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■ *Research Paper*

The Three Gorges Dam Project from a Systems Viewpoint

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The Three Gorges Dam on the Yangtze River is currently the largest construction project in the world. Because of its complexity, integration of social, environmental and technological systems, and tight coupling required by the schedule, the project should be managed using a systems approach. To find out if this was the case, the authors formed a research team, sponsored by the International Society of Systems Sciences, to tour the dam sight, interview managers and engineers, travel up the Yangtze to Chongqing, analyze problems posed by the critics of the dam and, finally, report back to the ISSS annual meeting in Shanghai following the trip. This paper reports on the team's observations, the results of the interviews and a systems model that analyzes the problems facing the dam builders. Finally, the paper concludes that the engineers and managers are aware of the interrelated problems and have planned for their solution. Copyright © 2004 John Wiley & Sons, Ltd.

Keywords Three Gorges Dam Project; Yangtze River reservoir; systems approach; complexity and coupling; large-scale engineering projects

INTRODUCTION

There is a gray fog hiding the peaks and valleys and hovering like a leaden cloud over the Yangtze River. Starting here, outside of Yichang, in 1993, China began moving people, pulverizing mountains, destroying riverbank cities and rebuilding them, high and white, on plateaus and mountain sides. This devastation and disruption was to facilitate the largest project of the century, the creation of the Three Gorges Dam Project (TGP). Phase 2 of this building project has been completed. In June 2003, ships were able to

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navigate through the locks. By 2009, the construction will be complete and the reservoir will reach its ultimate height of 175 meters. The dam, the largest ever contemplated and built, is 2309 meters long, 84 meters wide and rises 185 meters from the riverbed. In earlier stages, 30,000 people were employed in the construction; by summer of 2002, 20,000 were working. A new city exists at the dam site, 25 km up river from Yichang, where a smaller dam, the Gezhouba, was built on the city's west end as a working test model from which lessons were drawn.

Four of the authors were scheduled to present papers at the 47th Annual Meeting of the International Society for the Systems Sciences held in August 2002 in Shanghai, China. Three months before the meeting opening date, conference participants received a message from the conference organizing committee announcing that Dr Mitchel Bloom, the team leader, was in the process of arranging for a special pre-conference visit to the Three Gorges Dam Project—a visit that would offer an opportunity to speak directly with officials and engineers at the dam site, and with people in the vicinity, some of whom were going to be displaced, and to travel up the Yangtze River, passing the Three Gorges, and arriving at Chongquing, traversing a distance of 660 km. Much of the area through which we traveled was scheduled to be flooded beginning October 2002. Many existing tourist sites, cities, scenery and archeological places would be inundated as the river level rises up to 175 meters to form the reservoir. The trip plan included: a day of orientation in Shanghai; three days of touring the dam site, interviewing and visiting nearby cities; four days traveling up the Yangtze to Chongqing; and flight back to Shanghai in time to present our findings to the ISSS conference.

To prepare for our trip, team members[1] were referred to a number of Internet web sites containing large amounts of material about the dam project from other than systems perspectives; see, for example, the State Council Three Gorges Project Construction Committee (1994) and Sklar and Luers (1997). More than 500 pages of material were downloaded and read prior to arriving at Shanghai. It discussed the dam from a critical perspective of the effects on existing ecology and culture, relocation of cities and populations, corruption of officials, and engineering problems of the dam. Given that much of the existing physical, social and cultural status quo would be changed, the material posed difficult questions about the technical feasibility of achieving the stated objectives of the project: (1) generating sufficient electrical power to extend electrification from the dam site to a radius of 1000 km in all directions; (2) providing flood control for regions of China that had been historically subject to periodic inundation with much loss of life; and (3) creating areas for farming and living that would allow for a better life for the citizenry.

Because the reservoir created by the dam will impact on the cities and the environment both at the dam sites and the length of the Yangtze upriver to Chongquing, we wanted to be able to interview administrators and residents of a town that will be relocated because of the flooding of the dam reservoir. We were able to do that in the model city of Zigui. In fact, nearly all our requests were granted. We received red carpet treatment. We visited secure sites that ordinary tourists would not be able to enter. We took pictures of the dam, of workers, of our interviewees, asked questions freely and got answers to all of our questions from our interviewees, even the prickly ones involving relocation and corruption.

The team's two guide/translators, who met us at the airport, would remain with us until we embarked on the river journey. They brought other technical experts into the discussions as the need for their knowledge and understanding became clear. Well before the visit, the team leader had developed a list of questions based on material downloaded from the web sites. The questions had been translated into Chinese and provided to officials and engineers at the dam. These experts were asked to provide answers and respond to additional questions. The seven questions asked of the project engineers followed by six questions asked of the dam managers and administrators, together with their answers, are contained in the Appendix. The questions

[1]Quentin Perry, heavy equipment operator, accompanied the authors, produced notes and photographs which were incorporated in this report.

emphasized the engineering and ecological disasters and social ills that might be created by the project. They were a good reflection of the perceptions of the special interest groups opposed to the TGP.

The kinds of information the team collected included observations of all types: of the work, the workers, labor conditions, logistics, housing of workers, logistics of materials, quality of manpower and materials; photos of the dam and its progress; and interviews with the project managers and engineers. Also included was a large amount of Internet and published material on the dam. Finally, the dam site technical report (CTGPC, 2000), travel brochures, photos of towns that will be submerged, and relocation schemes were further items that we collected.

At the conclusion of our trip we had collected much information embracing many different points of view that we organized into a coherent whole. Our role as researchers was to determine the extent to which the TGP organization is using a systems approach in the planning and implementation of the project (Van Gigch, 1978, p. 37). What are the major construction problems and how are the engineers and managers attempting to solve those problems involving complex technological–environmental–social interactions and tight coupling (Perrow, 1999, p. 97)? What tools and techniques are they using in managing both hard and soft systems (Checkland, 1981, pp. 146–147)? When we go beyond the construction phase of the project and look at the projected various impacts, then what steps are being taken by the managers to anticipate problems and prevent undesirable consequences (Linstone and Mitroff, 1994, p. 319)? Our mission was to find answers to these questions.

The question arose as whether our study could be considered a first-round technology assessment. A complete technology assessment (OTA, 1972) includes eight steps ranging from identifying impacts to presenting findings to authorities. We only engaged in two of the eight steps, namely:

(1) identifying existing or probable impacts of technology or technological programs; and
(2) ascertaining cause-and-effect relationships.

We did not identify alternative technological methods or estimate impacts of alternative methods on society, nor did we present our findings to the authorities, although we interviewed them at length. Finally, we did not undertake additional assessment activities as requested by the authorities. Only in a very limited way could our study be construed as a first-round technological assessment.

