ONE

The Dam Is Not Going to Break

BY 6 JUNE 1983, OPERATORS OF Glen Canyon Dam on the Arizona-Utah border had run out of options. High temperatures had begun to melt the late spring snowfall that blanketed the western slopes of the Rocky Mountains, sending half a million gallons of snowmelt each second rushing down the length of the Colorado River and into Lake Powell. The reservoir's two giant spillways, designed to convey high water around the dam and discharge it harmlessly below, had begun to crumble. Water entering the spillways was clear as glass, but, emerging below the dam, the water had turned red, once again earning the river the name the Spaniards had given it: El Río Colorado. Chunks of concrete, some the size of a Volkswagen, shot out with the red spillway discharge. Evidently, water under high pressure was eroding through the concrete spillway linings and into the rust-colored bedrock below, the same bedrock that held up the massive dam.

The United States Bureau of Reclamation now faced its darkest nightmare. Only a few hundred feet of soft, porous sandstone separate the spillway tunnels from the base and sides of the dam. If the spillways continued to erode, water could exploit even the tiniest opening in the weak rock, like a supersonic water-pick drilling through a loaf of bread. As the opening widened, pressure would force still more water through the opening, enlarging it, until the nine trillion gallons of water in Lake Powell drained, likely undercutting and carrying away the dam as well.

Below Glen Canyon Dam, a 580-foot tidal wave would blast through the Grand Canyon at twenty-five miles per hour, denuding its steep walls and leaving nothing alive. Three hundred miles downstream, a wall of water seventy feet high would surge over the parapet of Hoover Dam, likely causing it to collapse.[1] Each of the smaller dams below Hoover on the Colorado River's stutter-step way to Mexico—Davis, Parker, Headgate Rock, Palo Verde, Imperial, Laguna, and Morelos—would topple in turn. From Glen Canyon to the Gulf of California, the river would have destroyed each obstacle that man had placed in its path, just as it had destroyed many natural obstacles in its multi-million-year history.

Today, reservoirs on the Colorado River supply thirty million people. Glen Canyon and Hoover dams generate part of the electricity that powers a $1 trillion regional economy. Colorado River water and power sustain Las Vegas, Los Angeles, Phoenix, and Tucson, metropolises that needed only water to rise from the dusty soil of the sidewinder and the Gila monster.

When the Bureau of Reclamation completed Hoover Dam in 1935, it was the tallest dam in the world. Glen Canyon Dam, completed some thirty years later, is almost as large. Had both dams collapsed in 1983, replacing them might not have been possible. Not only would the cleanup and reconstruction costs have been enormous, neither dam could pass today's environmental reviews. Without its mega-dams, the Southwest might never have recovered.

Commencement speaker Woody Allen once advised an assembly of college students, "Graduates, as you embark on your life's journey, you will come to a fork in the road. The way to the left leads to inevitable destruction. The one to the right, to despair and misery. Choose wisely." For the managers who had to decide how to handle the high water entering Lake Powell in 1983, using the vulnerable spillways risked the destruction of Glen Canyon Dam and the other dams downstream. Keeping the spillways closed—the other fork in Allen's road—would indeed bring despair and misery, for without its spillways, Glen Canyon dam could release no more than half the water entering that June. But the reservoir was already brimful. Seen from the air, the azure lake sat in the red and buff slickrock of the Colorado Plateau like a full bowl of water teetering on the edge of a high table. If the lake could not contain all the water that entered Lake Powell, a thousand tons each second would have poured over the dam crest and destroyed the $200 million power plant at the downstream toe of the dam, ending power generation at Glen Canyon.

Tom Gamble, power operations manager at the dam, said at the time that despite the problems in the spillways, "There's no fear of jeopardy to the dam." Asked if the undeniable erosion in the spillway tunnels was a danger to the dam, Gamble replied, "We don't think so." The shaking, rumbling, and booming noises that could be heard throughout the dam were "nothing to be concerned about," he said; "The dam is not going to break."[2]

Privately the bureau told a different story: "The concern upon the June 6 report of noises from the left tunnel was for the safety of the dam and its foundation. This concern predominated throughout the spill period," said one report.[3] According to author T. J. Wolf, a bureau official warned that "Any direct connection (of the reservoir through the spillway tunnels to the river downstream) could lead to erosion of the sandstone and the potential for uncontrolled release into Lake Mead."[4] For "uncontrolled release," read catastrophic flood and possible dam collapse.

