Fearnside, P.M. 1999. Social impacts of Brazil's Tucuruí Dam. Environmental Management 24(4): 483-495.

ISSN: 0364-152X

SOCIAL IMPACTS OF BRAZIL'S TUCURUÍ DAM

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17 June 1998
18 Jan. 1999

In press: Environmental Management

ABSTRACT

The Tucuruí Dam, which blocked the Tocantins River in 1984 in Brazil's eastern Amazonian state of Pará, is a continuing source of controversy. Most benefits of the power go to aluminum smelting companies where only a tiny amount of employment is generated. Often presented by authorities as a model for hydroelectric development because of the substantial power that it produces, the project's social and environmental impacts are also substantial. Examination of Tucuruí reveals a systematic overestimation of benefits and underestimation of impacts as presented by authorities. Tucuruí offers many as-yet unlearned lessons for hydroelectric development in Amazonia.

KEY WORDS: Tucuruí Dam; Amazonia; Hydroelectric dams; Brazil; Reservoirs; Mercury

The Tucuruí Dam, which blocked the Tocantins River in 1984, flooded 2430 km^2, including part of the Parakanã Indian Reserve (Figure 1). The reservoir is located in central Pará, between 3°43' to 5°15'S and 49°12' to 50°00'W. The power station has 4000 megawatts (MW) of installed capacity in its present first phase (Tucuruí-I), and would increase to 8000 MW in a planned second phase (Tucuruí-II). Brazil has ambitious plans for hydroelectric development in Amazonia, and the experience at Tucuruí contains many lessons that need to be learned if the country is to make wise decisions about these developments.

[Figure 1 here]

There have always been indications that Tucuruí is not the unequivocal success often described by ELETRONORTE, the electrical authority in northern Brazil. Before construction of the dam, the World Bank was approached for financing but refused (R.J.A. Goodland personal communication 1986). Residents along the reservoir edges have had a long series of complaints, and camped out for two years at the entrance to the ELETRONORTE compound to press their demands for alternative settlement sites. The economy of towns downstream of the dam was destroyed, creating virtually universal hostility to ELETRONORTE among the population of the lower Tocantins River. In 1991, a parliamentary commission of inquiry (CPI) in the Pará State Legislative Assembly investigated problems caused by the dam and endorsed a long list of complaints. Finally, the International Water Tribunal (1991) condemned the Brazilian government for the impacts of Tucuruí at its 1991 session in Amsterdam. Although the Tribunal has only moral authority, the condemnation brought world attention to existence of an underlying pattern of social and environmental problems caused by this would-be model undertaking (Informe Jurídico 1992).

The 2430-km^2 area for Tucuruí refers to the reservoir at the level for Tucuruí-I, 72 m above mean sea level (msl). Were the Tucuruí-II project implemented the water level would be raised to 74 m above msl, according to the original plan. Raising the water level to 74 m would increase the area flooded by 205 km^2 to 2635 km^2 (Brazil, ELETRONORTE 1989a: 243). ELETRONORTE officials have reportedly recognized that raising the water level above the present 72-m level would be politically impractical due to population displacement effects, and are planning to operate the Tucuruí-II configuration without increasing the water level (John Denys Cadman personal communication 1996). The lower amount of water storage in the Tucuruí reservoir, as compared to the original plan for Tucuruí-II, would presumably be compensated by greater regulation of the river flow by upstream dams.

Whether or not more area is flooded at Tucuruí proper, the Tucuruí-II scheme would require regulating the flow of the Tocantins River by building the Santa Isabel Dam on the Araguaia River, the first major tributary upstream of Tucuruí (Paulo Edgar Dias Almeida personal communication 1991). The impacts of this must therefore be considered in evaluating the Tucuruí-II proposal.

Until recently, Tucuruí-II has been presented by ELETRONORTE as a mere continuation of a construction project already underway prior to the 23 January 1986 requirement for a Report on Impact on the Environment (RIMA). In 1998, preparations began for a RIMA for Tucuruí-II; it will assess impacts for operation of the dam without raising the water level above the present 72 m (Andrea Figueiredo public statement 25 May 1998). However, on 14 June 1998 Brazil's president released the funds for construction of Tucuruí-II (Indriunas 1998), obviously prior to completing the RIMA.