A detailed bibliography of papers on technology assessment is found in Flowers (2003). For further information on technology assessment see OTA (2003), Hetman (1973), Blair (1994), Mohr (1999), and Mitroff and Turoff (1973). A complete list of OTA (Office of Technology Assessment) papers is available on the Internet (OTA, 1996).

Our research group had very limited experience in China. Dr and Mrs Alberts visited China more than 20 years ago. Our student member, Satu Teerikangas, visited more recently and spent time in China with her family as she was growing up. None of us pretended to be experts on China or on the technology of dam building. Our research was limited to our interviews of 9 hours, our observations as we toured the dam site and surrounding areas, our judgments based on our own specialties (engineering, science, management, social science and system science), and extensive readings from the literature and downloads from the Internet (Liou *et al.*, 2000; Embassy of the PRC in the US, 2000; International Rivers Network, 2002).

After completing the trip, the team organized the material gathered into five distinct subject classifications defined by the following questions:

(1) What are the functions the dam is supposed to perform when it is completed and operational?
(2) Is it likely, from an engineering perspective, that the project will be able to accomplish those functions?
(3) What will be the effects of the reservoir on the relocation of cites and populations and on the environment?
(4) What are the likely human factor considerations and the mental health effects of

relocation and how are they likely to arise and exhibit themselves?
(5) What losses of archeological and historical sites are most likely and how is this being handled?

The discussion below distills and focuses the information the team developed from its discussion with dam personnel and local Yichang residents around the dam site, and other affected people upriver and in Chongqing, plus information collected from the Internet and the literature.

WULI, SHILI AND RENLI

The Chinese approach to multiple perspectives is called the WSR (Wuli, Shili and Renli) method. It derives from the philosophy of Confucius and Tao, stressing harmony, balance, knowledge, sincerity and virtue. Have the dam administrators and engineers used the WSR approach in understanding the complexities and solving the problems of the Three Gorges Dam Project? (Zhu, 1996; 1999, 2000).

WSR views reality as a 'dynamic web of multiple relations: relations with the (material) world, relations with the self (or mind), and relations with others, that are called wuli, shili and renli, respectively' (Linstone and Zhu, 2000). Wuli involves the collection of information about the real world, in our case the collection of information about the construction of the dam, electric power, navigation, water transfer, irrigation, floods, earthquakes, population transfer, archeological artifacts and pollution. It would also involve bringing in outside experts to provide additional information. It is safe to say that the dam administrators and engineers have done their wuli well.

With respect to shili, we are considering the various models created to understand and forecast the impacts resulting from the dam project. These include both theoretical and physical models which encompass seasonal flooding, navigation, new ship lift technology, as well as destruction of old cities, construction of new cities and the transfer of over one million persons. They also include plans, programs and procedures for compensating the stakeholders who will suffer from the dam project—compensation in the form of housing and jobs, rescue of historical and archeological artifacts and provision for clean water supply and appropriate sewage treatment facilities. From what we were able to learn, from the perspective of shili, the dam administrators and engineers have done their homework and are prepared to deal with the consequences of the dam project.

Finally we come to renli and here is where there are potential problems, for renli deals with the dynamic interrelations, i.e., the politics, between groups. The major groups are the three layers of government (central, provincial and local), the dam engineers and administrators, the foreign groups critical of the dam project, domestic financial institutions and international investment banks, and Chinese experts in meteorology, archeology, environmental pollution, engineering and economics. The one group left out of the loop but which can ruin the project is the group representing the impacted farmers and urban residents who must be relocated as the reservoir behind the dam fills to its maximum height. Because in China the individual standing alone, not associated with any group, is ignored, there is a tendency for the major groups to disregard the needs of unorganized groups of affected farmers and urban dwellers until irreparable harm is done. Thus, up to the time of this writing we are not sure how well the engineers and administrators will deal with the renli part of the WSR method of multiple perspectives.

FUNCTIONS THE DAM IS SUPPOSED TO PERFORM

The Dam, in conjunction with additional dams (Adams and Mu, 2002) in Yangtze tributaries, is supposed to:

- form the central distribution point providing electrical power for a wide area of China: i.e., permit creation of an electric resource;
- provide a central focus for accomplishing effective flood control for the geographic region of the Yangtze River and a 1000 km radius from the dam site;

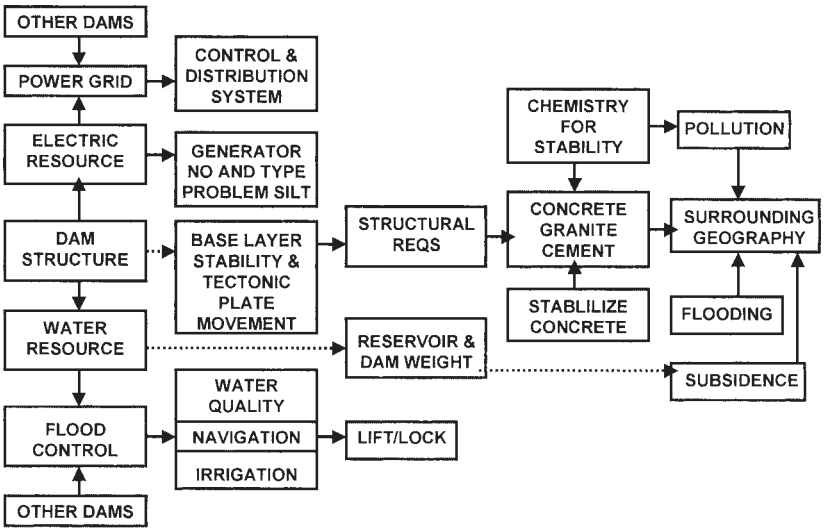

Figure 1. A relational network map of the physical components of the dam project

- provide for improved navigation for large vessels seeking to travel from the sea to the city of Chongqing and lesser population centers en route;
- provide water transfer to the Yellow River region, which is experiencing a severe water shortage;
- provide irrigation from the large quantity of water in the reservoir;
- create an environment for a more modern way of life for citizens within a 1000 km radius of the dam site by insulating them from some of the historical sources of natural disasters and limitations of the environment.

Unless it can be reasonably shown that the forebodings of disaster associated with the project are unlikely to become reality, the dam will not likely be able to satisfactorily perform the totality of its functions—engineering, electric power, flood control, water transfer, water supply, irrigation, relocation of people and cities, environmental purification, and ecological, cultural and archeological protection (Qing, 1998). Therefore, a relational network map of the elements and components of the project was created for the group to study and evaluate (Warfield, 1974, 1990a, b; Warfield and Cardenas, 1994). Figure 1 indicates the first relational map.

