

## **The Limits of Professional Autonomy: William Mulholland and the St. Francis Dam**

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### **Introduction**

Shortly before midnight on March 12, 1928, the St. Francis Dam, located in the Santa Clarita Valley north of Los Angeles, burst, cascading through the narrow San Francisquito Canyon at a rate of 70 miles per hour. In a 54-mile dash to the sea, the floodwaters carried with them farm buildings, equipment, cattle, and hundreds of people. The earth, once farmland, was scoured clean. William Mulholland, the dam's chief architect, was devastated; the incident marked the end of a distinguished career. How could such a catastrophe occur under the purview of Los Angeles' chief engineer, who had been hailed as the "founder of the modern city" (p. 278)?<sup>1</sup>

This paper explores this historical disaster through an ethics lens, first by providing a brief background and then by examining dam construction and collapse, the aftermath and outcomes, and ethical issues associated with autonomy.

Understanding the past can shed light on the present, and using historical cases in engineering and technology classes can help students comprehend why mistakes happen. And while this understanding does not necessarily guarantee a brighter present or future, students can see why mistakes occurred and how engineers, in this case, William Mulholland, could have circumvented them.

From a pragmatic point of view, using a case study approach can assist instructors in addressing ABET-ETAC criterion 3Bi, which involves an understanding of "professional and ethical responsibilities."<sup>2</sup> Was Mulholland acting within professional and ethical boundaries when he accepted sole authority for a project that could affect hundreds of thousands of people?

### **Background**

At the turn of the 20th century, Los Angeles was poised on the brink of explosive population growth: the coming of the railroads, the discovery of oil, and the flutters of the fledgling film industry all contributed to make Southern California a desirable place to live. Between 1900 and 1910, the population had spiraled by 196%, to nearly 334,000.<sup>3</sup> However, since Southern California has an arid, desert-like climate, with an average annual rainfall of a mere 15 inches, future expansion of the city depended on finding a more reliable and plentiful source of fresh water than the Los Angeles River, which was inadequate to support continued growth. And, notes *Smithsonian* writer Mark Wheeler, "as the population rose, the water table began to drop."<sup>4</sup>

Enter Frederick Eaton, William Mulholland, and what has been dubbed the "California Water Wars."<sup>5</sup> Scion of a pioneer family,<sup>6</sup> Eaton had a distinguished career in public service, as

superintendent of the Los Angeles Water Company, at that time a privately owned venture, and later as the mayor of the city from 1898-1900. After completing his public service tenure, he focused his energies on locating a new source of water for the burgeoning city, eventually settling on the Owens Valley, some 225 miles north of LA, on the eastern slopes of the Sierras.<sup>7</sup> He and city engineer William Mulholland joined forces to conceive and construct the controversial Los Angeles Aqueduct.

In contrast to college-educated Eaton, Mulholland was a purely self-educated man, an Irish immigrant who began his water works career as a *zanjero*, an irrigation ditch cleaner.<sup>8</sup> His dogged work ethic and his self-education in geology and hydrology<sup>4</sup> led to promotions, and, when the city incorporated the private water companies in 1902 as the Los Angeles Bureau of Water and Power, Mulholland was appointed “Chief Engineer and General Manager” (p. 20),<sup>9</sup> a position he retained for decades, and was affectionately nicknamed “the Chief” by his colleagues.

Eaton and Mulholland shared a common vision for the development of the Los Angeles area, one that depended on water. Eaton began buying up riparian rights and land in the Owens Valley, apparently by posing as a representative of the U.S. Reclamation Service.<sup>10</sup> Bonds approved by the residents of Los Angeles financed aqueduct-related purchases.<sup>11</sup>

After six years of construction, often through rugged terrain, the aqueduct officially opened on November 5, 1913, with Mulholland’s terse invitation: “There it is. Take it.”<sup>12</sup> The Chief received numerous accolades for accomplishing one of the greatest engineering feats to date. The desert bloomed, and Los Angeles resumed its meteoric growth. Initially, daily life in the Owens Valley changed little; however, when a drought in the 1920s forced the pumping of water from the underground aquifer to feed the aqueduct, Owens Valley farmers and ranchers saw their irrigation waters reduced to virtually nothing and resorted to active sabotage in 1924, seizing the headgates and dynamiting sections of the aqueduct in retaliation.

