FLUVICIDE: AN INDEPENDENT ENVIRONMENTAL ASSESSMENT OF NAM THEUN 2 HYDROPOWER PROJECT IN LAOS, WITH PARTICULAR REFERENCE TO AQUATIC BIOLOGY AND FISHES

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Preface to 2004 reissue

"Nam Theun 2 has the potential to provide a model for major development projects involving environment and resettlement issues"

—Panel of Environmental and Social Experts (www.namtheun2.com)

Nam Theun 2 is the Laotian version of Thailand's infamous Pak Mun Dam. Unlike Pak Mun, which kills fish and other aquatic organisms only in one river, the Mun, Nam Theun 2 hydropower project is brilliantly designed to kill them in three separate rivers: Nam Theun, Xe Bang Fai, and Nam Hinboun. No matter how badly Nam Theun 2 turns out, however, the World Bank predictably will represent it as another one of its success stories.

The present report, originally issued in January 1996, is based on field surveys done by me in the Nam Theun watershed in 1995. The last stage of the fieldwork was done under the auspices of the Nam Theun 2 Project Development Group (NT2 PDG) which contracted me to do an EIA on aquatic biology and fishes.

Copies of this report were mailed out by me and by Robert Goodland, Environmental Advisor to the World Bank during 1996-1997. It also was posted on a World Bank website for Nam Theun 2 but removed after only a year or two. When I learned of the removal, I contacted the Bank and was promised that the report would be reposted and would remain available on the Bank website.

Two other environmental impact assessments have been produced predicting and discussing probable impacts of the Nam Theun 2 on aquatic biology, fish biodiversity, and fisheries. The earliest was by TEAM Consulting Company of Thailand. Maurice Kottelat produced a report that represents a considerable improvement over the defective TEAM report. Because the work by me and by Kottelat was completed at about the same time, neither of us cited the work of the other. No work on impacts of Nam Theun 2 upon aquatic biology, fish, and fisheries has been done since 1996.

None of the three reports mentioned are available on current World Bank websites or recently issued CDRoms dealing with the NT2 project, presumably because they are too embarrassing.

The reports by TEAM and by me are not even included in the bibliography or reference sections. There are two entries by Kottelat in the bibliography, neither of them directly relevant to the NT2. His highly relevant EIA report is not included even in the bibliography.

Current Bank documents on Nam Theun 2 give only a brief summary of the report by Kottelat. Without access to his original report it is impossible to determine whether the statements supposedly based upon accurately reflect his views.

The Committee of Experts on Nam Theun 2 set up by the World Bank has done nothing to right these deficiencies. They have not called upon me for any interview, and have not taken my report into consideration in their annual reports, despite a promise by one

of the experts (Thayer Scudder). Another expert casually dismissed my report as "tendentious". My rejoinder to him is that his four-man committee is tendentious in its uncritically favorable attitude toward the entire project. What else could one expect, when the World Bank, acting on behalf of the vested interests of itself, the host country and the project organizers, selected the experts?

The World Bank habitually abuses the process of EIA of development projects in Third World countries by stacking the deck against it. According to a Bank directive on engagement of consultants on environmental and social impacts, consultants must be acceptable firstly to the Bank; secondly to the host country; and thirdly to the project contractors. Loyalities of the persons selected are roughly in the following order: 1) to themselves; 2) to the Bank; 3) to the host country; 4) to the project contractors; 5) to people at the national level; 6) to people at the local level; and 7) to the environment. This is exactly the reverse of what the priorities should be. It leads to what philosopher Ananda Coomaraswamy referred to as "the prostitution of the Western intellect to contingency."

Were the impacts on fish the only negative aspect of NT2 I would not be against the project. Familiarity with other aspects of the project has led me to the personal belief that it is badly flawed in many respects apart from aquatic biology and fishes. The World Bank has failed in its duty to discuss transparently and fairly the probable negative impacts of NT2 on the forests and terrestrial ecology of the Nakai Plateau and the potential negative impacts on Lao society and government. The present flurry of suddenly announced one-day meetings in Bangkok, Vientiane, Paris, and Washington, D.C. in August-September 2004 to address environmental and social impacts is exaggerating the benefits and downplaying the negative aspects.

Those who do not learn from the mistakes of the past are doomed to repeat them. This applies to the World Bank and its stance on hydropower development in the Mekong basin. The Bank firmly supported Pak Mun Dam on the Mun River in Thailand, insisting that it would provide numerous benefits and serve as a model for much larger hydropower installations on the Mekong mainstream. The Bank insisted on the importance of monitoring Pak Mun so that the lessons could be learned from it and applied to other dams. But then Pak Mun turned out to be a financial failure and an ecological, social, and political disaster. Bank officials have not acknowledged that Pak Mun turned out badly—they still describe it as a successful project. The Bank has yet to learn the lessons taught by Pak Mun.

To paraphrase the statement by the Nam Theun 2 Panel of Experts quoted above, "Nam Theun 2 has the potential for economic failure and for social and environmental disaster."

Tyson R. Roberts
Bangkok, 7 September 2004

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ABSTRACT

Hydropower installations are seldom environmentally friendly or environmentally neutral. In large tropical river basins with rich biodiversity they can be extremely destructive of terrestrial and aquatic ecosystems. Tropical rivers are a renewable natural resource, subject to sustainable exploitation. Tropical rivers with hydropower dams are not renewable, natural, or sustainable resources. Reservoirs and reservoir rivers—unnatural rivers with reservoirs as their source—pose a variety of diffciult and intractible environmental problems. The proposed Nam Theun 2 hydropower project in Lao Peoples Democratic Republic would have particularly severe environmental impacts. Mitigation measures to reduce negative impacts on aquatic biology proposed by the Nam Theun 2 Project Development Group are likely to be ineffective or marginally successful, or to contribute their own negative impacts.

Nam Theun is the third largest tributary of the Mekong River in Laos. Its mean flow is about 600 m^3/sec, and its total catchment area is about 15,590 km^2. Most of the basin is densely forested and sparsely populated, with perhaps the longest rainy season and highest rainfall of any river basin in Laos. It supports a very rich fauna and flora. It is one of the least explored and studied areas at comparable lowland elevations anywhere in the World. The Nakai Plateau, in the upper Nam Theun basin, is an oustanding place to search for signs of early man, but little prehistoric or paleoanthropological survey work done there. Although now heavily hunted, it still has one of the richest wildlife concentrations in Southeast Asia, with tigers, elephants, a diverse assemblage of ungulates and a highly distinctive fish fauna including many undescribed species, some of which may be endemic. Water from Nam Theun 2 reservoir will be diverted directly into the Xe Bang Fai and indirectly into the Nam Hinboun via the Theun–Hinboun Hydropower project. There will be severe negative impacts on aquatic biology, fishes and wildcapture fisheries in three river systems: Nam Theun, Xe Bang Fai, and Nam Hinboun.

The Nam Theun 2 hydroscheme, currently under consideration for sponsorship by the World Bank, is economically dubious as well as very destructive environmentally, and should be cancelled. Logging should be discontinued, greatly restricted, or carefully regulated in the watershed areas of the other Nam Theun hydropower projects. The entire upper Nam Theun including Nakai Plateau should become a National Biodiversity Protected Area and most of it a World Heritage site under sponsorship of the World Bank or other international organizations. All logging and hydropower development should be stopped there, and steps taken to permit natural recovery of the terrestrial and aquatic ecosystems and their biota.

Key concepts, key words: biodiversity; Bolisat Pathana Khet Phudoi (BPKP); *Chamaecyparis obtusa*; coffinwood trees; cumulative (synergistic) environmental impacts; *Cunninghamia sinensis*; dams; diseases; endangered species; fish; fisheries; floods; *Fokienia hodginsii*; food security; forests; hinoki; human health issues; hydropower; interbasin water diversions; logging; *Luciocyprinus striolatus*; mitigation; Nam Ngum

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[1] This is the original text, except for minor changes mainly to correct typographical errors, presented to the World Bank in December 1996.

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hydropower dam; Nam Nhouang fault; Nam Theun 1 hydroscheme; Nam Theun 2 hydroscheme; Norway; *Pinus merkusii*; pre-emptive environmental impact assessment; reservoir rivers; reservoirs; run-of-river hydropower projects; sedimentation; Sambor hydroscheme; Theun–Hinboun hydroscheme; tigers; *Tor*; Vu Quang ox; wildcapture fisheries; wildlife; World Bank; World Heritage site; Yadana gas field.

INTRODUCTION

The first objective of this paper is to contribute to the discussion of hydropower development in Southeast Asia and particularly in the Nam Theun basin. Its immediate intended audience includes the Nam Theun 2 Project Development Group (NT2 PDG), relevant Lao governmental agencies, and the World Bank, as well as non-governmental agencies (NGOs), conservationists, environmentalists, natural scientists, and other members of the public that are most concerned about Nam Theun and the Nakai Plateau.

The second objective is to predict the negative environmental consequences of hydropower development in Laos, and particularly in the Nam Theun basin-Nakai Plateau, for the benefit of present and future generations of Laotians and for anyone concerned about environmental degradation and loss of biodiversity due to large-scale extractive industries based on non-renewable resources, including rivers. Wild rivers are renewable resources, but rivers damaged by hydropower projects are not.

This paper is a contribution to the current policy debate on big dams and the environment (GOODLAND, 1996; GOODLAND, in press; MCCULLY, 1996). Despite increasing awareness of problems associated with big dams throughout the world, dam proponents focusing on Laos are exaggerating the benefits and viability of large hydropower projects—including their ability toprovide power, revenue from the sale of electricity, reservoir fisheries, and flood control. They have been overlooking, downplaying, or underestimating negative environmental and social impacts. Mitigation measures and resettlement and compensation schemes of doubtful efficacity and justness are being proposed. Nam Theun 2 is the flagship of these projects.

Laos, a small, land-locked mountainous country of bountiful natural resources and only 4.5 million population, is embarking on a far-reaching program of hydropower and other development, with profound implications for her future welfare and relationships with neighboring countries. Some 60 Mekong mainstream and tributary sites have been identified for installation of large hydropower dams. Almost all of the electricity generated by these projects will be exported to China, Vietnam, and especially Thailand.

Virtually all of the electricity from Nam Theun 2 will be sold to Thailand's Electricity Generating Authority (EGAT). The price EGAT is willing to pay for electricity from NT2 and other Lao hydropower projects is extremely low. Even so, EGAT is likely to impose stringent penalties, including fines, price cuts, or delayed payments if Nam Theun 2 fails to meet scheduled production. There is no guarantee of course that EGAT will always be in a position to honor its purchase commitments, even if it intends to do so.

Hydropower and other exploitation schemes are taking place or are being proposed in the Nam Theun watershed that will totally disrupt this floristically and faunistically rich, highly distinctive, and very little known ecosystem. Companies and consulting firms from Australia, France, Norway, Sweden, Switzerland, Thailand and other countries involved with the Lao government and with the World Bank, UNDP, ADB and other development agencies are soft-pedalling, misleading and degrading the EIA process in order to promote hydroprojects with unusually great negative environmental impacts. Documentation for this claim is provided at numerous points in this report.

Mitigation measures proposed for NT2 are unlikely to reduce the most serious negative impacts to acceptable levels, and might in themselves result in negative impacts. This is an attempt to catalog some of the most substantial individual impacts. Inevitably some important impacts will have been overlooked. The important point is that individual negative impacts will almost never work in isolation, but rather in combination with others, to produce cumulative or synergistic destructive effects greater than would be predicted simply by summing up the individual impacts.

The Nam Theun watershed, like Laos generally, is one of the least studied areas in the world. Systematic surveys of mammals, birds, reptiles, amphibians, fishes and other animal groups are far from complete. The first scientific study of Nam Theun fishes, with preserved voucher specimens for identification and study, was not conducted until February 1995. The first bird and mammal studies also were done in 1995 but did not involve extensive collecting of voucher specimens. It is highly likely that undescribed birds and mammals occur in the Nam Theun, some of which may be endemic to the area.

COMMON MISCONCEPTIONS OF HYDROENGINEERS AND OTHER DAM PROPONENTS ABOUT AQUATIC ECOLOGY AND FISHES

- Fishes of large tropical rivers (so-called "storage" or "reservoir rivers") such as the Mekong are preadapted to live in large reservoirs created by hydropower projects. **Tropical riverine fishes generally are adapted to riverine conditions and habitats with flowing water. Most cannot survive in reservoirs**.

- Migratory water birds and wildlife will be attracted to reservoirs and will benefit from them. **Birds and mammales will not find food or other suitable conditions and will not be benefitted by reservoirs.**

- Gains in reservoir fisheries will more than compensate for loss of riverine wildcapture fisheries due to hydropower projects. **This may be true during the supernormal riverine phase of the reservoir fisheries, typically lasting only about five years after the reservoir is filled or aerobic conditions are restored.**

- Fish below a dam need only the average dry season flow (or some large fraction or small multiple thereof) to maintain their populations and sustain the fisheries based upon them. **Dry season water levels are a time of great hardship and loss for fish, when food at the low end of the food chain is scarcest, predation and disease highest, water quality poor. Most of the fishes are adapted to and need seasonal changes including wet season flows in order to survive. Most wildcapture riverine fishes are highly dependent upon seasonal changes of flow.**

- Tropical rivers such as the Mekong have no true migratory fishes. **A large proportion of fish species in large tropical rivers such as the Mekong, including those most importance to wildcapture fisheries, are strongly migratory. The great majority of all riverine fish species are probably at least slightly migratory, and all need to go up and down the linearly organized river ecosystem to survive.**

- Fish ladders are an effective means of offsetting the barrier to fish movements created by dams. **Nothing could be farther from the truth when it comes to large tropical rivers with rich fish faunas. See Box on Pak Mun Dam fish ladder.**

- Reservoirs contribute to fish biodiversity**. Reservoirs are too short-lived for their fish stocks to diverge genetically very much from their riverine ancestors. Fish stocks may respond rapidly to conditions in reservoirs, but this is mainly due to their inherent genotypic and phenotypic variability. Genetic stocks of fish species in reservoirs will generally be less variable or diverse than those of the same species in their natural habitats. Typically only 20-40% of tropical riverine fish species become established in large reservoirs created by damming the rivers in which they live.**

- Loss of fish biodiversity caused by dams can be made up by fisheries personnel employing artificial breeding and stocking programs. **Such programs can augment fisheries productivity in reservoirs, but can never come close to making up for loss of fish biodiversity. Artificially reared offspring of migratory species often lose their migratory behavior and fail to become sexually mature and reproduce, so they have to be perpetually stocked. Efforts to re-establish stocks of highly migratory Mekong species such as the large striped carp *Probarbus jullieni* and the giant catfish *Pangasius gigas* generally have been unsuccessful. Even the most varied and best-supported stocking programs will "restore" only a small proportion of the species lost, and these will only be restored so long as the programs continue.**

Some observers think that 100 or more tigers (*Panthera tigris*) live in the Nam Theun catchment (pers. commun., Nancy Schoenewalt, Tiger Preservation Trust, Nov. 1995). This is a substantial number, given that the world population of wild tigers may be less than 3000. The Nakai Plateau lowlands may well be essential foraging grounds for the tigers. The relationship between tigers and the general ungulate population may very well be essential for survival of the Vu Quang ox (*Pseudoryx nghetinhensis*), a newly discovered endangered species of great scientific interest. It is a general principle of predator-prey relationships, first illucidated by Charles Darwin, that presence of a keystone predator or of a series of predators actually enhances biodiversity by permitting more prey species to co-occur. The Nam Theun basin-Nakai Plateau is perhaps the most favorable remaining area to study the interactions of tigers, elephants, and a diverse assemblage of ungulates and other mammals.

The Nakai Plateau, with its large low-gradient meandering river, equable climate, and former high concentration of game, is perhaps the best location to search for evidence of prehistoric man in Laos. Little paleoanthropological research has been done there. The sites most likely to have been inhabited by ancient man will be under 20-30 m of water if the Nam Theun 2 project is implemented.

Botanical exploration has also lagged far behind in the Nakai Plateau and in the Nam Theun basin. An aerial survey of the forests was carried out in the late 1980's, but apparently the ground-truthing was incomplete and poorly done. Consequently there is no accurate information available on the distribution of *Pinus merkusii* and other economically valuable tree species. The area is rich in species of Orchidaceae and many other flowering plant families that have not been adequately surveyed. There has been no survey of wild varieties or local cultivars of rice.

Perhaps the gravest negative impacts of Nam Theun hydropower projects will be loss of biodiversity. Depending on which projects or combinations of projects are carried out, many species may become extinct before they have been discovered and named.

Nam Theun 2 of course has substantial local social implications, by no means limited to the 900 or so families of oustees from the 450 km^2 area to bre flooded by the reservoir. The largest number of people who will be hit hard are those living along the Xe Bang Fai below the diversion input. Some people living above this point and on tributaries of the Xe Bang Fai may also suffer losses. Cumulative impacts of NT2 on Xe Bang Fai agriculture and fisheries will aggravate existing food security problems. Substantial readjustments will be necessary, possibly including resettlment—whether planned for or not. This issue is not dealt with in the present assessment but it must not be ignored. The study of the social implications of Nam Theun 2 commissioned by NT2 PDG deals only with people living in the upper Nam Theun-Nakai Plateau area (CHAMBERLAIN, 1996).

For purposes of general description, ecology, distribution of fish species, and environmental impact assessment, the Nam Theun mainstream can be divided into limnologically and biotically distinctive lower, middle and upper reaches. These may be defined as follows:
1. Lower Nam Theun. From the mouth of the Nam Theun into the Mekong River mainstream upstream to Geng Wang Fong, the proposed dam site for Nam Theun 1. This is a slow-flowing, meandering, low-gradient stretch only 28 km long, with only two small tributaries (Nam Sun and Nam Pang), and drains only 8% of the Nam Theun catchment. It is inhabited by a very large subset of migratory and other fish species typically found in the Mekong mainstream and in its larger lowland tributaries. None of the endemic Nam Theun fish species have been found here. The lower Nam Theun would be very badly impacted by the Nam Theun 1 hydropower project and badly impacted by the Theun-Hinboun project.

2. Middle Nam Theun. From Geng Wang Fong upstream to Geng Kuk (the damsite for the proposed Nam Theun 2 project). This is a moderately to very fast-flowing, high-gradient stretch of 134 km with many rapids. It has large numbers of the giant predatory carp *Luciocyprinus striolatus* and of several fish species known only from the Nam Theun watershed. It receives the two largest tributaries of the Nam Theun, the Nam Mouan and Nam Gnouang, together draining 50.5% of the entire watershed. Altogether this middle reach drains 62% of the Nam Theun catchment. Middle Nam Theun would be badly impacted by the Theun-Hinboun project, and severely impacted by the Nam Theun 2 project. Geng Wang Fang appears to be a boundary between the warm water fish fauna of the lower Nam Theun and the cool water fish fauna of the middle and upper Nam Theun. There are a series of low waterfalls and many rapids in the swift flowing narrows that extends above Geng Wang Fang, but nothing such as a high waterfall that would consitute a physical barrier to upstream or downstream fish movements.

3. Upper Nam Theun. From Geng Kuk upstream to the confluence of the Nam Theun and the Nam On. This stretch of the Nam Theun mainstream, 85 km long, runs the length of the Nakai Plateau and is mostly low gradient, with some meanders, and a few important rapids. It receives three moderately large tributaries, the Nam Xot-Nam Mon, Nam Theun-Nam Noy, and Nam On. Altogether it drains 30% of the Nam Theun watershed, including the entire flood plain of the Nakai Plateau with biologically distinctive wetlands south of the Nam Theun mainstream. Upper Nam Theun would be severely impacted by the Nam Theun 2 project.

We humans are living on—and could only have evolved and survived on—a planet that is user-friendly, but we have not been friendly users. We have to care for the Earth in order to survive in anything like the comfort and safety to which we have become accustomed. Certainly there are disadvantaged people all over the world that should be helped. But they cannot be helped if the environment we all depend upon is destroyed in the process.

Tropical rivers with their running waters, forested watersheds and other life-sustaining benefits are a renewable natural resource that can be sustainably exploited. Tropical rivers with large hydropower dams are not a sustainable or renewable resource. Decommissioning dams and restoring tropical riverine ecosystems is technically complex, financially prohibitive, and practically impossible. In most instances removal of sediment deposited in a large tropical reservoir is not feasible.

