Brink of Failure? High Hazard Potential Dams

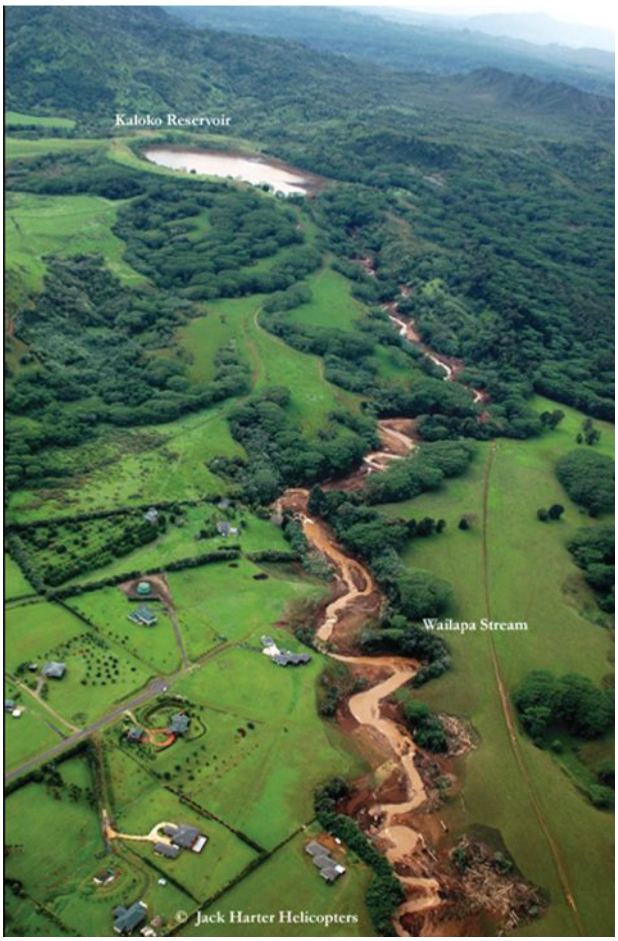
By **Trudy E. Bell** (©2017 Trudy E. Bell)

High hazard potential dams are ones whose failure would likely kill people. Over 15,000 exist nationwide. Half are older than half a century. More than a third are in poor or unknown condition. And some states exempt dams from safety requirements.

For six weeks straight, rain deluged Kauai, Hawaii. A rural 1,200-acre-foot irrigation reservoir impounded by the 42-foot-high Ka Loko Dam was full, with excess water pouring out the concrete-lined emergency spillway.

Just before dawn on March 14, 2006, a 200-foot-wide breach formed in the dam's 770-foot-long crest; 400 million gallons roared down the steep Waiakalua Stream valley. Within 16 minutes, the wall of water 10 to 30 feet high destroyed, swept away, or damaged over 50 homes and killed seven.

Investigations afterwards revealed that:



1) the 116-year-old earthfill dam may *never* have been inspected by federal or state regulators because, despite its intermediate size and the farmers living downstream, it was classed as a low hazard dam;
2) two decades earlier, a 1984 joint state-federal report had already cited a need for $1.9 million in repairs to the dam;
3) in 1997, without a permit, the dam owner bulldozed dirt to partially block the emergency spillway; and
4) the state dam safety office lacked resources to compel the owner to rectify violations or create an emergency action plan.

Ultimately, the owner was charged with manslaughter, convicted of reckless endangerment, and sentenced to seven months in prison.[1]

The 2006 Ka Loko Dam tragedy is significant because the dam was all too typical of the thousands of dams that pose risk around the nation: intermediate-sized or even small older structures inadequately inspected and under-maintained, likely without an emergency action plan, whose condition was long ignored despite concern expressed repeatedly by local residents and/or experts.

Many other dams around the country have failed nonfatally in the decade since. October 1–5, 2015 after historic rainfall (15 to 20+ inches[18]), 51 dams in and around Columbia, South Carolina—population over 130,000—were overtopped and rapidly eroded away.[21] A year later, nearly half the public roads washed out by those dam failures still remained closed,[22] in part because private dam owners were financially unable to repair or remove their dams. Moreover, last October (2016) almost exactly a year later, another 25 dams failed in the same state during Hurricane Matthew.[23]

Official numbers starkly reveal that credit for no fatalities since 2006 is primarily due to dumb luck.

