The Gigantic Yangtze Three Gorges Dam Must Never Be Built

A reasonable and accurate means of estimating the effect of the dam on upstream sedimentation is key to determining the viability of this immense project.

WILLIAM WANLI HUANG

The river bed of the Yangtze and its tributaries in the 1 million square kilometer drainage basin upstream of the intended Three Gorges dam is lined with cobble and gravel that are mobilized (scoured) by high flows and transported downstream as bed-load. The project designers have overlooked the vital importance of this coarse bed-load — estimated to average 100 million tons/year — that will quickly settle out in the relatively still reservoir. Yangtze River bed-load consists of boulders, cobble, gravel and coarse sand (> 1 millimeter). The major part of this bed-load is cobble.

The Three Gorges Project

The proposed dam is 1.9 kilometers long and has a maximum height of 175 meters above bedrock, creating a reservoir about 600 kilometers long, with an area of 1,084 square kilometers and storage capacity of 40 billion cubic meters at the normal operating water storage level of 175 meters above sea level. At this level, the reservoir will submerge 632 square kilometers of land, including 23,800 hectares of farmland and 5,000 hectares of orange orchard. Public information released in 1988 includes an estimate of 1.13 million local inhabitants who will have to be resettled by the year 2008. (Restricted information obtained from a State Council Resettlement Meeting in 1992 places this number at 1.98 million.) In a project report circulated at the 1992 National People's Congress, the total project is estimated to cost 57 billion yuan in 1990 prices, but this figure does not include interest charges during construction. (Unofficially, allowing for interest and inflation during construction, a total cost of 600 billion yuan is now being mentioned.) The present construction plan calls for the project to be in full operation at the normal pool level of 175 meters in 2013. The Chinese Government's feasibility report made in 1986-1988 supports the project. Construction began in 1994.

Hydrogeomorphological Impact

The project designers have recognized the suspended sediment (silt and sand [< 1 millime-