Cycling continental waters from atmosphere to the oceans, rivers are an essential part of the biosphere. Tropical rivers, with their extraordinarily rich biota, harbor a very significant portion of the earth's biodiversity. Damage them, and you damage the earth's ecology. And most of the earth's rivers have been damaged to some extent already.

The idea that water flowing to the sea is wasted unless it is used to generate hydroelecrtricity is erroneous. Damming all of the rivers is like cutting down all the forests: it is damaging to the human life-support system.

Perhaps the Lao government should have some large hydropower projects so that it can finance its operation and provide health, education, and other benefits for the Lao people. But the government needs to pursue its objectives cautiously and wisely, with due consideration for the environment, for the rights of all of its citizens, and for the impact of its activities on its neighbors and on the world. It is not always being well served by the foreign companies and consultants who have flocked to Laos, especially those with vested interests in promoting large development projects. In particular the government has not been getting good advice on environmental issues.

Brief review of Nam Theun hydropower projects

"Nam Theun 2 is a brilliant hydro site but has potential for high environmental damage"

– David Iverach, 8 August 1995

Eight potential sites for large hydropower projects have been identified in the Nam Theun basin (Table 1; Fig. 1). Four of these are on the mainstream of the Nam Theun, and four are on large tributaries of the Nam Theun. Two of the mainstream projects, Theun-Hinboun and Nam Theun 2, involve trans-basin diversion of Nam Theun water into adjacent basins. One project, Theun-Hinboun, is under construction.

Locations of Nam Theun hydropower projects are indicated in Fig. 1. A summary of the dam heights, reservoir areas, and other characteristics of these projects, accompanied by an estimate of their negative impact on aquatic ecology, is given in Table 1. The aquatic impacts have been ranked by increasing order of magnitude on a scale of 1-10, with the projects actually evaluated at 3 to 9. This is admittedly somewhat arbitrary, but it enables others to see how the projects are ranked in relation to each other, and provides a more solid basis for further discussion and clarification than if projects were merely rated "very bad", "bad", and "not so bad".

Nam Mouan. The Nam Mouan hydroscheme involves two large dams: 1) the main dam (and power station) on the Nam Mouan immediately below the confluence of the Nam Mouan and its small tributary the Nam Xouang; and 2) a diversion dam on the Nam Theun mainstream at the same site as that proposed for the Theun-Hinboun hydroscheme (ANON., 1992). All of nearly all of the Nam Theun mainstream flow would be diverted by a 7-km tunnel into the Nam Mouan Reservoir via the Nam Xouang.

Nam Mouan reservoir would flood a hilly forested area estimated at 455 or 5l5 km^2 (both figures given in ANON., 1992). But as topography of the Nam Theun basin is poorly known, the area actually flooded might be substantially greater. Environmental impacts generally and impacts on aquatic ecology in particular of the Nam Mouan project would be severe. The forest drowned by the reservoir could cause rotten (deoxygenated and otherwise toxic) water for ten years or more. This would have a major impact not only on fish in the reservoir but also in the Nam Theun mainstream below the mouth of the Nam Mouan and possibly also in the Mekong mainstream, at least during the dry season. The Nam Theun mainstream flow between the diversion dam and the mouth of the Nam Mouan would be eliminated or greatly reduced. Fish migration and dispersion up and down the Nam Theun mainstream and to and from the Nam Theun and the Nam Mouan would be totally blocked by the two dams. The fisheries of the lower 53 km of the Nam Theun mainstream (including those at Pak Kading) probably would be eliminated or badly damaged.

Presumably now that work on the Theun–Hinboun project is going ahead, the Nam Mouan project is no longer a possibility. If Nam Theun 1 also goes ahead, there will definitely be no possibility of a very big hydro project on the lower Nam Mouan.

Nam Theun 1. With the highest dam being considered in the Nam Theun basin, Nam Theun 1 would create a very large reservoir. Since dam height has not been fixed, and since topography is poorly known, the eventual size of the reservoir might be anywhere between 400 and 800 km^2.

Unless the area to be flooded is cleared of forest, the reservoir is likely to have rotten water for ten years or more. This would have a severe negative impact on aquatic ecology in the reservoir, in the Nam Theun mainstream, and possibly also in the Mekong mainstream. The rotten water due to drowned forest is likely to be exacerbated by water hyacinth, *Eichhornia crassipes.* Fish migration and dispersal up and down the Nam Theun mainstream would be totally blocked, not only by the dam, but by poor water quality downstream as well as upstream from it. However, migration up and down the Nam Theun mainstream past Geng Wang Fong may not be very important, so this potential impact may not be such a great problem. But the Pak Kading fisheries will be wiped out, and negative impacts on fish in the Mekong mainstream are to be expected, at least during the dry season. Assessment of some NT1 impacts on fish and fisheries is provided by WARREN, 1995.

Theun–Hinboun. All or nearly all of the water from the Nam Theun mainstream will be diverted through a tunnel out of the Nam Theun basin and into the Nam Hinboun mainstream via a seasonal tributary of the Nam Hinboun, the Nam Hai. Due to the small size of the reservoir, the high rate of flow in the reservoir, and its confinement to the maximum annual flood levels of the river, no forest will be drowned and there should be no rotten water resulting from the Theun-Hinboun reservoir.

It is important to realize that no hydropower projects are planned for the Nam Hinboun basin, and that Theun–Hinboun is the only hydropower project that will divert water into the Hinboun. If Nam Theun 2 is built, water discharged from its reservoir into the Nam Theun mainstream will flow into the Nam Hinboun mainstream because of the Theun–Hinboun diversion. If the Nam Theun 2 reservoir water is rotten, as predicted, it will have a very substantial negative impact on Nam Hinboun aquatic ecology and fisheries. If Nam Theun 3 is built, it may also send rotten water into the Nam Hinboun via the Theun-Hinboun diversion. These problems are not mentioned in the Theun-Hinboun environmental assessment by NORPLAN, 1995.

When I called it to his attention, Brian Glover, Director of Engineering for NORPLAN, insisted that the phrase "trans-basin run-of-river project", was a respected engineering term and a correct description of the Theun-Hinboun project. This is a typical example of the the obtuseness of hydroengineers when it comes to environmental matters. Once all or almost all of its flow is diverted for many months each year into the Nam Hinboun, the Nam Theun below the dam will be an abandoned river channel, not a river. And once that flow is diverted into the much smaller Nam Hinboun, the Nam Hinboun will have an unnatural water quality and an unnatural flow regime. An environmentally apt description of the Theun-Hinboun project would be "trans-basin ruin-of-rivers."

As an important mitigation measure for the Theun-Hinboun project, NORPLAN (1995) called for a minimum outflow into the Nam Theun mainstream below the dam of 6-15 m^3/sec. But technicians running the project will be under no constraint to respect this. Rather, they will be under pressure to generate as much electricity as possible.

NORPLAN's insistence on a minimum mainstream outflow and on installation of a fish ladder or pass was not favorably received in Vientiane. The contractors were not happy about having to make what they called "last minute adjustments", and indicated that there would be very little option as to the design and placement of the fish ladder or pass. It seems they really did not want to be bothered by environmental considerations.

Nam Theun 2. Although the dam is only 38 m high, the flooded area will be 450 km^2. It was previously estimated at 350 or 370 km^2; the upwardly revised estimate is based on topographic information obtained in 1995. Some 200 m^3/sec will be diverted from the tail-end of the reservoir through a tunnel into the neighboring basin, the Xe Bang Fai.

The large flooded area has very substantial consequences for terrestrial and aquatic ecology. Despite assurances by Nam Theun 2 Project Development Group, it is unlikely that the forest in the area to be flooded will be cleared before the dam is built. Thus there will be rotten water in the reservoir for some ten years, perhaps much longer, depending on the circulation in the stagnant headwater of the reservoir and other factors. The duration and severity of rotten water might be augmented by an infestation of water hyacinth.

Water diverted from the reservoir into the Xe Bang Fai will have major negative impacts on aquatic ecology and fisheries of the Xe Bang Fai afterwards as well as during the rotten period. The Nam Theun 2 dam and the poor water quality above and below the dam will completely block fish movements of all kinds up and down the Nam Theun mainstream. The reservoir will flood important fish breeding grounds and habitats, including several mainstream rapids, the only extensive wetlands in the Nam Theun basin, and the lower reaches of all of the upper Nam Theun basin tributaries. All fish passing into the diversion system will be killed. Riverine fish inhabiting the upper reaches of these individual tributaries will be forever isolated from the Nam Theun mainstream and from the other tributaries by the enormous extent of unfavorable water quality and unsuitable habitats presented by the reservoir. This will almost certainly lead to loss of fish biodiversity in the tributaries, with virtually no possibility of replenishment of stocks from neighboring sources.

The Xe Bang Fai is well known as a food security problem area. The most important foodstuffs are sticky rice and wild-captured fish, with fish the only important source of protein (local people have no significant source of plant protein). Although nearly all people living along the Xe Bang Fai are rice cultivators, they are also subsistence hunter-gatherers. When the rice crop fails, as it did in 1994 and again in 1995 due to flooding, dried fish is traded for rice. When no other food is available, it is always possible to catch some wild fish to keep from starving. Rotten water from Nam Theun 2 Reservoir could eliminate wildcapture fish as a significant resource for people living along the mainstream of the Xe Bang Fai from Mahasai downstream to

the Mekong River (152 river kilometers). The reduction of fish in the Xe Bang Fai is likely to last long after the rotten water has gone from the reservoir.

Nor should it be assumed that the negative impacts of toxic water in the Nam Theun 2 reservoir will be confined to the reservoir itself and to the Xe Bang Fai. While most of the time the reservoir will discharge only 6-15 m^3/sec of water into the channel of the Nam Theun mainstream below the dam, when the reservoir is already filled to capacity and then exceptionally heavy and prolonged rainfall occurs, it will not be possible to relieve the flooded reservoir by releasing more water than usual into the Xe Bang Fai. There will be no choice but to let water escape from the dam into the Nam Theun mainstream. If the water in the reservoir is rotten, it will kill fish for the length of the Nam Theun mainstream from the NT2 dam to the Theun-Hinboun dam, a distance of 71 km. This water, diluted a bit by input from the Nam Phao and Nam Gnouang, will be diverted into the Nam Hinboun mainstream to kill fish for another 52 km.

The Nam Theun 2 Project Development Group (NT2 PDG), with which I had considerable contact from July through November 1995, and again in January 1996, consists of Transfield Corporation, a private Australian company; Electricite de France, a French governmental agency; and a consortium of three Thai companies, Italian-Thai Development Co., Jasmine International, and Phatra Thanakit. Offices have been opened in Bangkok and in Vientiane. The main organizational effort is being provided by Transfield; Hans Fischer, the project director, is a Transfield employee. In June 1995 another Transfield employee, David Iverach, came to help Fischer with environmental, budgetary, and other aspects of the project. Most of my dealings were with him and with Brian McIllree, Senior Engineer and Project Manager in Vientiane, also seconded from Transfield. Iverach was recalled to Sydney around the end of October 1995. With the temporary departure of Iverach, NT2 PDG was left with no one willing to deal with environmental problems who had any influence with Transfield and NT2 PDG. Most of the consulting on environmental and resettlement issues had been done by Team Consulting Engineers, Co. Ltd., a Thai firm that specializes in "get the job done EIA" for EGAT (Electricity Generating Authority of Thailand).

The section of Team's July 1995 NT2 EIA dealing with fish and fisheries, reviewed by me at the insistence of Iverach, is so poorly done that it is practically useless. Only a few of the fish species present in the project area were collected, and several were incorrectly identified. There is no discussion at all of migratory behavior. The entire report has never been publicly released.

Phu Phet. Briefly considered as an alternative to Nam Theun, this involves a high dam on the Nam Theun mainstream about midway between the Theun-Hinboun and Nam Theun 2 dam sites. No water would be diverted out of the Nam Theun basin, and there would be a very large reservoir. No other information on this project available.

Nam Theun 3. This involves a high dam on the Nam Gnouang immediately below the confluence of its two largest tributaries, the Nam Huang and Nam Chot. It would have severe impacts on aquatic ecology of the Nam Gnouang basin downstream as well as upstream from the dam. Rotten water from the Nam Theun 3 Reservoir would flow downstream into the Nam Theun mainstream, to continue downstream in the Nam Theun or be diverted into the Nam Hinboun. Depending on whether Nam Theun 2 is built and on water quality in its reservoir, Nam Theun 3 might be the main source of negative impact through poor water quality and cold water on the Nam Hinboun.

Nam Theun 4. This project involves a high dam on the Nam Chot, a tributary of the Nam Gnouang. If Nam Theun 3 is done, it may not be possible to do Nam Theun 4.

Nam Theun 5. This project involves dams on two mountain streams in the uppermost high gradient part of the Nam Theun and the Nam Noy.

ECOLOGY OF LARGE TROPICAL RIVERS, RESERVOIRS, AND RESERVOIRS OUTFLOWS

The river as a life-supporting machine: essential role of natural hydropower

Rivers can be viewed as machines run by natural hydropower. The ultimate source of this hydropower is gravity, the attraction of the earth's mass that causes water to run downhill. The main work performed by the river machine is to transport water downstream, whether as a trickle or as a great flood. In the case of the Mekong, the initial source of its hydropower is in glacial sources in Tibet some 21,000 feet high. In addition to water, rivers transport sediments, minerals, organic materials, oxygen and other dissolved gasses, and, increasingly, pollutants produced by human activities.

Rivers performing their work universally minimize dissipation of energy, by finding the most efficient pathway of moving water downstream in any given locality (given geological constraints). This accounts for some of the otherwise seemingly strange things that rivers do, such as meander. Meanders allow rivers to flow with the least resistance from the stream bed and material deposited on it. Work done by rivers also is largely responsible for characteristic features constituting distinct habitats for fish and other riverine organisms, such as deep stretches, pools, uniformly gravelly or sandy areas, riffles, rapids, swamps and wetlands. Nearing the sea, the work of rivers combines with that of tides to create estuaries and contribute to other coastal habitats. Naturally occurring hydropower is essential to the maintenance and health of all of these habitats and of the organisms dependent upon them.

Elucidation of the many roles of natural hydropower in rivers and other aquatic ecosystems is one of the more demanding tasks confronting aquatic biologists. At any given point along a river, its potential hydropower is equal to the volume (or really, the mass) of the water in the river and its height above sea level. Once the river has reached the sea and mixes with it, its hydropower has been expended. Normally the river's potential energy is converted to kinetic energy, performing almost uniform amounts of work as the river meanders unobstructed for long stretches. Occasionally, as when a river has rapids or flows over a waterfall, there is a more sudden release of kinetic energy. The hydropower of big rivers thus progressively diminishes as it flows downstream, but is also usually augmented as it receives inputs from larger and larger tributaries.

What happens when a large hydropower dam is placed on a river? As the reservoir behind the dam fills, more and more of the river's kinetic energy is converted into potential or stored energy. The amount of stored energy can be calculated from the volume of water in the reservoir and its height above a baseline such as the average river level under normal conditions, or the height above sea level. When water is diverted from the reservoir through the turbines to generate electricity, its potential or stored energy is converted into kinetic energy outside the river ecosystem and converted into electricity, which is transported by electric lines to perform work elesewhere.

Hydropower remaining in a river or outflow channel below a hydroelectric dam is not the same as that of the river at the same point before it was dammed. It has been diminished proportionately to the amount of electric power generated divided by the efficiency of that generation. Hydropower installations typically have an efficiency of about 50%. Depending on the hydroelectric instllation and its operation, the loss of a river's hydropower at the site may be anything from about 5% to 95% (or even 100%, in the case of a total diversion scheme).

When 100% of the river volume flows through the hydroelectric turbines and into the old river channel, the mass of of the river has not been changed at all. Hydroengineers and other dam proponents have wrongly claimed that such a river or outflow will be a natural ecosystem and just the same for fishes and other aquatic organisms as the river was before it was dammed.

Water in hydropower dams often is released not through the turbines but through spillways. The spillway openings are always somewhat higher, and usually much higher than the turbine openings, and well above the height of the river at average flow. It is possible for spillway gates to be opened so that the normal volume of water is released into the outflow channel of the reservoir. In this situation, the hydropower released from the reservoir at the dam site will be the same amount as the natural hydropower that would pass by the site if there was no dam. But even such releases cannot be considered as "normal river flow" or "run of the river" because so much of the energy is dissipated immediately below the dam site.

To a casual observer, the great display of energy immediately below a dam with its turbines in full operation or its spillway gates wide open looks like a powerful river with its natural hydropower intact. This is an illusion. The water is being released from relatively small openings, and at unnatural levels. The hydropower of a normal river, at its normal height, even though it may exhibit not even a ripple at the surface, is of course far greater than its reduced power after it flows through the turbines of a hydroelectric dam. This is one of the reasons that the water flowing out of such a reservoir is no longer a river. Rather it is a reservoir outflow, which has lost or had greatly diminished several of the most important properties of a river. It only looks like a river because it flows in the old channel or streambed of what formerly was a river. Such an artificial river supports very few of the fishes and other organisms characteristic of a natural river, especially a tropical river with high biodiversity and distinctive species assemblages in rapids, riffles, pools, sandy stretches and other habitats.

All of the changes in riverine ecology induced by reduction of a river's natural hydropower will be negative impacts.

The reservoir river: major long-term cumulative impacts

One of the first lessons to be learned about the water coming out of a large, flow-through hydropower reservoir is that it is no longer a natural river. It only looks like one. As such a river flows on downstream and receives tributaries that have not been dammed it regains some natural riverine properties, but is never fully restored.

For a long time I have searched for an appropriate term for such a modified and unnatural river. "Reservoir outflow" is a possibility, but people tend to associate this term with what occurs or exists only in the area immediately below the dam. An appropriate term is "reservoir river." The same term has been used elsewhere for very large natural rivers, such as the Amazon, which store or "reserve" enormous quantities of water inland. In the totally different and new sense used here, it has a double-meaning: literally, a river that originates from a reservoir; also, an unnatural river having many of the attributes of a reservoir.

Thus the Mekong below Manwan Dam in Yunnan Province is a reservoir river, and so are nearly all of the larger rivers and many of their tributaries in Thailand. Plans are now on foot to dam the Bangpakong, Thailand's last remaining natural river, and turn it also into a reservoir river. If Nam Theun 2 is built, it probably won't be long before most of the rivers in Laos are reservoir rivers.

Really large reservoir rivers in the tropics are a relatively recent phenomenon—so recent that there has not been much time to experience or study their negative environmental impacts.

Water coming out of a reservoir has very different properties from water in a natural river. Two of the more important differences concern hydrologic regime and sediment load. Because of these and other differences, the behavior of a reservoir river is entirely different from that of a natural river.

Hydrologic regime of a natural river is determined primarily by inputs of rainwater and groundwater. Inputs of rainwater normally are by far the most important in determining the seasonality of flow levels, and whether a river overflows its banks in any given year. Some rivers overflow their banks almost every year, others only at intervals of several years. In a hydropower reservoir river, on the other hand, the flow regime is usually determined by demand for electricity generation. Since the demands are relatively constant over the year, the flow regime is relatively constant (ignoring variables such as "peak demands").
Reservoir rivers generally will not be permitted to overflow their banks. Thus farmers who traditionally relied on the annual floods to enrich their farmland by depositing silt, now have to apply fertilizers. But this is by no means the main problem of such reservoir rivers for humans.

The river bed of a natural river is normally cleared of much of its silt or sediment when it overflows its banks. As it overflows the banks, the sediment load is quickly dropped, thus building up the banks and actually serving as a flood-prevention device. A natural river is a far more competent hydrologic engineer than its human counterparts. In a reservoir river which is not permitted to flood, silt deposited in the river-bed remains in the river-bed which is thus constantly being built up.

Many of the mainstream rivers and tributaries flowing into large tropical reservoirs carry a moderate to heavy sediment load. Most of this silt is dumped at the upper end of the reservoir or where the tributaries flow into it. Water coming out of the reservoir tends to be clear and free of sediment. But as it has no sediment load, it is what hydrologists refer to as "sediment hungry." Thus it will eat away at the river banks, causing them to erode and cave in, until it is sediment-loaded.

