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Impact of the Three Gorges Dam

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Abstract
The Three Gorges Dam was built to provide hydroelectric power, flood control, and greater navigation access to the Yangtze River in central China. It is the largest hydroelectric dam in the world and as such is responsible for bringing both unprecedented benefits and risks to the people of the Yangtze River Valley and all of China. In some cases the dam has been the cause of great devastation including the destruction of both the environment and rich cultural heritage of the Yangtze River valley, but it has also spurred a greater concern for the protection and conservation of both the environment and the way of life for many of the Chinese people. While many of the consequences of the dam will not be felt for many years, both the Chinese and the world will be looking to the dam as an example of the future feasibility of hydroelectric power. This paper analyzes the drawbacks of constructing such an enormous dam as well as the benefits.

The Three Gorges Dam was built to provide hydroelectric power, flood control, and greater navigation access to the Yangtze River in central China, but what are the drawbacks of constructing such an enormous dam and will the benefits outweigh the numerous negative effects?

Planning and Construction

Preliminary construction of the Three Gorges Dam began in June 1993 following protests, social and economic unrest, and differing scientific opinions about the feasibility of the dam. These controversies had delayed its construction for 14 years, since 1979 when the first studies were conducted (Ponseti and Lopez-Pujol 2003, 156). According to an article by James Beattie in 2002, the resolution to construct the dam was voted on by the National People's Congress in April of 1992 "with 1,767 deputies in favor, 177 against, and 664 abstained. Thus, the affirmative votes were only 12 over the minimum of 1,755 – two thirds of the camera –required to approve the project, and unprecedented opposition in a body usually used by the government for rubber stamping projects" (quoted in Ponseti and Lopez-Pujol 2003, 157). The dam was to be constructed in three phases starting in 1994with completion slated for 2013. However, the plans were changed in 1994 "establishing 2009 as the year when the reservoir should rise to 175m four years ahead of schedule" (Ponseti and Lopez-Pujol 2003, 157). The dam has a total height of 185m, a total width of 2,310m, and a normal pool level of 175m which can hold 39.3 billion m3 of water (157). After more revisions to the construction plan the dam was outfitted with26 turbines capable of producing 22,400 mw making this the largest hydroelectric dam in the world. The complex also included a “double-way five-step ship-lock and a ship-lift for smaller vessels (both facilities will be the largest in the world)” (157).

Flood Control

The scale of this dam is certainly impressive but what benefits will it bring to the Chinese people? Flood control will be the most noticeable impact on the area - an area which over the years has been hit by numerous episodes of flooding killing several hundred thousand and costing billions in damages and lost productivity.According to a 2000 report by the Red Cross, in 1998 a large flood, “caused more than 3,000 deaths, affected about 200 million people, inundated more than 20,000km^2 of cultivated land, and caused a total estimated loss of 25 billion Euros, without taking into consideration indirect losses” (quoted in Ponseti and Lopez – Pujol 2003, 165). This most recent flooding was responsible for spurring into motion the construction of the dam.

Another factor in the dam’s importance as a flood control mechanism is the fact that the area downstream from the dam is becoming increasingly more populated and many of the natural flood control features such as lakes are being removed to support agriculture. A report by Zhen-Li Huang in 2001 indicated that for flood control purposes the Three Gorges Dam reservoir “will be reduced to 145m before each flood season to provide up to 22.1 billion m^3 of flood control capacity” (quoted in Ponseti and Lopez-Pujol 2003, 162). The Chinese government claims that this will “protect not only the 15 million people living in the flood-prone areas of Jianghan and Dongting plains and their 15,000km^2 of farmland, but also the roughly 80 million people and 60,000km^2 of croplands and the dense industrial network of the middle andlower basin of the Yangtze. In addition, outbreaksof infectious disease with food events… would also be avoided" (Ponseti and Lopez-Pujol 2003, 162).

