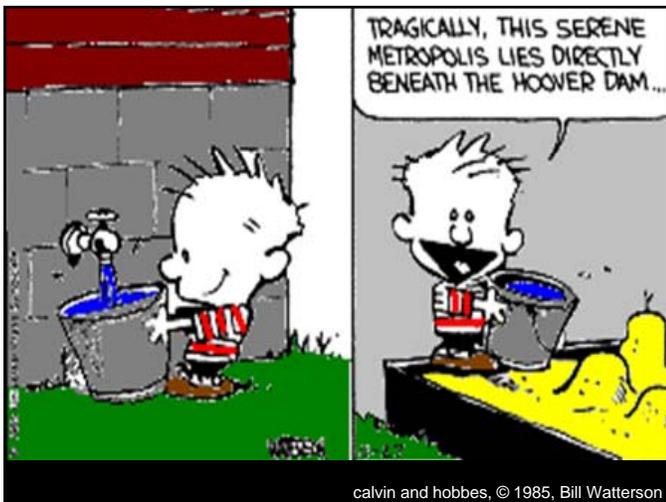
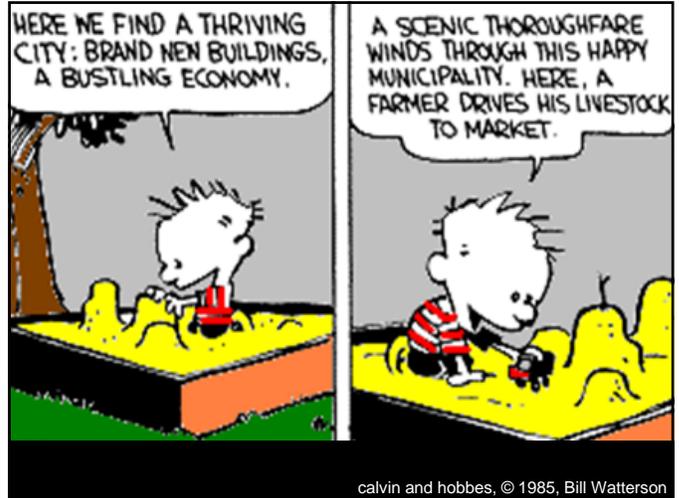


Dodging the Bullet: Lessons Learned From Recent Dam Emergencies

by
Hal Van Aller, P.E.
Maryland Dam Safety



Recent Dam Incidents

- Big Bay Lake, Mississippi (2003)
- Lake Needwood, Maryland (2006)
- Taum Sauk, Missouri (2005)
- Hadlock Dam, New York (2005)
- Lake Delhi, Iowa (2010)
- St Mary's Lake, Maryland (2011)
- Emergency spillway failures (2011)

Big Bay Lake Dam

- 15 years old (constructed 1999)
- 55 feet high. Lake 42 feet deep
- Well maintained, although 'minor' seepage along and into spillway conduit joints
- Inspected periodically by engineer
- Observed daily by maintenance staff

2004 3 16



Events leading to failure

- Afternoon of March 11, maintenance personnel detected new seepage near the left wing-wall of spillway conduit outlet and notified owner's engineer
- Engineer inspected the new boil and advised owner it should be watched overnight and he would look at it again the next morning

Events leading to failure

- Engineer returned Friday morning to inspect the seepage and noted that the flow from the new boil was clear
- Due to poor cell phone coverage, engineer left the site to call a contractor to start repairs
- However, before he got back to the office, the engineer was summoned to site because seepage began to rapidly increase

We've got a problem

- Around 1200 noon a pencil-sized stream of water had developed in the boil
- By 1230, the stream had grown to approx. four feet in diameter. At this point the EAP was activated by calling County EOC
- By 1235, EOC was directing a door to door evacuation and reverse call back to residents to warn them of the breach

