Going Against the Flow in China

As work continues on the massive Three Gorges Dam, engineers and scientists debate ways to slow the buildup of silt in the vast reservoir and minimize environmental disruptions

BEIJING—Last fall, when a convoy of trucks dumped the final load of stones to block the main channel of the Yangtze River, the Chinese government hailed it as a triumph of its decades-long plan to tame the world's third longest river, improve navigation, and generate electricity for a power-hungry nation. But achieving this important milestone for the controversial Three Gorges Dam, a $30 billion project scheduled to begin generating power in 2003, hasn't dried up debate about the undertaking, which will uproot an estimated 1.2 million people and create a 690-kilometer serpentine lake behind the dam.

As 10,000 laborers forge ahead with the next phase of the project, many Chinese scientists and engineers are still worrying about whether the dam—185 meters high and spanning 1600 meters—will work according to plan. Their chief concern, apart from the massive human relocation, is that a desire to maximize the dam's power output—26 turbine generators are expected to produce 18,200 megawatts of power—could lead to a buildup of sediment. That might cause the dam to do the opposite of what its creators intend, that is, hinder navigation upstream and lower agricultural productivity downstream. Indeed, an expert panel on sedimentation, one of 14 that endorsed the project in 1989 after looking at various scientific and technical issues, has been asked to continue monitoring the project as construction goes forward. Other groups are also studying the dam's considerable impact on the region's ecology (see sidebar).

Although the questions are not new, they have become more urgent as the project moves forward. Construction is certain to continue, but the concerns could change the way the dam is operated, and decision-makers are taking them seriously. "Those who have been opposed to the construction of the dam have made outstanding contributions to the project," observes Pan Jiazheng, a member of the Chinese Academy of Sciences (CAS) and former chief engineer with the Ministry of Water Resources and Electric Power. "They have compelled us to take every step with double or triple caution."

The idea of a dam at Three Gorges goes back at least 80 years. It captured the attention of Mao Zedong after 30,000 people died in 1954 in one of the worst floods to hit the middle and lower reaches of the river in this century.

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Waterworks. The Three Gorges Dam, the world's largest, will create a 690-kilometer reservoir along a portion of the Yangtze River *(inset)*.

Planning proceeded in fits and starts for the next 4 decades before the National People's Congress gave the project a final green light in 1992. However, the vote by the 2600 legislators generated 177 nays and 664 abstentions, an unprecedented show of opposition to a project for which the government had lobbied heavily and tolerated scant criticism.

One panel member who is sharply critical of the current design and is willing to speak publicly is Lu Qinkan, former deputy chief engineer for planning at the Ministry of Water Resources and Electric Power. He predicts that Chongqing, the country's largest city and the biggest port in southwest China, will face a serious problem of silting if the planned water level of the massive reservoir to be created behind the dam is not decreased by 15 to 20 meters from its planned depth of 175 meters.

The 85-year-old Lu was among the first Chinese to work on the Three Gorges project. In 1946, he went to Colorado to work with the late John Savage of the U.S. Bureau of Reclamation, which had drafted a plan at the request of the Kuomintang government. "At the time, we intended to build a dam with a reservoir water level of 200 meters," he says, "because we didn't foresee the sedimentation and resettlement problems."

Muddy numbers

The bigger the reservoir, the more power the dam can generate. But increasing the depth of the reservoir also increases the buildup of sediment. "The silt load of the Yangtze River averages 520 million tons per year, the fourth largest in the world," says Lu. "To reduce the sedimentation in the Three Gorges Reservoir, it is proposed to store clear [less silted] water after flood seasons and sluice muddy [silt-laden] water during flood seasons by means of lowering the water level with large-capacity outlets. But that runs counter to the project's prime function of flood control, as silt-laden water peaks during the flood season."

With the reservoir at 175 meters, he says, the most severe sedimentation will take place along harbors in Chongqing, blocking the outlet of the Jialing River as it joins the Yangtze. He says a proposed initial stage level of 155 to 160 meters would ease the problem, for the reservoir would extend only to Tonglu Gorge below Chongqing and the outlet of the Jialing River. That depth would also reduce the amount of land that must be flooded, preserving the homes and farms of nearly 500,000 people now being resettled.

