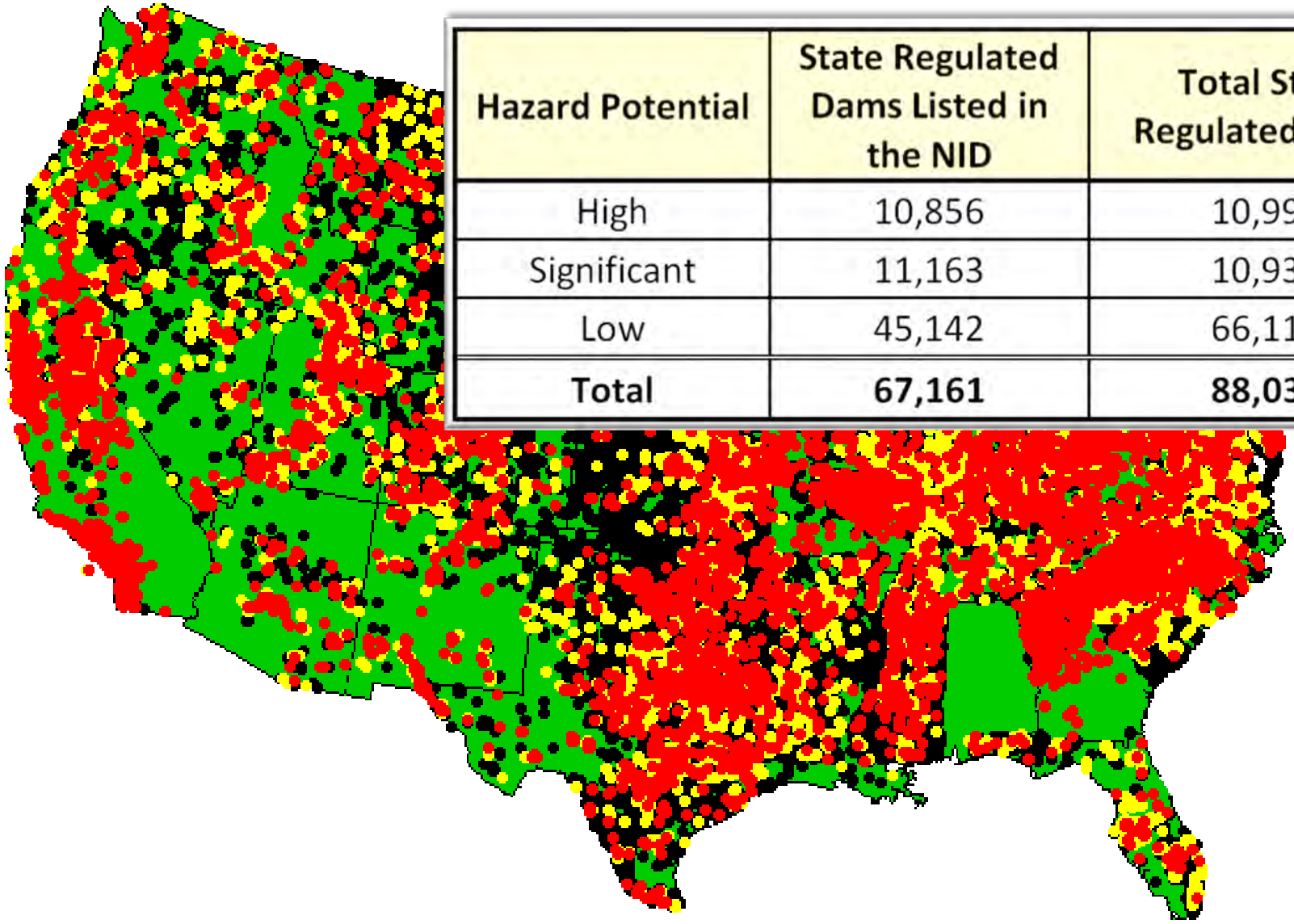
~~2,524 Dams~~

669 Dams

49 Dams

U.S. Dams by Type

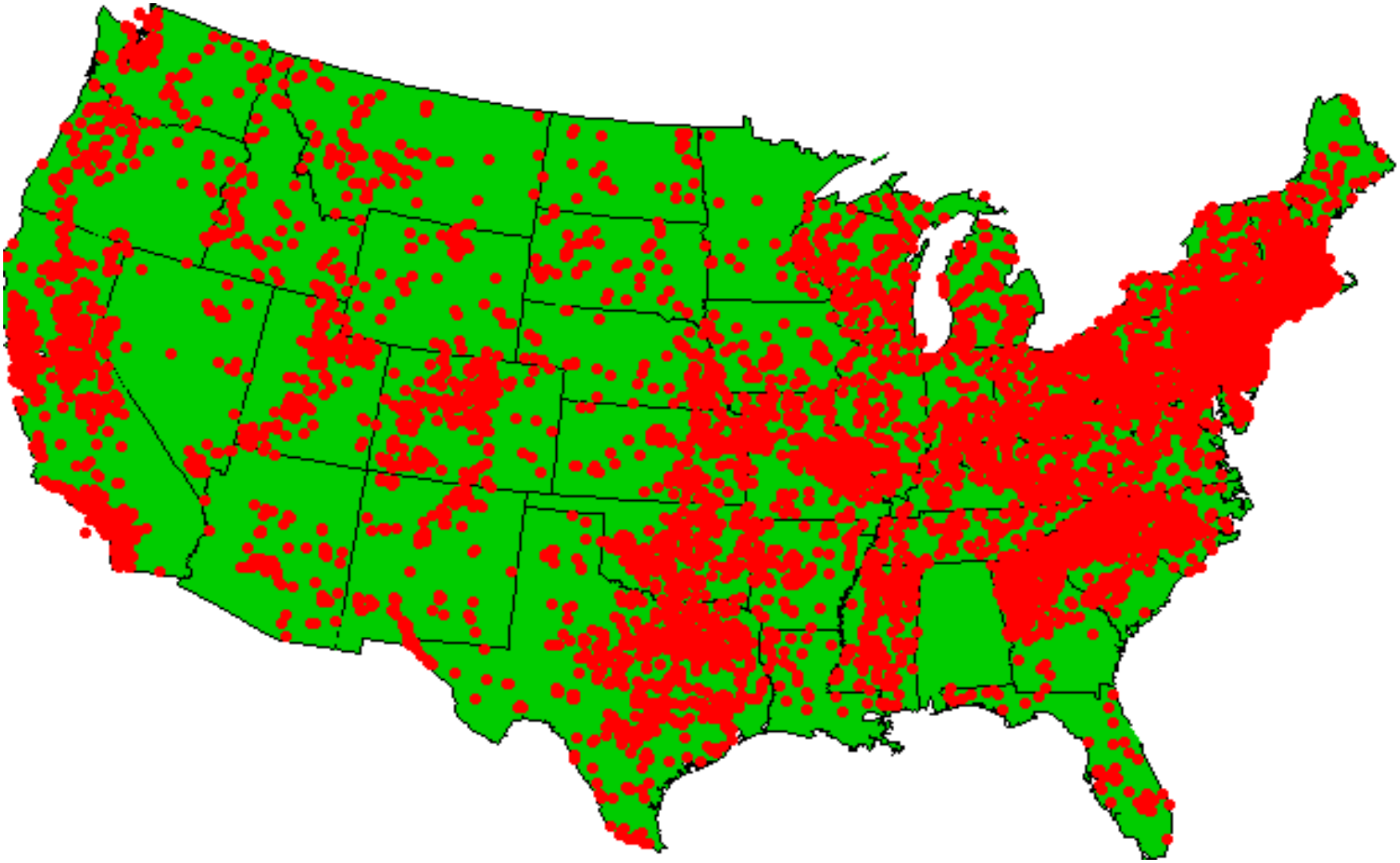
Data Source: USACE National Inventory of Dams



Hazard Potential	State Regulated Dams Listed in the NID	Total State Regulated Dams
High	10,856	10,993
Significant	11,163	10,931
Low	45,142	66,112
Total	**67,161**	**88,036**

□ = high-hazard potential □ = significant-hazard potential ■ = low-hazard potential

State-Regulated Dams According to Hazard Potential



~11,000 State-Regulated High Hazard Dams

New Creek Site 1, WV, 1957


N
Hilltop Ave
Valley View Ave
Grand Ave
Lincoln St
Loughs Ln
Parrish St
Ridge St
Poplar St
Ward Ave
Oak St
Locust St
Richmond St
Hawthorne St
Chestnut St
Maryland St
Baker St
S Main St
Newton St
Southern Dr
Reynolds Terrace
S Mineral St
220
Cornell St
Lynmar St


Apr 16, 1991
1991
Patterson
Creek Site 1


1991
Patterson
Creek Site 1


Dec 30, 2003
1991
2011
2003
Patterson
Creek Site 1


2007
Aug 24, 2007
Patterson
Creek Site 1

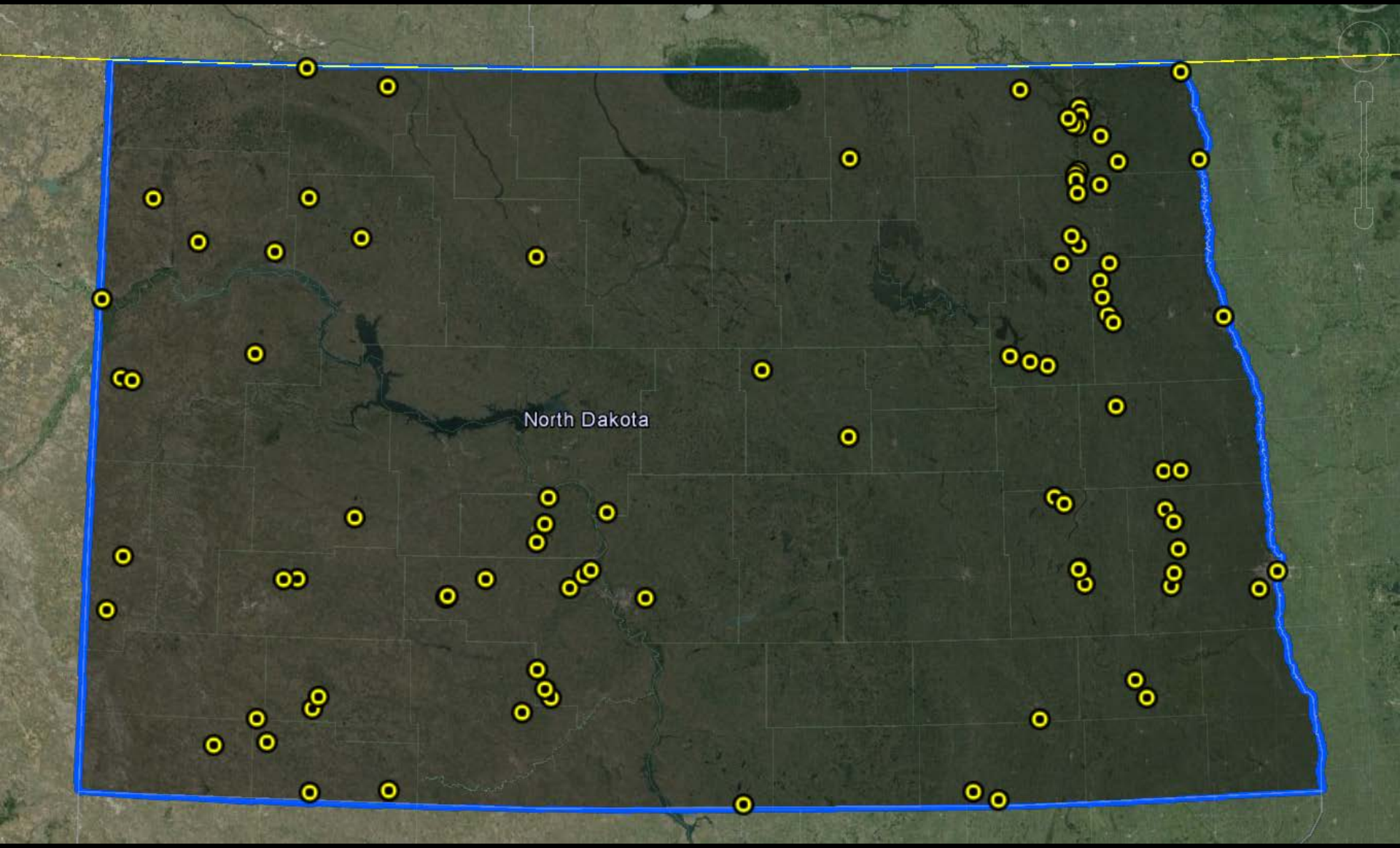

4/29/2002
2002
Berkeley Lake Dam, GA
Chattahoochee River
Image U.S. Geological Survey
© 2012 Google
Google earth
Imagery Date: 3/31/2002
1993
33°59'27.61" N 84°11'16.12" W elev 899 ft
Eye alt 5897 ft