Power Generation

Power generation is another important benefit to the population surrounding the dam. In the 1970s the supply of power in China began to fall short of demand and with the economic reforms of the late '70's and large expansions of economic development, these problems were made worse (165). In a 1999 report by the Yangtze River Valley Water Resources Protection Bureau or YWRP, the government turned to coal fired power plants in the early 1980's to meet these rising demands but "the high pollution associated with coal-burning power plants emphasized the need to find an alternative source of energy" (quoted in Ponseti and Lopez – Pujol 2003, 165). This alternative energy source was hydroelectric power which China has the greatest potential of any nation to exploit. In 2003 China was only exploiting 26 percent of their hydro power generation potential (Ponseti and Lopez – Pujol 2003, 165). But new plans call for hydropower development on many of China's great rivers, in addition to the Yangtze.These rivers have enormous potential because of their large drop in elevation and high velocities (165). On the Yangtze alone 23 large dams have been projected but the power output of the Three Gorges Dam will account for nearly 25 percent of the projected power from the cascade (165). More than half of the power from the dam will be supplied to central China providing a stable energy source which will remove the need to have coal from northern China brought to powerplants in the dam's power distribution area, according to a Three Gorges Dam fact website in 2006 (quoted in Ponseti and Lopez – Pujol 2003, 165).

Navigation

In addition to flood control and power generation, navigation on the Yangtze will be of huge benefit to the people of China. The Yangtze is the "Chinese 'Golden Waterway'. Its navigability has made the Yangtze River to be a key artery of communication, connecting east, central, and west China since ancient times. The Yangtze waterway system (the Yangtze main channel, its secondary channels, but also its tributaries)is formed by about 3,600 navigable rivers, stretching more than 77,000km; of these about 2500km are navigable for vessels over 1,000 tonnes" (Ponseti and Lopez – Pujol 2006, 166). The Yangtze also provides the main form of transportation to the city of Sichuan, but navigation of the waterways in the Three Gorges area has always been difficult, especially where "the sandbars and the shallowness and instability of the river courses have put many risks to the shipping" according to the YWRP in 1999 (quoted in Ponseti and Lopez – Pujol 2003, 167). This will all change with the completion of the dam and the filling of its reservoir which will provide a dramatic improvement in navigability over a 660km stretch of the Yangtze. In 2003 Hartman and Becker stated that the deepening and widening of the river channel will inundate dangerous shoals, decrease the flow velocity and allow the removal of one way restrictions on the river (Ponseti and Lopez – Pujol 2003, 167). In addition, "the minimum discharge downstream of Yichang in the dry season will be increased from 3,000m^3/s to 5,000m^3/s" (Hartman and Becker, 2003). These improvements will combine to allow shipping capacity on the Yangtze to jump from 10 million to 50 million tons annually. This is due to the ability of the larger river to support 10,000 ton vessels for half the year and 5,000 ton vessels during the drier six months, a large improvement over the 3,000 ton ships which previously covered the route (Ponseti and Lopez – Pujol 2003, 167).

Tourism

Yet another benefit of the increased navigability in the Three Gorges region will be increased tourism. The Three Gorges area has long been one of China's major tourist attractions but the "Chinese authorities claim that the dam filling will not greatly modify the spectacular scenery of the Three Gorges… since the peaks along the gorges range from 800 – 1500m, and the reservoir water rising will be only about 10m (to175m), the height of the gorges will be diminished only about one tenth, and the visual sense of the landscape therefore will not be significantly altered" (168). While the reduction of the mountain's height relative to the water level may affect the landscape somewhat, tourism will also benefit from the increased water depth which will allow "not only an increase in the number of visitors to the best known spots in the Yangtze River, but also the chance to visit new scenic spots upstream of some tributaries, previously inaccessible" (168).

Water Accessibility

A fifth benefit of the dam complex will be increased availability and access to water. The enormous Yangtze basin will provide not only a greater supply to the lower reaches of the Yangtze over the duration of the year but it will also provide much needed water to areas of northern China. Much of northern, and in particular northwestern China, are experiencing water shortages on an enormous scale. This is due to the lower annual rainfall amounts. The response has been to draw on large rivers, lakes, and aquifers to meet industrial and agricultural needs; but the increased demand has left large sections of the Yellow River dry, and has lowered aquifer levels significantly (Ponseti and Lopez – Pujol 2003,169). According to

McCormack in 2001, this drop in water level can be observed near Beijing where "the water table has fallen about 40m in the past 50 years, a similar trend observed for the whole of North China" (quoted in Ponseti and Lopez – Pujol 2003, 169). This huge expansion in water consumption has led to a shortage of water for some 400 million people and 600 cities in northern China. This water shortage and continuing increase in demand is being counteracted by a plan to divert water from the upper sections of the Yangtze to several other reservoirs which will then be discharged into the Yellow River to provide for northern China (Ponseti and Lopez – Pujol 2003, 170). There is no doubt that these five benefits of the dam complex will have a profound effect on all of China but what negative consequences will the dam produce and what dangers are there to the dam and its effectiveness?