The public would have been justified in taking Gamble at his word. After all, the Bureau of Reclamation is the premier dam-building agency in the world. Surely its projects provide such a margin of safety that for one to fail is unthinkable. Yet dams do fail. Only seven years before, in 1976, the bureau's Teton Dam in Idaho collapsed with fatal consequences.

No sooner had the reservoir behind the earthen Teton Dam filled than the dam fell to pieces. Eighty billion gallons of water tore downstream. The disaster forced 300,000 people to evacuate, took eleven lives, wiped entire towns from the map, and cost nearly $1 billion in property damage. According to former Bureau of Reclamation and U.S. Geological Survey geologist Luna Leopold, more than one scientist had written the bureau saying, "Look, this is wrong. You're putting that dam in a very unsafe place."[5]

Another example, though not on the bureau's watch, took place in March 1928. Los Angeles water czar William Mulholland had inspected the city's St. Francis Dam and pronounced it sound. A few hours later, the abutment turned to mud and the dam collapsed, sending a seventy-five-foot wall of water downstream. In less than one hour, 1.5 billion gallons drained. The flood killed over six hundred people and destroyed 1,200 homes. To his credit, Mulholland took true responsibility for the disaster. It cost him his career and his health and left him to die a broken man.

In the decades after the building of Hoover Dam, the Bureau of Reclamation provided pork barrel projects to western politicians and water to thirsty irrigators and cities. In the process, "BuRec" achieved God-like infallibility. One photograph from the bureau's early days captures a hard-bitten Dust Bowl couple with Model T Ford, mule team, and in the background, scrub brush as far as the eye can see. Beside them a homemade sign proudly announces: "Desert-Ranch: H. J. Mersdorf–Prop." The second line reads, "Have Faith in God and US Reclamation."[6] The sign reflected not only the couple's confidence that the bureau would take care of them, but also the presumption that the dam-builders had a biblical mandate based on Isaiah 35:1: "The wilderness and the dry land will be glad; and the desert will rejoice and blossom like a rose."

According to then-reclamation commissioner Robert Broadbent, the 1983 crisis *was* an act of God. "Sure, in retrospect we could have been releasing 30,000 to 40,000 cubic feet per second [225,000 to 300,000 gallons per second] a long time ago," Broadbent told the *Los Angeles Times.* "But how could you predict that Salt Lake City was going to have 100-degree temperatures on Memorial Day? It was the late May snowstorm and then the heat wave that caused the problem." The bureau "couldn't really have done anything differently," the commissioner explained, "except maybe save a few days, that's all."[7]

Was he right? Was the crisis unpredictable, or could the bureau have foreseen and better managed the high water? To answer, we first have to understand why the great dams and reservoirs on the Colorado exist in the first place. That knowledge will have the added benefit of helping us to judge proposals for new mega-dams, proposals that the current western water crisis is already spawning.

Before Hoover Dam, the reputation and budget of the Bureau of Reclamation had sunk so low that only a super-dam could restore them. Hoover Dam not only revivified the bureau, it made other large dams inevitable. Hoover was the first dam to rise five stories; today some 45,000 dams are as high or higher. Three decades after Hoover, Congress approved the Colorado River Storage Project (CRSP). It included another high dam at Glen Canyon and several smaller dams and irrigation projects upstream. Curiously, not a drop of water from Glen Canyon Dam runs directly to irrigators or cities. Instead the releases flow down the Grand Canyon and into Lake Mead. What then was the purpose of Glen Canyon Dam and Lake Powell? That question we will explore in depth, but one justification was that as water passed through the dam, it would spin turbines and generate electricity, whose sales would finance the entire CRSP. Glen Canyon would be a "cash-register" dam. The more water a reservoir stores, the greater the hydraulic head and force on the turbines, the faster they spin, the more power they generate, and the more cash that power earns. It was no accident that the spokesman for dam safety during the 1983 crisis was the manager of electrical power operations at Glen Canyon.

