Downstream ecological implications of China's Lancang Hydropower and Mekong Navigation project

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ABSTRACT

China intends to develop Lancang or Mekong mainstream hydropower in Yunnan and make the Mekong mainstream navigable from Yunnan to the South China Sea, a distance of some 2,500 kilometers. This poses unprecedented environmental and social problems for the downstream countries Myanmar, Laos, Thailand, Cambodia and Vietnam. Severe ecological deterioration of the Mekong River is a foregone conclusion if this plan proceeds. And of course the impacts will not be limited to the river. The downstream countries will be forced to undertake exhausting and largely futile efforts to protect themselves and make up for the damage to their agriculture, fisheries, forests, and way of life. Cambodia and Vietnam, the two countries farthest downstream, will benefit little and will experience the worst negative impacts from the scheme. Particularly at risk are Cambodia's Great Lake and Vietnam's Plain of Reeds and Mekong Delta. China itself will not be immune to adverse impacts. Of particular concern will be sedimentation of the Lancang hydropower dam reservoirs. Sediment in the Lancang mainstream, already great, is likely to increase due to larger and more frequent landslides and other effects brought about by the dams and their reservoirs. The useful lifetime of China's Lancang cascade of hydropower dams is likely to be only about thirty years rather than the one hundred years foreseen by project proponents.

Key words: flood plains, "chamkar" farming, riverbank truck gardening, pro-environment EIA, ecological simplification, deforestation, global warming, flood control, natural hydropower, biodiversity, rubber tree plantations, sedimentation, erosion, landslides, slumping, earthquakes, Cambodia, Laos, Thailand, Vietnam, Yunnan, Tibet, Lancang, Manwan, Xiaowan, Nuozhadu, Jinghong, Plain of Reeds, Mekong Delta, Great Lake

INTRODUCTION

In addition to providing electricity the "Lancang cascade of hydropower dams" proposed by the Peoples Republic of China (location maps Figs. 1-2) supposedly would permit "regulation" of the downstream water flow and eventual full development of the Mekong River for shipping. Purported benefits of this hydropower cum navigation project for the downstream countries (Chapman and He, 2000; Plinston and He, 2000) require careful scrutiny and evaluation.

Benefits from the hydropower-navigation scheme will accrue largely to China. Electricity generation is likely to be far less than half (perhaps about one-fourth) of the installed capacity of 15,400 MW. The useful hydropower lifetime of the dams also is likely to be much shorter than predicted, perhaps only thirty years instead of one hundred years. Unforeseen costs and negative impacts began soon after completion of Manwan Dam in 1993. They will continue long beyond the useful life of the dams. The countries

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to suffer most severely will be Vietnam and Cambodia. Local and national opposition to the Lancang hydropower dams and navigation scheme will increase as riverside towns of Myanmar, Laos and Thailand experience the earliest obvious negative impacts of the dams. With the possible exception of Myanmar, the downstream countries will have to devote large amounts of their development funds and other resources to mitigate adverse effects.

Social and environmental negative impacts are cause for the gravest concern. Six or seven hydropower dams 110 to 300 meters high would be installed on the mainstream of the Mekong River or Lancang Jiang in Yunnan province to generate electricity by the year 2020. The dams will be a menace to livelihoods, property, and life in all of the downstream countries. Due to their massive size and their huge storage or “cistern” reservoirs, the two tallest dams (254 and 300 meters high) will be extremely dangerous. The “cascade” or “domino” arrangement of the dams jeopardizes the entire system. Logging, forest clearing for agriculture, forest fires, and road building will increase the rate of erosion in the Mekong gorges above the dams. Frequency and magnitude of earthquakes and landslides, serious threats to the Lancang dam cascade, probably will increase. The threat from landslides is universally acknowledged. That from earthquakes is regarded as very great by some, scoffed at by others. Scoffers included some knowledgeable geologists (anon., pers. comm. June 2001). It should be noted that geologists tend to regard the threat from earthquakes associated with faults in terms of the most recent known large-scale geological activity. The greater the length of time passed since such activity the less danger they foresee. Of course this is generally correct and a reasonable initial assumption. Perhaps they fail to consider that low-scale activity of the sort that would leave little or no trace in the geological record but that could cause big problems for large hydropower dams may be an unrecognized property of many of the large faults in Southeast Asia.

The 300-m high Xiaowan (with 169-km long reservoir) is scheduled to be completed and to start filling in 2010. The 254-m high Nuozhadu (with 226-km long reservoir) is not scheduled for completion until 2017 at the earliest. Their “dammed waterhead” or “height to normal maximum water level of storage” will be 248 and 205 m respectively (Chapman and Daming, 2000: 3). Presumably it would take each dam at least ten years to fill to this level. This is based on several assumptions including that only about half of the water coming down the Lancang would be held back during the filling period.

