Some of the most sophisticated 20th-century technologies have been applied to build the largest hydroelectric dam in the world, the Three Gorges Dam Project (TGDP) of China. The author administered a study abroad course in China from May 27 to June 10, 2000, to study the massive project as it approached the halfway mark of its second and most critical stage, namely Phase II. This article sheds some light on this sizable project and summarizes information and observations gathered first-hand during this study abroad course on the construction of the Three Gorges Dam (Wahby, 2000).

As students, teachers, and other practitioners in the various technology professions read this article, it is hoped that they may get a better understanding of this substantial project, its main components, and the challenges that faced and still are facing its construction, as well as the technologies used to complete it. It is also hoped that the readers may see the tremendous effects of this massive undertaking on different aspects, on China as well as on the rest of the world. Those aspects include but are not limited to water conservancy, hydroelectric power generation, environment, ecology, geology, geography, economy, politics, transportation, society, culture, business, industry, and even technology itself.

In particular, technology is being challenged and stretched to the limit as never before to construct the Three Gorges Dam. Unprecedented production rates are becoming the norm in order to keep the sizable project on schedule, while adhering to the highest quality requirements of construction codes. After the completion of the project by 2009, the technology used in the construction of the dam will probably need to be reviewed and enhanced in light of lessons learned.

In addition to a description of the main components of the project and the phases of its construction, a historical background and a timeline of the events that culminated in China’s decision to build this dam are presented in this article. The article also points out the reasons why this sizable project is being built and discusses the results that are anticipated after its completion. Some of the challenges faced in the construction of the project are analyzed, together with how they were dealt with.

Background

The TGDP is projected to become the world’s largest dam—nearly four times larger than Hoover Dam, with a height of 607 ft (185 m) and a length of approximately 1.4 miles (2.3 km; Kosowatz, 1999). The TGDP is composed of the dam, two power plants, and the navigation facilities. The dam is composed of three sections: the spillway dam, the intake dam, and the non-overflow dam. The permanent navigation structures include a ship lock and a ship lift. A temporary ship lock is also a part of the project that is being used during Phase II of the TGDP.

TGDP Location

The Three Gorges is one of the world’s most famous scenic sites around Qutang, Wuxian, and Xiling gorges. The TGDP is located almost 750 miles (1,200 km) south of Beijing and 650 miles (1,000 km) west of Shanghai, China. More specifically, the TGDP is being constructed in Sandouping Village, Yichang County, Hubei Province, in the Xiling Gorge, about 25 miles (40 km) upstream from the existing Gezhouba Project located at Yichang City.

TGDP Site

The site for the TGDP was selected at Sandouping, along the Yangtze River, after about 15 other sites were studied. The site has many advantages. The crystalline rock, intact granite with 100 MPa of compressive strength, forms a good foundation bed for the dam. In addition, there are no major unfavorable or injurious geologic structures in the vicinity of about 9 miles (15 km) around the dam site, while the regional seismic activities are small in intensity, low in frequency.

Interestingly, the river valley at the construction site of the TGDP is relatively open and broad, with the hills on both sides of the river fairly flat, providing for a good-size lake right at the upstream of the dam. Also, the existence
The 60-story high dam is a concrete gravity type that is composed of three sections: the spillway dam, the intake dam, and the non-overflow dam. The total length of the dam axis is 0.24 mile (1,244 ft) long, 727 ft high, 660 ft thick at the base, and 45 ft thick at the crest.

The spillway dam, located in the middle of the river course, is 0.3 mile (483 m) long in total, where there are 23 bottom outlets and 22 surface sluice gates. The dimensions of the bottom outlets are 23 x 30 ft (7 x 9 m), with the elevation of the inlets at 300 ft (90 m). The net width of the surface sluice gates is 27 ft (8 m), with its sill elevation at 525 ft (158 m).

On both sides of the spillway dam section there are the intake dam and non-overflow dam sections. With a maximum discharge capacity of 102,500 m³/s, the spillway dam is capable of producing 847 TWh of electricity output annually.