Ecological Impacts

Along with all other dams, the Three Gorges Dam project will have a severe impact on both biodiversity and the environment in the Yangtze River valley and beyond. Blocking a river involves a series of physical, chemical and geological consequences that affect the air, soil and water. Many levels of biodiversity will be affected including both ecosystems and individual species (Ponseti and Lopez – Pujol 2003, 170). It had been suggested by the World Commission on Dams and the YWRP in 2000 that the reduction in greenhouse gas emissions from coal fired power plants would counteract these negative effects, but considering the use of fossil fuels during the dam's construction and the decay of organic materials within the reservoir continuing to release co2, the argument begins to weaken (quoted in Ponseti and Lopez – Pujol 2003,171). The largest impact on the various ecosystems of the Yangtze River valley will be by far the loss of the 600km^2 of land and the resettlement of nearly 1.2 million people which will involve more expansive building projects and the destruction of forested areas as they are adapted for agricultural use (Ponseti and Lopez – Pujol 2003, 170). Large areas of land which have now been submerged were once home to an unprecedented variety of vegetation and animals. This biological hot spot developed because the region played a role as a refuge of life during the late Tertiary and Quaternary periods and today we can find a collection of many ancient endemic species (171). According to a YWRP report in 1999, this biological hotspot is home to more than 6,400 different plant species, almost 20 percent of China's total, including many which are endemic to the region. The reservoir inundation and the resettlement of close to 1.2 millionpeople will affect "at least 36 vegetation types, totalizing up to 550 plant species" (quoted in Ponseti and Lopez – Pujol 2003, 171). Of the 550 species affected only four face serious damage but all four are endemic to the reservoir area (Ponseti and Lopez – Pujol 2003, 171). It was stated in a 1999 YWRP report that since all four plant species are endemic to the inundated area the Chinese government began a series of conservation programs which include "translocation of populations, the establishment of species – specific reserves and the maintenance of germplasm banks" (Ponseti and Lopez – Pujol 2003, 171). Plant species might be the largest group threatened by this dam but there are other groups in danger as well. One of these groups is the collection of terrestrial animals which call the reservoir area home. These animals will be forced upwards as the reservoir begins to fill, a move which will prove difficult for many species that are highly adapted to specific habitats (Ponseti and Lopez – Pujol 2003, 171). This difficulty is better understood when the area's ecosystems are considered. According to a work by Z. Shen in 2000, below 800m the area surrounding the reservoir is comprised of evergreen broadleaf forest; between 800 and 1700m the composition has changed to evergreen and deciduous broadleaf mixed forests, and finally, above 1700m the ecosystem is deciduous and coniferous forest (quoted in Jianguo, et al., 2003, 1239). The presence of this ecosystem change will make adaptation difficult for species being forced upwards by the reservoir but fortunately no "terrestrial animal species endemic to the Three Gorges region have been reported. No species would be lost as a consequence" (Ponseti and Lopez – Pujol 2003, 172).

A smaller but no less important group is the community of freshwater fish which, according to a work by Fu C., et al. (1993), includes 361 species "accounting for 36 percent of all freshwater fish species in China" (quoted in Ping, et al., 2003, 1149). A 1998 report by Yue P. and Chen Y. stated that of these 361 species "there are as many as 177 endemic fish species in this area, of which 25 already have endangered status, accounting for 27 percent of all freshwater fish species in China" (quoted in Ping, et al., 2003, 1149). Many factors have contributed to this destruction of the fish population, but according to Xie P. and Chen Y. in 1998, the most significant change has been to the Yangtze channel and surrounding water features. Originally the Yangtze basin included a huge floodplain, a common feature of a large interconnected river network and many large lakes which were connected to the main channel(quoted in Ping, et al., 2003, 1149). As the population and urban development of the floodplain increased, flood control systems were constructed to protect the urban and agricultural areas. These flood control systems severed the connections between the many channels and lakes on the floodplain restricting the mobility of many migrating fish species. This situation was worsened with the construction of the Gezhou and later the Three Gorges dams which completely blocked the migration routes of several large fish (Ping, et al., 2003, 1149). After the completion of the Gezhou dam in 1981 sharp declines were reported by Wei Q., et al. (1997)in the populations of these endemic ancient fish species: Chinese Sturgeon, River Sturgeon, and Chinese Paddle-fish (quoted in Ping, et al., 2003, 1149). In addition to restricting mobility the dams also alter the level and velocity of the rivers; many of the fish in this region had coevolved with the floodplain and monsoon climate and will have a difficult time adapting to the significant changes caused by the construction of the Gezhou and Three Gorges Dams. The reduction in fish species will also have a negative impact on food produced from fishing in the region.