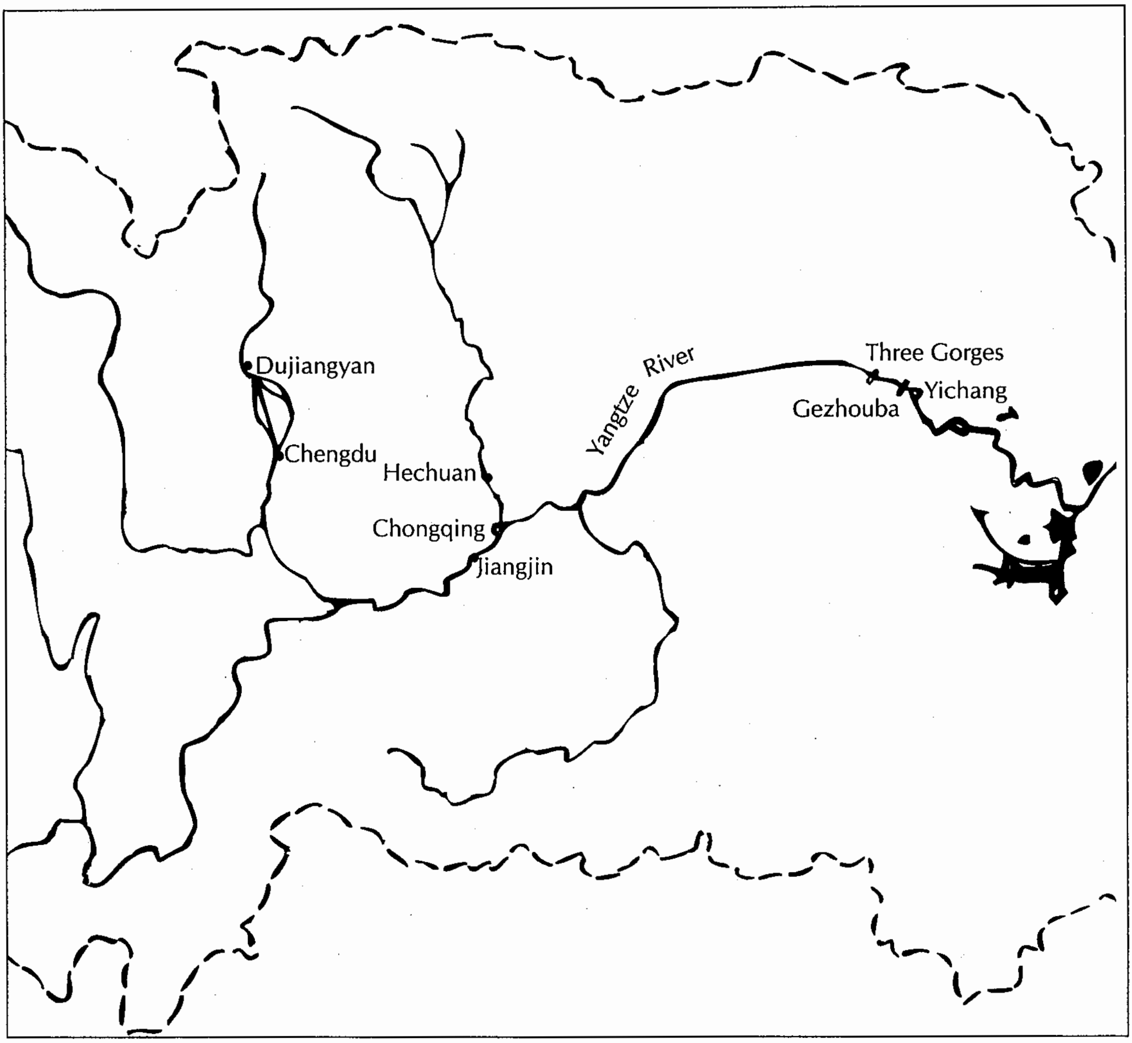

FIGURE 1. Project and upstream locations.

ter]) load of the rivers tributary to the reservoir but have evidently misunderstood the coarse bed-load. Although it is impossible to measure bed-load with any accuracy when the river bed material is mobilized to a significant depth during high flows under 35 meters of water, the advancing science of hydrogeomorphology has provided methods to make realistic estimates of the average annual bed-load that will be deposited in the reservoir. The designers' incorrect measurement of the present yearly average discharge of cobble and gravel — only 277,000 tons per year at Chongqing and 758,000 tons per year at Yichang, some 24 miles below the dam site (see Figure 1) — is unrealistically low and demonstrates a lack of awareness of the known characterisitics of bed-load movement.

Engineers, who accept as reasonable the gravel estimate of 2 million tons per year at Dujiangyan — which is located in the Upper Yangtze basin and drains 23,000 square kilometers — have evidently not raised concern about the obvious hydrogeomorphologic inconsistency in the measurement of 277,000 tons per year downstream at Chongqing, which has a drainage area of 1 million square kilometers.

An accepted way to estimate total yearly bed-load is to sum the bed-loads moved by typical water courses in the small tributary drainage areas. These bed-loads are measured by collecting the cobble and gravel rolling into