The impacts of the large reservoir river that would arise from a 45-m high dam just 26 km upstream from Luangprabang may well be imagined. In 1993 the Mississippi experienced what the U. S. Army Corps of Engineers called a "500-year flood", a shorthand expression for a flood so large that it had been predicted to occur only once in 500 years. Calculation of such probabilities is an arcane procedure usually considered the domain of hydroengineers. Needless to say, it is often based on insufficient data and unwarranted assumptions. One unwarranted assumption is that there is no such thing as climatic change. Another is that there have not been any substantial negative impacts on the watershed. And another is that the river under consideration has not deviated from acting like the natural river upon which their data is based. Of course this assumption is wrong. The Mississippi River in 1993 was acting like a reservoir river, not like a natural river.

Reservoirs, reservoir rivers, and floods

Hydropower proponents frequently claim that the large dams they build provide protection against floods. This is one of the major benefits—apart from hydropower—that China's enormous Three Gorges Dam on the

Yangtze supposedly will provide. This thinking is seriously flawed, just like Mao's thinking at the time of the Great Leap Forward. Under the most favorable conditions, large dams can provide a measure of safety from floods that are not too big or too frequent. But let us resolve the question of whether big hydropower dams will provide safety from the really large floods which are likely to come. The answer is a resounding no, and for reasons so simple that even bureaucrats uneducated in scientific matters should be able to understand.

Hydropower dams are almost always kept full. This is done so as not to loose any of the water needed to generate electricity. If the dam is very large, it stores the equivalent of several years of river flow. When a really big flood happens upstream from the reservoir of such a dam that is already filled with water, how can it provide any protection at all? It must release the full flood, or risk being overflooded itself. If the entire dam is destroyed by a large flood, it will release all of the floodwaters and all or most of the water it has stored, resulting not in a normal natural catastrophe, but in a super-normal man-made catastrophe. The larger the dam that is built, and the greater the human population living below it, the larger the potential catastrophe. But this is not the only problem, and it may not even be the worst problem.

The worst problem may be due to the reservoir river coming out of the dam. Its sediment-hungry waters will continually erode its banks and build up the sediment bed for the length of the river, constantly increasing the probability of larger and larger floods. This was part of the problem with the Mississippi River in 1993, and with the Red River at Hanoi in 1995 and 1996, and it will be a problem for the Yangtze after Three Gorges is completed. Removing the sediment from the bed of a reservoir river that is not permitted to overflow its banks will almost certainly prove to be more difficult than removing sediment from a reservoir.

Before closing this topic, one related problem should be mentioned. Global warming is generally accepted as a long-term phenomenon that will have profound impacts on human affairs. On a global scale, melting of the Himalayan ice-capes will not have any significant effect on sea level. But it could cause floods larger than any previously known in rivers such as the Indus, Ganges, Brahmaputra, Salween, Mekong, and Yangtze. For this reason alone, it is imprudent to build mainstream dams on any of these rivers. Those that have already been built probably should be decommissioned.

To run or not to run: more than just a communication problem between hydroengineers and environmentalists

"Theun-Hinboun is a trans-basin run-of-river project"

– Brian Glover, November 1995

When is run-of-the-river not run-of-the-river? Brian Glover and other hydroengineers will have to speak for themselves. I have attempted to provide an ecological critique of the run-of-the-river concept as it has been misapplied by proponents of Pak Mun Dam (ROBERTS, 1993) and more recently by the Mekong Secretariat to dams on the Mekong mainstream (ROBERTS, 1995).

The main points of my argument can be repeated here, with reference to hydropower projects in the Nam Theun basin. In true run-of-river projects water quality and flow should not be seriously changed. There can not be any significant diversion of water out of the system. The classical small-scale model of such a device is the water wheel or water mill, examples of which can still be seen in operation throughout Laos. Modern high technology versions may include turbines, but they have to rely solely on kinetic energy of the otherwise unimpeded river. All of the water in the river and all that is carried by it or that lives in it must be able to pass freely by the installation. Anything else cannot be considered "run-of-the-river" by an ecologist or environmentalist.

In the Theun-Hinboun diversion hydroscheme, all or almost all of the water in the Nam Theun mainstream will be diverted into the Nam Hinboun, a much smaller river. The Nam Theun immediately below the dam will no longer flow at all, or will flow at only the rate of 6-15 m^3/sec (average normal flow of the Nam Theun at this point is about 400-500 m^3/sec). The Nam Hinboun will have greatly altered temperature and other limnological characteristics, and a totally abnormal flow regime with severe ramping effects. To call Theun-Hinboun a trans-basin run-of-river project, as NORPLAN project director Brian Glover insists (Theun-Hinboun EIA and pers. commun., November 1995) is highly imprudent and misleading from the standpoint of biology, ecology, and environmental impact assessment.

Water quality

"Water quality of the Nam Theun 2 diversion will be better than the Xe Bang Fai dry season water quality"

– Brian Mc Illree, November 1995

"I will lose my job if I let you have a copy of the [Nam Theun 2] water quality report"

– Brian McIllree, November 1995

In July 1995 I began extensive discussions with NT2 PDG officials concerning the implications of Nam Theun 2 for aquatic biology and particularly fishes. NT2 PDG was highly concerned about the potential problem of deoxygenated water in Nam Theun 2 reservoir and therefore of the water that would be diverted from the reservoir into the Xe Bang Fai. This was regarded as the worst impact of the project on aquatic ecology and one that would have to be substantially mitigated. It was believed that the problem would be severe if the area flooded by the reservoir was not cleared of forest beforehand, but that the forest could be cleared. David Iverach of NT2 PDG vehemently denied that most of the timber coming out of the Nam Theun 2 area was being cut at elevations much higher than the 538 m maximum elevation of the NT2 reservoir when full. He also thought that if worse came to worse, anoxic water generated in the reservoir could be re-oxygenated by appropriate measures in the diversion channels before it reached the mainstream of the Xe Bang Fai.

I agreed that some degree of mitigation should be possible and to work on the problem, indicating that a specialist in limnology and water quality would have to work with me and would have to get into the field. Iverach replied that he already had limnologists working on the problem, but declined to identify them.

Presumably the limnologists referred to were the Electricite de France water quality specialists who worked up the short draft document on "water quality of the Nam Theun 2 project." I suspect that the document is a desk-top study hurriedly done in France by a person or persons using field data from a site they never visited or visited but very briefly. I was given only the opportunity to scan it and to study (but not copy) one table and one graph. It evidently is a very preliminary document. The graph presented two scenarios for water quality in the Nam Theun 2 reservoir (and of the water to be diverted in to the Xe Bang Fai): 1) oxygenated water if the area flooded by the reservoir is entirely cleared of forest: and 2) deoxygenated water if the area is not cleared. The table showed a few water quality parameters. I was not permitted to take notes or to have a copy of the table, but did observe that many substances that might contribute to bad water quality were not included.

My request to meet the limnologists working on Nam Theun 2 was denied. It was proposed that NT2 PDG would model systems for reoxygenating water diverted into the Xe Bang Fai. I said that there might be some useful mitigation measures for oxygenating water going into the Xe Bang Fai, and that it would be a pleasure to work with him on this. But I also indicated that water quality problems other than deoxygenation were highly likely, and that I would still need to have a specialist in water quality and limnology working with me, and that the person would have to get into the field. A few days later I submitted to Fischer and Iverach the name and CV of a suitably qualified person.

NT2 PDG proposed to improve the quality of water diverted into the Xe Bang Fai by a combination of mechanical mixing and using alternative outlets into the Xe Bang Fai. One suggestion was to turn the entire diversion channel of the Nam Phit into one long rapids by moving boulders into it. The potential problem of the difference in Nam Theun and Xe Bang Fai water temperatures was brought up, but mitigation measures for this were not identified or discussed. Several kinds of negative impacts of cold water on upstream/downstream migrating/dispersing fish (eggs and fry as well as adults) were pointed out, and also the possibility of various kinds of toxic inorganic and organic substances arising in the reservoir. Iverach admitted that these problems had not been considered and would have to be worked on. Relevant data on water temperatures and on some potentially toxic substances were not available.

On 20 September 1995, at Fischer's request, I submitted a proposal for field surveys and analysis of NT2 impacts on aquatic ecology and fisheries to the NT2 PDG. Before the end of September Iverach temporarily was withdrawn from the project and returned to Sydney, although I did not learn this until after returning from a trip to Bhutan toward the end of October. Iverach had stated emphatically that he would remain with the project until the dam was built, and that I would be hired as an consultant. But the last time I saw him, he indicated that the decision to hire me would be up to Fischer and the NT2 PDG. Discussions were resumed with NT2 PDG in November 1995 and January 1996, but did not result in resolution. The Lao Hydropower Office refused to provide me with an appropriate visa to complete the EA work on Nam Theun I had been contracted to do for NORPLAN. Meanwhile NT2 PDG hired a more compliant consultant on aquatic biology and fisheries, who provided them with the report they wanted (KOTTELAT, 1996).

THE NAM THEUN FISH FAUNA

"Nam Theun is just like tributaries of the Mekong River in Thailand"
– Amnat Prommasutra, May 1995

"Nam Theun fishes are just common species"

– Wit Tarnchalanakut, May 1995

Nam Theun is a very special tributary of the Mekong River, with no equivalent in Thailand or anywhere else in the Mekong basin. If Laos had a program of National Protected Rivers, the Nam Theun would be my first nomination. When asked for his impressions of the Nam Theun, Amnat Prommasutra, Executive Director of Team Consulting Engineers, Co. Ltd., replied that it was just like tributaries of the Mekong River in Thailand, and specifically mentioned the Si Songkram (a tributary in northeastern Thailand). How could anyone think that the silty low gradient Si Songkram, with its thick mud deposits, is at all like the swift, clear, high gradient Nam Theun, with its rocky, gravelly or coarse sandy bottom and numerous rapids?

Fishes of the Nam Theun (that is, of the middle and upper Nam Theun above Geng Wang Fang) are not at all common species. Senior colleague and Team consultant Wit Tarnchalanakut is a fine fisheries biologist and a talented administrator, but is not trained as an ichthyologist or ecologist, and is not qualified to evaluate fish biodiversity or environmental impact assessment of hydropower projects in poorly known parts of the Mekong basin such as the Nam Theun. The fishes of the Nam Theun are anything but common species. Engaging distinguished and respected experts to report on topics for which they are not qualified is one of the chief ways EIA is subverted.

The composition of the Nam Theun fish fauna (Table 2) is remarkably different from that of any of the Mekong tributaries in Thailand (the fish fauna has been relatively well surveyed now throughout Thailand) or in any other Mekong tributary in Laos or elsewhere that has been ichthyologically explored. The fish faunas of the Nam Hinboun and of the Xe Bang Fai, the two fairly large Mekong tributaries immediately adjacent to the east and southeast of the Nam Theun, are typical of large lowland Mekong tributaries and thus utterly different from that of the Nam Theun.

Nam Hinboun and Xe Bang Fai are both populated by a rich and diverse fish fauna representing a large or very large subset of the migratory and other fish species inhabiting the mainstream of the Middle Mekong River and its largest lowland tributaries (such as Thailand's Si Songkram and Menam Mun prior to construction of Pak Mun Dam). That is, both have at least 100 and probably over 200 species that are widespread in the Middle Mekong basin. Many of the same species occur in the Chao Phraya and Bangpakong rivers of Thailand. Many of the species in the Nam Hinboun and Xe Bang Fai migrate to and from them and the Mekong mainstream. A few of the species in the Nam Hinboun and Xe Bang Fai are still undescribed, but all or almost all of them have already been found elsewhere in the Mekong basin or even in the Chao Phraya. Thus there are very few if any species that are endemic to the Nam Hinboun or to the Xe Bang Fai.

The Nam Theun fish fauna does not have as many species as other Mekong tributaries of comparable size. Thus far only some 85 Nam Theun fish species are known, and the total number present in the basin (excluding the tiny part of the basin below Geng Wang Fang) seems unlikely to be very much greater, perhaps around 100. But remarkably many of the species are undescribed, and some of these newly discovered species might be endemic to the Nam Theun basin (i.e. species that evolved in the Nam Theun basin and occur nowhere else).

Nam Theun fishes are similar to those that have been reported from tributaries of the Mekong basin in China's Yunnan province. Many of the Nam Theun genera and species (e.g. *Folitor, Hemibarbus, Hemiculturella, Luciocyprinus, Tor, Pseudecheneis*) are characteristic of large, clear, coldwater mountain tributaries. Perhaps the most notable absence of all is that of Pangasiidae, the family including the two giant Mekong catfishes and several of the most important wildcapture fishes in the Mekong basin. Clupeidae are also entirely missing, and so are many characteristic lowland and warmwater Mekong genera and species of Cyprinidae. When the upper Nam Ou of Laos's northernmost Phongasaly province is ichthyologically explored, its fish fauna will probably resemble that of the Nam Theun and the Mekong mountain tributaries in Yunnan. Fishes of the Xe Bang Fai and Nam Hinboun, on the other hand, are those characteristically found in the Middle Mekong mainstream and in lowland Mekong tributaries such as Thailand's Si Sonkram and Menam Mun. Thus the Nam Theun is populated by what appears to be mainly a coldwater fish fauna, while the Xe Bang Fai and Nam Hinboun are populated by a relatively warmwater fish fauna.

Of the Nam Theun fish species, 33-55% (28 to 45 of a total 85) are strongly migratory. This includes nearly all of the middle-sized and larger cyprinid species of most importance in Nam Theun wildcapture

fisheries. Some 6 to 8 of the Nam Theun migratory species are also found in the mainstream of the Mekong, and commonly migrate to and from large lowland tributaries and the Mekong mainstream. But it has yet to be confirmed that any of these species are migrating to and from the Nam Theun and the Mekong mainstream. Rather it seems more likely that the Nam Theun populations of these species are confined to the Nam Theun, and that their migrations occur only within the Nam Theun system. Certainly there are many highly migratory Nam Theun fish that migrate only between high gradient Nam Theun tributaries and the Nam Theun mainstream.

Relevant information currently available on the Nam Theun fish fauna is summarized in Table 2. For present purposes, the Nam Theun fish fauna includes all fish species known from the Nam Theun mainstream and its tributaries above Geng Wang Fong. The 28 km stretch of the lower Nam Theun mainstream and its two small tributaries (representing 8.5% of the basin) are populated by a large subset of migratory and other species typically inhabiting the Mekong mainstream and its larger lowland tributaries.

Conservation of Nam Theun fish species

Conservation status of fish species known thus far from the Nam Theun basin is indicated in Table 2. It should be stressed that this table probably is far from complete. The first scientific collections of fishes from the Nam Theun were not made until February 1995, and further ichthyological exploration is likely to lead to discovery of additional endemic and otherwise important species.

The presently known species of greatest conservation concern (indicated with ** in Table 2), may be discussed briefly here.

Luciocyprinus striolatus (Lao name pba kang in lower and middle Nam Theun, pba gang in upper Nam theun). This undoubtedly is the outstanding fish species in the Nam Theun. Known in the lower Nam Theun as pba kang and in the upper Nam Theun as pba gang, it grows to at least 2 m long and 60 kg. But there are reports of much larger fish, to 3 m and 100 kg or more. Local people say it eats monkeys. The rhesus macaque, *Macaca mulatta*, abundant in the Nam Theun basin and "strongly associated with rivers" (Anon., 1995) presumably is the species of monkey most often taken. But of course the fish is primarily a piscivore or fish-eater. Nam Theun fishermen more familiar with it report that it eats most of the larger carp species found in the Nam Theun, as well as young and medium-sized *Mystus microphthalmus* catfish.

Luciocyprinus striolatus possibly belongs to the Eurasian cyprinid subfamily Aspiinae, which includes virtually all of the giant predatory carp species previously known from in Asia. There are about 4-5 giant piscivorous aspinines, distributed from the Tigris-Euphrates system in western Asia to Siberia and China in the east. Almost all of the giant Asian cyprinids are endangered or threatened throughout all or most of their range. The Nam Theun population of *Luciocyprinus* is one of the few robust populations of giant cyprinids remaining in the world. The species is endemic to the Mekong basin. It is present in the Upper Nam Ngum but has failed to populate Nam Ngum reservoir. It may also occur in other Mekong tributaries in Laos and in Yunnan, but has never been found in the Mekong mainstream or in Mekong tributaries in Thailand.

Extirpation of the entire Nam Theun population of *Luciocyprinus* is a distinct possibility if two or more mainstream dams are placed on the Nam Theun. While this in itself would not mean the extinction of the species, large hydroschemes also are planned for the upper Nam Ngum and for most or all of the other rivers in Laos and Yunnan where the species might occur.

Hemiculturella macrolepis (local Lao name pba seht). Possibly the most abundant small fish species in the Nam Theun basin, and therefore an important forage species and possibly an ecological keystone species. Migratory behavior unknown. Erection of one or more mainstream dams on the Nam Theun could cause its extinction, with substantial repercussions on the Nam Theun aquatic ecosystem.

Poropuntius cf. *deauratus*. An apparently undescribed species of the herbivorous carp genus *Poropuntius*, possibly endemic to the Nam Theun. Locally known as pba jaht, it is definitely an ecological keystone species. It is by far the most abundant medium-sized fish species throughout the Nam Theun mainstream and in lower gradient parts of its tributaries. It probably is the most commonly captured prey species of the top level piscivorous Nam Theun fish species *Hampala macrolepidota, Luciocyprinus striolatus, Mystus microphthalmus,* and *Bagarius yarrelli. Poropuntius* species are common in rivers in Thailand and Laos. Apparently they never become established in reservoirs.

Onychostoma new species and *Scaphognathops* new species are medium-sized carps apparently endemic to the Nam Theun and of moderate importance to wildcapture fisheries. Both occur mainly or only in the mainstream of the Nam theun and in lower gradient parts of its larger tributaries, and both probably are

strongly migratory. Construction of mainstream dams could cause both species to become extinct due to loss of habitat and spawning grounds and blockage of migratory routes. Neither species is likely to become established in reservoirs.

Last but not least are three species of *Tor* of great conservation concern. Two apparently are endemic to the Mekong basin, and one is known only from the Nam Theun. There are altogether about 10-12 species of *Tor,* 5 or 6 in the Indian subcontinent including Burma, and 5-6 in Southeast Asia including the Malay Peninsula, Borneo, and Java. Two species endemic to south India are thought to be extinct (pers. commun, K. Jayaram, October 1995); *Tor* populations in Java are greatly reduced and may be facing extinction. Among the only relatively healthy *Tor* populations anywhere are those in the Mekong basin of Yunnan, Laos, and Cambodia. All of these populations may be threatened soon. *Tor* live in clearwater mountain streams and feed largely on figs and other forest fruits and on clams. When forests are cleared and streams become charged with sediment, they are among the first species to disappear. While *Tor* are relatively abundant in many mountain streams of the Mekong basin in Laos, they have never been found in the Mekong basin in Thailand. The combination of deforestation and dams is likely to have severe impacts on all Nam Theun populations of *Tor,* and could cause their complete disappearance from the ecosystem.

In addition to the 6 Nam Theun fish species of greatest conservation concern, 18 species are of some concern (Table 2). One of these, *Anguilla marmorata*, deserves special mention. Until recently, no true eels were known from the middle portion of the Mekong basin. But they have recently been recorded from the Mekong River near Nakorn Phanom, Pakse and Stung Treng, and tentatively identified as *Anguilla marmorata* (Roberts & Warren, 1995). Local fishermen interviewed by me and my Lao counterpart Phouthalom Vongsay in April 1995 reported that the species also occurs in the Nam Theun. Large fish were caught in the Nam Theun mainstream at Geng Bit (the Theun-Hinboun dam site) in November 1994 and near Ban Sop Mouang in March 1995. We are still trying to obtain voucher specimens from the Nam Theun, where the fish is known as pba laht meao.

All true eels have an obligatory "diadromous" life history: that is, the young grow up in fresh water, and adults spend most of their life there. But reproduction only occurs more or less far out to sea. The sexually mature adults, before they can reproduce must migrate out of the rivers and into the sea to reach the spawning grounds. The young eels, or elvers, migrate back to the inshore waters, find a river mouth, and then go more or less far upstream to grow and mature into adults. This may require 20 years or longer. *Anguilla marmorata*, attaining a length of 2 m and 10-20 kg, is possibly the largest and longest lived species of *Anguilla*. It occurs or formerly occurred in many large tropical Asian rivers from India eastwards to the East Indies. Like other species of eels, it is widely threatened by pollution and dams. A single mainstream dam on the Nam Theun (or on the Mekong mainstream) would lead to the disappearance within 20 years or so of all eels living further upstream. None of these eels would be able to migrate downstream to reach the sea and spawn again, and they would not be replaced by young eels migrating upstream.

