The Three Gorges Project: Key to the Development of the Yangtze River

This project will provide immense flood control and power generation benefits; any negative impacts can be offset by using extensive studies conducted over the last 70 years.

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The building of a large dam at Three Gorges on the Yangtze River — at the most dangerous and steepest section of the world's third longest river to control floods, generate electricity and bring other benefits — has been a dream of the Chinese people since the time of Dr. Sun Yat-sen (1866-1925), the pioneer of the Chinese democratic revolution. In order to translate this vision into reality, many experts and scholars, both Chinese and foreign, have devoted a great deal of time and energy. What is the Three Gorges Project? Why should it be built? Can the major problems encountered in the course of its construction — such as the build-up of silt and the resettlement of local residents — be successfully tackled? And how can these problems be solved? What will be the impact on the ecological environment? What will this project cost and will China be able bear the necessary investment?

Project Description

Located in Sandouping of the Xiling Gorge, the proposed site of the Three Gorges Dam is 38 kilometers upstream from the Gezhouba Project (see Figure 1). It is an exceptionally large water conservancy scheme possessing enormous, comprehensive utilization benefits for flood control, power generation, navigation, the breeding of aquatic products and water supply.

The project consists of a large dam across the river, a hydroelectric power station and navigation structures. It will provide a one-cascade development of the Yangtze from Chongqing to Sandouping. The elevation of the dam crest is 185 meters above sea level. Its normal water

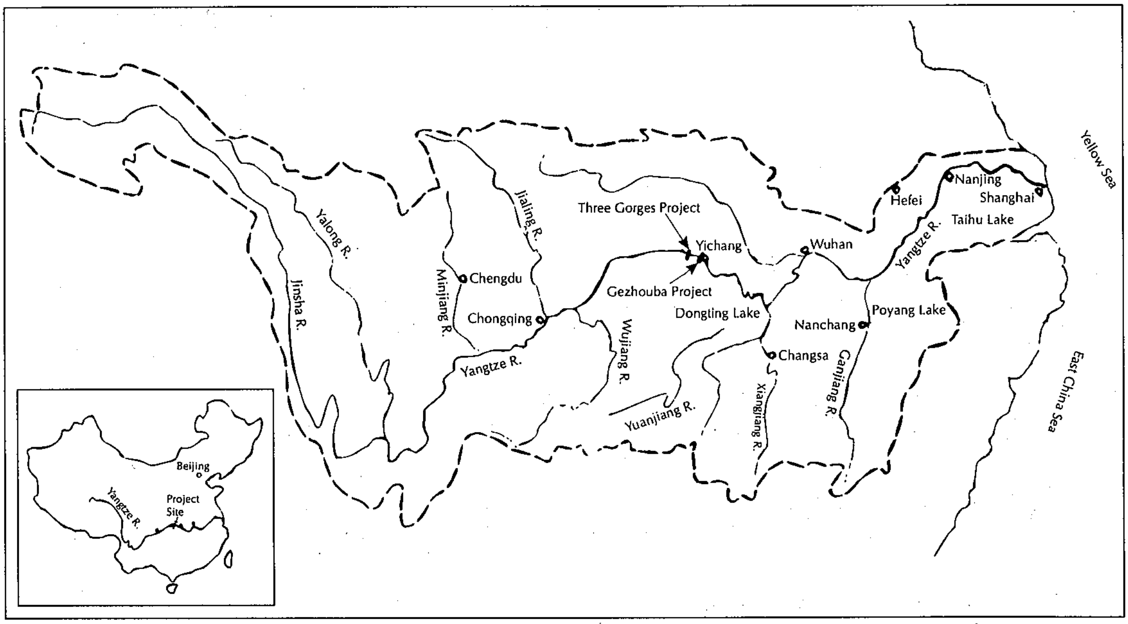

FIGURE 1. The location of the Three Gorges Project along the Yangtze River valley.

storage level is 175 meters and total storage capacity is 39.3 billion cubic meters, with a flood-control storage capacity of 22.15 billion cubic meters. The power station would install 26 sets of power generating facilities, with a total installed capacity of 17,680 megawatts and an annual output of 84 billion kilowatt hours. The navigation structure's annual one-way passage capacity would be 50 million tons. About 650 kilometers of channels would be upgraded.

Construction of the project will be divided into three stages. The general construction period for the principal part of the project will last 15 years. In the ninth year after construction begins, permanent navigation structures will be put into use and the first power-generating facility will begin delivering electricity. Calculated in terms of 1990 prices, the total investment — including project construction, resettlement of residents and power transmission — could reach 57 billion yuan ($12.7 billion).

Historical Context

The Three Gorges section of the Yangtze River represents one of the world's largest treasure houses of water resources. The proposed Three Gorges Project has drawn attention both in China and abroad because of its massive scale, potentially remarkable benefits and decisive significance for China's four socialist modernizations. It is more than 70 years since people began to consider exploiting the water resources there. In particular, since the founding of the People's Republic of China (PRC), specialists in all fields have done a great amount of groundwork and have repeatedly conducted feasibility studies and research on the site.

Proposals for & Early Studies of the Three Gorges Project. Dr. Sun Yat-sen, pioneer of China's democratic revolution, first suggested the Three Gorges Project. In his 1919 article "Industrial Plan," Sun proposed improving shipping conditions on the river's Sichuan section and developing the hydroelectric power potential of the Three Gorges. "Store water with gates to enable ships to navigate and to exploit the water resources," he wrote. In 1924, Sun further expounded the importance of using the waters of the Three Gorges. In his article "Principle of People's Livelihood," he said:

> "The Kuixia Gorge on the upper reaches of the Yangtze River has massive water power. Some people believe that waterpower from Yichang to Wanxian County could generate 30 million horsepower of electricity. That is much more than the electricity generated by any country at present!"

Initial studies of the Three Gorges Project began in the early 1930s. In October 1932, the Construction Committee of the Kuomintang government organized a prospecting team to survey the hydroelectric power generation capability of the upper reaches of the Yangtze. Bearing in mind the scope of electricity supplies and the technical conditions, the team compared several plans and then recommended the building of a project at Gezhouba or Huanglingmiao on the upper reaches at Yichang in Hubei Province. The project would include a 12.8-meter-high water head dam with an installed generating capacity of 300 megawatts and equipped with shiplocks. The team compiled a report entitled "A Survey Report on the Hydroelectric Capability of the Upper Reaches of the Yangtze River."

In April 1933, the Committee for the Realignment of the Yangtze River produced a study entitled "The Hydroelectric Power Generation Plan for the Upper Reaches of the Yangtze River," but it was immediately filed away for reference only.

In 1936, after studying the issue of improving the channels and exploiting the water resources at the Three Gorges, Brandtl (an Austrian engineer who was an adviser to the Yangtze River Water Conservancy Commission) said that such a gigantic project would be difficult to complete during a period of economic depression. Even if it succeeded, the engineer added, its prodigious power output could not be effectively handled. Thus, the project was again put aside.

In 1944, the earliest specific development plan was put forward. The American economist G.R. Passhal, an adviser to the China Wartime Production Bureau, suggested building a hydropower plant at Three Gorges with an installed capacity of 10,500 megawatts. He also proposed taking advantage of the cheap hydropower to build a fertilizer plant with U.S. investment, machinery and equipment, which would be repaid to the United States with fertilizer over a 15-year period. In May of the same year, the Resources Commission invited J.L. Savage, chief design engineer of the U.S. Bureau of Reclamation and a world-famous dam expert, to come to China. After personally surveying the Three Gorges area, Savage compiled "A Preliminary Report on the Yangtze River's Three Gorges Plan." He suggested locating the dam between Nanjinguan and Shipai, five to 15 kilometers upstream from Yichang, and raising the water level to 200 meters elevation. The project would generate 10,560 megawatts of electricity while also controlling floods and improving irrigation and navigation. He compared five plans and estimated that an investment of about $1 billion would be needed. He also put forward a work plan for further survey and design. Savage's plan was original in that it called for comprehensive utilization, with primary emphasis on power generation. In addition, Savage discussed with Qian Changzhao, deputy director of the Resources Commission, the possibility of technical cooperation with the U.S. Bureau of Reclamation and the Tennessee Valley Authority (TVA) as well as a plan to train Chinese technicians.

Soon afterwards, the Resources Commission launched a series of surveys and investigations. In 1945, the commission invited related agencies to form a committee for planning and technical study of the Three Gorges Project, with Qian as chairman. This committee discussed all aspects of the plan — including navigation, irrigation, inundation of the reservoir area, population resettlement, fertilizer production and surveying. In August of the same year, the Three Gorges prospecting team was formally set up.

In early 1946, after assigning another survey, the Yangtze River Water Conservancy Committee and other agencies compiled three reports: "Survey Report on the Three Gorges Reservoir on the Yangtze River," "Economic Investigation Report on the Three Gorges Reservoir Area" and "Report on the Geology of the Yichang Gorge." In the same year, a contract was signed with the U.S. Bureau of Reclamation for the latter to take charge of the reservoir's design. More than 50 Chinese engineers and technicians were sent to the U.S. to participate in designing the project.

In 1947, with civil war raging, the Kuomintang government decided to suspend design work for the Three Gorges Project.

Flood Control on the Yangtze River. In the first half of 1949, the middle and lower reaches of the Yangtze were liberated and the birth of the

New China (the PRC) was in sight. That year, a serious flood occurred along the Yangtze River and many dikes on the middle and lower reaches of the river burst, causing widespread disaster. The Jingjiang Dike, the most important in the area, had a big landslip in Qijayuan near Haoxue. The precarious situation revealed the urgent need for flood control on the middle and lower reaches of the Yangtze, especially in the Jingjiang section.

Because flood control on the river was an issue of national significance, the Ministry of Water Resources of the new Central People's Government proposed in November 1949 to set up a special organization in charge of the river. In February 1950, the Yangtze River Water Conservancy Commission (later renamed the Yangtze Valley Planning Office in 1956) was established in Wuhan, directly under the leadership of the Ministry of Water Resources. Special organizations were established that spent five years on sorting out hydrological data from the era prior to the founding of the New China. Then, these basic hydrological data were collected for the comprehensive utilization plan of the valley as well as the subsequent design of the Three Gorges Project.

In early 1952, the Government Administration Council issued the decision to build a flood diversion project in the Jingjiang area. It was pointed out that "before a project for permanent control of the Yangtze can be implemented, the reinforcement of the Jingjiang Dike and opening of a flood diversion area on its southern bank are imperative measures to guarantee the safety of the lives and property of millions of people in Hubei and Hunan provinces." The issue of constructing a project to permanently control the Yangtze was clearly raised.

From the second half of 1952, the Yangtze Upper Reaches Engineering Bureau, under the Yangtze River Water Conservancy Commission, began to study plans to construct flood-control reservoirs on the Jinsha River (the mainstream of the Yangtze down to Yibin in Sichuan Province) and three major tributaries, including the Minjiang and Wujiang rivers. The subsequent reports appeared in the first half of 1953. Their conclusion was that even after the four rivers were placed under control, if the rainstorm that occurred in July 1935 around Wufeng in Hubei Province had instead occurred in the Three Gorges area, the flow of the flood peak at Yichang would still be around 100,000 cubic meters per second. Flood control on the middle and lower reaches of the river, especially in the Jingjiang River, would remain unsolved. At that time, some experts suggested constructing a dam at Three Gorges primarily for flood control. After hearing these reports, Chairman Mao Zedong said, "If after so much effort has been put into the construction of reservoirs on tributaries and flooding still cannot be controlled, then why not put a check to it at the Three Gorges?"

Key Project in the Overall Plan. From May to August 1954, a series of heavy rainstorms struck the Yangtze valley. The middle and lower reaches of the river were threatened by the biggest flood in the century. The Jingjiang diversion project was used three times to reduce the water level at the city of Sashi by 0.9 meters and to protect the Jingjiang Dike. Other temporary flood-diversion measures were also adopted, but the losses caused by the disaster were still quite serious. About 3,170,000 hectares of farmland were inundated and 18.88 million people were affected, with 30,000 deaths. These figures further revealed the gravity of flood disaster on the middle and lower reaches of the Yangtze. They also showed that the ultimate solution to the problem was to construct control reservoirs and to adopt comprehensive harnessing measures, which necessitated an overall plan for the whole valley. In 1954, the central authorities decided to commence planning work for the Yangtze valley. In 1955, the Yangtze River Water Conservancy Commission began drawing up a comprehensive utilization plan for the valley and conducting a large-scale work of surveys, planning, design, scientific research and economic investigation.

The "Report on the Main Points in the Comprehensive Utilization Plan of the Yangtze Valley" was compiled in 1959 by the Yangtze River Water Conservancy Commission. It was revised and supplemented in 1983. A revised "Brief Report on the Comprehensive Utilization Plan of the Yangtze Valley" was formally approved by the State Council in September 1990 after examination and discussion by the National Water Resources and Soil Preservation Leading Group. In the process of planning work for the valley, the issue of the Three Gorges Project was again brought up. After repeated discussions, comparison and verification, it was concluded that the project would consist of more than just a giant hydropower station in the overall planning work for the comprehensive control and development of the Yangtze valley. More importantly, the project would be key because it would play a decisive role in controlling floods on the middle and lower reaches and in improving shipping conditions on the river's Sichuan section.

Active Preparation. From the 1950s on, the Central Committee of the Chinese Communist Party, the State Council and veteran proletarian revolutionaries Mao Zedong, Zhou Enlai, Deng Ziaoping and other members of their generation all showed concern for the plan and for the construction of the Three Gorges Project. Great efforts were put into conducting surveys, design and scientific research for the project.

During February and March 1958, Premier Zhou led a delegation composed of leading central and local authorities plus over 100 Chinese and foreign experts to the Jingjiang Dike and the site of the Three Gorges for a survey. On the way, Zhou presided over a symposium and listened to different opinions on the matter.

In March, at a meeting called by the Central Committee in Chengdu (the capital of Sichuan Province), an important document entitled "Opinions on the Three Gorges Project and Yangtze Valley Planning" was passed. This document pointed out that:

> "From the standpoint of the country's long-term economic development and technical conditions, construction of the Three Gorges Project is both necessary and possible. All relevant work should start in accordance with the principles of active preparation and full reliability."

At the same time, concrete stipulations on the principles and process of the Yangtze valley plan and the Three Gorges Project were worked out.

After the meeting, surveys, design work and scientific studies for the scheme were conducted. The Chinese Academy of Sciences and the State Science and Technology Commission organized about 10,000 scientific and technical personnel from more than 200 agencies across the country to participate in joint studies of the main problems. Their efforts were fruitful and partially solved some crucial technical problems concerning the project.