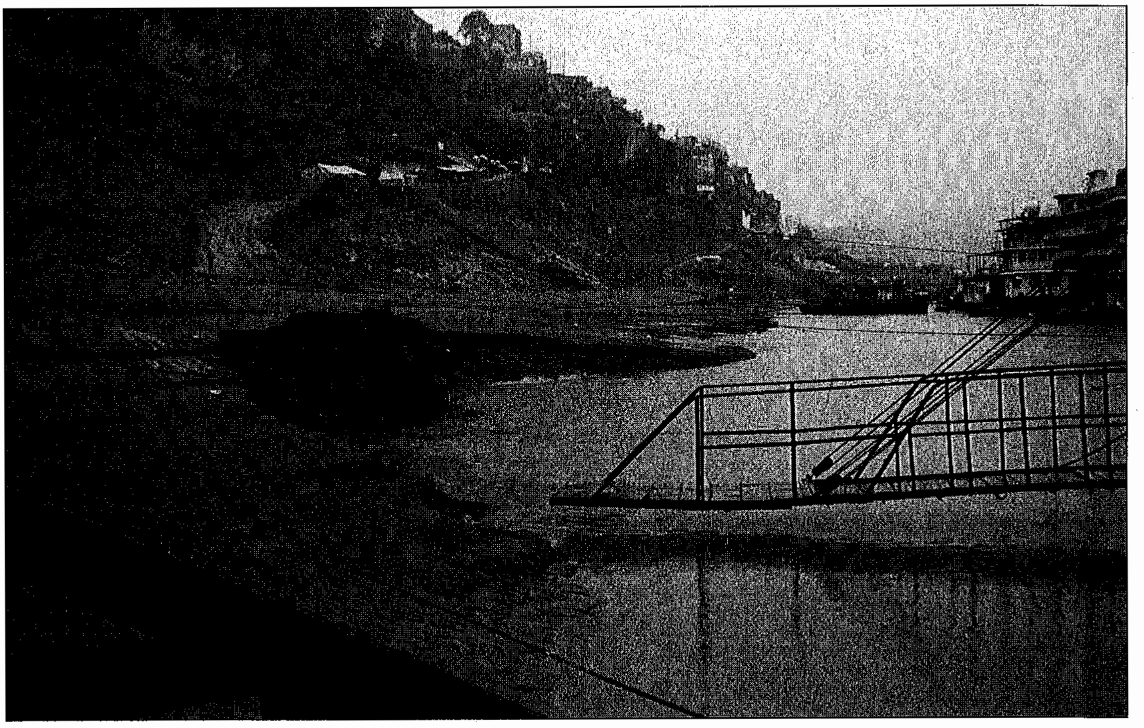

Photo by Shigeki Harada

FIGURE 2. A view of sediment deposits in the Three Gorges district.

steel wire nets along the crude rock beds. The entire upstream drainage basin of the Upper Yangtze is covered with rounded igneous rock, so that the eroded materials are cumulative as one moves downstream. The Dujiangyan bed-load estimate of 2 million tons per year for a drainage area of 23,000 square kilometers was based on steel wire net measurements of typical tributaries. If an average of 100 tons per year of cobble and gravel are estimated to erode from each square kilometer, then the cobble and gravel load through Yichang (with a drainage area of 1 million square kilometers) would be about 100 million tons each year, which is several hundred times more than the 758,000 tons per year at Yichang estimated by the Three Gorges Project designers. The deposition of 100 million tons per year of cobble and gravel will certainly block Chongqing harbor, inundate the land upstream and, because of the suddenness of a large flood that transports excessive sediment, threaten great loss of life.

Discussion

The dam site across the gorge is located below the degrading or scouring reach of the upstream Yangtze River. The fact that bedrock is overlain by a 30-45 meter deep layer of cobble and gravel alluvium indicates that the deposition reach downstream of the dam site extends upstream into the Three Gorges. The bed-forming material — boulder, cobble, gravel and coarse sand laid above solid rock bed in the degrading reach of the upstream Yangtze — is the critical component of the fluvial process affecting the Three Gorges Project. This material in the steep mountainous reaches of the tributaries (with bed-slopes of about 1 percent) moves constantly downstream, even in the clear low flow of December and January when there is no suspended load. It may stop for some time along the middle reaches of the main tributaries, but it certainly rolls on downstream in the long run during flood times.

When heavy rains occur, the river flow at once turns muddy with an attendant suspended load of silt and sand, and the bed-load accelerates under the raised depth of faster flow (see Figures 2 and 3). The river bed along the Three Gorges reach is covered with thick layers of cobble and gravel deposited by floods during their periods of recession, but there is no deposited sand and silt along the course of the gorge.