The Mekong ecosystem is in a relatively healthy condition at present. Installation of high mainstream dams on the Lancang Jiang and construction of the navigation channel will cause great ecological damage and deterioration. Major negative impacts will be caused by sequestration of upstream sediments and nutrients in reservoirs and by “regulated” flow regime based on controlled outflow from the hydropower dams. Reduction of the river’s natural hydropower (Roberts, 1996), irregular discharges related to electricity generation (Roberts, in press), and other gross systemic changes also will cause harmful ecological simplification and deterioration of the Mekong ecosystem. The environmental impacts will not act individually, but cumulatively. Massive loss of biodiversity is only one of several predictable results. There would certainly be extinction of some fish species but also, and of even more consequence in terms of adverse effects on people, reduction of populations of many of the migratory fish species that are most important in Mekong wild-capture fisheries.

Natural hydropower, of course, is an essential property of rivers. The productivity, healthiness, and maintenance of a river and special attributes of riverine habitats such as rapids, river mouths, and deltas are directly linked to natural hydropower. It transports sediment and nutrients downstream and deposits water and silt on the floodplains, replenishing the water tables and enhancing fertility and productivity. For a detailed discussion of the interplay between natural hydropower and animals inhabiting rivers (with extensive bibliography) see Hart and Finelli, 1999.

While there will be negative impacts in all of the Mekong countries including China, the worst impacts will be in the countries furthest downstream, Cambodia and Vietnam. These countries have the least to gain as well as the most to lose. Negative impacts of China's Mekong modifications include those on fisheries, agriculture, water quality, health, and forests. Capital cities and larger population centers situated on the banks of the Mekong in Laos, Thailand, Cambodia, and Vietnam will be subject to physical impacts such as erosion and flooding caused or aggravated by the Lancang hydropower dams.

Creation of an adequate navigation channel in the Mekong would involve removal of reefs, sandbars and islands and other extensive modification of the river bed and stream banks. Channel maintenance would require continuous and extensive dredging. Downstream impacts of the navigation works alone would cause extensive deterioration of fish habitat and water quality. Heavy boat traffic inevitably would result in severe pollution affecting riparian communities and their cultivated crops, as well as fish and other aquatic organisms. Channeling of the Mekong to maximize its navigation capacity—undoubtedly the aim of the Chinese—will decrease substantially resistance to stream flow in the entire Mekong mainstream below Yunnan. Water will flow much more rapidly to the sea. The resulting loss of retention capacity will cause faster run-off in the Mekong mainstream at all times, in the dry season as well as in the wet season. This will result in increased risk of floods (including flash floods) as well as droughts. Loss of retention capacity also will cause major changes in the aquatic ecosystem and shorter agriculturally productive seasons.

China's Yunnan Province—site of the proposed Lancang cascade of hydropower dams—has been extensively deforested since 1950. The Chinese are attempting to protect the watershed of the Lancang hydropower dams by tree plantations but it remains to be seen just how successful their efforts will be. Just south of Yunnan, in Laos and Myanmar, are large tracts of relatively intact forest, protected until now mainly by their remoteness. The stretch of the Mekong running right through the middle of this area is particularly difficult to navigate because of its rocky streambed, narrow channels, and numerous rapids and islands. Making this section navigable will immediately expose the forests to large-scale logging. Port facilities already are nearly completed on the Myanmar side of the Mekong mainstream just downstream from the China border and an access road has been built from the port through part of the forest. Undoubtledly loggers will create many roads and landing sites elsewhere along this 250-km stretch of the Mekong solely for timber exploitation. Destruction of forest in this relatively large area will increase the irregularity of rainfall and run-off and contribute to severity of downstream floods and droughts.

AGGRAVATION OF FLOODS

In September-October 2000 Cambodia and the Mekong delta portion of southern Vietnam experienced unprecedented flooding of the Mekong River. Hardest hit were rural folks in the Mekong flood plains of southern Vietnam. I was in Phnom Penh at the time, and the city was very nearly flooded. Comparably large floods occurred in Bangladesh and in India's West Bengal province at about the same time. In South Asia the floods were attributed to exceptional rainfall due to global warming and to mismanagement of hydropower dams and irrigation dams.