The “California Water Wars” came to end in 1927, but Owens Lake, which once occupied 108 acres with depths of 50 feet, was completely drained. Ironically, the water war has re-emerged, as the 4 million tons of toxic dust—including fine particulates of cadmium, arsenic, iron, sulfur, and other elements not amenable to human breathing<sup>11</sup>—that blow annually from the arid lakebed pose a significant pollution threat to valley residents; just this year, the State of California has fined Los Angeles more than \$1.5 billion for dust control, and the city, in return, is suing several state agencies.<sup>13</sup>

The aqueduct project resulted in a career quantum leap for Mulholland, who was lauded not only for his civic consciousness but for his engineering acumen and his visionary foresight. While the aqueduct, which received national attention, resolved LA’s immediate water problem, a long-term strategy was necessary as the city continued to grow. Mulholland then set his sights on developing a series of dams, “a 5-year plan to increase municipal storage by 67,000 ac-ft” (p. 14).<sup>14</sup>

Mulholland was a natural choice to lead the effort, as he was held in high esteem by his colleagues; W. W. Hurlbut aptly encapsulates the perspective of Mulholland’s colleagues: “In

the profession of water works engineering there is an outstanding figure, a leader who . . . has proved to be a builder of an empire—an empire of unsurpassed progress in municipal development—William Mulholland” (p. 17).<sup>15</sup>

## Dam Construction

While Mulholland had a wealth of practical experience in water conveyance systems, he had little in dam design and virtually none in engineering geology, although he proclaimed that geology was a hobby.<sup>9</sup> His prior dam design experience consisted of several small earthworks dams, much less complex structures than the St. Francis.<sup>16</sup>

Due to the stunning success of the aqueduct project, however, LA city officials willingly gave Mulholland *carte blanche* for the St. Francis Dam. While in our time giving one individual sole authority over a major project would be unthinkable, it stands as testimony to the faith bestowed on Mulholland by colleagues and city administrators alike. That faith was reinforced by a 1917 state law that “exempted municipalities from supervision by the State Engineer when building dams” (p. 15).<sup>15</sup> In other words, Mulholland could follow his own vision for the dam, unfettered by outside review. The result was a series of poor engineering and ethical decisions that would culminate in the dam’s collapse.

### *Errors in Engineering Judgment: The Site*

While a dam near the terminus of the aqueduct was ideal, the San Francisquito Canyon was actually chosen because the land value of Mulholland’s original choice dramatically increased; it simply became too expensive.<sup>16</sup> Nevertheless, the canyon, located on federal land, offered some attractive features: it was deep and narrow, with an existing, albeit primitive, road, and power plants were already on site. The area was capable of storing a year’s supply of water for the Los Angeles area, should the aqueduct fail.

What Mulholland more or less ignored was the geology of the site, a critical mistake, since the dam, an arch-gravity design, would anchor into the canyon walls. At that time, however, geological opinion was not required for dam sites. Had it been mandatory, the dam would never have been built on what was clearly unstable land. In at least one case, though, an informal opinion was sought: Charles Heath, area superintendent of transmission for the Edison Company, purportedly visited the dam on March 12, 1928, with a geologist, who then proclaimed that the dam would fail within four days.<sup>9</sup>

The canyon’s east side consisted of layers of mica schist and was “exceedingly rough,” (p. 14),<sup>15</sup> larded with layers of talc.<sup>17</sup> The west side was characterized by a highly unstable red Sepse conglomerate,<sup>18</sup> which had a tendency to disintegrate in water. After the collapse, Cal Tech geologist F. L. Ransome would confirm this feature by taking a 2-inch piece and putting it in a beaker of water; within 15 minutes, it was reduced to a gritty sediment at the bottom of the container. Ransome concluded that “the particles of the conglomerate are held together merely by films of clay and when the mass is wet practically all cohesion is lost” (p. 557).<sup>19</sup>

Interspersed throughout the conglomerate were veins of gypsum, which also tend to soften and eventually dissolve in water.<sup>16</sup> Apparently, Mulholland conducted his own testing on the conglomerate material before dam construction and pronounced it sufficient, although this decision was opposite of his observation during aqueduct construction that the canyon walls displayed “dangerous conditions which would make side hill excavation difficult.”<sup>17</sup> But Mulholland was no geologist, and, as Yale University geologist Chester Longwell noted in July 1928, “The geologic conditions in the valley . . . were well known to geologists before the dam was built. No competent geologist would have approved the dam site without serious reservation, and probably very few would have consented to the construction of the dam in that place under any consideration” (p. 36).<sup>20</sup>

Further investigations after the disaster revealed that the area was the site of numerous paleomegalandslides, specifically, more than two dozen landslide areas that have existed for 500,000 years.<sup>21, 22</sup> In addition, the area also showed clear evidence of an earthquake fault.<sup>9</sup> While the San Francisquito fault was inactive at the time of dam construction, previous slippage had filled it with “gouge,” a fine powder that can help to lubricate and thus weaken the fault.<sup>23</sup> When wet, it turns into a slippery “ooze.”<sup>24</sup>

In short, Mulholland’s lack of formal engineering/geological training and schooling affected his judgment regarding the geology of area appropriate for the dam, and his prior successes perhaps blinded him to the possibility of failure.

#### *Errors in Engineering Judgment: Design Issues & Modifications*

The St. Francis was designed as an arch-gravity dam, with a stepped downstream face, and combined features of two distinct styles. Gravity dams are “solid concrete structures that maintain their stability against design loads from the geometric shape and the mass and strength of the concrete” (p. 2-2),<sup>25</sup> while an arch dam “obtains its stability by both the self weight and, to a great extent, by transmitting the imposed loads by arch action into the valley walls” (p. 2-1).<sup>26</sup> Although these are definitions from contemporary engineering manuals, the same concepts were accepted in the 1920s.