The suggestion received strong support from a dozen senior engineers involved in the feasibility studies of the 1980s, who still support the idea. But it was rejected for economic reasons, says Zhang Ren, a hydraulics expert at Tsinghua University and a member of the panel, which reports to the State Council's dam construction commission: "It would reduce the reservoir's storage capacity of 39.3 billion cubic meters by 10 billion cubic meters, thus reducing its flood-control capability considerably."

Less stored water would also mean less electricity generated, Zhang adds, and the shallower reservoir would prevent larger ships from reaching Chongqing, assuming

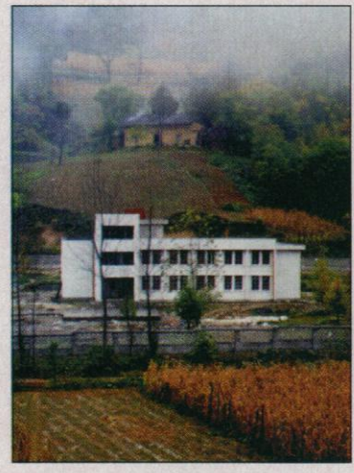
Taking the Eco-Pulse of a Giant

Ecologist Chen Guojie admits that he's a longtime opponent of the Three Gorges Dam. But with construction a reality, he and his colleagues at the Mountainous Disaster and Environment Institute in Chengdu have joined other labs affiliated with the Chinese Academy of Sciences (CAS) "to minimize the project's possible hazardous impact on ecology and environment."

Chen is setting up an experiment station at Wanxian, an area where some 800,000 residents are being relocated. The team will monitor environmental changes during construction of the reservoir as well as the fate of the residents. It's one of seven such facilities set up by CAS, according to Tian Erlei, a senior engineer in charge of regional development and environmental management at CAS's Bureau of Science and Technology for Resources and the Environment. Those stations, in turn, feed into a broader network of several hundred scientists in 70 institutions who are part of a $110 million project to monitor a dozen aspects of the project's impact through its completion in 2009.

"We hope to provide timely forecasts on any environmental pollution or damage to resources that may occur," says Tian. For example, geologists working with the network identified unstable banks along the main channel of the reservoir and its 31 large tributaries in time to mitigate the damage from rainstorms caused by some 255 landslides, rock falls, or muddy-rock flows in 1996 alone.

Other projects are trying to preserve features that could be lost once the dam goes into operation. "The Yangtze is an important gene bank of freshwater aquatic life," says Cao Wenxuan, an ichthyologist and a member of CAS. "But some rare species are already directly or indirectly endangered by the Gezhouba Dam in the early 1980s and the ongoing Three Gorges project."



C. WEILIE

Ground zero. Scientists at Shennongjia station hope to preserve biodiversity of reservoir region.

One such species is the Chinese River Dolphin. Known as the *baiji*, or white-fin, dolphin and unique to the Yangtze, the animal is the living fossil of a 30-million-year-old species. But fewer than 100 specimens are left, and the dam could deal it a final blow. "Clear water released from the dam will scour the downstream riverbed and wash away river islets that constitute its habitat," Cao says. "Its range will probably be narrowed by 155 kilometers, and a decline in fish stocks downstream from the dam might affect its food source. Meanwhile, increased shipping may expose the animal to more accidental deaths from ship collisions."

Cao and his colleagues at the CAS Hydrobiology Institute in Wuhan have tried unsuccessfully to relocate the dolphin to natural reserves on the Yangtze. However, efforts to preserve some of the 40 fish species unique to the reservoir region are more promising, he says, including finding alternative habitats along the Chishui River, a tributary of the Yangtze in northern Guizhou. "So long as the river's water resources remain largely untapped," he says, "we hope to continue to resettle some species."

Sixty kilometers north of the dam, Chen Weilie and his colleagues have set up the Shennongjia biodiversity research station, the first of its kind in China. A plant ecologist with the CAS Biology Institute in Beijing, Chen is trying to preserve rare plant and animal species unique to the reservoir region. Field studies have identified more than 3000 higher plant species in the reservoir region, 10% of the country's total, of which 36 are rare and unique to Three Gorges. Two species unique to the area that face the impending flood have already been successfully cultivated at the station, Chen says proudly. "It's boosted our confidence in preserving the biodiversity of the region." –X.L.

that sedimentation doesn't choke the harbor. "The project's power-generating capacity would fall by at least 13%, and navigation on the rapids-strewn upper reaches where the Yangtze cuts through mountains with gorges would not be improved," he says. The government has projected that a deeper reservoir would quadruple business at Chongqing's port and lower shipping costs by 30%.