As is the norm in Brazil to date, impacts of upstream dams would not be considered under the RIMA to be prepared for Tucuruí-II. Each upstream dam would be required to have its own RIMA prior to construction. However, these dams are, in fact, a consequence of the decision being taken on Tucuruí-II without a RIMA covering these upstream impacts. Provisions are needed in impact assessment requirements to assure that the consequences of initial decisions are fully included, as when river basin development is set in motion by an initial construction decision at the bottom of a chain of dams. The most dramatic example is the case of the Xingu River, where large areas of indigenous land would be flooded by dams made "necessary" by an initial structure (the proposed Belo Monte Dam, formerly known as Kararaô) that would appear highly attractive if viewed in isolation (Fearnside 1989).

II.) SOCIAL IMPACTS

A.) Displaced Population

ELETRONORTE originally did not include any study of social impacts in its assessment of the dam. No mention of these is included in the viability study (Brazil, ELETRONORTE 1974). In 1977, two years after construction had begun, a single consultant (Robert Goodland) was contracted to prepare an "environmental assessment;" he was allotted a period of only one month (July 1977) for a field visit (Goodland 1978, p. 1). The terms of reference specifically excluded any possibility of modifying engineering decisions such as the water level. The report points out (p. 39) that one- to two-thirds of the displaced families would have no claim to compensation due to lack of land titles or acceptable equivalents. The high end of this range, in fact, proved to be the case (Magalhães 1990). Goodland's report emphasizes ELETRONORTE's plans for a survey of the affected population (i.e., Brazil, ELETRONORTE nd [1979]), and makes a rough calculation that about 15,000 people would have to be moved (Goodland 1978, pp. 38-39).

The resettlement program for residents in the submergence area created severe social problems (de Castro 1989, Magalhães 1990, Mougeot 1987, 1990). Preliminary estimates indicated that 9500 people in 13 villages would be displaced (Brazil, ELETRONORTE nd [1979]; see also Monosowski 1990, p. 39). The deficiencies of the studies made before filling the reservoir have been reviewed by Mougeot (1987, 1990) and Teixeira (1996, pp. 198-200). Estimates made after the reservoir had been filled indicated 3350 families (17,319 people) (Monosowski 1990, p. 32). These people filed 3636 indemnity claims (Monosowski 1990, p.

32). Official estimates of the number of people subsequently increased to 23,871 people (World Rivers Review 1991, p. 12; dos Santos and do Nascimento 1995, Teixeira 1996, p. 198 based on Brazil, ELETROBRÁS 1987). ELETRONORTE (1984, cited by Magalhães 1990, p. 106) also calculated 32,871 people were dislocated, in addition to the indigenous population. In 1985, one year after closing the dam, 1500 families remained homeless (Brazil, Comissão Interministeral 1985, cited by Teixeira 1996, p. 225). As of February 1988, 2539 rural families and 1433 urban families had been relocated (Brazil, ELETRONORTE 1989a, p. 437).

Several segments of the affected population were excluded from ELETRONORTE's estimates of the population to be displaced and from the resettlement programs based upon these estimates (Teixeira 1996, p. 199). One factor leading to underestimation was considering only people whose residences were located within the submergence area, but not the population living adjacent to this area who used the seasonally flooded várzea for their subsistence. Another was ignoring all population growth, including immigration, during the five-year period (1980-1984) between the survey and the filling of the reservoir.

A total of 3700 people who had been resettled by ELETRONORTE had to be relocated to new areas when their first resettlement sites were flooded by the reservoir (Magalhães 1990, p. 111). This was the result of gross errors in the topographic map of the area to be flooded, with some areas mapped as more than 76 m above msl (the cutoff for resettlement) in reality being below the 72-m water level. Topographic errors occurred in both directions, with some areas being unexpectedly flooded and others unexpectedly left above the water line. Further tensions arose when some of the population that had been relocated by ELETRONORTE spontaneously moved back into the strip between the 72- and 76-m marks. The upper limit for resettlement was originally set at 86 m and subsequently reduced to 76 m (partly on the basis of improved topographic information) after most of the residents had already been displaced; movement back into the 76-86 m strip created numerous injustices, particularly for the many original residents who lacked legal title to their land (Mougeot 1986, p. 405). Some of the settlers whose land was only partially flooded in sections of the shoreline where water levels rose to points higher than expected chose to remain in place despite their reduced land area (personal observation).

