

Teton Dam Collapse: Was It a Predictable Disaster?

Theoretically, what happened could not happen. But it did.—GILBERT G. STAMM, commissioner of the Bureau of Reclamation, explaining the failure of the Teton Dam, *New York Times*, 9 June

All this was predictable three years ago . . .—ROBERT R. CURRY, professor of geology, University of Montana, quoted in *Time*, 21 June

The shocking collapse of the Teton Dam in southeastern Idaho on 5 June has spawned a number of inquiries aimed at uncovering the cause of the disaster. But even before the findings are in, charges have been made that the Bureau of Reclamation, the federal agency in charge of building the dam, recklessly ignored warnings that the geology of the area was unsuitable and that the structure would be unsafe.

These allegations have been widely circulated in the press. The *Washington Star* reported that the Bureau was "warned by government geologists more than three years ago that the Teton River Dam in Idaho was dangerous and should not be built. The warnings were ignored and the dam burst Saturday. . . ." Similarly, *Newsweek* asserted that "one of the most tragic elements in the disaster was that it had been warned against in advance."

But such charges seem wide of the mark. The fact is that, while several geologists and environmentalists did indeed raise questions about the dam project, not one of them is known to have challenged the structure's safety under such normal conditions as appear to have prevailed at the time the dam collapsed. At this point it is not clear whether the dam failed through some unforeseen and perhaps unforeseeable fluke of nature, or through malfeasance on the part of contractors and inspectors, or because the Bureau goofed up and built the structure in an unsuitable location. But, if the latter is the case, the real tragedy of the affair may be, not that the Bureau refused to heed prior warnings, but that the Bureau made a mistake in engineering judgment and there was no one around both willing and able to second-guess its decision.

The Bureau, which is a subunit of the Interior Department, is one of the major dam builders in the country. In its 74-year history, it has designed and constructed more than 300 major dams, in-

cluding such well-known giants as Hoover Dam on the Colorado River between Arizona and Nevada and Grand Coulee Dam on the Columbia River in Washington. Some 250 of these dams are of earth-fill construction—as was the Teton Dam. According to the Bureau, "all of those dams, with the single exception of Teton, have performed satisfactorily."

The Teton Dam was intended as a multipurpose facility that would provide irrigation water, flood protection, electrical power, and water-based recreation. It was built across a deep, narrow canyon on the Teton River, in the watershed of the Snake River, about 44 miles north-east of Idaho Falls in southeastern Idaho. The dam rose some 300 feet above the streambed and was about 3200 feet long at its crest: it held a reservoir that extended roughly 17 miles up the canyon.

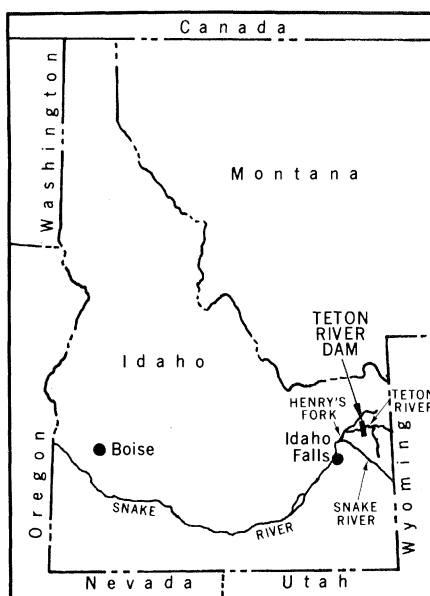
Some 10 million cubic yards of selected earth materials—dug mainly from the bed of the reservoir area—were used to build the multilayered structure. The center of the dam was a mixture of clay, silt, sand, gravel, and cobbles tightly

compacted by tamping rollers to form a core that Bureau engineers consider virtually impervious to water. This was overlain by four additional layers of materials of various kinds. Bureau engineers, on the basis of preliminary investigations, doubt that the dam itself was the cause of the catastrophe.

The most likely explanation, according to the Bureau, is that water got around the dam by traveling through the right wall, or abutment, of the river canyon, whereupon it triggered the washout that led to the dam's collapse. The Bureau had recognized in designing the project that leakage through the highly fractured rock formations might pose serious problems. So it worked out with its key contractors an extensive grouting program aimed at plugging the leaks. A trench was dug into each abutment to remove the upper 70 feet of rock, which was deemed too jointed and fractured to be readily sealed. Then grout—a mixture of cement, sand, water, bentonite, and calcium chloride—was injected under pressure into holes drilled into the rock at the bottom of the trench. The holes were in three parallel lines spaced 10 feet apart. Holes in the two outer lines, or curtains, were separated from each other by 20 feet; those in the center curtain were 5 to 10 feet apart, depending on the spacing needed to achieve "closure," the point at which a hole refuses to accept the grout mixture, indicating that cracks in that area have been completely filled. When grouting was complete, the 70-foot trench was filled with supposedly impervious earth materials.

