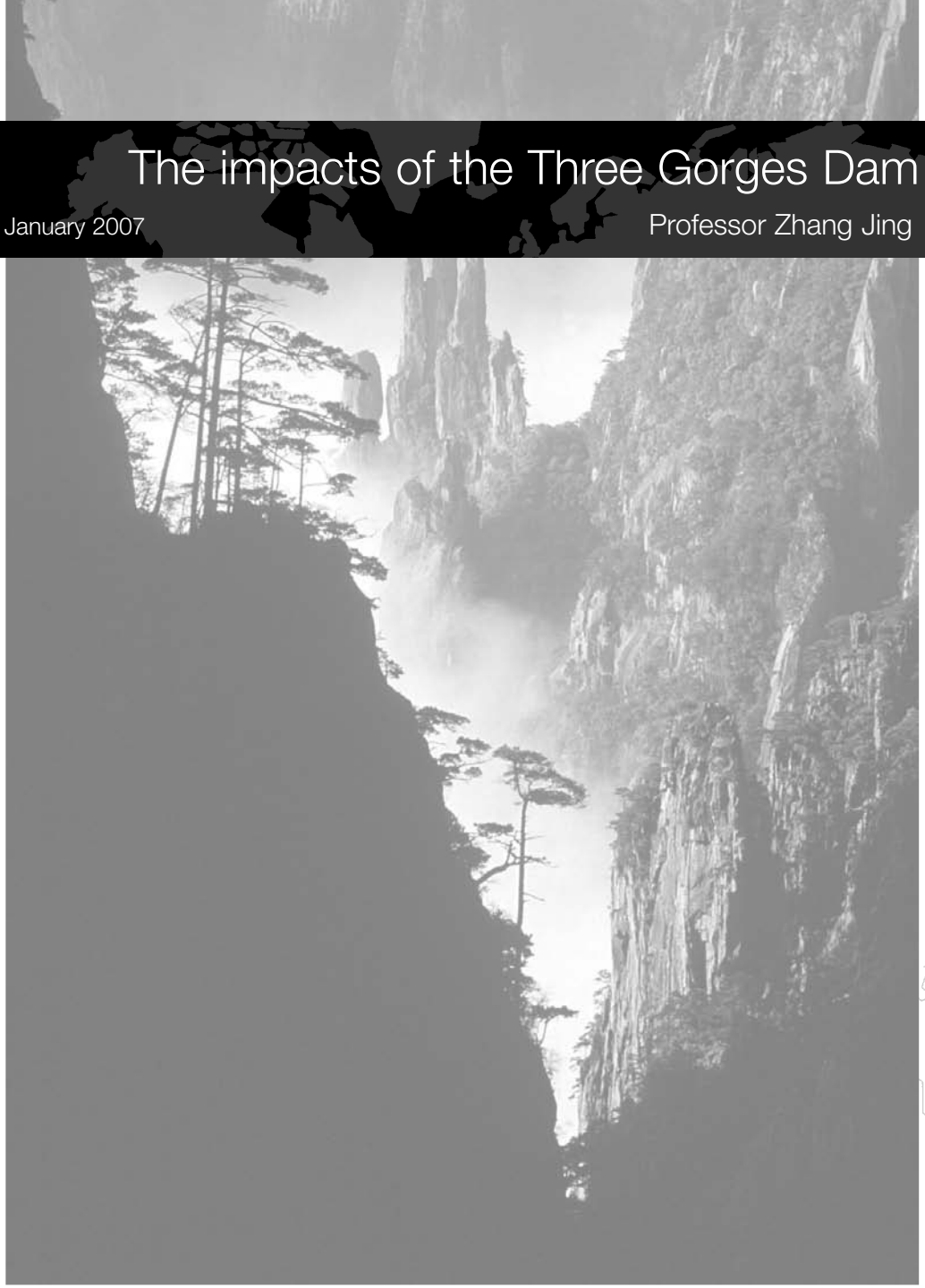
The impacts of the Three Gorges Dam

January 2007

Professor Zhang Jing



It is my great pleasure to be here and give a presentation of our research on the effects of the Three Gorges Dam, or Sanxia Dam as it is known in China, on the Yangtze, or Changjiang River. I shall start with an introduction of the number and type of dams we have in China and a broad outline of the Three Gorges Dam (TGD), including its construction and the benefits it has brought, as well as some of the costs. I will follow on with details of three case studies covering the middle reaches of the river, the lower reaches and the coastal environment, and some of the economic and social aspects of dam construction. In the last part of my presentation I shall tell you a little about the post-Three Gorges Dam period, as there are further dams currently under construction or being considered for construction, along with other activities that will have an effect on the Yangtze River as well as the TGD.