Anyone trying to manage the Colorado River first must come to terms with its unpredictable annual flow. In 1932, for example, the river carried 17.2 million acre-feet (MAF) of water. (An acre-foot equals 325,851 gallons and covers an area about the size of a football field to a depth of one foot. The choice of unit reflects the typical use of large volumes of water: to be poured onto fields.) By 1934, the river's flow had dropped by two-thirds. How much water might it carry from one year to the next? No one knew then; the best we can do now is cite the statistical probabilities. Between 1920 and 1922, the river averaged 21 MAF, flows that we now know were well above its long-term average. Unfortunately, the commissioners who met to divide the water of the Colorado River among the seven states of its basin did so in 1922, in the midst of the high flows. Misled by the wet years, they believed that the river carries at least 2 MAF more on average than today we know it does.

Lakes Powell and Mead and the reservoirs above them on the Colorado River can store a total of about 60 MAF. The bureau is supposed to reserve 5.5 MAF of capacity for incoming floodwaters. Given the river's variability, that would seem to be a minimal insurance policy. But more space means less water in the reservoirs, less hydraulic head on the turbines, and less cash generated. Therein lies the dilemma.

The mandate to the dam managers is to generate maximum electrical power while just keeping their reservoirs from overflowing. As one bureau employee acknowledged, "The system's prevailing philosophy is, keep *your* reservoir full."[8] At Lake Powell, in practice this means having the reservoir full by 1 July. The operators of Glen Canyon Dam know that several million acre-feet of snowmelt will arrive each spring and early summer, but not exactly how much or when. To monitor the mountain snowpack and forecast weather and the amount of water in western rivers, the bureau relies on the National Weather Service. But forecasting runoff is even dicier than predicting weather; runoff depends not only on the amount of rain and snow, but also on temperature, plant cover, soil moisture, slope angles, and the like.

In the winter of 1982–83, knowing that runoff predictions are inexact, logic would have dictated that the bureau should draw down Lake Powell enough to make ample room for the unknown volume of incoming water.

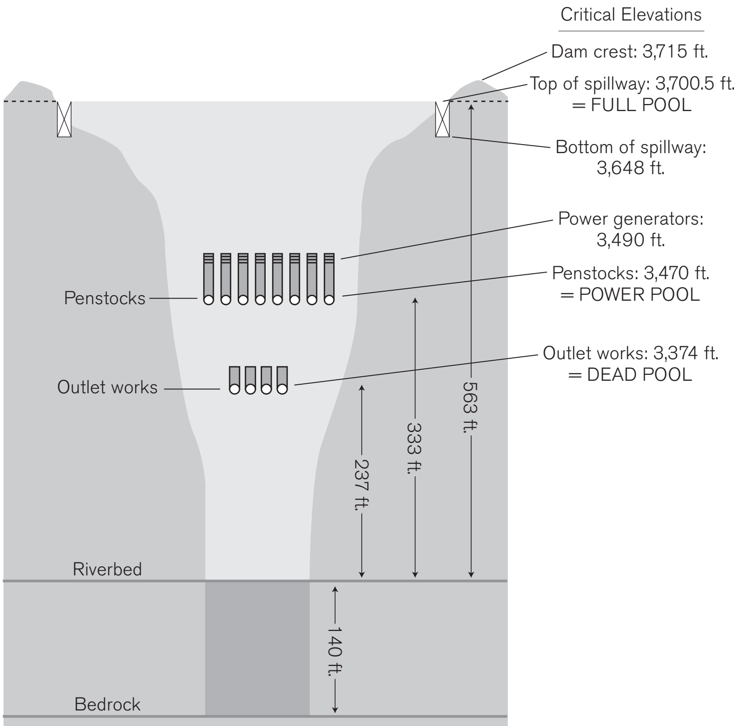

Figure 2. Schematic cross section of Glen Canyon Dam (Adapted from Glen Canyon Institute)

But those in charge of policy—officials of the Western Area Power Administration and the bureau—were judged not on how much room the reservoirs maintain but on how much electrical power the dam generates.

They had little experience with either. Lake Powell had taken from 1963 to 1980 to fill, allowing the bureau only three years of experience in managing the Colorado River system of dams and reservoirs. It was about to have to learn the hard way.

As 1983 began, the elevation of Lake Powell stood at 3,685 feet, fifteen vertical feet below the top of the spillways. The reservoir held 22 MAF and was 90 percent full. The January forecast from the National Weather Service predicted that late spring runoff would be more than 10 percent above average. To lower the risk of flooding, dam managers could have released more water to make room for the above-average snowmelt. The water would have flowed through the turbines, generated electricity, and earned cash. Instead, that January the managers let out only about half the amount they could have. Why, after receiving the forecast of higher runoff, did the bureau hold water- back? What was it waiting for? The answer may have been, peak power rates.[9] Charges for electricity rise with demand. A kilowatt-hour sold in July, when air conditioners from Tucson to Los Angeles are running full blast, sells at a higher rate than one sold in January.