2017
Google E
Imagery Date: 3/31/2017 lat 33.991460° lon -84.185858° elev 895 ft eye alt

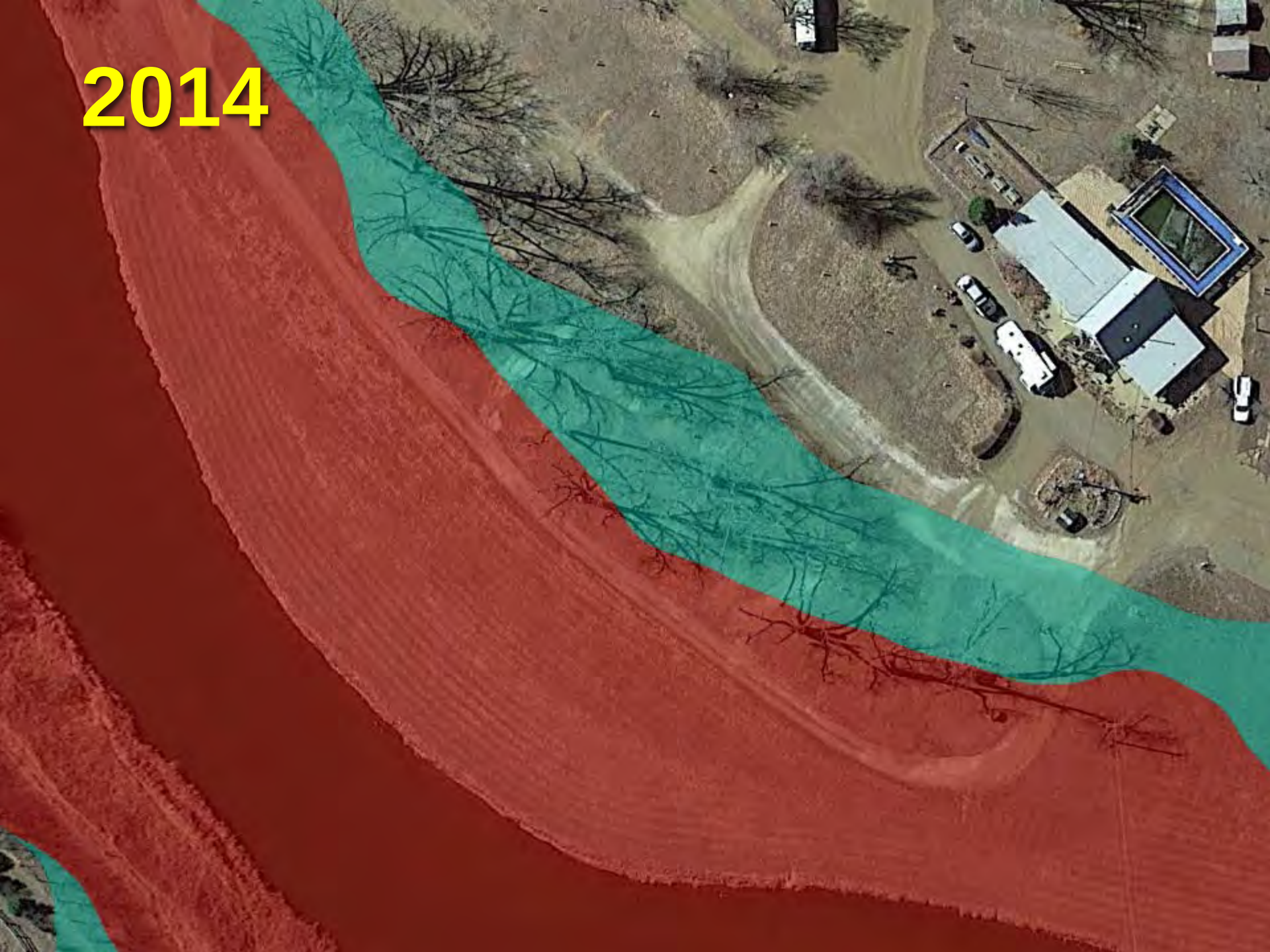
Hazard Creep

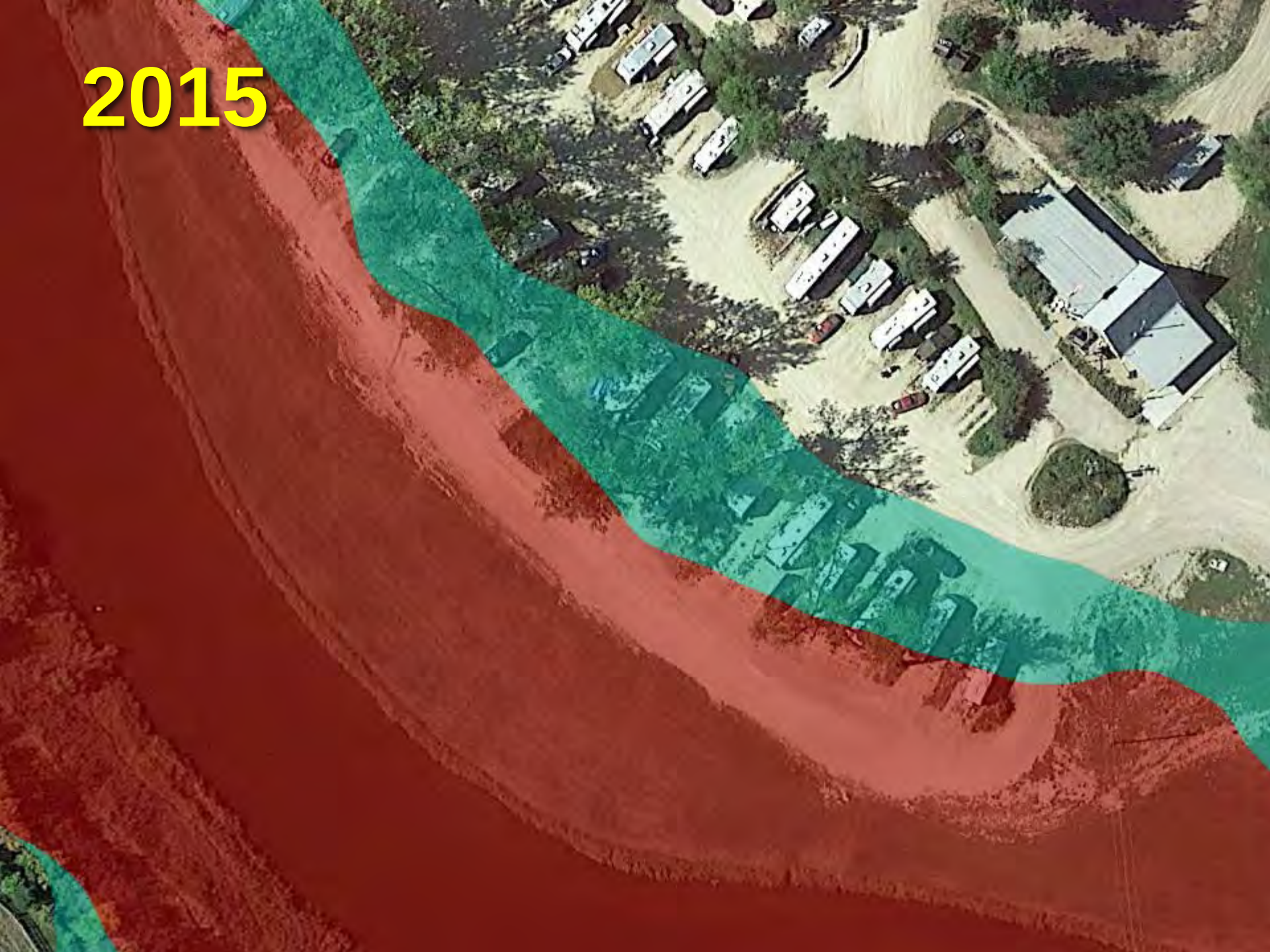
Refers to a dam originally constructed and operated as low or significant hazard that is now reclassified as high hazard due to new downstream development. Such dams often do not meet design and maintenance requirements for high hazard dams and must be improved or removed.