Yet another group negatively impacted by the dams is riverine mammals including manatees, dugong, and the Chinese river dolphin, which are even more susceptible than fish to the effects of the dam according to a report by Xie P. and Chen Y. in 1998 (quoted in Ping, et al., 2003, 1150). In the case of these aquatic mammals "sedimentation, altered food web and physical injures and noise disturbance from increased navigation" (Ping, et al., 2003, 1150) are all likely to lead to a population decline in these species. Although the biodiversity of the Three Gorges region will be severely impacted by this dam, it will also give researchers a valuable chance to study habitat fragmentation and the process of extinction. When the reservoir is filled many animals will be forced upward but in some cases they will be confined to newly formed islands. Many theories regarding the process of habitat fragmentation exist and are best tested through field research involving long term monitoring stations (Jiangou, et al., 2003, 1240). This opportunity for unplanned field research is important according to J.M. Diamond in 2001. Because of the barriers to planned research of this nature, "planned experiments are usually prohibited by laws, moral scruples, and logistic and scientific obstacles" (quoted in Jiangou, et al., 2003, 1240). Other areas of unplanned research have yielded startling results; a study of Lake Guri, "created by damming in 1986, showed that small islands lost 75 percent of their biological species within fifteen years, and that all islands lost their top predators within four years" (Jiangou, et al., 2003, 1240).

When faced with a possible loss of biodiversity and environmental damage on such a massive scale, W.F. Laurance et al., reported in a 2002 article that the Chinese government began establishing national and local nature preserves and now boasts over 1757 preserves which cover about 13 percent of the nation's area. They have also "set an ambitious goal of increasing the number of reserves to 1800 (covering 15 % of the area) by 2010 and 2500 by 2050" (quoted in Jianguo, et al., 2003, 1240).

Archaeological Impacts

As the water level rises it will cover not only thousands of square miles of habitat but thousands of years of history as well. The Three Gorges area has had a rich archeological and cultural heritage with a record of inhabitance stretching back to Neolithic times. (Ponseti and Lopez – Pujol 2003, 173). The preservation of this vast record of Chinese history depended on fast, planned rescue but it was impossible to "collect and document all the cultural and archaeological sites threatened by the reservoir before its filling" (174). In the year 2000, Shenestimated that the area to be inundated contained at least 1,282 cultural heritage places" (quoted in Ponseti and Lopez – Pujol 2003, 174). Recently the previous figure has been increased significantly "due to the many archaeological campaigns performed in recent years"

(Ponseti and Lopez – Pujol 2003, 174). Any information which was not collected before the filling of the reservoir in 2009 was lost forever. During the approval process for the dam, apanel of 412 experts were consulted on the various issues surrounding the construction and impacts but missing from that panel were sociologists, cultural anthropologists, and archaeologists (174). This lack of concern for the heritage of the Yangtze River valley would result in a number of programs which rushed to save as many artifacts as possible. According to a report published by Childs – Johnson et al., in 1996, it was only after the approval of the Three Gorges Dam project that the government assigned the State Administration of Cultural Heritage the task of preserving the artifacts at the thousands of sites which would be inundated (quoted in Ponseti and Lopez - Pujol 2003, 174). The aboveground "cultural sites (453 in total, Shen, 2000)… include four categories: ancient buildings, stone sculptures, bridges, and cliff paths. In order to protect them, three types of preservation measures have been implemented"(Ponseti and Lopez – Pujol 2003,175). The three types of preservation included preserving the aboveground cultural sites at their present locations, relocation to higher or safe ground, or intense data collection before a site is submerged (175). In addition to the above ground sites, a report by Childs – Johnsonand others in 2000 stated that underground sites were also being examined. The work on underground sites was conducted by the National History Museum of Beijing and included more than 829 archaeological sites (quoted in Ponseti and Lopez - Pujol 2003, 176). Despite many setbacks and problems the excavation and preservation programs were able to record or protect many significant sites and bring a wave of new information on Chinese history to light (Ponseti and Lopez - Pujol, 2003, 175).