The upper reaches of the river that eventually forms the Yangtze are known as the Jinshajiang River, with the Yangtze itself stretching from Nanjing to the coast at Shanghai. The overall river system is more commonly known in China as the Changjiang River. Some 6,000 kilometres long, the Changjiang is Asia's longest river and the world's third longest (after the Nile and the Amazon), and its watersheds cover around 20 per cent of China's land area.

China has constructed more than 50,000 dams in these watersheds over the last 50 years, with a total water capacity of more than 200 cubic kilometres (200 billion cubic metres). The majority are small – under a billion cubic metres – but some are very large indeed. Of the total, around 20 account for more than 50 per cent of overall capacity, and a number of these reservoirs are already at their peak in terms of water storage. Notable amongst these large dams is the Three Gorges Dam, with a capacity of more than 39 billion cubic metres. Another of these very large dams is on the Hanjiang River, one of the tributaries that joins the Changjiang at Wuhan.

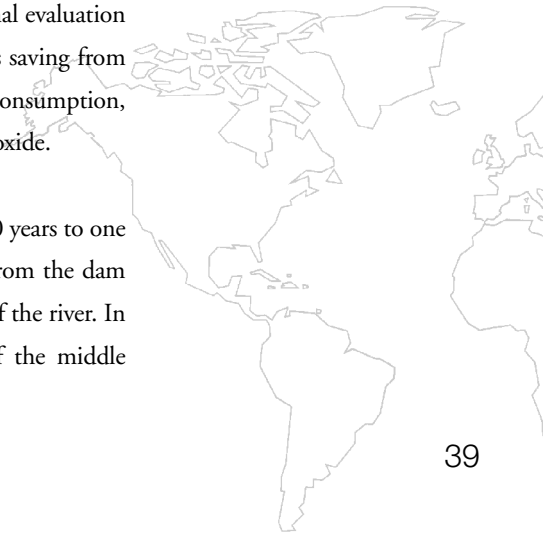
There are a few places that I shall refer to repeatedly in my talk. Datong is a large hydropower station about 600 kilometres from the river mouth, the last one on the river due to the tidal effects reaching upstream from the East China Sea. It is a major collection point for data on the water flow and quality of the Yangtze, and it is the changes in flow here that determine adjustments to the discharge rates at the TGD. In the middle reaches of the river is the city of Wuhan, about 1,200 kilometres from the river mouth, with the Hankou station nearby. The Three Gorges Dam lies a further 600 kilometres to the west, at Yichang.

If we put China's dams into a global context, we find that China has more electricity-generating dams than any other country in the world; that Japan has the largest number of dams of more than 100 metres high; and that Brazil has the greatest number of dams with high water-storage capacity. As far as the Three Gorges Dam is concerned, it has the largest electricity generation capacity in the world, generating more than 18 million kilowatts. If you consider the height of the dam, at 181 metres, it is overtaken by several, including the Ertan Dam (also in China) at 240 metres, and the Hoover Dam at 221 metres. And then if you look at its water storage capacity, the TGD has less than a quarter of the capacity of the world's largest – Egypt's Aswan High Dam at almost 170 billion cubic metres.

The Three Gorges Dam has a long development history. A dam was first proposed for the area by the first president of China, Sun Zhong Shan (Sun Yat-sen), around 90 years ago after the Ching Dynasty had come to a close. Then towards the end of the Second World War, the famous American engineer John Lucian Sovage was invited to work in China, and drew up the initial plans for the construction of the TGD. This original 1944-46 design was for a dam of around 200 metres high. Then in 1953 the idea was again raised, this time by Chairman Mao. National Congress gave their approval in 1992 and the whole project got under way in 1994. In 1997 the temporary cofferdams were closed and by 2003 the water level had reached 135 metres, with construction more or less finished. In 2006 the water level had moved up to 156 metres and by 2009, once the construction plain has been flooded, the water level will be up to 175 metres. The whole budget for the project is RMB200 billion (approximately $25 billion).