From 1959 to the end of 1960, on the basis of the scientific research that had been conducted, the "Report on the Main Points of Preliminary Design" and a draft for "A Report on Preliminary Design" were hammered out by the Yangtze Valley Planning Office. These reports proposed a normal water storage level of 200 meters and recommended Sandouping as the dam site.

Because of temporary economic difficulties and an unstable international situation, the PRC after 1959 had to slow down plans for the ambitious Three Gorges Project, which had been scheduled to begin in the early 1960s. But keeping alive the spirit of the Central Committee's instructions, the planning office continued feasibility studies related to the project, including topics such as silting, geology and phased construction.

Actual Preparations. At the end of 1969, Hubei provincial leaders again proposed building the Three Gorges Project as a means of controlling flooding at Jingjiang and easing central China's power shortage. But this proposal was shelved by the central authorities since it came at a time when the country was preparing for the possibility of war.

Under these conditions, the Gezhouba Project at Yichang was also put on the agenda. In the overall planning for the Yangtze valley, it was to be part of the Three Gorges Project. Originally, its construction was to be undertaken simultaneously with, or after, the Three Gorges Project in order to overcome the adverse impact of the latter's daily regulated flow on navigation conditions.

Towards the end of 1970, the central authorities decided to build the Gezhouba Dam first in a bid to alleviate a power supply shortage in Central China and to start making preparations for the Three Gorges Project.

During the construction on the Gezhouba Project, rich experience was gained concerning the problem of silting, the building of cofferdams in deep water, the closure of the river, shiplocks and mechanized construction. Simultaneously, it created a contingent of experts and skilled workers for the design, construction and scientific research of large-scale water control projects.

In the late 1970s, as the first stage of the Gezhouba Project was coming to a close, the Three Gorges Project was put on the agenda of the state's Sixth Five-Year Plan (1981-85).

In September 1979, the Ministry of Water Resources held a meeting to choose the site for the future dam. In November of the same year, the Ministry of Water Resources submitted "Suggestions on the Three Gorges Project" to the State Council, stating that the Three Gorges Project should be regarded as a strategic part of China's modernization program. It hoped the central authorities would make a decision on construction of the project as early as possible and strive for its completion in the 1990s.

Reexamination of the Three Gorges Project. The central authorities of the PRC have consistently adopted a positive and prudent policy towards the Three Gorges Project and considered it from the perspective of a development strategy based on the building of a batch of backbone projects necessary for the nation's modernization. An executive meeting of the State Council held in August 1980 entrusted the State Science and Technology Commission and the State Construction Commission with continuing to organize experts to draw up a verification plan. Subsequently, the Yangtze Valley Planning Office, with the coordination of the agencies concerned, compiled "A Verification Report on the Three Gorges Project."

During 1982 and 1983, "A Feasibility Report on the Three Gorges Project" was compiled studying the project's flood control aspects, and recommended a water storage level of 150 meters. In May 1983, the State Planning Commission gathered more than 300 experts to examine the report. The State Council approved it in principle in April 1984 and decided to commence preparatory work so that the project could begin in 1986.

After the feasibility report — which set 150 meters as the normal water storage level — was adopted, various departments and public figures put forward their opinions and suggestions. Proceeding from the principle of adopting a scientific and democratic approach in major decisionmaking and stressing care, accuracy and reliability, the Communist Party's Central Committee and the State Council instructed the Ministry of Water Resources and Electric Power to organize a reexamination of the Three Gorges Project. The State Council called for a new feasibility report on the project based on a full, democratic airing of views by scientists and technicians as well as on a basis of conscientious study and discussion.

A leading group was set up, headed by Qian Zhengying, former Minister of Water Resources and Electric Power. In addition, 21 persons from affected government departments were invited as special advisors. Fourteen expert teams were set up to study the following subjects: geological and seismological problems, the project's main structures, hydrology, flood control, silting, navigation, power systems, machinery and electronic facilities, resettlement of the inhabitants, ecological and environmental impact, construction, investment estimation, comprehensive planning and water levels, and overall economic appraisal. Altogether, 412 specialists and scholars from many disciplines were involved.

These expert teams reexamined all the previous research results and performed considerable supplementary work on major and unclear issues, in cooperation with related surveying, designing and scientific research departments, colleges and universities. Finally, they came up with 14 special reports, nine of which were unanimously passed by all the experts. The other five were passed but not signed because nine experts disagreed.

On the basis of the findings of the three-year reexamination, the leading group instructed the Yangtze Valley Planning Office to recompile a "Feasibility Report on the Three Gorges Project on the Yangtze River." In May 1989, this new report was presented to the State Council for approval. The main conclusions of the feasibility study report were that:

- The Three Gorges Project is essential for China's four modernizations;
- It is both technologically feasible and economically reasonable;
- It is better to build it than not to do so; and,

- Starting construction of the project is more beneficial than delaying.

The group urged the government to make a decision as soon as possible. In July 1990, the State Council held a meeting to hear the findings of reexamination on the Three Gorges Project. During the session, the State Council decided to set up an Examination Committee for the project, headed by Zou Jiahua, to examine the recompiled feasibility report. The work was conducted under separate subjects and by stages. The 21 members of the committee separately presided over the work of the ten preliminary examination groups, which were composed of 163 specialists. Then, the Examination Committee collectively reexamined the report. In August 1991, the committee finished the work, passed the feasibility study report and submitted it to the State Council for formal approval. It was presented to the National People's Congress for review.

It has been 70 years since the proposal to build the Three Gorges Project was first put forward. Not only have several generations of Chinese scientists and engineers put lots of painstaking efforts into the scheme, but experts from the Soviet Union, the United States, Canada and other countries have also participated in the planning, design, research and consulting work of the project. The massive amount of human and material resources and work that went into the project is rare in the history of world engineering.

The construction of any great water conservancy project — either past or present, at home or abroad — is bound to bring economic prosperity to the nation and the locality, as well as benefits to future generations. China's ancient Dujiangyan Project in Guanxian County of Chengdu, capital of Sichuan Province, has been written into the history books because of its significance. The Hoover Dam in the United States has also proved its value. So, it is not difficult to understand why, for such a long time, so many people have shown sincere concern for the construction of the Three Gorges Project.

Selecting the Project Configuration

One of the major problems facing the configuration of the Three Gorges Project is the selection of the normal pool level of the reservoir. Since the 1950s, research has recommended levels ranging from 128 to 260 meters. In 1958, a meeting of the Central Committee in Chengdu stipulated that the normal level should be kept under 200 meters, mainly to avoid inundating Chongqing's main city area. The dam site is suitable for the building of high dams due to its superb location and topographical, geological and hydrological conditions. Moreover, the higher the normal reservoir level, the greater the comprehensive utilization of the project. So, during the 1970s the Yangtze Valley Planning Office mainly concentrated its research on levels from 190 to 200 meters. However, as the construction date of the project has been delayed and constant increases have occurred in population and economic strength in the reservoir area, losses caused by any inundation have also grown rapidly. Consequently, difficulties in the resettlement of inhabitants have become restrictive factors for the selection of the normal reservoir level, which has led to a study of the possibility of implementing phased construction.

At the beginning of the 1980s, a design proposing the normal level of 150 meters was put forward as a means of reducing resettlement problems and for promoting the start of construction as soon as possible. Although this criterion would mean a considerable reduction in comprehensive efficiency compared to setting levels at 190 to 200 meters, it would still provide highly efficient flood control, electricity generation and navigation capacity. The major shortcomings would be the overfilling of reservoirs and temporary inundation of the upper reaches of the Yangtze in the event of floods over 20-year frequency. A special problem would be the fact that when the reservoir backwater cannot reach Chongqing, that section of the river remains in its natural state and 10,000-ton towboats cannot proceed straight to Chongqing harbor.

After the state approved in principle the feasibility report on the 150 meter reservoir level, the city of Chongqing and the Ministry of Transportation suggested that the normal level be raised to 180 meters, to enable direct access to Chongqing harbor for 10,000-ton towboats. In the reexamination stage, the focus was on a comparison of four reservoir levels: 150, 160, 170 and 180 meters. Because the amount of population and cultivated land affected by inundation with a 180-meter level scheme would be 100 percent higher than those at a 150-meter level, a two-cascade development alternative was studied. Such a design modification could both reduce inundation and make the entry of 10,000-ton towboats into Chongqing harbor feasible. Therefore, a lower reservoir level than was originally planned was considered for the Three Gorges Project and another key project was proposed at the end of the reservoir to provide backwater up to Chongqing.

The key to selectng a normal reservoir level is attaining the correct balance between comprehensive utilization and the restrictive factor of the area to be inundated. Thorough comparison and research on technology and the economy showed that the other four plans were technically feasible and economically reasonable. Each plan differed in efficiency and degrees of resettlement difficulty, but the two-cascade alternative was clearly economically unreasonable.

Following repeated study and discussion, and the solicitation of opinions from departments in charge and local governments, a scheme of "one-cascade development, one-time construction, phased water storage and continuous resettlement" was recommended. Its main contents included:

- The construction of a key project in the stretch from Three Gorges to Chongqing;
- The building of a dam with an eventual elevation of 185 meters; and,
- Storage of reservoir water at 156 meters in the initial stage and 175 meters in the final stage.

A unified plan provided for the uninterrupted relocation of residents. This scheme better harmonized the contradicting requirements for comprehensive utilization and the restrictive factors of resettlement and silting.

Setting the initial stage of water storage level at 156 meters provides numerous advantages, while the final level of 175 meters can basically meet needs for flood control, electricity generation and navigation (including supplying sufficient water level for direct access of 10,000-ton towboats to Chongqing). The reservoir's backwater in the initial stage cannot reach Chongqing, thus ensuring that deposits of sedimentation would not affect Chongqing harbor. The problem concerning the impact of silting on Chongqing harbor in final stages can be resolved by adopting other measures. The low water storage level in the initial stage will halve the number of persons who will need to be resettled, greatly reducing difficulties involved in their resettlement. This recommended scheme for development has been submitted to the Central Committee and the State Council for approval.

Urgency & Necessity for Flood Control

The debate over whether to start construction of the Three Gorges Project has been unprecedented in world history in terms of its duration, scope and thoroughness of study. Now, a consensus has been reached on the important issues. The urgency and necessity of flood control, in particular, has drawn special attention from the people.

A Chinese proverb says, "it is wise to weigh the advantages and disadvantages before a commitment to action." The question of whether a construction project should be undertaken hinges not only on its technical feasibility but, more importantly, on its economic benefits. In other words, gains must be weighed against losses.

There is no denying the fact that the Three Gorges Project entails some disadvantages. For example, it will take a long time to complete and require a huge amount of capital. Even if it were started now, it would not bring any economic returns before the end of the century. In addition, it will have some impact on the environment.

However, it should be noted that it possesses great potential to promote China's modernization. It occupies an important strategic position in the national economy and it will bring unparalleled comprehensive benefits to the nation in terms of flood control, generation of electricity, shipping, water supplies and the breeding of aquatic products.

As is common knowledge, flooding causes considerable losses to China's national economy. The Yangtze valley (the river's middle and lower reaches in particular) is vulnerable to serious flood disasters. Historical records show that during the 2,000 years from the Han Dynasty (206 B.C.-220 A.D.) to the late years of the Qing Dynasty (1644-1911) serious flooding swept the Yangtze 214 times. This century has so far seen three immense floods, two of which (one in 1931 and the other in 1935) submerged 3,393,300 and 1,509,333 hectares of farmland and killed 145,000 and 142,000 people, respectively. Although the 1954 floodwaters of the Yangtze failed to destroy the Jingjiang Dike and rush into the city of Wuhan, an area of 3,170,000 hectares of farmland was inundated, 18.88 million people became victims and 30,000 others were killed. Direct losses from the flood reached more than 10 billion yuan. In addition, the country suffered incalculable, indirect losses from the flood (such as the Beijing-Guangzhou railway line being unable to offer normal services for 100 days).

Therefore, the control of flooding in the middle and lower reaches of the Yangtze has become a major task since the founding of the New China in 1949. Based on a careful analysis of flooding characteristics and the socioeconomic and natural conditions of the region, Chinese water conservancy specialists have worked out plans to prevent floods (see Figure 2). The basic principle behind these plans is the adoption of comprehensive measures, which include elevated river dikes, flood detention areas on the plains, reservoirs along the Yangtze and its tributaries, and strengthening of river course regulation in the middle and lower reaches, as well as water and soil conservation in the upper reaches.

In conjunction with flood forecast and prevention measures, large-scale flood control construction has been carried out over the past 40 years. A total of 30,000 kilometers of dikes have been reinforced and heightened using over 4 billion cubic meters of earth and stone. The Jingjiang and Dujiatai flood-diversion projects have been completed. Arrangements were made for a group of diversion and detention areas providing flood detention capacity of 50 billion cubic meters. A group of multipurpose reservoirs such as the Danjiangkou Reservoir have been built and river courses improved. At present, efforts have been made to reinforce key dikes to the water levels defined in the 1980 flood-control plan. However, although remarkable achievements have been obtained in flood-control work (which has played an important role in ensuring economic development in the middle and lower reaches), the flood-control situation still requires additional attention.

The main reason behind the serious flood threat in the middle and lower reaches of the Yangtze River is the high peak and large volume of the floodwater from torrential rainfall in the upper reaches when it exceeds the safe discharge capacity of the river. Currently, the safety limit in flow capacity along the Jingjiang section (including the flow towards Dongting Lake) is about 60,000 cubic meters per second, while for the Wuhan and downstream Hukou sections, it is 70,000 and 80,000 cubic meters per second, respectively. Data gathered since 1877 show there have been 24 floods in Yichang with peaks flow above 60,000 meters per second. In the 800 years after 1153, there were eight floods with peak flow larger than 80,000 cubic meters per second and five topped 90,000 cubic meters per second. During the 1860 and 1870 floods, at the Zhicheng Station at the entrance to the Jingjiang River the peak's flow reached 110,000 cubic meters per second — obviously greatly exceeding the safe flow capacity of the river.