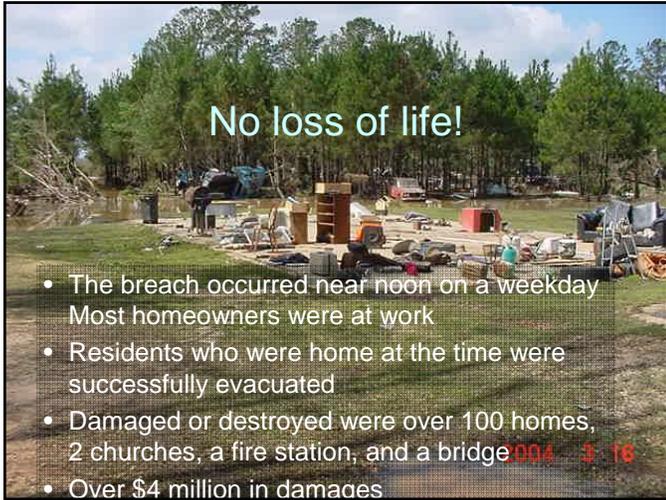
We've got a problem

- Around 1240 NWS issued a flash flood warning for two downstream counties
- State Dam Safety was notified of complete breach of dam at 1240









Breach numbers

- Entire lake drained in approximately 90 minutes
- Breach width was 385 feet wide
- Flow path was 19.5 miles long and stopped at the Pearl River.
- USGS gage at Bogalusa showed a 0.5' rise on 3/14/04.

Questions

- Were the inundation map and EAP adequate? (Only 3 miles downstream to point where the computed flood depth was less than 1' above 100-year elevation)
- Actual flood wave extended 19 miles
- What should a qualified professional engineer provide the dam owner in similar situations?

Adapted from EAP Postscript by Thomas I. Roberts, P.E. – Virginia Dam Safety

Inspections

- Dam was observed every day!
- Dam had a history of 'minor' seepage and 'minor' leaks into joints of conduit pipe
- New seepage which was discovered the day before the breach is less than what is often found at typical earthen dams

Comments by Thomas I. Roberts, P.E. – Virginia Region IV Dam Safety Engineer

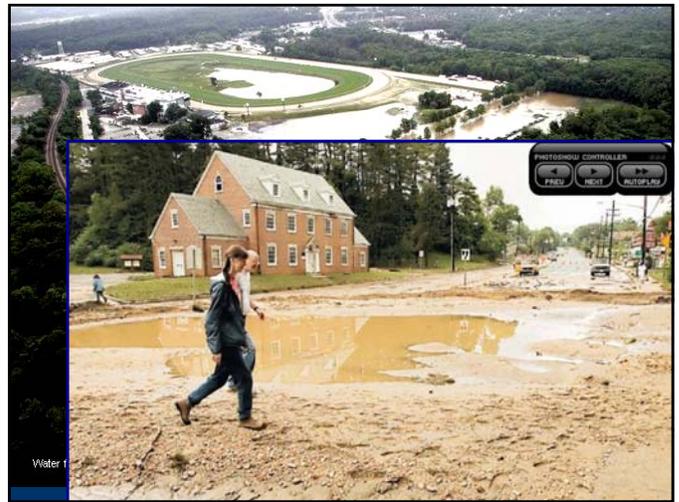
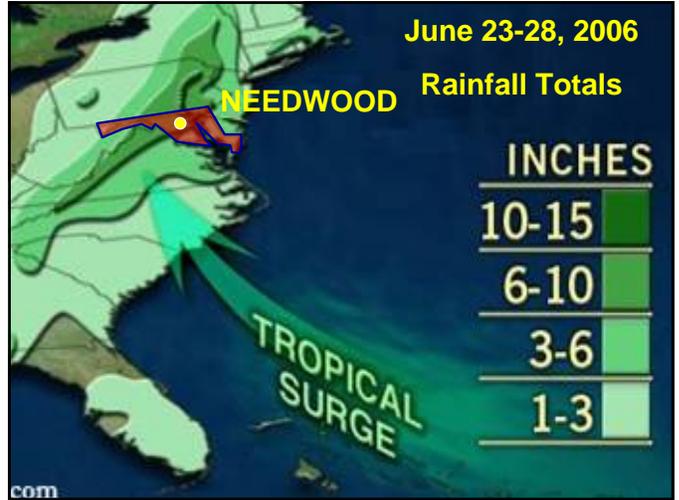
Lessons Learned

