STRAIGHT FLUSH

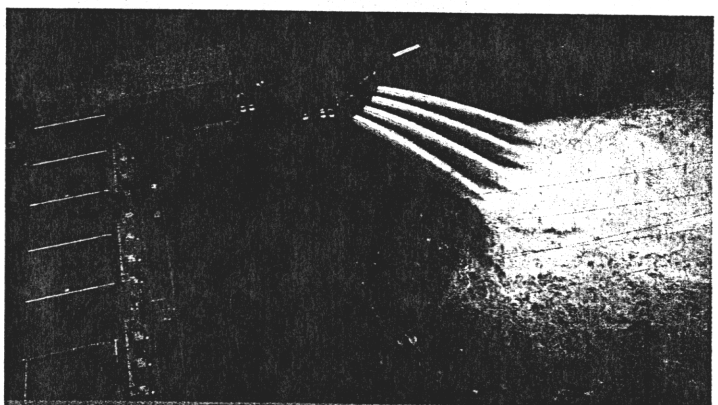
Researchers' latest effort to shape the Grand Canyon

BY SID PERKINS

Last November, the Grand Canyon experienced its largest flood in more than 8 years. For nearly 4 days late that month, flow rates along the Colorado River swelled as much as 20 percent above typical peak flows. The massive inundation, rather than resulting from the series of storms that had soaked the region for months, occurred when engineers at Arizona's Glen Canyon Dam cranked open the floodgates to send extra water downstream.

The planned flood, designed and scheduled by scientists, was intended to rebuild the sandbars and beaches along stretches of the river near the dam. In the 4 decades since the massive dam was built, those river features have been, on average, losing more material than they gain. That's because this now-tamed stretch of river carries much less sandbar-building sediment than it did before the dam was built.

The riverside landforms are important for several reasons. Ecologically, they provide habitat for wildlife and vegetation as well as spawning grounds for fish. The fine-grained features also serve as campsites for the multitude of rafters and hikers passing through the Grand Canyon. Finally, the sediments safeguard hundreds of archaeological sites along the waterway, protecting them from the forces of erosion and the prying eyes of vandals or artifact collectors.



IT'S A WASH — Water surging through Glen Canyon Dam's bypass tubes during last November's artificial flood boosted flow rates downstream to about 1.16 million liters per second for several days.

U.S. GEOLOGICAL SURVEY

November's flood is the second artificial inundation in the last decade designed to shore up the all-too-ephemeral sandbars and beaches. The dozens of scientists who surveyed the canyon as the floodwaters passed through and again afterward were heartened to find that sediments restored the riverbank in some areas. However, only repeated monitoring of the canyon in months to come will reveal whether the renewed waterfront property can stand up to the long-term ravages of a sediment-starved Colorado River.

DAM SHAME Things just haven't been the same in the Grand Canyon since the Glen Canyon Dam began impounding massive volumes of the Colorado River to form Lake Powell.

First, most of the silt and sand carried by the river now drops out of suspension when the current meets the still waters at the head of Lake Powell. Just below the dam, the Colorado typically bears only about 2 percent of the sediment that it did decades ago, says Jack Schmidt of Utah State University in Logan. That lack of fresh material means that, in the long run, the erosion of sandbars and beaches far outpaces their accumulation of sediment.

Second, environmental conditions in the river have been altered significantly since the Glen Canyon Dam became operational. Before the dam moderated the Colorado's flow, water temperatures in the Grand Canyon ranged from 0°C in the winter to 30°C in the summer. Now, because the water spilling through Glen Canyon Dam's turbines is drawn from deep within Lake Powell, river temperatures typically vary only between 7°C and 10°C.

Fish indigenous to the river haven't responded well to the changes, says Rebecca A. Cole of the U.S. Geological Survey's National Wildlife Health Center in Madison, Wis. Of the 10 native species found in the Grand Canyon before 1850, 5 have disappeared there and 2 are so scarce that they're considered endangered.

Finally—and largely as a consequence of how the dam is operated—the size, cycle, and frequency of the canyon's floods have changed. The peak flow rate during November's flood—the largest in the Grand Canyon since a similar headline-grabbing event in the spring of 1996—is almost equal to the rate during the average flood that the canyon experienced in the pre-dam era. In the past decade, the maximum flow through the dam has been about 60 percent of that flood rate.