This problem cannot be resolved by expanding the flow capacity of river courses. The above-mentioned safe flow capacity can only accommodate the flow of a 10- or 20-year frequency flood. When a larger flood occurs, flood diversion and detention measures need to be implemented to ensure safety in key areas and important cities. However, since the flood diversion and detention locations are all sited in developed areas, flood diversion can cause great losses. For example, if a flood like the one in 1954 were to recur, it would require the diversion and detention of 50 billion cubic meters of floodwater, which would inundate 667,000 hectares of cultivated land and lead to the temporary resettlement of about 5 million people, along with direct economic losses of about 20 billion yuan (calculated in terms of 1986 prices). Moreover, dikes would be breached

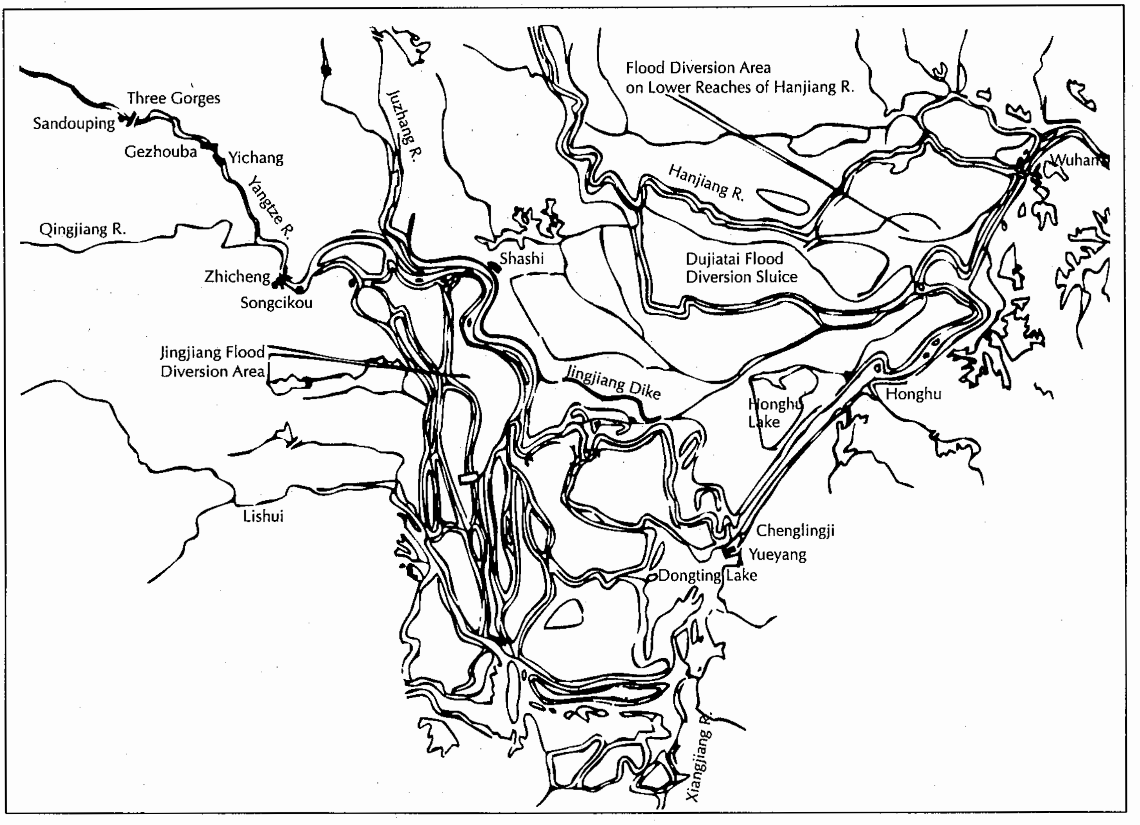

FIGURE 2. Yichang to Wuhan flood control map.

during flood diversion and detention operation. In cases where floods were not properly controlled, disasters would ensue in important areas and cause more serious losses.

The Jingjiang section is especially critical, even when flood diversion measures are used. It can safely handle up to a 40-year flood coming from Zhicheng and with water flowing at 80,000 cubic meters per second. If floods to the scale of those in 1860 and 1870 occurred (even after diversion measures were implemented), there would be an additional 30,000 cubic meters per second of flow that could not be safely discharged. This increased flow would cause the dikes to burst on both banks of the Jingjiang River. If the north bank were breached, the flood would spread across the Jianghan plains and could cause hundreds of thousands of human casualties. It would also seriously threaten the safety of Wuhan. If the south bank burst, the flood would directly flow into Dongting Lake, also leading to the deaths of tens of thousands of people. Such a burst in either bank would bring about serious consequences and far-reaching socioeconomic impacts. It could even disrupt China's four modernizations. The threat of especially large floods to this area is a major and serious problem for both the Yangtze and China as a whole.

Presently, Dongting Lake is still an important natural flood detention area in the middle reaches of the Yangtze River. During flood season, floodwaters from the Jingjiang River account for one-third or one-fourth of the water entering the Dongting Lake. The natural flood detention potential of the lake can reduce peak flow by about 10,000 cubic meters per second. It is obvious that its regulation and detention role remains of great significance for flood control in the middle reaches. If Dongting Lake shrivels until it disappears, it will further weaken the natural regulation it provides. The water level of small and medium floods in lake areas will rise further, making the issue of flood control in lake areas more glaring. Contradictions raised by balancing flood control between rivers and lakes will be aggravated.

Based on the research and evidence of specialists, it is necessary to adopt overall harnessing measures to solve the serious flood control issue. Such measures include heightening and reinforcing dikes, arranging for and setting up flood diversion and detention areas, building reservoirs in the Yangtze mainstream and tributaries, and realigning rivers, as well as improving flood forecasts and emergency response time. The most crucial of these measures is the building of the Three Gorges Project.

The Three Gorges Project is to be sited at the place where the Yangtze River's middle and upper reaches meet. Its unique location and topographical conditions, as well as its reservoir with a flood control storage capacity of 22.15 billion cubic meters, would enable it to effectively control floods resulting from heavy rains in the Yangtze's upper reaches. The project's flood prevention role would be decisive in the Jingjiang area, and it would also play a fairly good role in controlling floods of a whole-valley type and a middle-lower reach type. In addition to those two floodwaters, water from Yichang still constitutes the main part of a flood threat. Statistics show that as regards the total volume of floodwater during July and August in the worst flood years, floodwater from Yichang accounted for 95 percent of the Jingjiang river section, 61 to 80 percent at Chenglingji and 55 to 76 percent at Wuhan.

The Three Gorges reservoir, once completed, can raise flood control capacity from the present 10-year frequency to 100-year frequency. In addition, in case a flood larger than the 100-year frequency occurred, it could (if other temporary flood diversion works are used) prevent breaches of the Jingjiang dike and accompanying devastating destruction. Simultaneously, by effectively controlling upstream floods, it is possible to reduce any flood threat to Wuhan, reduce water and sand discharge into the Dongting Lake and ensure the safety of the lake's environs. It is estimated that such flood controls could save 970 million yuan annually (in 1986 prices). However, its benefits cannot be measured solely by economic criteria. If an exceptionally huge flood similar to that of 1870 should occur, the project would reduce losses caused by inundation by 35 billion yuan, and also prevent a great number of casualties caused by burst dikes.

If the Three Gorges Project was to be abandoned in favor of building reservoirs on the upper reaches of the Yangtze and its tributaries, these reservoirs would have some impact on the middle and lower reaches of the mainstream. However, they would not be able to control floods precipitated by torrential rainfall in the 300,000 square kilometers from the lower reaches of these reservoirs to Yichang. A serious flood threat to the Jingjiang area would still exist. The flood-control role of the Three Gorges Project cannot be replaced by other reservoirs in the upper reaches.

Some people fear that the Three Gorges Project might aggravate flooding in the upper reaches of the Yangtze. Experts have ruled out this possibility after a careful study on the potential impact of the project. People living below the normal water level of the reservoir, as well as at the level of a 20-year frequency flood, would be resettled in places above the safety line during the construction of the reservoir. If more severe floods should occur, part of the inhabited area at the end of the reservoir would be inundated but there would be far fewer flood victims than before the reservoir was constructed.

The 125,000 square kilometers of plains in the middle and lower reaches of the Yangtze River constitute China's relatively developed areas for industrial and agricultural production. Through years of flood-control efforts since liberation, earlier serious and frequent flood disasters have been toned down in scale. But at present, only 10- to 20-year frequency floods can be prevented. The dangers of mammoth floods still exist. Moreover, economic build-up in the region means that a substantial increase in losses would take place in the event of huge floods.

Over the last hundred years, we have not seen gargantuan floods like those of 1860 and 1870 but the possibility of exceptionally large floods is increasing. The 1991 flood disasters in the Huaihe River and the Taihu Lake and Shuhe River sections of the Yangtze River once again reminded people of the need to strengthen efforts to eliminate the serious threat of mammoth flooding in the middle and lower reaches of the river. They enhanced the sense of urgency to build the Three Gorges Project as soon as possible.

Other Benefits

Of the many benefits the Three Gorges Project promises, the most direct and most obvious will be its enormous ability to generate electricity.

Electricity Generation. The hydroelectric station for the Three Gorges Project will be the biggest in the world, with an installed capacity of 17,680 megawatts and an annual generation of 84 billion kilowatt hours. It will provide electricity mainly to central and east China and a small amount to eastern Sichuan. The amount of electricity generated would provide an alternative to the consumption of 40 million to 50 million tons of raw coal, and be equivalent to ten Daya Bay nuclear power stations or to seven 2.4 million kilowatt coal thermal power stations. It would replace coal mine production capacity by 50 million tons and reduce related railway transport costs.

The central and eastern regions of China are economically developed but the main factor limiting their progress is an insufficient supply of power. The coal resources of these two regions are very meager, accounting for 3.2 percent and 3.6 percent, respectively, of nationwide reserves. Unexploited water resources in eastern China have been used up while 70 percent of these resources in the central region are concentrated in the Three Gorges.

Under the electricity development plan for these two regions, in the years from 1986 to 2015 there will be the need for an installation of generators with 170,000 megawatt capacity. Even if the hydroelectric station at Three Gorges is built and other hydroelectric and nuclear stations are developed as far as possible, in 2015 the amount of coal taken from the northern coal base will come to 285 million tons, 13 times the 1985 figure. Coal mining, and particularly its transport, will face a grim situation. If the hydroelectric station at Three Gorges is not built but instead seven coal thermal power stations are constructed, the difficulties will be exacerbated and environmental pollution will worsen.

Coal resources along the Yangtze River are insufficient but water resources are rich. However, 80 percent of the water resources of the Yangtze River are concentrated in the mainstream and tributaries on the upper reaches west of Yichang. A hydroelectric station at Three Gorges, close to the power consumption and supply center, would be in an exceptionally advantageous geographical position. The distance for transmitting electricity to central China is under 500 kilometers and no more than 1,000 kilometers to east China. Detailed economic comparisons have indicated a hydroelectric station at Three Gorges would prove the best solution to the problem of supplying electricity to these two regions.

The huge amounts of energy it would generate could draw big profits and serve to repay loans. Even during the construction period, accumulated electricity output would reach 435.8 billion kilowatt hours and earn about 40 billion yuan at a rate of 9.2 *fen* per kilowatt hour. After normal operation commences, the annual income of the project from sales of electricity alone will amount to 7.5 billion yuan. After all loans are repaid, the project will be able to hand over 3.56 billion yuan annually to the state. Total profits and taxes turned over to the state treasury could reach 5.41 billion yuan annually.

In addition, by replacing an equivalent thermal power station, the Three Gorges Project will generate tremendous social and environmental benefits. It will reduce the consumption of coal by 40 million or 50 million tons every year and cut carbon dioxide, sulphur dioxide, carbon monoxide and nitrogen-oxide emissions by 100 million tons, 2 million tons and 10,000 tons and 370,000 tons, respectively. It will also greatly reduce the amount of industrial liquid waste and play a great role in cutting sources of environmental pollution (such as acid rain).

Shipping Benefits. The Yangtze River, with its mainstream and tributaries running through 18 provinces and cities, provides very favorable water transport conditions and has always been China's main transport artery linking its eastern, central and western regions. Its navigable mileage is more than 70,000 kilometers, accounting for 70 percent of the nation's inland navigation mileage. Its annual freight volume accounts for 80 percent of the country's riverborne freight, earning the Yangtze the name of the "Golden Waterway."

After the PRC was founded in 1949, the government conducted large-scale reconstruction work on the Yangtze River shipping facilities and ports. However, progress in navigation along the Yangtze still cannot meet the development needs of the national economy. In particular, the 660-kilometer-long section of the river from Yichang in Hubei Province to Chongqing in Sichuan Province is difficult to navigate since it runs through hills, high mountains and gorges, with a 120-meter drop and a swift current. There are 139 dangerous shoals and 46 one-way control sections. The section is not wide or deep enough for the passage of large ships. All these factors create many problems such as a low towing capacity and high overland freight costs.

The Three Gorges Project, if constructed, will completely change navigation conditions on the section from Yichang to Chongqing. Once it is completed, 10,000-ton towboats will be able to sail right up to Chongqing because the shoals will be eliminated, shipping lanes will become deeper and wider, and the river current will slow down. With the construction of ports and the modernization of ships, annual shipping capacity will increase to 50 million tons from the present 10 million tons and transport costs will be cut by 35 to 37 percent.

In dry seasons, the minimum river flow will increase about 2,000 cubic meters per second as a direct result of the project. Such a regulatory role will not only facilitate shipping on the Jingjiang River, but will also help strengthen ties between the three economic zones of eastern, central and southwestern China and promote economic development along the Yangtze River.

The construction of the Three Gorges Project will also play a comprehensive role in fish breeding, city water supplies and provision of adequate water resources for the transfer of water from the south to the north.

Investment Assessment & Analysis

How much investment does the Three Gorges Project require? Opinions vary. The answers range from a few dozen billion to several hundred billion yuan. Some analysts liken the investment to fishing, saying that the amount of investment is small at the beginning but grows larger later. Some even go so far as to say that investing in the project is like throwing money into a bottomless pit.

Amount of Investment. True, the cost of the Three Gorges Project will be huge in comparison with other large projects already built as well as those already under construction in China. However, the amount is not unknown, as some outsiders have asserted. Investment in a hydroelectric power project usually covers expenses on construction, machinery and electric equipment as well as the resettlement of residents. Once the geological conditions are determined and designs are drawn up, the cost of the project can, by and large, be calculated.

Based on the plan recommended by the feasibility study report, and in accordance with related state regulations on investment assessment and 1990 prices, "static" investment in the project (excluding interest and any price hikes during construction) will reach 57 billion yuan. Of this amount, 29.8 billion yuan will go toward project construction, 18.5 billion yuan for resettlement and 8.7 billion yuan for power transmission and transformation.

It is unlikely that any major items have been inadvertently excluded since research on the hydrological and geological conditions as well as design work have been repeatedly examined over the years. Therefore, the estimated amount of funds needed could be considered to be on a solid basis. Moreover, the feasibility study stipulates that an additional 10 percent be added in to the total estimated to account for unforeseen costs. It should be said that the investment budget has left some margin. Calculations were performed along the lines commonly used in China's other water conservancy and hydroelectric projects.

Is the Project Worth the Investment? The Three Gorges Project is undoubtedly the largest and most costly of all the hydropower projects China has ever completed or planned. Is putting such a huge amount of money into the Three Gorges Project worthwhile? Is the project financially beneficial?