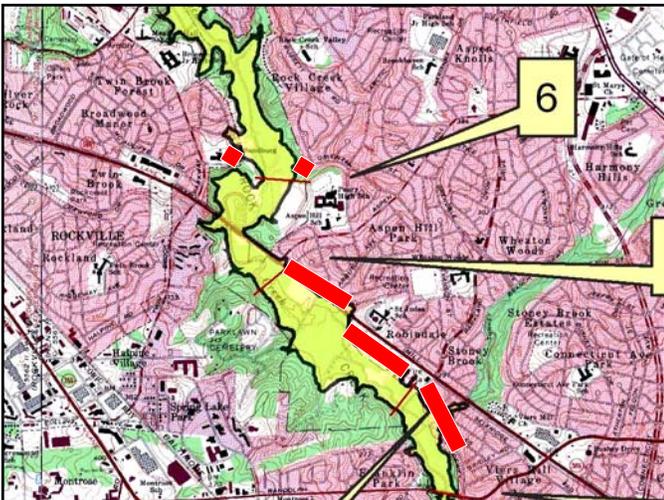
- Situation can go from "normal" to "emergency" overnight
- Flooding from a sunny day event may extend farther than inundation maps indicate



Lake Needwood Dam

- 65' high flood control dam constructed in the 1960s above Rockville
- Normally only about half-full
- Heavy rains in late June 2006 increased lake level 25 feet
- About 1130pm State was advised of leak at downstream abutment contact
- 2400 people evacuated after midnight
- Emergency repairs implemented









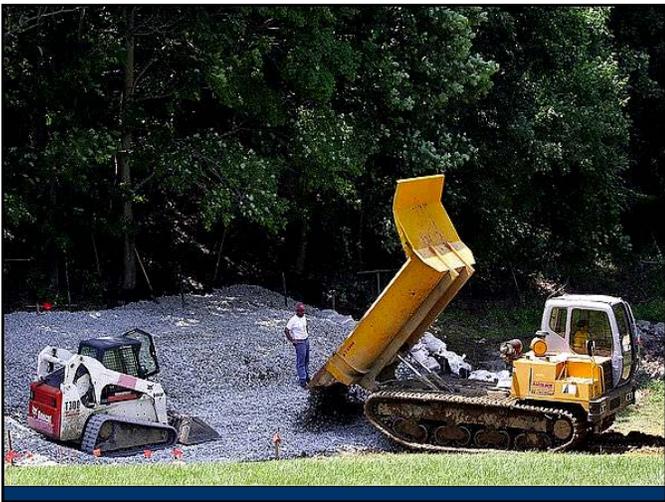


In an effort to prevent more flood damage to the Washington area, workers put gravel on a leak where water is sweeping through the dam.



Area workers use sandbags as a temporary fix to stop the over flooding of the dam. Engineers and workers repair the damaged dam at Lake Needwood in Rock Creek Regional Park. The lake is 25 feet above normal and over 2,300 local residents were forced to evacuate.







Public: When can we go home?

- 2400 People have been evacuated for 2 days, with July 4 holiday approaching
- Monitoring of the dam 24/7
 - Lake level
 - Seepage
 - Observation wells
- Continuous evaluation of safety of dam

Evacuation order lifted after 48 hours of evaluation

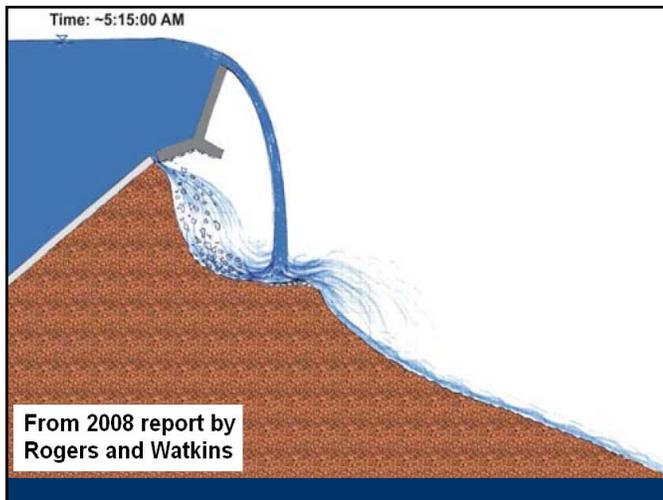
- All observation well levels dropped for 2 consecutive readings (4 hrs)
- “out of imminent danger” but not “all clear”
 - Dam still leaking
 - Lake still 20 feet above normal
 - Additional monitoring 24hrs/day
- Evacuees advised to monitor local radio and TV in case they need to evacuate again on short notice (1-2 hours)

Success!