One of the dam's major benefits is its electricity generation capacity. In line with national evaluation guidelines for environmental protection, it affords a huge carbon dioxide (CO_2) emissions saving from the reduction in fossil-fuel burning, equivalent to about 50 million tonnes per year of coal consumption, representing a reduction of 100 million tonnes of CO_2 and 1 million tonnes of sulphur dioxide.

A further benefit is flood control, reducing the probability of flood from one in every 10 years to one in every 100 years. And another is the facility for increasing the discharge of freshwater from the dam during periods of drought, providing water for irrigation in the middle and lower reaches of the river. In addition, the dam improves fivefold the navigation facility of about 600 kilometres of the middle stretches of the river between Yichang and Chongqing.



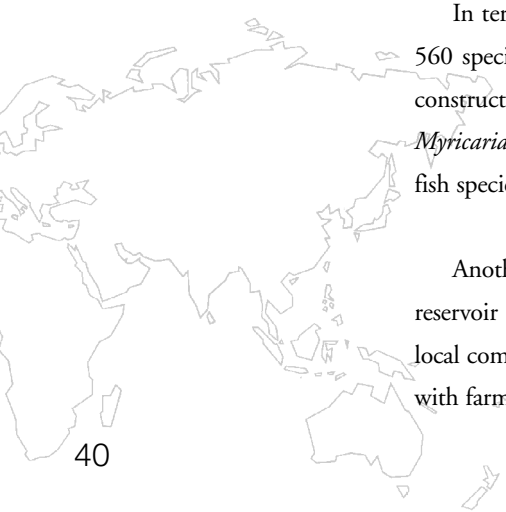
In the economic arena, the Three Gorges Dam will offer opportunities for tourism and for new jobs. On the social side, it will alter farming activities owing to improved soil and water conservation, and it will produce new population centres, transforming regional lifestyles from rural to urban.

There are many other advantages. But how we judge the benefits and pay-offs depends on our point of view. So I am also going to talk about the negative effects of the Three Gorges Dam, some of which had not been properly foreseen before construction was complete. There are two contributory factors to this lack of anticipation: one is simply a lack of knowledge, so that the kinds of problems that might arise were simply unrecognized and unevaluated, particularly with regard to sustainable development and the health of ecosystems, and another is that even if certain impacts were foreseen, their seriousness was underrated.

The effects of the dam stretch right across from the watersheds of the Changjiang River system out to the edge of the continental shelf in the East China Sea. The inundated area covers about 650 square kilometres straddling the provinces of Hubei and Chonqing along the middle reaches of the river, and includes a large amount of cultivated land. Local climate has been affected, sediment loads have altered and pollution has given rise to eutrophication. This is a highly ecologically sensitive area, and has become even more so due to both the high water levels and the storage of standing water. There has consequently been a change in the diversity of the region, including the loss of endangered species such as the river dolphin. As the river has become a lake, there have been shifts at all levels of the ecosystem, from low plankton to phytoplankton through to fisheries, and so on through the food chain.

In terms of biological diversity, the TGD region is home to 120 different families, 360 genera, and 560 species, including the Chinese sturgeon, which is now highly endangered as a result of the dam construction. Some are so special that we do not even have English names for them, for example *Myricaria laxiflora*, a riverside plant endemic to the Yangtze. In addition, the migration patterns of certain fish species have been disrupted.

Another issue surrounding the dam is the huge human population that had to be moved. The whole reservoir is about 600 kilometres in length, affecting five different cities and provinces with around 20 local communities in the area of inundation. Some 1.2 to 1.4 million people in total have been moved, with farmers making up around 40 per cent of that figure. About 20 per cent have been relocated to the



coastal region where economies are better developed but, even so, human population movements of this size inevitably lead to cultural clashes and conflicts over resources.