North Dakota Dam Hazard Assessments




2014

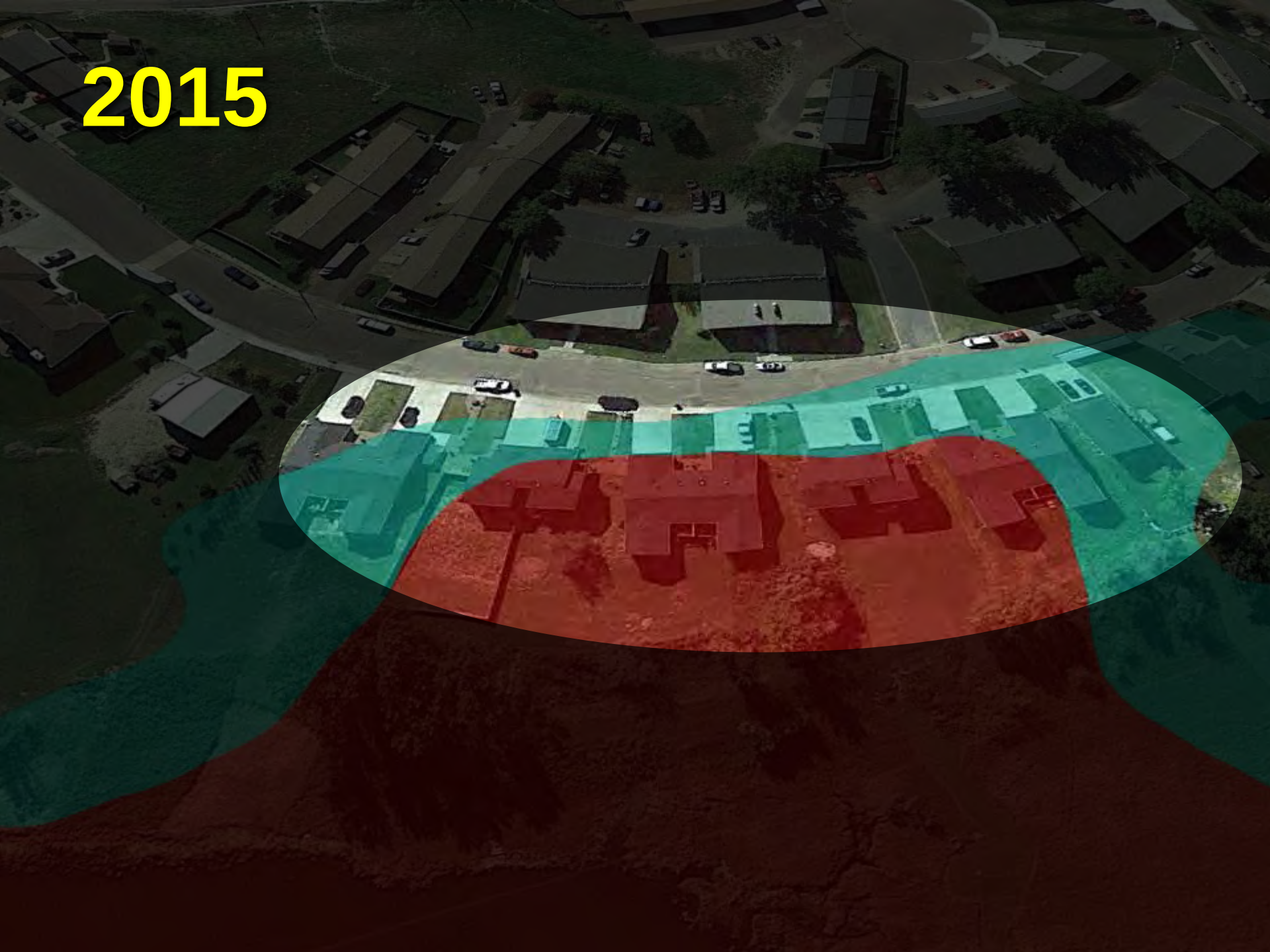

2014


2015


2014
17


2014


2014


2015

Ka Loko Dam Failure

Low Hazard Dam?

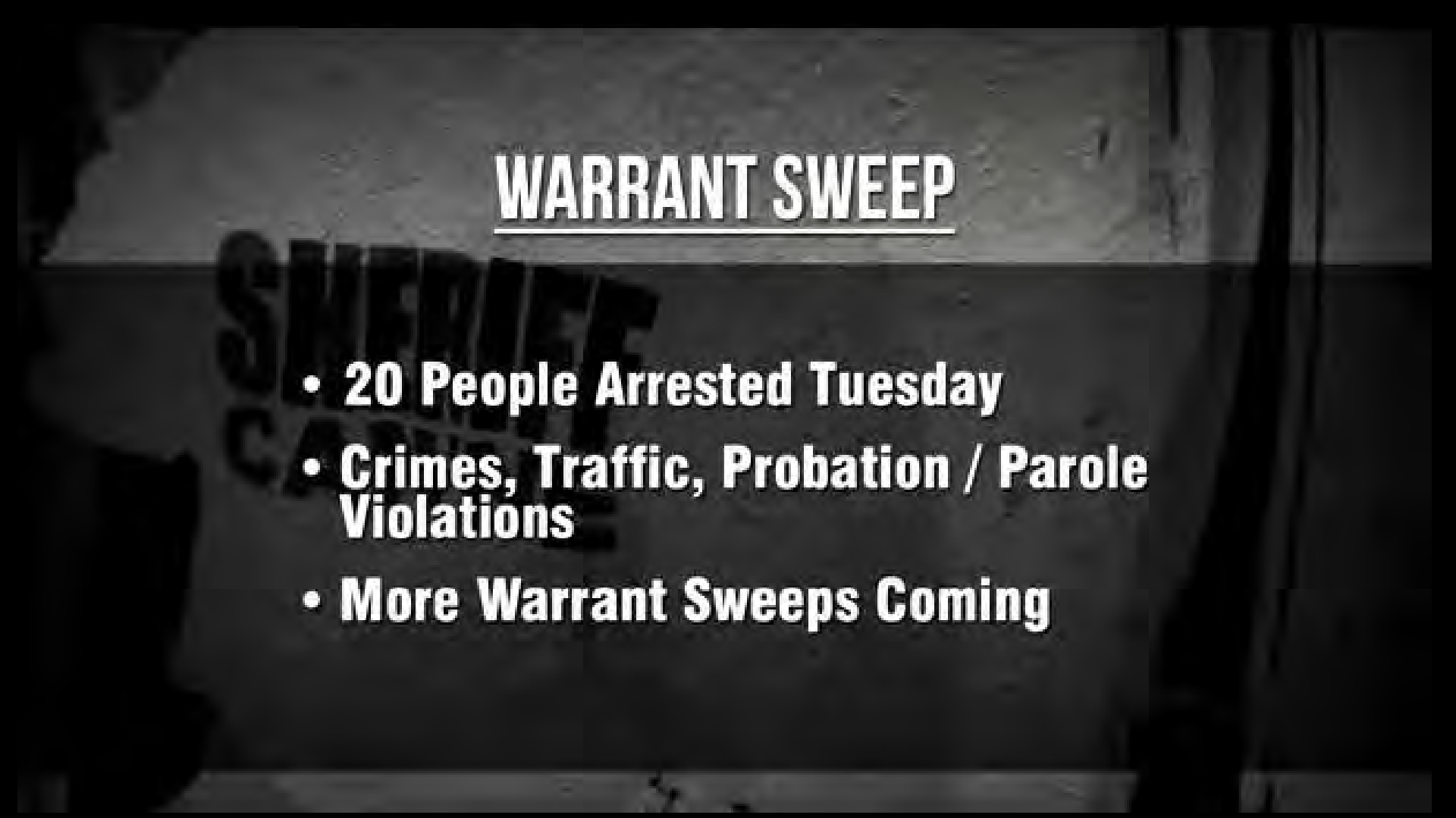
Kaloko Dam Failure

- Capacity of 1200 ac-ft
- Classified as “Low Hazard”


Before


After


No O&M Manual
No Formal Inspections …
Little Maintenance …
Unintended Modification ..
No enforcement …

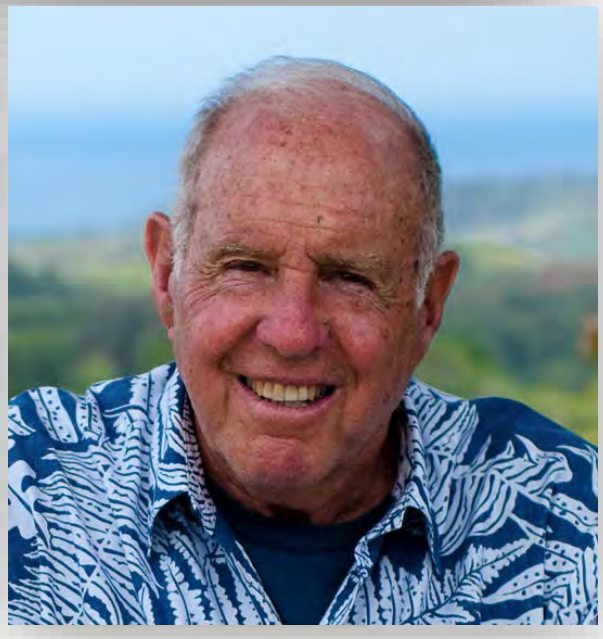

WARRANT SWEEP
• 20 People Arrested Tuesday
• Crimes, Traffic, Probation / Parole Violations
• More Warrant Sweeps Coming

Posted on: Sunday, November 8, 2009

$25M agreement settles lawsuits over Kauai dam tragedy

Manslaughter charges stand in Pflueger appeal

BY Rick Daysog
Advertiser Staff Writer



In one of the largest legal settlements in Hawaii in recent years, the families of seven people killed in the Kaloko Dam tragedy and several Kauai property owners will receive $25 million in an out-of court settlement, The Advertiser has learned.

The global settlement of multiple Kaloko Dam lawsuits was announced Oct. 29 in circuit court in Líhu'e, but details of the settlement, including how much the injured parties would receive, were not released.

The money will be paid by retired car dealer Jimmy Pflueger, the state of Hawaii, Kauai County, current and former owners of the land under the dam and their insurers, several people familiar with the deal said.

Insurers, engineering firms and contractors — some paying as little as $100,000 — also will contribute to the settlement, which resolves more than half a dozen lawsuits stemming from the