The elements on the leftmost side of the map were thought to be the fundamental project building blocks on which functional performance would depend. The two major functions of providing electrical and water resources are shown as being dependent upon construction of other dams on Yangtze tributaries. Also shown is a power grid box. Creating a power grid requires the integration of a control and distribution system, while creating the power itself requires installation and operation of a number of generator elements. These unfortunately have associated with them a probability that silt from the water passing through them will create a problem of reduced capability and increasing rates of wear and tear on the generators (Leopold, 1998).

We asked the Vice Director of Engineering[2] of the dam about silt accumulation in the generators. His reply was that the intake to the generators is at a height of 108 meters. The sluice gates are at 90 meters so when they open they can flush out the silt; and there is another gate at 75 meters between generator numbers 6 and 7. If silt accumulates at the base of the dam, dredging can be used if the flushing does not get rid of the silt. Extensive physical model tests were conducted

[2]Interview with Mr Hong, Vice Director and Senior Engineer of the Three Gorges Project and Mr Yong, Division Chief for Project Information Systems, Three Gorges Project Hotel, July 26, 2002.

and the tests showed that the silt could be flushed out. The policy of operating the dam will be to impound the clear and discharge the turbid waters (CTGPC, 2000, p. 9).[3] Regarding silt accumulation at Chongqing, the engineer stated that this may pose a problem. Due to the natural rise of the river from the dam to Chongqing, the city is only 10–20 meters higher than the planned flooding level of the reservoir. However, according to the official TGP document, 'sedimentation will not bring any serious adverse impacts to the navigation and power generation, whether in the site area or in the backwater region (Chongqing) ... adverse impact can be solved by combined measures as optimizing the reservoir operation (raising and lowering the water level), proper river training ... (and) engineering measures' (CTGPC, 2000, p. 11).

Referring to the water resource box in Figure 1, the water resource function requires construction of a flood control system element that is interconnected with the other tributary operating dams. The control elements will need to monitor water quality throughout the system and integrate the information to provide the basis for taking appropriate action to maintain acceptable quality levels throughout the system. It must also provide for controlling navigational capability along the extent of the integrated water resource system. Finally, it must permit distribution of the water resource for irrigation purposes, an especially important activity considering recent changes in regional climatology.

The extent of the reservoir created upstream of the dam also has implications for its surrounding area. Provision for accommodating the weight of the stored water resource must be made. As shown by the dotted lines, reservoir and dam weight may create conditions favoring ground subsidence that would affect the surrounding geography as well as the required dam structure.

The stability of the earth layer upon which the dam is constructed also has implications on the dam structure (see dam structure box). Of primary importance are the stability of the tectonic plate on which the dam site rests and the base layer of material that covers it. Information appearing in an official publication of the China Three Gorges Dam Project Corporation said that after the impounding of the reservoir the highest-intensity earthquake expected would be 6 on the Richter scale. The dam was designed to withstand an earthquake of magnitude 7 (CTGPC, 2000, p. 11). Regarding subsidence of the base layer underlying the dam, our group was told that tests made had indicated there would be no subsidence that would imperil the integrity of the dam.[4] Taken in the context of the entire series of discussions with dam personnel, we had no reason to doubt the veracity of the assertion. Notwithstanding, however, we did see a number of locations where work on the dam had caused slides of material from hillsides on to the lower levels of terrain. When we questioned the cause of the slides, we were told they were due to the mining of granite from the mountains.

In Figure 1, base layer and stability considerations are shown to directly influence the dam structural requirements, and these in turn are shown to affect the concrete granite cement used. The dam builders have established a process for making concrete by producing it on site using crushed granite mined from the mountains surrounding the dam site, treating the mixture with chemical stabilizing substances and then permitting the mixture to cure for suitable time periods. Consequently, there are possible effects on surrounding geographic pollution potential from the addition of stabilizing chemicals to the cement mixture. Also shown is the possibility that as the surrounding area becomes flooded, geographical changes will occur that can cause subsidence and consequent structural effects on the dam. Additional relationships arising from considerations of the surrounding geography are shown in Figure 2.

[3]In a personal communication with Patrick Megonigal, ecologist, he was concerned about the effects of the dam on deposition of the silt in the reservoir and not in the Yangtze River delta. Because of the outlets and sluices in the dam, the practice of dredging if silt is trapped at the dam and the policy of impounding the clear and discharge the turbid, the engineer, Mr Hong, was confident that the dam will be capable of passing the sediments through.

[4]Geologic data indicate that the mountains surrounding the gorges over the past 70 million years were raised 1 kilometer in elevation. That computes to an average of 0.00143 cm/year, which implies consistent stability during that period in which there have been many cases of changes in underlying tectonic plates as recorded by earthquake disturbances (CTGPC, 2000).

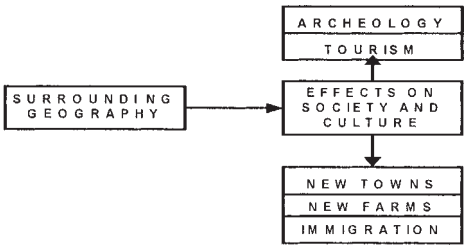

Figure 2. Additional relationships from the surrounding geography

As shown in Figure 2, effects of the dam on surrounding geography will have effects on the society and culture not only in the surrounding areas but also throughout the region within which the electrical and water resource distribution systems are operational. The scenic changes and inundation of archeological sites might result in a decrease in tourists visiting the sights. Conversely, tourism possibly could increase because of improved navigation of large ships up the previously shallow tributaries of the three smaller gorges. Additionally, the increase of the reservoir level will create the need for newly developed areas and cause large-scale outmigration from flooded areas.

It seemed to the team that the actions taken and contemplated represent reasonable assurance that the project will accomplish its immediate engineering objectives (power production and distribution, water resource creation and distribution) but not necessarily its social, environmental and cultural objectives. It appeared that modern technology, together with the level of skills of the Chinese engineers, descendents of men who built the Great Wall and the Grand Canal, had been applied to the Three Gorges Dam Project (CTGPC, 2000). Notwithstanding, however, after the discussions were complete, three questions emerged as of great importance to issues of stability and utility of the dam when built as planned (Table 1).