When reappraising the project, experts compared it with a number of other projects under construction or in the planning stages (see Table 1). The table shows that in comparison with other hydropower projects:

TABLE 1.
A Comparison Between the Three Gorges Project & Other Hydroelectric Power Projects for Every 10,000 Kilowatt Hours Generated

Project	Concrete (buci meters)	Stone Work (cubic meters)	Earth Work (cubic meters)	Number of People to Be Resettled	Farmland to Be Submerged (mu = 0.067 hectare)
Three Gorges	3	119	54	1,347	513
Wuqiangxi	6	8,512	74	1,575	819
Geheyan	10	4,619	67	653	493
Dongjiang	12	9,531	67	3,980	4,354
Yantan	6	931	97	764	878
Ertan	3	677	94	181	153
Manwan	3	3,521	47	48	74
Longyangxia	5	66	32	496	1,378

- The scale of resettlement per unit of power generated for the Three Gorges Project is high;
- The amount of farmland to be submerged (per unit power) is in the middle; and,
- The amounts of engineering work and investment, as well as costs per unit of power, are comparatively low.

In order to thoroughly re-confirm the economic basis of the Three Gorges Project, national economic and financial assessments have been made in accordance with the State Planning Commission's stipulations on the economic assessment of the construction project.

During the national economic evaluation, the state stipulated discount rates and shadow prices (the value assigned to something when a market price is not available) were adopted. Dynamic calculation was conducted on the basis of multiple scenarios such as variations in input and output, equivalent substitution and commencement of construction. The conclusion reached was that the internal rate of return on investment in the project would be 14.5 percent, exceeding the state criterion for evaluation. Therefore, the project is viewed as economically feasible. The differential investment internal benefit rate for beginning construction as soon as possible as opposed to delaying construction is 16.5 percent, indicating that it is more beneficial to build earlier rather than later.

The result of an economic sensitivity analysis shows that if any crucial factors change unfavorably, they will not affect the conclusion. An economic risk analysis indicates that the risk probability value of the project is only 1.2 percent, which is minimal.

Financial feasibility was also analyzed on the basis of China's current financial and tax systems and prices. The conclusion was that the price of electricity to be generated by the Three Gorges power station will be low (9.3 fen per kilowatt hour in 1986 prices). Various finance indicators are also good. The internal financial rate of return will be 11 percent, and the profit and tax rate will be 12.1 percent. The project has a strong capability to return loans. All loans will be repaid and all investments will be recovered the year following completion. A project of this high caliber has been rare in China. Therefore, it is worthy of investment.

Can the State Afford It? At present, China is in a rather difficult financial situation and is undertaking reforms. Under these circumstances, can the nation afford to start construction of the Three Gorges Project right away? This question is crucial to construction of the project.

Gross national product (GNP) and national income are the major barometers of a country's national economic strength. A macro-

TABLE 2.
A Comparison of the Three Gorges Project & Newly Built Power Stations in Terms of Per-Unit Investment

Power Station	Investment in Power Station (100 million yuan)	Investment in Transmission Facilities (100 million yuan)	Investment in Installed Generating Capacity (100 million yuan)	Investment in Electricity Generated (yuan per kilowatt hour)	Operating & Maintenance Cost of Electricity Generated (0.01 yuan per kilowatt hour)
Three Gorges (Costs Not Shared)	301.83	62.82	2,218	0.44	1.7
Three Gorges (Costs Shared)	266.37	62.82	1,759	0.35	1.4
Tankeng	12.8	1.2	2,456	1.61	5.9
Shidi	12.84	2.6	1,825	1.15	4
Jiangya	7.4	0.62	287	0.88	3.2
Pankou	9.92	0	2,047	0.9	3.5
Shuibuya	32.04	4.2	2,494	0.67	2.6
Goupitan	36.43	7.2	2,346	0.45	1.8
Shatuo	15.97	3.36	2,598	0.46	1.8
Silin	15.07	3.36	2,360	0.46	1.8
Pengshui	24.13	4.1	2,530	0.44	1.6
Xiangjiaba	74.1	40.8	2,580	0.46	1.9
Xiluodu	116.7	91	2,315	0.43	1.9
East China 600,000-kilowatt coal thermal	9.42	1.2	2,006.8	0.38	6.3
East China 600,000-kilowatt coal thermal (including railway to coal mine)	13.38	1.2	2,780	0.53	6.3
Central China 600,000-kilowatt coal thermal	8.46	1.2	1,823.7	0.34	6
Central China 600,000-kilowatt coal thermal (including coal mine & railway)	12.42	1.2	2,467	0.49	6

judgment of a country's ability to undertake a project can be made from the proportion of the total investment to the GNP and national income. Investment in the Three Gorges Project will account for 0.073 percent of China's GNP and 0.123 percent of the national income. Both figures are lower than those for Egypt's Aswan Hydropower Station and the Itapua Hydropower Station built jointly by Brazil and Paraguay. They also rank below those for the Shanghai Baoshan Iron and Steel Complex and the Sichuan Panzhihua Iron and Steel Complex.

It is estimated that the Three Gorges Project will need 10.82 million tons of cement, 1.95 million tons of rolled steel and 1.60 million cubic meters of timber. The Three Gorges Project will consume 0.33 percent, 0.197 percent and 0.133 to 0.123 percent, respectively, of the total national output of these materials. All of those percentages are affordable. Certain quantities of timber and rolled steel can be imported in the event of a shortage.

There is the view that during the construction of the Three Gorges Project price hikes and interest charges will greatly increase the costs of the project. It is undeniable that since China is currently in the process of instituting economic reforms and straightening out its pricing system, price increases for certain raw materials and a slight degree of inflation are unavoidable, but these factors would be offset by an increase in the amount of investment. However, it should be noted that as the prices of materials rise, the price of output (electricity) also will have to increase accordingly. Therefore, generally speaking, price hikes do not affect the conclusion drawn from the economic appraisal and financial evaluation of the Three Gorges Project. In the face of a rational price rise, the national economy can still develop normally, and the conclusion based on an analysis of national strength will not change.

When making a national economic appraisal of the project, according to state regulations consideration should not be given to interest because, if the national economy is viewed as a whole, interest belongs to the internal shift of state funds and is not an "item" in state financial expenditures. But when making a financial evaluation of the project in accordance with the current stipulated financial and tax systems and current prices, it is necessary to consider interest factors. It is inappropriate to regard "principal and interest" as the project investment.

Funds Collection. Stable and reliable financial sources need to be considered for the building of the project. Though the amount of investment required for the project is great, it can be attained as long as the PRC adopts multiple ways to raise funds over the course of the nearly 20-year construction sequence.

First of all, the Gezhouba Project, a coordinated part of the Three Gorges Project, has already been completed. The annual electricity output of the Gezhouba Hydroelectric Power Station is 15.7 billion kilowatt hours. But the current cost of electricity is relatively low at only 3.9 fen per kilowatt hours. If this fee can be properly raised, it can be used as a major financial source for the initial construction of the Three Gorges Project.

Secondly, two generating units providing a total of 1,360 megawatts will be put into operation in the ninth year after the formal start of project construction. After that, four units totaling 2,720 megawatts will be started up each year. During the construction period, an aggregate 435.8 billion kilowatt hours and 40 billion yuan in revenue can be earned. At the same time, when the project begins to generate electricity, the amount of capital input will have accounted for only half of total investment. Thus, remaining fund requirements may be mainly self-sustaining.

In addition, efforts will be made to raise funds for the project by undertaking capital construction investment within the budget, loans from domestic banks, use of foreign capital, collection of a water and electricity construction fund, local fund-raising shares in central and east China, issuing bonds for the construction of the project and allocation of special funds from the nation's central finance. Through economic improvement and rectification, China's economic status has further strengthened. Therefore, China can afford spending money on the project by raising funds through multiple channels, by relying on the people throughout the country to carry forward the fine tradition of plain living and hard struggle, building the nation through thrift and solid work.

Technical Feasibility

Since it is China's biggest water conservancy project, Three Gorges will certainly face many complicated technical problems. For years, China's water conservancy specialists have gained much advanced experience, both at home and abroad, with the help and cooperation of related national economic departments, scientific research institutes and institutions of higher learning. Their conclusion is that although comparatively complicated technical problems exist in the project, they fall within China's technical capability and none are insoluble and, therefore, the scheme is technically feasible.

Reliable Data. China's experience from the lessons learnt from the construction of water conservancy projects over the past 40 years indicates that the success or failure of such a project hinges on the reliability of basic hydrological and geological data. Examples of projects both at home and abroad that failed, were delayed, faced increased investment or did not achieve the anticipated results on completion have been commonly reviewed. All of these projects were affected by problems in the areas of hydrology and geology.

Complete, accurate and reliable data exist for the Three Gorges Project. This information provides a solid foundation for guaranteeing the technological feasibility of the project. The hydrological data for the Three Gorges Project are comprehensive and reliable. The hydrological stations at Yichang (near the dam site) and at Cuntan (at the end of the reservoir) have collected hydrological data for over 109 and 94 years, respectively. Such a background is a rare occurrence both at home and abroad.

To meet the need of the designs for the Three Gorges Project, repeated surveys of floods down through history have been undertaken. Traces have been uncovered of more than 1,200 instances of flooding since 1153 along the 660-kilometer section of waterways from Chongqing to Yichang. The data collected on the immense floods in 1788, 1860 and 1870 are highly accurate. Experts have on numerous occasions referred to their veracity, depth and exactitude of their dating.

Surveys of silting along the Yangtze have a long history. Nearly 40 years of data have been accumulated from them and they are a reliable source for designing the project.

The Three Gorges Dam is to be built on a base of intact solid granite. Both Chinese and foreign engineers and geologists rate the site as an excellent one for a dam. Geological studies that cover various aspects connected with the project construction have been conducted for more than three decades. Regular and advanced surveys — as well as advanced testing technology — have been used in the process. A drilling hole at the dam site in Sandouping extends down 1,000 meters and there have been nine exploratory adits. More than 4,000 sets of rock mechanics tests have been carried out, and over 140 main findings have been submitted to the authorities involved. Major nationwide meetings have been convened to discuss and review geological issues on 14 occasions. Consequently, geological research for the Three Gorges Project is adequately broad and deep, providing a favorable foundation for the project construction.

Design & Construction. The main buildings of the Three Gorges Project consist of the dam, a hydroelectric station and navigation structures. Main features of the project are listed in Table 3. The Three Gorges Dam will be a conventional concrete gravity type dam 175 meters high (see Figures 3, 4 and 5 on pages 57 and 58). Rich experience has been accumulated in the construction of high concrete dams both in China and abroad. Twenty-five concrete dams over 200 meters high have been completed including the 285-meter-high Grand Dixence Dam in Switzerland. China has built the 177-meter-high Longyangxia Dam on the Yellow River. Work has recently started on the 240-meter Ertan arch-dam on the Yalong River. With the favorable geological conditions of the Three Gorges Dam, China is more certain of its ability in mastering the necessary design and construction technology.

Although the hydroelectric station at Three Gorges will be huge and its total installed capacity will be the largest in the world, its shape, layout and size will resemble other large powerhouses in both China and overseas. Therefore, there are no difficult technological problems to be resolved.

The permanent navigation structures will consist of a double-line of five-step continuous shiplocks. The chamber size of all the locks will be the same as at Gezhouba. The maximum water head of operation and maximum discharging capacity of the locks are higher than similar ones constructed both in and outside China, but the major technological problems can be resolved after extensive study and experimentation.

The maximum water head and maximum navigation tonnage for the shiplift will be higher than at completed projects in other domestic and overseas projects. The recommended scheme, based on conventional technology, was drawn from many years of design work and scientific research, plus from experience learnt from examining the operations of shiplifts in other countries. As such, design and manufacturing as well as navigation safety will be assured. At present, the Chinese government has decided to construct a medium-term experimental shiplift on the Geheyan Project for the Qing River, to develop relevant experience for the shiplift at Three Gorges.

TABLE 3.
Main Features of the Three Gorges Project

Reservoir		
	Initial Stage	*Final Stage*
Normal Pool Level (m)	156	175
Flood Control Level (m)	135	145
Dry Season Drawdown Level (m)	140	155
Level of 1,000-Year Flood (m)	170	175
Total Storage Capacity Below Normal Pool Level ($10^9 m^3$)	23.5	39.3
Flood Control Storage at Normal Pool Level ($10^9 m^3$)	11.1	22.15
Active Storage ($10^9 m^3$)	8.9	16.5
Regulated Discharge During Dry Season (m^3/sec)	5,130	5,860
Improvement of Navigation Channel (km)	500-570	570-650
Main Structures		
Concrete Gravity Dam		
Dam Crest (m)	185	
Maximum Height of Dam (m)	175	
Power Station at Downstream Toe of Dam		
Installed Capacity (MW)	17,680	
Mean Annual Power Generation (10^9kwh)	70 (initial)	84 (final)
Number of Generating Units	26	
Generating Unit Capacity (MW)	680	
Double-Line, Five-Step Permanent Navigation Locks		
Effective Lock Chamber Size (m)	280 × 34 × 5	
Single-Line, One-Step Shiplift		
Effective Size of the Lift Chamber	120 × 18 × 3.5	
Reservoir Inundation		
Farmland (hectares)	23,793	
Citrus Orchard (hectares)	74,960	
Population of Inundated Area as of 1985	725,500	
Estimated Population to Be Resettled by 2008	1,131,800	
Construction		
Earth Rock Excavation ($10^6 m^3$)	87.89	
Earth Rock Fill ($10^6 m^3$)	31.24	
Concrete Placement ($10^6 m^3$)	26.89	
Rolled Steel (10^6ton)	255,200	
Reinforcing Bars (ton)	290,100	
Total Construction Period (years — includes 3 years of construction preparation)	18	
Period Before First Batch of Power-Generating Units Are Commissioned (years)	12	
Cost (static, in 1990 prices)		
Total Costs (10^9yuan)	57.0	
Project Constuction (10^9yuan)	29.8	
Resettlement Efforts (10^9yuan)	18.5	
Power Transmission (10^9yuan)	8.7	

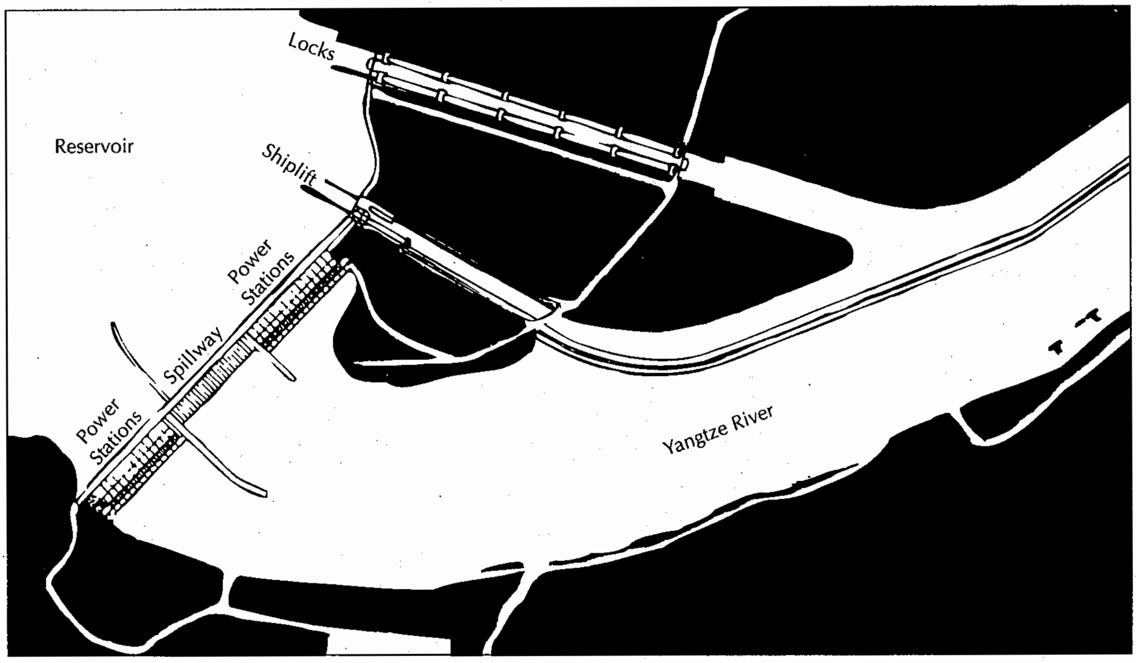

FIGURE 3. Layout of the Three Gorges Project.