The permanent navigation structures consist of the permanent ship lock and a ship lift. The ship lift is designed as a one-stage vertical hoisting type with a ship container sized 80 x 13.3 ft (240 x 4 x 4 m). The ship lift is designed to accommodate 10,000-tonne ships and is capable of handling up to 8,470 TWh of electricity output annually. The permanent navigation structures include the TGD Reservoir Project, which is the largest water conservancy project ever built in the world. The TGD Reservoir Project will completely block the Yangtze River course to impound a narrow, ribbon-like reservoir. This ribbon-like reservoir will have a total length of over 400 miles (600 km)—longer than the reservoir of Lake Mead—and an average width of 0.7 miles (1.10 km)—less than twice the width of the natural river channel.

The total water catchment area is about one million km². The surface area of the reservoir will reach 1.084 km², and the land area to be inundated will be 632 km²—almost twice the original water surface area. The average annual runoff is 451 billion m³ and 526 million tons of annual sediment discharge. With the normal pool level (NPL) at 570 ft (175 m) above sea level, the total storage capacity of the reservoir is 39.3 billion m³.

The dam is a concrete gravity type, 60 stories high, 660 ft thick at the base, and 45 ft thick at the crest. The powerhouse on the left is 0.4 mile (0.65 km) long, with 14 sets of hydro turbine generator units (Francis type, 700 MW each), with a total capacity of 18,200 MW, and the powerhouse on the right is 0.37 mile (0.6 km) long, with 12 sets of hydro turbine generator units (Francis type, 700 MW each), with a total capacity of 16,700 MW. The total installed capacity of the dam is 34,900 MW, with a total electricity output of 847 TWh annually.

The dam is 210 ft (64 m) high, 1,100 ft (335 m) wide at the base, and 1,700 ft (518 m) long. The dam is composed of two sections: the left and right banks. The left side of the dam is 210 ft (64 m) high, with 14 sets of hydro turbine generator units (Francis type, 700 MW each), with a total capacity of 16,700 MW. The right side of the dam is 90 ft (27 m) high, with 10 sets of hydro turbine generator units (Francis type, 700 MW each), with a total capacity of 10,200 MW. The total installed capacity of the dam is 34,900 MW, with a total electricity output of 847 TWh annually.

The TGD Reservoir Project is the largest water conservancy project ever built in the world. The TGD Reservoir Project will completely block the Yangtze River course to impound a narrow, ribbon-like reservoir. This ribbon-like reservoir will have a total length of over 400 miles (600 km)—longer than the reservoir of Lake Mead—and an average width of 0.7 miles (1.10 km)—less than twice the width of the natural river channel.

The total water catchment area is about one million km². The surface area of the reservoir will reach 1.084 km², and the land area to be inundated will be 632 km²—almost twice the original water surface area. The average annual runoff is 451 billion m³ and 526 million tons of annual sediment discharge. With the normal pool level (NPL) at 570 ft (175 m) above sea level, the total storage capacity of the reservoir is 39.3 billion m³.

The TGD Reservoir Project is the largest water conservancy project ever built in the world. The TGD Reservoir Project will completely block the Yangtze River course to impound a narrow, ribbon-like reservoir. This ribbon-like reservoir will have a total length of over 400 miles (600 km)—longer than the reservoir of Lake Mead—and an average width of 0.7 miles (1.10 km)—less than twice the width of the natural river channel.

The total water catchment area is about one million km². The surface area of the reservoir will reach 1.084 km², and the land area to be inundated will be 632 km²—almost twice the original water surface area. The average annual runoff is 451 billion m³ and 526 million tons of annual sediment discharge. With the normal pool level (NPL) at 570 ft (175 m) above sea level, the total storage capacity of the reservoir is 39.3 billion m³.
The Journal of Technology Studies

TGDP Costs
In 1990, the cost of the project was estimated at US$12 billion (Y90.09 billion). A more recent estimate is US$27 billion (Y223 billion). Nearly half of the project’s cost is being applied to the resettlement of hundreds of villages and towns along the river’s edge. If the estimated cost is increased by a factor of 2.25 within 10 years, it might well be possible that the actual cost by the end of the project would reach the $50 billion mark—more than virtually any other single construction project in history.