An unusually wet fall in 1982 had filled Utah's lakes and reservoirs. By February of 1983, Terry Holzworth, flood control director of Salt Lake County, began to release water from Utah Lake to make room for the incoming snowmelt. "We prepared all through the winter," said Holzworth. "We also had an extensive program to get the public ready. With the April snow, we realized the magnitude of what we were facing by the first of May—but we were way ahead by then."[10] Salt Lake City is home to one of the five major western offices of the Bureau of Reclamation. Senior officials of the bureau live there, read its newspapers, and cross its bridges. During the crisis, water from flooding City Creek was routed down State Street, the address of the bureau's Salt Lake City office. The Utah capital also hosts the Federal Colorado River Basin Forecast Center.

During February, as Salt Lake City prepared for high water, managers at Glen Canyon again released about half the water they could have. In March, the National Weather Service reduced its runoff forecast slightly. Operators cut Glen Canyon's releases by nearly one-third. April found Salt Lake County in the midst of its tenth week of flooding. The ski resort at Vail closed but reopened after eight feet of new snow fell. Copper Mountain extended its ski season by a week. The National Weather Service raised its runoff forecast to 14 percent above normal. But operators at Glen Canyon released no more water than they had in February. By the end of April, Lake Powell stood almost exactly where it had on New Year's Day.

In mid-May, the National Weather Service increased its runoff forecast to 20 percent above normal. For the month, operators again let out half the water they could have. Water ran in the streets of Salt Lake, the late mountain snowmelt streamed its way toward Lake Powell, every rill and rivulet in the west ran high. In spite of months of warning, the bureau had managed Lake Powell so that by the end of May it was 96 percent full and held more water than it had on New Year's Day.

By 1 June, 90,000 cubic feet—675,000 gallons—entered Lake Powell each second, more than twice the water that could leave through the generators and the lowest exit from the dam, the river outlet works. Now the bureau faced its anathema: "spilling" water by having it exit via some other route than through the cash-producing generators. The time had come to turn to Lake Powell's safety valves—the twin spillways, with gates 40 feet wide and 52.5 feet high, located high on the walls of Glen Canyon.

Engineers had designed and tested the spillways but had never had to use them to expel high water. To gauge the hundred-year flood, especially on the Colorado River, it helps to have at least a hundred years of data. When the bureau planned Glen Canyon Dam, it had only about fifty years of accurately gauged flow. It designed Glen Canyon's spillways, generators, and outlet works together to pass 319,000 cubic feet per second (cfs). Would it be enough? The largest flood since the white man had arrived occurred in 1884, but there were no instruments to record it. Using the high water mark on the walls of the Grand Canyon and the readings on gauges upstream and downstream, hydrologists later estimated that the 1884 flood reached 300,000 cfs.[11] Geologic studies suggest that a flood that occurred sometime between 1,200 and 1,600 years ago approached 500,000 cfs.[12]

In 1941, when Lake Mead's spillways had to be used to shunt high water around the dam, cavitation shattered the spillways' concrete linings. From a few feet away, concrete appears smooth, but up close or under a microscope it reveals an irregular, bumpy surface. Water passing at high speed over these bumps creates a momentary vacuum beneath. The vacuum pockets implode like miniature firecrackers and blast out cavities. The shock wave from one cavity leapfrogs downstream and starts another. The resulting runaway erosion can quickly eat through a spillway lining into the bedrock behind. Cavitation can cause concrete and rock debris to break loose and fall, clogging a spillway tunnel. At worst, an entire spillway could crumble, exposing the bedrock beneath to massive erosion. At Glen Canyon, that could have created the fatal connection between the ocean of water in Lake Powell and the cavernous Grand Canyon downstream.