Zhang says that engineers have a plan to reconcile the need for low water levels to reduce sedimentation with the need for high water levels to improve flood control. During the flood season from June to September, he says, muddy water will be sluiced at 145 meters. At this level, Zhang says, the dam will drain silt while still being able to withstand floods more serious than the one in 1954. One advantage, he adds, is that flood torrents from the upper reaches of the river pass through the Three Gorges Dam very quickly. "It is unlikely that the dam has to store water at a high level for more than a few days, so not much silt will be deposited." At the same time, he concedes that big ships cannot pass through the gorges at the lower water level.

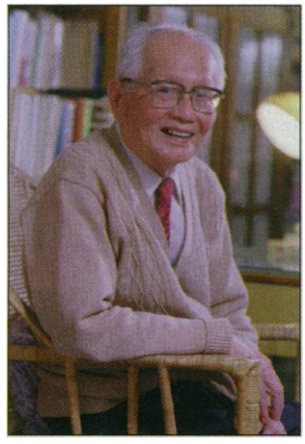
According to Zhang, engineers have applied lessons learned while building the Sanmenxia Reservoir on the Yellow River in the early 1960s and the Gezhouba Dam in the early 1980s to devise a formula for calculating a reservoir's capability to hold silt deposits. Mathematical models and tests based on actual hydraulic data show that some 30% to 40% of sediments will be discharged from the reservoir during the dam's first 30 to 50 years of operation, he says, while silt deposit and discharge are expected to be equalized after 80 years.

But Lu says the theory doesn't solve the problems facing the Three Gorges because it doesn't account for where the most serious sedimentation takes place. Other geologists have noted that the unprecedented scale of the Three Gorges project—its height, the length of the reservoir, the amount of sediment carried by the Yangtze, and the potential severity of flooding—makes it hard to apply lessons from existing projects. Zhang admits that the sedimentation panel recognizes that questions remain. "We are supposed to solve any sediment problems that may crop up during the construction that were not foreseen," he says.

In the meantime, the commission is examining three possible solutions to the sedimentation problem. One would set the initial water level at 160 meters and postpone opening the dam's sluice gates until November, after the flood season has ended. Zhang says clearer water at this time of year supports a higher level while still allowing sediments to be washed out. But this method may restrict the dam's generating capacity. Another approach would be to relocate Chongqing's docks, away from banks and out to the main stream of the river. However, the move would narrow the river's course and speed up its water flow. The third proposal is to dredge Chongqing's channels and berthing areas regularly. But that work would disrupt traffic. "Each approach has its pros and cons," says Zhang, "and the problem is still under study."

Downstream effects

If a buildup of sediment does choke waterways behind the dam, commerce on the river won't be all that will suffer. The discharge from upstream has contributed to the thriving delta region more than 1000 kilometers downstream, creating one of the country's most fertile farming areas. Although the annual outflow entering the sea is expected to remain unchanged after the dam is completed, some scientists worry about the effect on the river of an irregular discharge of the life-giving muck that disrupts natural patterns. A 1995 environmental impact statement, drawn up by scientists from CAS and the Research Institute for Protection of the Yangtze Water Resources, predicts that the reduced discharges in October and November "will make the saltwater intrusion appear earlier and its duration last longer, [and will] lead to variation in the process of deposition and erosion of the beaches in the estuary region."



JAMES ZENG-HUANG/CHINA FEATURES

Swirling debate. Lu Qinkan says planners understate the problem of sedimentation.

It is still too early to forecast the project's impacts on the estuary region and the entire lower and middle reaches, but many scientists fear the damage could be considerable. "The project's overall adverse impact on ecology and environment far overshadows its positive effects," says Chen Guojie, an ecological and environmental scientist with the CAS Mountainous Disaster and Environment Institute in Chengdu who has studied the issue. "We divided the systems of natural and social ecology and environment into subsystems and elements" ranging from terrestrial fauna to climatology, he explains. "We found only nine elements to have a positive effect, six to be unaffected, and 63 to suffer negative impacts."