Those dam statistics

After several major fatal dam collapses in the 1970s, the U.S. Army Corps of Engineers (USACE) set up the National Inventory of Dams (NID): a publicly accessible database of dams of any size that potentially threaten at least one human life, plus dams bigger than a certain size (25 feet high storing more than 15 acre-feet, or 6 feet high if storing more than 50 acre-feet; an acre-foot, a volume unit for measuring reservoirs, is 325,851 gallons) regard-

PHOTO: TVA

Five Times Bigger Than Deepwater Horizon Spill!

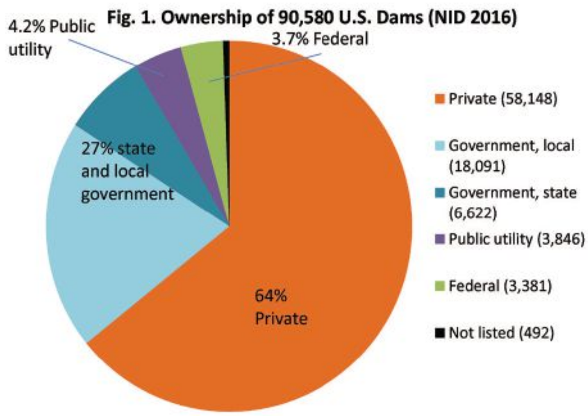
Not all dams in the National Inventory of Dams (NID) impound water. According to the National Dam Safety Act of 2006, a dam is defined as "any artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material, for the purpose of storage or control…" Some 1,300 dams nationwide (about 1.4%) were constructed by public utilities, mining corporations, or other facilities to impound coal waste, uranium or other mine tailings, or other toxic substances.[9]

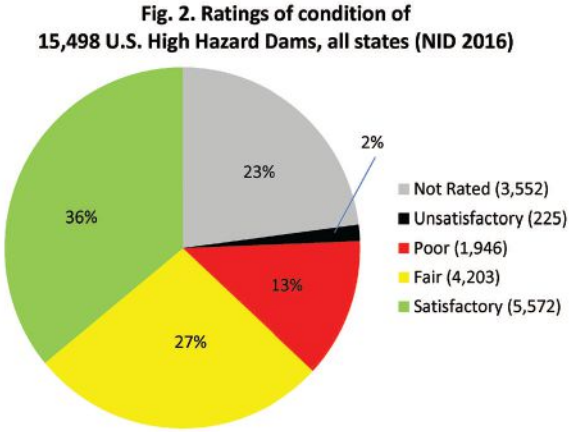
Unlike embankment dams built to impound water, tailings dams are commonly made of drilling debris or other loose, unconsolidated material. A 2010 analysis of tailings dam failures over the previous century reveals the failure rate of tailings dams is about 1.2%—"more than two orders of magnitude higher than the failure rate of conventional water retention dams."[6]

One of the nation's worst tailings dam failures was in Buffalo Creek Valley, WV; it released a suffocating mass of coal waste, wiping out 16 downstream communities and killing 125 people.[13] On December 22, 2008, the Tennessee Valley Authority's Kingston Coal Waste Dam near Harriman, TN, collapsed, releasing 1.1 billion gallons (5.4 million cubic yards) of a slurry of ash—a volume five times greater than the massive 2010 BP Deepwater Horizon oil spill in the Gulf of Mexico—into the Emory and Clinch rivers, contaminating water supplies for Chattanooga and other downstream cities in three states [see photo]. While Tennessee does have dam safety laws, regulations specifically exempt coal-ash dams.[25] The most recent U.S. tailings dam failure was just last August 27 (2016), when a phosphate tailings dam in Mulberry (Polk County, FL) failed; contaminated liquid reached the Floridian Aquifer,[10] a major water supply for central and northern Florida and southern Georgia.