While there is no indication that the scale of this project extends current 'states of the art' beyond their limits, the team did raise the question with the engineering staff. It is hoped they will explore the implications of scaling and take appropriate measures to ensure integrity of structural stability in the dam and its component systems. Similarly, although the engineering staff tests indicate that the granite-based concrete will be stronger and last longer than other much used mixtures, the team shared concerns with the engineering staff and recommended incorporation of structural tests and warning measurements within the body of the dam and its surrounding geography. As for future natural environmental changes, neither the team nor the engineering staff knew of any mechanisms to predict extreme environmental changes which could cause potential effects on the dam over time. As has already been demonstrated by other studies, the environmental models based on prior historical data may not be useful in predicting future events, especially if continuing temperature, upper-altitude wind patterns and rainfall levels change in unpredictable ways (Bernstein, 1996, pp. 202–203).

EFFECTS ON RELOCATION AND THE ENVIRONMENT

Chinese authorities will have to meet a severe challenge before they can allow the water in the

Table 1. Three questions relating to the stability of the dam

1.	*Scaling* This is the largest project of its type in the world. What is the robustness of the technical base when scaled to this dimension that extends outside the range of previous experience?
2.	*New methods and construction materials* Use of granite as a base for concrete mix might not have much prior experience in use for such structures. What is the effect of chemical stabilization on the likely life of structures built with this material?
3.	*Natural environmental change* What effects are likely to be felt from global temperature and rainfall changes and how have such changes been factored into the project?

Table 2. Areas to be submerged along the Yangtze River by 2009

Farmland	31,000 hectares
Villages	1,300
Towns	140
Cities	13

Yangtze River to rise to 135 meters in 2003 and to 175 meters in 2009, that is, to clear a land area of 632 square kilometers and to resettle a large number of people (see Table 2). Originally, 844,000 individuals were targeted for resettlement. It is expected that this number could grow to 1.2 million people before the project comes to an end. Both farmers and city dwellers are now living on the land that will be submerged when the dam becomes fully functional.

To implement such a massive relocation plan involving families who have been farming their land for generations, as well as city people used to enjoying urban facilities as part of their lifestyles for their work or entertainment, would constitute a major challenge for any government (Wu, 1999). Who will be accountable for the redistribution of resources? Who will take responsibility to guarantee equity in the processing of so many individual claims, with different profiles? Who will take care of the well-being of the person versus the 'higher good of the nation'? These are some of the questions we asked Dr Ma Xiang, who heads the relocation effort of the TGP.

In a lengthy interview[5] Dr Ma Xiang stated that the government is actively involved and will meet the relocation challenge. Dr Ma Xiang is the person in charge of relocation in the reservoir area[6] indicated on the map in Figure 3. Dr Ma Xiang's description gave us some insight into how the relocation and environmental cleaning efforts are actually carried on in a limited area. He helped us envision the full extent of the work involved to cover the 1084 square kilometers and the 3000 pollution points officially identified, across the two provinces of Hubei and Sichuan and the municipality of Chongquing. Dr Ma Xiang identified three levels of supervision (Table 3) involved in the Relocation Plan and in the Environment Cleaning Program. He expressed his great satisfaction with the results obtained up to then in relocating people and cleaning the environment in the reservoir area. However, his explanations did not establish whether the area around the dam came under county authorities or provincial authorities, nor the scope of the intervention power at each level.

Dr Ma Xiang indicated that he had personally met with many of the individuals covered by the Relocation Plan in the area he was supervising, and he seemed confident his team could meet the target for the Environment Cleaning Program around the dam site. He insisted that the Central government had in 2002 allocated an additional 40 billion yuan (US $4.8 billion) to improve the quality of water, to treat waste water and to plant trees. But he did not specify how this total amount was to be allocated between the two provinces and the municipality of Chongqing.

HUMAN FACTOR CONSIDERATIONS AND MENTAL HEALTH EFFECTS

Acknowledging that the central government has moved forward with good intentions, there still remains the issue of whether enforced life style changes, granted even with improvements, will bring happiness. Resettled people have alternatives, but no choice to remain where they are. Their former homes will be destroyed. The trees will be cut down. Their terraced farm land will be flooded. From new cities on the hilltops, they can watch the destruction of their old homes. (In the People Square Park in Chongqing there is a photo exhibit with a picture of an old woman being carried out of her home with both eyes closed).

There seems to be a dichotomy between city and farm options. The city dweller may double living space from 50 to 100 square meters and upgrade to a new, clean, broad-streeted city with trees and shops, medical clinics, schools and even hotels and a movie theater if the model city

[5]Interview with Dr Ma Xiang, Specialist in Relocation, and Mr Tang Wan Bing, Specialist in Installation of Equipment, Gorges Project Hotel, July 27, 2002.
[6]For a satellite photo and a complete set of maps indicating the river, the dam, the gorges and their location in China, see Sun (2002).

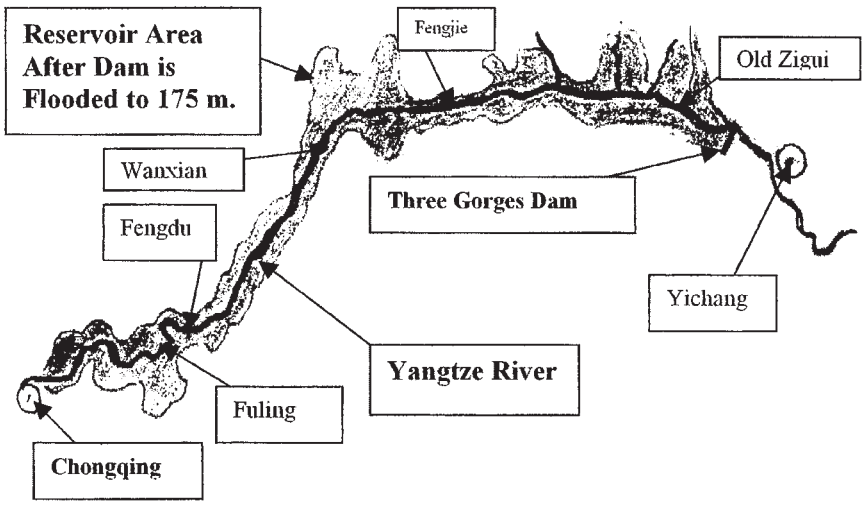

Figure 3. Yangtze River and reservoir after the dam is flooded to 175 meters

Table 3. Three levels of supervision of relocation budget

	Relocation plan	Pollution points targeted in the cleaning program (factories, mining sites, hospitals, waste water, etc.)
County authorities	Relocation budget is administered	Thorough examination of not less than 30% of the area
Provincial authorities	Coordination between county and central government	Thorough examination of not less than 30% of the area
Central government	Total relocation budget is determined	3 months before the flooding, thorough examination of not less than 20% of the area

is the new city of Zigui replacing old Zigui. But not every city is Zigui. In most places smaller, two to three-storey housing is being replaced by larger 10-to 12-storey apartments. This is a subtle change with more neighbors and less community. It is a picture of big city living dotting the countryside. Possibly more problems will exist for older people as some of the new cities have streets too steep for bicycle use and plazas must be reached by ascending stairways. A talk with a non-official person about resettling elicited this response: he smiled and said 'Rich!' The 1993 evaluation price paid out as compensation to those being resettled has been upped by at least 20% based on the cost of living and in some cases even more based on current values.