Some scientists have also posited that creating a lake in the deep mountains will lead to increased fog in the region. Mixed with industrial pollution, they say, the fog could aggravate an already serious smog problem in Chongqing.

But other scientists have criticized that approach, saying it fails to account for the relative importance of the different elements. "The dam will save 50 million tons of coal [a year] and reduce the amount of carbon dioxide released by 100 million tons," says Li Zhennan, former chief engineer with the Changjiang (Yangtze) Water Resources Commission. "That can hardly be compared with such environmental problems as a slight drop in temperature or one or two more foggy days a year. The feasibility study concluded that the project will have both positive and negative environmental impacts," Li adds, "and that many adverse impacts can be solved through appropriate measures."

Some scientists have less faith in those remedies, however. Sun Honglie, a geoscientist and a former vice president of CAS, says that most of the 1.2 million people to be relocated will simply move higher up the mountain slopes around the reservoir region, putting additional strain on the already deteriorating environment. "The land in the region is already overused, and soil erosion on the mountain slopes by the reservoir is serious," says Sun, a consultant to the project's steering group in the 1980s.

With construction moving forward, there may be little time to accommodate the project's critics. But Three Gorges is not the last big dam on the drawing board. Work on two smaller dams located 500 kilometers upstream of Chongqing is scheduled to begin in 2003, and Zhang notes that their presence "will reduce the sedimentation [entering the Three Gorges Reservoir] by nearly half." Observers see his comment as belated recognition of the importance of some of the issues raised during the debate over the Three Gorges project.

–Xiong Lei

Xiong Lei writes for China Features *in Beijing.*

ESA

Industry Links Debated, Moon Shot Killed

Last summer, when Italian electrical engineer Antonio Rodotà took over as director-general of the European Space Agency—the first ESA head to come from industry—he promised to reinvigorate the faltering agency by forging new partnerships with Europe's rapidly growing aerospace industry (*Science*, 5 September 1997, p. 1426). Last week, delegates from ESA's 14 member states were given their first taste of Rodotà's new strategy at a meeting of ESA's Council at its Paris headquarters. While leaving ESA's science program untouched, Rodotà presented a "menu" of new initiatives that would all require the involvement of industry.

The reaction of delegates was largely favorable, but there were calls for the scheduled June meeting of the Council at ministerial level—when major funding and strategic decisions are made—to be postponed while details are hammered out. And, in a separate action, the Council nixed plans to develop a European lunar project early in the next century.

The new suite of programs that Rodotà proposed to the Council last week included:

- a mainly French proposal for upgrading the Ariane 5 launcher, increasing its launch capacity and reducing its cost.
- the development of a small launcher, proposed by Italy, that can place 1-ton spacecraft into 700-kilometer polar orbits.
- an Earth observation program that would encompass both research-oriented "Earth Explorer" missions, wholly funded by ESA, and applications-based "Earth Watch" missions developed in collaboration with industry (*Science*, 16 January, p. 316).
- a satellite navigation program that would make Europe independent of both the U.S. Global Positioning System and the Russian GLONASS system.
- a program to develop multimedia satellite systems and mobile and personal satellite telecommunications.

ESA

New broom. ESA Director-General Antonio Rodotà.

Rodotà's vision of ESA as the technological standard bearer for Europe's space industry apparently got a mixed reception. Bartolomeo Pernice, who coordinates European cooperation at ASI, the Italian space agency, says the reaction of the majority of delegates was positive. Europe, he says, needs such industrial partnerships to compete with the United States, where "most [space] applications are supported by development funded by the Department of Defense. We don't have this huge expenditure of military activity in Europe." German delegate Walter Kröll, board chair of Germany's space agency DLR, agrees: "I completely agree with Rodotà that a reformed ESA has to try to go along the way which he outlined if ESA really wants to be a major player in space." But Gérard Brachet, director-general of the French space agency CNES, says the plan was received with "a mixture of sympathy and skepticism." Noting that ESA initiated the development of satellite communications in Europe, but was soon outrun by the industry consortium EUTELSAT, Brachet says, "ESA does not have very much experi-