Who actually designed the St. Francis is unclear. According to testimony at the post-collapse coroner’s inquest by William Hurlburt, an office engineer, the dam was “designed under [Mulholland’s] instructions”; and “they got out the computations and studies on the Hollywood Dam, and the matter was gone into with Mr. Mulholland and others at that time” (p. 20).<sup>15</sup> Whether Mulholland had a hand in the “revamped” design or relegated it to others is unclear, but, as presiding engineer, Mulholland was ultimately responsible for the design plans.

According to the original design, the dam would rise 175 feet above the stream bed—185 feet above the foundation— and stretch nearly 700 feet between the canyon walls, large enough to provide 30,000 acre-feet of water storage. The foundation was poured on a hot day in August 1924 with virtually no publicity, since by then the tensions with Owens Valley residents were readily apparent; Mulholland wished to keep a low profile with the dam to avoid similar rancor with Santa Clarita Valley residents.<sup>9</sup>

Shortly after construction began, however, it was obvious that the population of Los Angeles was growing at such a rapid rate that the reservoir would be inadequate before construction was completed. To increase storage capacity, Mulholland raised the height by 10 feet without increasing the base width. In 1925, he added yet another 10 feet to the height, also without widening the base, for a total of 38,000 acre-feet of storage, a 25% increase over the original design.<sup>16</sup> But since the strength of gravity dams depend on a height/width ratio, increasing the height without also increasing the base width created a “dangerous situation” (p. 16).<sup>14</sup> The extra height also necessitated the addition of a wing to the west abutment.<sup>27</sup>

In addition, the 130,000 cubic yards of concrete in the dam contained no reinforcing steel, and there were no contraction joints. The latter is particularly important to allow for controlled cracking; without them, cracking is haphazard. Other design oversights included no drainage galleries for inspection purposes, and no cut-off walls or grout curtain to control seepage under the dam and help to prevent uplift. The result is a “less than conservative” design.<sup>16</sup> In addition, there were few drainage wells built into the dam, just 10 in a 120-foot center section, which, significantly, was the only section left standing after the disaster. Near the canyon walls, there were none. These omissions were probably the result of Mulholland’s desire to finish projects on or under budget; he was extremely thrifty, at the expense of public safety.<sup>15</sup>

More recent research has revealed that the situation with the base was much worse than a lack of additional width: “The truth of the matter was that the dam had been born with a stubbed toe” (p. 230);<sup>9</sup> the base was some 20 feet thinner than the dimension indicated in official drawings, which “reduced the dam’s stability and made it more vulnerable to the effects of uplift” (p. 23).<sup>15</sup>

Despite the many design modifications and shortcomings, construction proceeded on schedule and filling of the reservoir began in March 1926, about two months before completion. Cracks soon appeared in the concrete; workmen were ordered to pack them with hemp and oakum,<sup>28</sup> the latter being a substance used to caulk joints on ships. But a dam is not a ship, and the oakum proved inadequate, especially for a rather significant leak in the wing addition, which eventually required the installation of a drainage pipe.<sup>9</sup>

By 1927, the water was within 10 feet of the spillway, and Mulholland was delighted with his creation, stating, “Of all the dams I have built and of all the dams I have ever seen, it was the driest dam of its size that I ever saw” (p. 46).<sup>9</sup> All of that would change dramatically within a year, when the reservoir was filled to capacity.

## **The Collapse**

The St. Francis Dam disaster is considered to be California’s second worst disaster, after the 1906 earthquake and subsequent firestorm in San Francisco.<sup>29</sup> But unlike an earthquake, the dam break was predictable, had Mulholland possessed the engineering expertise and the objectivity to recognize warning signs.

Hints of trouble began in the morning of March 12; damkeeper Tony Harnischfeger was worried about leaks. While the dam had developed numerous leaks, his concern was piqued by the muddy character of the most current one, which could indicate seepage under the foundation.

Alarmed, he called Mulholland, who then examined the area with assistant Harvey Van Norman and pronounced it safe; the muddy water that had so concerned the damkeeper was clear at its source.<sup>9</sup> Mulholland also ignored a five-foot sag in the roadway along the east abutment.<sup>30</sup>

At three minutes before midnight on March 12, just 12 hours after Mulholland's expert inspection, the St. Francis Dam catastrophically failed, unleashing 12.5 billion gallons of water on thousands of sleeping residents in the valleys below. Since the first structures to be destroyed were the two powerhouses, the terrifying flood occurred in total darkness.