TGDP Controversy
The construction of China’s Three Gorges Dam, the largest dam in history, is already in its ninth year and is expected to be completed by 2009 with a cost currently estimated at over $27 billion. Perhaps more than any other project in the history of China, the TGDP has attracted the attention of many individuals and groups in China, as well as worldwide, and created much controversy, particularly among the experts, due to its almost equally compelling advantages and disadvantages. Supporters of the project believe that the advantages of the project far outweigh the disadvantages, and, obviously, this is the view of the decision makers in the Chinese government because the project is indeed moving forward. Following is a list of both the advantages and disadvantages for the readers to think and decide for themselves:

TGDP Advantages
1. Flood Control: The TGDP is projected to allow a precise control over the Yangtze River, reducing the severity of flooding by 90%, thereby saving life and property from destruction.
2. Power Generation: With its 26 turbines at full capacity, the TGDP is estimated to generate 18.2 billion MW annually, making it the biggest hydropower producer in the world. This would provide 15% of China’s electricity mostly in the Yangtze River basin area. That output is equivalent to approximately 50 million tons of coal or that of 18 nuclear power plants, producing 84 billion kilowatt output per year.
3. Navigation Improvement: The TGDP is projected to allow the passage of 10,000-ton ships to Chongqing instead of the limited 5,000-ton ships, increasing the annual one-way navigation capacity from the present 10 million tons to 50 million tons, meanwhile decreasing the navigation cost by 35% to 37%. With almost 15 million people, Chongqing will become the largest “seaport” in the world.
4. Other: The project is expected to promote the development of fishery in the reservoir, as well as tourism and recreational activities. To a certain extent, it should improve the water quality and the wildlife of the Yangtze River, reducing the severity of flooding by 90%, thereby saving life and property from destruction.

TGDP Disadvantages
1. The reservoir will flood approximately 75,000 acres of the best agricultural and cultivated farm land in the region, requiring farmers to start cultivating lesser quality lands.
2. Over 110 sites of cultural and historical importance will be forever lost.
3. It is feared that the project will alter the entire ecological system and adversely affect the environment in the area.
4. The reservoir will flood approximately 75,000 acres of the best agricultural and cultivated farm land in the region, requiring farmers to start cultivating lesser quality lands.
5. It is feared that the project will alter the entire ecological system and adversely affect the environment in the area.
6. The dam construction will divert funds from more beneficial, less risky projects such as constructing smaller scale dams along the Yangtze and building new canals or branch canals that may work as safety outlets when the Yangtze floods attack, which also brings water to new areas.
7. The dam and the reservoir will destroy some of China’s finest scenery and an important source of tourism revenue.

TGDP Status Highlights
The second of the three construction phases of the TGDP is already halfway completed. This critical stage presents perhaps the TGDP’s biggest challenge: keeping to an aggressively ambitious schedule while constructing—according to the highest technical specifications and foreign inspection—the permanent five-story ship lock, the dam’s spillway, and left intake structure, which will house 14 giant turbines. The schedule calls for the first two turbine generators to be producing power by the middle of the 1990s. The river will begin flowing, from its roots and creating all kinds of social instability associated with a “river refugee new community.”

Because heavy sediment buildup in the reservoir is likely to continue to hinder navigation.

11. Flood control benefits are overstated; the reservoir could at best store only a fraction of the floodwaters entering the Yangtze during a peak-flow year.

12. Dam construction will divert funds from more beneficial, less risky projects such as constructing smaller scale dams along the Yangtze and building new canals or branch canals that may work as safety outlets when the Yangtze floods attack, which also brings water to new areas.

13. The dam and the reservoir will destroy some of China’s finest scenery and an important source of tourism revenue.

14. The dam and the reservoir will destroy some of China’s finest scenery and an important source of tourism revenue.

9. Pollution and slow-moving water could also threaten fish, reptiles, and other wildlife that depend on the river for their survival. Almost 80 species of fish, Yangtze dolphin, finless porpoise, Chinese sturgeon, and giant panda will be endangered (“China’s Three Gorges Dam,” 1996).