The area under inundation is rich in history, and some 1,100 sites have either been lost or have required some form of protection. These historical sites go back around 3,000 years. In addition, there are hydrographic records of the region that go back 1,400 years.

Another problem associated with the dam is landslides in this geologically sensitive area. Examples include one at Yunyang/Chingqing in 1982, which shifted 15 million cubic metres of soil and rock, one in Zigui/Hubei in 1985 (13 million cubic metres) and another one in Yunyang/Chingqing in 2001 (50 million cubic metres). Large quantities of this soil and rock have moved directly into the river, blocking it to some extent.

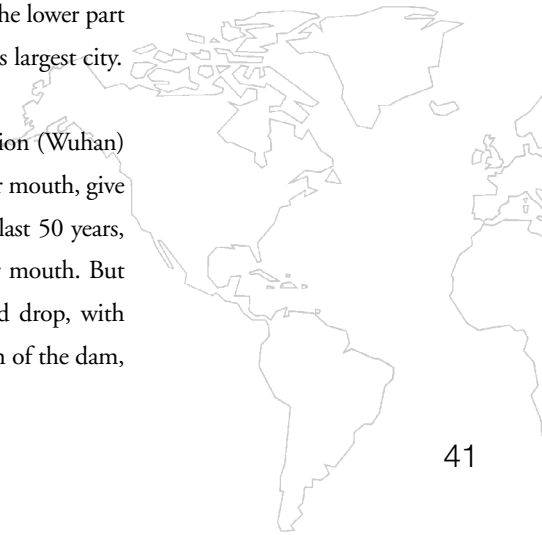
So that is the overview of both the good side and the bad. And while we must enjoy the benefits of the huge amount of electricity generation, flood protection and drought alleviation that the TGD has afforded, we must also bear in mind the negative consequences, both unforeseen and under evaluated.

Case studies

Case study 1: From the middle reaches to the Yangtze delta

We have to ask ourselves how well we anticipated changes in water flow and sediment loads resulting from the dam and how these might affect the stability of the delta region, as well as the risks of eutrophication in the reservoir and a resulting deterioration in the aquatic environment and water quality. The lower part of the Yangtze River is a heavy navigation channel with a busy harbour at Shanghai, China's largest city.

Data taken every decade from the Yichang station just below the dam, the Hankou station (Wuhan) 1,200 kilometres from the river mouth, and the Datong station 600 kilometres from the river mouth, give us an idea of the changes. As the number of dams in the watershed has increased over the last 50 years, there has been a series of drops in sediment load recorded between the TGD and the river mouth. But when the TGD came into operation in 2003, there was a much larger and unanticipated drop, with sediment loads 50 per cent lower than expected. This has negative consequences downstream of the dam, particularly in the estuary.



With regard to chemical loads in the Changjiang following closure of the TGD, phosphate loads increased considerably immediately downstream of the dam, decreasing a little nearer to the estuary. Silicate levels also increased following closure of the dam, though these appear to have dropped according to a 2006 study. Nitrate concentrations, which increased in the vicinity of the dam following its closure, are now heavier closer to the estuary. Observational data for dissolved organic carbon, particulate organic carbon and dissolved inorganic carbon remained fairly stable between 1997 and 2003. Samples collected in a more recent study are currently being analysed and the data should be available soon.

Eutrophication resulting in algal blooms is a common problem around the tributaries in the dam region and in the reservoir, with a considerable effect on aquatic systems and biodiversity. All the tributaries discharging directly into the reservoir have five- to tenfold higher nutrient loads than the mainstream, as well as higher levels of chlorophyll (resulting from purification processes) and biomass. Of course the application of fertilizer in the watersheds has also increased over the last few decades, in part contributing to the greater flow of nutrients both into the reservoir and to the East China Sea.