In Cambodia and Vietnam the floods were attributed to exceptional rainfall. There was no mention of mismanagement of hydropower dams in Thailand, Laos, or Vietnam, all of which could and probably did contribute to the high levels of the floodwaters. More to the point there was no mention of the role of Manwan Dam. Even though Manwan's storage capacity is not very great, it had to play a role one way or the other. Did it hold back the floodwaters (thus lessening the flooding that did occur downstream)? Or did it contribute to high water levels in the lower Mekong during the months of September and October 2000? When I posed this question to appropriate officers in the headquarters of the Mekong River Commission in Phnom Penh, they replied that since China was not a member of MRC they did not have any data. I suggested that since what happened in China was of vital concern to MRC it was their job to get the information from whatever sources they could. I still don't have the answers to this question about Manwan Dam and its role during the floods of September-October 2000.

Vietnam's controversial Yali Dam, on the Se San about 70 km upstream of where it flows into Cambodia's Ratanakiri province, apparently contributed to the floods in Cambodia and Vietnam during September-October 2000 (Ian C. Baird, pers. comm. January 2001).

All of this calls into question the frequent claims of promoters that big dams help to provide security from floods. Will China's Lancang hydropower dams provide flood security for downstream countries? The answer is a highly qualified "yes". Hydropower dams can provide a measure of flood security, but only under ideal circumstances, and only in case of moderate or normal floods. People who promote the multi-purpose aspect of hydropower dams tend to forget that the main purpose of the dams is to store water for generation of electricity. For this reason the dams are kept fairly full of water (with some concession to safety). This is particularly so in the wet season when water is retained to build up capacity for dry season generation of electricity. Thus when a really big flood comes suddenly and unexpectedly, the reservoirs tend to be too full to absorb it. Rather than hold back the floodwaters, they have to let them go by, if they can. For the safety of the dams usually some of the stored water is also released, thus contributing rather than subtracting from the severity of the flood downstream. Presumably this happened on a small scale at Manwan Dam in September-October 2000.

When a really big flood comes along, one larger than any predicted, or as large as a flood predicted for only once in 500 years (the hydro-engineers so-called "five hundred year flood") big storage dams like the proposed Xiaowan and Nuozhadu are a real menace. They must store the equivalent of five or more years of "normal" seasonal floods to attain their normal storage level. When a larger than expected flood comes they must release as much water as possible as soon as possible. And if the unthinkable happens and the dam gives way, then the downstream flood will be the total of the upstream flood plus several years of flood waters stored behind the dam, and all coming down at once. Thus may

Lancang hydropower dams cause an environmental disaster far greater than any that would occur in their absence.

SEDIMENTATION PROBLEMS

> The most serious threat to the sustainability of [Lancang] hydropower generation comes from the progressive reduction in storage capacity due to sediment inflows to the reservoir[s]. All indications at present are that soil erosion is taking place at an increasing rate and, possibly, that sediment transport rates in the river derived using data from previous decades might have resulted in a significant underestimation of the capacity of the reservoirs to absorb the sediment loads (Plinston and He, 2000: 247).

The Lancang contributes only an estimated 16% of the total flow of water in the Mekong River when it reaches its delta but an estimated 50% of the estimated 150-170 million tons/year of sediment load. This is partly due to the much higher gradients in the upper Mekong. These are about 1-1.5% in the Lancang-jiang in Yunnan.

Chinese measurements, estimations, or approximations of Lancang sediment transport probably are too low. There are several reasons for this. Lancang sediment is largely coarse grit or sand that is carried as bed load rather than in suspension, and this is always difficult to measure. Bed load transport and suspended sediment load are virtually impossible to measure during times of the greatest flooding. At such times men and equipment had better not be on or in the river or they are likely to be lost. Even though the strongest floods do not last long, they carry disproportionate amounts of the annual total of suspended and base load sediments.

There is also reason to believe that the amount of sediment transported in both ways and its coarseness are both increasing due to accelerated rates of erosion caused by deforestation. And of course global warming probably will contribute to greater ice melt and heavier rainfall. Retreat of ice will expose more areas to erosion and increased flow from melt-off and rainfall will lead to greater erosion.

Additional factors that will contribute to Lancang sediment loads have been overlooked. Among them are underwater landslides or "slumping" and increased local rainfall due to the presence of the reservoirs. The occurrence and extent of slumping will depend upon the geology of the slopes submerged by the reservoirs. Otherwise slumping is directly related to reservoir length and slope of the submerged mountainsides. The worst slumping is likely to occur near the dams themselves due to the effects of draw-downs related to generation of electricity during peak demand.

Increased rainfall due to reservoirs will be a problem mainly with the two large storage reservoirs, Nuozhadu and Xiaowan. Their huge water surface and windy conditions in the Lancang gorges will combine to increase local rainfall and hence erosion.

The situation with regard to sedimentation in Manwan Reservoir already is instructive. Two supposedly independent estimates of sedimentation rate done prior to dam construction resulted in calculations that it would take 15-20 or 16-17 years before sedimentation would incapacitate Manwan Dam (Plinston and He, 2000: 250). Manwan was said to have "sufficient dead storage capacity to allow for deposition of the sediment inflows for only about 20 years [without impairing its capacity to generate electricity and contribute to regulation of Lancang flow]" (Plinston and He, 2000: 250). But this is not what actually happened.