IMPACTS ON FISHES AND WILDCAPTURE FISHERIES

Negative impacts of Nam Theun 2 on fish and aquatic ecology in general will be severe (see Box). Environmental damage resulting from this project is likely to be greater than that from any of the 49 large hydropower projects that have been installed in Thailand, none of which involve diversion of water out of one river sytem and into another. Impacts of Nam Theun 2 are also likely to be greater than those likely to arise from almost all of the 50 or so hydropower projects being considered on Mekong tributaries in Laos. Only megaprojects, such as China's Three Gorges, India's Sardar Sarovar, Cambodia's Sambor, and Vietnam's Song La, or those involving numerous dams and largescale diversions from major rivers (such as from the Salween into the Chao Phraya) are likely to have more serious environmental impacts (including possibly even greater losses of biodiversity) than Nam Theun 2.

Impacts of Nam Theun 2 hydropower project on aquatic biology, fishes and wildcapture fisheries include but are not necessarily limited to the following. An important point to remember is that the impacts are expected to act cumulatively or synergistically:

- Disruption of the linearity of the upper Nam Theun riverine ecosystem. The middle Nam Theun linearity is already disrupted by the Theun–Hinboun dam, but the upper Nam Theun could very well still function as an intact large subsystem of the Nam Theun. The argument that since there already is a dam at the Theun–Hinboun site, another dam at the Nam Theun 2 site will not further damage the system is invalid.
- Prevention of upstream and downstream movements of virtually all life history stages of all fishes and other aquatic organisms.
- Prevention of downstream flow of nutrients from upper Nam Theun headwaters.
- Creation of a large body of water (reservoir) unfavorable to riverine fish life; may be largely or totally deoxygenated for decades due to rotting terrestrial and aquatic vegetation.

- Isolation of fish populations inhabiting upper Nam theun headwaters by reservoir, effectively preventing migration and recruitment from one tributary to another.
- Trapping of nutrient flowing downstream from headwaters, most or all of which will be anaerobically degraded in the bottom of the reservoir.
- Reservoir may be focal point for outbreaks of plant pests such as *Eichhornia.*
- Reservoir may be focal point for outbreaks of fish diseases such as EUS.
- Reservoir may facilitate logging, log transport, and related activities deleterious to aquatic ecosystem.
- Reservoir waters may dissolve Nakai Plateau salt deposits, causing salinization of aquatic ecosystems.
- Reservoir may increase bioavilability and biomagnification of mercury.
- Diversion of anoxic and otherwise toxic water into Xe Bang Fai and Nam Hinboun.
- Diversion of cold water from NT2 reservoir into relatively warm water Nam Hinboun and Xe Bang Fai rivers
- Natural hydrologic regime of Nam theun, Nam Hinboun, and Xe Bang Fai will be severely altered, creating highly unfavorable conditions for fish and other aquatic life.
- Large volume of diverted water with little or no nutrient will make it difficult for fishes and other aquatic organisms living downstream to find food.
- Difference in water temperature, quality etc. of waters diverted from NT2 reservoir into Nam Hinoun and Xe Bang Fai may block upstream and downstream movements of fish and other aquatic organisms.
- Nam Theun hydropower project will rob Nam Theun River of much of its natural hydropower, thus reducing it to a reservoir river with greatly reduced life-supporting qualities.
- Hydrologic regime and reduced natural hydropower in Nam Theun downstream from reservoir is likely to result in increased, continuous and more uniform sedimentation of fish habitats, resulting in poor feeding and spawning conditions.
- Rapids habitats of importance to many fish species will be eliminated.
- Mouths and lower parts of Nam Theun tributaries joining Nam theun mainstream on Nakai Plateau will be deeply flooded, eliminating important fish habitats and migratory pathways.
- Distinctive wetlands swamp habitats on the Nakai Plateau will be eliminated.
- Subterranean aquatic ecosystem of Khammouane Limestone Protected Area could be impacted by seepage from NT2 reservoir.

Cold Water

Cold water from diverted Nam Theun 2 Reservoir into the Xe Bang Fai will have severe negative impacts on fish and fisheries. Fishes generally are more sensitive to temperature changes than are terrestrial vertebrates and many other animals. Many tropical warm-water species are particularly sensitive to sudden drops of temperature.

Nam Theun fishes are relatively cold adapted, while those of the Xe Bang Fai and Nam Hniboun are adapted to warm water. Cold water diverted from Nam Theun 2 reservoir will probably be the worst impact of Nam Theun 2 on fish and fisheries of the Xe Bang Fai.

Fishermen interviewed by me and my Lao counterpart Phouthalom Vongsay at Ban Sensi (on the Nam Gnouang below Nam Theun 3 dam site) and at Ban Sop Gnouang (on the Nam theun mainstream opposite the mouth of Nam Gnouang, just upstream from Theun–Hinboun dam site) related that a cold spell caused in January-February around 1985-86 or 1987-88 caused massive fatality of fishes for the whole length of the Nam Gnouang and for a long way down the Nam theun mainstream. Villagers at Ban Sensi said that the mortality occurred during a single week, those at Ban Sop Gnouang that it lasted one or two months. Otherwise their accounts closely agreed. They indicated it was the coldest weather they had ever experienced, and that it caused frost on trees. Large species hardest hit included the carps *Cirrhinus molitorella, Labeo pierrei, Tor sinensis,* and *T. tambra* and the catfishes *Bagarius yarrelli* and *Mystus microphthalmus.* Species that did not die included *Hypsibarbus* sp. and *Poropuntius* spp. For several years afterwards, catches of many species remained low, and at least one large carp (species not identified) disappeared and has still not returned to the Nam Gnouang.

The upper Nam Theun mainstream, on the Nakai plateau at an elevation of 500+m, or some 300 m higher than the Xe Bang Fai and Nam Hinboun mainstreams, and receiving water from a number of large mountains tributaries arising at elevations up to 3000 m, is probably always several degrees colder than that in the Xe Bang Fai and Nam Hinboun. Water in the Nam Theun Reservoir is likely to be even cooler, especially at the outlet depth of 10 m. The 35 km of flow below the turbines in the Nam Phit before the diverted water enters the Xe Bang Fai mainstream is unlikely to contribute much warming. The artificially rapids or baffles installed in the Nam Phit to oxygenate the water may cause enough evaporation to cool it slightly more.

Cold water from Nam Theun 2 Reservoir entering the Xe Bang Fai mainstream will have compex negative impacts on all life history stages of Xe Bang Fai fishes. Eggs, larvae, and very young juveniles drifting downstream from the upper Xe Bang Fai at all times will be unable to escape from an abrupt temperature drop that will kill them. The same will apply earlier life history stages drifing down the Nam Oula, the major tributary of Xe Bang Fai which enters the mainstream just a few kilometers downriver from Ban Mahasai. Adult fish undergoing reproductive migrations from the Mekong mainstream and from the lower Xe Bang Fai up the mainstream of the Xe Bang Fai and then on into the Nam Oula or continuing up the Xe Bang fai mainstream will encounter first increasingly cool water, then abruptly warm water as they enter the Nam Oula or continue up the mainstream past the entry point of the cold water diverted from Nam Theun 2 Reservoir. This will be a very strong curb to their migratory behavior. Of Xe Bang Fai fish species, about 25 to 40% are strongly migratory, but this element includes most of the larger species important in wildcapture fisheries. An episode of very cold water from the Nam Theun would almost certainly cause a massive mortality of Xe Bang Fai fishes, resulting in the temporary or permanent diseappeance of a number of species that are of most importance to wildcapture fisheries and food security not only in the Xe Bang Fai mainstream upstream and downstream from the diversion input, but also in its largest tributaries.

Rotten water

When Laos's Nam Ngum reservoir began filling in 1971, only a small amount of high quality timber in the 450 km^2 area it would flood had been logged. The rotting of the forest drowned by Nam Ngum reservoir, while well known to people in Laos, was not noticed by the outside world, even though it lasted for 8 years. During this time the only fishes living in the reservoir were air-breathing snakeheads which supported a very small fishery (pers. commun., Chanthaviphone Inthavong, Lao Department of Forestry).

The Nam Ngum experience presumably contributed to Lao awareness of rotting vegetation in newly formed reservoirs, and may explain in part the Government of Lao practice of granting a timber concession upon the signing of an MOU (Memorandum of Understanding) for hydropower projects.

The NT2 PDG has been aware for quite some time that Nam Theun 2 Reservoir would have a major water quality problem if the forest in the area to be flooded was not cleared. David Iverach mentioned this to me on our first meeting in July 1995, and he was surely aware of it long before then. Water quality experts employed by Electricit, de France were working on a water quality document for Nam Theun 2. The 13-page document has not been made public, but I was permitted to view selected pages, including one table and one graph.

The graph visualized two scenarios for water quality in Nam Theun 2 Reservoir: 1) oxygenated water if the forest was completely cleared; and 2) anoxic water with very high BOD (biological oxygen demand) if the forest was not cleared. This anoxic water would not be permanent, but it might well last 10 years or longer. It would not only kill nearly all fish species in the reservoir, but might kill all or most fishes in the Xe Bang Fai for all or most of 125 km length below the inflow of water diverted from the Nam Theun 2 Reservoir.

Even if the area to be flooded by the reservoir is cleared entirely of vegetation, it does not mean that the reservoir water quality will be good for humans. Many potential water quality problems have not been considered at all in Nam Theun 2 EIA statements available as of October 1996. Thus *Eichhornia* and EUS are likely to be problems in the reservoir even if it was cleared of terrestrial vegetation. Additional potential problems include, but are by no means limited to: 1) substantial difference in temperature of water diverted from Nam Theun into Xe Bang Fai; 2) substantial differences in water chemistry; 3) toxic substance problems, such as mercury.

Water hyacinth

The floating water hyacinth, *Eichhornia crassipes* (pak tohp in Lao), is the worst aquatic plant pest in the world. Originating in northern South America, and introduced to tropical Asia about one century ago, and has become established in most of the river systems of tropical Asia and Africa. The worst outbreaks occur in artificial water bodies such as canals, ponds, and reservoirs and in rivers heavily impacted by human activity. In general, when plant or animal pests have explosive outbreaks, they suddenly decline just as rapidly. But outbreaks of *Eichhornia* tend to persist, sometimes for decades. Efforts to control extensive *Eichhornia* infestations by chemical or mechanical means invariably fail, because they are too expensive and enough plants survive even the most concerted erradication efforts to recoup rapidly the moment the effort is relaxed. Efforts to convert *Eichhornia* into useful products (fertilizer, fodder, fuel, pulpwood or whatever) are rarely if ever commercially profitable and seldom contribute much to solving the problem of large outbreaks, because the pest is too abundant and too widespread to be effectively collected for processing.

Probably biological control is the only effective remedy. There may be an effective single control agent, such as an insect or fungus that feeds on *Eichhornia.* Two weevils and a moth have achieved some success in reducing infestations in Thailand (pers. commun. Banpot Napompeth, Director, Research Center for Biological Control, Bangkok, 6 August 1996). The weevils and moth used in control are native to parts of South America where *Eichhornia* originally came from. Apparently none of the insects native to Southeast Asia feed on it. Effective biological control may only be possible combined with other measures, including pollution reduction and otherwise maintaining the integrity (including biodiversity) of natural and man-made aquatic habitats.

Negative impacts of water hyacinth include massive water loss by evapotranspiration; and deoxygenation. The main cause of deoxygenation is due to the enormous biomass of water hyacinth and its high rate of overturn due to bacterial decomposition. As the plants die, they sink to the bottom and rot. Well oxygenated reservoirs with massive outbreaks rapidly become deoxygenated. Tropical reservoirs contribute significantly to global warming by production of greenhouse gasses carbon dioxide and methane (Fearnside, 1995). *Eichhornia* probably is the most important aquatic plant source of these gasses throughout Southeast Asia. *Eichhornia* also is probably the most important plant species in tropical Asia involved in absorption of mercury and increasing its bioavailability through anaerobic metabolism in reservoir bottom sediments.

While *Eichhornia* has become widespread in tropical Asia within a few decades since introduction, and has been a serious pest in the Meklong and the middle Mekong, other rivers have none at all or are at least relatively unaffected. Thus the mainstream of the Irrawaddy in Burma and of the Mekong in southern Laos and northeastern Cambodia have virtually no *Eichhornia* at all, despite their direct connection to badly infected water bodies. Ponds, ditches, and canals in Mandalay are choked with water hyacinth, and there is plenty *Eichhornia* in the middle Mekong mainstream where the river is shared by Thailand and Laos.

Eichhornia is widespread in temporary roadside ditches, ponds and waterholes in the Nam Theun and Xe Bang Fai catchments but is not to be seen in the mainstream of the Nam Theun or of the Xe Bang Fai, presumably because both streams still have high biodiversity including intact fish faunas.

Fish disease

EUS, or epizootic ulcerative syndrome, is the most serious disease confronting wild as well as cultured freshwater fish in Southeast Asia. A major outbreak began in 1980's which did not abate until 1990. In some remote areas, especially in Laos, it is still spreading. A leading researcher on this disease is Kamolporn Tonguthai, Director of the Aquatic Animal Health Research Institute, National Inland Fisheries Institute, Bangkok. According to her it is still not known why EUS (the causative agent of which is a virus) broke out in the 1980's, or why it suddenly abated. Also, she notes that although the disease occurs in Laos, there has been very little information on its distribution and present status there.

In April 1995 I found that a fish disease tentatively identified as EUS was rampant on the Bolaven Plateau in southern Laos. Many Bolaven streams are highly impacted by agriculture, fertilizers, and pesticides. Evidence was obtained that the disease was still spreading on the plateau and that it may have spread down from the plateau into larger and relatively unimpacted rivers in the Se Kong basin. These and other observations are reported in detail in the rapid assessment of the impacts of the Xe Nam Noy-Xe Pian hydroscheme by ROBERTS & BAIRD (1995), in which we suggested that hydropower reservoirs on the Bolaven plateau could lead to a greatly increased incidence and spread of this disease.

In July-October 1995 my Lao colleague Phouthalom Vongsay heard from Nam Theun villagers about the incidence of fish disease every year during the cold season (December-January) which sounded very much like EUS. On 1 December 1995 we collected a badly infected *Channa striata* some 20 km upstream from the Nam Theun 2 dam site. This air-breathing snakehead is the one species most frequently attacked by EUS, and most often associated with spread of the disease. The specimen was sent to the Aquatic Animal Health Institute where histological examination by Kamolporn confirmed the disease as EUS.

The long period of anaerobic and otherwise toxic conditions expected in Nam Theun 2 Reservoir are highly likely to stimulate a population explosion of *Channa striata* and other air–breathing fish including *Channa gachua, Channa* new species, *Anabas testudineus*, and *Misgurnus anguillicaudatus*. These species are all known to be or (in the case of *Misgurnus*) likely to be highly susceptible to EUS. Water diverted from an infected Nam Theun 2 Reservoir into the Xe Bang Fai, while it would not be accompanied by any living fish that are infected, would nevertheless be extremely infectious (pers. commun. Kamolporn). A Nam Theun 2 Reservoir infected with EUS could be the focal point for a major outbreak in the Nam Theun basin, the Xe Bang Fai, the Nam Hinboun (via the Theun–Hinboun diversion), and the Mekong mainstream.

Mercury

Natural levels of mercury are generally high in tropical Asia, but public awareness of this is recent. A long series of articles on this topic, mainly by reporter James Fahn, has been published in *The Nation* in 1996. Some big companies drilling for oil and gas contend that since natural mercury levels are high anyway, their drilling operations should not be blamed for mercury pollution. Nevertheless, their operations are directly responsible for local increases of mercury bioavailability by many orders of magnitude.

Reservoirs of all kinds are potentially another point source of increased mercury bioavailability. EGAT officials were informed that there was a potential mercury problem in Thai hydropower reservoirs as early as 1991 (pers. commun., Bangkok environmental consultant, 22 October 1996).

Brian MacIllree of NT2 PDG emphatically declared that "there is no mercury in the Nam Theun area" (pers. commun., November 1995). In January 1996, however, a Lao-based geologist confirmed that at least five mercury deposits had been reported recently in or near the area to be flooded by Nam Theun 2 reservoir. These deposits probably are associated with hot springs. It is likely that only a few of the deposits have been located. There could easily be 150 of them on the Nakai Plateau. The Lao Department of Geology and Mines in Vientiane and the Department of Natural Resources of ESCAP in Bangkok were unable to provide specific references to mercury deposits in the Nam Theun basin in January-February 1996.

Mercury is one of the most dangerous and persistent of naturally occurring substances, and one of the few that is biomagnified by a variety of aquatic and terrestrial organisms, including fishes and man. Biomagnification means accumulation over two or more trophic levels in the food chain. In any aquatic ecosystem, mercury tends to accummulate in the substrate. Thus higher organisms that feed on substrate are most likely to absorb mercury directly from the environment. The form of mercury most readily assimilated by organisms (i.e. most readily bioavailable) is methyl mercury. This is produced mainly or entirely in anaerobic substrates by bacterial decomposers with lots of plant input such as dead *Eichhornia* that sinks to the bottom of a reservoir. *Eichhornia* is extremely efficient in absorbing and concentrating mercury.

In natural and artificial aquatic ecosystems in the Nam Theun basin, mercuric biomagnification is most likely to be initiated in bottom-feeding invertebrates and fishes such as clams, snails, crustaceans, mayflies and detritivorous fishes such as *Garra* and *Labeo* and to be completed in piscivorous fish species such as *Channa* sp., *Luciocyprinus striolatus,* and *Mystus microphthalmus*. Biomagnification can then be further continued in terrestrial predators feeding on fish, such as kingfishers, fishing eagles, otters, and humans.

Rock salt

Thick deposits of rock salt, laid down over millions of years of Cretaceous marine incursions, underlie parts of the Nakai Plateau and therefore of the inundation area of Nam Theun 2 reservoir (ESCAP, 1990). The entire area occupied by the rock salt would be flooded by Nam Theun 2 reservoir. It is essential that these salt deposits be accurately mapped and measured so that their full extent and geological associations are known and can be evaluated in terms of potential impacts on the dam, the reservoir, and the environment. Dissolution of the salt by water seeping into the deposits from the reservoir could conceivably have a number of negative impacts, including 1) salinization of reservoir water; 2) saline seepage from the Nakai Plateau into the groundwater and subterranean rivers of the Khammouane Limestones National Biodiversity Protected Area (sponsored by IUCN and the World Bank); 3) incapacity of Nam Theun 2 reservoir to hold water; 4) direct threat by subsidence to Nam Theun 2 dam if it overlies salt deposits; and 5) activation of Nam Nhouang Fault, parts of which apparently must pass through the salt deposits.
Perhaps none of these problems will arise, but this cannot be adequately assessed until the salt deposits and the layers above and below them have been adequately surveyed and studied.

Sedimentation

"From the above table [on projection of sedimentation stages] it is apparent that the life of Bhumiphol Dam will be about 400 years. Because in financial practice EGAT has calculated depreciation for the Dam in such a rate that the cost of the dam will be depreciated to zero in 80 years, the 320 years of extra service can be regarded a bonus…!"

– *This is EGAT*, 1973

From Thailand's Bhumibol to Vietnam's Hoabinh, hydroengineers and dam proponents have underestimated the rate of sedimentation of hydropower dams in South East Asia by an order of magnitude. Thus Bhumibol is seriously threatened by sedimentation after only 30 years. So much for the predicted 300+ years of free service, or for breaking even on the investment in Bhumibol after 80 years. Nam Ngum Dam is also threatened by sedimentation. Ad hoc diversions are now under way to prolong the useful lifetime of Bhumibol and Nam Ngum, and the massive Son La Dam (second in size only to China's Three Gorges Dam) is being promoted partly to relieve sedimentation in Hoabinh. No one knows how rapidly Son La Reservoir will silt up, but it should take a few years at least. Nam Theun 1 and Nam Theun 2 reservoirs could silt up as rapidly as Bhumibol and Nam Ngum. This is one reason for predicting that Nam Theun 2 will turn out to be a **BOATL** project: **B**uild, **O**wn and operate an **A**sset (for 25 years), **T**ransfer a **L**iability (to the Lao government).