- EAPs work! (even if out of date)
- The evacuation was a remarkable success
- Good cooperation between dam owner, designer, regulatory agencies, law enforcement, and emergency management officials
- Despite the leakage, the dam functioned as intended by attenuating downstream flooding

Taum Sauk Upper Dam, MO

- 85 foot high earth/rockfill embankment, 1 mile long
- Concrete slab facing with membrane liner
- 10 foot high retaining wall at top
- 50+ acre reservoir
- Overtopped and failed in December 2005 when newly installed water level sensor detached from wall causing pumps to keep running (inflow of 5,000+ cfs)
- Reservoir emptied (4,350 ac-ft) in 25 minutes
- No loss of life, but three residents nearly drowned when home was swept downstream

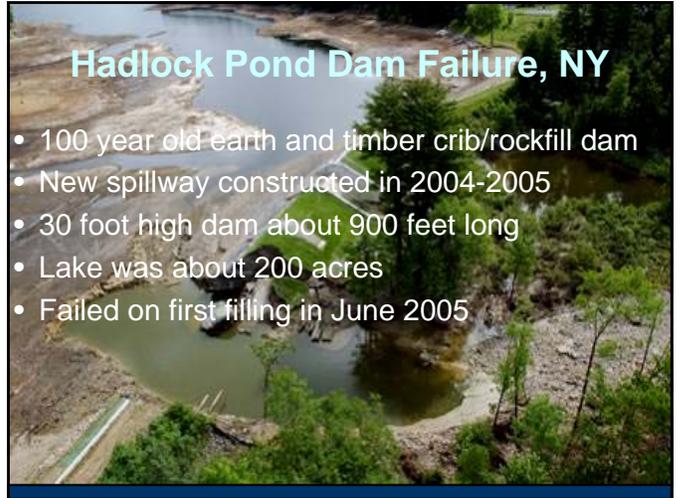


Lessons Learned

- Owner decided to operate dam from remote location with minimal on-site staff
- 1960's era sensors replaced with new system during upgrade completed in 2005
- Over-reliance on new sensors
- Reservoir was routinely filled to within 1 foot of top of wall, leaving little room for error when pumps running (>5000 cfs inflow)
- Very long dam (1 mile) made it difficult to detect that crest elevation was not uniform

Hadlock Pond Dam Failure, NY

- 100 year old earth and timber crib/rockfill dam
- New spillway constructed in 2004-2005
- 30 foot high dam about 900 feet long
- Lake was about 200 acres
- Failed on first filling in June 2005





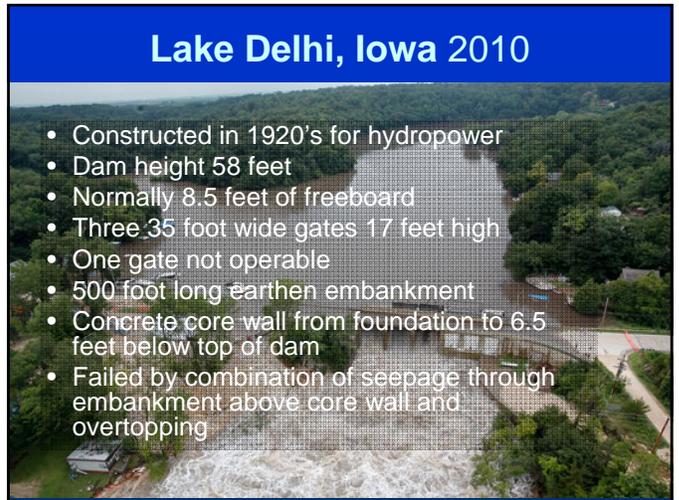
Engineering Investigation

- Interviews with Eyewitnesses
 - *Observed subsidence 1.5 weeks before failure*
 - *Observed sediment discharge*
 - *Observed water discharging from toe of the dam*
 - *Observed a bottom up failure*
 - *Observed water level about 1 to 2 inches over the ogee spillway*