Relocation

With such a large construction and inundation of such a wide expanse of land, relocation posed an extreme challenge to the Chinese government. The original estimated population to be relocated was 725,000, but after the project's approval the number quickly rose to 846,000. After factoring in population growth the number could reach 1.2 million people according to an article published in 2006 by GorildHeggelund (quoted in Ponseti and Lopez – Pujol 2003, 178). Some independent assessments by Sukhan Jackson, Adrian Sleigh, and later, Qing Dai would later raise the relocation projection to 2 million or more (quoted in Ponseti and Lopez – Pujol 2003, 178). According to the World Commission on Dams, in many other cases in China, the relocation estimates have been much lower than the actual population removed and the current Three Gorges Dam projections do not take into account the population upstream which will be affected by siltation or the population of subsistence farmers downstream which rely on the river's disposition to replenish their soils on the floodplain (quoted in Ponseti and Lopez – Pujol 2003, 178). Heggelund's article in 2003,stated that resettlement in China previously involved "paying an amount of money that the house and land were worth, without (any) further consideration about the new livelihoods of migrant people" (quoted in Ponseti and Lopez – Pujol 2003, 178). Resettlement policies changed though, and a greater importance was placed on the livelihoods of the displaced populations. According to a 1999 YWRP and a later 2003 report by Heggelund, this new-found concern translated into a huge project designed to provide displaced residents with not only houses but jobs and a stable local economy. In addition, relocation subsequently involved "the construction of new infrastructures, the improvement of sanitation and the whole health system, and the investment in education and training, instead of mere compensation" (quoted in Ponseti and Lopez – Pujol 2003, 178).

Pollution

Another area of change for the Chinese government was their concern for the potential pollution in the dam's reservoir area. A major cause for the pollution concern is the fact that water velocity will be slowed in the reservoir allowing pollutants to collect behind the dam where previously they were diluted and washed down river into the ocean (quoted in Ponseti and Lopez – Pujol 2003, 173). Areas to be inundated will also cause pollution as pollutants begin to leach into the reservoir from below. Alan Sutton's 2004 article states that the source of these pollutants within the inundated area include "about 1300 factories and mines, about 4,000 hospitals, around 40,000 graveyards, and about 200 garbage dumping sites" (quoted in Ponseti and Lopez – Pujol 2003, 173). To prevent this,a 2003 newspaper article reported that the Chinese government lead a campaign to clean the banks of the Yangtze before the first inundation in 2003 (quoted in Ponseti and Lopez – Pujol 2003, 173) but an earlier newspaper report by David Rennie in 2002 cast doubt on the long-term effectiveness of any decontamination work (quoted in Ponseti and Lopez – Pujol 2003, 173).

According to an article by Jun Ma in 2006, another issue facing the dam is the lack of treatment for all but 10 – 20% of water released into the Yangtze (quoted in Ponseti and Lopez – Pujol 2003, 176). To deal with this issue the Chinese plan to construct a network of wastewater treatment plants for both industrial and domestic water "with the final goal of treating at least 85% of sewage and garbage in the region by 2010" (quoted in Ponseti and Lopez – Pujol 2003, 173).