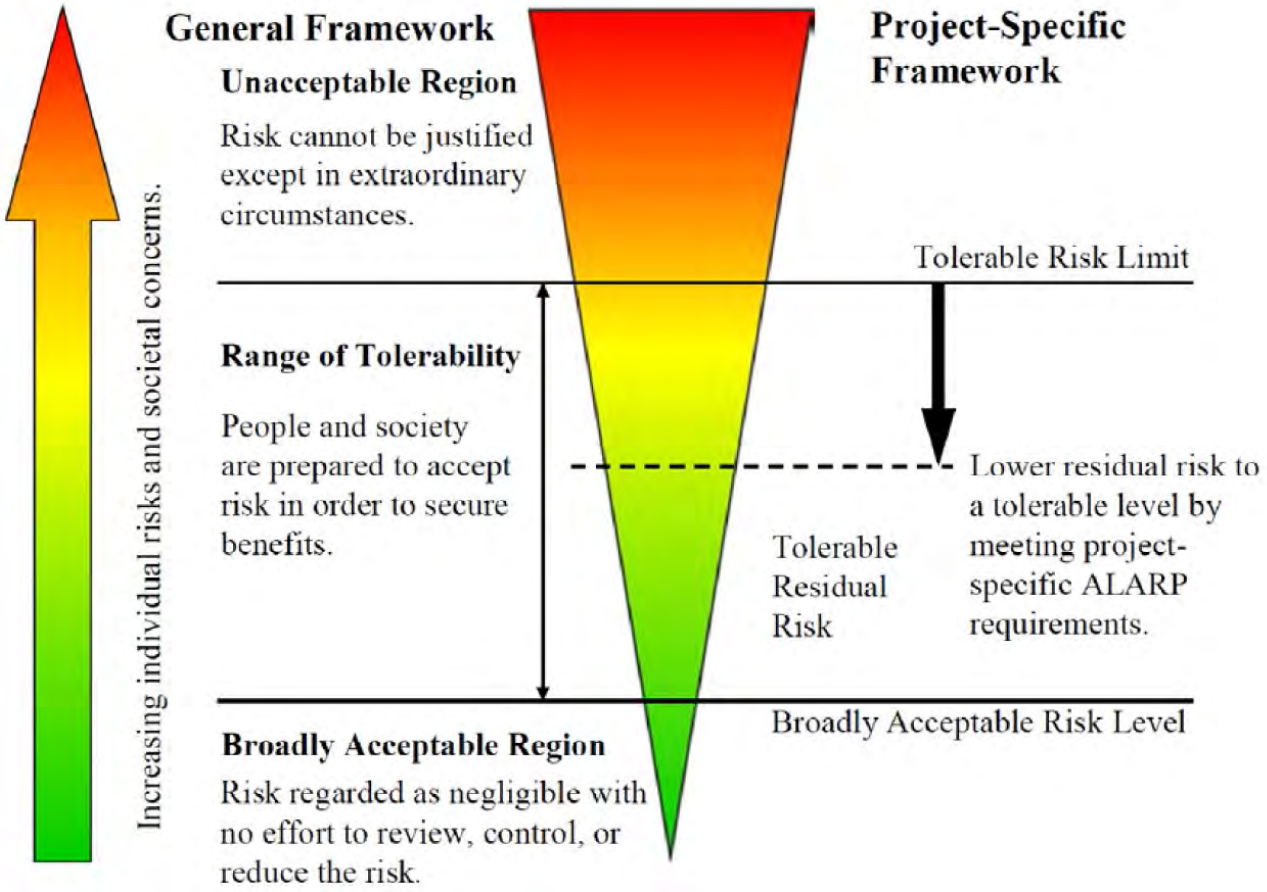

Pohick Dam No. 4, VA
Burke


N


N

Risk Informed Decision Making

ER 1110-2-1156 provides guidelines for assessing tolerable risk




Potential Failure
Mode Analysis

Loading Condition

Flaw Exists

Initiation

Continuation

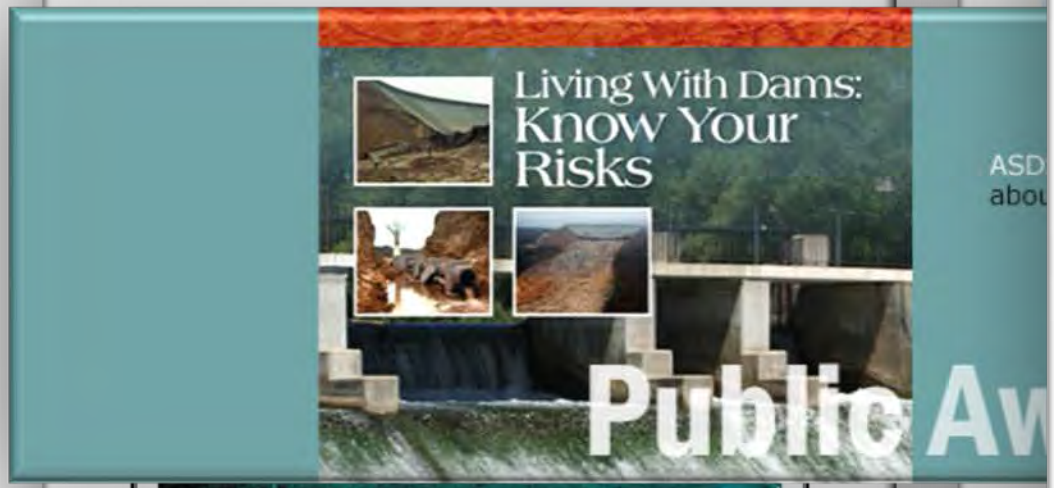
Progression

Detection and Intervention

Failure

Failure Mode Sequence of Events or "Event Tree"

The Future …



Guidelines for Public Safety Around Dams

2011

WITH
TECHNICAL BULLETINS

Signage for Public Safety Around Dams

Booms and Buoys for Public Safety Around Dams

Audible and Visual Signals for Public Safety Around Dams

CDA ACB

Canadian Dam Association
Association Canadienne des Barrages

www.cda.ca

Technical Service Center
Denver, Colorado

October, 2007

Public Safety Around Dams …

Hearthstone Lake, August County, VA

$2 million settlement in child's drowning

By Peter Boylan
Advertiser Staff Writer

The family of a 5-year-old girl who drowned last year in a drainage ditch at a Navy housing complex settled a lawsuit against the military and private contractors for $2 million, the family's attorney announced yesterday.

Charlotte Paige Schaefers, affectionately known by family and friends as "Sharkey," died Feb. 28, 2004, after jumping into a rain-swollen retention pond to save a 3-year-old child who couldn't swim.

Before her death, residents of the housing complex had filed more than two dozen com-plaints about the pond, saying it was a safety hazard because it

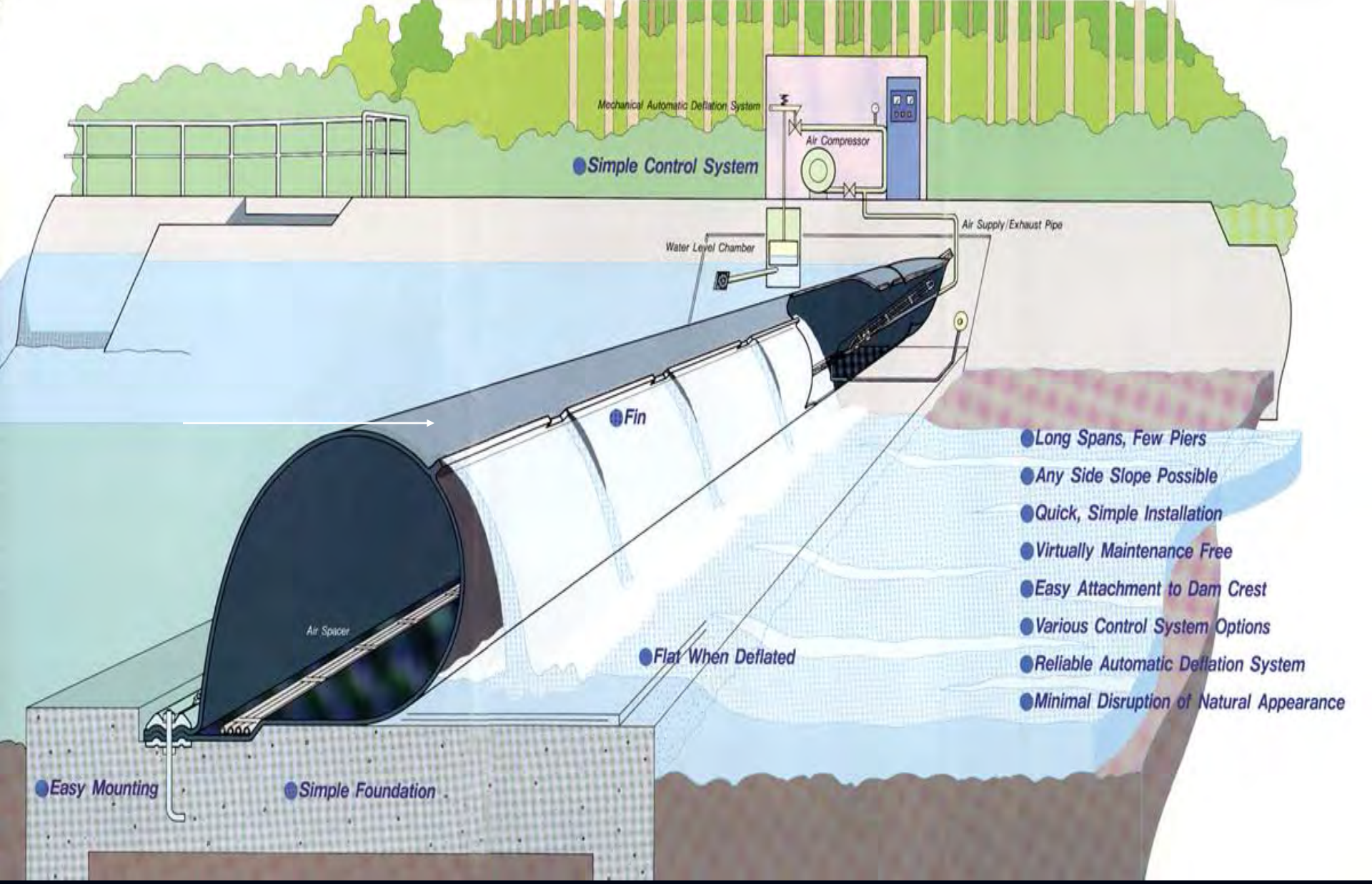
This photo, taken shortly after Charlotte Schaefers' drowning in February 2004 at Pearl City Peninsula, shows the drainage ditch and retention pond. Since the drowning, the Navy installed a safety barrier.

U.S. Navy

Timber Crib Dam


04/08/2002

Sunbury Inflatable (Bridgestone) Dam, PA



Bridgestone Rubber Dam

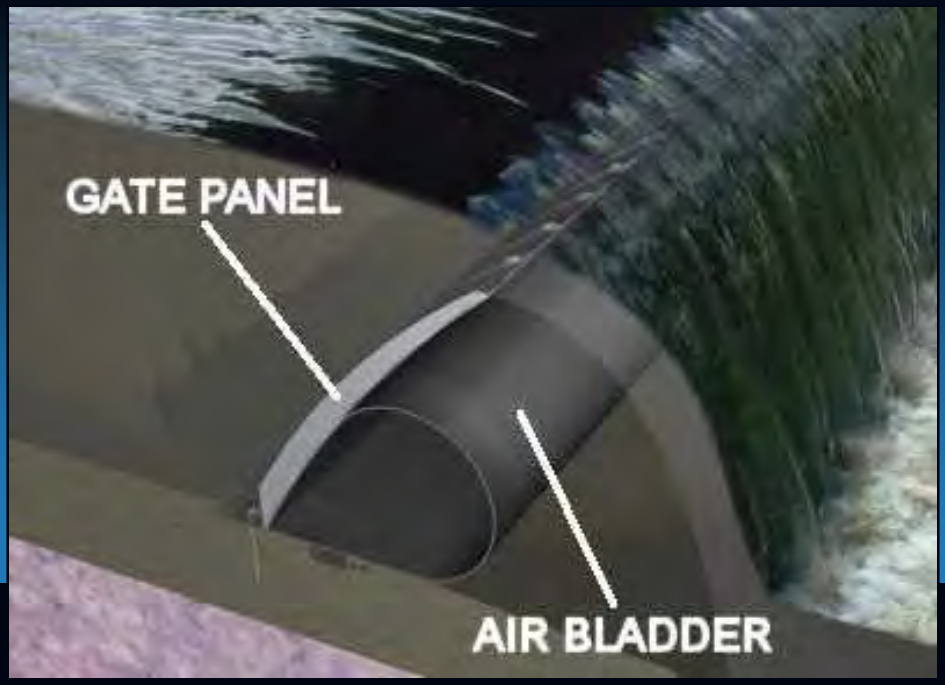
Sunbury Dam - Fully Inflated

Sunbury Dam - Fully Deflated


Tempe Lake Inflatable (Bridgestone) Dam, AZ

Tempe Lake Inflatable (Bridgestone) Dam, AZ

Obermeyer Hydro Gates



Granite Reef (Obermeyer) Dam, AZ

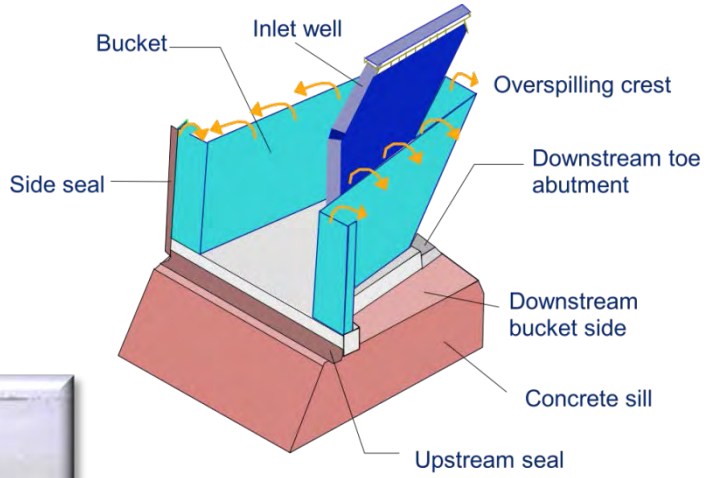

21.3 Feet

FUNCTIONING OF THE FUSEGATES

A simple concept…

Free-standing blocks, so called Fusegates, are installed

side by side across the spillway sill…



… in such a way that they form a watertight barrier.