> By 1996, after just three years of operation, the loss of total storage had reached that assumed for the fifth year of operation, and the loss of the effective storage reached that

expected after 15 years of operation (Plinston and He, 2000: 250).

The rapid sedimentation threatens to make Manwan non-functional long before its first twenty years is up. According to Plinston and He, "this situation will only be mitigated when Xiaowan is constructed upstream, shielding Manwan from further significant sediment inflows. Sediment will then be deposited primarily in Xiaowan where the dead storage is at least an order of magnitude greater than that at Manwan."

Here Plinston and He are lose with figures. According to their Table 59, Xiaowan dead storage will be 4,750 million cubic meters or mcm, while that of Manwan is 662 mcm. Thus Xiaowan dead storage is only 7.3 times that of Manwan, or less than one order of magnitude greater. This is not quibbling. The estimate that Xiaowan will be able to absorb Lancang sediments for 100 years probably is hugely exaggerated (although not by an order of magnitude). Thirty years would be a safer guess but even that might be too optimistic (see below).

Manwan definitely is under threat of excessive sediment inflow. Important consequences include:

- increased risk of sediment intake into the powerhouse and damage to turbines;
- reduced generation of electricity during the dry season as active storage of the reservoir is gradually reduced;
- greatly shortened lifetime of Manwan as an independently functional hydropower dam; and
- increased physical threat to the dam in case of unexpectedly severe flash flooding.

The immediate threat to Manwan Dam as an economic producer of electricity would of course be lessened as soon as Xioawan Dam is built. The Chinese will have to move fast to built Xiaowan in time. And then they will have a breather of perhaps two or three decades before they have to start worrying about the build up of sediment in Xiaowan. And this time there will not be any possibility of building a still larger "Xioawan" farther upstream. Then what will the Chinese do? Presumably they have not thought that far ahead. It seems "decommissioning" has not yet entered into the planning process or even the lexicon of Chinese hydropower developers.

As environmental degradation of the Lancang basin continues to mount, new threats will arise from larger and larger mountain landslides. This is one of the reasons I predict that the storage life even of such a large dam as Xiaowan may be only 30 years (as implicitly recognized by Plinston and He, 2000) rather than the 100 years predicted by other proponents of the Lancang hydropower cascade.

DEFORESTATION

The fate of the reservoirs created by the Lancang cascade of hydropower dams will be determined largely by the condition of forests in the gorges and valleys of the Lancang mainstream and the valleys of the several tributaries flowing into the Lancang up stream from the dams. The prospects are bleak. The natural vegetation of the entire area was forest. It is likely that the naturally occurring climax forests characteristic of different parts of Yunnan were relatively capable of retarding soil erosion.

A large part of the province has been deforested. In many areas natural forest has been replaced by monoculture tree plantations. In Xishuangbanna (Sipsongpanna) district in southern Yunnan the main plantation tree species is rubber. To establish a rubber plantation the natural forest is first cleared away entirely. Trees are planted in rows and take several years to reach productive age. When the trees are young their crowns are only a short distance above the ground and provide very incomplete cover. Unlike natural forest there is often no sub-story and no ground cover. The ground in rubber plantations in Xishuangbanna is bare. It is doubtful that such a tree plantation retains soil and retards erosion anywhere near so effectively as the natural forest it has replaced. After a number of years the rubber producing capacity of the trees declines. Then the old trees are removed and new seedlings planted. Each time the land is cleared and re-planted the quality and stability of the soil declines and the tendency to erosion increases.

In China, as in Thailand and other Asian rubber-producing countries, erosion rates in rubber plantations probably are higher than in most official reports with pro-development, pro-agriculture, and pro-rubber plantation bias.

DOWNSTREAM EROSION

Because much of the in-coming sediment load is deposited in the reservoirs, and bed-load transport is blocked by the dam, reservoir outflows are relatively "clean" and "sediment-hungry". In the case of China's Lancang dams, special releases through sluices are designed to keep the intake area of powerhouses relatively free of sediment so that the turbines will not be damaged. During normal operations for power generation, and especially at such times as the sluices are opened to permit lowering of the reservoir level under unusual flood conditions, the downstream sediment load and bed-load transport may be greater than under river conditions without dams.

There are several possible consequences of the resulting erosion. Below the dam the removal of "finer" sediment from the stream bed theoretically could result in a lowering and "armoring" of the streambed by the bigger stones. This process may move downstream for considerable distances. Stream banks as well as stream beds may be seriously eroded. This may pose major threats in places such as Luang Prabang, Vientiane and Nongkhai.