Retraining centers reputedly are, or will be, established in every city receiving these immigrants, as the available factory jobs may be different. Industries are being encouraged by tax advantages to relocate to new cities. Yet, a young female guide in Fengdu (Ghost City) said she was sad, as her home would be flooded out by October 2002, and though her family has a house in new Fengdu, that city has been built on the other side of the Yangtze from where she works.

Farmers, although given similar compensation and replacement options, have reason to be less happy. They tend to be more traditional with a history of a commitment to a particular location and a pattern of close family connections and

ancestor worship. Many have chosen to stay close by, and have moved up the mountains. However, life seems to get harder as you go up the mountainside. The slopes are steeper, at times canted at 30° or more, and in some cases rockier. Although Dr Ma Xiang said that the bottom land, being abandoned, was poor, the areas we saw boating up the Yangtze looked fertile, and were reported to be growing corn, rice, wheat and potatoes as main crops as well as, in some places, a full assortment of fruit and vegetables. Some of the relocation slopes are too steep to grow these traditional area products and the farmers have been encouraged to replace them with sesame seeds, tea bushes, orange and pine trees. There is a two-year tax forgiveness for tree planting and the farmer is paid by the government. Will the farmer who changes crops need retraining, and is that offered to farmers? Whole villages, such as Pipa village, with its 200 people on the DaNing River, will be moved to Guangdong Province. Pipa village is on a tributary of the Yangtze in the area of the Small Three Gorges, with clear jade green water, spectacular mountains of over 1000 meters and a history of primitive people going back 3000 years. What is the psychological effect of such a move?

In the United States, scientists have studied the effects of stress. Forced displacement, seeing your home destroyed, being told your ancestor who has died within the last 20 years will be cremated and older ancestors' graves will be flooded, are real life stressors which can bring about belated physical and mental illness. Chinese responses to stress may be sufficiently different to make it difficult to predict what will happen. Traumatic stressor research found an 18-month delay factor. At the later date, alcoholism, family dissolution and intergenerational problems appear. In our discussion, when asked whether these factors had been taken into account in relation to relocation, Dr Ma Xiang laughed and dismissed the question with the response that 'Chinese people drink but can hold their liquor.' Dr Ma Xiang stated that he had personal contact with many of the 12,000 settled people in his area and so did the employees he supervised. A computer listing capable of checking on each displaced person annually is in the planning stage. We are talking about at least 1.2 million people. When asked how many workers were assigned to the checking task, he said, 'maybe 100', which computes to an average caseload of 12,000 persons per worker.[7]

LOSSES OF ARCHEOLOGICAL AND HISTORICAL SITES

The loss of cultural heritage is another consequence of the Three Gorges Dam project. This stems from the importance of the future reservoir area to the rise and development of Chinese civilization. The Three Gorges of the Yangtze River hold a special place in the cultural history of China (Winchester, 1996). The Yangtze River, 6300 km in length, is the largest and greatest of the Chinese rivers. Moreover, its geographic position at the center of the country provides both a uniting and a dividing role in the country. Geographically, the Three Gorges have been the center of China, uniting the country's northern and southern parts, and eastern and western parts. Navigation along the river has enabled contact between different parts of the country.

Recently, archeologists found that the earliest signs of Chinese civilization came from the Yangtze area. The long history of the area also explains its archeological importance. Relics, such as the Kong Ming tablet, can be found from times as far back as the Three Kingdoms (AD 220–280). Finally, on the Yangtze River, the area of the Three Gorges is considered the most beautiful. The beauty of its landscapes has inspired Chinese poets, painters and philosophers for centuries. The landscapes appear on numerous Chinese paintings. Temples and pagodas have been built along its shores.

Once the water level of the reservoir rises, the loss of archeological sites and monuments range between 44 (CTGPC, 2000, p. 24) and 1282 (Lin, 1999). These include archeological sites dating as far back as the Paleolithic Age, fossil remains, sculptures, temples, ancestral burial groups and

[7]Interview with Dr Ma Xiang, July 27, 2002.

Table 4. Some of the archeological and cultural sites from Yichang to Chongqing

Area	Archeological Artifact
Zigui county	Grave of Qu Yuan, a great poet of the Warring State period (475–221 BC)
Badong county	Gezihe Stone forest
Wushan	Wushan ape-man fossil, found at Damiao Longgu Ruins, is one of the earliest human fossils ever found
Daxi Town	Ruins of a Stone Age hamlet built by people of the Daxi Culture 4000–6000 years ago
Qutang Gorge	Eight Armies Array, Bellows Gorge, Mengliang Stairs, White Wall, etc.
Baidicheng	Baidi temple, Mingliang Hall, the Star Viewing Pavilion, the Forest of Steel, etc.
South bank of river	Zhang Fei temple (to be rebuilt on a hill)
North bank of river	ShibaoZhai, a 13-storey pavilion built during the Ming Dynasty (AD 1545)
Zhongxian county	Baigong Ancestral temple and a stone tablet of Confucius painted by Wu Daozi during the Tang Dynasty
Fengdu county	The 'Ghost City' of Fengdu; Mingshan Hill in the northeast, with its 70 temples (the city will be inundated and the hill will then stand by the river bank)
Fuling (1 km west)	Baihe, a natural stone ridge in the center of the Changjiang River; 163 pieces of poetry have been carved on the ridge since the Tang Dynasty

old villages. These sites span the historical and cultural development of the Chinese civilization.