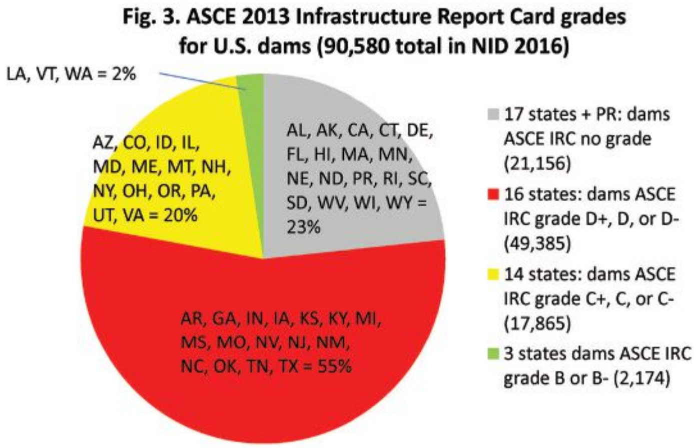
[Fig. 1] A whopping majority of U.S. dams—nearly two-thirds—are privately owned, whether by corporations, homeowner associations, or individual property owners. Federal agencies own under 4 percent of the nation's dams (although they regulate additional non-federally owned dams on federal agency lands).[16] Public utilities own more dams than the feds. Over a quarter of all dams are owned by state or local governments. About 70 percent of dams are state-regulated. All charts by Trudy E. Bell based on NID and/or ASCE data.

LEFT: As a result in part of poor maintenance and lack of inspections, Ka Loko Dam in Hawaii breached and the reservoir's 400 million gallons of water and mud thundered down the river valley, destroying houses and killing seven in the farming community below. The predawn tragedy of March 14, 2006, was the last fatal U.S. dam failure. But two thirds of fatal dam collapses have been of significantly smaller dams. *PHOTO: Jack Harter Helicopters*

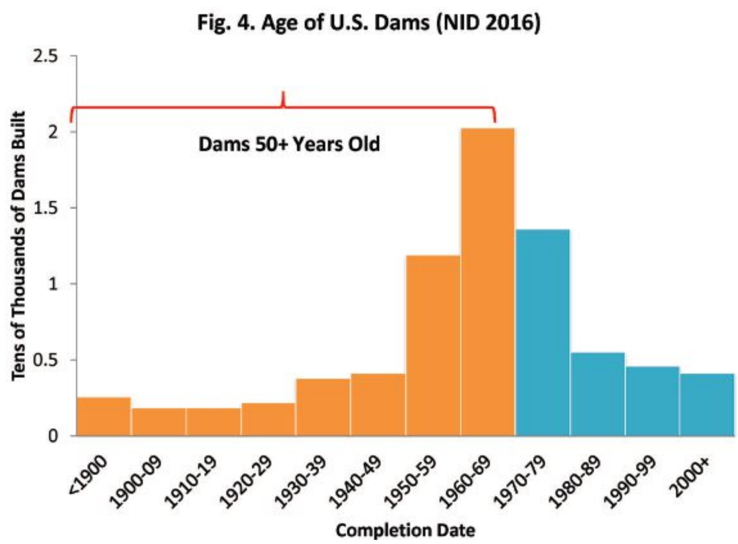




[Fig. 2] About 14% (2,171) of the 15,498 high hazard potential dams in the NID are rated poor (red) or unsatisfactory (black). Moreover, the condition of another 23% (3,442) is not rated, either because it is unknown or undisclosed;[20] however, if the same proportion (14%) of the unrated dams also is in poor or unsatisfactory condition, then another 500 or so of the unrated dams likely are also deficient. (Numbers do not total to 100% due to rounding.)



[Fig. 3] In nearly a third of states (16), the ASCE awarded dams (of all hazard potentials) grades of D+, D, or D- in 2013; information was insufficient for dams to be graded in another third of the states (17).



[Fig. 4] Of the 76,361 dams in the NID (of all hazard potentials) giving completion dates, 63 percent (48,516) were built before 1970, so are now at least 47 years old.[28] Moreover, well over 15 percent are 75+ years old (built before 1942), including some of the largest U.S. dams (Hoover, Grand Coulee, and Fort Peck, with Shasta hard behind).

less of hazard to human life.[27] As of the 2016 update, the NID included 90,580 dams, half of which (45,402) are under 25 feet high [Fig. 1].