10. Navigation benefits are exaggerated
cranes have swinging telescopic conveyors that are designed to pour concrete at the impressive rate of more than 600 cubic yards per hour. A mobile crane delivers concrete from a large hauler to construct the dam’s left training wall. Because concrete generates a considerable amount of heat as it sets, large volumes can become exceedingly hot, damaging the material’s structural strength. Hence, curing of concrete is essential to keep it at a temperature of about 45 °F (7 °C) as it hardens.

The construction pit for erecting the main dam was dug to a depth of 260 ft, allowing the foundation work to begin. Numerous holes (with a total length of more than 60 miles) are currently being drilled into the ground and filled with pressurized grout. This “grout curtain” will help protect the main dam from uplift by preventing water from seeping underneath the structure. (For the same purpose, 870,000 sq ft of concrete walls were sunk below the transverse cofferdams.)

To facilitate transporting thousands of workers to the construction site, the government built a four-lane highway from Yichang, the nearest city of significant size. By any standard, the $110-million road, which cuts through the mountains that frame Xiling, was itself a considerable undertaking: 40% of its total length of 17 miles consists of bridges and tunnels, including a twin bore that is more than 2 miles long. Additionally, a 2,950 ft suspension bridge, the longest in Mainland China, outside of Hong Kong, was built at Sandouping for access to the project’s right bank.

The double-way, five-step flight ship lock was carved from granite on the river’s left bank and lined with concrete. To carve space for the lock chambers, concrete placement, underground excavation of the water feed system and lining of inclined shafts and gate shafts, concrete lining.

Non-overflow dam sections: The concrete placement of the left and right bank non-overflow dam sections was started in 1996 and 1997, respectively. Currently, several segments have reached an elevation of 120 m with the left abutment dam sections having reached to the crest elevation of 185 m.

Left bank intake dam sections and powerhouse: Concrete placement of No. 1 to 6 intake dam sections of left bank was started at the end of 1997. No. 1 to 6 units of the left bank powerhouse are planned to be the first batch of generators put into operation. Because of its convenient construction condition, the excavation of the powerhouse for No. 1 to 6 was arranged in the first construction stage and was finished at the end of 1997. The concrete placement was started in January 1998. At the end of 1998, the No. 1 to 5 powerhouse concrete placement of the basement and the tailrace tube were basically finished. The excavation for No. 7 to 14 units was finished by the end of 1998. Concrete placement is in progress.

Conclusions

When completed, the TGDP of China will be the largest water conservancy project as well as the largest hydropower station and dam in the world. Technology is being challenged and stretched to the limit as never before to face a variety of engineering challenges in the construction of the TGDP. This includes many aspects such as site preparation, the dam’s foundations, the details of the project’s main structures, some of which are carved in very hard rocks, not to mention having to work under ever-changing weather. Production rates never before attained are becoming the norm in order to keep the sizable project on schedule. After the completion of the project by 2009, the technology used in the construction of the dam will probably need to be enhanced in light of lessons learned.

References


After the completion of the TGDP, precise flood control can be achieved and enormous hydroelectric energy will be produced annually, replacing coal consumption and saving the environment. However, this will not be without cost considering the negative effects such as submerging numerous cities, towns, and villages and inundating some of the best farmland, besides threatening wildlife, not to mention the resettlement of almost 2 million people.

The TGDP is a massive effort in technology transfer. The author asked the chair of the Association of Retired Engineers in Chongqing whether Chinese people are proud of the Great Wall more than they are with the TGDP. After a moment of deep thinking, he stated with a smile that “the Great Wall was built by the Chinese people, and it is indeed their pride, but the Three Gorges Dam is being built by the whole world, so it should be the pride of the whole world!”

Wafeek S. Wahby serves as the coordinator of the Industrial Technology Program, School of Technology, Eastern Illinois University, Charleston. He is a member-at-large of Epsilon Pi Tau.