It is claimed that the original budget for the Dam did not include allocations for saving the scenic or cultural heritage. This changed in 1998, when a historical relic, a rare candelabra, from a Han Dynasty (206 BC to AD 220) tomb in the Three Gorges area was sold in a New York art auction for US $2.5 million (Yang, 2002). The Chinese administrators realized the economic importance of preservation and not only for the sake of face-saving. Since then, a budget for the archeological excavations has been set up. Experts still claim that at best only 8% of the total cultural heritage would be saved. Today, administrators claim that intensive digging is taking place around the clock. Schemes to relocate or save key sites (Liu, 1996) have been made (see Table 4). On a hill outside of the new city of Zigui we saw a Bhuddist temple in the process of being rebuilt. Along the Yangtze, an ancient sculpture that will be submerged will be the site of an underwater museum. In the famous Ghost City, Fengdu, the lowest part of the temple park will be inundated but the famous temples of Bhuddism, Confucianism and Taoism will remain above the waterline. To make up for this loss, a huge modern ghost sculpture bust of what appeared to be Mao is being constructed on the hills behind the temple. However, to save money, rebuilding relics involves modern construction and material in which salvaged ancient lintels, doors, windows and artifacts are reassembled to model the historic structures.

China is currently a country with 1.3 billion people and the majority seem to be obedient and law abiding. Much time and money have been allocated to making the relocation project a success. Time will tell the whole story. Time also allows for re-evaluation of ideas and concepts that are not working correctly. The TGP planning staff hopefully will continue to re-evaluate the effects of the project and keep an open mind regarding mid-course corrections. They will have brought about a monumental, planned, human endeavor of the magnitude of the Great Wall and the Grand Canal. Will everyone be happy or satisfied? Probably not. But no one is undoing what has been done, and so our best hope is that, as problems arise, beneficial solutions will be found. By watching and reporting, critics can help make that happen.

CONCLUSIONS

The team concluded that the engineers and managers of the TGP are indeed using a systems approach in their execution of the project. They are well aware of the potential problems in building the dam and filling the reservoir. They

know all about silt, earthquakes, landslides, shoreline pollution, relocation of people and production of electricity. They have plans to make the TGP work for the benefit of all the stakeholders. What we do not know at this time is whether there will be resources and the political will to carry out the plans. Only time will tell.

With regard to the unrelenting criticisms posted on the Internet that the project will fail, we have this to say. Despite the huge scale and the difficult technical and social challenges posed by the Three Gorges Dam, the Chinese engineers have been able to overcome the obstacles at each phase of the project. (Bridle, 2000, concurred). But that does not mean that the criticisms were invalid or useless. What the critics did was to focus the engineers and administrators on problems which they might have ignored or treated with less attention (see Haggart, 2002). As a result of the criticisms, management was forced to test out their assumptions with detailed physical models, bring in outside experts, allocate funding where it was insufficient or entirely absent, and consult with affected stakeholders before plans were fixed in place. Thus, the role of the critics and their use of the Internet to arouse public opinion would seem to have had a beneficial and countering effect on the traditional Chinese practice of top-down decision-making in the case of the Three Gorges Dam Project.

The 'higher good of the nation' appears to be the driving force in China. The prestige of the dam, the usefulness of the dam, the thrust to improve living standards through greater electricity, water supply, navigation, irrigation, flood control and water transfer have the highest priority. The individual has never figured highly in the calculus of Chinese governments, whether dynastic, Kuomintang, Communist, or the current market-socialist government. The goal of economic development in China has the support of both capitalists and communists and, as we observed, the man in the street. China desires, above all, to take its place among the developed nations and to emerge as the world's second superpower in the twenty-first century. By building the largest dam in the world, the Chinese government is demonstrating that China is on the way to fulfilling its goal.

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APPENDIX

Questions and answers

The following are the questions we asked and the answers we received from our interviews with engineers,[8] managers[9] and administrators[10] of the dam project. All questions were translated in to Chinese and distributed to the respondents a week before the interviews. The respondents answered all questions in Chinese, which were then translated to English by our guides. No tape recorders were used at the interviews but detailed notes were taken by the group and the guides.[11] The general layout of the Three Gorges Dam is shown in Figure 4.

Q: Is the dam able to withstand floods?

A: The dam can withstand a flood of 100-year frequency (71,000 cubic meters per second) but

[8]Interview with Mr Hong, Vice Director and Senior Engineer of the Three Gorges Project, and Mr Yong, Division Chief for Project Information Systems, Three Gorges Project Hotel, July 26, 2002.
[9]Interview with Dr Ma Xiang, Specialist in Relocation, Three Gorges Project Hotel, July 27, 2002.
[10]Interview with Mr Zhen Qi Fu, Economic Development Administrator, New Zigui, July 28, 2002.

[11]Many accusations were made against the dam project and we framed our questions to address them. Accusations were often not supported by valid data; were one-sided in that they did not present opposing views; assumed nothing could be done to meet the criticisms; and finally were contradictory in nature, especially regarding relocation of residents, the level of water in the dam, the electricity generated and sold as opposed to the demand for electricity (Sklar and Luers, 1997).