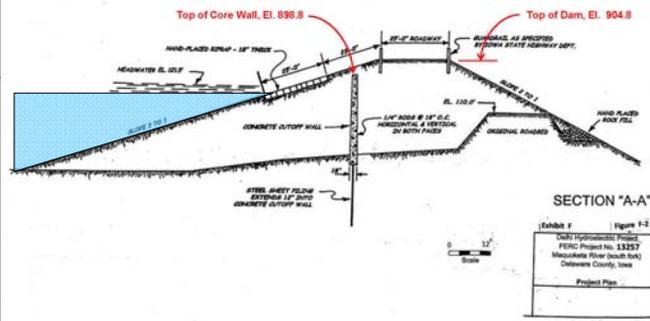


Lake Delhi, Iowa 2010

- Constructed in 1920's for hydropower
- Dam height 58 feet
- Normally 8.5 feet of freeboard
- Three 35 foot wide gates 17 feet high
- One gate not operable
- 500 foot long earthen embankment
- Concrete core wall from foundation to 6.5 feet below top of dam
- Failed by combination of seepage through embankment above core wall and overtopping



Embankment Cross Section



From Schwanz publication for ASCE



Hazard Classification ?

- FERC – **High Hazard** (but not regulated by FERC after hydro power production ceased in 1968 and license terminated)
- IOWA DNR – **Significant Hazard**
- Engineer performing 5 year comprehensive inspections – **Low Hazard**





Photo by Justin Hayworth



Julie Koehn/SourceMedia Group News



Dam Failure Consequences

- No loss of life
- Towns of Hopkinton (9 miles downstream) and Monticello (15 miles downstream) were impacted by the dam breach
- Formal EAP not in place but communication with downstream communities was excellent
- Property damage due to the dam failure has been estimated in the millions of dollars

From Schwanz publication for ASCE

Lessons Learned

- Annual inspections by state noted maintenance issues (trees, non-functional gate)
- Design defect (i.e., core wall did not extend to top of dam or to the maximum flood elevation) was not recognized
- Inability to operate one gate worsened overtopping potential
- There was confusion regarding the Hazard Classification of the dam

St Mary's Lake Dam



St Mary's Lake Dam

- In 2010 a storm caused flooding of a downstream community, although not because of the dam
- Subsequent review of the EAP for the dam noted that the trigger elevation for dam failure notification was after flow through emergency spillway occurred
- There was concern that evacuation could then not occur as many roads would be inundation
- So, the EAP trigger elevation was lowered to below the emergency spillway, but unfortunately the text of the notice was not changed, which stated that "dam failure is imminent"