Extensive deforestation, like that going on in the upper Nam Theun watershed, is associated with destruction of land surface and soil loss. Lost soil does not simply evaporate. It washes into streams and accumulates in river bottoms and other water bodies and in their water-land interfaces (beaches and draw-down areas).

In river systems such as the Nam Theun, where all of the tributaries and even the mainstream itself normally have clear water (or at least a very low sediment load, even in the high water season), the direct effects of heavy loads of suspended sediments and of thick sediment deposits upon fish and other aquatic life can be devastating. A l0-km landslide into a tributary of the Nam Ou in northern Laos in March 1995 reportedly caused massive fish mortality for some 140 km, i.e. from the landslide site on the tributary all the way down the Nam Ou mainstream to the mouth of the Nam Ou into the Mekong near Luangprabang. Dead fish picked up near the mouth of the Nam Ou reportedly had their mouths and gill cavities completely packed with silt. The landslide supposedly was caused or exacerbated by local tree felling.

But fish death from sedimentation is seldom so pronounced or so highly visible as this Nam Ou episode. Chronic sedimentation, such as that caused by large scale mining, logging, or in some causes by slash and burn agriculture, is a more serious problem than episodic sedimentation. Chronic sedimentation can kill fish eggs and larvae as well as adults without anyone noticing anything. Even greater impact than direct mortality is caused by sedimentation or siltation of feeding grounds and spawning grounds. The great majority of fish species living in the Mekong and other great tropical rivers and their tributaries are bottom feeders and bottom spawners. In streams that normally are very silty, many fish species are adapted to feeding on silty bottoms. Some of the species ingest quantities of silt from which they digest edible organisms. But even these species cannot survive if the ratio of sediment to food items becomes too great, and few if any of them deposit their eggs on silty bottoms. It is probably a safe guess that none of the Nam Theun fish species are adapted to silty rivers, and that most of them can only feed and reproduce in rivers with relatively clear waters.

Perhaps the most spectacular process of inland aquatic siltation is reservoir siltation. Reservoirs in country after country have had their useful capacity completely filled in after only a few years of operation. In addition to shortening the life of the hydroscheme, siltation is likely to have serious impacts on the aquatic ecology of the Nam Theun 2 reservoir.

Sedimentation is exceptionally low in the Nam Theun river system at the present time. But this is misleading, and entirely dependent on the integrity of the forested watershed. Although it cannot be documented, it is likely that sediment loads in the Nam Theun mainstream have increased markedly in recent years due to logging, road building, and other impacts. The mainstream was not nearly so clear as I had expected it would be during my dry season visits in 1995.

The Nam Phao, the Nam Theun tributary nearest Laksao, had a very heavy sediment load, which it has had for some time, and which now evidently persists throughout the year. This is apparently due to a combination of road building, logging, and other disturbances along the length of the Nam Phao. Just below the small power station on the upper Nam Phao (near Vietnam border) the Nam Phao is suddenly very clear and already very large. This tributary provides an indication of what will happen to other tributaries in the upper Nam Theun catchment when roads and logging are extended to them.

Forest fires will be more and more likely as logging continues, especially if the upper Nam Theun catchment is subjected to even mild desiccation (as predicted). A serious fire in the catchment of any of the 3-4 large tributaries flowing into the Nam Theun 2 reservoir would greatly increase the rate of sedimentation in the reservoir for years.

Another factor that will contribute to sedimentation in Nam Theun 2 reservoir is that of slumping in the reservoir itself. As the reservoir is dendritic, it has a very complex coastline, with numerous bays. Slumping may be caused mainly by storm-generated waves and by drastic changes in the reservoir water level of 8-10

m. Fire damage to lakeshore forest (a consequence of clearing the forest from the reservoir area) will aggravate the problem.

Sedimentation, incidentally, is the main reason why it will be impossible to decommission dams such as Nam Theun 2 and restore their rivers to anything remotely resembling their natural condition (pers. commun., Brian Glover, May, 1995). For further discussion of sedimentation, see sections above on reservoir rivers and on floods.

Khammouane limestone area

Between the elevated part of the Nam Theun basin constituting the Nakai Plateau and the Lao border with Thailand is a very special area known as the Khammouane limestones. It has been designated as a National Biodiversity Reserve by the Lao government, and its conservation is being funded by The World Bank. The area is extremely sensitive ecologically, and any infiltration of Nam Theun 2 reservoir waters in to the Khammouane limestone groundwater could have a major negative impact. Such infiltration could conceivably occur by 1) seepage from the reservoir on the Nakai Plateau via the escarpment; and by 2) seepage from the Nam Phit (the outflow of water diverted from the reservoir into the Xe Bang Fai. Neither possibility seems to have been seriously considered by NT2 PDG or its environmental consultants as of November 1995.

Problems with the forest

"We want to exploit all kinds of wood and shrubs in the [Nam Theun-Nakai] forest. They can be raw material for the chipboard factory."

– Sunthone Thammavongsay, 1995

The rising standard of living in China has been accompanied by a rising standard of dying, with more and more people wishing to be buried in coffins made of *Cunninghamia sinensis* and other beautiful but increasingly rare and expensive tree species. In Japan the wood of this species is used to restore or reconstruct traditional buildings in Kyoto and other historically important cities. It is the most expensive wood in Laos, possibly the last place with sufficient populations of this tree species to be viably self-perpetuating. It grows too slowly to be of interest to Jaako Pohry and other commercial companies promoting tree plantations in Southeast Asia.

When the Memorandum of Understanding for Nam Theun 2 was signed by the Lao government and the NT2 PDG, the government gave the BPKP (Borisat Phatana Khet Phudoi, literally "Company for Mountain Development") a Lao company directed by General Cheng Sayavong, permission to log the parts of the Nam Theun watershed that would be flooded by NT2 Reservoir. Supposedly the terms of the concession call for trees to be cut down only if they are below the 538 m elevation—the maximum height to be attained by the reservoir. The entire watershed above 538 m, including numerous future islands in the reservoir area, should not be touched by loggers.

It now appears that cutting has been done almost entirely above 600 m, to elevations of 1500 m and more. This was hotly disputed by David Iverach of Transfield Corporation and NT2 PDG in July 1995, but information subsequently provided by other sources confirms it. BPKP reportedly has already logged the largest pines (*Pinus merkusii*) from 25% of the upper Nam Theun area, and intends to log the rest of the area in as short a time as possible, i.e. within the next four years.

Specialists in the economics of forest exploitation based in Vientiane state that BPKP could double the price it is getting and increase its profits ten-fold. This would involve exploiting the timber over a longer time frame (at least 10-15 years), selling a larger part of the logs in first class condition, and providing buyers with a more reliable long term source.

Pinus merkusii (Pinaceae, Lao name mai pek), with a market value of US$250-300/metric ton, is the mainstay of the Nam Theun timber industry. Profitable stands of *Pinus merkusii* are all or nearly all above 600 m. These trees are removed by truck to Thailand or to the harbor of Vinh in Vietnam. BPKP has a fleet of aging Sikorsky helicopters to transport more valuable trees which can thus be removed from more remote areas and higher elevations than would be possible otherwise.

The most valuable tree in the upper Nam Theun catchment is the Chinese coffinwood cedar, *Cunninghamia sinensis* (Taxodiaceae, mai long leng). This species is relatively rare, and only occurs on

mountain ridges above 900 m, but its market value of US$2,000-3,000/metric ton assures that it is profitable even if individual trees have to be removed by helicopter. Another rare coffinwood tree, of only slightly less market value, is *Fokienia hodginsii* (Cupressaceae, mai lenh ley). It only grows at elevations in excess of 1000 m.

Mai long leng is being purchased from Laos mainly by Japanese, and reportedly being marketed as "hinoki pine" or "Pinus hinoki" (*The Nation*, 22 November 1996). It is being used mainly to repair or restore temples and other old wooden buildings made of the true Japanese hinoki, or hinoki cypress, *Chamaecyparis obtusa*, a species protected in Japan. The Japanese demand for mai long leng greatly exceeds the supply and may lead to its disappearance. The situation needs to be investigated. An appropriate solution might be for the Japanese government or public-spirited private organizations create hinoki plantations in Japan which would provide the wood for national monuments.

Even limited removal of trees from higher elevations of the upper Nam Theun watershed is likely to have impacts on Nam Theun aquatic ecology and particularly on the Nam Theun 2 reservoir. It involves construction of access roads, extensive damage to trees not removed, increase in poaching, increased risk of forest fires, and increased sediment load in rivers draining into the reservoir.

BPKP is cutting only those trees that are profitable. The only numerous trees being cut are large adult *Pinus merkusii* (mai pek), all or nearly all of which occur at elevations above 600 m. Relatively little cutting is being done in the inundation area of the Nam Theun 2 reservoir, which has a diverse, largely riparian forest with very few if any pines trees and not much other exploitable timber .

The Nakai Plateau forest below 538 m includes only 10% harvestable timber (according to a Lao based forester who has surveyed the area). The rest is dense bamboo and scrub. Some interprete this area as secondary forest highly degraded by humans. Its special characteristics may have more to do with the activities of elephants and other large mammals than of humans. In any case, it is prime habitat for some kinds of wildlife, with plenty of cover and room for them to avoid the local human population involved in normal levels of subsistence hunting. The upper Nam Theun tiger population may do its most important foraging in the area to be flooded by Nam Theun 2 reservoir.

In order to avoid a prolonged period of rotten water in Nam Theun 2 reservoir, the entire area to be flooded should be cleared of vegetation. BPKP should be encouraged to take out the exploitable timber, but this is supposed to be only 10% of the total. BPKP is not equipped or experienced for the job of removing the rest of the vegetation, and should not be expected or asked to do this job. In fact, there is no company in Laos or Thailand with the ability to do the job. NT2 PDG seems to expect BPKP or the Lao government to do the job, while the Lao government expects NT2 PDG to do it. Such large areas have virtually never been cleared before dams are built and their reservoirs filled (pers. commun., Owen Lammers, International Rivers Network, 13 February 1995). The approximately 60-80% of the area dominated by bamboo represents a particularly difficult problem: about half of bamboo biomass is typically underground, and will be very hard to remove.

Nearly all of the vegetation will have to be destroyed outright, using a combination of 1) defoliant chemicals to kill it, 2) teams of bull-dozers linked by huge ball and chain devices to knock it down and clear fire-breaks, 3) fire and 4) extensive labor-intensive mopping up operations. There will be very little time to manufacture and market furniture and other items from the forest that has to be destroyed, so it will have to be either be a complete economic write-off, or will be turned into chipboard, as envisaged by Sunthone Thammavongxay, BPKP project manager, cited by Malee Traisawasdichai in *The Nation*, 15 January 1996).

One "solution" to the problem of rotting "logs" in Nam Theun 2 reservoir likely to be proposed in future is underwater logging. Such a practice has been employed in Thailand since the beginning of large hydropower dams there, and usually leads to unauthorized and illegal logging of reservoir watersheds. In 1996 the Thai Ministry of Agriculture banned underwater logging throughout Thailand (*The Nation*, 24 August 1996). "Underwater logging" is still going on in Nam Ngum Reservoir, or was at least into 1995.

The Wildlife Conservation Society, employed by the NT2 PDG to design a wildlife conservation program for the upper Nam Theun area, is recommending a long term watershed protection and wildlife management program. This is based on at least two dubious assumptions: 1) that watershed protection will be agreeable and enforceable; and 2) that BPKP will be able and willing to re-direct its upper Nam Theun logging operations to other areas. Judging from past performance, BPKP will continue logging in the upper Nam Theun 2 area until exploitable timber is gone. The reservoir will facilitate logging by providing greatly improved access to remote areas as well as much cheaper and more efficient transportation of logs and plenty of water in which to store pine logs while they are awaiting transporation.

The very rapid uncontrolled logging operations in the Nam Theun catchment will of course have pronounced negative impacts on the ecosystem. Apart from sedimentation, perhaps the worst impact could be desiccation—reduced rain fall, less stream flow and lowered water tables—with enhanced probability of major forest fires. The direct and indirect impacts of logging—including habitat destruction and greatly increased hunting pressure—will have a pronounced negative impact on wildlife.

Bans on logging have been in effect in Cambodia, Laos and Thailand for years. This has not stopped the Cambodian government from selling virtually all of its forests to Malaysian and Thai logging companies *(Bangkok Post*, 3 December 1995; *The Nation*, 5 February 1996). The ban on logging in Thailand, passed in 1991, has caused the greatest boom in the history of Thai logging, with many companies moving their entire operations into Burma and Cambodia. As the saying goes, when the going gets tough, the tough get going. Thai loggers are tough. They have repeatedly engaged in illegal logging operations and other risky business for which they sometimes pay with their lives.

Biodiversity

Tropical forests and rivers generally contain the richest continental biodiversity. Organizations involved with Nam Theun 2 and other hydropower projects in Laos have tended to equate biodiversity with birds and mammals—especially the big, fierce and cuddly ones. Nam Theun biodiversity, of course, includes much more, notably plants and insects as well as lower vertebrates.

The Nakai Plateau is often described in pro NT2 literature as biologically degraded and poor in biodiversity. This is disputable on both counts. That the Nakai Plateau is biologically distinctive and important is certain. It includes large, slowly meandering Nam theun River mainstream and distinctive wetlands which are certainly not degraded. The plateau may be subject to fire, hunting, logging, and other human activities that may or may not have had much impact upon its overall biodiversity. It may well be influenced by man more than upland areas in the basin, but still be extremely rich.

Mammals and birds are important, but no more so than plants, insects, and fishes. Conservation organizations involved with Nam Theun 2 including the Wildlife Conservation Society and IUCN, while not entirely ignoring other organisms, have been overly concerned with higher vertebrates and especially large mammals. Birds, small mammals, reptiles, and amphibians have not been seriously surveyed. Plants and insects have hardly been investigated. Even the scientific identification of such “well known” Nam Theun plant species as *Pinus merkusii* and *Cunnunghamia sinensis* may have to be revised.

Drought

The entire Nam Theun catchment and especially the upper Nam Theun watershed is very rainy, perhaps moreso than anywhere else in Laos. This is perhaps due to the peculiar circumstance that it receives rains from May to September from the SW monsoon, and also rains from September to December from the NW monsoon which otherwise fall mainly in Vietnam. Proponents of Nam Theun 2 and other Nam Theun hydropower projects have totally discounted the possibility of diminished rainfall and drought. But the rainier a tropical forest is, the more subject to drought it will be if it is deforested. Thus the Nam Theun catchment may be effected not only by logging in Laos, but also in Vinh province of Vietnam. Vinh is the poorest province in Vietnam, with perhaps the highest rate of illegal or uncontrolled logging.

Any substantial reduction of rainfall in the Nam theun area will have negative impacts on the biota and on the long-term ability of Nam Theun hydropower projects to generate electricity.

Macroenvironmental impacts

"The Mekong is a virgin river. It is a large river but each year it flows uselessly into the sea. This is a loss, that is why we should harness this river."

– Dr. Prathes Sutabutr, December, 1995

For present purposes, macroenvironmental effects may be defined as those having a regional or global significance. The impact of an individual project may be relatively insignificant globally, but thousands or millions of such projects throughout the world may have macroenvironmental implications. Large reservoirs have such implications and may already be having major macroenvironmental consequences.

Potential macroenvironmental impacts of large hydropower projects are numerous, with probable or possible subtle effects of long duration that may be difficult to detect or separate from impacts due to other causes, but that are none the less highly significant. It is partly because of such large scale negative impacts that many opponents of dams suspect that the costs of all or almost all dams will outweigh the benefits. Only a few of the macroenvironmental impacts will be indicated here.

A classic attitude of hydroengineers is that water flowing freely to the sea is wasted. I had imagined that such ignorant beliefs—fashionable among Bureau of Land Reclamation and U. S. Army Corps of Engineers personnel in the USA before World War II—were as extinct as dinosaurs in this environmentally enlightened New Age. Thus it is interesting to see in print the current views of a high ranking Thai official (quoted by Malee Traisawasdichai in *The Nation*, 29 December 1995). Certainly the negative impacts of overfishing cannot be dismissed. But when fishing pressures diminish and marine fish stocks fail to come back, one has to ask if other factors might not also be involved—such as the world-wide damming of rivers and the resulting qualitative changes of their important contribution to the health of the World's oceans.

Thai backers of the proposed Stung Mnam dam in southwestern Cambodia's Goh Kong province reportedly have used the same argument—that water flowing to the sea is wasted—in efforts to convince their Cambodian counterparts that the Stung Mnam should be dammed (pers. commun., Cambodian government official, January 1996).

All dams resulting in large impoundments of water inevitably result in some loss of water to the atmosphere. The loss is greater in tropical than in temperate countries, and is greatest in dams with heavy infestations of evapotranspiring aquatic plant pests, such as water hyacinth. Proponents of dams consistently overestimate the amount of water available for hydropower projects, and consistently ignore or underestimate the amount of water loss directly or indirectly caused by such projects. It seems particularly difficult for them to comprehend that watersheds that have lost much of their forest may become progressively drier, with diasastrous consequences for their favorite hydropower projects.

That we entered a period of global warming some time ago is now generally accepted. There may possibly be some beneficial effects, mostly localized. Effects harmful to humanity, to biodiversity in general and to agriculture in particular, probably will far outweigh any benefits.

There is mounting evidence that large reservoirs, especially in tropical countries, contribute substantially to generation of greenhouse gasses thought to be primarily responsible for global warming (e.g., FEARNSIDE, 1995). For further discussion of global warming, see section above on reservoir rivers and floods.

A very faulty project

Faults and fractures dominant the earth's surface layers, in Laos as elsewhere. Crisscrossing these layers in three dimensions, they control the flow of groundwater and the behavior of earthquakes. A hydrogeologist familiar with faults and fractures examined a geological map of the Nam Theun–Nakai Plateau area and concluded that the entire area was probably defined by a complex system of faults and fractures. Further investigation may very well confirm his hypothesis.

The proposed Nam Theun 2 dam site is right on top of, or at most no more than few kilometers from, the Nam Nhuong (=Nam Gnouang) fault (Fig. 4). This NW-SE trending fault, some 430 km long, closely parallels the Nam Theun valley for 150 km, including the entire 85 km to be inundated by NT2 reservoir (COATS & ANNELLS, 1990). The Geng Kuk rapids or waterfalls, about 3 m high, immediately above the dam site, presumably are on the fault line. Between the dam site and the mouth of the Nam Gnouang some 48 km downstream, the mainstream of the Nam Theun apparently lies on or is defined by the fault.

It is not known whether the Nam Theun-Nakai area is seismically active at the present time. Most people living there arrived after 1975, and they reportedly have not experienced any earthquakes in the area. But large reservoirs can stimulate seismic activity, even in places that have been long dormant.

Presuming that NT2 dam is built and the reservoir fills to the 538 m level, the weight of the water in the 450 km^2 reservoir could be enough in itself to cause an earthquake. This may occur within one year of filling or some years later. The annual draw down of the reservoir during the dry season to the 528 m level may release enough pressure to cause an earthquake. Aqueous infiltration of the seismic terrain underlying virtually the entire reservoir could be decisive. A substantial Cretaceous deposit of rock salt of unknown reserve (ESCAP, 1990) sits astride the fault a few km above the dam site. Its solution could provoke an

earthquake. Any earthquake with a force greater than 5 on the Richter scale could be sufficient to bust the Nam Theun 2 dam unless it is especially built to withstand greater shocks.

Groundwater

No EIA of a large hydropower project can be considered complete without an exhaustive study of the impacts on groundwater, both above and below the proposed dam site. Here the topic can only be discussed in the most general terms.

Standard accounts of rivers state that their flow is due to rainfall. In the case of the Mekong, it is generally considered that flow is due to two main causes, rainfall and snowmelt, which peak at different times, producing a bimodal flow in the mainstream. Groundwater is not mentioned as a significant contributor to river flow. But groundwater probably always contributes to flow, especially during the dry season, when nearly all of the flow is due to groundwater contributions. In continental areas with megapotamic rivers such as the Mekong, it is likely that most groundwater flows to the sea through the largest river channels such as the Mekong mainstream.

It may be supposed that groundwater is generally maintained or restored by inputs from rainfall. The relative importance of riverine flooding, however, may be greater at certain times or places than rainfall.

Groundwater relationships in tropical areas with large river systems such as the Mekong are not well known. The Mekong Commission should be concerned with this, but it is preoccupied with fund raising and promoting hydropower projects.