As the 180-foot tidal wave raced down the narrow canyon at a speed of 70 mph, it collected debris: trees, mega-ton sections of the dam itself, cattle, buildings, barbed wire fences—and people, lots of people. The first deaths, after damkeeper Tony and his family, occurred at Powerhouse No. 2, where 64 of 67 workers lost their lives. Following the Santa Clara riverbed, the flood then swept through the SoCal Edison camp, collecting 84 more casualties, more than 50% of the workers stationed there.<sup>31</sup> The force of the water was so strong that it tore the clothes off of victims and survivors, surprising rescuers who arrived later to pull people out of trees and off of floating debris.<sup>9</sup>

Upon reaching flatter terrain, the floodwaters slowed to about 30-40 mph and spread out to a depth of 30-45 feet.<sup>32</sup> Table 1, adapted from various sources, shows a brief timeline of the event.

Table 1. Flood timeline<sup>32, 33, 34</sup>

<i>Time (a.m.)</i>	<i>Location</i>	<i>Time (a.m.)</i>	<i>Location</i>
12:02	Powerhouse No. 2	3:05	Santa Paula
12:40	Saugus substation	4:05	Saticoy Bridge
1:18	Ventura County Line/ Edison camp	5:25	Pacific Ocean
2:25	Fillmore Bridge		

While the electrical lines had been destroyed, phone lines were still functional, and the Ventura County Sheriff's Office called to warn towns downstream of the impending flood.<sup>9</sup> Among those honored as heroes that night were the "Hello Girls," Santa Paula telephone operators headed by Louise Gipe who stayed at their posts and called as many people as possible in the surrounding communities.<sup>33</sup> And in another heroic effort, motorcycle policemen Thornton Edwards and Stanley Baker, dubbed the "Paul Reveres of Santa Paula," rode fast and furiously, at first knocking on doors to arouse sleeping occupants in Santa Paula and then simply riding up and down residential areas, making as much noise as possible to awaken people.<sup>36</sup> By the time the flood reached Santa Paula, the largest town in the affected area, it had slowed considerably and spread out; the tidal wave had been reduced to 20 feet.<sup>30</sup> However, the accumulation of debris destroyed the Santa Paula Bridge,<sup>9</sup> thus isolating the community.

As the floodwaters raced to the Pacific Ocean, they left behind at least 450 dead, including "half the student body of Saugus School"<sup>37</sup> and numerous ranchers, farmers, transients, and Mexican migrant workers. In fact, the exact number of dead is not known, and recent estimates raise the count to about 1,000,<sup>38</sup> although the number of migrant workers and transients in the area

remains unknown. A number of bodies were washed out to sea and drifted as far south as Mexico, to re-emerge in the 1950s;<sup>28</sup> in addition, bodies and flood artifacts are still being recovered: in the 1970s, a 1920s-style car, with occupants inside, was found buried in a riverbed, and in 1992, a body was discovered in Newhall, California.<sup>39</sup> In 1997, historian Frank Rock, searching for the remains of damkeeper Tony Harnischfeger and his son, discovered a 1916 touring car buried in the mud; four years later, he found its steering wheel.<sup>40</sup> The damage caused by the floodwaters' 5½ hour march to the sea was almost unbelievable, totaling about \$20 million<sup>41</sup> (\$252.2 million in 2010 dollars): in addition to the human cost, 909 structures were destroyed and 331 damaged;<sup>42</sup> thousands of acres of farmland, orchards, and cattle ranches were scoured clean; and those living in the towns of Castaic Junction, Piru, Fillmore, Santa Paula, and Saticoy were traumatized, many for the rest of their lives.

At daybreak on March 13, residents emerged from their hiding places to survey the wreckage. Even 80 years later, survivors' memories of the event are vivid: Don Grainger, 5 years old at the time, recalls escaping with his family to higher ground, only to be confronted the next day by the sight of "bodies laid side by side that they had dug out of the mud and were hosing off",<sup>29</sup> Lucille (Moore) Sparkman, then 9, recalls the harrowing experience of her brother's landlord: "Her little house washed away, and she rode the rooftop clear over to Saticoy," about five miles away.<sup>33</sup> Mary Caldwell was 8 the night the dam broke and is still haunted: "The noise was the first thing I'll never forget. You couldn't tell what was going on. It was just horrible."<sup>43</sup> Clemore Topping, also an 8-year-old in 1928, remembers, "It was so scary that night. My sister and I were crying because we didn't understand why we were going out in the middle of the night in our nightgowns. It was very traumatic, and I had nightmares for years after."<sup>44</sup> Perhaps the attitude of surviving residents in 1928 was best summed up by a sign, placed in the front yard of a woman who exhausted herself trying to deal with the ubiquitous, sticky mud that clung to everything: "Kill Mulholland" (p. 167).<sup>9</sup>

### **Aftermath and Causes**

Relief efforts commenced as soon as possible after the flooding subsided. Agencies such as the Red Cross, the American Legion, local organizations, and area physicians immediately sprang into action. A tent city was established for the homeless, and volunteers even served breakfast to 168 families on the morning of March 13. The Public Health Service in Sacramento provided technicians and physicians to assist in four areas: chlorinating the water supply, since sewage treatment facilities at Santa Paula and Saticoy had been compromised; guaranteeing the distribution of pasteurized milk; immunizing more than 3,000 people against typhoid, which results from drinking contaminated water; and general "sanitary inspections," including clean-up of dairy farms and homes spared from destruction, disposal of dead animals, debris removal—all of those actions necessary to safeguard public health. The city of Los Angeles also sent 2-3,000 men to help, "in military fashion," with the clean-up effort.<sup>45</sup>