Rattling Lake Spillway, Newfoundland

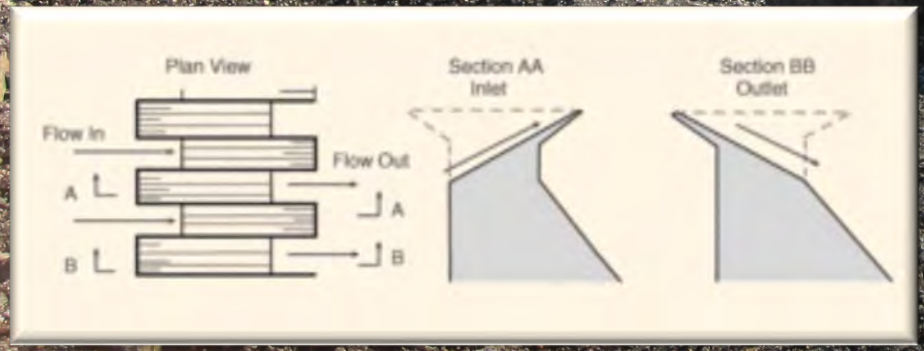


Photo courtesy of David Ball, P. Eng, Newfoundland Power


Rattling Lake Spillway, Newfoundland
Photo courtesy of David Ball, P. Eng, Newfoundland Power

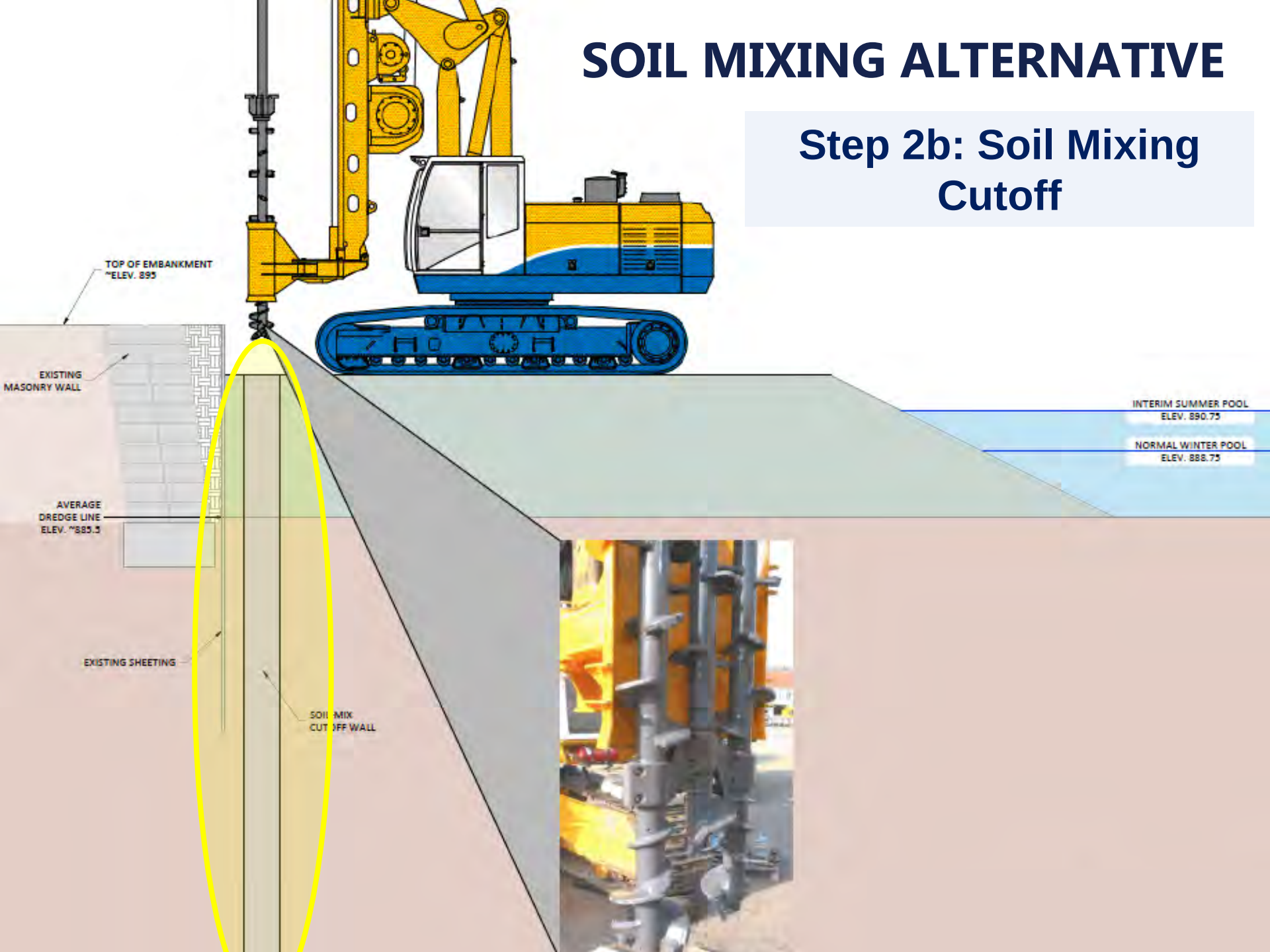
Soil-Cement

Articulating-Concrete Blocks (ACBs)


High-Performance Synthetic Liners & Geotextiles
2014.04.26 13:38

SOIL MIXING ALTERNATIVE

Step 2b: Soil Mixing Cutoff

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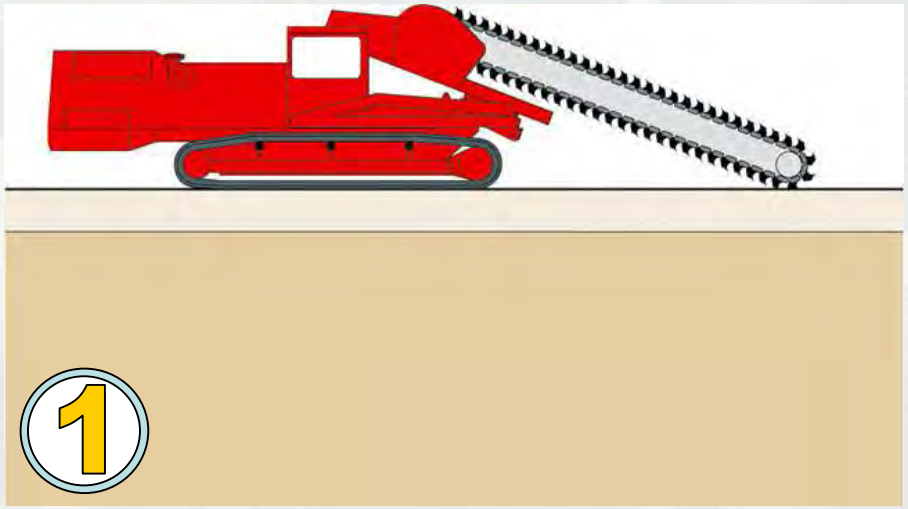
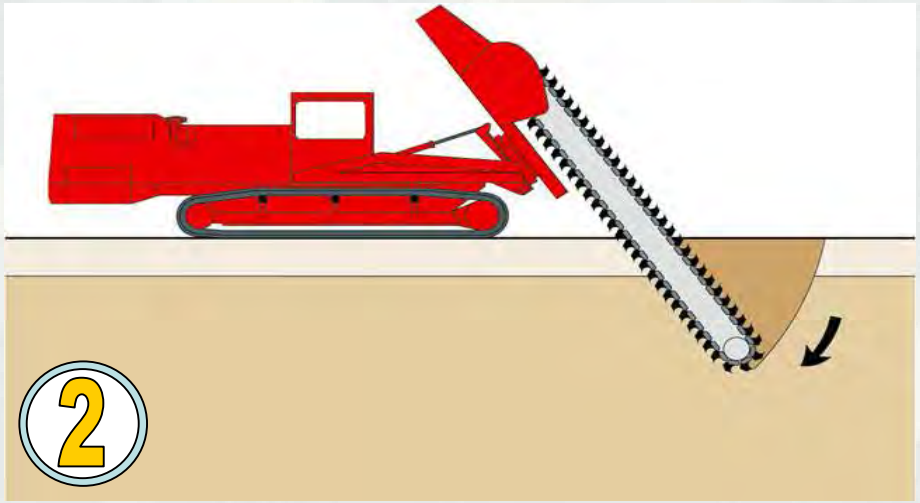
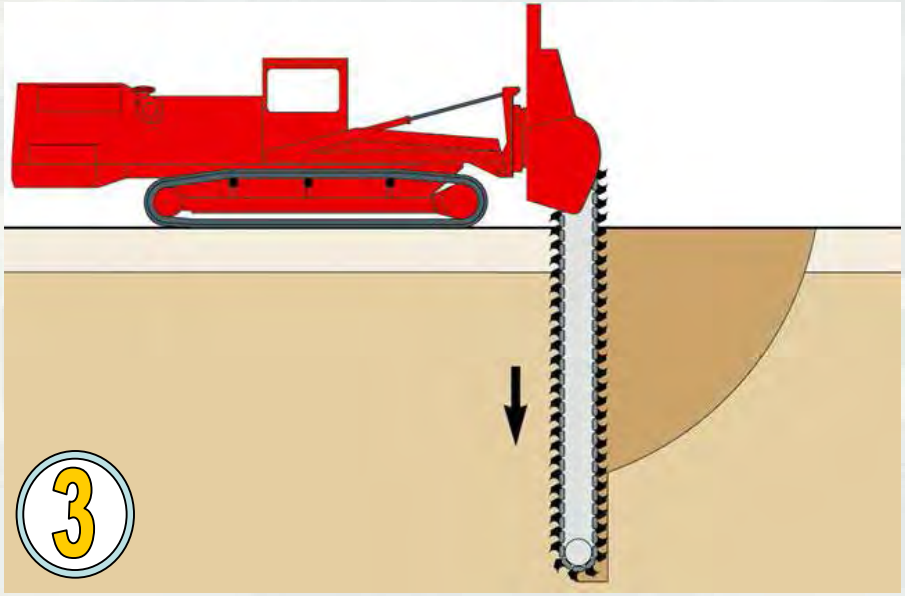
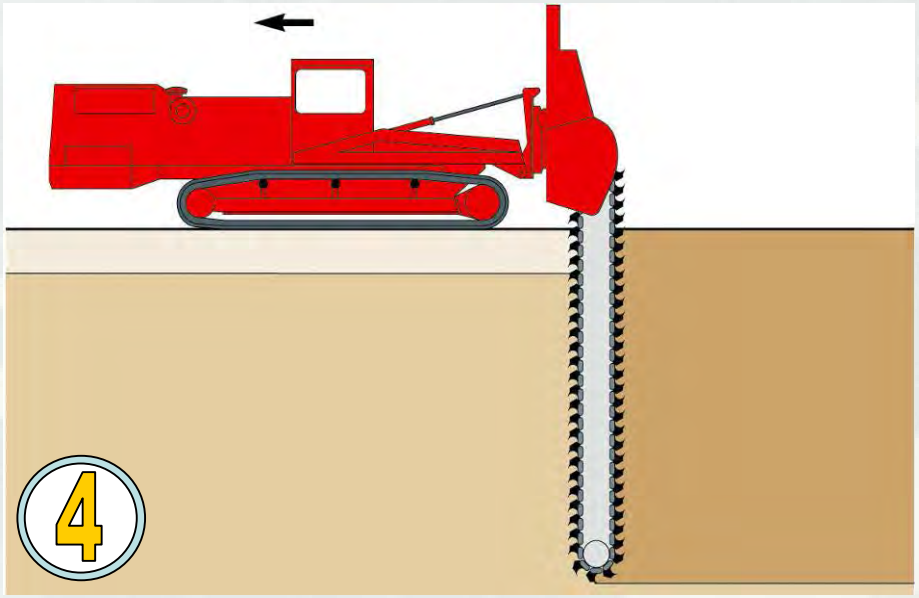
2015.05.04 14:59