At the time the bureau built Glen Canyon Dam in the late 1950s, the only way to prevent cavitation was to make the spillway linings as bump-free as possible. But a decade later, bureau engineers had found a better solution. In June and July of 1967, high water required the agency to use the tunnel spillway at Yellowtail Dam on Montana's Big Horn River for twenty days. The resulting cavitation gouged a hole in the lining as large as a tractor-trailer rig. Experiments subsequently showed that introducing air into the water traveling through a spillway reduced turbulence and prevented cavitation. The agency built tubes to inject air into the Yellowtail spillways and could have installed similar aerators at Glen Canyon in the late 1960s or early 1970s. It had the technology and the evidence from Yellowtail that the aerators worked. A retrofit into a dry spillway tunnel would cost far less than repairing one after cavitation had damaged it. But the bureau did not take advantage of the opportunity.

W. L. Rusho served as public affairs officer of the Bureau of Reclamation for many years, including the 1983 crisis. In an honest reprise of his career, Rusho asked and answered the obvious question of why designers specified spillway tunnels at Glen Canyon that were almost certain to suffer cavitation damage when used. His response: "A well-managed reservoir should almost *never* spill, and then only for very short periods, after which the cavitation could be repaired."[13] Thus the bureau intended to manage Lake Powell so well that Glen Canyon's spillways would almost never need to be used. Man would control Nature, not the other way round.

By early June 1983, Nature was rapidly gaining the upper hand. Operators gingerly raised the gate on Glen Canyon's left spillway (facing downstream) to release 10,000 cfs. When all appeared well, they doubled the flow. Soon the dam began to shake and shudder like a race car about to throw a wheel. Hundreds of feet downstream, the jet exiting the spillway turned red and entrained large blocks of concrete and sandstone, sure signs of cavitation. Continuing to use the left spillway was risky—cavitation might dislodge debris that would clog the tunnel completely, or water might burrow through the bedrock and undercut the dam. Both could happen. On the other hand, closing the spillway gates risked overflowing the dam.

Bureau officials decided they had to close the left spillway in order to allow crews to inspect the damage. The lake was rising visibly, so they had no time to lose. To compensate for the loss of the left spillway, operators opened the right spillway gate and for the first time began to use the outlet works. A crew of brave inspectors boarded a cart boldly christened, "I Challenge U2." A winch lowered them into the spillway's cavernous maw. Behind and above the inspectors, the steel spillway gate held back the entire volume of Lake Powell. Have faith in U.S. Reclamation indeed!

The inspectors knew where to look for cavitation damage: at the "elbow." When the bureau built Glen Canyon Dam, it piled up a temporary earthen barrier in the floor of the canyon just upstream from the future location of the dam. This cofferdam diverted the river from its bed

Figure 3. Diversion tunnel at Glen Canyon. Once the diversion tunnels were no longer needed, they became the downstream end of the spillways. (Courtesy of Timothy L. Parks, *Images of America: Glen Canyon Dam* [Arcadia, 2004] and Bureau of Reclamation)

and into two huge tunnels carved near the base of each canyon wall. The diversion tunnels discharged the water hundreds of feet downriver, leaving the dam site dry so that construction could proceed. Once contractors finished the dam, the diversion tunnels were no longer needed. As they had done at Hoover Dam, bureau engineers designed the spillway tunnels at Glen Canyon to plunge from high on the canyon wall above the dam down to intersect the old diversion tunnels, which could then serve as the downstream half of the spillways. To understand the geometry, point your upper arm down steeply and extend your forearm horizontally. In between is your elbow; as athletes know, it is a vulnerable joint.

Because the bureau did not have to bore the lower section of the spillways out of solid rock, re-using the diversion tunnels saved a lot of money. But any engineering design for a large project trades off cost against safety. A design that will contain the two-hundred-year flood costs more than one that will survive the hundred-year flood. The decision to use the diversion tunnels saved money but introduced a vulnerability: the elbow. Engineers could have avoided the old tunnels and designed the spillways to run from intakes far enough upstream to exits far enough downstream so that the spillways sloped at a constant low angle—with no elbow. That would have reduced the speed and the turbulence of water flowing through the spillways. On the other hand, drilling the longer tunnels would have cost more and taken longer. If the bureau would manage the reservoir so that the spillways would almost never be used, why bother? Instead, Glen Canyon's spillways descend at 55 degrees, then make a sharp bend where they meet the nearly horizontal older tunnels. To prevent water from flowing back up the old diversion tunnels, toward the lake, several hundred feet of concrete plug the sections above the elbow.