Dams in the NID are categorized by hazard potential. Hazard potential is not condition; it is purely an assessment of the likely severity of downstream damage should the dam fail, given its location, size, reservoir capacity, downstream assets and population, etc. A high hazard potential dam—also called Class 1 (or I) by some states—is one whose failure would probably result in loss of human life regardless of property damage. A significant hazard potential dam (Class 2 or II) is one whose failure would likely result in severe environmental or property destruction and possibly result in the loss of human life. A low hazard potential dam (Class 3 or III) is one whose failure is not expected to endanger human life and whose damage might even be limited to the owner's property.

Smaller Dams = Bigger Hazard

Some 17%—15,498—of the dams in the NID are categorized as high hazard potential. They do not have to be big to threaten lives. According to a 2011 statistical analysis by the U.S. Department of Homeland Security, at least two-thirds of fatal dam failures since 1900 resulted from the collapse of dams considered "small" or "intermediate" between 20 and 49 feet high. Indeed, most were considerably lower and smaller than Ka Loko, with half a dozen impounding less than 100 acre-feet.[30]

The number of high hazard potential dams is inexorably growing—a phenomenon called "hazard creep." One cause is increasing population around the country, which encroaches into previously uninhabited downstream hazard zones of dams originally built in comparatively isolated areas. Another cause is the decades-long increasing trend toward exceptionally heavy rainfall events.[19] Both factors are forcing regulators to reclassify dams. Indeed, across the country, the number of dams now classified as high hazard has grown by nearly 60% in less than two decades, up from 9,281 in 1998.[4]

Dams in the NID are also rated by condition or structural soundness. The USACE and the Association of State Dam Safety Officials (ASDSO) use a five-point scale: satisfactory, fair, poor, unsatisfactory, or not rated.[29] As of the 2016 NID update, 14% of high hazard potential dams are considered deficient—having not only potential to take lives, but also being at significant risk of failure[20]—and another 23% are not rated [Fig. 2].

Independently, the American Society of Civil

Engineers (ASCE) in its quadrennial Infrastructure Report Card reports, awards letter grades (A, B, C, D, F, plus ?) for condition[2] of various types of infrastructure in each state. [Table 1]. For the nation as a whole, the ASCE assigned dams a grade of D, meaning "Poor: At Risk" [Fig. 3]. (Note: The letter grades in this article are those given in the ASCE's 2013 report card. ASCE's 2017 report card was to be published on March 9, and they declined to share any updated state grades in advance; however, it is hard to imagine that many—if any—of the ASCE dam grades would have improved over the past four years.)

The 59-foot-high Lake Delhi Dam in Iowa failed in 2010 when it was overtopped during record rainfall. A 2009 inspection of the 80-year-old dam had revealed one of three spillway gates was inoperable; also, a strengthening concrete core wall did not reach the embankment's maximum height, allowing seepage to weaken the dam. Emergency responders evacuated downstream residents fast enough that no lives were lost. PHOTO: *Iowa Department of Natural Resources.*

Age and Neglect

By 2020—just three years hence—nearly two-thirds of U.S. dams will be older than half a century [Fig. 4]. Since many dams, like much other heavy infrastructure (such as interstate highways and power plants), are built with a nominal design life of 50 years, that means a "staggering percentage of our dams… have either just surpassed the extent of their intended design lives or will do so in the very near future," noted the Center for American Progress (a public policy think tank) in 2012.[9]

Heavy infrastructure can long outlast its design life if it is well-maintained. But, therein lies the rub. Age exacts a heavy toll with neglect.

According to the Federal Emergency Management Agency (FEMA), an analysis of 656 U.S. dam failures from 1975 to 2011 reveals that the single greatest cause of dam breaches (70.9%, 465 incidents) is flooding and overtopping from heavy rainfall. The second biggest cause of failure (14.3%, 94 incidents) is piping or seepage through or under a dam.[14]

Overtopping can happen to a dam of any age, but how well the dam withstands it depends also on the soundness

U.S. Army Corps of Engineers Rating in National Inventory of Dams (NID)[29]	
Rating	Definition (abbreviated)
Satisfactory	No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic).
Fair	No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency.
Poor	A dam safety deficiency is recognized for realistic loading conditions. Remedial action is necessary.
Unsatisfactory	A dam safety deficiency is recognized that requires immediate or emergency remedial action.
Not Rated	The dam has not been inspected, is not under state jurisdiction,or has been inspected but, for whatever reason, has not been rated.