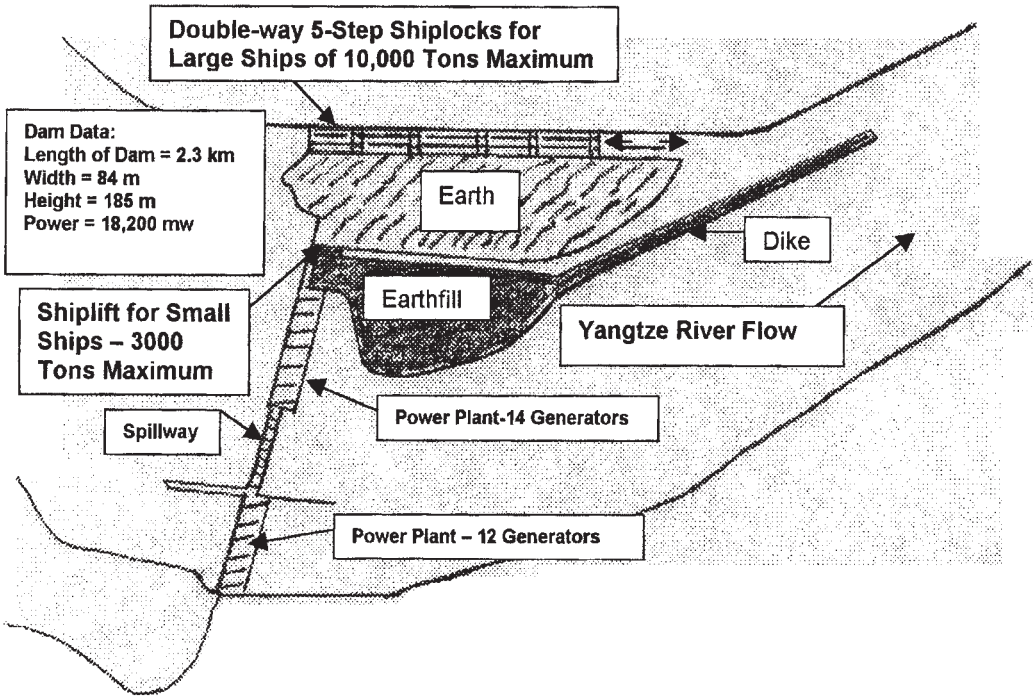

Figure 4. Map of Three Gorges Dam Project

not a flood of 1000-year frequency (120,000 cubic meters per second). If a big flood is expected, we would lower the level of the dam to allow room for the larger than normal flow. Upstream dams will be developed; an entire dam system will be built consisting of four or five dams with reservoirs whose levels can be adjusted to flow conditions. The National Flood Control Office in the provincial capital, Wuhan, downstream from the dam will manage the system of flood control by controlling the sluice gates that allow additional water to pass through the dam. The amount of water in all the reservoirs will be 5 billion cubic meters, consisting first of three dams, then four or five dams later on. The Three Gorges Project (TGP) improves the ability to control floods from the 10-year flood to the 100-year flood.

Q: What are the main factors to prevent failure of the dam and to achieve success?

A: This question took our respondents, two engineers, by surprise. It was not one of the written questions. Their answer was three-fold. First, there was a long period of preparation and research work, especially geological research at the dam site. A lot of technical research went into the design of the locks, the ship lift, the concrete matrix (due to the use of crushed granite instead of sand, gravel and pebbles), and construction research as a result of the huge scale of the dam. Second, the engineers have very good cost control. The budget was 20 billion yuen[12] but the actual construction costs will be 18 billion yuen. Finally, the managers and engineers made sure every small project performed by contractors had an insurance guarantee including foreign companies (operating under joint ventures with Chinese companies). Contract and project management was something they learned on the job and not in school.

Q: Are you able to keep on schedule? This question arose from the Three Rivers Network assertion that the project was falling behind schedule on the one hand and that it was being rushed to completion without proper attention to detail on the other. The accusation was that the

[12]Current exchange rate is 8.28 yuen per US dollar.

schedule was moved up from completion in 2013 to completion in 2009 for political reasons.

A: The construction completion date of 2013 never appeared on the schedule. The plan was always 2009. By 2007 all construction work will be completed and the level of the reservoir will go from 135 meters to 156 meters. By 2009, the level will rise from 156 meters to 175 meters, its maximum height. Normal operation of all the generators will be by the year 2013 with all 26 generators producing a total of 18,200 megawatts, 25% of China's current hydroelectric capacity but only 6% of its total capacity.[13] The flood control level of the dam will be at 145 meters when the dam level is lowered with the anticipation of summer rains. As a result, power production will be reduced at that time.

Q: What about cracks in the dam?

A: Cracks really happened but they are a minor problem; the concrete quality is reliable. Cracks, however, are being repaired. Tests showed that the concrete composed of a crushed granite matrix is stronger than normal concrete and is stable chemically. On the other hand, it should be noted the matrix has not been tested over long time periods.

Q: Is it true that the quality of the generators may not be high because never before has China built such large generators? (This kind of criticism, that what the Chinese are doing will be likely to fail because it has never been done before or done on such a large scale, was made at every step of the way in the project. Yet the Chinese engineers have been able to overcome difficult obstacles at every stage in the project.)

A: According to the Three Gorges Project official document, 'The TGP power station is planned to be equipped with 26 sets of hydro turbine generators having a rated capacity of 700 megawatts each' (CTGPC, 2000, p. 20). The engineer interviewed said that of the 26 generators only 12 will be built by China; 14 will be manufactured on contract by foreign companies such as GE of Canada, Voith and Siemens of Germany, Alstom of France and ABB of Switzerland.

Q: What about cracks in the generators?

A: Regarding cracks in the generators, the engineer stated that cracks don't seem to be a problem; it is not unusual to have them; and cracks were found in all foreign generators. The cracks are being repaired.

Q: Will there be an excess of electricity generated because demand has fallen as a result of many government factories along the river being closed?

A: First, the price of electricity will be competitive with coal. Secondly, demand is expected to go up because living standards of relocatees will be going up, i.e., more more air conditioners, various appliances, TVs, etc. Finally, as we found out in the interview with the economic development administrator of the new city of Zigui, industry is being offered tax breaks to relocate to the new cities on the Yangtze. It is expected that increased sales of electricity will be sufficient to compensate for the decrease in demand resulting from the closure of government factories.

Q: Will you be able to recoup your investment through the sales of electricity?

A: Yes. Even when the level of the dam is lowered for flood control, the central government will compensate the TGP for any electricity production loss as a result of decreasing the pressure head from 113 meters to 52 meters (CTGPC, 2000, p. 19).

Q: What happens to the thousands of workers once the dam is built?

A: There are currently (August 2002) 20,000 workers on the dam. In the initial phases of construction, there were 30,000 workers. The workers belong to contractors and are not employees of the TGP. After the Three Gorges Dam is built, the contractors will have much work to do on tributary dams, although they will have to compete for the work. The hydroelectric market (for projects and workers) is up for the next 20 years. Workers will find employment with the firms that win the contracts.

[13]A large percentage of electricity is still generated by heavily polluting coal power plants.

Q: Is it true that the dam is built on a geologically unstable area that is prone to landslides and earthquakes? Will the huge body of water in the reservoir be likely to cause earthquakes and landslips? What steps have been taken to avoid natural disasters resulting from earthquakes and landslips?

A: The dam is built on a huge anticline, a 700 million year old granite formation which is 50 to 60 kilometres long. The dam was designed to withstand an earthquake of magnitude of 7.0 on the Richter scale while only a 6.0 at most is expected. As for the reservoir causing earthquakes, they will be small, not strong enough to damage the dam. Regarding landslips, there are some unstable places along the Yangtze River but they are 30 to 40 kilometers up-river from the dam. If they occur, they will not affect the dam. In addition, from 1998, we have budgeted 2 billion yuen (US $242 million) to do geological treatment far away from the dam.

Q: Questions on the ship-lift: (The ship-lift is a large box into which ships of 3000 tons or less, together with water, can be lifted 600 feet in half an hour from the bottom to the top of the dam.) Is it true that the ship-lift will be the largest in the world? Is the technology to operate the ship-lift complicated and as difficult to operate as the Germans say? Is the construction of the ship-lift on schedule? How long will the shipping on the river be suspended while the ship-lift is being constructed? What steps are being taken to speed up the passage of ships up the Yangtze?