One Pass Trench (OPT)

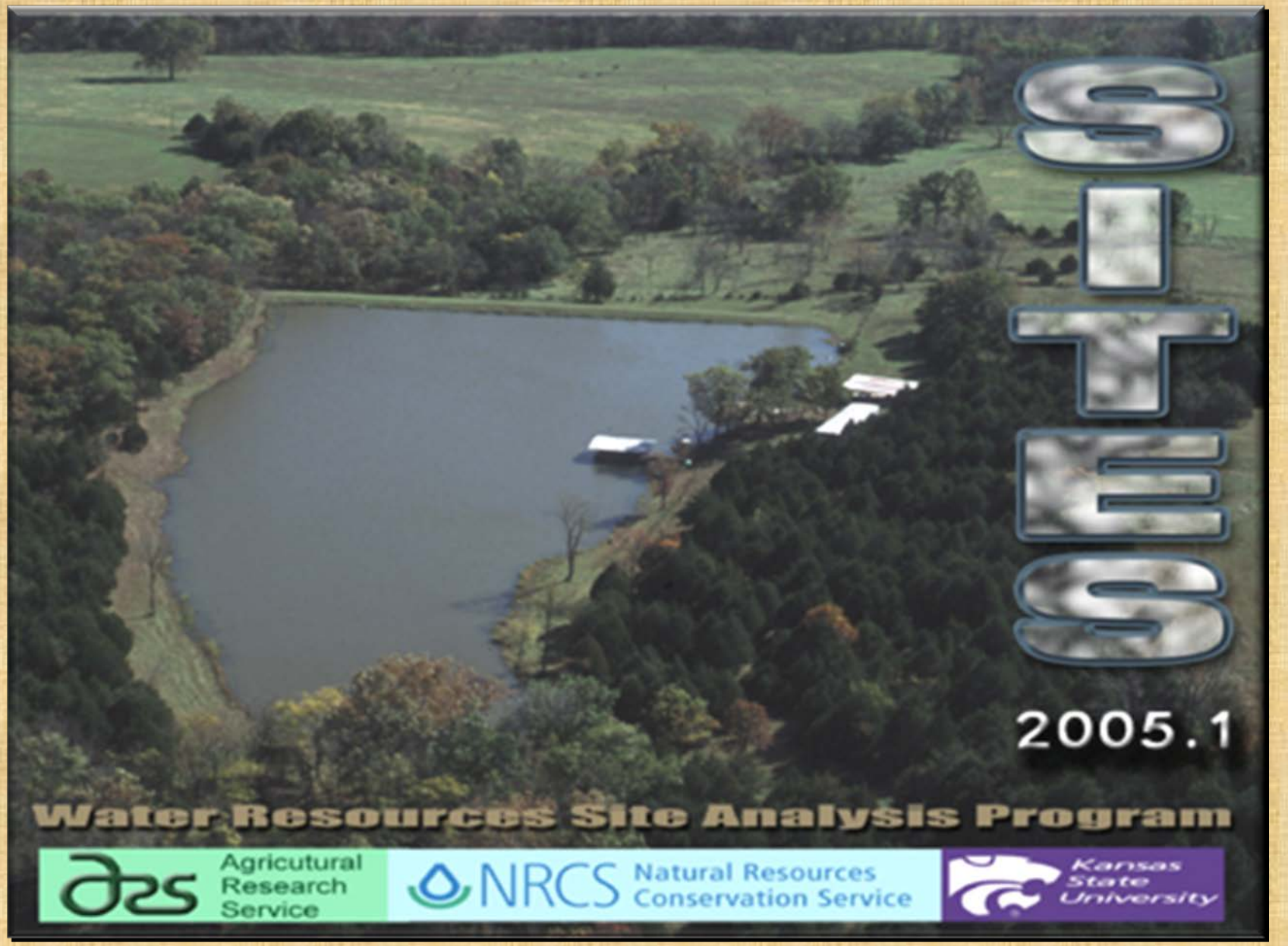








Spillway Erosion Assessment



Need For Emergency Planning

The Tribune-Democrat, Johnstown, Pa. Sunday, March 19, 1995

DANGER ZONE

Forewarned, not forearmed

Nearly half of the 1977 flood deaths could have been prevented, reports show

By ROBERT LONG
THE TRIBUNE-DEMOCRAT

Nearly half of the 85 deaths in Johnstown's 1977 flood could have been prevented, according to court documents and engineering studies never before made public.

A series of reports dating back to 1943 warned the owners of the Laurel Run Dam that the World War I-era barrier could not hold back heavy floodwaters, a six-month investigation by The Tribune-Democrat has found.

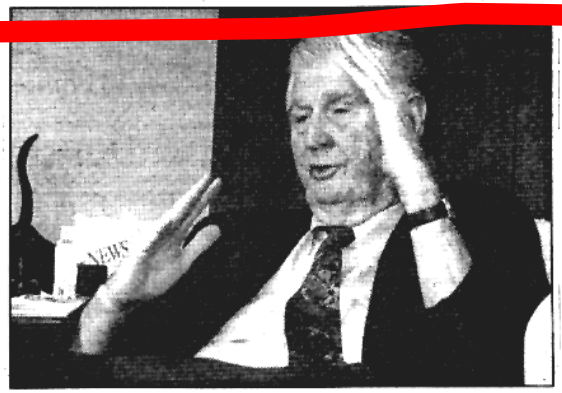
At best, the warnings were misunderstood. At worst, they were ignored.

The dam break

The Laurel Run Dam collapsed on July 20, 1977, killing 39 people in the small working-class community of Tanneryville, west of Johnstown. The dam break came 34 years after engineers raised the first of at least four warning flags about the dam's condition.

The collapse occurred as torrential storms dumped 11.8 inches of rain on the Johnstown area in eight hours. The storm caused flooding that spread death and destruction across five counties. Below the Laurel Run Dam, the effects were catastrophic.

A wall of water reaching heights of 20 feet and speeds of 12 mph ripped down the narrow valley, crushing the community of



Charles Kunkle Jr., top stockholder in Laurel Management Co., acknowledges that he learned of the spillway deficiencies in the early 1960s, but didn't rush to act.

dam's owner by at least four engineering studies prior to the flood. A spillway is like the overflow drain on a bathtub. It is designed to prevent water from rising and spilling over the top of the dam.

A series of heavy electrical storms centered over the area at about 9 p.m. on July 19, 1977. Four hours and 20 minutes of heavy rain overtaxed the spillway, raising the water level to the top of the Laurel Run Dam. By 1:45 a.m. water cascaded over the breast of the dam, cutting into the earthen embankment. Just before 2:30 a.m., the dam gave way.

Long Moffitt

Six-month effort

Reporters Robert Long and

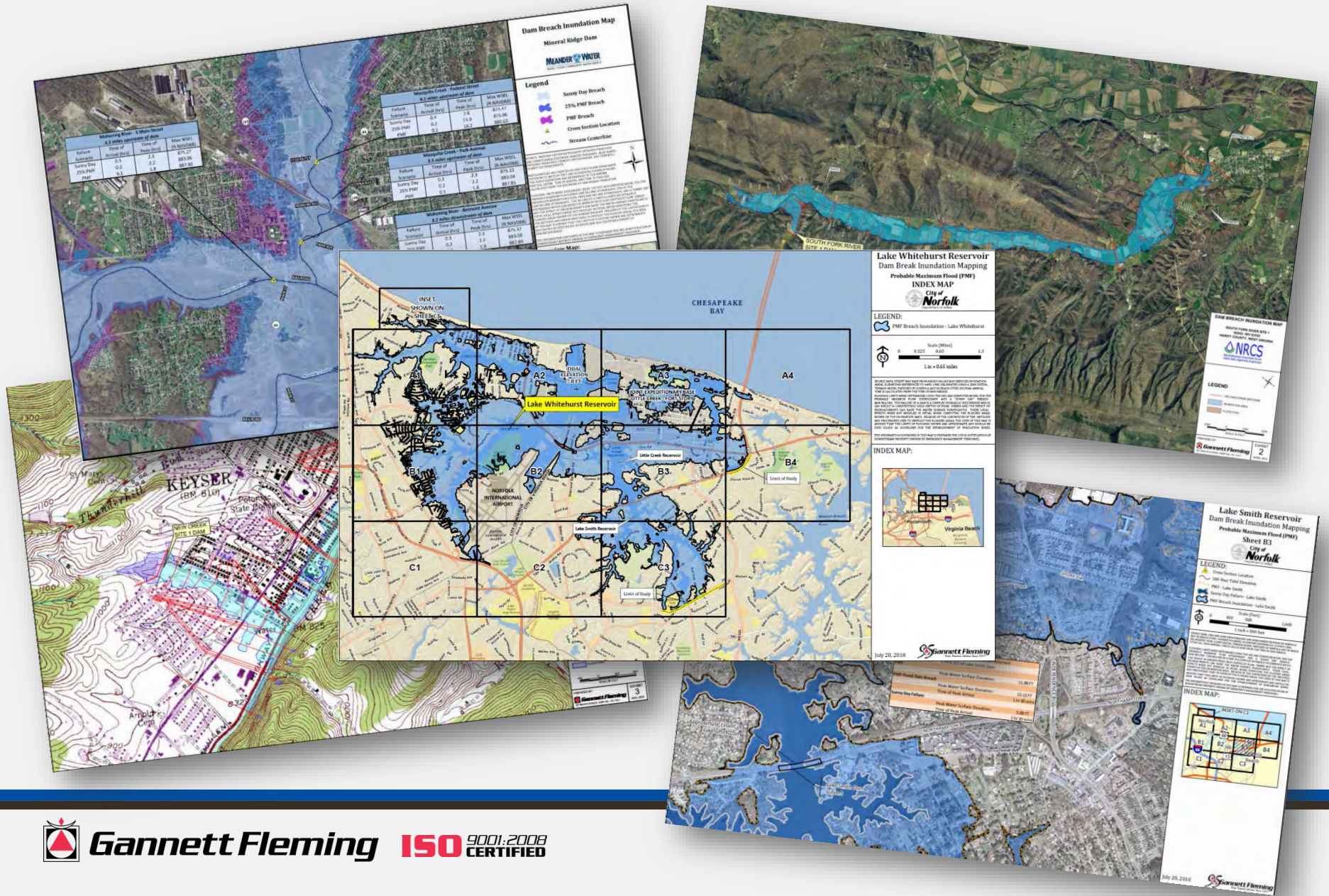
The flood ravaged some parts of the small working-class community of Tanneryville, west of Johnstown, while other areas in the community remained virtually untouched. Court documents show that the damage caused by the flood could have been prevented.