Nam Theun 2's potential impacts upon groundwater probably have not been addressed. Depending upon geological circumstances, groundwater levels above the dam will be abnormally high, and those below it abnormally low. Such conditions can have substantial negative impacts upon terrestrial as well as aquatic ecology.

Human health problems and Nam Theun hydropower projects

Creation of a large reservoir and several reservoir rivers with poor water quality, in wilderness and semi-wilderness areas with large populations of wild species of rodents, ungulates, and primates has important implications for human health. Dam proponents don't like to face such issues, but health authorities cannot afford to ignore them. They should not be left out of EIA for hydropower projects in Laos.

Foremost among diseases to fear from Nam Theun hydroprojects are those born by mosquitoes, especially those with mammalian reservoir hosts. The most important expected ones are malaria and dengue fever, both recently resurgent in southeast Asia and in Laos. Unexpected and previously unknown viral diseases are a definite possibility. Most of these will doubtless be relatively benign, and will be experienced only as fevers or aches, and misidentified as malaria or dengue. Very frightening viral diseases like those associated with reservoirs and wild animals in Nigeria could easily occur in Laos. It would be particularly sad if Laotian and international health authorities find it necessary to kill off large numbers of wild animals in order to protect humans from epidemics arising from projects like Nam Theun 2.

Bilharzia due to *Schistosoma mekongensis* is endemic to the lower Mekong basin and southern Laos in particular. Although the incidence is low or even trivial compared to bilharzia in other areas due to other species of *Schistosoma*, the disease apparently can be just as severe. There has never been a major recorded outbreak of *S. mekongensis*. It is generally assumed that this particular Southeast Asian *Schistoma* species is transmitted only by two or three species of small pulmoinate snails of the genus *Neotricula.* It will be fortunate indeed if this turns out to be true.

Other water-born and water-related diseases likely to be increased by Nam Theun hydropower projects include but are certainly not limited to opisthorchiasis, paragonimiasis, and several kinds of filiariasis. Pulmonary paragonimiasis may or may not have been recorded in Laos, but has been reported in recently arrived Laotian immigrants living in the San Joaquin Valley in California who presumably contracted the disease in Laos (YEE and HSU, 1992). The intermediate hosts are crabs and shrimps, commonly consumed raw or semi-cooked in Laos.

The NT2 reservoir itself, with its vast extent and potential for anaerobic conditions, and unnatural hydrologic regime, could lead to population explosions of various kinds of intermediate disease hosts

including but not limited to several of the most important dipteran and molluscan vectors. The heavily impacted outflow of Nam Theun 2 reservoir into the Nam Theun mainstream, the entire Nam Phit outflow channel into the Xe Bang Fai, and the Xe Bang Fai mainstream just below the diversion point are also likely focal points for disease vectors, which could, however, proliferate almost anywhere within the impacted system.

DISCUSSION

Which comes first: politics or the environment?

"Seek ye first the political kingdom."

_Kwame Nkrumah

No political system can survive continued environmental deterioration. The slogan quoted above, by a great African socialist and leader of the movement that led to the Independence of Ghana in 1957, could well be that of the Lao Peoples Democratic Party. But issues concerning the people and government can never be separated from the environment. All kinds of political regimes need to recognize the primacy of the environment in everything that concerns humans. They should seek the political kingdom but never lose sight of the environmental kingdom.

Nkrumah also brought his people the Volta Dam in 1965, at the time Africa's largest hydropower installation. He promised (as he was advised) that it would bring prosperity and abundant fisheries. He vowed that none of the 80,000 people that had to be resettled would be worse off. The resettlement projects did not go as well as planned, and most of the oustees scattered, leaving behind the resettlement villages with no compensation for their losses and no educational or financial subsidy to start out new someplace else. After some 30 some years the project is not producing much in the way of fisheries and its electricity production is erratic, due to drought and sedimentation. It has certainly not brought prosperity to Ghana.

From 1961 to 1964, including four months in 1964 as a consultant for the Volta Basin Research Project of Ghana's Volta River Authority, I surveyed the fishes and fisheries of the Volta River. There were fisheries for long-armed prawn (*Macrobrachium*) at Kpong, just below the future dam site, and for clams (*Egeria radiata*) at Bator and other sites further downstream, as well as fisheries involving over 100 species of fin-fishes in the upper, middle and lower Volta including some highly productive freshwater lagoons near the sea. All of these fisheries are now gone or greatly diminished due to negative impacts from the Volta Dam. Ghana's nearshore sea fisheries also have declined, but this decline is more complex. It started before the dam was built. Whether the dam also contributed to the continued sea fisheries decline is a moot point that may never be resolved, but is probable.

Unlike Laos, Ghana does not have numerous potential hydropower sites. The Volta Dam represents its only site with major hydropower potential.

Whither Laos?

The rich and highly distinctive biota of Indo-China is threatened by extremely high population growth and unprecedented economic development based largely on unsustainable exploitation of natural resources. Laos has the least population and by far the lowest population density of any country in Indo-China. It also has the highest rainfall, densest fluvial network, almost certainly the richest biota, and by far the best opportunity to conserve a substantial part of its biota.

Laos has the unusual but not unique position of extraordinary natural resources, low population, and relatively stable politics. Sustainable development of only a small portion of the natural resources should finance the government and its public projects for many years. Development much more rapid than this is likely to harm more than to benefit the country. If a large proportion of the infrastructural, hydropower, timber, and mining projects now under consideration is pursued, it is likely to result in environmental dmage and human suffering greatly exceeding that inflicted by the Secret War of 1964-73. Such rapid development is being urged upon the Lao government by a large number of foreign companies and foreign experts, each promoting their own relatively narrow interests. Individually the projects being promoted may be moderately beneficial, but collectively they can only be regarded as dangerously destructive.

The dire environmental, social, and political consequences of too rapid or excessive "development" of countries too rich in natural resources for their own good can be seen in Nigeria, Sierra Leone, Papua New Guinea and Indonesia. Laos and its situation is different in almost ever way from these countries, but the consequences of too hasty and unwise destruction of natural resources and the resulting environmental degradation could be just as menacing and unpleasant.

In a just world, possibly the one we are living in, the Congress of the United States of America might review the environmental and other negative impacts resulting from the Secret War conducted by U.S. military forces in Laos in 1964-73 and conclude that the U.S. should pay Laos reparations of U.S.$20 billion. The Lao government would then have to decide what to do with the money. It might decide to spend 1-2 billion dollars for aid to war victims and their families, and for clearing away unexploded landmines and other ordinance. Another 1-2 billion might be invested to defray long term expenses of running the government, and another for a university and a university hospital. There would still be billions of dollars for other purposes, including development projects.

The Lao government might then choose among the 50 or so sites for hydropower that have been identified in Laos and not yet developed, which it could then pay for and have 100% ownership of from the outset.

How would the government go about chosing a hydropower project? Would it request advocates of all 50 projects to each present their best case and then try to chose from them? Or would it request a third party such as the World Bank to form a team of disinterested engineering and other consulting experts including environmentalists to evaluate and compare the projects? If the decision to invest one or two billion dollars on a major development project was entirely up to the Lao government, and it had all the environmental and other information needed to make a wise decision, would it chose to develop hydropower at all?

The Nam Theun 2 project is described as "build, own, operate, transfer", or BOOT. That means it will be built, owned and operated by the NT2 PDG for 25 years. Then ownership will be transferred to the Lao government. At that point the Lao government might have the capacity to run the project itself, or would have to negotiate a new contract with someone to operate it. Judging from the environmental impact assessment and other long term problems associated with the project, a more appropriate acronym for Nam Theun 2 would be BOATL: "build and own an asset, transfer a liability." This is presumably not a hydropower project the Lao government would choose if it was well informed.

The suggested US$20 billion compensation or restitution for the Secret War is based on the estimated more than $10 billion ($7 billion on ordinance alone) expended to conduct the war (Shoemaker, 1994), adjusted for inflation. Reparations equal to the amount spent on bombs that literally blow people to bits seems the least the U.S. should provide. About 100 people, mostly women and children, are still being killed every year in just a single province in Laos by American landmines and other explosive devices.

When a country such as Laos damages its rivers and its forests it is damaging itself. The current Lao leaders (and the experts who are advising them) need to reconsider the wisdom of their crash development program. Nam Theun watershed and Nakai Plateau are not “undeveloped.” Rather, they are tropical environments with a rich, unique, and largely unstudied biota, a natural resource of immeasurable value that could enrich and sustain human life and contribute to the Lao economy in perpetuity.

Norway: exporting the national hydropower industry

“Conditions for hydropower development in Laos closely resemble those in Norway.”

“The Norwegian hydropower sector is like a bunch of hungry wolves desperately searching for prey.”

Norwegian engineering companies and consultants have been working hard to influence the Lao government to built hydropower projects, and to get some of the contracts for themselves. They are giving the Lao government poor advice on environmental impacts, possibly because they lack tropical experience. Norwegians built the 50 Kilowatt Xe Set hydroproject in southern Laos in 1987, apparently without any environmental impact assessment. They are now building the Theun–Hinboun project, and are working behind the scenes to support Nam Theun 2 in which they are not now directly involved but hope to get contracts from down the line.

The "wolves" statement is by a former Director of Kvaerner Engineering Co. one of the world's largest produces of turbines, while the comparison between Norway and Laos is a favorite of engineers and others working for NORCONSULT.

Norway has some 700 hydropower installations. Most were built in frigid and treeless mountain areas where no people live, by the simple expedient of damming glacial lakes. The native fauna in these recently deglaciated lakes and in the rivers associated with them is impoverished, with few or no fish species. The fishes present, usually salmonids, support only recreational fisheries. No one's livelihood or food security is dependent upon them. The heath soils in these granitic basins release virtually no sediment. Thus Norwegian hydropower installations generally have very long life expectancies.

The entire freshwater fish fauna of Norway comprises some 46 species. The greatest number in any one river, the Glomma, is 27. The great majority of rivers in Norway with hydropower installations probably have only 0-3 fish species. In contrast, the Nam Theun has at least 85 species, other Mekong tributaries in Laos have 200 or more species, and the entire Mekong basin well over 1000 species.

Cumulative environmental impacts

The worldwide threat to freshwater fish species because of cumulative environmental impacts (CEI) with synergistic negative effects is now widely recognized by ichthyologists and fisheries scientists (BEVERTON, 1992; MOYLE & LEIDY, 1992; ROBERTS, 1993; BRUTON, 1995). Particularly harmful combinations of impacts include deforestation, dams, pollution, and introduced species.

An example of an important Mekong tributary that has been subjected to severe CEI is Menam Mun in Thailand (ROBERTS, 1993). Industrial waste disposal, mostly from industries based on hydropower, resulted in chronic and episodic impacts by many different toxic chemicals. The already synergized impacts from pollution were further synergized by non-chemical impacts, including introduction of an exceptional number of exotic species in an attempt to compensate for loss of native species (ROBERTS, 1993).

Imminent impacts on the Nam Theun include (but are not limited to) deforestation, sedimentation, and construction of several large hydropower dams. Together, these impacts will cause blockage of migratory and other essential fish movements; loss of breeding grounds and habitats; isolation of tributary streams; loss of food resources; poor water quality; reduction of natural hydropower; diversion of water out of the basin; and interference with natural flow regimes. A number of fish species that are ecological keystone species in the Nam Theun ecosystem and/or endemic to the Nam Theun basin may disappear. Large-scale disruption or destruction of the terrestrial as well as aquatic ecosystem is to be expected.

In Table 1, aquatic environmental impacts of the various Nam Theun hydropower projects are indicated on a scale of 1-10. A rating of 10 would involve substantial destruction of the entire Nam Theun ecosystem. None of the projects have been rated this high. But Nam Theun 2 has been given a rating of 9, mainly based on the negative impacts it is expected to have on the upper Nam Theun catchment. If Nam Theun 2 were expected to have no impact whatever on the Xe Bang Fai, it would still have a rating of 8.5 or 9.

The expected negative impacts on the Nam Theun ecosystem if Theun-Hinboun and Nam Theun 2 both are constructed would be rated at 10. This is irrespective of the considerable negative impacts of the Theun-Hinboun project on the Nam Hinboun, and of Nam Theun 2 on the Xe Bang Fai.

Nam Theun 2 in combination with Theun-Hinboun will effectively destroy the Nam Theun mainstream and the Nam Theun ecosystem. The entire mainstream will either be permanently flooded or greatly reduced. Fish spawning grounds and habitats in the mainstream will be eliminated or severely impacted. Ecologically keystone fish species, such as *Hemiculturella macrolepis* and *Poropuntius* cf. *deauratus* will entirely or nearly disappear from the mainstream. Fish and other organisms will no longer be able to move upstream or downstream past the mainstream dams. Fishes in tributaries will be effectively isolated from the mainstream and from other tributaries, resulting in a series of isolated fish populations with no possibility of migration or recruitment from one to another. The downstream flow of nutrients, upon which food chains sustaining the mainstream fish populations is dependent, will be totally arrested by the mainstream dams. The loss of naturally occurring hydropower and total disruption of natural flow regimes, to be replaced by seasonally irregular flood regimes based on demand for electricity, with severe ramping, will reinforce all of the negative impacts.

Cumulative environmental impacts of Nam Theun 2 and Theun-Hinboun combined would irreversibly damage the Nam Theun aquatic ecosystem, leading to extinction of Nam Theun ecological keystone fish species. Impacts on terrestrial components of the ecosystem, while perhaps not so severe, will be substantial.

The myth of mitigation

Proponents of hydropower and other large development projects, including the World Bank, Asian Development Bank, UNDP, and NT2 PDG propose that mitigation measures can make up for much of the negative environmental impact. Concerning fish biodiversity and fisheries, at least, most mitigation measures that have been proposed and occasionally executed have had relatively little beneficial effect.

One of the standard mitigation measures for the impact of dams on migrating fish and fisheries resources is a fish ladder. Most fish ladders are poorly designed by people who evidently know very little about tropical freshwater fishes and their behavior. It would be difficult if not impossible to design a fish ladder that could be used by many of the highly diverse kinds of fish in tropical rivers. But this is not really the problem. Fisheries biologists, in the temperate as well as in tropical areas, are now generally agreed that fish ladders have not been effective. Dams create a downstream habitat that is very poor for fish, and an utterly different kind of habitat upstream that is also very poor for fish. What good is a fish ladder that permits fish to move from one place where they barely survive to an entirely different but equally difficult place? The result, as Pak Mun Dam is in the process of demonstrating, is that each year there are fewer and fewer individuals of fewer and fewer species using the ladder (see box on Pak Mun fish ladder).

For hydropower projects involving diversion of all or most of the water out of one basin into another, an important mitigation measure (one that is virtually always acknowledged by engineers) is that of "minimum permissible discharge", i.e., what is the least amount of water that must be left to flow in the old stream channel below the dam to sustain fish populations and fisheries. The engineers usually conceive of this in terms of some large fraction or small multiple of the dry season flow. Almost every engineer that I have discussed this problem with is firmly convinced that, since there is obviously enough water in the river (according to them) for fish to survive during the dry season, that the same amount of water ought to be enough for the fish to survive throughout the year. What they don't realize is that fish suffer starvation, disease, higher predation rates, and very heavy mortality during the dry season, and that the wet season with its abundance of food and hiding places is essential for reproduction and population recovery.

The fish biologist, even one with considerable field experience of tropical rivers, is hard pressed as to how to advise on the issue of minimum permissable discharge. Certainly the average dry season flow will not permit anything remotely like normal fish populations. A more rational proposal would be to establish a flow regime that mimics that of the natural river, with higher flows during the wet season. But the fisheries biologist familiar with the history of hydro projects in tropical countries realizes that whatever minimum flow or semi-natural flow regime is settled upon, it will not be observed or enforced. The moment there is insufficient water to maintain electric output, the minimum flow requirement will be ignored. The only way for environmentally beneficial flow regimes to be maintained is to have 1) constant monitoring; and 2) adequate enforcement. Perhaps the only effective enforcement measure would be a device that automatically shut off electric generation whenever the required outflow was not being provided.

PROBLEMS WITH THAILAND'S PAK MUN DAM FISH LADDER

1. Ladder is too steep. Original design plans called for a much loigger, more gently sloping ladder that would have cost some 10 million baht (US$400,000). The version installed, for budgetary reasons cost only 2 million baht (US$80,000).
2. Baffles on steps are too close and too wide, creating a difficult pathway with turbulence and unfavorable currents.
3. No flowing water in ladder for six months of the year.
4. Strong outflow from power house turbine attracts fish away from ladder to their deaths.
5. Mouth of ladder is too narrow, so fish don't find it.
6. Dam has only a single ladder on one side of the reservoir outflow, the entrance to which is difficult to find even for fish moving up that side.
7. Catfishes (which generally migrate at night) use ladder very little or not at all. The very important family Pangasiidae, all species of which are highly migratory, do not use the ladder at all. Mun River formerly had 10 pangasiid species contributing to wildcatprue fisheries.
8. Clupeidae or herrings do not use ladder at all, apparently because they are too delicate or too small.
9. Sexually mature fish cannot use ladder. The most important link in the life history is also the weakest one when it comes to surmounting fish ladders. Gravid females, with poor hydrodynamic design, ovaries increasing body weight by 30%, and limited energy resources, cannot make it up the ladder.
10. Fishes moving upstream or their offspring must eventually move downstream again. They are often killed or injured if they pass through the turbines, and sluice gates are open only part of the time. They cannot use the ladder to move downstream.
11. Rapids below and above the dam, providing important resting, feeding, and spawning sites, have been destroyed.

Regarding mitigation measures for Nam Theun 2, diverted water should be drawn off at the surface of the reservoir, rather than at a depth of 10 m, and constantly monitored for water quality. Then if water quality suddenly deteriorates, the diversion into the Xe Bang Fai could be cut off. But hydroengineers

strenuously resist any suggestion that electrical generating capacity should be subject to regulation for environmental reasons.

So far as fisheries are concerned, mitigation measures proposed by dam proponents and their favored environmental assessment consultants are unlikely to be effective, or if effective, are unlikely to be honored. More specificially regarding Nam Theun 2 project, it is doubtful that any of the proposed measures to mitigate impacts on aquatic biology will be more than partially successful. As to oxygenating the reservoir water at the entry to the diversion by means of penstock baffles, in November 1995 Brian MacIllree insisted that they were expensive and would not be effective. It is extremely doubtful that the area to be flooded by the reservoir will be cleared of bamboo and vegetation before filling. No mitigation measures have been identified for 1) blockage of fish migration by Nam Theun 2 dam; 2) fragmentation of upper Nam Theun tributary fish populations by the reservoir; or 3) coldwater input from the reservoir into the Xe Bang Fai, presently regarded by me as the most serious impact from Nam Theun 2 on the Xe Bang Fai. Artificial rapids or baffles installed in the 35 km stretch of Nam Phit might mitigate somewhat or entirely the problem of deoxygenated water from the reservoir flowing into Xe Bang Fai, but evaporative cooling due to the rapids or baffles could aggravate the problem of cold water.

Productive reservoir fisheries: another myth

Many dam proponents claim that large reservoirs resulting from hydropower projects will "create" important new fisheries that will more than make up for the loss of riverine fisheries negatively impacted by the projects. This is a myth based mainly on two misconceptions: 1) that the riverine fisheries negatively impacted by the reservoir are only those that were present in the river reach actually flooded by the reservoir; and 2) that the reservoir fisheries will be long term, highly productive, and sustainable. These false ideas have had many proponents, notably the Indian fisheries biologist V. Pantulu, Senior Fisheries Advisor to the Mekong Secretariat from 1960 to 1985. His ideas on productive reservoir fisheries (based mainly on short-term observations of newly created reservoirs in India), although dated, are still influential in some circles.

What Pantulu and others repeatedly observed is the one-time biological response to the supernormal riverine event that occurs only when a reservoir is filled for the first time. The riverine fishes "captured" by the reservoir respond to this event as if it were an unusually large and prolonged wet season flood. Thus they reproduce explosively and feed on the abundance provided by the flooded area. Growth is rapid, fish biodiversity is as high as under normal riverine conditions, and fish populations rapidly outstrip their natural and human predators. But this riverine phase of a reservoir seldom lasts more than 10 years, and usually is much shorter, about 5 years.