When the operators opened the left spillway tube in June 1983, a thousand tons of water a second crashed down and struck the elbow section. The design was almost certain to produce cavitation, and as Rusho explained, it did. The inspectors found that the imploding water had peeled away several feet of the concrete lining and penetrated the soft, porous Navajo sandstone below. Continuing to use the spillway was obviously dangerous. But the right tube was potentially more so, for it lies closer to the abutment where the dam wedges against the sandstone on the canyon wall. The engineers realized that if they could increase the height of the spillway gates even a few feet, the lake would have room to rise and they could buy time until the peak snowmelt passed. They hit on the ingenious solution of mounting four-by-eight-foot sheets of plywood, bought at a local supply store, to the tops of the spillway gates. Though it seems curious at first thought, the water lapping at the surface of even a giant reservoir has no more sideways force than the handmade waves sloshing the rubber duckies in our bathtubs.

As workers prepared the wooden flashboards, there was no mistaking the pressure the dam was under. Leaks sprang from joints in the outlet works. High pressure popped up manhole covers all over the dam, as if a master magician had levitated them. Everything leaked that could.

The water rumbling through the spillways and the vibrating dam produced a cacophony of sound. Standing in the access tunnels in the dam abutments was like being inside a factory in a rainstorm, as the enormous pressure forced water through the porous sandstone. Those approaching the dam from downstream could hear the noise from four miles away. At two miles, large waves stirred the surface of the river and a violent rainstorm fell from the mist emitted from the spillways. Springs spurted from the sandstone walls of Glen Canyon. Closer to the dam the jets from the spillways began to eat into the protective apron that led back to the base of the dam where the generator releases emerge.[14] To one making the trip upstream, that the largest dam disaster in human history might be underway did not seem far-fetched.

Once the flashboards were in place, operators could open the gates on both spillways. On 19 June, the jet from the left spillway faltered and then stopped. Operators had no choice but to increase the flow, cavitation be damned, hoping to flush out the unknown obstruction. It worked.

Near the end of June, over 100,000 cfs were entering Lake Powell and even higher flows were on the way. Writer T. J. Wolf interviewed the valiant bureau staff responsible for managing Glen Canyon Dam during the crisis and imagined how they might have felt:

> Put yourself in the control room that June 27 morning, when you feel frantic about the left spillway discharge, and you are under orders to reduce the dam's noise and vibration before the turbines start to wobble on their axes and spin themselves into destruction, just before the spillways also self-destruct. You can't shut down the power system, and you dare not shut down the river outlet works. So you turn the dials regulating the left spillway not down, but up—up from the 25,000 cfs that is already performing a tonsillectomy on the left spillway, up to 32,000 cfs. Your other hand revs the right spillway (the one you are really afraid to use) up, up from 10,000 to 15,000 cfs. Counting everything, your dials

tell you the total discharge is 92,000 cfs. What the discharge really is you have no idea. There are no flow gauges down in the bedrock.[15]

A tsunami-like crest of high water rushed past Lee's Ferry a few miles downstream of the dam and fell onto hikers and rafters in the Grand Canyon. The National Park Service had dropped leaflets warning that higher water was on the way and advising those in the canyon to camp high. But at Crystal Rapid, forty-foot, nearly unflippable rubber rafts capsized. The rafters, supported only by their life vests, took the whitewater ride of a lifetime through the next seven rapids. Helicopters evacuated 150 people; many were hurt and one drowned. The surging waters scoured the canyon walls, removing riverine plants and vital sediment.

Back at the dam, the ominous noises continued. Chunks of concrete and sandstone again appeared in the rusty water exiting the left spillway. Operators lowered its discharge and raised the flow through the more dangerous right spillway. Now the plywood sheets became a concern. If the operators closed the spillway gates completely, water flowing over the tops of the sheets (as opposed to merely lapping against them) might wash the sheets away. To prevent that, they decided to replace the wooden sheets with steel ones four feet higher. But the latest forecast predicted that the lake would rise above them.