Sedimentation

Similar to pollution but posing a greater threat to the efficiency of the dam is sedimentation and mass movement in the reservoir area. A1998 report by Luna Leopold stated that sediment deposition "can seriously threaten the flood control capacity of the dam because of silt accumulation within the reservoir. Sediment deposition has become a major problem in about 230 large dams in China, causing an average loss of 14% of their total storage capacity and in some cases reaching more than 50%" (quoted in Ponseti and Lopez – Pujol 2003, 163).A 2002 report by Jiazhu Wang indicated that the Yangtze River was once a waterway that was fairly clear of sediments, but in recent years the expansion of agriculture and deforestation have increased erosion and made the Yangtze the fourth river in terms of silt deposition in the world (quoted in Ponseti and Lopez – Pujol 2003, 173). During the first "decades of operation a significant part (about 60 – 70%) of the sediments carried by the inflow water will be deposited in the reservoir (and 30 – 40% sluiced through the dam) until reaching a balanced state after 100 years of operation when more than 90% of the annual incoming sediment will be flushed through the dam, and the flood control capacity of the reservoir will still remain at 86 – 92%" (according to a 1998 YWRP and a later 2003 report by Jiazhu Wang,quoted in Ponseti and Lopez – Pujol 2003, 163). Although the projections for sedimentation in the Three Gorges basin have been positive many researchers have pointed to examples of dams which quickly lost most of their capacity to sedimentation. One of the examples pointed to in a 1994 work by Quig Dai is only 40km downstream from the Three Gorges Dam.The Gezhouba or Gezhou Dam "lost about 44% of its water storage capacity due to sedimentation after only seven years of operation" (quoted in quoted in Ponseti and Lopez – Pujol 2003, 164). Sedimentation will not only affect the storage capacity of the reservoir but the dam's power generation capabilities as well. A 2001 Journal article by McCormack provides an extreme example of sedimentation affecting power generation.In the "Sanmenxia Dam, power production has been reduced from 1200 MW to 250 MW, i.e., it conserves only about 21% of the original power generation capacity" (quoted in quoted in Ponseti and Lopez – Pujol 2003, 178).

To help prevent future sedimentation issues the Chinese government has prohibited cultivation of slopes with a grade greater than 25% and instituted a logging ban to prevent further deforestation (Ponseti and Lopez – Pujol 2003, 164). Other programs have also been working to reverse the deforestation trend by paying peasants to maintain their property as a forest which can be a more stable income option when compared to growing crops. This reforestation not only prevents sedimentation but absorbs water which will help regulate the flow of the Yangtze (Zhangwei, et al., 2007, 1158). This forest conservation program will require the cooperation of both peasants and the group in charge of the Three Gorges Dam, but the profits derived from reforestation's benefit on power production outweigh the potential of using the land for agriculture (1158).

Reforestation projects will help reduce sedimentation, but more importantly they will improve slope stability and reduce the chance of landslides. Several landslide susceptibility studies have been completed which indicate the steep cliffs near the edge of the reservoir pose a high risk of landslides which will only be worsened by the filling of the reservoir (Bai, et al., 2009, 19). Luckily the dam's designers incorporated the possibility of a large landslide into their plans and, as stated in a report by R. Fuggle and W.T. Smith in 2000, "the dam has been designed to cope with an extreme flood event (its safety would not be compromised even if it overflowed)" (quoted in Ponseti and Lopez – Pujol 2003, 165). Even if overtopping of the dam would have no effect on its integrity it would have devastating consequences downstream of the dam in areas which are becoming increasingly more populated.

Seismic Effects

The final and arguably most serious threat to the structural integrity of the Three Gorges Dam is earthquakes, including reservoir induced seismicity. The area surrounding the dam and reservoir is seismically active with numerous earthquakes ranging from smaller than a magnitude 2 to larger than a four. The largest quake in the area was a magnitude 5.5 which occurred on May 22, 1979. Its epicenter was located about 70km from the Three Gorges Dam (Crampin, Gao, and Peacock 2006, 3). This event indicates that even without reservoir induced seismicity there is a potential for moderate sized earthquakes and the potential for fault movement near the dam (3). The importance of this information became clear after researchers examined the locations of earthquakes which occurred from 1970 – 2002. What was found was a pattern of quakes indicating fault lines in the vicinity of the dam, one of which passes very close to, and possibly under, the dam.