As the food supply generated by the enormous flooded area inevitably declines, the fish and fisheries decline with it. By this time reservoir fisheries biologists are busily exhorting the fisheries merits of some other newly formed reservoir, and blaming the declining fisheries of the old reservoir on poor management (i.e. overfishing). But the truth of the matter is, the lacustrine (or lake) phase of tropical reservoirs is poor for tropical riverine fishes. Many species cannot feed or reproduce in reservoir habitats, with the result that fish populations and biodiversity decline markedly in virtually all older reservoirs that start out with productive fisheries.

In virtually all old established reservoirs originating in large tropical rivers the initially high fish biodiversity has declined precipitously and is typically only 20-40% of that of the wild river reach that has been replaced. The only way to find anything like the naturally occurring riverine fish biodiversity in these old reservoirs is to survey fish in the river mouths and immediate vicinity of rivers where they flow into the reservoir, and where riverine conditions still prevail–a ploy utilized by reservoir fisheries experts who need to prove that fish biodiversity in their favorite reservoirs has not declined.

Many reservoirs resulting from hydropower dams don't have productive fisheries even in the riverine phase of their existence. This is likely to be the case for the Nam Theun 2 reservoir. Before looking at fisheries potential of Nam Theun 2 and other reservoirs in the Nam Theun basin, it is worth taking a brief look at the history of fisheries in Laos's Nam Ngum Reservoir.

Fisheries of Nam Ngum Reservoir and Nam Ngum River

Laos's only large hydropower project until now, Nam Ngum Dam was completed in 1971. The reservoir was filled in two major episodes separated by two or three years. For about eight years (some say ten) the reservoir was anoxic, due to rotting of the extensive forest it had drowned. Around 1979 conditions improved

rather suddenly: the reservoir became oxygenated, and this was immediately followed by an explosion of populations of many fish species, notably the large predatory catfishes *Mystus microphthalmus, Wallago leerii* and *Wallago attu***,** predatory carp *Hampala macrolepidota*, and herbivorous buck-toothed giant goramy, *Osphronemus exodon*. This explosion led to a rapidly expanding fisheries which peaked around 1985 and remained high for about five years. The annual catch probably reached at least 1,400 tons and may have been as much as 5,000 tons (pers. commun., Lao officials, 1995-1996).

Around 1990 Nam Ngum reservoir fisheries began a precipitous decline, and are now down to a few hundreds of tons, or probably about 5-10% of the peak catches of 1985-1990. Overfishing and lack of regulation have been blamed for the decline of Nam Ngum reservoir fisheries, but it was almost certainly due to predictable large scale ecological changes typical of reservoirs with declining fisheries throughout the tropics.

Reservoir fisheries during the explosive riverine phase should be treated as windfalls, one-time benefits to be exploited as much as possible while they last. Care should be taken not to overcapitalize or build up too much infrastructure based on such fisheries, for they are truly temporary, seldom lasting more than 5-10 years.

Discharge of anoxic and oherwise toxic water from Nam Ngum reservoir from 1971 until 1979 or later presumably caused large scale mortality and substantial reduction of the fish in the Nam Ngum downstream from the dam. Laotian fisheries officers say that fish disappeared from the Nam Ngum below the dam soon after 1971, and that the fish populations have not recovered, or recovered only slightly, since water quality improved after 1979. If Nam Ngum dam had not been built, the Nam Ngum below the dam presumably would support an intensive subsistence fisheries today.

While deoxyenated water disappeared from the upper layer or epilimnion of Nam Ngum Reservoir about 15 years ago, the hypolimnion or layer layer (and thus the outflow into Nam Ngum below the dam) may still be deoxygenated.

Fisheries potential of Nam Theun hydropower reservoirs

Creation of new fisheries in reservoirs has been cited recently by the World Bank and others as a potential large scale secondary benefit arising from Nam Theun hydro projects. Such thinking needs debunking.

As indicated above, the general prognosis for fisheries arising from hydropower projects on tropical rivers is not very good. At best, 5 to 10 years of high fisheries productivity can be expected before a sharp decline from which there is no recovery. But not all hydropower reservoirs in tropical areas get even that. What is the prospect for a highly productive reservoir fishery in the Nam Theun 2 or other reservoirs resulting from hydropower projects in the Nam Theun watershed?

The prospect is not very good. Nam Theun fish species likely to become established in reservoirs are indicated in Table 2. Of the total of 85 fish species known from the Nam Theun basin, only 27 are likely to become established in a reservoir. Of these 27, no fewer than 14 are small or very small species of no direct fisheries significance and probably not even important as forage species for larger fishes that are significant. Six species have been identified as likely to be of minor fisheries significance in reservoirs. These species may be important in subsistence fisheries, but will hardly support mechanized or large scale fisheries necessary to exploit reservoir fisheries effectively. And then there are eight species likely to be of substantial importance in Nam Theun Reservoir fisheries. It is worth taking a closer look at them.

Only three of the eight species feed low on the food chain: the herbivorous carps *Cirrhinus molitorella* and *Puntioplites proctozysron* and the introduced African cichlid fish *Tilapia nilotica.* The other five—a carp, two catfishes, and two snakeheads—are predators. It is unlikely that any of these species will be able to utilize the most abundant offshore midwater and deepwater benthic food resources produced by the reservoir during its lacustrine phase.

Perhaps the most significant unanswered question about the potential of native Nam Theun fishes to contribute to reservoir fisheries is whether the ecological keystone species *Hemiculturella macrolepis* can become established in reservoirs. If it does, then the reservoir fisheries might be more productive.

Some biologists might think the obvious solution is to introduce their favorite exotic fish species into Nam Theun reservoirs. But they know very little about biology of tropical riverine fishes, and the introductions they propose might do more harm than good. Introductions should only be considered if they involve native Mekong species, and only after the reservoir is past the initial riverine phase of fisheries development and well into the definitive lacustrine phase. Premature introductions (i.e., during the riverine phase) are unlikely to

add anything to the riverine phase of the reservoir fisheries based on native species. Introductions of exotic species could easily have basin-wide negative impacts.

Macroeconomic blunders

From 30 October-10 November 1995 a World Bank team visited Vientiane to review the status of the Nam Theun 2 hydropower Project with NT2 PDG, Lao government officials, NGOs, and others. One result of this visit was that the World Bank agreed to do a "Macroeconomic study" of the project. The results of this and other studies supposedly will be available around March 1996, and will provide part of the basis for a final evaluation that may lead to World Bank participation in the project. The results of the macroeconomic study are also of concern to environmentalists.

Several economic issues should be explored carefully and the results submitted to public scrutiny before the Bank joins the NT2 PDG or the Lao government gives its final approval for construction of Nam Theun 2. One question is whether Laos will be getting a fair price for the electricity from Nam Theun 2 and its other hydro projects. If the price is lower than it should be, then Laos will have to have more and bigger hydro projects to get the same amount of revenue, with environmental and social costs correspondingly greater than necessary.

There is a widespread feeling in Laos and in Thailand (reflected in several articles in Thailand's English-language press) that EGAT (Thailand's Electricity Generating Authority) is giving Laos the shaft in pricing negotiations (see Box). The most explicit exposition of this Thai viewpoint of EGAT's unfair pricing policies and dirty tricks applied to their Lao hydroelectricity purchases is provided by Malee Traisawasdichai (*The Nation*, 20 Sept. 1996, p. A10). Thailand represents the only immediate consumer for all or nearly all of the electricity produced by Lao hydroprojects, and EGAT the sole buyer representing Thailand. Two incidents may indicate why Laos may not be getting a fair price.

Houay Ho (on the Bolaven Plateau) was the first or one of the first recent Lao hydropower projects (after Nam Ngum, of course) for which the price of electricity was negotiated. Rumor has it that negotiations were handled personally on behalf of Laos by Prime Minister Khamtay Siphandone. Each time he tried to get a better price for Houay Ho electricity, the high cost of the Houay Ho power line was used as an argument against him. The Prime Minister finally agreed on the rather low price of 4.22 cents/Kwh. Later the Lao government tried to renegotiate the price of Houay Ho electricity upwards to 4.35 cents *(The Nation*, 24 October 1995). (It is precisely to prevent this sort of "renegotiating" by the GOL that NT2 PDG wants the World Bank to join them).

To this observer, admittedly with only newspaper accounts and other secondhand information about pricing negotiations, it seems that the low price obtained from Houay Ho has plagued the Lao government ever since.

When Hans Fischer representing NT2 PDG and GOL negotiated with EGAT for the price of Nam Theun 2 electricity he hoped to get 5.2 cents/Kwh. But EGAT would give only 4.55. Fischer could not get EGAT to agree to his fall-back bargaining price of 4.7 cents (pers. commun., David Iverach, 8 August 1995). The 4.55 is a relatively good price compared to the 4.22 that EGAT will give for other Lao hydropower projects, or the 3.2 that it has recently renegotiated for Nam Ngum electricity (here again, the reader should consult the article by Khun Malee in *The Nation*, 20 Sept. 1996). But is is well below the current standard of 6-7 cents being negotiated in other Southeast Asian countries.

If the Houay Ho price of 4.22 cents/Kwh did indeed handicap Fischer in his negotiations with EGAT, it is most unfortunate because Laos almost certainly should have and could have gotten a better price for Houay Ho.

The Thai company Electricity Generating Plc (EGCO) currently is negotiating to sell electricity from a power plant they built in Bien Hoa, Vietnam to the Vietnamese for a price of more than 6 cents/Kwh (*The Nation*, 18 December 1995). It seems the Thais have a double standard when it comes to pricing electricity. The difference between 4.22 cents for Houay Ho and 6 cents for Bien Hoa is related to who has to pay for expensive installations, power line in the case of Houay Ho and diesel engines in the case of Bien Hoa. But if the cost of environmental impacts that Laos and Vietnam will have to internalize had been factored into the price negotiations, the price for the elctricity might have been about 5.5 cents for both projects. That is Laos should be paid more for its electricity because of the environmental impacts it will have to bear, and Vietnam should be paying less for the same reason.

As mentioned above, perhaps the most important factor contributing to the low price agreed for Houay Ho electricity was the expensive power line. Now Houay Ho is located in the southeastern corner of the Bolaven

Plateau immediately next to Xe Nam Noy-Xe Pian hydroscheme. Both schemes involve tunnelized diversions from the tail-end of a moderately large reservoir on the plateau into the Se Kong valley some 600 m lower in elevation. The projects, as they are being constructed, involve separate diversion tunnels, separate power stations with expensive high speed turbines, and separate power lines. This duplication of installations only a few kilometers apart was probably completely unnecessary. Either Houay Ho could have been diverted into the Xe Nam Noy or vice versa, creating a single larger and more efficient and more economic hydroscheme, with less environmental impact.

The problems of the Houay Ho hydroscheme may be even more serious than just a doubling of costs and environmental impacts because of unnecessarily duplicated installations. Houay Ho is located in the extreme southeast corner of the Bolaven plateau, with no possibility of increased water input from diverting other streams and the lower rainfall in the entire area. Very little data on rainfall is available for Houay Ho, and it may receive too little water to be economically viable.

How could such a terrible planning blunder occur? There seem to be two main reasons. First, Houay Ho and Xe Nam Noy-Xe Pian were both considered in the JICA master plan for hydropower development of the upper Se Kong basin (JICA, 1993). Houay Ho (as Houay Katak Tok) was treated in virtually its present form. But numerous plans were considered for hydropower development separately or jointly involving the Xe Nam Noy and Xe Pian, each treated very briefly. Second, the contract for Houay Ho was given to Daewoo, that for Xe Nam Noy-Xe Pian to Dongah. The fierce competition between these Korean firms and their mutual distrust of each other extended from their homeland to the Bolaven Plateau, where they would not readily cooperate or share information, let alone engage in a general discussion of their respective projects or join forces to produce a more environementally friendly and more profitable hydropower scheme

Electrowatt Engineering Services Ltd. (Zurich) were the main geological and engineering consultants for Xe Nam Noy-Xe Pian and also consulted on Houay Ho. Apparently Electrowatt never considered the possibility of combining the two projects into one. The simple and relatively inexpensive topographic and hydrologic studies needed to determine the feasibility of diverting Houay Ho into Xe Nam Noy or vice versa were never undertaken (pers. commun., Michael Osborne, geological consultant to Xe Nam Noy-Xe Pian hydropower project, 10 April 1995).

Secrecy has surrounded nearly all of the EIA work done in connection with the Nam Theun 2 project. All Nam Theun 2 EIA through the end of 1995 was contracted by the NT2 PDG to TEAM Engineering Consultants, Ltd., of Thailand. TEAM's entire operation has consisted of providing EIA for various projects undertaken by EGAT (Electricity Generating Authority of Thailand) or in which EGAT has been involved. EGAT is of course the only Thai purchaser for power generated in Laos, and thus has an interest in the Nam Theun 2 project.

EGAT has just cancelled its power purchase agreement with the Lao government for Nam Theun 2 electricity, ostensibly because Laos could not begin electricity delivery by the year 2000 as promised (*The Nation*, 1 October 1996). Thus the contract will eventually have to be renegotiated. It would be nice if this resulted in Laos getting a better price for its electricity.

"HYDROELECTRICITY FROM LAOS IS INCREDIBLY CHEAP…."

- The base price of Nam Theun 2 electricity, 4.55 cents/Kwh, while higher than that being given for other Lao hydropower projects, is still way below the regional baseline price of 6 to 7 cents (as in several power projects in Vietnam, Sarawak's Bakun hydropower project).
- Allowance for inflation over a 25-year period works out to only about 2.8% compounded annually. This is far below the likely price increases of petroleum, rice, technology, and other items likely to be imported by Laos and paid for by its foreign exchange earnings.
- In essence. Laos is expected to subsidize industrial and other power demands in Thailand by internalizing environmental and social costs due to hydropower development.

The Thais and the Laos have an expression for taking advantage of someone: "Tam na nai lang khone" (in Thai) or "Het na tung lang khone" (in Lao), which literally means "to plant rice raddy of another person's back" and is particularly apt in the present context.

CONCLUSIONS AND RECOMMENDATIONS

Regional implications

The Lao national plan for hydropower development has grave implications for the downstream countries of Cambodia and Vietnam. Cambodia's Great Lake or Tonle Sap and Vietnam's Mekong Delta are these countries fish bins as well as their rice baskets. About 70% of Vietnam's entire rice production comes from the delta. Delta fisheries are comparably important—and whereas productivity has been declining in Vietnam's sea fisheries and inland fisheries elsewhere (e.g. Red River, Hoabinh Reservoir) it is still increasing in the delta. The Great Lake is if comparable importance to the welfare of Cambodians.

The ecological integrity and productivity of these highly dynamic Mekong ecosystems—upon which so many people depend—requires the Mekong's natural hydropower and natural hydropower regime. Every large dam built upstream, including those on the Nam Theun, will have cumulative or synergistic impacts on the Mekong ecosystem downstream.

Installation of Manwan and other large dams planned on the Mekong mainstream and tributaries in China'a Yunnan Province will definitely have negative environmental consequences for the downstream countries as well as for Yunnan. Cambodia also has plans—although not so grandiose as those of China and Laos—to develop Mekong hydropower (*The Nation*, 1 November 1996, p. A11). Cambodia can opt for projects with relatively great or relatively little impact on the Great Lake and the Mekong Delta. A 3,300 megawatt proposed installation on the Mekong mainstream has the gravest upstream as well as downstream environmental implications. If this gigantic Sambor project is built, whatever hydropower development occurs in Laos will have relatively little environmental consequences for Cambodia and Vietnam. Vietnam would understandably if not entirely justifiably hold Cambodia responsible for any ecological problems arising in the Mekong Delta as a result of the Sambor dam.

Faulty EIA

Environmental impact assessments on hydropower projects in Southeast Asia generally have been very defective, and those being done in Laos are no exception. What are the root causes of poorly done EIA?

First of all, EIA has become a service industry, dedicated to promoting large projects that provide it with lucrative contracts. All current and recent EIA on hydropower projects in Laos including Nam Theun 2 has been commissioned and paid for by the consortia or firms promoting the projects. Despite the barrage of criticism that has been levelled at NT2 PDG for the way it has handled NT2 EIA, it continues to exercise rigid control of the EIA process and EIA purse-strings. Reports on NT2 EIA are still not being made public (as of November 1996).

Neither sufficient time nor sufficient funding has been provided for EIA on hydropower projects in Laos. Thus Electrowatt Consulting Engineers, Ltd., of Zurich, subcontracted for an original study of impacts of Nam Theun 1 on migratory fish and wildcapture fisheries for which they provided a budget of only $7,000 and one month for completion. At the same time, they were sub-contracting for a revised hydrologic study to be completed in four months with a budget of $100,000. It is obvious that Electrowatt considered the hydrologic survey to be far more important than the fisheries survey.

From the above and numerous other examples, it may be concluded that:

1. Dam proponents in Laos (as elsewhere) usually regard environmental impact assessment as the lowest priority on their agenda (Nam Theun 2 Project Development Group claims to be an exception to the general rule, but then they are trying very hard to get World Bank support). The amount of money spent on EIA by NT2 PDG has been minuscule. Virtually all of the reports done for NT2 PDG will be "Secret" until the project is finally approved. Consultants working on related aspects are not permitted to consult each other or to see relevant reports and documents; rather they are "briefed" by NT2 PDG officials. This is no way to do EIA.

2. EIA firms and consultants are chosen by dam proponents with vested interest in getting project approved as soon and with as little outlay for environmental assessment as possible. Budgets generally are woefully inadequate.

3. Adequate time is almost never provided for EIA of hydropower projects. Engineers know that they need at least 5-10 years of meteorological and hydrological data for a hydropower project. How then could a single year or three-month period possibly be enough time to gather information on much more complicated matters such as ecological relationships and environmental impacts?

4. Engineering companies and other contracting for EIA typically demand that it be done in a hurry, i.e. within the next few months, and these months typically are during the rainiest time of the year, when it is extremely difficult if not impossible to visit project sites, let alone carry out field surveys. This is because the engineering company wants to have the EIA completed in time so that it can go to work on construction during the dry season.

5. Largescale projects such as Nam Theun 2 do require a great deal of economic analysis and feasibility (as distinguished from environmental) assessment. Dam proponents are relatively adept with these issues, and comfortable with the economists and other consultants who deal with them. Also, the issues themselves, albeit complex, are generally more amenable to objective evaluation. Environmental assessment is often difficult, dealing as it must with long-term intangible outcomes of cumulative or synergistic impacts, and dam proponents tend to be unfamiliar and uncomfortable with the issues involved.

6. All too often the so-called environmental consulting firms and the consultants they engage were trained as engineers, and lack the fundamental education and experience necessary to conduct valid environmental assessment. An engineer's concept of environmental requirements for fish to stay alive seldom corresponds with reality (see Box).

7. EIA on important or controversial projects should be subject to peer review and publication—probably the most effective tools for improving the EIA process. NT2 has permitted extremely limited peer review of its EIA documents and then only on an in-house, secret basis.

8. Professional EIA consultants need to realize that their primary obligation is to represent the environment to the best of their ability. Only in this way can they carry out their important responsibilities. Consultants with such a credo usually have been barred from EIA work, but they should not give up.

Confidentiality and public information: the transparency issue

In hydropower and other projects involving huge investments, competition, and lengthy negotiation, there occasionally is a need to safeguard some proprietary information. It is not so difficult to keep track of such information, and see that it is deleted from documents turned over to consultants. Instead, it is used as an excuse not to make relevant information available.

In Laos EIA on one hydropower project after another is being hastily or inadequately performed, kept from public scrutiny, or postponed until after the project is underway. Little or no discussion or explanation is offered for this secrecy beyond the project group saying it cannot release the information because of an agreement with the Lao government, and the Lao government saying that it cannot release the information because of an agreement with the project group. Thus the project is deprived of potentially invaluable (and potentially decisive) inputs from outside environmental experts having knowledge and skills otherwise unavailable to it. EIA without critical peer review is almost worthless.

In July 1995 the UNDP office in Vientiane announced that it was arranging for a public review of the TEAM Nam Theun 2 EIA and Resettlement Plan at the request of the NT2 PDG, and that the meeting would be held in September 1995. Before the scheduled time for the meeting the Lao government and the NT2 PDG carefully reviewed the TEAM EIA and decided that it would not stand up to the light of day. NT2 PDG staff worked very hard to revise the report, but concluded that they could not get it into decent shape for presentation. Nothing came of the public meeting and NGO review promised for September. The NT2 PDG told NGOs and others UNDP would hold the review soon after The World Bank team's visit to Vientiane in November 1995, probably around 15 December, but this date also passed without a review. In January 1996 a UNDP official informed me that NT2 PDG and the Lao government intended to postpone any public review of the Nam Theun 2 project until after the World Bank had formally committed itself to support the project.