The Bureau felt confident that it had constructed an essentially watertight barrier. The grout holes reached downward, in some cases, to 300 feet or more. And the three parallel grout curtains extended some 1000 feet into the abutment beyond the edge of the canyon. There was also a single grout curtain across the canyon floor, and grout was injected into other areas where fissures were detected. In theory, there was no way that water could get around or under the grouting without traveling a long and circuitous route through the rocks, presumably returning to the river some distance downstream where it would pose no threat to the dam structure. The Bureau was so proud of its grouting achievement that one of its engineers has actually prepared a paper for publication describing how it was done.

Yet something clearly went wrong. The dam had just been completed and the reservoir was nearly full for the first time when catastrophe struck. As the reservoir rose, some small springs issued



from cracks in the rock well downstream of the dam; these caused no concern because they are often encountered in such situations and they posed no threat to the dam. Then, on 5 June, at 8:30 a.m., water was reported leaking from two points in the right abutment close by the dam. One leak was at the junction of the dam and the right abutment some 130 feet below the crest of the dam; the other was at the downstream toe of the dam near the valley floor. Contractors tried to fill the holes with large rock and to channel the flow of water away from the dam; the structure itself did not appear to be in critical danger because no erosion was taking place. Then suddenly, at about 10 a.m., a large leak developed in the dam itself, on the downstream face, about 15 feet from the right abutment and some 130 feet below the crest, at roughly the same elevation as one of the earlier leaks. The new leak grew rapidly in size and started to wash away material from the downstream slope of the dam, thereby weakening the structure. At 11 a.m. a whirlpool developed on the upstream side of the dam, indicating that water was now pouring directly through the dam in some quantity. Two bulldozers that tried vainly to plug the opening had to be abandoned by their operators and were lost in the rapidly widening hole. At 11:57 a.m. the dam was finally breached and a tremendous wall of water surged through the opening; some 40 percent of the dam was swept away.

What caused the collapse? A preliminary report by H. G. Arthur, the Bureau's director of design and construction, cited the fact that leaks were first observed in the abutment as evidence that water traveled through the abutment and not through the dam itself, although this judgment was "not conclusive." Assuming the water did travel through the abutment, Arthur cited two possible paths. It might have traveled through a defect in the grout curtain, a possibility Arthur found "difficult to accept because of the care with which the grout curtains were constructed and the fact that three curtains were provided where normally only one curtain is constructed." Or it might have traveled some 1000 feet into the abutment, gone around the end of the grout curtain, and then doubled back by some unexpected route to reemerge at the face of the dam instead of downstream, as is usually the case. The preliminary investigation was "unable to pinpoint the cause of the failure," Arthur reported.

In the wake of the catastrophe, some commentators have suggested that the Bureau should never have pushed ahead



Bureau of Reclamation Photo by Glade Walker

Remains of Teton Dam. Downstream side at top of photo.

with the dam because it received ample warnings that the structure would be unsafe. But that interpretation of events requires a rather complete rewriting of history. The fact is that none of those who are supposed to have warned the Bureau ever explicitly raised the possibility of such a dam failure.

One source of such warnings, for example, was supposedly the U.S. Geological Survey, a sister agency of the Bureau of Reclamation within the Interior Department. But the letters and memoranda that have been cited to illustrate the Survey's concern do not even mention the possibility of water leakage causing a dam failure. For the most part, they are concerned with possible earthquake hazards based on the fact that southeastern Idaho is a region of high seismic risk and is crisscrossed by geologically young faults.

The most widely quoted Survey document was an internal memorandum written by geologist David L. Schleicher on 26 December 1972. It asserted that "flooding in response to seismic or other failure of the dam" would make an earlier flood "look like small potatoes." And it concluded: "Since such a flood could be anticipated, we might consider a series of strategically placed motion-picture cameras to document the process of catastrophic flooding." But Schleicher told *Science* that, while he no longer remembers just what he meant by those lines, he is virtually certain he was concerned only about possible seismic hazards. He said he used "melodramatic" language to communicate those concerns to "three of my buddies" within the Survey, but that he certainly wasn't predicting that the dam would fail. "I wish I had predicted the problems," he said. "I'm



Bureau of Reclamation Photo by Glade Walker

View of Teton Dam after collapse of structure.

appalled that we didn't anticipate these other potential hazards. I wonder how they could have passed us by."

Schleicher's memorandum was never forwarded to the Bureau of Reclamation. But a report signed by Schleicher and three other geologists was forwarded to the Bureau in June 1973; it discussed the seismic hazards but left out Schleicher's "melodramatic" paragraph. "At no time did the Geological Survey issue a prediction that the dam would fail," states Vincent E. McKelvey, the Survey's director.