### *Errors in Engineering Design: Site Geology*

Within a week following the disaster, more than a dozen commissions and panels were busily investigating the causes of the collapse, including a commission appointed by California Governor C. C. Young; a public coroner's inquest; and a committee formed by the Los Angeles

District Attorney's Office. Technical experts also contributed their professional opinions, which were published in full in *Western Construction News* and summarized in *Engineering News-Record*,<sup>15</sup> publications widely read by the engineering community.<sup>16</sup>

The governor's commission, which consisted of four engineers and two geologists, focused on the site. The commission began meeting on March 19, made one site visit, and submitted a final report five days later, apparently wishing to bury this disaster quickly to avoid a detrimental effect on Congressional consideration of the Boulder (Hoover) Dam, also a concrete gravity structure to supply water to the seemingly insatiable Los Angeles area.<sup>46</sup> In its report, the commission found that the failure occurred along the west abutment, at the site of the old fault line, and was attributed to "defective foundations" (pp. 203-4).<sup>9</sup> In addition, the commission recommended that "the police power of the State . . . be extended to cover all structures impounding any considerable quantities of water" (p. 46),<sup>17</sup> reflecting the governor's concern for increased oversight: water was the lifeblood of communities in the semi-arid environment of Southern California, and access had to be protected.

Reports authored by civil engineer C. E. Grunsky, a former president of the ASCE; E. L. Grunsky, a consulting engineer for his father's firm; and Stanford University geology professor Barry Willis found that collapse was due to a combination of four factors: "unsuitability of the foundation, old landslide, uplift, and inadequate design" (p. 27),<sup>15</sup> specifically citing the instability of the east abutment, an opinion that countered the commission's statement that the collapse began on the west side of the dam.

More recent investigations, however, have revealed other possibilities. Outland, for example, identifies the collapse starting at the east abutment. In fact, he notes, that section of the dam "possessed the strength of a deck of cards that is pushed obliquely on the table" (p. 202).<sup>9</sup> Based on post-collapse photographic evidence, Rogers has posited that the pressure of the reservoir water reactivated an old landslide area on the east abutment, involving "1.52 million tons of schist moving against the dam's 271 thousand tons of concrete."<sup>47</sup> He also suggests that the addition of the last 10 feet was the tipping point: "Aside from the geologic shortcomings, all of the structural analyses predicted overstressed conditions when the reservoir pool rose within seven to 10 feet of crest. Had the dam not been heightened that last 10 feet, it might have survived."<sup>48</sup>

### *Errors in Engineering Design: Uplift*

Pressures on the dam as a result of uplift also played an important role in the collapse. Despite popular opinion that engineers of the early 20th century were not knowledgeable about uplift, its effects on gravity dams were well known for at least a dozen years prior to the St. Francis construction and, according to Jackson and Hundley, date back to the 1890s. Within a decade, "serious concern about uplift on the part of American dam engineers was neither obscure nor unusual" (p. 40).<sup>15</sup>

Indeed, several books and articles had been written on the subject, and the 1911 collapse of the concrete gravity Austin Dam in Pennsylvania, which took 70 lives, exacerbated the effort to spread the word and disseminate technical solutions. After visiting the Austin site, noted



engineer John R. Freeman attributed the failure to the effects of uplift: the cause “was the penetration of water-pressure into and underneath the mass of the dam, together with the secondary effect of lessening the stability of the dam against sliding” (pp. 223-4).<sup>46</sup> And Arthur Powell Davis, chief engineer for the US Reclamation Service, offered a similar opinion: “the failure . . . was caused by an upward pressure on the base of the dam, due to the height of water in the reservoir” (p. 224).<sup>46</sup> Davis’ concerns about uplift resulted in redesigns of the Elephant Butte Dam in southern New Mexico (1911) and Idaho’s Arrowrock Dam (1913) to include features that counteract uplift.<sup>46</sup>

That uplift was a major contributing factor in the disaster has been more or less proven by Rogers: some 40 minutes before the collapse, the damkeeper noted a 3.67-inch drop in the reservoir level, corresponding to a forward tilt of about ½ degree, a phenomenon that can only be explained by uplift.<sup>49</sup> “It should be all too clear by now,” note Iglesia, Stiadly, and Shoaf, authors of a 2008 study of the role of uplift in the disaster, “that neglecting to consider the hydraulic uplift pressures in the design of a dam is both a fundamental and potentially fatal mistake—a mistake that should never, ever, be repeated” (p. 25).<sup>50</sup>

#### *Errors in Engineering Design: Faulty Materials*

The recent research of Thomas McMullen, who serves as the director of the College of Computer, Math and Physical Science at the University of Maryland, revealed surprising results about the nature of the dam’s concrete. McMullen conducted his own tests on samples from original pieces of the dam and concluded that the quality of the concrete was suspect, specifically practices that caused deterioration before the reservoir was even filled: voids around the aggregate attributed to use of unwashed mica schist, lack of temperature control during the initial pour, and the presence of ettringite, which can cause expansion and cracking.<sup>17</sup> The St. Francis Dam was literally rotting from the inside out.