IMPACTS ON FISH AND FISHERIES

Annual yield of Mekong fisheries is estimated at one million tons (Jensen, 1996; 2000). About 400,000 tons or 40% of the total production is in Cambodia. Cambodia's Great Lake or Tonle Sap accounts for over 100,000 tons (Jensen, 2000). Freshwater fish provides perhaps 80% of all animal protein consumed in Cambodia. Incapacity of the mainstream Mekong to take the wet season flow results in inundation of vast areas of the Cambodian flood plain including the Great Lake. This creates vast spawning and feeding grounds for hundreds of fish species. If regulation of the Mekong flow eliminates or greatly reduces the annual flooding of the Mekong it will have severely deleterious impacts on all of the downstream fisheries including those of Cambodia's flood plains generally and particularly those of its Great Lake or Tonle Sap. Vietnam's Mekong delta flood plain and especially the Plain of Reeds will be extremely hard hit. Vietnam's Mekong mainstream and floodplain artisanal fisheries and important Mekong mainstream cage-fish culture also would be adversely affected.

Endemic Mekong fish species including those inhabiting the upper mainstream of the Mekong River will be threatened by extinction because of the Lancang hydropower dams. Many fish species downstream will be adversely affected, including those important for human consumption. Particularly badly impacted will be the many large and small migratory species of great importance to fisheries. Many very small species not captured by fishermen (particularly herrings of the clupeid subfamily Pellonulinae in the lower Mekong) are exceedingly abundant and make an important contribution to the food chains of species of direct economic importance.

IMPACTS ON AGRICULTURE

Agriculture all the way to the Mekong Delta and the South China Sea will be adversely effected. Much of the downstream rice paddy is located in flood plains. Rice production is directly linked to the extent of the annual floods. Although the amount of rice grown by rain-fed systems has increased recently in Cambodia, perhaps 80% of its entire rice production still is linked directly to water, silt, and nutrients provided by flooding of the Mekong.

Another important kind of agriculture likely to be badly impacted or even terminated in many places by Chinese upstream projects is riverbank truck gardening. Known as “chamkar” in Cambodia and “kaset rim fang menam” in Thailand and Laos, it involves farming the islands and banks of large rivers such as the Mekong mainstream and the Tonle Sap. A great variety of cash and subsistence crops are involved. Annual terrestrial crops include are tobacco, corn, watermelon, cucumber, squash, pumpkin, bitter melon, eggplant, tomato, chili peppers, green peppers, potato, sweet potato, taro, casava, carrot, radish, turnip, okra, lettuce, mustard greens, Chinese kale, lemon grass, cabbage, cauliflower, onion, garlic, soy bean, green bean, mung bean, banana, papaya, domestic sugar cane, peanuts, and a great variety of mushrooms, medicinal herbs and ornamental plants including many with showy flowers. Aquatic or semiaquatic annual crops include water mimosa (Khmer “kanchait”, Thai “pak kachet”), water morning glory, and lotus. Orchards of perennial fruit trees including mango and a variety of citrus fruits (oranges, lemons, limes, pomelo) often lie adjacent to annual chamkar plots. Aquatic chamkar crops grow in seasonally impounded water that may also yield a readily accessible supply of fish, crabs, shrimps, and snails.

Some chamkar products (e.g., tobacco, chili, maize) have been introduced only in the last 200 years or so but others probably have been cultivated in the middle and lower Mekong basin for well over 1000 years. Collectively they make an enormous contribution to the local quality of life. They require almost no commercial fertilizers or pesticides. The area of land available to grow them depends upon how much the river rises and then falls within a given year. Productivity also is related to the amount of river silt deposited each year. Such farming will be extremely hard hit and perhaps eliminated entirely from the mainstream banks of the Mekong River if the flow is modified so that the difference between high water and low water levels is minimized (as planned by the Chinese) and there is less silt of poorer quality. Hundreds or even thousands of distinctive cultivars or genetic plant variants could be lost if the Lancang cascade of hydropower dams is completed and the Mekong developed for navigation.

OTHER IMPACTS AND DOUBTFUL BENEFITS

The Chinese still claim, despite increasing evidence to the contrary from China and elsewhere, that large hydropower dams can have sustainable long-term multipurpose benefits (Plinston and He, 2000). It is in the best interests of all countries concerned that China defer further large-scale Mekong development until the projects have been individually and collectively subjected to competent and honest pre-project social and pro-environmental impact assessment (Roberts, 1995). Probable social and environmental impacts unacceptable to the downstream countries are valid grounds for the projects to be rejected. Social and environmental impact assessment is valid only if undertaken on behalf of rural as well as urban society and on behalf of the environment. Assessments done by or controlled by organizations promoting the projects are seldom reliable. Such assessments usually overestimate economic and other benefits while ignoring or underestimating social and environmental impacts.