After the dam closure in 2003, seasonal variations in the delta could still be seen, but overall the elevation of the coastal wetlands has decreased rapidly. Although sediment loads from the tributaries have increased a little, and erosion of the riverbed has also contributed to the sediment load, there has overall been a fourfold drop in sediments reaching the estuary and a corresponding drop in accretion rates. Erosion has deepened the channels in some places, and the delta front as a whole is moving landwards. This decrease in sedimentation of the estuary is of particular concern because of its effect on the local fauna. Polychaetes, molluscs and crustaceans have all decreased considerably, with a dramatic drop in total species numbers. Traditionally, the Yangtze River Delta is a spawning and fishing ground for important economic species such as the Chinese mitten crab and the grenadier anchovy, as well as a migration route for these species. But the change in the sediment load and the reshaping of the delta region due to human activities has had a major effect: some of the spawning grounds have been totally destroyed.

In summary, our most important findings have been that the response of the delta region to dam construction has been very rapid even though the dam is 2,000 kilometres upstream. The significance

of this kind of response is not only in the decrease of the amount of sediment flowing to the delta, but also the changing shape of the delta itself.

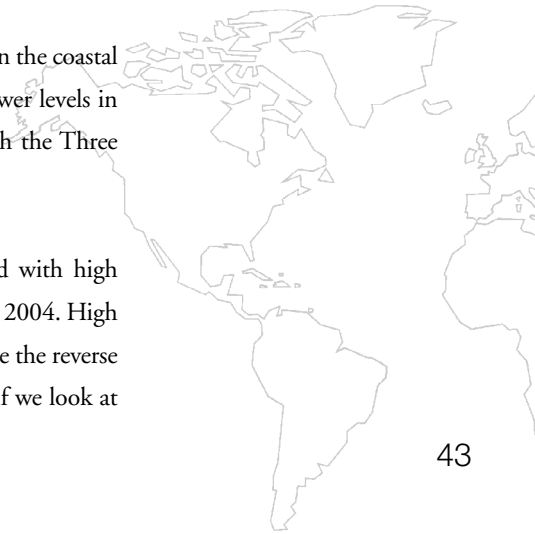
Case study 2: The coastal region and the East China Sea

Our second study has been on changes in the quality of the coastal waters, including eutrophication and hypoxia, nutrients and trace elements, and changes to the habitat and food web that affect the broader ecosystem. Historically, the Yangzte River discharges a huge amount of freshwater to the East China Sea. In the flood season when the river is in full spate, the freshwater outflow can reach as far as the continental shelf break, several hundred kilometres from land. The coastal region is also an important spawning and hatching ground for commercial fish species that spend their early stages in the coastal areas and then move to the deeper waters in the outer part of the shelf region. So any changes in terms of water and sediment load may also cause problems between neighbouring countries in the area that have claims on the region's marine resources.

Some of you may not be familiar with the circulation pattern of the East China Sea. In summer the Changjiang waters move eastward, joining with the Taiwan current from the south and affected by the very powerful Kuroshi current that moves northwards at the outer edge of the East China Sea. In the winter under the monsoon effect, most of the water coming off the Yangzte River moves southwards along the coast towards Taiwan. The influence of the river can be tracked several hundred kilometres from the river mouth, with heavy nutrient levels in the coastal waters leading to eutrophication problems when temperatures are high.

A study comparing nutrient loads and phytoplankton biomass in 1998, 2003 and 2004 in the coastal waters at the Yangtze River mouth, undertaken by colleagues in Taiwan, in fact recorded lower levels in 2003-04 than in 1998. And we are right to wonder whether this change is connected with the Three Gorges Dam. But of course there is no simple answer.

There were relatively low levels of salinity in these waters in 1998, usually associated with high freshwater discharge rates, and these were in fact 40 per cent higher in 1998 than they were in 2004. High discharge rates were accompanied by low salinity levels and high nutrient loads in 1998, while the reverse was true in 2003-04. But we must not assume that this had anything to do with the dam: if we look at



water discharge rates measured at the Datong station during the period 2001 to 2005, covering the time when the dam came into use, we see no significant change in water flow. Nutrient loads in the coastal waters may have dropped between 1998 and 2004, but phosphate and nitrate loads recorded at Datong actually rose slightly over the period 1998 to 2005, while other nutrients and silica remained more or less stable. And there are other factors to take into account. Estimates suggest that nutrient concentrations both in the Kuroshi current and in the Taiwan current, which carries street runoff, are higher than in the Yangtze discharge waters. The Yangzte accounts for as much as 95 per cent of the whole river discharge into the East China Sea. Nonetheless, the effect of Changjiang's waters on the biochemistry of the East China Sea may be overestimated owing to lack of data for all the elements that impact the marine waters.