The most striking feature of the Three Gorges Project is its gargantuan scale. The civil engineering work will be 2 to 2.5 times that of the Gezhouba Project. Construction will entail some difficulties but the technical problems are not insoluble.

The PRC has accumulated rich experience in water conservancy construction work since its founding. The construction of the Gezhouba Project especially raised this experience to new heights and resulted in a highly trained corps of technicians. Gezhouba has established a comprehensive base for the construction of the Three Gorges Project. A tremendous amount of highly professional work needs to be done on Three Gorges during the construction stage. This work also will necessitate using highly sophisticated machinery. During the building of the Gezhouba Project, 2 million cubic meters of concrete were poured into the structures each year. For the Three Gorges Dam, the concrete volume may reach 4 million cubic meters during the peak years.

To increase construction efficiency, speed up construction and ensure faster benefits generated by the project, advanced technology and machinery will be introduced from overseas.

Turbogenerator & High-Tension Transmission Technology. The installed capacity of each turbogenerator at the Three Gorges hydroelectric station will be 680,000 kilowatts. Since the 1970s, over 50 turbogenerator units of 500,000 to 700,000 kilowatts have gone into operation one after another overseas. The technology for their manufacture and installation has matured. At present, China's most powerful turbogenerator unit delivers 300,000 kilowatts. The installed capacity of the units at the Ertan hydroelectric power station (currently under construction and due to go on-line in the late 1990s) will be 550,000 kilowatts. Results jointly scrutinized by China's design and scientific research institutions and manufacturers indicate that China can make the turbogenerator units for the Three Gorges power station but it will require some technical transformation and the import of advanced technology. To ensure the quality of the units, China will first import several turbogenerators and then manufacture them on its own or in cooperation with foreign companies.

The Three Gorges Project hydroelectric power station will transmit 500-kilovolt alternating current and ±500 kilovolts direct current. Several 500-kilovolt AC transmission

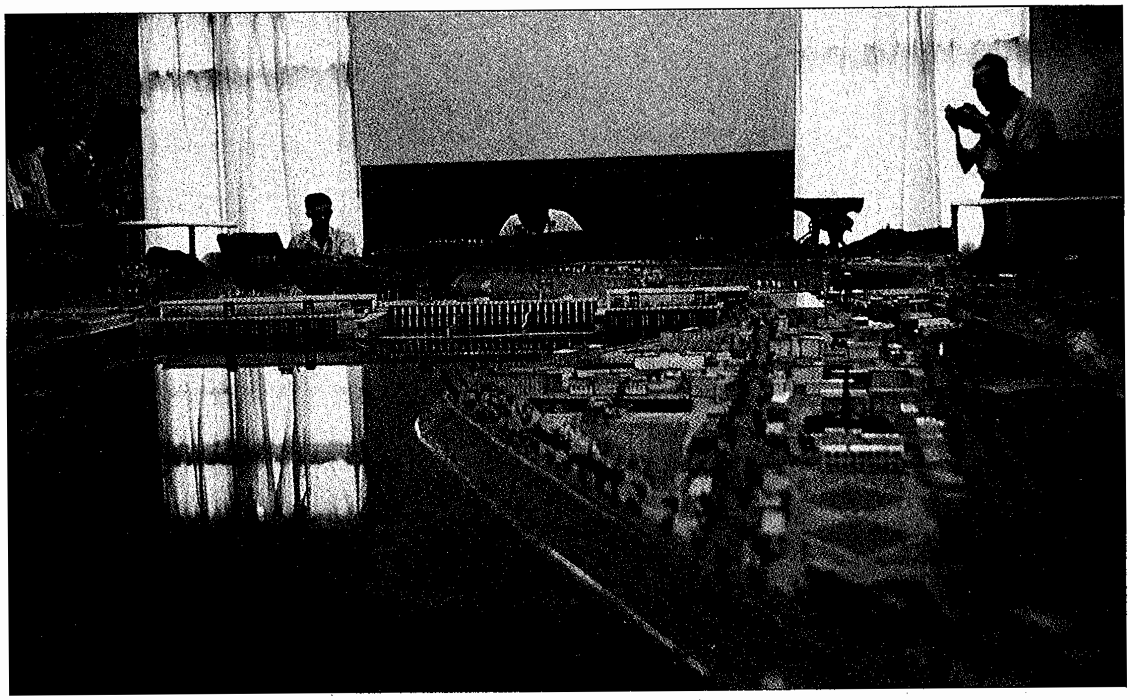

FIGURE 4. A model of the Three Gorges dam on display at the Visitor's Center in Yichang.

lines have been erected in China. In addition, several ±500-kilovolt direct current lines have been installed between Gezhouba and Shanghai. Feasibility studies have concluded that most of the equipment can be made by China except for a few key items that may have to be imported.

Reservoir-Induced Earthquakes & Landslides

One major project concern is whether the huge reservoir will induce earthquakes and trigger landslides, thus affecting project safety and suspending navigation on the river.

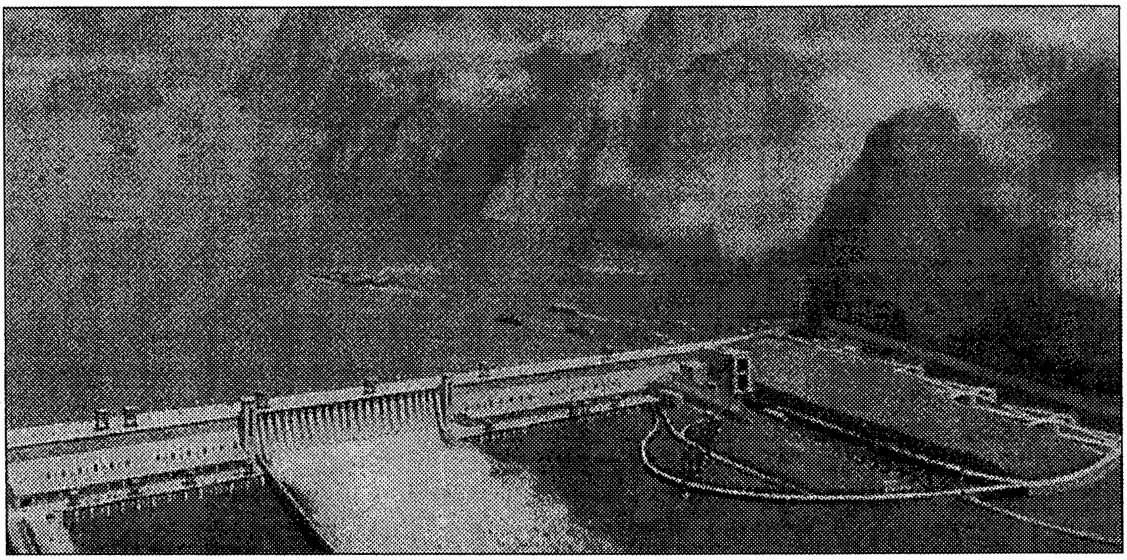

FIGURE 5. An artist's rendering of the Three Gorges dam.

Earthquakes. Although large dams have been constructed for several thousand years, the study of reservoir-induced earthquakes began only decades ago. To date, no one can give a complete and accurate answer to the question about the formation mechanism and the process of earthquakes since knowledge on the subject is limited. Nevertheless, some insight has been acquired into the general laws governing the formation of earthquakes and their potential damage.

Up to now the world has not witnessed the destruction of a dam caused by a reservoir-induced earthquake. Even the two most severe quakes set off in such circumstances, one in India and the other in China's Xinfeng River reservoir, caused only slight damage to the dams. These earthquakes had magnitudes of 6.5 and 6.1, respectively, on the Richter scale and an intensity of 8 at their epicenters. Following partial repairs and reinforcement, the dams resumed normal operation. Most other earthquakes have been under a magnitude of 2 to 4 on the Richter scale and all occurred soon after a reservoir was filled with water. With the gradual adjustment of stress on structures over time, the tremors have died away.

Based on these facts, geologists, seismologists and engineers maintain that as long as the investigation and adequate work is done in advance and sufficient estimations are made, induced earthquakes, if any, will not pose a serious threat to the dam. The salient point is that not every reservoir inevitably causes earthquakes. According to incomplete statistics, only about 100 reservoirs (or 0.1 percent of the world total) have induced earthquakes. The world register book and figures from the United States Dam Committee indicate that only 0.7 percent of large reservoirs have the potential to cause earthquakes of any practical significance. China's statistics show that only 5 percent of its reservoirs — each with a storage capacity of more than 100 million cubic meters of water — have set off tremors.

While the evidence indicates that reservoir-induced quakes may not necessarily occur, their likelihood increases under particular conditions. A publicly acknowledged international view holds that strong (stronger than 4 on the Richter scale) earthquakes are closely related to a region's geological and seismic conditions.

The Three Gorges Project is located in an area where the earth's crust is relatively stable, ruling out the possibility of any major ruptures or other abnormal geological features that might trigger strong earthquakes. Moreover, a look at the map showing the distribution of seismic intensity and epicenters in China reveals that the Three Gorges area is far from all major regions of earthquake activity. The upper part of the reservoir is in the eastern Sichuan Basin, an area with low earthquake intensity (below 6), and most of the reservoir's lower parts and adjacent areas of the dam site are below 6 in intensity. Earthquake activity is relatively weak in these areas.

Historical records covering the past 2,000 years show that no destructive earthquakes have ever occurred within a 300-kilometer radius of the site of the dam. Four earthquakes measuring between 6 and 6.5 in magnitude (all with an intensity of 8 at the epicenter) have been reported in localities 200 kilometers from the dam. Tremors of 5 to 6 magnitude have taken place about 130 kilometers away. No devastating earthquakes have been recorded at the site of the Three Gorges Dam and the reservoir area or in a dozen adjacent counties and cities.

Since 1959, China has set up seven seismic monitoring stations in the dam's vicinity. A total of 1,019 shocks of a magnitude of 1 or higher have been recorded within a 300-kilometer radius of the dam site. Of these tremors, three were of 4.8 to 5.1 magnitude but they all happened 60 to 70 kilometers away. Moreover, although their intensity was 6 at the epicenter, the intensity decreased to less than 5 at the site. In the past 30 years, only ten or so tremors with a magnitude of less than 2 have been recorded within the huge Huangling crystalline rock massif on which the Three Gorges dam will be based.

All the evidence indicates that the Three Gorges Project is not located in a dangerous seismic area. It would be hard to find an area of weaker seismic activity elsewhere in China. Based on four appraisals (the last — made in 1987 — was examined and approved by the State Commission for the Appraisal of Earthquake Intensity), state geophysical and seismic departments have determined the area's basic earthquake intensity at 6. The conclusion by experts is that the site of the Three Gorges Project lies in a typically weak seismic environment.

Nevertheless, when the enormous scale of the project and its important geographical position are taken into consideration, the intensity of any potential earthquake (whether natural or induced by the reservoir) that might occur at the dam site will not be over 6 (estimated in terms of the worst situation), the project is being designed to withstand an earthquake with an intensity of 7. Therefore, there is much leeway left for resistance to seismic destruction.

Landslides. Could the Three Gorges Project, after its completion, cause large-scale collapse of the reservoir banks, silt up the reservoir and block the river? Could these landslides generate surging waves and threaten the safety of the dam?

Studies of the stability of the reservoir slopes have been going on for several decades. Particularly in recent years, a number of state departments — including the Yangtze Valley Planning Office, the Ministry of Geology and Mineral Resources, the Chinese Academy of Sciences and the Ministry of Water Resources and Electric Power, as well as the geological and mineral departments of Hubei and Sichuan provinces — have conducted a huge amount of research. To facilitate their work, they employed various advanced methods — such as aerial remote sensing, surging wave model testing and calculation, analysis of stability sensitivity and deformation monitoring. Their separate efforts have all produced similar findings in terms of estimating the number and magnitude of collapses and landslides. It can be said with certainty that sufficient data have been acquired about the basic conditions of the reservoir banks, potential rockfalls or slides of a volume of over 1 million cubic meters and their impact on nearby cities and towns. These studies indicate that the reservoir slopes are very stable.

Prospecting surveys have shown that the banks of the Three Gorges Reservoir are composed mainly of solid or semi-solid rock. Only a few faults have been found in the area and the incidence of neo-tectonic movement and earthquakes is low. On the whole, these banks are much more stable than the river banks in the country's western mountainous areas. About 90 percent of the 1,300-kilometer-long reservoir banks are stable or fairly secure and only 8.8 percent are not very stable. The only really unstable section is merely 16 kilometers long, just 1.2 percent of the reservoir's total shoreline.

Of the total 140 landslides and rockfalls counted — each measuring 1 million cubic meters or more in size — eight are precarious and an additional 14 are stable now but may buckle after the reservoir is filled with water. However, given the overall stable condition of the slopes and the stability of the existing slide areas, the slopes of the Three Gorges Reservoir are basically firm.