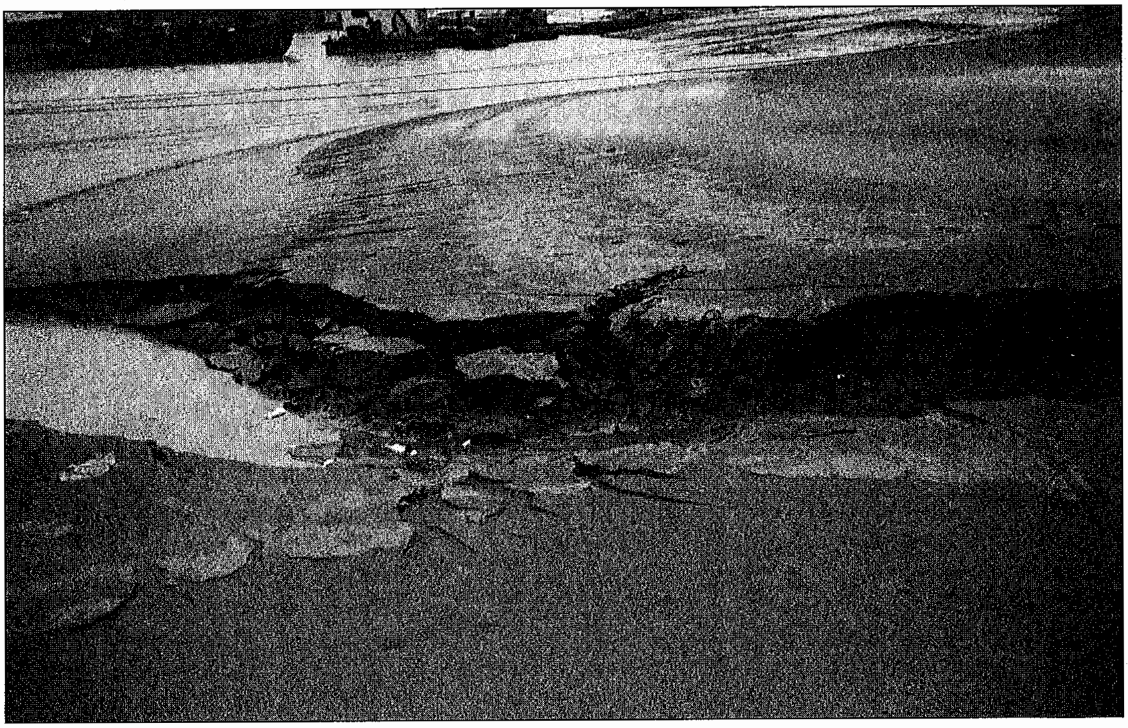

Photo by Shigeki Harada

FIGURE 3. Another view of sediment deposits in the Three Gorges district.

These conditions are what exist before dam construction. The rounded cobble and gravel originates from underground igneous intrusions that extensively cover the entire upstream watershed of the Yangtze River. Rolling down to the streams, the cobble and gravel is a left-over from the glacial recession in the last geologic epoch. The silt and sand soil components, in contrast, are disintegrated and decayed shale and sandstone, respectively, which have been produced by the wind and water weathering of ledge outcrops left behind by the receding glaciers. The sand and the silt are continually being washed down to the streams by surface runoff. This difference in sediment origin brings about different regimes of flow.

Depending on the river flow and the dimensions and slope of the various stretches of the river channel, some or all of the depth of the cobble and gravel river bed is always in motion (as bed-load), continually grinding away at and degrading the river beds of the Upper Yangtze and its tributaries. The suspended load — even though it facilitates the bed-load movement — has no effect on the river bed itself. The two components move by different flow regimes. The velocity distribution of water and sediments along the curve of any vertical from surface to bottom is continuously reduced.

Techniques for measuring sediment discharge are not yet fully developed. The actual amount of partially suspended bottom load (the coarser sand component of the suspended load) cannot be reliably measured, and no way has been found to directly measure the bed-load throughout the entire depth of moving coarse sediment. The average annual suspended load discharge at the Yichang Hydrological Station is reliably known to be 523 million tons, 72.9 percent of which occurs between July and September. Using a ratio borrowed from Yellow River data, the government report estimates the annual partially suspended bottom load discharge to be 10 percent of the suspended load discharge. Therefore, the government estimates the total average annual suspended load to be composed of about 52 million tons of bottom load and 518 million tons of fully suspended load — essentially assuming a negligible bed-load. The choice of the suspended load of silt and sand instead of the cobble and gravel bed-load as the main focus and target for analysis of the upstream Yangtze fluvial process has been a grave mistake.

The feasibility study suggests that sand (actually cobble and gravel) deposition on the upstream margin of backwater in the reservoir can be flushed out by lowering the reservoir level during the months of March and April (before the onset of flood) and holding this low level during the whole flood period so that the heavily sediment-laden flows can move downstream. The reservoir can again be filled during the following autumn, toward the end of the high-flow period in order to maintain greater depths for navigation and higher heads for power generation during the low-flow period, when the flow carries little sediment. However, the unpredictability of Yangtze River floods, together with the limited storage capacity of reservoir and the discharge capacity of the dam, will demonstrate that the proposed operational strategy cannot work as planned.

The deposited cobble and gravel, mixed with coarse sand, will heap up higher and higher, year by year, relentlessly raising upstream flood levels so that within a few years after the reservoir is filled, Hechuan, Jiangjin and other upstream communities and farmlands will begin to experience progressively more frequent and more destructive flooding. Eventually, the deposition will migrate upstream to where the equilibrium deposition profile of the gravel/cobble-laden bed intersects the natural profiles of the upstream river and tributaries intersect. One quarter of Sichuan Province will be severely affected.