Significantly, Mulholland had been accused of using inadequate materials in the aqueduct project 17 years earlier by distinguished engineer and geologist Frederick Finkle,<sup>15</sup> who had served as either chief engineer or consulting engineer on 18 different dam projects.<sup>51</sup> Finkle’s 1915 article in the *Journal of Electricity, Power, and Gas* criticized not only the high cost of cement produced by the on-site plant but declared that “its inferior quality has made the cement work on the aqueduct defective” (p. 27).<sup>52</sup> Finkle was not alone in his criticism; three years later, Michael O’Shaughnessy, San Francisco city engineer, complained about Mulholland’s “sloppy . . . slipshod and crude” construction techniques that had resulted in a partial failure of the earthworks Calaveras Dam (p. 42).<sup>15</sup>

#### *Ethical Errors*

Most of the reports generated by various investigatory commissions and panels focused on the site. The public coroner’s inquest, however, concluded that much of the fault lay with the chief engineer, William Mulholland. Convened on March 21, the inquest interviewed 66 people and issued its judgment on April 12.

Mulholland, now 72 years old, was called to testify several times and was reluctant to admit fault. In fact, some of his testimony was rather puzzling and contradictory: he first proposed that sabotage similar to that inflicted on the aqueduct by angry Owens Valley residents was the main cause, although, as Rogers has noted, that would have required “12,000 lbs of dynamite beneath 30 feet of water on the dam’s upstream side” for the action to succeed, and such a blast would have caused aberrant readings on local seismographs.<sup>49</sup> Even more curious was his suggestion that “hoodoo” was involved, that the area “was haunted by a spirit opposed to human violation” (p. 30).<sup>15</sup> At one point, Mulholland stated that he had, on his own volition, called upon State Engineer Wilbur McClure to examine the dam after its completion but then later noted that “in the last ten or twelve years, I haven’t consulted with anybody, or very few” (p. 31).<sup>15</sup> Harvey Van Norman, Mulholland’s assistant on the project, had no recollection of McClure’s site visit.

Mulholland later poignantly stated, “Don’t blame anyone else, you just fasten it on me. If there was an error in human judgment, I was the human, and I won’t try to fasten it on anyone else. I envy those who were killed.”<sup>29</sup> The “if” is curious, as clearly the inquest’s decision questioned Mulholland’s professional competence. According to the verdict, the dam failed for two reasons: “an error in engineering judgment and an error in fundamental policy regarding public safety” (p. 24).<sup>15</sup> In addition, the inquest questioned the wisdom of granting one individual sole authority on a project that could, “if” errors were made, result in loss of life: LA city officials and state administrators should have in place “proper safeguards . . . making it impossible for excessive responsibility to be delegated to or assumed by one individual in matters involving great menaces to public safety” (pp. 24-25).<sup>15</sup> Had Mulholland requested outside consultation, hundreds of people would have been spared an agonizing death.

## Outcomes

As is true with other tragic events, the St. Francis Dam disaster, considered to be “the greatest American civil engineering failure in the twentieth century,”<sup>53</sup> spawned several outcomes that benefitted both the field of civil engineering and public safety. Four in particular are worth noting: professional registration for engineers, mandatory geology reports on damsites, state (and later federal) review of existing dams, and mandatory soil compaction testing.

### *Professional Registration*

In the year following the dam’s collapse, California joined a growing number states requiring professional registration of engineers.<sup>14</sup> Wyoming legislators led the charge in 1907; by 1947, all states had in place a professional registration process that included experience *and* formal education.<sup>54</sup>

In California, the state legislature passed the Civil Engineering Registration Bill in July 1929, although, notes Rogers, it “was vigorously opposed by a number of professional organizations, such as the American Institute of Mining Engineers and the American Society of Mechanical Engineers.”<sup>55</sup> The act defined civil engineering quite precisely and included a provision that anyone practicing in the field must be registered, including those offering their services as expert witnesses. The application process was rigorous, requiring references by at least four engineers,

an internship period, and passing marks on a written examination. The results were overwhelming: 5,700 applied for registration in the first year.<sup>55</sup>

### *Mandatory Geology Reports*

Geology at the St. Francis site was certainly a major factor contributing to the failure. In fact, had the geologists who commented on the issues associated with the abutments been more vocal *before* construction began, perhaps the outcome would have been different. As a result of this failure and others, however, geologic assessment is now mandatory for any proposed damsite, and engineering geology is a required course in most civil engineering curricula.<sup>14</sup>