Along the 1,300-kilometer-long banks there are 22 large slopes that are unstable or may become so once the reservoir is filled with water. These slopes vary in size from several million to 80 million cubic meters. The result of an analysis and calculation of several large slopes show that after the formation of the Three Gorges Reservoir, any slope failure will not clog the Yangtze.

In addition, the Three Gorges Project and Sichuan Province sections of the Yangtze are quite narrow due to high mountains and steep slopes. In this section, a large landslide has the potential to create dangerous shoals in the river, which would hinder navigation. However, after the reservoir is filled with water, the river would broaden and the water deepen in these sections. A landslide, which may hinder navigation under natural conditions, will not do so under the new situation. For instance, the 1985 landslide in Xiantan, Hubei Province, hurled 2.6 million cubic meters of earth and stone into the river, forming a 55-meter-high hillock, the top of which projected five meters above the water level in the dry season before the construction of the Gezhouba Reservoir. However, the existence of the reservoir, which began storing water in 1981, has resulted in the water level of the river's Xintan section standing at about 65 meters all year round, or about 10 meters higher than the top of the landslide-created hillock, making the river now deep enough for normal navigation.

This example indicates that any collapse of slopes that might occur after the Three Gorges reservoir is built would not clog the Yangtze nor form a blockage. Moreover, the total mass of the 22 unstable slopes is only 380 million cubic meters. Even if the entire bulk slid into the reservoir, it would only fill up 2.2 percent of the reservoir at the 145-meter water level and would not threaten either the reservoir's enormous storage capacity or its service life.

Surveys also indicate that there are no large, potentially unstable slopes within 26 kilometers of the dam. Calculations and model testing predict that any surging waves generated by large unstable slopes would not threaten the safety of the dam or other structures.

The Problem of Sedimentation

Sedimentation at the Three Gorges Project is a problem of concern to Chinese water conservancy experts and their foreign counterparts. Extensive studies on sedimentation in the Three Gorges Reservoir began in the 1950s. The solution to the problem of sedimentation achieved in the Gezhouba Water Conservancy Project in Hubei Province during the 1970s and 1980s laid the foundation for similar work on the Three Gorges Project.

Since 1983, China has organized thorough research on the sedimentation problem of the Three Gorges Project by national sedimentation experts. In addition to conducting surveys and investigations as well as performing calculations using mathematical models, China has drawn up nine models to examine sedimentation in the reservoir's fluctuating backwater regions and two more to study sedimentation at the dam site. Research has also been carried out concerning the reservoir's impact on downstream riverbed erosion, on the development of shoals and on the river estuary. Such a series of sedimentation studies is rare in the history of water conservancy project construction, either in China or abroad, in terms of its thoroughness and meticulousness.

The main sedimentation problems that may crop up in the Three Gorges Project include:

- Will the reservoir become useless when it is silted up?
- Will a change in the channel of the backwater region constitute an obstacle to navigation due to sedimentation?
- Will the flood level forced up by sedimentation at the end of the reservoir pose a threat to Chongqing?

After conducting extensive studies, sedimentation experts have concluded that these problems can be overcome.

Sediment Load. How much sediment could enter the reservoir? According to the Yichang Hydrologic Station's 30-year survey, the Yangtze River's suspended load averages 526 million tons annually and the bed load is 8.6 million tons (which includes 760,000 tons of cobbles).

In recent years, some people have noted that the sediment yield in the Yangtze has increased due to serious soil erosion in the upper reaches, plus the influence of human activities. Repeated analysis of data and numerous discussions by experts have reached the conclusion that sediment yield on the upper reaches of the Yangtze changes in an irregular, periodic manner. In the early 1980s, the runoff and sediment yield did not exceed their normal limits, even though they were at their peak, which conforms with the law governing the change of sediment in the upper reaches of the Yangtze. In the years after 1985, the sediment yield once again dropped below average. It is true that the sediment yield increased over several years in the early 1980s, but it does not follow that sediment from upstream of the Three Gorges tends to build up.

Can the Reservoir Function Over a Long Period? The Three Gorges Reservoir will be a stream-channel type with a length of over 600 kilometers and an average width of 1,100 meters. Although the water level will rise after the reservoir is filled with water and the water velocity in the reservoir will decrease, the flow will still be able to shift some sediment, unlike the case in a lake reservoir, where wide beaches on either side of the main trough can easily be silted up. The Three Gorges Reservoir offers geographical conditions that are favorable to the removal of sediment.

To ensure that the Three Gorges Reservoir maintains a permanent, effective storage capacity, a method of operation that impounds clear water and releases muddy water was suggested on the basis of the law governing sediment movement as well as on the basis of successful engineering results at home and abroad. As designed, the dam would be equipped with adequate flood-discharge and sediment-release facilities. During flood periods, when more sediment washes down from the upper reaches, the reservoir would operate at a low water level to allow more sediment to move out. The remaining sediment would be kept mostly in the dead reservoir. At the end of flood period when there is less sediment, the reservoir is filled with water for use during dry periods. Such a method of operation is basically identical with the project's flood control requirements. For the sake of flood control, it would be necessary to keep the reservoir at a low level even during flood periods, in order to reserve more space for storing flood water. In other words, the reservoir would operate under a low water level when normal floods occurred and would store excess flow to raise the water level in the event of major floods. The water level would be lowered once again when the flood waters retreated. The Three Gorges Reservoir could release the sediment deposited during the flood-control periods.

The reservoir is designed to have a normal pool level of 175 meters. The flood control level is 145 meters, while the flood control storage capacity is 22.15 billion cubic meters. Studies show that if the method of retaining clear water and releasing muddy water is applied, after a century of operation the reservoir's storage capacity would remain at 86 percent for flood control and 92 percent for power generation.

Resolving Navigation Problems. The issue of whether the sediment at the reservoir could become thick enough to affect navigation and turn Chongqing into a dead port worries many people. To get a clear picture of this problem, many scientists, technicians and sedimentation experts have conducted comprehensive studies of sedimentation in the river course of Sichuan section of Yangtze River and the navigation channels of a dozen or so existing reservoirs in China. Simultaneously, experiments and studies on nine sedimentation models have been held for the fluctuating backwater region of the reservoir.

The results indicate that the reservoir area can be divided into two regions: the normal backwater region and the fluctuating backwater region. A drastic rise in water levels on completion of the reservoir would place many rocks and shoals far below the surface, changing the nature of steep slopes and rapids of the river in mountainous areas. Consequently, shoals would be submerged all the year round in the normal backwater region and passage for navigation be greatly improved. Navigation would also be improved in the fluctuating backwater region.

Improvement in the navigation channels differ to varying degrees in the upper, middle and lower sections of the fluctuating backwater region. Generally, within the fluctuating backwater region, the annual change of the mainstream — whether in the crooked, forked or straight section — is smaller than what it is before the reservoir is built. Such improvement would help stabilize and deepen the navigation channel and, thus, improve navigation conditions.

Nevertheless, after several decades of operation, sediment would indeed affect navigation in some sections of the fluctuating backwater region and have an impact on operations in harbor areas during extremely dry years when the reservoir's water level dropped early in the year. However, experiments and studies on sedimentation models indicate the problem can be solved by optimized regulation of the reservoir, simultaneously with the transformation of harbors and harnessing of navigation courses.

Sediment Deposits No Threat to Chongqing. Following decades of operation, some sediment would build up at the end of the reservoir. This build-up would affect the floodwater level of Chongqing. Sedimentation experts have concluded from intensive analysis and sediment model examination that with the adoption of a normal pool level of 175 meters, after a hundred years of reservoir operation the Chongqing Chaotianmen water level of a 100-year flood would rise from the current 194.3 meters to 199 meters (and when a 3-meter margin is added, it would not exceed 202 meters) — not taking into account new reservoirs built in the future on the upper reaches to retain sediment and regulate floodwaters. Since Chongqing is a mountain city, most of the urban areas are above this water mark (the elevation of the city center is about 250 meters). Therefore, Chongqing would not be threatened by floodwater.

Sedimentation at Three Gorges is a complicated problem that deserves close attention. But studies and surveys conducted over the many years indicate that any possible problem can be solved if appropriate measures are taken.

Danger From Military Attack

The Three Gorges dam will store an enormous amount of water. When the water level of the reservoir reaches 175 meters, the total volume will amount to 39.3 billion cubic meters. Concern exists that if the dam were destroyed during wartime, a huge volume of water would cause an unimaginable disaster on the middle and lower reaches of the Yangtze River.

However, that would not be the case. A study of potential harm that might be caused by the destruction of the dam during wartime began as early as the 1960s. The Ministry of Water Resources and Electric Power, the Yangtze Valley Planning Office and military departments carried out a series of studies and experiments on the protection of the Three Gorges Project and performed mathematical calculations on the effects of dam-collapse flooding.

The Three Gorges dam — a mass concrete gravity structure with a maximum width of 121 meters at the base — would be capable of standing up to fairly powerful conventional weapons. In the case of an attack, only part of the dam would be damaged and there would be no serious consequences for areas in the middle and lower reaches.

If the dam were hit by nuclear weapons and completely destroyed, model experiment results show that appropriate managerial measures would limit damage caused by flooding. The most effective measure would be to lower the water level before the outbreak of hostilities. A number of low elevation and large flood release outlets would be built on the dam. The ability of the river course on the lower reaches of the Yangtze to absorb these increased water flows is fairly high.

Military experts can be counted on to reliably predict the outbreak of a modern war. In the event of a conflict starting, the water level of the reservoir could be lowered to 145 meters within seven days at most, leaving a reservoir storage of about 17 billion cubic meters. If the dam should be destroyed suddenly, only the 100-kilometer river valley from the dam to Zhicheng would suffer heavy flood damage. The major part of the water would flow along the main river trough and a small part would enter the flood diversion and detention region. A flood disaster caused by a collapsed dam could be restricted to areas upstream of Shashi and would have not much impact on Jianghan plain, Dongting Lake and the Wuhan areas. It would not create havoc in the entire valley. If the water level of the reservoir were lowered to 130 meters, then reservoir storage would be about 10.3 billion cubic meters and flooding would be even lighter.

The disaster caused by dam collapse of the Three Gorges reservoir would not be so serious as people imagined because:

- The capacity of the reservoir is large, but when compared with the river's runoff of a single flood of the Yangtze that has ranged from several dozen billion cubic meters to more than 100 billion cubic meters, it cannot be considered large. The safe daily discharge of the river is over 5 billion cubic meters. The river channel itself has the capacity to regulate and store flood waters. There are also flood diversion and detention areas with a capacity of 30 billion cubic meters in the Jingjiang River and the Dongting Lake areas. Consequently, the capacity to absorb a dam-collapse flood is large.
- The Three Gorges reservoir is a 600-kilometer-long river course reservoir, with an average width of 1,100 meters. The lower part of the reservoir consists of a 200-kilometer canyon of the Three Gorges, which includes wide and narrow sections with many turns. After a collapse of the dam, therefore, the water of the reservoir, unlike that of a lake-patterned one, is liable to flow down section by section and be slowed by a 40-kilometer-long narrow river valley below the dam.

Experimental data indicate that regardless of whether the width of the collapsed dam is

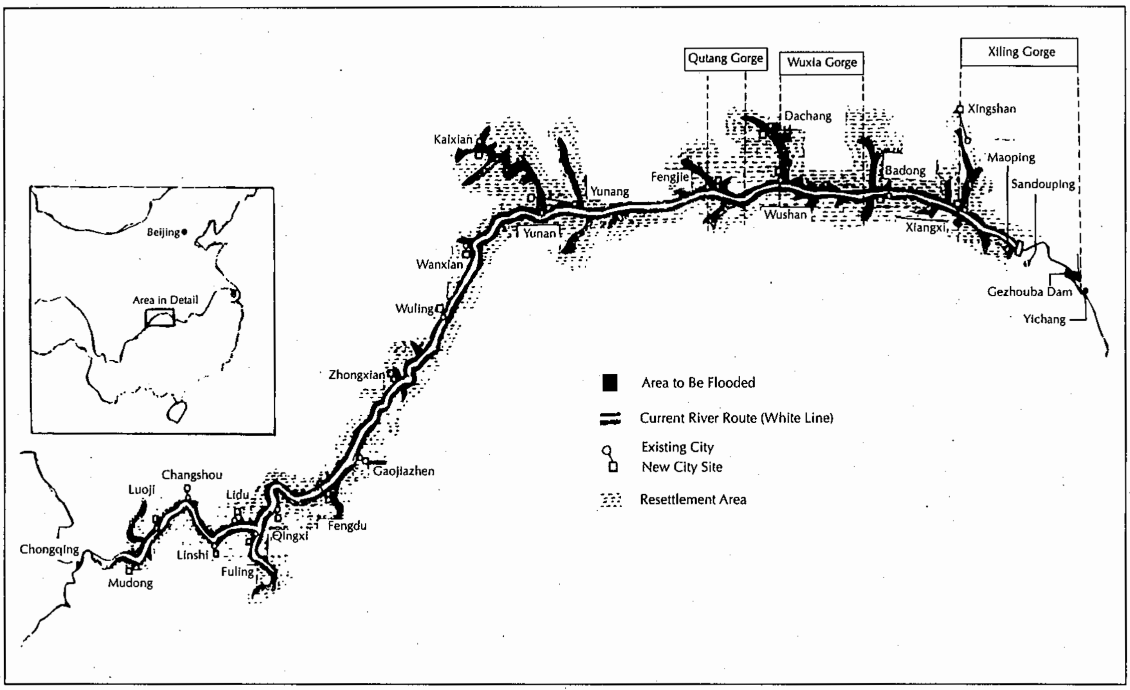

FIGURE 6. The extent of the reservoir and resettlement areas for the Three Gorges Project.

1,000, 700 or 400 meters, the highest water level at Nanjinguan (the outlet of the Three Gorges) would be basically the same, indicating that the canyon below the dam would exert a restraining force on the flood waters. Therefore, as long as appropriate measures are taken to lower the water level of the reservoir before the outbreak of a war, the total volume of floodwater and the losses would be small. Even if the dam were destroyed when the reservoir was high, the canyons and channels along the river would regulate the floodwater as would water-diversion measures below the dam and flooding would be similarly limited.

Resettlement Issues

The number of people to be displaced and the area to be inundated by the project are unprecedented. If the reservoir's normal pool level is set at 175 meters, a total of 19 counties and cities, 13 county towns, 140 towns and 4,500 villages would be affected by inundation. A survey performed at the end of 1985 determined that:

- 725,500 people would be dislocated (of these, 285,200 live in urban areas, 107,800 in towns and 332,500 in villages);
- 23,793 hectares of farmland (7,380 hectares of paddy fields and 16,413 hectares of dry land) and 4,960 hectares of citrus orchards would be inundated;
- 956 kilometers of highways would be inundated;
- 657 factories and mines would be submerged; and,
- The original value of fixed assets that would be affected total 819 million yuan.