That said, the chemical loads in the Yangtze River outflow do have an influence on the coastal environment. Nutrient levels in the East China Sea are very considerably higher close to the coast, where we have seen an increase in the number of harmful algal blooms in the surface waters. Deeper in the water column, at depths of 20 to 50 metres, a large area just off the Yangtze River mouth is very low in oxygen, with levels of only 1 or 2 milligrams per litre. But it is difficult to make any direct link between this hypoxic zone and the Three Gorges Dam because the decrease in oxygen levels in the near-bottom waters has in fact been roughly linear over the last 50 years.

If we are to get a true picture of the effect of the Three Gorges Dam on the highly sensitive ecosystems of the coastal region, monitoring and research must take place at the basinwide level over several decades. That is something we are doing in China right now.

Case study 3: Social and economic aspects

Building a dam is initially an engineering issue, but it is also where problems of science, politics, society and engineering come together – and with profound impacts. Our third case study has looked into the social and economic effects of the TGD.

Migration associated with the dam has taken place over the last 10 years, and has involved the involuntary resettlement of between 1.2 and 1.4 million people to 11 different provinces and cities. The government's resettlement expenditure has been RMB40 billion (approximately $5 billion), about one fifth of the total budget for the dam construction.

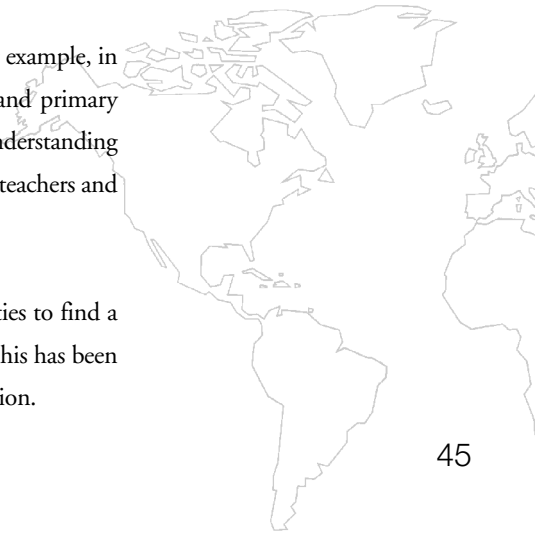
The inundated area behind the dam covers around 650 square kilometres and has involved the loss of some 24,000 hectares of cultivated land as well as some 1,600 companies and factories. The majority of the affected population has moved eastwards, with around 20 per cent to coastal areas, including about 5,000 people to Shanghai, 8,000 to Guangdong and around 10,000 to Jiangxi.

In theory this could be a good thing, because people from the TGD region are having an opportunity for a new life by moving from a less-developed region to a well-developed one. But there are several problems that were not properly considered prior to the construction of the dam. For example, little consideration was given to people's ability to abandon their traditional lifestyle and adapt to a new one, losing, in the process, their community and family networks, and their properties and farmlands. They are having to learn new forms of cultivation requiring different farming skills, moving from the drier regions of Chongqing where maize and some fruits predominate, to a humid area where rice is the dominant crop. So while on the one hand there is an opportunity for improved economic well-being, there are difficulties of adaptation on the other, as well as competition with the existing communities for natural resources.

The social and economic consequences of TGD resettlement take place at a variety of different levels, some of which go unnoticed. At a national level the resettlement programme is managed according to national legislation under Congress; at the local level it is managed in a different way by the local governments; and at an individual level it is managed differently again according to cultural traditions, lifestyles and mentalities that can be quite alien to the new environment. All this can sometimes cause very serious conflicts between newcomers and existing communities.

Older people and young children have particular difficulties in adapting to a new life. For example, in most of the coastal region, even though Mandarin is the official language in high schools and primary schools, there are very strong regional accents. So newcomers to the coast have problems understanding and being understood, the children struggle to keep up in class, and communication between teachers and parents is awkward.