On the first of July, 122,700 cubic feet of water, the all-time high since Lake Powell began to fill, entered each second. The next day, inflow dropped slightly and the weary staff took hope. But since several days have to pass for the lake at the dam to adjust to high water entering at the head, 186 miles away, there was no time for complacency. James Watt, President Reagan's secretary of the Interior, arrived just in time to proclaim, "The system is working beautifully. Inflows at Glen Canyon are reducing each day."[16] Meanwhile, inside the gallery passageway nearest the right spillway tunnel, drain holes spewed great gulps of air and water.[17] As author Stephen Hannon reports, "Down in the employee dining room, located at the base of the dam adjacent to the left abutment, a worker later said that it sounded like the artillery barrages he had experienced in Viet Nam."[18]And now there was a new worry: operators feared that the motors used to lift the spillway gates might not be powerful enough to open and close them given the extra weight of the steel flashboards.

By 6 July the steel flashboards were in place, allowing operators again to close the left spillway gate and send in an inspection team. The intrepid investigators found broken concrete, tangles of twisted rebar, a hole the size of a large house, and a truck-sized boulder. The amount of debris clogging the floor convinced the inspectors that the erosion had indeed been working toward the dam. In the right spillway they found another large hole and rebar bent like spaghetti.

By mid-July, the lake level climbed to 3,708.34 feet, only seven feet below the dam crest and, had the steel flashboards not been in place, well above the tops of the spillway gates. On 15 July, the lake level dropped one-half inch. It had fallen by that much a few times before, only to rise again. But this time was different. On 16 July, the level dropped another half inch. And another half-inch the next day and the day after that. At last, the crisis at Lake Powell was over. The hard work of the dam operators, under the greatest stress imaginable, and the do-it-yourself ingenuity of engineers and contractors, had averted a calamity. But there was no time to lose: the spillways were shattered and in only nine months, as the next spring's snowmelt arrived, Lake Powell would again start to rise.

As soon as the lake level fell below the spillway gates in the late summer of 1983, crews entered the spillways and began to fill the holes in the linings, a job that took 2,300 cubic yards of concrete. They cut air slots in the spillway tunnels to prevent cavitation, as they had done at Yellowtail sixteen years before. The next spring, just before the snowmelt began to arrive, operators brought the lake to within nine feet of its April 1983 level. Inflows during the second half of May and early June 1984 topped 100,000 cfs, again requiring use of the spillways, but there was no sign of cavitation.

Afterward, Broadbent and other bureau officials said that nothing could have been done to prevent the crisis and in any case, there had been no serious danger. But other bureau staff disagreed. "How close did we come to losing Glen Canyon in 1983?" asked a future reclamation commissioner. "We came a hell of a lot closer than many people know. I mean, it was digging sandstone when they finally got a handle on it."[19]

The bureau presented its official history of the emergency in a film. According to the narration, the crisis began "in May [when] heavy snowstorms hit the high country. It was cold then, but the heat of summer cut like a hot knife and the heavy snowmelt was on." The subsequent repair of the spillways and the belated cutting of the air slots was a "monumental accomplishment"; more than that, it was a "victory for the human spirit [and] for the leaders who cut through the red tape."[20]

Broadbent blamed "a faulty computer model that needs some revision."[21] As James Udall pointed out, this was the perfect bureaucratic cop-out. It succinctly "supplies the scapegoat (the computer), the cause (its faults) and the cure (its revision)."[22] And no bureau employee, indeed, no human being, could be found at fault.

No geologist is surprised that the Colorado River threatened Glen Canyon Dam—the river has removed every grain of rock that once occupied each of its many canyons, including Glen and Grand. The Grand Canyon is roughly three hundred miles long, fifteen miles wide, and one mile deep. This means that the river and its tributaries have excavated an average of 125 million tons of solid rock from the Grand Canyon—each year for the last five million years or so. Not only that, the Colorado has removed even larger dams than Glen Canyon and Hoover. In the last half a million years, the river has blasted to smithereens a whole series of hard lava dams in the Toroweap section of the Grand Canyon, strewing their remnants downstream for eighty miles.

Held in our hand, water is a puny thing. One could spend a lifetime dribbling it over a block of basalt or concrete with no noticeable effect. Yet give it a slope of several feet per mile, increase its volume to thousands of cubic feet per second, and wait for only an eyeblink of the deep time of geology. Then rock and concrete turn out to be puny.

In 1983, not on a geologic time scale, but on ours, the Colorado came close to removing the latest obstacle in its path. Less than two decades later, as the twenty-first century began, Glen Canyon Dam and Lake Powell face a new threat. Rather than too much water, this time the problem is too little. Unlike earlier floods and droughts, this one gives no signs of ending anytime soon.