ASCE 2013 Infrastructure Report Card Grades[3]	
Grade	Definition (abbreviated)
A	90-100%: Exceptional, fit for the future. Excellent condition, new or recently rehabilitated, meets future capacity needs. Resilient to withstand most disasters and severe weather.
B	80-89%: Good, adequate for now. Some elements show signs of general deterioration that require attention. A few exhibit significant deficiencies. Safe and reliable with minimum risk.
C	70-79%: Mediocre, requires attention. Fair to good condition, general signs of deterioration. Some elements exhibit significant deficiencies. Increased vulnerability to risk.
D	51-69%: Poor, at risk. Poor to fair condition, mostly below standard. Significant deterioration; many elements approaching end of service life. Strong risk of failure.
F	<50%: Failing/critical, unfit for purpose. Unacceptable condition, widespread advanced signs of deterioration. Many components exhibit signs of imminent failure.
?	Incomplete; data available are insufficient to provide a grade.

[Table 1] The ASCE grades for condition by state—grades intended to apply to all kinds of national infrastructure ranging from airports to highways—approximately but not exactly correlate to the USACE and ASDSO ratings for the condition of dams. Colors shown are the ones used in the pie charts in Figs. 2 and 3 (in 2013, the ASCE did not grade any state's dams either A or F).

of its internal structure and maintenance of its exterior. Risk of overtopping increases if a reservoir's capacity is diminished due to the deposition of sediments, or if runoff increases from pavement and other impermeable surfaces from subdivisions and businesses later built upstream, stressing the dam's original design.[15] Dams can also be weakened by the burrowing of rodents, the penetration of tree roots, or the rusting of metal pipes or structural components. Such risk factors can be managed only through thorough inspections and timely maintenance.

Underfunded and Understaffed

ASDSO keeps tabs on state dam safety programs, including their annual budgets and full-time equivalent state employees (FTEs). Nationwide, in 2015 state dam safety programs collectively received $49.4 million—which sounds pretty good until you realize that more than a quarter of that was the budget for California alone ($13.2 million). Another 13 states have budgets ranging between $1 and $2.6 million, subtotaling another $19.5 million. But the remaining $16.7 million in state budgets is split unevenly among 35 states—and Alabama has no dam safety budget at all.[4]

But wait, there's more. Six states (Oklahoma, Iowa, Kansas, South Dakota, Missouri, and Mississippi) have dam safety budgets so tight that they translate to between $22 and $93 annually per dam—scarcely enough to reimburse mileage for travel to/from a dam, much less the costs of the inspection itself or any needed maintenance.[32]

Similarly, out of the nation's 395 FTEs responsible for the safety of all state-regulated U.S. dams, nearly half (195) work in the 14 top-funded states. The other half are spread among 35 states (with 0 in Alabama). Nationwide, each dam safety FTE must oversee an average of 205 dams (of all classes)—indeed, more than 1,000 dams in Iowa, Oklahoma, and South Dakota. The result, predictably enough, is that some states are chronically behind in dam safety inspections—meaning that even high hazard dams can go longer than five years between inspections.[9]

The federal situation is only marginally better. Repeatedly throughout federal agency reports in FEMA's most recent (fiscal years 2014–15) biennial report to Congress on the National Dam Safety Program (NDSP), the theme was lack of resources. Despite the fact that since 2008 the National Dam Safety Review Board passed a requirement for all federal agencies and participating states to establish an emergency action plan (EAP) for every high hazard potential dam (inundation maps, warning systems, evacuation plans, community emergency shelters, etc.), by 2015 not even high hazard dams under federal regulation had achieved 100% compliance.[16]

Secrecy vs. safety and liability

FEMA's 32-page booklet *Living With Dams: Know Your Risks* states that anyone near a manmade lake "requires an understanding of what that proximity entails." Even if property lies above any potential inundation zone, "in many cases the dam is owned by a neighborhood association of lakeside property owners who are responsible for the dam's maintenance and are liable for any risk posed by the dam." The booklet recommends asking state officials about the dam's hazard potential classification, when it was last inspected, what is its condition, whether the owner is financially capable of properly maintaining the dam, and whether there is an emergency action plan (EAP) in place in the event of a dam failure.[15]