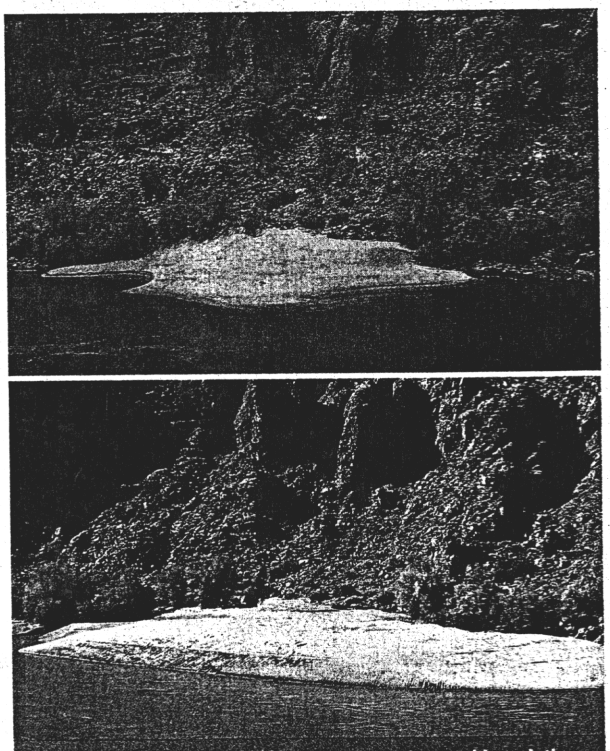
Engineers typically send smaller amounts of water from Lake Powell through the turbines at night, when demand for electric power is lower than during the day. Flow rates and river depths just downstream of the dam therefore fluctuate over each 24-hour period rather than with the seasons, as was the case before the dam existed, says Denny Fenn, director of the USGS Grand Canyon Monitoring and Research Center in Flagstaff, Ariz.

The decrease in the volume and frequency of floods caused by the dam has had an effect on the amount and size of sand and rocks that the river transports downstream. While the Colorado River has been consistently sweeping downstream the few fine-grained sediments that are brought in by its tributaries, researchers have discovered a different trend for large rocks and boulders.

Those hefty stones, which often reach the Colorado's channel via landslides or floods along its tributaries, riddle the Grand Canyon's famed rapids, says Peter G. Griffiths of the USGS in Tucson. In the pre-dam era, many floods were large enough to scour landslide debris from the channel and restore river flow. Boulders can more easily hold their position during today's weaker floods.

Between 1984 and 2003, more than 100 landslides or other debris flows occurred in the Grand Canyon. Massive amounts of material tumbled into the river, and five of the debris flows resulted in major changes to rapids. The recent rate of debris flows in the canyon, about 5.1 per year, is about the same as the long-term frequency of flows that can be estimated from photographs taken between 1890 and 1983, says Griffiths. He and his colleagues describe their findings in the Dec. 28, 2004 *Journal of Geophysical Research (Earth Surface)*.

Because that rocky debris isn't being scoured away as effectively as it was in the pre-dam era, the Grand Canyon is slowly filling up, says Christopher S. Magirl, a hydrologist with the USGS in Tucson. Elevation data collected at 80 sites in the canyon—primarily at pools just upstream of major rapids—suggest that the debris damming those pools is on average 26 centimeters higher now than it was when those same spots were surveyed in 1923. Magirl and his colleagues report their results in an upcoming *Water Resources Research*.



GROW WITH THE FLOW — The experimental inundation added sediment to some riverbanks, at least temporarily. Images taken 50 kilometers downstream of Glen Canyon Dam before (top) and after (bottom) the flood.

M. SCHMEECKLE

TIMING IS EVERYTHING It took just minutes to open the floodgates at Glen Canyon Dam last November, but the inundation was an event 3 years in the making. Scientists designed the experiment in 2002 but couldn't conduct it until nature provided just the right conditions.