The main fault which passes nearest the dam was most likely exploited by the Yangtze as it cut downwards though the weakest rocks (Crampin, Gao, and Peacock 2006, 3). This faulting along the Yangtze river “suggests that any slippage of the fault, if it led to a surface break, would be likely to be in the bed of the reservoir along the line of the Yangtze River, close to and possibly cutting the Three Gorges Dam”(3). Designers of the dam decided on a concrete faced gravity dam or a wide based dam, faced by concrete with a less consolidated rock fill interior (6). If a dam like the Three Gorges developed cracking which allowed water to pass through, the intense pressure would quickly enlarge the cracks possibly causing structural failure which would allow most of the impounded water to escape (6). An event of this scale would be made worse by the sediments held in the reservoir which, if released, would cause greater damage and complicate recovery by burial (6). According to a 1999 report by J. Uzarski, M. O’Rourke, and N. Abrahamson, a recent example of fault movement cutting the face of a dam occurred in Taiwan on the 21st of September, 1999 as part of the 7.6 magnitude Chi Chi quake (quoted in Crampin, Gao, and Peacock 2006, 7). The fault moved approximately 10m vertically and 2m horizontally cutting the face of the Shih-Kang Dam even though it was located 50km from the earthquake’s epicenter (quoted in Crampin, Gao, and Peacock 2006, 7). Despite being a much shallower dam than the Three Gorges, the Shih-Kang was almost completely destroyed and lost nearly all the water in its reservoir (7). Also of importance is the fact that the Shih-Kang was a concrete faced gravity dam, the same type as the Three Gorges Dam and the fault which was located under the dam was not identified until after the quake. Iin addition if there is a fault located under the Yangtze River it would be difficult to recognize under the sediments of the flood plain (7).

Another danger to the Three Gorges Dam is the phenomenon of increased seismicity surrounding large reservoirs.Reservoir induced seismicity is the increase in earthquakes surrounding large reservoirs which occurs after their filling. A 1997 report by P. Talwani explained that the magnitude of this seismicity varies based on several factors, including reservoir size, the orientation of local faults, and the type of rock below the reservoir (quoted in Crampin, Gao, and Peacock 2006, 4). A subsequent 1998 report by L. Chen and P. Talwani, involving a study of several cases of reservoir induced seismicity in China revealed that nearly 74% of the areas studied were situated above carbonate rocks such as limestone and while "the actual site of the Three Gorges Dam is on a granite core it may be significant that a ~5km-thick layer of limestone underlies the reservoir for well over 100km upstream of the dam"(quoted in Crampin, Gao, and Peacock 2006, 4). According to a 2002 and later a 2004 articles by S. Crampin and others, this seismicity can be explained by the fact that "fluid-pressures control low-level deformation and trigger fracturing and earthquakes" (Crampin, Gao, and Peacock 2006, 4). Reservoir induced seismicity is also sorted into two categories based on the length of the period of increased seismicity.

Initial seismicity occurs because of the instantaneous effect of loading or unloading and the delayed effect of pore pressure diffusion (Talwani 1997, 474). With initial seismicity, the largest event usually occurs after the maximum water level has been achieved and the largest events may be delayed for months or even years depending on local site characteristics (474).This type of reservoir induced seismicity is also accompanied by "a general stabilization and (usually) an absence of seismicity beneath the deepest part of the reservoir and widespread seismicity on the periphery migrating outwards in one or more directions"(474). The pattern of seismicity occurs because of pore pressure diffusion or the transfer of pore pressure through underlying rock outwards from the deepest part of the reservoir. In the case of initial seismicity, activity will begin to subside over a period of months to years until the amount of activity reaches preimpoundment levels (474).

Reservoir induced seismicity which occurs over a much longer period is termed protracted seismicity, which according to a 1988 report by E. A. Roeloffsis “related to the frequency and amplitude of lake level changes” (quoted in Talwani, 1997, 474). Seismicity in this category is “associated with reservoirs with large and/or rapid lake level rises and longer frequencies (lower frequencies) of water level changes. Seismicity is observed both beneath the deepest part of the reservoir and in surrounding areas. This seismicity is continuous for decades and does not appear to die out”(Talwani, 1997, 475). The causes of protracted seismicity seem to fit the planned raising and lowering of the Three Gorges Reservoir so this type of increased seismicity could affect the dam and surrounding areas for many years to come. It is the combination though of “dam height, reservoir size, regional seismicity, carbonates in the area underlying the reservoir, and particularly the intersection of faults which appear to make the Three Gorges Dam susceptible to hazard (Crampin, Gao, and Peacock 2006, 5).

The Three Gorges Dam is the largest hydroelectric dam in the world and as such is responsible for bringing both unprecedented benefits and risks to the people of the Yangtze River Valley and all of China. In some cases the dam has been the cause of great devastation including the destruction of both the environment and rich cultural heritage of the Yangtze River valley, but it has also spurred a greater concern for the protection and conservation of both the environment and the way of life for many of the Chinese people. While many of the consequences of the dam will not be felt for many years, both the Chinese and the world will be looking to the dam as an example of the future feasibility of hydroelectric power.

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