Although such information was long a matter of public record in the NID, after the terrorist attacks of September 11, 2001, the USACE redacted downstream hazard potential and condition assessment from the publicly accessible version of the NID because of national security concerns.[12] To be sure, only one incident near a U.S. dam seems a possible candidate for a terrorist attack: two Molotov cocktails were detonated on an access road to the embankment Black Rock Dam in Thomaston, CT, on July 4, 2010; neither the dam itself nor any people were harmed.[31] However, in 2002 some laptop computers confiscated from Al-Qaeda in Afghanistan indicated plans for launching cyber-attacks on control systems for U.S. dams. And in 2013, a USACE database containing the hazard and condition information redacted from the NID was hacked.[8]

Similarly, some states no longer disclose basic safety data about hundreds of small to intermediate individual dams—even though such literally life-or-death information is crucial for both informed public policy and nearby residents. For example, North Carolina restricted access to EAPs and inundation maps for coal ash dams [see sidebar *Five Times Bigger Than Deepwater Horizon Spill!*] to the general public and even to first responders.[11] Other states have no requirements for acquiring such data. Texas has 7,395 dams (of all classes), the most of any state; but in 2013, state legislators exempted nearly 3,000 dams (close to 40%) from inspections—216 of them of significant hazard potential and impounding up to 500 acre-feet when full—and freed the owners from meeting safety requirements of the Texas Commission on Environmental Quality.[7] And Alabama collects no dam safety data so has no data to share.

The inaccessibility of data about the hazard potential and condition of thousands of U.S. dams concerns some citizens and groups more than national security. "Far more worrisome, factual, common, and fatal have been actual dam-failure disasters caused by poor engineering, shoddy construction, poor geological information, human error, neglected maintenance, cost-cutting, lack of inspection, political pressures, government corruption, captive regulators, ice floes, bad weather, mud slides, and flooding," noted the Society of Environmental Journalists (SEJ) in 2013. "And today, earthquakes are increasingly a concern."[24]

The specific concern is earthquakes induced by the high-pressure injection of hydraulic fracturing wastewater into disposal wells. A study of induced seismicity in central Oklahoma and Kansas found that induced earthquakes can occur up to 21 miles away from a wastewater injection site, potentially damaging the structural integrity of dams.[33]

Upshot: in the absence of information, any location below the elevation of a nearby dam should be assumed to be at some physical risk.

Moreover, upstream property owners may unknowingly be at legal risk for downstream damages. "Today, virtually all states impose some form of strict liability on owners of water control structures that cause harm to others even if the owner utilized utmost care," concluded an Association of State Floodplain Managers (ASFPM) white paper.[26] In some states (e.g., Montana), liability extends to owners of land on which the dam sits or to a homeowners association of residents around a reservoir, even if they do not own the actual dam.[17]

What will it take?

Four years ago, the estimated tab for rehabilitating the nation's dams was of the order of $54 billion.[5] That's a good 1,000 times more than the nation's collective state and federal annual budgets for dam safety. But as every longtime homeowner knows, ignored deterioration doesn't go away: it inexorably grows more extensive and expensive.

The most recent NDSP report was blunt: "FEMA… strongly believes…that many Americans are living below structurally deficient high hazard dams; Americans are unaware of the risk; there is no plan in place to evacuate them to safety in the event of a failure; or there is a plan in place but they are not aware of it."[16] As daunting as the magnitude of investment to rehabilitate U.S. dams may be, CAP warned: "…the costs of inaction are exponentially higher and will likely not be measured only in dollars spent but, more importantly, in lives lost."[9]

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Postscript: This article was completed before the February evacuation of nearly 200,000 people below Oroville Dam in California after record rainfall damaged both the regular and emergency spillways. The fact that concerns raised in 2005 official documents about needed safety measures (e.g., armoring the emergency spillway with concrete) were not pursued is yet another clarion warning for all high hazard dams nationwide.

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