### *State Review of Existing Dams*

If one thing was clear after the St. Francis Dam failed, it was the need for more stringent oversight. In April 1929, California passed legislation establishing the Division of Safety of Dams, with a clear mission: “To protect people against loss of life and property from dam failure.”<sup>56</sup> In August, the state embarked on a review of all dams in California. The results were alarming: between 1929 and 1931, 837 dams were inspected, with only a third rated as “adequate,” another third as requiring “further examination,” and the final third “in need of alterations, repairs or changes.”<sup>56</sup> Shortly thereafter, the federal dam oversight commission followed suit, conducting reviews of all dams under federal purview.<sup>57</sup>

Since that time, the California dam division has maintained an impressive safety record, with only one failure since the St. Francis—in 1963, at Baldwin Hills—and it has a reputation of being “one of the most demanding dam safety bureaucracies in the world” (p. 18).<sup>58</sup>

### *Mandatory Proctor Testing*

The field of geotechnical engineering was also affected by the St. Francis collapse, and the Proctor test for soil compaction became standard in California.<sup>46</sup> Ralph Proctor was a field engineer with the Los Angeles Department of Water and Power from 1916 to 1959; for the last 23 years of his career, he was responsible for the “design, construction, and maintenance of all dams in the LADWP system,” including the Bouquet Canyon Dam, which was intended as a replacement for the St. Francis.<sup>59</sup> Proctor’s “standard” test offered key advantages over prior methods, mainly that it could be implemented on site, calculated quickly, and allow “immediate adjustment of the soil water content, which was the *critical variable* the contractor needed to know.”<sup>59</sup> Accurate knowledge of soil conditions allows engineers to compensate for potential foundation seepage.<sup>60</sup>

### **Ethics and Autonomy**

While the St. Francis Dam disaster yields a number of ethical issues for contemplation, perhaps the overriding one is autonomy, which has been the subject of a rather significant body of literature and is generally accepted as a defining characteristic of a professional. Kasher provides a succinct definition of the term: “one has to use reason and be genuinely free in every context

of professional action” (p. 88).<sup>61</sup> Specifically in the context of engineering ethics, autonomy refers to “independence of the individual’s judgment.”<sup>62</sup>

Autonomy in modern engineering, however, differs from that of the classical professions of law and medicine, as most engineers are corporate employees. While the paradigm is professional autonomy, the reality is that many contemporary engineers are subject to corporate forces that curtail, to a certain extent, that freedom.

The contemporary view of autonomy contrasts sharply with Mulholland’s world, where trust was an overriding factor and a man’s experience was a valuable commodity, regardless of educational stature. Of formal training and education, Mulholland had very little: he dropped out of a Dublin high school at age 15<sup>63</sup> and never received his high school diploma. Many have commented on his “native intellectual ability” and his “intensive” self-study in public libraries,<sup>64</sup> which were impressive and allowed him to rise from a lowly *zanjero* to a position of significant responsibility. His zeal for engineering is attributed to a job as a well driller; at a depth of 600 feet, they hit a tree and then fossils. His curiosity piqued, he “got ahold of Joseph LeConte’s book on the geology of this country. Right there I decided to become an engineer” (p. 17).<sup>63</sup> His subsequent success with the aqueduct project even earned him an honorary doctorate from the University of California at Berkeley, ironically inscribed in Latin, a language that Mulholland could not read: “*Percussit saxa et duxit flumina ad terram sitientum*” (He broke the rocks and brought the river to the thirsty land)” (p. 4).<sup>63</sup>

While Mulholland had no formal engineering training, he unquestionably valued knowledge. He read voraciously in his early years but as he aged, “his interest in self-education apparently waned. Or at least his interest in state-of-the-art concrete gravity dam design and construction was limited when he set out to construct the St. Francis Dam” (p. 6).<sup>58</sup> Mulholland’s frame of reference was practical, rather than academic, which probably accounts for his lack of knowledge regarding evolving engineering concepts, such as uplift. A university education would have instilled in Mulholland an appreciation for keeping current with his field, imparted a research methodology that he could have used for the rest of his life, stressed the importance of affiliations with professional organizations, and reinforced an understanding of peer review.

Participation in professional groups such as the ASCE would also have acquainted him with a code of ethics, which the ASCE has had in place since 1914. While early engineering codes tended to focus on the behavior of individual engineers and client relationships, the ASCE 1914 code specifically mentions the importance of honor and “dignified bearing” of its members.<sup>65</sup> Public safety is implied, as designing and building a structure that fails and kills hundreds of people is neither honorable nor dignified and reflects badly on the entire profession.