Since 1950 China has been taking steps towards large-scale exploitation of the vast Tibetan forests, mineral deposits, and energy resources. The combined Lancang cascade of hydropower dams and Mekong navigation scheme should be seen as part of this process. China will not be satisfied until the entire Mekong River below Yunnan has been turned into a navigation channel for the largest ocean-going cargo vessels that can be accommodated. For decades China's strategy to carry out its designs on the Mekong River has involved silence and secrecy. China built Manwan Dam (1986-1993) in a remote area without consulting any of the downstream countries. China still has not joined the Mekong River Commission (MRC), and did not make any effort to keep MRC informed of her Mekong projects until very late. Now that her Mekong strategy can no longer be hidden, China now is proceeding with speed and assertiveness.

The limited time, effort, and participation proposed for social and environmental impact assessment is grossly inadequate. The minimum of seismic studies, to find out whether earthquakes could significantly contribute to landslides, and whether the massive dams and their reservoirs could cause enhanced seismic activity, would require years of well-equipped and highly skilled fieldwork and study. Once the dams are built and their reservoirs start filling the seismic conditions will have to be constantly monitored. Emergency procedures including effective downstream emergency warning systems and evacuation procedures should be in place well before construction of any more dams is completed.

Several potential benefits of Mekong flow regulated by China's Lancang cascade of hydropower and storage or cistern dams are identified by Chapman and He, 2000:

> The outstanding immediate downstream benefit will be in/for Laos [and also Myanmar and Thailand?] in the much greater (and regulated) volume of water available for hydropower generation at the mis-named 'run-of-the-river' generating projects identified for further investigation by the Mekong Secretariat in 1994. Economic viability of all seven proposed projects between Pak Beng and Vientiane is likely to be increased substantially by their ability to produce so much more power for the Thailand market in the dry season period of peak demand. The Pak Beng and other projects in northern Laos recommended for further study, would certainly deserve a higher rating after Xiaowan began to release water (Chapman and He, 2000: 6).

These supposed benefits are dubious. The destructive potential of these "ruin-of-the-river" mainstream projects including Pak Beng has been pointed out by Hill and Hill, 1994; Hill, 1995; and Roberts, 1995. The Mekong River Commission no longer advocates these projects. The profound environmental problems associated with Thailand's so-called run-of-the-river Pak Mun Dam on the Mun River, a large Mekong tributary, are only now beginning to be recognized (Roberts, in press).

Another dubious benefit involves increased potential for downstream irrigation including large scale water diversions:

> Additional water in dry season months following completion of Xiaowan is likely to increase available supplies significantly in most years, assuming that there is no major extraction of water upstream. This opens up once more the possibilities of large-scale irrigation in Northeast Thailand, water diversion to Bangkok and/or water for residential and industrial use in Northeast Thailand. It also gives a further twist to the critical question of upstream inter-basin diversions and their effects downstream which continues to be a main issue for the four member countries [Thailand, Laos, Cambodia, and Vietnam] of the Mekong River Commission (Chapman and He, 2000: 6).

The Mekong River Commission has substantially revised its views on Mekong mainstream dams. A similar revision of MRC views is developing concerning large-scale interbasin water transfers. Such diversion projects are still popular with Thai politicians wishing to prop up failing dams in Thailand. This is not sound thinking, and Thai politicians with such attitudes are popularly known as "dinosaurs". Dry season irrigation projects in Northeast Thailand (Isan) often result in soil deterioration due to alkalinization and salinization.

> "In Cambodia and the Mekong delta (Vietnam) the residual of the increased dry-season flow from the Lancang Jiang, together with increased dry season flow from tributary projects such as Nam Theun 2 in Laos will assist irrigation and, in the delta, will help combat salt intrusion" (Chapman and He, 2000: 6).

Laos's proposed Nam Theun 2 hydropower project is controversial. It has the potential to kill fish and fisheries in three spearate river basins: Nam Theun, Nam Hinboun, and Xe Bang Fai (Roberts, 1996). Plans for resetttlement and forest protection are hopelessly unrealistic. It is doubtful the project will deliver the benefits promised by project promoters. Should Nam Theun 2 be built it is likely to result in a Laotian environmental, social, and political debacle comparable to Thailand's Pak Moon Dam (Roberts, 1996).