On the whole, young adults find it easier to adapt as they usually have better opportunities to find a job, but even then, retraining and reemployment have not been taken sufficiently seriously. This has been exacerbated by bureaucracy at the level of local government and even by problems of corruption.

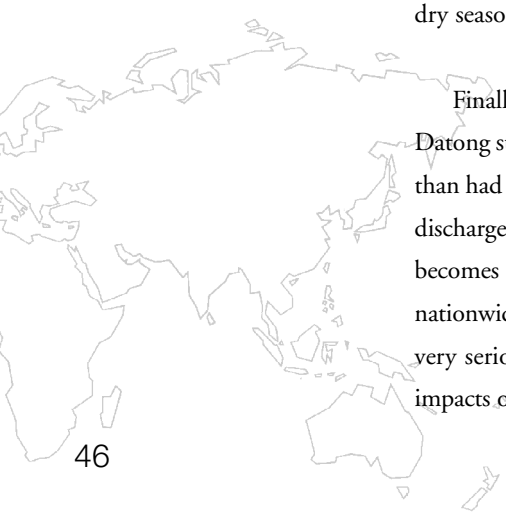


And then there is the issue already touched upon of the loss of historical sites. All of these factors have been painful for our country: cultural change; resource competition; cultural conflict; interrupted education and the loss of sites of historical significance.

Looking ahead

The story of the TGD is far from over. A great deal of activity is going on in the Yangtze River area during what I call the post-TGD period. Further dam construction and other human activities are continuing in the watersheds, all of which will affect the functioning of the TGD and make the story yet more complex. Four other major dams are either planned (Wudongde and Baihetan) or already under construction (Luoxidu and Xiangjiaba) upstream of the TGD towards the Jinshajiang River. Together, they will have even higher electricity generation and a larger water-storage capacity than the Three Gorges. This will have a considerable effect, given that the Jinshajiang supplies around 16 per cent of Changjiang's water flow and almost 60 per cent of its sediment load.

The flow of the Yangtze will also be affected by water extraction to supply the north of the country. Government plans, approved by National Congress, are to build canals from the upper stream of the Yangzte River to the upper stream of the Yellow River; from one of the big tributaries at Hanjiang in the middle reaches up to the north; and from the lower reaches via the 'Grand Canal' to Beijing and Tianjin. Between them they will have an average water transport capacity of 2,000 cubic metres per second. The main question is how these 2,000 cubic metres per second will be managed seasonally. If this water is moved in the flood season it will be manageable, but if it is moved during the Yangtze's dry season it will cause new problems.



Finally, beyond all this immediate human activity, there is the question of climate change. The Datong station recorded exceptionally low water flow in 2006, more than 30 per cent lower at peak flow than had been recorded for the years 1996 to 2005. At the beginning of this lecture I said that the TGD discharge rate is regulated according to changes in flow at the Datong station, so that if flow at Datong becomes very low, more water is released from the TGD. On the whole this has worked well, but nationwide drought in 2006 was beyond the capacity of the TGD to correct. This situation could become very serious indeed, as the effects of a river running dry can be as catastrophic as flood, with major impacts on an important navigational waterway as well as on local needs for irrigation and water supply.

So all these ongoing activities, coupled with the unknown impact of climate change, make it very difficult to isolate and analyse the impacts on the wider water system and coastal waters of the Three Gorges Dam itself. It is a very complex scenario. The only thing that we are quite sure about is that the reduction of sediment in Yangtze waters downstream of the dam has been much greater and more serious than was anticipated. But any conclusive analysis of environmental and marine impacts will require data gathering and monitoring over decades, as the life cycles of affected species, including commercial ones, can take place over several years. With regard to the socioeconomic effects of the dam, analysis would have to be carried out at the national level for it to be truly meaningful.

So taking all this information together, and sediment loads aside, the only conclusion I can draw is that any so-called conclusions would at this point be premature.

I would like to thank the University of Cambridge for the invitation to give this lecture, and also the research team and colleagues who have worked with me to prepare it.

Professor Zhang Jing
Key State Laboratory of Coastal and Estuarine Studies,
East China Normal University, Shanghai