The engineers of the Yangtze Administration deny the existence of this critical issue by arguing that the annual cobble and gravel load is only a trifling amount, as if the riverbed in Sichuan could maintain a steady form of cobble and gravel distribution without motion, even under flood flow. On the contrary, it can be seen that all the Sichuan tributaries embrace a series of steady flow reaches and rapids about 10 kilometers apart. On the rapids, small gravel and course sand can be seen dropping down all the time with their positions shifting gradually in low flow, but considerably during floods.

The 35-meter deep gravel and cobble layer now covering the rock bottom at the proposed dam site must have come from upstream as flood flow eroded the rocky river bottom. Although the slope appears stationary now, the degradation proceeds inexorably. Along all courses of all tributaries, the gravel and cobble move downward at all times in all seasons, even under the clear shallow fair weather flows. Situated in the degrading reach as they are, all this cobble and gravel (without the dam) will eventually be transported out of the gorge — although its transport will be intermittent, in accordance with the law of the continuity of average annual flow. On the other hand, the flow of the suspended sediment of sand and silt derived from normal erosion of the surface soil occurs only as a result of rainfall and moves steadily downstream.

From various observed data, Tson-Tai Fang, a renowned engineer, has estimated the unmeasured bed-load at Yichang as about 11.7 million tons per year. Combined with the measured bed-load, his estimate leads to a total of about 12.5 million tons per year, which is 1670 percent of the 0.758 million tons per year measured incorrectly by the project designers (and 12.5 percent of the 100 million tons per year estimated here).

Conclusions

Whether the actual bed-load is closer to 12.5 million or 100 million tons per year will only be known with some certainty when the dam is built. Either amount could prove disastrous. Once the dam is built, all the bed-load will be deposited in the upstream end of the reservoir, whose location will depend on the reservoir level being maintained at the dam, where the velocity becomes too slow to drag the material along the river bed. Eventually, the deposited bed-load material (cobble and gravel) will extend upstream through subsequent floods and inundate the populous cities and farms on the Yangtze and Jialing rivers. The only way to prevent this disaster was expressed long ago by former Premier Zhou Enlai when he pointed out that "if a dam in the Yangtze River hinders navigation, this dam must be blown up." It would cost at least one billion yuan ($121 million) to clean up the debris. It is for this reason that the Three Gorges dam must never be built.

NOTE — *The systematic analysis presented here supplements a previous infrastructure analysis of the Three Gorges dam and reservoir presented elsewhere by the author.*

WILLIAM WANLI HUANG *is the most senior hydrologist in China. He received his M.C.E. from Cornell University in 1935 and a Ph.D. in engineering from the University of Illinois in 1937. He has been involved in many of the major water resources engineering projects in China during the last half century, including the Three Gorges Project and the Sanmen Gorge Project on the Yellow River. He proposed innovative approaches to control the Yangtze and Yellow rivers in concert with utilization of groundwater resources. His two books,* Engineering Hydrology *and* Estimation of Floods, *published in 1956 and 1957, respectively, have had a great influence on Chinese hydraulic engineers. He is versed in hydrology theory and estimation, engineering design and construction, as well as geology, meteorology and astronomy. Huang is well acquainted with the generation of eminent American engineers whose early careers were shaped by John R. Freeman. Five of the engineers who were in the first group of Freeman Scholarship recipients to study hydraulic laboratory practice in Germany were colleagues of his. Francis G. Seery (1875-1945), his professor and friend at Cornell, was a colleague of Freeman's; and when Huang spent six months at the University of Iowa in 1935 he became acquainted with F.T. Mavis (1901-1986), one of the Freeman Scholars who had studied in Germany. He worked short stints at the Tennessee Valley Authority, U.S. Bureau of Reclamation and U.S. Army Corps of Engineers. He returned to China in 1937, where he has held numerous positions, including: Chief Advisor in Water Engineering Technologies at the State Commission of Economic Affairs, Chief Engineer of the Bureau of Water Resources of Gansu Province, Chief Advisor to the Northeast China General Bureau of Water Resources, Chief of Surveying the Yangtze Tributaries and Manager of the Great Wall Engineering Corporation. He was Professor and Head of Hydraulics at Tangshan Engineering College. In 1953, he joined Tsinghua University as Professor of Hydraulic Engineering and is now Professor Emeritus. He is the author of over 30 papers and a collection of poetry,* Poems About River Works.