Salt intrusion in the Mekong delta is essentially a natural phenomenon. The Mekong estuarine ecosystem is based on tidal characteristics including "salt-water intrusion." Human agricultural practices as well as mangrove flora, nipa palms, and other estuarine and coastal organisms are in tune with the tides and associated salinity changes. Thailand's famous "Jasmine rice", a high-priced international sensation, is adapted to high salinity soils. Rice cultivars identical or similar to Jasmine are extensively grown in the Mekong Delta. Irrigation in the delta is based largely upon tidal hydropower being utilized to push freshwater into the irrigation canals and onto the paddies. Due to lower wet season flows and reduced flushing, salinization and alkalinization of the flood plains including the extensive paddy in the Mekong Delta is more likely to be aggravated than alleviated by China's "regulation" of Mekong wet- and dry-season flows.

The greatest benefits that China's Lancang cascade of dams might provide for the downstream countries, particularly Cambodia and Vietnam, could be in flood control and in drought prevention or mitigation. Mekong floods have increased in frequency and intensity in recent years, and this trend is likely to continue. It is due mainly to deforestation and global warming. In the short run China's Lancang dams, especially the two large storage dams, would indeed provide a measure of protection against floods as they retain water to fill their reservoirs. The conservative dammed water heads (height to normal maximum water level of storage) of 248 m for 300-m high Xiaowan and 205 m for the 254-m high Nuozhadu offer an additional measure of security from floods. But in the long term the dams could cause greater floods than would occur if they were not built. The main objective of these dams always will be to provide electricity for China's industrialization. This is incompatible with a role in prevention of exceptionally great floods. In a worst-case but not unrealistic scenario the dams could cause a flood far greater than what would otherwise occur.

People in the Mekong region and especially in the lowermost downstream countries of Cambodia and Vietnam are particularly worried about floods. Drought is even more menacing and deserves the utmost attention. Terrible as floods may be, they theoretically are easier to prepare for and respond to than are droughts. Death and destruction from floods usually is spectacular and attention getting. But drought can occur over a longer time with ultimately more devastating results including the long-term incapacity of a country or region to feed itself.

Drought is not so readily defined as flood. It is complex temporally and spatially, and difficult to describe or quantify adequately. Any definition of drought is selective and subjective, depending upon the point of view and objectives of the definer. Entirely different definitions would arise based upon anthropocentric and historical (social impact assessment) versus biotic and ecological (environmental impact assessment) criteria. Definitions of drought are entirely different for forests, for farmers, and for fish populations. Drought probably is the single most important cause of mortality of freshwater fishes in tropical river basins. Fishes differ enormously in ability to avoid the effects of drought (such as by upstream or downstream evasive movements) and capacity to withstand drought. While some swamp-dwelling and air-breathing species are extremely drought resistant, numerous other species cannot live without constantly flowing water. For the great majority of freshwater fishes living in flowing habitats from largest river to smallest stream, insufficiency of water or drought begins when flow is arrested. Adaptive behavior of the great majority of riverine fish species when confronted by drought involves fleeing upstream or downstream to areas with flowing water. Other species burrow into the riverbanks and riverbed where they remain inactive until flow is restored.

Humans living in densely populated areas with large cities in areas with abundant rainfall or surface water (such as Bangladesh, Cambodia, and Vietnam) especially susceptible to the menace of flood also are particularly susceptible to drought. China's Lancang hydropower cascade and navigation scheme may contribute to drought in several ways. During the three years it took to fill its relatively small reservoir, 1993-1996, China's Manwan Dam caused lower than normal dry season flows in northern Thailand and Laos downstream from Chiang Saen. This interfered with local navigation even of small riverboats and may have had some impacts upon farmers, but was not devastating. Filling the enormous reservoirs of Xiaowan and Nuozhadu could cause extremely damaging drought downstream with negative impacts on agriculture, fisheries, and the human population.

Water retention in large reservoirs inevitably results in losses to evaporation. The amount of evaporation from reservoirs can be substantial. It depends upon many factors, including reservoir surface area, water temperature, wind velocity, humidity and atmospheric pressure. Floating aquatic plants such as water hyacinth (*Eichhornia crassipes*) with extraordinarily high rates of water transpiration can cause substantial water loss from reservoirs. This exotic plant pest (originally from tropical America) is now widely distributed in the lower and middle Mekong basin at least as far north as Jinghong in Yunnan and has infested literally thousands of reservoirs as well as the Mekong mainstream and Cambodian floodplain including the Tonle Sap. Regulation of the Mekong flow planned by China is likely to increase the spread of water hyacinth, resulting in great loss of water directly to the atmosphere and loss of water quality. Creating and maintaining a navigation channel in the Mekong mainstream also will contribute to rapidity of run-off favorable to sudden droughts as well as flash floods, depending upon prevailing conditions.