Dam warning sounded long ago

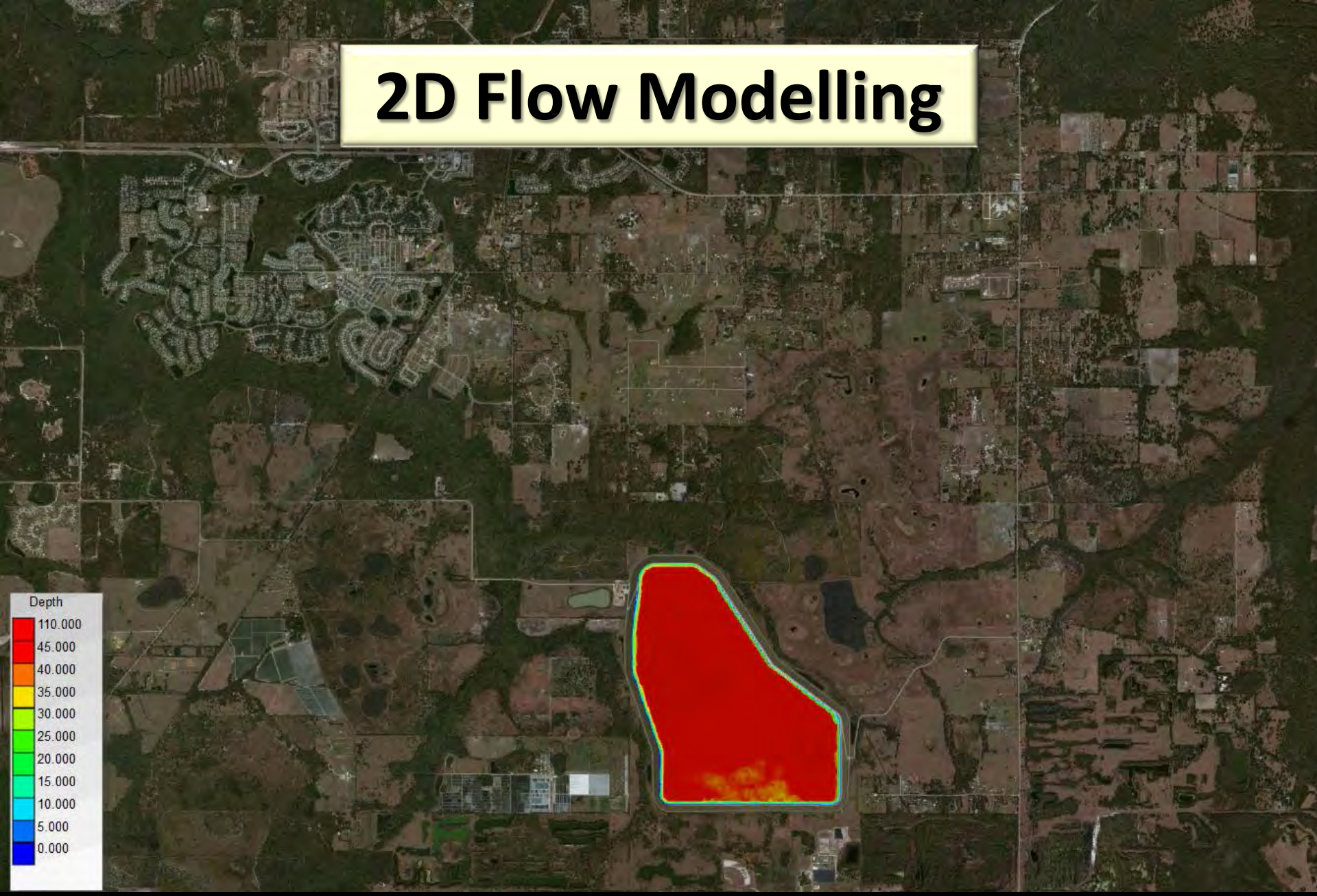
THE TRIBUNE-DEMOCRAT

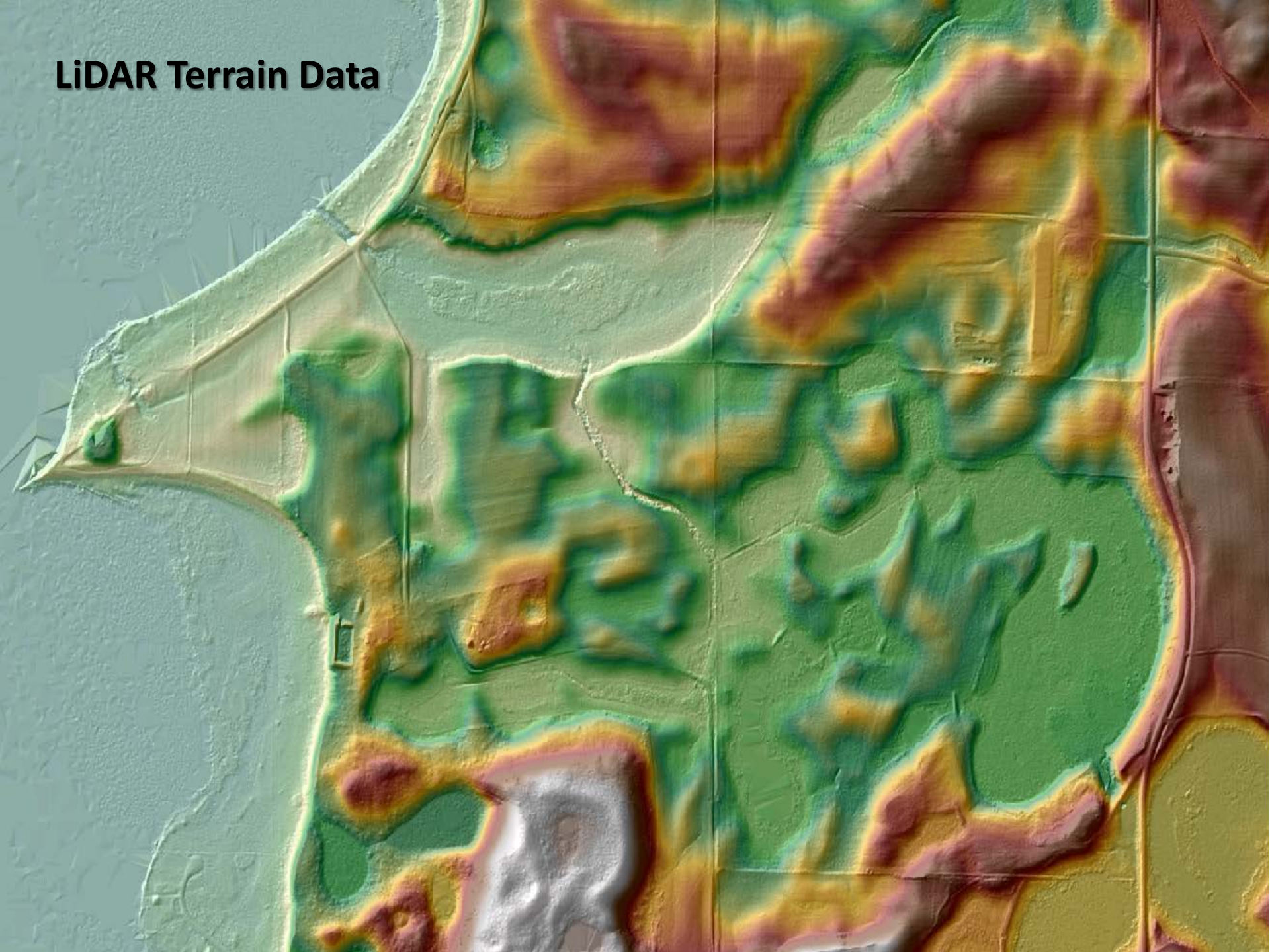
used as a base for the new structure

Inundation Maps and Reports

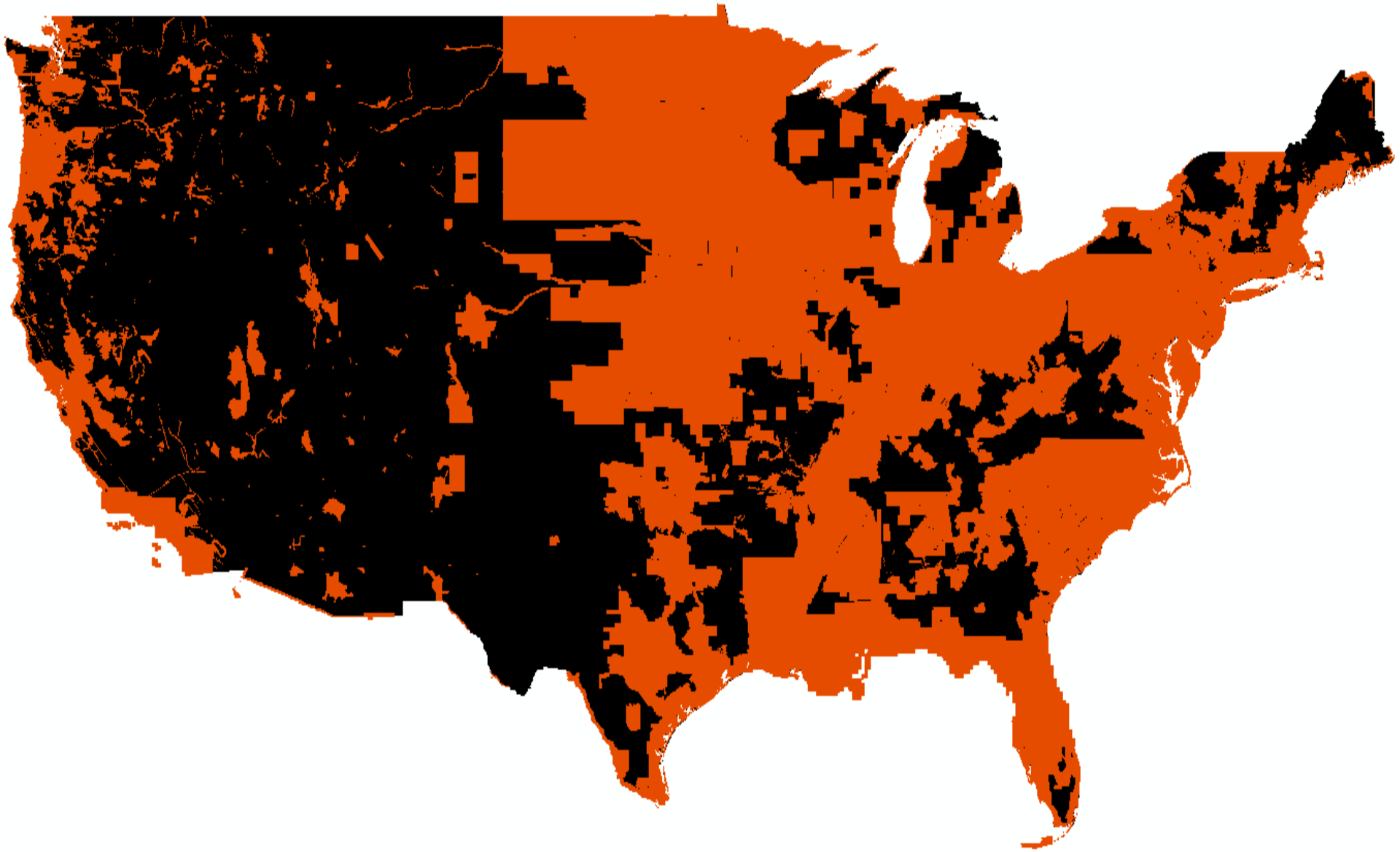


2D Flow Modelling

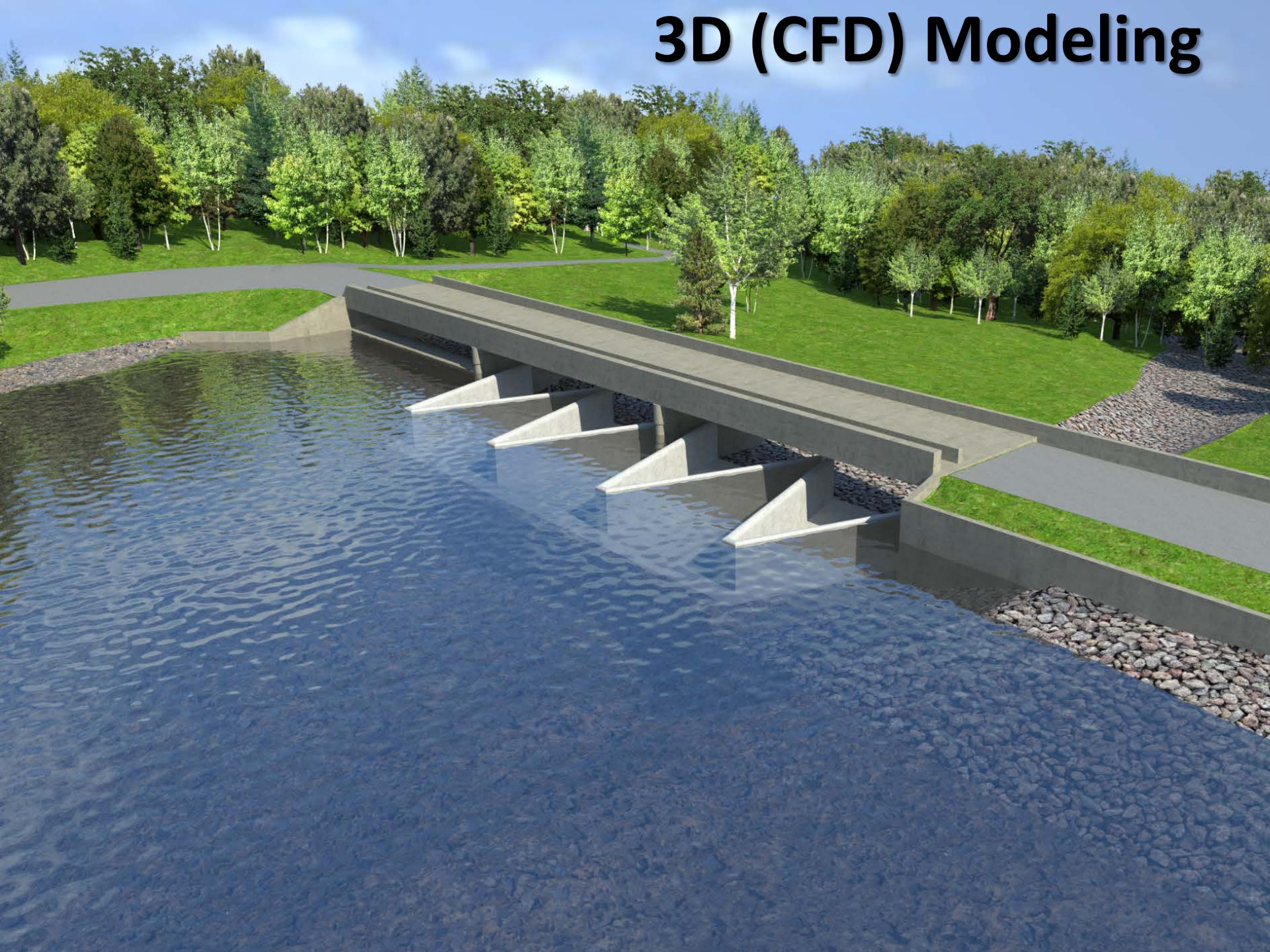


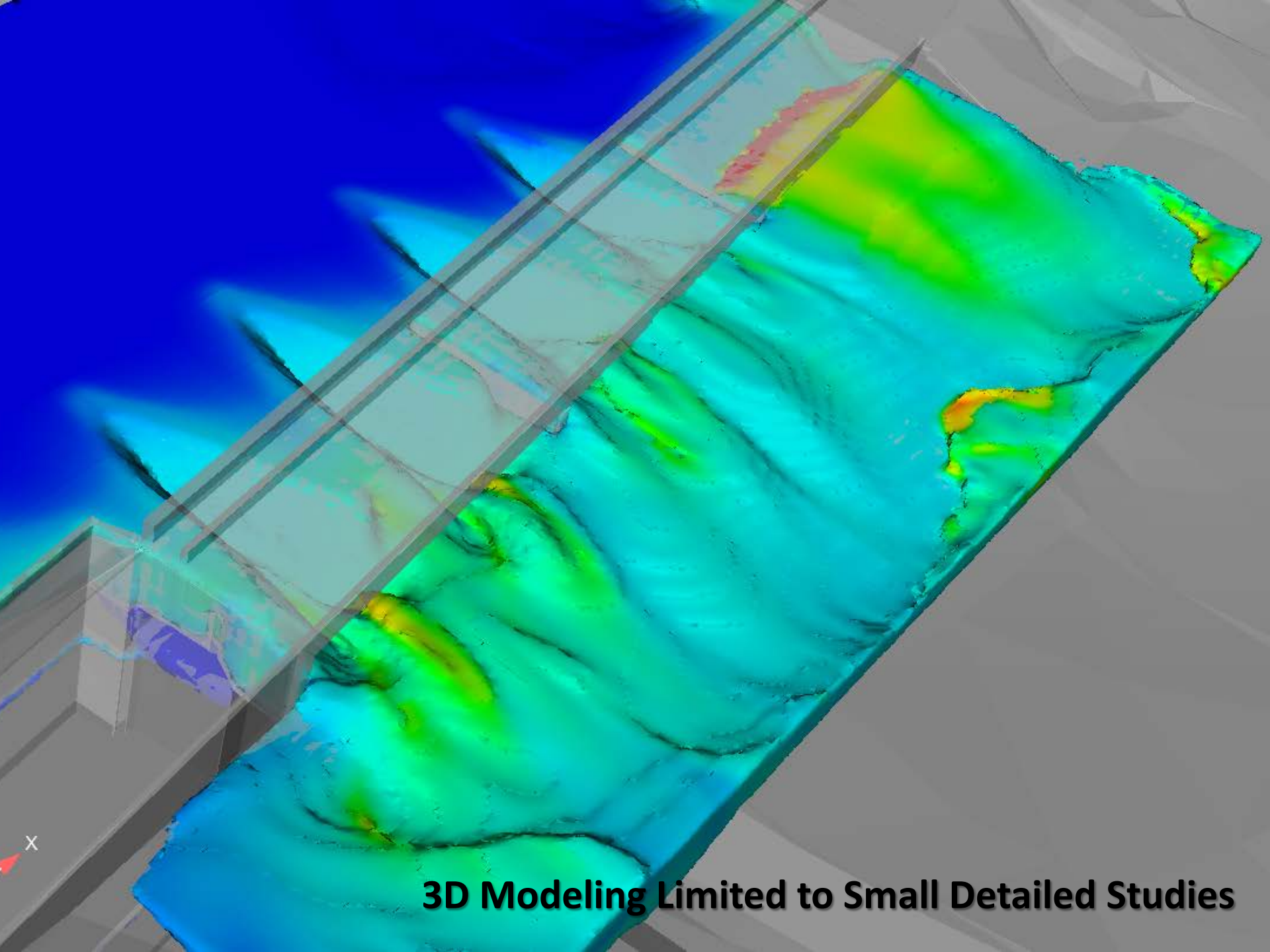

LiDAR Terrain Data

LiDAR Terrain Data Coverage as of 2015