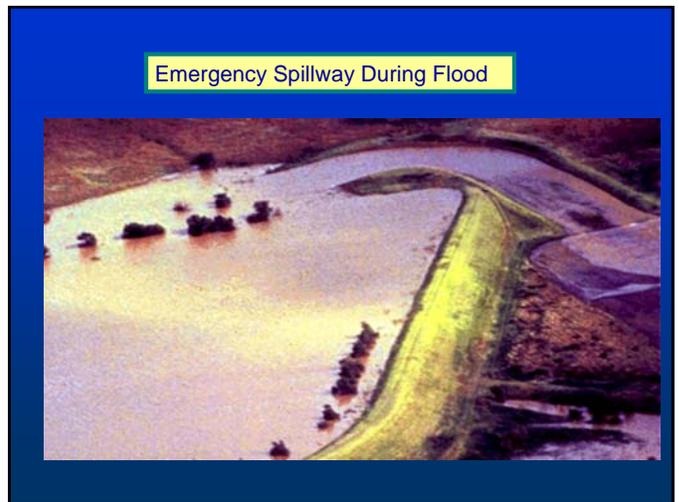


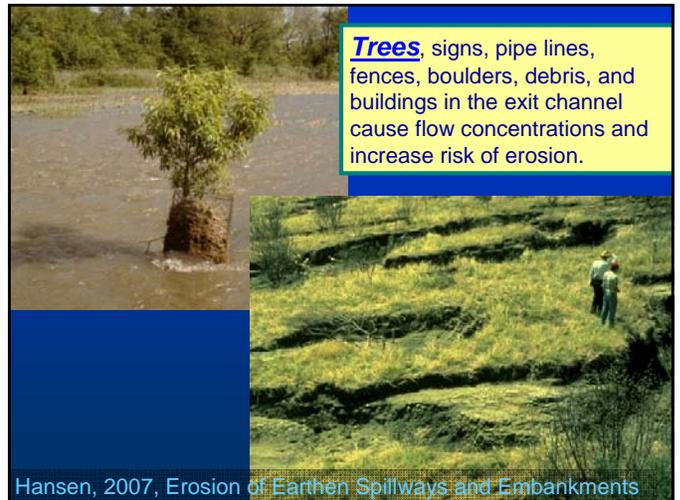
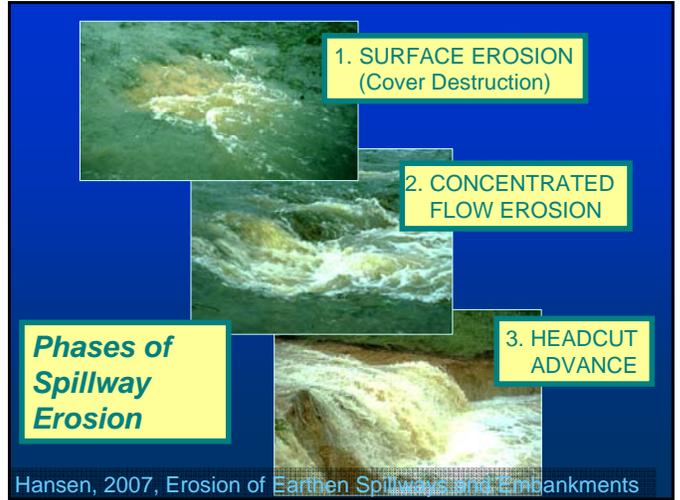
- When lake elevation reached the Level III trigger during Hurricane Irene, the public notice incorrectly advised that dam failure was imminent
- However, no flow occurred through the emergency spillway and the dam was never in danger of failure
- 2012 EAP update adds a new warning level to evacuate residents before flow through the emergency spillway

Lessons Learned:

- Travel during a Hurricane is difficult
- Cell phone communication unreliable-good to have more than one provider
- High winds exceeding 50 mph made it dangerous travel for dam safety staff and owner to get to the dam (bay bridge closed)
- Downed trees blocked access roads
- The standardized evacuation message created the false impression that the dam was about to fail, and word escalated to the national news level. This in turn reached the Governor in an undesirable manner, and we had to immediately travel to a distant section of the State to verify the condition of the dam

2011 8 25





Trees, signs, pipelines, fences, boulders, debris, and buildings in the exit channel cause flow concentrations and increase risk of erosion.



Hansen, 2007, Erosion of Earthen Spillways and Embankments



Figure 19. Maplecrest Dam - Storm flow through the left emergency spillway

Hurricane Irene, August, 2011 (New York)

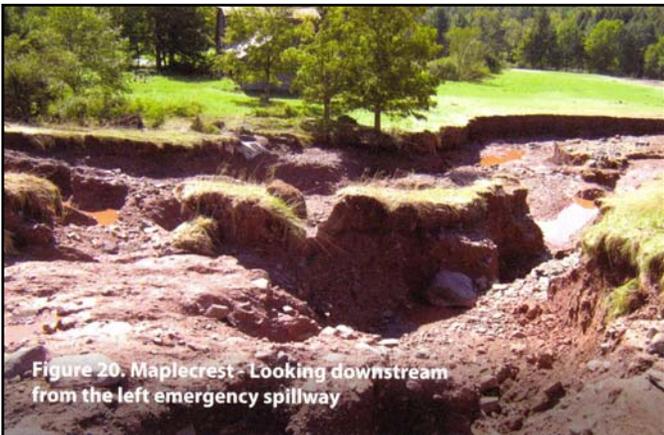


Figure 20. Maplecrest - Looking downstream from the left emergency spillway

Hurricane Irene, August, 2011 (New York)