Particularly serious drought is likely to occur in the inland floodplains of Cambodia (including the Great Lake) and of the Mekong delta in Vietnam. Failure of Mekong floods to reach these areas, or lessening their volume, duration, and extent, will contribute to widespread drought. Of particular concern is the fate of the water table. For six months or so of every year most of the Cambodian flood plain is dry and receives very little or no rain. Water is scarce, people suffer, and there are no crops. Harvests are very much at the mercy of conditions. In a single year parts of the plains area may have bumper harvests, other parts crop loss due to floods, and still other parts crop loss due to drought.

Should China regulate the Mekong and diminish the flooding of the flood plains upon which Cambodia's agricultural as well as fisheries productivity depends, there will be two alternatives: reliance on the unpredictable rain fall and tapping the water table. The water table is to at least some extent maintained by annual flooding of the Mekong. Reduction of lower Mekong water tables would be another long-term negative impact inflicted by China's hydropower and navigation scheme on the downstream countries.

Attempts to solve the problem of unpredictable and unreliable water supply for agriculture in the lower Mekong plains areas by tapping the ground water for irrigation might not be successful. Foreseeable difficulties include problems of alkalinization, salinization, expense, and exposure of farmers to the risk of flood disaster. The problem of arsenic contaminated ground water (as in Bangladesh) might also arise.

CONCLUSION

> The ultimate question may be 'what matters most? … sustaining the fish populations and greater biodiversity, or providing a better life for the human population (now and in the future) in two of the world's poorest countries, Laos and Cambodia?'
>
> —Chapman and He, 2000:6

China recently obtained tacit agreement that Thailand will purchase electricity from the Jinghong hydropower projects (Plinston and He, 2000). A "Note on Development of Hydraulic Resources in Yunnan and Export of electricity" was signed by PR China and Thailand in 1993. An "Agreement of Cooperative Development of Hydropower Projects and Export Electricity to Thailand" followed in February 1994. Both governments signed the "understanding Note on Export of Electricity to the Kingdom of Thailand from PR China" in November 1998 (Plinston and He, 2000: 256).

China also has tacit approval from Myanmar, Laos and Thailand to undertake extensive "navigation improvements" on some 300 kilometers of Mekong mainstream mainly where the Mekong forms the border between Laos and Myanmar. These documents should not be construed as agreement from the downstream parties for China to go ahead with her Lancang hydropower program.

Thailand should consider revoking its agreement to purchase Jinghong electricity. Myanmar, Laos, and Thailand should reconsider their tentative approval of the Mekong navigation plans, which was not accompanied by any public discussion including social and environmental impact assessment. Cambodia and Vietnam, the two downstream countries with perhaps the most at stake, should resist Chinese designs on the Mekong as stoutly as they can. In the long run the recklessly impulsive Mekong development being pursued by the People's Republic of China will be detrimental to the best interests of all of the countries involved. China will not escape the negative consequences of its Mekong hydropower and navigation extremism. When the enormity of the social and environmental costs become apparent the blame will fall squarely on China.

China's Lancang hydropower plans and Mekong navigation scheme will turn the Mekong into a biologically degraded, badly polluted, dying river like the Yangtze and other big rivers in China. Little of sustainable, productive value will come of this. Long term benefits are doubtful. China will not be able to regulate the Mekong any more than she can regulate the Yantgze, Europe can regulate the Danube, or the USA can regulate the Mississippi. Damming the Lancang for hydropower and turning the Mekong into a navigation highway will force the downstream countries into exhausting and largely futile efforts to protect themselves from the environmental impacts and make up for the damage to their agriculture, fisheries, and way of life.

To paraphrase the "ultimate" question posed by Chapman and He (2000: 6), 'What matters most?… developing the expensive, risky, and unsustainable Lancang cascade of hydropower dams and Mekong navigation, or sustaining the fish populations, biodiversity, and integrity of the Mekong River so that it continues to support the human population of Laos, Cambodia and Vietnam's Mekong Delta?' The Lancang hydropower dams will kill the Mekong and sedimentation will kill the Lancang hydropower dams. China as well as the downstream countries will pay the full price for this extravagant and unwise development scheme.

ACKNOWLEDGMENTS

David Blake kindly brought several items to my attention. He also provided relevant information and extended discussion. Support for my fieldwork and research has been provided by the Smithsonian Tropical Research Institute; the Committee for Research and Exploration of the National Geographic Society (grant 6943-00), and a John Simon Guggenheim Foundation fellowship for 1999.

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Figure legends:

Figure 1. Mekong basin in its regional setting. Part of the Mekong mainstream known to the Chinese as Lancang-jiang is outlined (see Fig. 2)
Figure 2. Lancang (Mekong) basin in China's Yunnan province, with locations of hydropower dams proposed on the Lancang mainstream.
Word count: 7,444

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