Pre-emptive environmental impact assessment: no nonsense and no nasty surprises

As a project enters its feasibility period, policy makers must meet the environmental implications head-on. The strategy of maximum confidentiality is fundamentally unsound and dangerous. At best, it can contribute to distrust, poor public relations, delays, inadequate environmental study, loss of investors. At worst, it can lead to environmental disaster, litigation, lawsuits for criminal negligence, and fall of governments. The practice of employing "pliable" consulting firms and consultants cannot be condoned. The only viable course is "pre-emptive environmental impact assessment", involving some or all of the following steps:

1. Frequent periodic releases of environmental information, including worst-case scenarios, emphasizing the tentative nature of the information or its analysis as appropriate. The initial releases should include Tentative Terms of Reference (TTOR) for environmental impact assessment, so that they can be publicly discussed and improved upon.

The releases can be organized jointly or separately by the government and/or the project consortium, but should permit participation of NGO's, independent consultants, and the concerned public. Identification of unforseen impacts must be welcomed. In case of great uncertainty about an environmental issue, detailed description and discussion can be deferred until further information is gathered, but the matter should be put before the public as soon as possible.

2. Whenever serious potential impacts are recognized, special studies by qualified independent consultants should be commissioned and announced. The resulting reports can be reviewed by the government and project consortium before release, but should be made public without undue delay. Discussion and or qualification may be added by the government and or con sortium, but the contents of the original document should not be altered.

For highly technical topics, such as chemical impacts, a popularized version should be prepared by the consultant as an aid to all parties concerned, but the full technical text should also be publicly available.

3. During the feasibility stage—i.e. before the project has received the official go ahead—there should be one or two full scale public debates on the environmental issues. The case for the project can be made by government and consortium representatives, but independent consultants should also explain their studies and results, and members of the public including journalists should be permitted to query the proceedings and express their concerns. Proceedings of the debate(s) should be made public immediately afterwards.

4. Documents relevant to the environmental review(s) should be made publicly available well in advance.

5. Closing dates for final environmental critiques of the project should be announced well in advance.

"No nonsense" implies full public participation from the earliest opportunity. "No nasty surprises" literally means that there should be no unexpected or unpredicted environmental damage or disaster resulting from the project. Use of this strategy implies that environmentally unsound projects will be identified very early and nipped in the bud before large sums are spent on them.

Conservation of the Nakai Plateau-Nam Theun ecosystem

The environmental destruction of the Nam Theun ecosystem inevitably resulting if present "development" plans are realized will not result in sustainable development or a better standard of living for people living in the Nam Theun and other areas directly affected by "development". Sedimentation and diminishing rainfall in the Nam Theun catchment directly caused by deforestation will shorten the life of the hydropower reservoirs and add to the impacts on aquatic ecology. Water diverted from the Nam Theun will have large negative impacts on the Hinboun and Xe Bang Fai, and to a less extent on the Mekong mainstream. Nam Theun 2 reservoir will produce toxic rotten water that may well endure 10 years or longer.

If mainstream dams are constructed on the upper as well as the lower Nam Theun, and if deforestation goes on unchecked, the aquatic ecology of the entire Nam Theun mainstream and of all of its tributaries will be severely impacted. Several of the most important Nam Theun fish species probably will be exterminated, including the magnificent pba kang or giant predatory carp. Loss of other wildlife—mammals and birds—will also be great. The Nakai Plateau–Nam Theun ecosystem will be destroyed.

Such ruinous exploitation—with irreversible ecological change and long term losses outlasting and outweighing the short-term gains—should be instantly curtailed.

Much of the loss can be averted by confining Nam Theun hydropower projects and timber exploitation to parts of the middle Nam Theun basin. By leaving the upper basin naturally forested and free of dams, about half of the entire ecosystem could be saved and hopefully none of the species will become extinct.

Nam Theun 2, the most ruinous hydropower project planned in the Nam Theun basin, should be cancelled immediately, together with all logging activities in the upper Nam Theun basin.

The Lao government should enact legislation recognizing the upper Nam Theun and its tributaries as a National Protected River System. The boundaries of the National Biodiversity areas in the upper Nam theun should be redefined and greatly expanded so that they are much larger contiguous areas connecting large tracts of riparian forests of the upper Nam Theun tributaries with the Nam Theun mainstream.

A significant part of the revenues from Nam Theun lower basin forest and hydropower industries should go towards protecting the Nam Theun ecosystem, watershed, and protected areas and helping the people who live there get along in harmony with nature. They need help in irradicating malnutrition and disease and in obtaining education for their children but this need not and should not be done at the expense of the ecosystem.

The forest of the entire Nam Theun watershed (and for that matter, all of Laos) should be regularly monitored by aerial surveys and by satellite, with ground truthing and protection provided by appropriate Lao government agencies with adequately trained staff. Part of the proceeds of the Theun-Hinboun project should be used for forest monitoring and protection. Laos could thus protect its own vital forest interests and contribute to regional environmental security.

The Theun-Hinboun project, the lesser of two evils, is going ahead and is expected to be completed within about two years. This project should be closely monitored for environmental impacts. Quite possibly it is the only hydropower project that should be done in the Nam Theun basin. Compared to Nam Theun 1 and Nam Theun 2, it will have relatively little impact on the Nam Theun mainstream, on Nam Theun tributaries, and on the Mekong mainstream. It will have substantial negative impact on the Nam Hinboun, but this would be confined to a smaller area and would be much less than the impacts of Nam Theun 2 on the Xe Bang Fai. The Nam Mouan and Nam Gnouang, the two largest tributaries of the Nam Theun, should be given the status of National Protected Rivers. The National Biodiversity Conservation areas within them should be enlarged considerably, and made as coextensive as possible, with the eastern limits at the mountainous drainage divide between Laos and Vietnam, and the western limit at the base of the escarpment.

Loss and liability

Companies involved in large-scale extractive industries—including logging, mining, and hydropower—should be liable for environmental damages. How much should they be penalized for destroying an ecosystem, killing off a species, or causing the decline of a healthy tiger population in a National Biodiversity Protected Area? The penalties could be very high in tropical countries with unique ecosystems and high biodiversity.

Broken Hill Proprietary (BHP), the largest company in Australia, recently faced a U.S.$3 billion law suit filed in Melbourne (BHP corporate headquarters). This amount would have payed for just a part of the damages resulting from the Ok Tedi gold and copper mine on the Ok Tedi and Fly Rivers in Papua New Guinea. It is doubtful whether Transfield Corporation or NT2 PDG has the sort of assets necessary to pay for environmental damages likely to result from Nam Theun 2. If they go ahead with the project, Transfield and its partners and backers should post a “performance bond”, and have adequate insurance or financial assets to cover damages that could easily exceed U.S.$3 billion.

Alternatives to Nam Theun 2

Proponents of NT2 say that if it isn't built, Thailand won't be able to meet its power needs and will turn to nuclear power. This is just another example of jaw-boning in favor of NT2. At one point, hydropower provided nearly 50% of Thailand's energy consumption. But this has declined steadily, mainly due to increasing consumption of natural gas. In 1991 hydropower contributed less than 10%. By 1994, natural gas was the most important source of energy consumed (44% of total), followed by fuel oil (28%) and lignite (20%); hydropower contributed only 6% (DEDP, 1995). With Myanmar’s Yadana and other gas fields coming on line, natural gas will continue to predominate.

Yadana gas reserves have been re-estimated very recently upwards from 5.7 to 9.6 trillion cubic feet (*The Nation*, 30 Oct. 1996, p. B1). This windfall, perhaps not entirely unexpected, will have a depressant effect on gas and other energy prices in the region. Prior knowledge of this may have played a key role in EGAT’s recent decision not to extend its contract for purchase of NT2 electricity as requested by the Lao government.

Whenever Nam Theun 2 comes on line, in 2000 or in 2004, how much will it contribute to Thailand's total energy consumption? Very little indeed, possibly less than 0.2%. Whether Thailand goes ahead with nuclear

power plants will have nothing to do with the amount of energy provided by Laotian hydropower. Nam Theun 2 power is insignificant in the larger scheme of things.

An environmentally less damaging alternative to the NT2 hydropower scheme was proposed in the SMEC feasibility study. The dam site for the alternative is just 60 km downstream from the NT2 site. This original alternative, now called the Theun-Hinboun hydroscheme, already is being built. There is no need to look for any other alternative to NT2 so far as Thailand is concerned because it is simply not that important. Laos has some 50 other potential hydroschemes including some that should be environmentally and otherwise less objectionable than NT2 and which could be alternative to it. Ideally, all potential hydropower projects in Laos should be evaluated before one or two are chosen as alternatives to Nam Theun 2.

The way Lao government is spending beyond its current means and practically giving away its electricity, all of these projects will have to be implemented regardless of environmental and social costs. In this way a poor nation will become more and more impoverished.

Nam Theun 2 and The World Bank

For the past decade The World Bank has urged the Lao government to exploit its forest, water and mineral resources in order to stimulate its economy. The Bank identified Nam Theun 2 as possibly the most profitable hydropower project in Laos. Since then Transfield Corporation and the NT2 PDG have pursued the project avidly, and have kept up pressure on the Bank to join them. Executive officers of Transfield, Electricite de France, and the Thai Consortium for Nam Theun 2 all publicly declared toward the end of 1995 that they could not go ahead on NT2 without the Bank's involvement.

SOME ECONOMIC DRAWBACKS OF NAM THEUN 2 HYDROPOWER PROJECT

- Only about 10% of the reservoir inundation area is covered by timber that can be profitably logged. It will be an expensive and profitless task to remove the dominant bamboo, scrub, and other vegetation from the area, but unless this is done the reservoir is liable to have rotten water from top to bottom for five to ten years, and an anaerobic hypolimnion or bottom layer even longer.
- Despite the high value of hardwoods in the upper Nam Theun catchment, the poorly planned logging operation there has been marginally profitable. Nam Theun 2 Reservoir will greatly facilitate extension of logging to as yet untouched areas, which will in turn contribute to watershed deterioration and sedimentation of the reservoir, hence shortening its economically productive lifetime. When ownership of Nam Theun 2 is transferred to the Lao government after 25 years, its profitability is likely to be nil.
- The price negotiated for Nam Theun 2 electricity is well below the current regional price of 6-7 cents/Kwh, and increases to allow for inflation over 25 years at only 2.8% compounded annually are grossly inadequate.
- In essence, Laos is subsidizing part of Thailand's energy needs, while internalizing heavy environmental and social costs. Barring a change of heart on the part of Thailand's EGAT, there is little Laos can do about this, since there is no alternative buyer for Nam Theun electricity.
- Current estimate for construction cost alone of Nam Theun 2 Dam is way, way over US$800 million (*The Nation,* 17 September 1996). If construction plans have to be modified to provide a measure of security from earthquakes, it would add some 25% to the cost and push it up to US$1.2 billion or more.

Food security is an economic as well as a moral or ethical issue. Rich nations can guarantee their food security by purchasing imports, but poor ones like Laos must rely more on their own resources. Nam Theun 2 will adversely effect wildcapture fisheries and other food resources of many villages on the Nam Theun, Nam Hinboun, and Xe Bang Fai. Prognosis for mitigation measures to offset these food losses is poor, so that financial compensation to villages that have had their food secuity compromised by Nam Theun 2 will be necessary. Food will have to be imported if it is not available within Laos. In deciding whether to support NT2 the Bank is faced with two larger but extraneous issues: 1) if it does not support NT2 it may cease to be a player in large scale developments in Laos; and 2) its failure to support NT2 may have an overall negative impact on development of hydropower in Laos.

It seems highly unlikely that the World Bank will be denied the opportunity to invest in Laos just because it drops Nam Theun 2. Talk of this kind is typical of the kind of jaw-boning in favor of projects that goes on all the time in Vientiane.

Failure of the World Bank to sponsor Nam Theun 2 might have a depressant effect on other hydropower projects in Laos, but this is not necessarily a bad outcome. The Bank needs to take care that it does not start a precedent of supporting poorly conceived projects in Laos that are environmentally, economically, socially harmful. And economically questionable.

Judging from its own stated standards on environmental impacts, the Bank should not support NT2. The Bank's Operational Manual Statement 2.36 "Environmental Aspects of Bank Work" (May 1984) paragraph

9(b) states that the Bank "will not finance projects that cause severe or irreversible environmental degradation, including species extinctions, without mitigatory measures acceptable to the Bank"; and paragraph 9(d) that the Bank "will not finance projects which would significantly modify natural areas designated by international conventions as World Heritage sites or Biosphere Reserves, by national legislation as national parks, wildlife refuges, or other protected areas."

Nam Theun 2 will cause severe and irreversible environmental degradation, probably including species extinctions, in the unique Nam Theun-Nakai Plateau ecosystem. It is doubtful that mitigation measures will have any substantial beneficial effects. They might do more harm than good. Nam Theun 2 will substantially (i.e., more than significantly) modify important natural areas, large parts of which were designated (and all of which should have been designated) as natural wildlife refuges years ago, i.e. before discovery of the Vu Quang ox and of numerous undescribed fish species in the Nam Theun, and before much of the forest was removed by logging. The area was under serious consideration as a World Heritage Site, eligible for substantial GEF and other funding from the World Bank, until conflict with the NT2 project was recognized and the areas sponsorship for World Heritage status was ignominously dropped. It is unlikely that that Nam Theun 2 will be the great money making proposition that the NT2 PDG groups claims.

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Table 1. Hydropower projects proposed for the Nam Theun basin.
ic=installed capacity in megawatts; ag=annual generation in gigawatt hours;
hgt=dam height in meters; area=reservior area in km^2; imp=environmental impacts
on aquatic biology on a scale from 1 to 10.

	ic	Ag	hgt	area	imp
Nam Mouan	1,080	5,630	170	515?	7.5
Nam Theun 1	400	1,000	140-180	565?	7.5
Theun-Hinboun	210	1,380	25	20-30	6
Phu Phet	?	?	?	?	?
Nam Theun 2	680	4,530	38	450	9
Nam Theun 3	200	1,000	110	?	4
Nam Theun 4	80	410	?	?	3
Nam Theun 5	65	326	?	?	4

Table 2. Fishes of the Nam Theun above Geng Wang Fang. MIG = migratory; WF = importance in wildcapture fisheries; RP = reservoir fisheries potential; CS = conservation status. Lao names (all preceded by prefix "pa" for fish) are those in use in Nam Theun—Nakai Plateau area.

	Lao name	MIG	WF	RP	CS
Anguillidae (true eels)					
Anguilla marmorata	laht meao	+	0	0	+

Cyprinidae (carps)					
Bangana sinkleri	wa soi	+	1	0	-
Barilius pulchellus	sam mai	?	0	0	-
Cirrhinus molitorella	gaeng	+	3	++	-
Cyclocheilichthys sp.	dok mai; oop	?	1	+	-
Cyprinion cf. *Burmanicus*		+	2	0	?
Cyprinus carpio	nai	-	1	+	-
Danio sp.	siu	?	0	0	-
Folitor brevifilis	chawn	+	2	0	+
Garra cambodgiensis	gaw	?	0	0	-
Garra fasciacauda	chiko	+	1	0	-
Garra imberbis		+	2	0	-
Garra cf. *Nasutus*	sa	+	2	0	-
Garra new sp.		?	0	0	?
Hampala macrolepidota	soot	+	2	++	-
Hemibarbus labeo	goom; gohm	+	1	+	-
Hemiculturella macrolepis	seht	+	1	?	++
Hypsibarbus sp.	pak gai	+	3	0	+
Labeo pierrei	wa kai	+	1	0	+
Luciocyprinus striolatus	kang; gang	+	3	0	++
Mekongina erythrospila	ee	+	3	0	+
Mystacoleucus cf. *Greenwayi*	ka dalm	?	1	0	-
Mystacoleucus cf. *Marginatus*	ka chai	?	1	0	-
Onychostoma new species		+	2	0	++
Onychostoma new species?	king	+	2	0	+
Neolissochilus blanci	sawng	+	2	0	+
Poropuntius cf. *Deauratus*	jaht leuang	+	3	0	++
Poropuntius new sp.	jaht dahm	+	2	0	+
Puntioplites proctozysron	sagang	+	2	++	-
Puntius leiacanthus		-	0	0	-
Puntius sp.		-	0	0	-
Raiamas guttatus		+	2	0	++
Rasbora cf. *Sumatrana*	siu	-	0	0	-
Rhodeus new sp.		-	0	0	+
Scaphognathops new sp.?	dawk tong	+	1	0	++
Tor sinensis	daeng	+	2	00	++
Tor tambra	tohn	+	2	0	++
Tor new sp.		+	1	0	++
Gyrinocheilidae (spiracled carps)					
Gyrinocheilus aymonieri	gaw	+	?	0	-
Gyrinocheilus pennocki	hua koowan	+	?	0	-
Balitoridae (loaches)					
Balitora sp.	tit hin	?	0	0	-
Hemimyzon sp.	tit hin	-	0	0	-
Homaloptera sp.	tit hin	-	0	0	-
Homaloptera sp.	tit hin	-	0	0	-
Homaloptera sp.	tit hin	-	0	0	-
Cobitidae (loaches)					
Lepidocephalichthys new sp.	eet	-	0	(+)	-
Lepidocephalichthys new sp.?	eet	-	0	(+)	-
Misgurnus anguillicaudatus	lai	-	1	++	-
Pangio fusca	eet	-	0	0	-
Schistura new sp.	lai; pahn lai	-	0	0	?
Schistura new sp.	lai; pahn lai	-	0	0	?
Schistura new sp.	lai; pahn lai	-	0	0	-
Schistura new sp.	lai; pahn lai	-	0	0	-
Schistura new sp.	lai; pahn lai	-	0	0	-
Schistura new sp.	lai; pahn lai	-	0	0	-
Schistura new sp.	lai; pahn lai	-	0	0	-

Bagridae (catfishes)					
Leiocassis siamensis	nyang bohn	-	0	0	-
Mystus microphthalmus	keung	?	3	++	-
Schilbeidae (catfishes)					
Laides sinensis	nyawn	?	0	0	?
Siluridae (catfishes)					
Pterocryptis new sp.	gin	-	1	0	-
Sisoridae (catfishes)					
Bagarius bagarius	kae	?	1	+	-
Bagarius yarrelli	kae	?	3	++	-
Glyptothorax laosensis	kae ngeng	-	0	0	-
Glyptothorax sp.	kae ngeng	-	0	0	-
Glyptothorax sp.	kae ngeng	-	0	0	-
Oreoglanis cf. *Delacouri*	bpeh	-	0	0	-
Pseudecheneis new sp.	Kae ngeng	-	0	0	-
Clariidae (catfishes)					
Clarias batrachus	dook	-	1	++	-
Oryziidae (ricefishes)					
Oryzias mekongensis	dok khao	-	0	(+)	-
Oryzias sinensis	dok khao	-	0	(+)	-
Oryzias new species	dok khao	-	0	(+)	-
Ambassidae (glass perches)					
Parambassis siamensis	kahp kawng	?	0	(+)	-
Cichlidae (cichlids)					
Tilapia nilotica	nin	-	0	+	-
Eleotridae (sleepers)					
Percottus new sp.	boo	-	0	(+)	-
Gen. undet., new sp.		-	0	0	?
Gobiidae (gobies)					
Rhinogobius sp.	boo	-	0	0	-
Rhinogobius sp.	boo	-	0	0	-
Gen. undet., new sp.		-	0	0	?
Anabantidae (climbing perches)					
Anabas testudineus	keng	-	0	(+)	-
Belontiidae					
Trichopsis schalleri		-	0	(+)	-
Channidae (snakeheads)					
Channa gachua	gahng	-	1	+	-
Channa striata	kaw	-	2	++	-
Channa new species	goowan	-	2	++	-
Mastacembelidae (spiny eels)					
Mastacembelus armatus	laht	-	1	+	-
Mastacembelus favus	laht	-	0	+	-
Chaudhuriidae (swamp eels)					
Chaudhuria new species?		-	0	(+)	-
Synbranchidae (swamp eels)					

Monopterus albus	ien	-	1	+	-