These figures are the result of two on-the-spot investigations conducted in the 1980s by the Yangtze Valley Planning Office and the local governments of the Three Gorges reservoir area. They have been verified by the departments involved.

The Three Gorges Project would be constructed within 20 years according to the principle of "one-cascade development of the stretch from Chongqing to Sandouping finishing the project construction once to the final scope, storing water step-by-step, and resettling the people persistently." The total population to be moved (accounting for natural growth) would reach 1.1318 million by 2008. Do the surrounding areas have the environ-

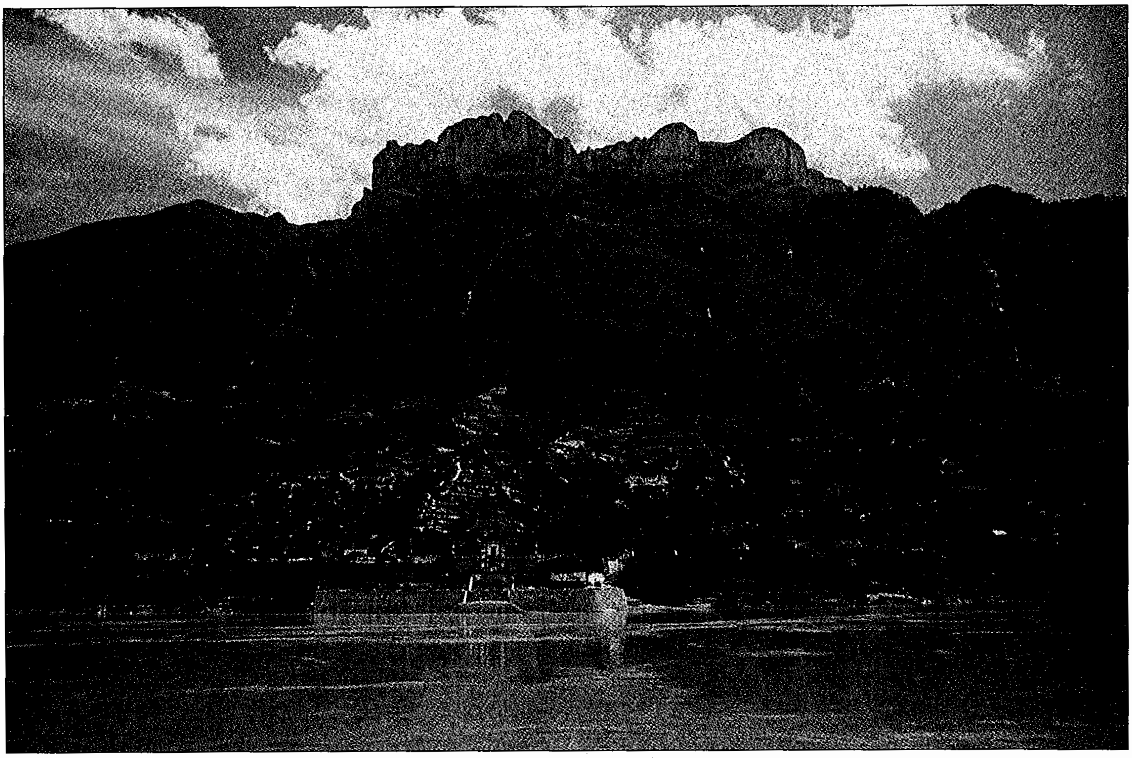

Photo by Megan Epler-Wood

FIGURE 7. The town pictured above will be flooded and its residents resettled.

mental capacity to accommodate such a large population?

Ample Space for Resettlement. The number of people an area can accommodate is determined by its natural conditions, resources, and economic, technical and scientific developmental levels. The water surface of the Three Gorges Reservoir covers 1,084 square kilometers (see Figure 6). If the surface of the existing river channel is deducted, the total area of land to be inundated is 632 square kilometers, or about 1 percent of the total area of the 19 counties and cities to be affected. Since the number of resettlers is huge and the land resources in reservoir areas are limited, certain difficulties will be encountered in properly resettling them. But from the macro point of view, there is sufficient space for resettlement.

The people to be resettled live in over 300 towns and villages scattered about the more than 2,000 kilometers of the mainstream and tributaries of the Yangtze River (see Figure 7). Kaixian County has the largest number of residents to be resettled — 92,000, or about 7.6 percent of its inhabitants. Of the total population to be displaced, urban dwellers make up about 54 percent. Urban employees, when resettled in the surrounding areas, would continue in the same jobs. Work would need to be created only for their 300,000 rural counterparts.

The core of environmental capacity for resettlement centers on the problem of cultivated land. Farmland to be flooded represents only a small percentage of the total in the reservoir area, and the largest proportion would be low-yield hillside land. A breakdown indicates that the cultivated fields and citrus orchards that would be inundated account for only 2.9 percent of the total farmland of the 19 counties and cities. Paddy fields make up only 2.2 percent of the total rice fields.

Endowed with a temperate climate, plentiful rainfall and rich flora, the Three Gorges area boasts optimum conditions for the promotion of agriculture, forestry, fruit growing, aquatic farming and animal breeding. There are 5.4 million hectares of land resources in the 19 counties and cities — farmland (including citrus orchards) accounts for 18.8 percent, wooded land 28.7 percent and barren hillsides

25.2 percent. About 667,000 hectares of barren hillside land can be cultivated and utilized, equivalent to 20 times the extent of submerged land. Therefore, land capacity is adequate for resettlement within the counties and cities surrounding the reservoir.

According to an initial plan based on the intentions of local governments and settlers, the afflicted people will be resettled in 361 townships with 1.23 million hectares of total land surface area. Of this area, cultivated land makes up 23.5 percent, wooded land 21 percent and barren hillsides 20 percent. About one-third of the barren hillsides have a gradient of less than 25 degrees and are grown mainly with weed and bush. Vegetation covers 70 percent of these hillsides, which could be utilized. Of the cultivated land, more than half are low-yield hillsides. These relatively untapped parcels need to be transformed in order to develop production, prevent soil erosion and improve the ecology.

Experiments in the reservoir area indicate that if one hectare of barren hillside is transformed into a high-grade terraced citrus orchard, it would be able to produce an output equal to as much as three to four hectares of paddy fields. If one-third of the wasteland and low-yield land were developed, the surrounding areas would have the capacity to accommodate more than 1 million settlers. Therefore, sufficient land capacity can be created.

The Three Gorges Reservoir, if constructed, would have a water surface of 67,000 hectares for aquatic farming, which has proved successful in many other reservoirs.

Urban dwellers in the reservoir area represent less than 10 percent of the area's total population — well below the national average of 20 percent. If the local urban population reaches the nation's present average by the year 2000, more than 1.8 million rural dwellers from the reservoir area would have moved into towns and cities. The reservoir area has rich deposits of phosphorus, rock salt and many other mineral resources that can be used to develop local industries. In addition, communications and transportation will develop rapidly once the trunk waterway is improved and the navigation channels of the tributaries of the Yangtze River system are expanded following construction of the reservoir. Tertiary industry will also develop quickly when the rich potential of tourist resources are tapped.

From this comprehensive analysis of the land resources and other crucial environmental factors, it is evident that although land resources are relatively limited in the Three Gorges area, there is still potential environmental capacity to be tapped. The whole surrounding area could be transformed and developed comprehensively in combination with environmental protection if adequate funds, technology, information, manpower and materials are made available, the industrial structure readjusted, and the layout of cities and rural areas are reasonably arranged. It could provide space for as many as 1 million people.

Development Policy for Settlers. Since the founding of the PRC, the country has set up more than 80,000 reservoirs and has resettled nearly 10 million people. Reviewing previous experience and resettlement setbacks, the central government decided to develop a new resettlement policy. Its basic point is to change over from earlier forms of compensation for settlers to forms of overall arrangements for their production and living conditions after moving. It calls for a unified plan and responsibility borne for this task from beginning to end so that the affected people around the reservoir area will be properly settled and long peace and stability achieved. In accordance with local conditions and the requirements for soil and water conservation, environmental protection and local economic development plans, efforts will be made to open multiple avenues for developing local resources, to readjust the distribution of industry and agriculture, and to improve the industrial structure and production.

Before any resettlement project is implemented, feasibility studies and an in-depth evaluation of its impact on the environment must be carried out to ensure its technical feasibility, economic rationality and resettlement reliability. Among the affected people, those with farming skills will be employed in agriculture, forestry, fruit tree growing, fishing and animal breeding, while those suitable for industrial production will be transferred to urban enterprises. At the same time, more job opportunities will be created in the tertiary industries to ensure that the standard of living in the new settlements will be raised, the local economy will grow quickly and the environment will be enhanced.

Measures & Policies. Resettlement involves many people, a large area and many agencies. It is not only an economic but also a social problem. Resolution of this problem requires the formulation of a series of policies and measures. The expert panel for settlement conducted repeated investigations, studies and debates for more than two years before they put forward a comprehensive set of policies offering preferential treatment for the displaced and for bringing about the sustained development of the reservoir area's economy.

For instance, resettlement funds are to be allocated in advance to the settlement areas for construction and education. Losses from inundation are to be compensated by earmarking a proportion of the income to be derived from power generation after the project starts yielding economic returns that will be used as funds for economic development in the reservoir areas. Food supplies for the affected people will be guaranteed and regularly subsidized to offset possible price differences between state-rationed and market-supplied food. The displaced will have reduced taxes or be exempted from taxes altogether, and enterprises will be allowed to retain a bigger share of their foreign exchange earnings. Loans, which can be repaid before taxes, will be granted for the reservoir area's economic development. These preferential policies have been warmly welcomed by the local people and governments at various levels.

Pilot Projects Prove Feasibility. Resettlement of people in Three Gorges reservoir areas will be carried out by group and by stage according to a unified plan. At present, overall schemes have been initially drawn up by various counties and cities along the reservoir areas.

The Communist Party Central Committee and the State Council have paid great attention to the resettlement work. Special funds have been earmarked for trial settlement in pilot areas since 1984. Up to 1989, a total of 98 million yuan had been allocated. In these pilot areas, more than 100 experimental projects have been constructed for settlers. New residential areas have been built in accordance with urban development plans, new factories have been constructed and old ones renovated to provide jobs for settlers. Barren hillsides have been reclaimed as terraced citrus orchards and tea plantations (these efforts dovetail with water and soil preservation). Dairy farms have been set up as examples for settlers to follow. Most of these projects have already achieved tangible economic returns.

About 46.045 million yuan was invested in pilot areas to cultivate wasteland, build terraced fields, grow citrus trees, tea and other cash crops, and raise silkworms. Around 4,867 hectares of wasteland, which can provide for 40,000 settlers, have been reclaimed. Some 20.47 million yuan has been put into building small factories, and 28 plants have been set up, which can absorb 2,421 rural laborers. About 9.155 million yuan has been used for the construction of infrastructure facilities for cities and towns. These pilot projects not only accumulate practical experience for moving displaced persons, but have also attracted several hundred million yuan of investment into new areas and discouraged growth in fixed asset investment in the affected reservoir areas. Gratifying results have been obtained from investment of 3.8 million yuan put into three factories that previously had bad economic performances. Moreover, arrangements have been made for more than 100 rural laborers.

Such proper organization for resettlement has been warmly received by local governments, natives and settlers — an indication that this approach to resettlement is feasible. These steps will ensure that people in the reservoir area are properly resettled despite their great numbers (about 1 million) and a sound environment will be created to benefit not only present but also future generations.

Environmental Impact

The environmental impact of the Three Gorges Project is a matter of concern both to China and the international community. Many years of research (which has been repeatedly corroborated in recent years) have led experts to conclude that the problem of environmental impact does not constitute a factor restricting construction of the project.

Like any other major water conservancy project in the world, the construction of the Three Gorges Project features both favorable and unfavorable environmental aspects. Beneficial impact would be concentrated mainly on the river's middle reaches, while negative impact would be felt in the reservoir area. However, since the reservoir would be of a stream-channel type, it would have a relatively small storage capacity in comparison with the annual runoff at the dam site.

The Three Gorges Project would benefit the river's middle reaches since it would:

- Reduce damage and fears caused by disastrous floods in the densely populated and economically developed plain and lake areas of the river's middle reaches;
- Help to eliminate snail fever in the river's middle and lower reaches;
- Cause less pollution than a coal thermal power plant of the same generating capacity;
- Improve the local climate;
- Reduce sedimentation in Dongting Lake; and,
- Regulate the Yangtze River's flow.

The project's potential adverse impacts can be divided into the three categories:

- Irreversible impact (for example, the flooding of certain cultural and historical sites and arable lands);
- Major impact (which could be mitigated by taking appropriate effective measures — for example, environmental imbalance caused by city and town rebuilding and resident resettlement); and,
- Minor impact (which could also be reduced by adopting effective measures — for example, negative impacts on public health as well as flora and fauna).

Impact on Local Climate. Any change induced by the reservoir on the climate of the surrounding areas will be negligible. Once the reservoir is completed, average annual wind velocity may increase 15 to 40 percent and relative humidity may rise 2 to 8 percent. Any impact on the frequency of foggy days, or on the volume and distribution of rainfall will be minimal.

Average summer temperatures may drop slightly by 0.9°C to 1.2°C on a monthly basis; while in winter the average temperature may rise slightly by 0.3°C to 1.3°C, with the minimum temperature up by 3°C. Such annual changes would help citrus and tung trees and other cash crops that need a warmer climate to survive the winter.

Impact on Water Temperature & Quality. The worst forecast is that thermal stratification of the mass of reservoir water would begin around April and end in May. It would take an extra 20 days for the temperature of downstream water to rise to the spawning temperature of 18°C.

In the reservoir area, the flow velocity would decrease and, therefore, the water's capability to reaerate and disperse pollutants would also decrease. Consequently, strict controls would be necessary on the discharge of wastewater by surrounding factories, mines and towns. Because sediment would settle in the reservoir, organic matter would be deposited and decompose, while downstream water quality would be improved. Heavy metal content in reservoir water would decrease along with sediments, but heavy metal content in sediments would increase. However, the construction of the reservoir would not alter their absorption by sand and mud; therefore, no secondary pollution by heavy metals would occur. Therefore, water quality in the lower reaches would improve.

Impact on Land Flora & Fauna. Because there are no vast stretches of natural forests and vegetation in the reservoir area below 200 meters above sea level, the Three Gorges Project's impact would be insignificant. In the vicinity, rare plants usually grow in areas over 200 meters above sea level. There are few rare animals in the areas to be flooded. Generally speaking, the impact on land flora and fauna would be small.