A: It is true that the ship-lift will be the largest in the world whether one considers ship's tonnage, total lift weight or lift height. The most important issue is safety, especially the reliability of the safety-locking device. The ship-lift is not the main method of getting ships through the Three Gorges Dam; the locks are a main method. The locks, which can handle ships up to 10,000 tons, take 2.5 hours to transport a ship 600 feet in elevation. The ship-lift can lift a smaller vessel of 3000 tons in a half hour. The total weight of the ship, the water and the lift can be not more than 11,800 tons. The TGP have experimented on several models plus the experience collected on the Jin Jan Jian River with a smaller 300 ton ship-lift. Although the Germans have been studying the problem of the ship-lift for 10 years, as yet they have not settled on a solution. The project is currently open to design bids from several countries. The technical problem is that the four points on the corners of the box need to be lifted up at the same time and a safety lock has to be activated if the lift is stuck so that it cannot collapse. The problem is with the control system, with the software and with the supporting cables. Because of all the problems connected with scaling from an 8000-ton ship-lift in Belgium to 11,800 tons in the TGP, the designers are not sure it will work. Still, the construction of the ship-lift remains on schedule since the engineers have until 2009 to complete it. Shipping on the river will not have to be suspended while the ship-lift is being constructed because the locks will be in operation as early as 2003.

Q: We have heard of cases of corruption and bribery regarding money appropriated for construction and relocation of people. Is it true that in the year 2000 97 officials were convicted of embezzlement from the dam fund? What has been their punishment? Is it true that a number of culprits have vanished with the money? How can this happen?

A: The answer to this question came from the administrator, Dr Ma Xiang, who is a specialist in relocation and now responsible for relocating all the people displaced by the dam. On the subject of bribery and corruption, he stated, 'it is an open system. Each family knows how much it is supposed to get (in terms of compensation). Supervising this is easy. A special office does the supervising, independent of local government, but out of Beijing. An official from the central government is in charge of relocation. Cooperation with officials in Hubei Province and Chongquig Municipality are good. Any corruption was at the local level. There is a three-step process: report to supervisor; follow-up on relocatee; then independent audit. Nobody can interfere with this system.[14] As for corruption,

[14]Interview with Dr Ma Xiang, Specialist in Relocation, Three Gorges Project Hotel, July 27, 2002.

1.25% of revenues from the sales of electricity from the TGP are allocated to the relocatees. If embezzlers are caught, they are punished according to the law. Later on, we learned from the economic development administrator of Zigui that 1,000,000 yuen stolen (approximately $125,000) means the death penalty. Penalties are proportional to the amount embezzled or bribes received.[15]

Q: How have the culprits vanished?

A: They have changed their ID (not difficult to obtain forged documents), emigrated abroad, first to Hong Kong then to Canada. (With an investment of $400,000 Canadian ($252,000 US) and new identity, an embezzler can be accepted into Canada as an investor immigrant.) As for the 97 officials convicted of embezzlement from the dam fund in year 2000, Dr Ma Xiang did not believe the figure and asked the source of our information. We replied, the Internet.[16]

Q: What actions are you taking to ensure that the reservoir is not polluted by the land which will be inundated? What steps are being taken to clean up the hillsides and the soil from industrial and human pollution that will be under water when the reservoir has risen to its planned height of 175 meters (574 feet) by year 2009?

A: We will be investing 40 billion yuan (US $4.8 billion) to improve the environment, the soil, the water, for reforestation and to treat wastewater. Water treatment facilities are being improved. People are getting money for planting trees. According to a 1993 UN report, 3000 pollution points have been found in the reservoir area. The government has demanded that the quality of water will be improved relative to that before the TGP. All land along the banks of the Yangtze River has been cleared to the 135 meters elevation markers. We now must clear the land to the height of 175 meters, the maximum height of the reservoir at the dam. The cost of clearing and cleaning the hillsides has been fully estimated. For example, toilets and pig houses will be buried more than 2 meters. Hospital and factory waste will be burned. Not less than 30% of the cleared hillsides will be checked by officials of the province and country. The central government will check more than 20% of the hillsides independently before the water floods the reservoir. The work of clearing and cleaning started by the end of 2001.

Note on water pollution: According to the TGP document, 'The fundamental measures to protect water quality are to treat pollution sources according to the national environmental protection laws. The Chinese government takes water quality protection of large rivers and lakes as the most important task. The State Council has made a decision that all industry pollution sources must be treated to reach a discharge standard according to the environment protection requirement before 2000. A number of small paper mills which discharge heavy pollution water have already been closed and various large wastewater treatment plants have been under construction or planned to be constructed in Chongqing city, Wanxian city, Fuling city and Yichang city (see Figure 3). On the basis of wastewater reaching discharge standard, the cost used to treat the additional pollution induced by the reservoir operation will be financed by TGP (CTGPC, 2000, p. 25). It should be noted that on our trip up the Yangtze we saw many places on the river banks that had large catchments of coal, the products of mines that will be flooded, waiting for shipment. These surely will have to be cleaned up. Dr Ma Xiang concluded, 'According to our experience, it looks to be a hard job. Each local government has been assigned its area to clean up. We are confident that every place can accomplish the job on time.'[17]

Q: What sort of farmland are you moving the farmers to? Will the land be level or steep hillsides? Will the soil be rich or filled with rocks? Will they have enough land to feed themselves?

[15]Interview with Mr Zhen Qi Fu, Economic Development Administrator, New Zigui, July 28, 2002.

[16]One more recent official report said that the government had found 234 cases of corruption and embezzlement, involving 42 million yuan (Cheung, 2002).

[17]Dr Ma Xiang interview, TGP Hotel, July 27, 2002.

A: In answering these questions, Dr Ma Xiang also discussed the quality of housing of the urban relocatees, the question of removal of grave sites, an important issue in a society that worships its ancestors, and the compensation to farmers. He stated that the relocatees must be compensated. Their new homes will be an improvement over their old homes, especially for city, town and village dwellers. They will have a choice. They can take the money and move to another city entirely or they can obtain a new flat in a newly built city. Farmers are offered land, equal in amount to their present land, in another location. The new land could be at a higher elevation than their present farms or it could be a great distance away. If it is at a higher elevation, and the slope is greater than 25 degrees, the government has offered to pay them to plant tea, orange and pine trees to hold the soil on the steep hillsides (and not rice crops), which would provide income for them in the initial period after moving. A farmer who plants more than 50 trees will receive a bonus. A second method of compensating farmers is to lend them money at no interest to get them started in the new location. Regarding pollution on the new land, Dr Ma Xiang said that in the Three Gorges area farmers use much less chemical fertilizer and more natural fertilizer. Farmers will receive bonuses for reporting pollution to the authorities.