Above all, to rebuild its sandbars and beaches, the stretch of Colorado River just below the dam needed a large infusion of sand and silt in a short period of time, says USGS' Fenn. That's why researchers had suggested that the planned flood take place right after a delivery of sediment from the Paria River, which flows into the Colorado about 25 kilometers downstream of Glen Canyon Dam. They decided to wait until the Paria had dumped 800,000 metric tons or more of sediment into the Colorado River's channel within a span of just 2 or 3 months. That condition was met last autumn, when an unusually wet spell brought an end to an extended drought.

For a few days before the inundation, engineers held the flow rate through the dam to a modest 225,000 liters per second. From that baseline, they ramped up the water release over the course of a day to a peak of 1.16 million liters per second—enough to fill about 120 Olympic-size swimming pools per minute. They sustained that flow rate for 60 hours and then gradually scaled it back to the 225,000-liters-per-second baseline flow.

Some teams of scientists assessing the effects of the flood stayed in place at specific river sites, but others followed the flood downstream. Roderic A. Parnell Jr., a geochemist at Northern Arizona University in Flagstaff, was part of a group that made three data-gathering rafting trips down the river—one just before the planned release, one beginning a week after the flow returned to baseline level, and one that shoved off about 5 weeks after the flood.

On each 10-day excursion, the team surveyed dozens of sandbars and beaches between Glen Canyon Dam and the mouth of the Little Colorado River, a tributary that meets the Colorado about 125 km downstream of the dam.

Parnell, Schmidt, and others on the assessment teams are still analyzing their data. However, preliminary results indicate that at many sites—especially those near the dam—the flood apparently scoured sediment from the river channel and redeposited it along the riverbanks, just as scientists had predicted.

Sandbar growth at some sites was "very impressive," says Parnell, both in terms of the volume of accumulated sediment and the new land area that it created. The largest amounts of sediment were deposited on sandbars and beaches in the first 50 km or so below the dam, he notes. Farther down river, below the mouth of the Little Colorado River, results were mixed. Some sandbars there grew and others shrank, says Schmidt.

While full analysis of the hydrologic and topographic data may take months, biologists might need years to understand the ecological effects of November's flood. Riverbank vegetation grows much more slowly than flood-built sandbars do, and fish populations are subtly influenced by myriad factors.

In fact, numbers of juvenile fish trapped by scientists before and after this flood don't match a previously observed trend, says Lew Coggins, a biologist at the USGS' Grand Canyon Monitoring and Research Center.

Seven times a year, Coggins and his colleagues deploy 30 fishnets for 3-day intervals at three sites on the Colorado just downstream of its confluence with the Little Colorado River. In a sampling session just before the planned flood, the researchers nabbed 312 juvenile humpback chub, one of the Grand Canyon's endangered fish. After the flood, nets snared only 114 juveniles of the species. Scientists observed an anomalous decrease in other fish species, Coggins notes.

UNCERTAIN FUTURE Despite the substantial growth of sandbars and beaches along several stretches of the Colorado as a result of the flood, the long-term stability of those features remains unclear.

Over time, the low peak-flow rates associated with power production at Glen Canyon Dam will probably erode the recently deposited material, says Fenn. That's what happened in the wake of the slightly larger planned flood that occurred over a week in the spring of 1996. The sandbars and beaches that were shored up during that inundation gradually lost ground in the next 3 to 4 years.

Because the sandbars and beaches bolstered by the 2004 flood may have more gently sloping surfaces than those reshaped by the 1996 flood, Parnell says that he's hopeful that they'll last somewhat longer.

Schmidt, who plans another field trip on the Colorado this month, is more dubious. He points to an ecology experiment now under way that was also sponsored by the Grand Canyon Monitoring and Research Center. In January, scientists designed a plan to vary the Glen Canyon Dam's flow rates to bolster native fish and hamper fish that aren't indigenous to the Colorado. That regime, however, has the potential to rapidly erode the sandbars that were just built up.

Scientific knowledge about the dam's effect on its surroundings accumulates slowly because large-scale experiments occur infrequently. Having to strike a balance between the effects of floods intended to bolster sandbars and floods meant to benefit native fish doesn't make the job any easier.

One thing remains sure, says Schmidt: "The canyon's not even remotely close to how it used to be." ■