Perhaps the biggest sticking point in considering Mulholland as an engineer is his apparent inability to seek outside consultation. During his testimony at the coroner’s inquest, he mused, “We overlooked something here” (p. 30).<sup>15</sup> But after Mulholland had achieved national recognition for the aqueduct project, there was no “we”; there was only “I.” He had achieved such stature that, even after the dam collapsed, his contemporaries were reluctant to criticize him directly and certainly not to the press. John Freeman, a close personal friend, is one of the few to do so, but his comments were relayed in letters to colleagues, not for general consumption: “[he]

does not appreciate the benefit of calling in men from outside to get their better prospective [sic] and their independent point of view”; “. . . I can but feel that he trusted too much to his own individual knowledge, for a man who had no scientific education” (pp. 45, 47).<sup>15</sup>

In fact, it was not until Charles Outland’s book, *Man-Made Disaster*, first appeared in 1963 that blame for the dam failure was laid squarely on Mulholland. To Los Angelinos, he was a hero, the man who, by providing water to the desert, gave rise to the modern city. Vestiges of Mulholland still abound in the LA area: besides the famous Mulholland Drive, there is a fountain (dedicated in 1940 in a ceremony attended by more than 3,000<sup>66</sup>), a dam, a highway, schools, a learning center—all named after Mulholland.<sup>67</sup>

While autonomy is an important professional attribute, too much can result in what the ancient Greeks called *hubris*—excessive pride. Hubris has marked the tragic downfall of many a dramatic hero, and, in many ways, Mulholland’s story is similar; a great man, in a position of significant responsibility, is brought down by his own devices: William Mulholland, the self-taught engineer who knew it all and based current decisions on past triumphs.

Except, of course, he didn’t know it all. Failure investigations, both at the time and retrospectively, reveal that Mulholland’s knowledge was antiquated, perhaps the result of a decrease in his ambitious self-education efforts. Frederick Finkle, who had previously criticized the quality of the aqueduct’s concrete, noted that the base of the dam was “insufficient and not in accordance with sound engineering practice” (p. 43).<sup>15</sup> San Francisco engineer Michael O’Shaughnessy wrote to Edwin Hyatt, California’s state engineer, expressing concern that Los Angeles made a grave error in Mulholland granting sole authority for the design of the St. Francis: “There was no justification for entrusting him with the design of a high head masonry dam, hence they are now paying the bill” (p. 42).<sup>15</sup> And the last statement in the coroner’s inquest report reads, “The construction of a municipal dam should never be left to the sole judgment of one man, no matter how eminent.”<sup>17</sup>

Current criticism is less genteel: Donald Jackson, for example, bluntly states that “any engineer with an understanding of gravity dam technology knew that Mulholland’s design fell far short of acceptable practice . . .” (p. 15).<sup>58</sup> J. David Rogers, one of the foremost geological authorities on the St. Francis disaster, primarily blames a huge landslide as the failure catalyst, but he also notes that Mulholland made poor engineering decisions, especially his reluctance to ask for outside opinions, which he calls a “weak link” in the design process, and his decision to increase height but not base width (p. 639).<sup>68</sup> Perhaps the most scathing criticism occurs in Donald Jackson and Norris Hundley, Jr.’s 2004 article, which states that “Mulholland stood apart from his contemporaries on this crucial issue of safety” (p. 42) and ends with the following statement:

Despite equivocations, denial of dangers that he knew—or reasonably should have known—existed, pretense to scientific knowledge regarding gravity-dam technology that he possessed neither through experience nor education, and invocations of “hoodoos,” William Mulholland understood the great privilege that had been afforded him to build the St. Francis Dam where and how he chose. Because of this privilege—and the decisions that he made—William Mulholland bears responsibility for the St. Francis Dam disaster (p. 47).<sup>15</sup>

“Pride goeth before the fall,” an old saying goes. Mulholland, the self-made engineer, is the embodiment of this maxim. But with professional autonomy comes great responsibility, and he failed to protect the life and property of those inhabiting the valleys below the concrete behemoth.

## Conclusion

The name “Mulholland” is still very much alive in Los Angeles and commands great respect: “Without William Mulholland, there would be no modern Los Angeles,” noted a 2011 *Los Angeles Times* editorial,<sup>69</sup> echoing an encomium from 1938: “He had little pity, much strength, great ambition. There is no one else in sight, past or present, whom Los Angeles is more likely to remember” (p. 4-5).<sup>63</sup> History has borne out these words, despite the failure of the St. Francis Dam, which left Mulholland a broken man: he resigned his position at the LADWP in November 1928 and lived in isolation for the rest of his life, dying in 1935 of Parkinson’s disease.<sup>58, 70</sup>

A study of the St. Francis disaster has much to teach us about the necessity of lifelong learning and peer review, about the limits of professional autonomy. Although the area’s geology was the primary reason for the failure, misreading the land can only be attributed to Mulholland’s belief in his own technical knowledge, which was sparse in engineering geology and, by 1928, simply outdated. As a result, he caused the deaths of hundreds of people, destroyed thousands of acres of arable land, and ended his professional career in disgrace. History has smoothed out the edges a bit, but in the final analysis, the disaster was Mulholland’s fault. Henry Petroski sums it up aptly:

No engineer should have such hubris to think that past successes are sufficient to guarantee the success of the next project. Each new project rests on a new foundation, whose hidden faults may or may not be within prior experience. When all dams and the foundations upon which they rest begin to look alike to an engineer like William Mulholland, he himself should question his own expertise.<sup>16</sup>

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