Impact on Aquatic Life. After the reservoir is built, those species of freshwater fish that thrive in rapids would have to swim upstream to find a new habitat. The expanded water surface created by the construction of the reservoir would enable aquatic farming in the reservoir bays of the tributaries. The existing eight spawning grounds located in the section between Chongqing and Zigui would be inundated in part or in whole. The breeding of farm fish would be moved to the uppermost end of the reservoir or even farther. In addition, the spawning and breeding period would occur later in the 12 spawning grounds in the section from Yichang downstream to Chenglingji due to changes in flow swell and in water temperature.

Chinese sturgeon usually swim upstream to spawn and then return to their home. The Gezhouba Project has made it impossible for the fish to swim back and forth during the spawning period. But the species has spawned naturally in the neighborhood below the dam. Artificially induced breeding of fry has also been successful.

The white-flag dolphin, another rare Yangtze species, usually frequents certain sections below the planned dam. Changes in sluicing flows and consequent channel erosion may undermine its habitat. However, this endangered species could be protected through the establishment of a nature reserve. No obvious impact has been established on the living conditions of the Yangtze alligator, giant salamander and black finless porpoise.

Impact on Public Health. Many years of investigation and study in the reservoir area have not uncovered any evidence of *oncomelania* (a snail that is the intermediate host of the blood fluke) and snail fever has never been prevalent there. Once the project is completed, the fluctuation of water levels would make it hard for such snails to breed. In addition, the alleviation of flooding along the river's middle and lower reaches would make it easier to eliminate the pests and snail fever in swamp areas.

Impact on the Plains & Lake Areas of the Middle Reaches. One function of the Three Gorges Project would be flood control. Demonstrable benefits would include the promotion of local economic development and protection of the environment in the plains and lake areas of the river's middle reaches. With the reservoir regulating water storage and discharge from January through April, the water level in the river would rise. But since erosion of the river course in the lower reaches would take place once the reservoir is built, the water level in the river would fall somewhat. Even if this factor is not considered, the level of water would still not surpass the ground level in the valley without affecting the drainage by gravity and the groundwater level. Therefore, the gleization or swamping process of the valley would not be aggravated. The drainage system must be improved, whether the Three Gorges Project is built or not.

Impact on the River's Estuary & Surrounding Sea. The Three Gorges Project is expected to store water in October to reduce downstream flow. In years of ordinary water flow, the river's flow would be higher than necessary to control salt content in the Shanghai area. From January to April when sea water makes its most serious inroads, the increase in flow caused by the project would have the obvious effect of diluting salt water and reducing salt content.

Because the water level at the outlet would rise and fall between 5 and 15 centimeters after the reservoir was built, the desalinization trend of salted soil would continue. It is predicted that there would be no major change in suspended finer sediments near the outlet. The water near the mouth of the river would still remain high in nutrients.

Inundation's Impact on the Environment. Farmland in reservoir areas will be inundated. The Three Gorges Project would submerge cultivated land and force great numbers of people to move. The localities are densely inhabited and the economy is relatively backward. Water and soil loss is also very serious. Failure to carefully handle the resettlement of the numerous residents would have an unfavorable impact on the ecosystem and environment.

There should be no large-scale expansion of cultivated land but efforts should be made to increase input in agriculture and transform low- and middle-yield land. Grain problems should be solved outside the reservoir areas. At the same time, it is necessary to readjust the agricultural structure, and actively develop citrus, tung tree and other cash crops, as well as animal husbandry and fisheries in order to create environmentally safe places for settlers.

The plan for resettlement should combine the development of reservoir areas with protecting the ecosystem and environment. The development of urban and rural enterprises in reservoir areas should focus on agricultural and by-product processing industries and tourism that generate less pollution and have less negative influence on the ecology. At the same time, efforts should be made to strictly control population growth in order to raise the quality of life.

As is well known, any major water conservancy project will have both positive and negative repercussions. The Three Gorges Project is no exception. The Three Gorges Project can provide huge environmental benefits. Therefore, effective and forceful measures must be adopted to minimize its drawbacks.

How the Project Will Affect the Scenery

The Three Gorges are famous for their spellbinding natural charm. Hemmed in between overhanging cliffs strewn with exotic caves, this place is where the Yangtze River takes a zigzag course on its way downstream, creating an awesome pattern of swirling whirlpools and roaring rapids. To sail down the river through the gorges is like passing through a corridor hung with the tableaux of an ever-changing riverscape. A touch of mystery is added to the scene by the plank paths skirting the precipices, ancient coffins hanging improbably halfway up perpendicular bluffs, as well as the graveyards of aristocrats of bygone days. But will this place of unmatched beauty disappear if the controversial Three Gorges reservoir materializes? What will become of all the tourist attractions?

After the reservoir is completed, the dam will raise the water level by nearly 100 meters. The backwater will extend as far as Chongqing harbor in Sichuan Province, which means a number of scenic spots and places of historical interest will be submerged. Experts have racked their brains for ways to preserve these priceless treasures.

The conservation of ancient relics and places of historical interest has become part of a resettlement plan for the Three Gorges reservoir area. Some of them will be removed or rebuilt, some will have to be duplicated elsewhere and the others will be put into museums. Yunyang County's Temple of Zhang Fei, a legendary general of the Three Kingdoms Period (220-280 A.D.), will be rebuilt strictly according to its architectural style and layout near a new resettlement center. The famous iron railing columns and the Han watch tower will be re-created in suitable places. The carvings on the Moya Cliff will be either recreated according to stone rubbings or cut down and relocated on another cliff. In the Hubei part of the future reservoir area, archaeologists have basically finished excavating all the cultural relics and ancient tombs, while in the affected areas of Sichuan, the work has gotten off to a good start and the excavation of the Daxi Culture site has entered its preliminary stage. Plans have been mapped out to explore all the remaining cultural sites and tombs before the reservoir is put into use.

The raised water level will have little impact on the breathtaking vista of the cliffs towering several hundred meters above the Three Gorges. The mountains that flank the Qutang Gorge, for example, reach more than 1,000 meters above sea level and the landmark peak of Kuimen stands at 350 meters. Their net height above the water will be cut somewhat with the construction of the reservoir; however, the magnificent riverscape — known as the "most gorgeous under heaven" — will remain intact. The 12 peaks of the Wuxia Gorge are around 1,000 meters high, with the famous Goddess Peak rising 900 meters. The water level increase there will amount to only 50 meters, so the Goddess will remain unscathed.

The birth of a vast lake among spectacular mountains will only add to the beauty of the Three Gorges. Baidicheng in Fengjie County will become an isle, with the curved royal-yellow roofs of pavilions tucked away amidst luxuriant trees, set off against a vast expanse of clear water. The reservoir will turn the 12-story, 210 meter-high pagoda poised on pedestals with an elevation of 165 meters in Zhongxian County's Shibao Village into yet another isle, accessible by boat.

These areas that will be part of the reservoir are criss-crossed by gurgling streams hidden in quiet, picturesque ravines, yet they are little known to mankind because of their inaccessibility. The inaccessible streams will become accessible once the water level is raised. The Daning River, for example, is known for its kaleidoscopic beauty characterized by numerous gorges, rapid torrents, high mountains and clear water. The small Three Gorges in the Daning River, the highest peak Shennogjia in central China, the famous Gaolan Scenic Spots, the newly discovered karsts in Badong County and the Stone Forest in the Gezihe River are all near the reservoir areas and have great potential for development.

Once completed, the Three Gorges Project itself will become a new wonder of the world. The giant dam will stand upstream to hold back Wushan Mountain's clouds and rain. A gigantic shiplock will stand there to lift towboats with a total tonnage up to 10,000 over the dam. The hydropower station, as dazzling as a palace, will shoot out its mighty current through an extensive power-grid. Like the ancient Temple of the Yellow Emperor not far from the dam, the modern building complexes are bound to draw flocks of travelers from all over the world.

The Gezhouba Component of the Three Gorges Project

As the first dam built on the mainstream of the Yangtze River, the Gezhouba Water Conservancy Project will become part of the future Three Gorges Project. The completion of the former has furnished valuable experience for the construction of the latter.

Gezhouba is located 2.3 kilometers downstream from Nanjinguan, the outlet of the Three Gorges. As a power-generation and navigational facility, the Gezhouba Project's major task is to overcome the adverse impact of irregular water flow caused by the Three Gorges hydroelectric power station's daily operations. It also raises the water level to submerge dangerous shoals, reduces water speed and widens the river in order to improve conditions for navigation through the mountain-flanked stretch from the Three Gorges dam to Nanjinguan.

Gezhouba dam is 2,606.5 meters long with a dam crest level 70 meters above sea level, a normal pool level of 66 meters and a total storage capacity of 1.58 billion cubic meters. The project provides power generation, navigation aid and flood regulation (including silt removal). The Gezhouba hydroelectric power station — counting two stations built on the first and second channels with seven and 14 power generating units, respectively — has a total installed capacity of 2,715 megawatts and an annual output of 15.7 billion kilowatt hours. The navigational facility incorporates three shiplocks and its one-way passage capacity is 50 million tons. Shiplocks No. 1 and 2 — being 280 meters long, 34 meters wide and taking 5 meters minimum water depth — are among the world's largest on inland waterways (see Figure 8). The project has a maximum discharge capacity of 110,000 cubic meters per second. It includes three flood discharge and silt sluices, of which the 27-outlet second channel sluice is a major flood-discharge structure, while the first and the third channel sluices have nine and six outlets, respectively.

Construction of the Gezhouba Project started towards the end of 1970, and by 1981 the first-stage construction work began to open to navigation and power generation. The second-stage construction was finished in 1988. By the end of June 1991, the project had generated a total of 98.032 billion kilowatt hours of electricity. By the end of 1990, the shiplocks had been used 878,000 times, and allowed the passage of 21.38 million passengers and 55.31 million tons of cargo aboard some 565,500 ships.

Scientists and engineers from research institutes, colleges and universities across the land have cooperated in areas such as sedimentation, navigation, energy dissipation, protection of the sluices and treatment of the foundation under complex geological conditions. They have also contributed to the diversion and closure of large deep water flows, the construction of cofferdams, and the manufacture and installation of huge water-turbine generating sets and other metal structures. The solving of these major problems has helped promote the development of China's science and technology in the field of water conservancy and power generation. Some of the work is unsurpassed in the world. In May 1986, the Gezhouba Project was awarded a state-class special prize for scientific and technological achievement.

Gezhouba is by far the largest water conservancy project China has designed and constructed on its own. Experience acquired from it — from geological and topographical surveys, scientific research, planning and designing to construction and manufacture and in-

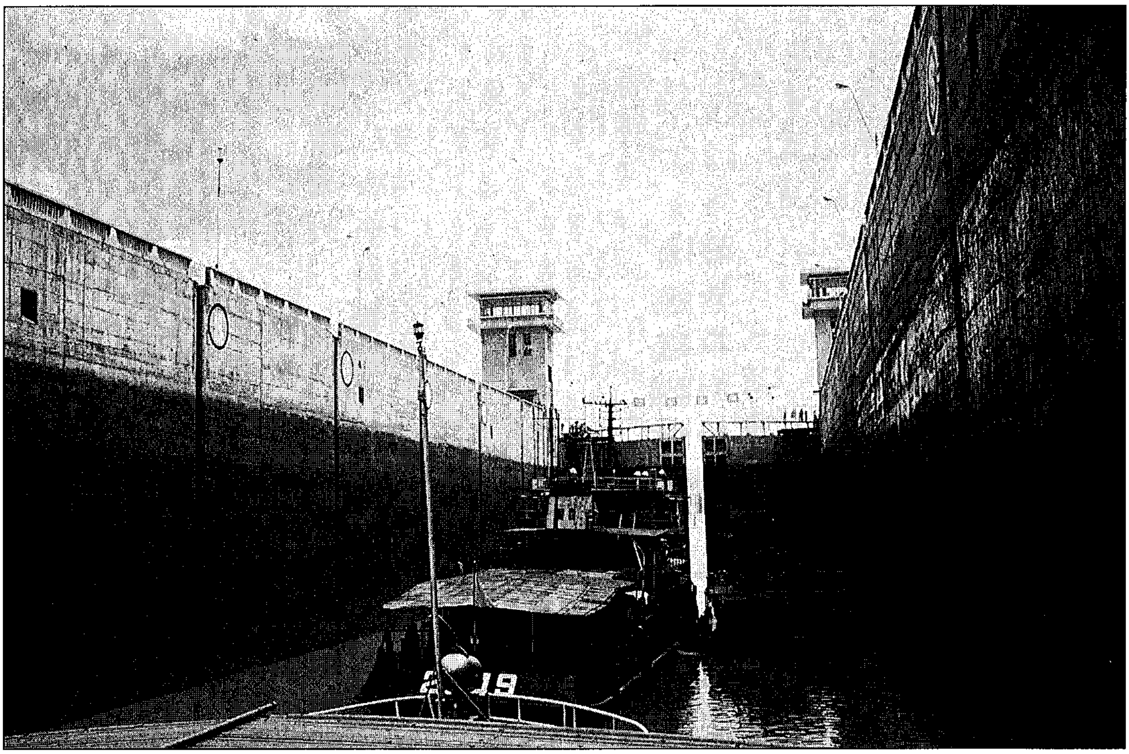

Photo by Megan Epler-Wood

FIGURE 8. A ship lock at Gezhouba dam.

stallation of equipment — has paved the way for the building of the Three Gorges Project. Gezhouba undoubtedly marks a new level in China's water conservancy construction and power generation.

NOTES — *The Freeman Fund Committee considered several outstanding pro-Three Gorges papers for inclusion in this issue: one by an American consultant to the World Bank; another by a Chinese-born U.S. citizen and Professor of Civil and Environmental Engineering at California Polytechic State University in San Luis Obispo who also led the session on the Three Gorges at the 1996 Annual ASCE Conference in Anaheim, California. We selected this Chinese government publication for its clarity and scope, and because it addresses the key points raised by Dai Qing and William Wanli Huang. This paper was compiled by the* Beijing Review, *under Managing Editor, Yao Jianguo, and was originally published in November 1992 by New Star Publishers, 24 Baiwanzhuang Road, Beijing 100037, China (ISBN: 7-80085-631-3/T-2). The English-language edition was printed by the Foreign Languages Printing House. William Wanli Huang used this publication as a reference in writing his own article and gave a copy to Susan Murcott in Beijing in January 1996. Hong Qingyu and Wang Jiazhu served as copy editors of the original version. The publication is presented here in its entirety; some of the language has been restated for clarity and five new figures (Figures 4-8) have been substituted for those in the original that would not reproduce well.*