As a result of the Survey's concerns, an array of seismographs was installed in and around the dam to study possible activity along faults in the area. The instruments recorded the seismic noise generated by the dam's failure and the ensuing flood but showed no evidence whatever of any earthquake that might have caused the failure. "We are quite confident it was not caused by an earthquake," McKelvey says.

Another supposed source of prior warning about the dam's safety was a lawsuit filed by several environmental groups in an effort to block the dam because of its adverse environmental impacts. One witness at the trial—a former employee at the dam site—testified that she was on a survey team which found

that several test holes drilled in the reservoir floor soaked up water at a high rate, indicating that there might be serious leakage. But the thrust of her testimony (which was disputed by Bureau of Reclamation experts) was that the leakage might harm water quality downstream or make it impossible to fill the reservoir. The lawyer who prosecuted the case—Anthony Ruckel, of the Sierra Club's Legal Defense Fund—told *Science*: "I did not raise the possibility of leakage causing a dam failure. The safety issue had never occurred to me." He also noted that "environmentalists don't have the experts or the ability to prove a dam is unsafe in advance."

The most vociferous critic of the Bureau's performance has been Robert R. Curry, professor of geology at the University of Montana at Missoula, who first made public Schleicher's memorandum. Curry has been quoted in some press reports as virtually predicting in advance that the failure would happen. But he told *Science* that neither he nor anyone else to his knowledge explicitly warned that the geological conditions in the area would cause the dam to burst. He says such predictions lie outside the expertise of geologists, who can point to hazards in the rock structure but are not qualified to say what effect such hazards

will have on an engineering project such as a dam. Still, Curry believes that the Bureau of Reclamation, which employs both engineers and geologists, "could have predicted" the failure and was "irresponsible to ignore the geological hazards."

In speculating on possible mechanisms for the failure, Curry says that the young volcanic rocks in the area tend to contain lots of voids that are not interconnected, making it difficult to pump in grout and be sure it forms a continuous curtain. He also suggests that the pressure of the water in the reservoir might have compacted the porous rocks, possibly fracturing the grout or otherwise opening a pathway for water.

A quickie investigation into the causes of the catastrophe has been launched by an interagency task force; and a longer-term, independent investigation will be conducted by a blue-ribbon panel of eight outside experts, headed by Wallace L. Chadwick, of Los Angeles, a member of California's Earth Dams Board. Some Bureau of Reclamation engineers believe it will be necessary to dig an exploratory tunnel or tunnels into the abutment before it will be possible to determine just what caused the disaster that theoretically couldn't happen.

—PHILIP M. BOFFEY

Kennedy Hearings: Year-Long Probe of Biomedical Research Begins

Senator Edward M. Kennedy (D-Mass.), as chairman of the Senate health subcommittee, has just begun what he describes as a "year-long process of review and examination of public policy in the areas of biomedical and behavioral research." Out of this may come legislation that substantially reshapes the National Institutes of Health (NIH), by mandating a new emphasis on clinical research and the assessment of new biomedical technology.

"... Our committee does not come to these hearings with any deep distrust or disillusionment with biomedical and behavioral research," Kennedy declared at the outset of the first day's session. But as the morning wore on, it became apparent that though "disillusionment" may

be too strong a term to express his feelings, "dissatisfaction" certainly is not. For more than a year now, Kennedy has been challenging the research community to throw itself into activities that would show it is responsive to its social obligations (*Science*, 20 June 1975) and he leaned on that theme as heavily as ever. His subcommittee colleague Richard S. Schweiker (R-Pa.) was even more persistent, indeed, strident, in asking scientists to tell him why they have not done more for him (the public) lately. It is going to be a rough, and extremely important, year.

By design, legislative authority for several NIH programs expires next year. The cancer and heart programs, training grant authority, and special initiatives in

genetics and diabetes are among programs that will be up for renewal, making 1977 an ideal year during which to wipe the slate clean and begin again, should Congress decide it wants to. The questions foremost in the Senate's mind are whether research is being directed at the problems that most concern the tax-paying public and whether the fruits of research are being rapidly and broadly disseminated. The opening premise seems to be that the answer to each question is "probably not."

Lead-off witnesses on day 1 (16 June) of the hearings were the seven members of the Kennedy-initiated President's Biomedical Research Panel* who have just completed a 15-month study of the nation's research effort as sponsored by NIH and the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA). The panel report, com-

*Franklin D. Murphy, Times Mirror Corporation, Los Angeles; Ewald W. Busse, Duke University Medical Center; Robert H. Ebert, Harvard Medical School; Albert L. Lehninger, The Johns Hopkins University School of Medicine; Paul A. Marks, Columbia University; Benno C. Schmidt, J. H. Whitney and Company, New York; David B. Skinner, University of Chicago Hospitals and Clinics.