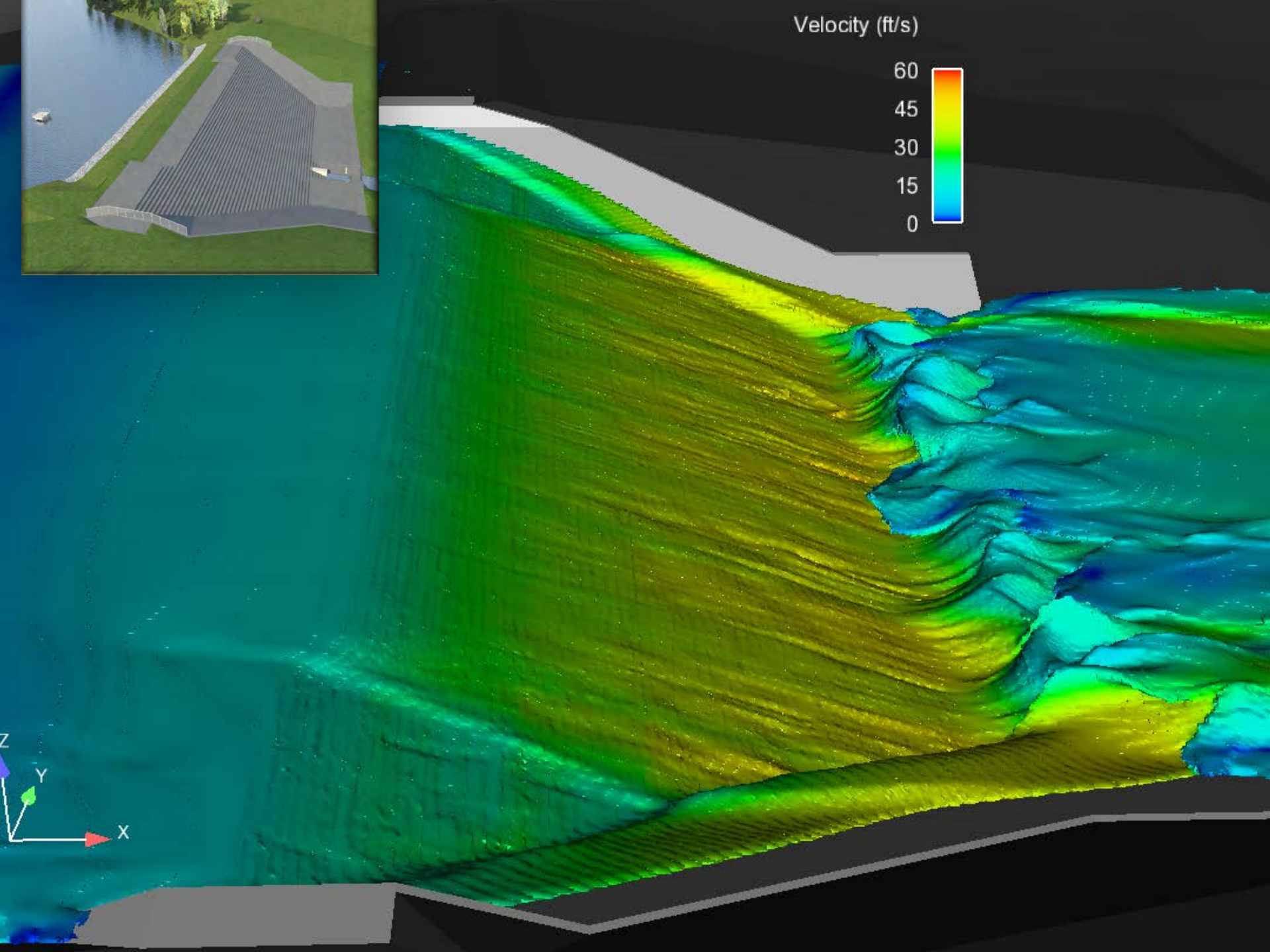


3D (CFD) Modeling





3D Modeling Limited to Small Detailed Studies


Velocity (ft/s)
60
45
30
15
0
Z
Y
X

Drone Inspection of Mill Creek Dam, PA

Organizations have no memory, only people have memories, and they move on.


15 Minute Break

Lessons Learned From Dam Failures
A Look at the Past and a Look Forward

Gannett Fleming

Maryland
Department of
the Environment