One of the most basic problems in ELETRONORTE's dealing with the displaced population was that the company limited its assistance to cash payments in most cases. ELETRONORTE's objective of relieving itself of further legal responsibilities may have been served, but the social result was that the most of the displaced population was reduced to indigence and effectively had to fend for themselves. The amounts of compensation were small, and payment was subject to repeated delays (which, in the context of insufficient correction for inflation in Brazil at that time, implied substantial losses of value). Most important is the fact that, regardless of the monetary amounts paid, money evaporates quickly in the hands of people inexperienced in dealing with finances, leaving most families with nothing a few months later. In March 1985, three months after taking office as Brazil's first civilian president since 1964, José Sarney visited Tucuruí and authorized creation of an interministerial commission to deal with the resettlement problems that had, by then, become politically explosive. The commission recognized the problems that had resulted from ELETRONORTE's reliance on cash indemnification (Brazil, Comissão Interministerial 1985, cited by Magalhães 1990, p. 108).

The relations between the displaced population and ELETRONORTE deteriorated steadily in the decade following the closing of the dam. These problems have been aptly described as having "already assumed Kafkaesque features, so that the directly involved parties lost all their hopes of conflict regulation" (Schönenberg 1994, p. 36).

The population affected by Tucuruí is not limited to the persons resettled from the submergence area, but also includes others who are drawn to the area because of its roads, markets and off-farm employment opportunities. ELETRONORTE classifies such migrants as beyond their ken. However, the attraction of population is a predictable consequence of dam building. Displaced persons have experienced additional problems, and have provoked additional deforestation and other impacts. This resulted from plague of Mansonia mosquitos causing much of the resettled population that had been moved by ELETRONORTE to the Gleba Parakanã resettlement area to relocate to an area (Rio Gelado) located on a logging road that had been built by mahogany cutters linking the Transamazon Highway with the town of Tucumã. In April 1993, after a group of displaced persons had been encamped at the entrance to the ELETRONORTE compound for two years, the company agreed to provide some infrastructure at the Rio Gelado site. As of 1993, only 103 of the 1500 families to be settled at Rio Gelado had received land titles (Teixeira 1996, p. 227). Tensions between the arrivals from Gleba Parakanã and other claimants at Rio Gelado, especially loggers, forced the leader of the Gleba Parakanã group to flee the area and remain in hiding from 1996 to 1999.

Plans for dam construction upstream of Tucuruí (Figure 2) include 26 dams (see Junk and de Mello 1987, Fearnside 1995a, 1997). Mougeot (1987, p. 97) estimates that all of the planned dams in the Tocantins/Araguaia basin would displace a total of 85,673 people. This estimate was based on the assumption that the population of these areas will remain constant at their 1985 levels; as Mougeot (1987, p. 97) recognizes, these figures will have been "exceeded manyfold by the time all likely impoundments are formed." One of the first such impoundments would be the 3840 km^2 Santa Isabel reservoir on the lower Araguaia River, which would oust a population "well in excess of the 1980 estimate of 60,000" (Mougeot 1990, p. 98).

[Figure 2 here]

B.) Downstream Residents

The population of residents in the lower Tocantins has suffered severe disruption as a result of the Tucuruí Dam. Closing the dam radically altered the aquatic environment both above and below the dam (Fearnside 1995b). The 670-km stretch of the Tocantins River affected by Tucuruí (500 km below the dam and 170 km above) supported a flourishing fishery that provided both a cash income and most of the animal protein to riverside residents. Prior to closing the dam, fish consumption averaged 49 kg person^{-1} year^{-1} (de Merona 1985).

In the first year following closing of the dam the fish catches in the lower Tocantins remained at approximately the pre-dam levels, since the migrating fish trapped at the foot of the dam were easily caught by fishermen. The following year (1986), however, the total catch was three times smaller (Brazil, INPA/ELETRONORTE 1987, Leite and Bittencourt 1991). The fish catch per unit effort, as measured either in kg per trip or kg per fisherman, dropped by about 60%, while the number of fishermen also fell dramatically. In addition to declines in fish catches, freshwater shrimp harvests also decreased: local production in the lower Tocantins did not change from 1981 levels in the first year after closing the dam (1985), but fell by 66% in the following year (Odinetz-Collart 1987). Water passing through the turbines is particularly low in oxygen during the dry season. This water does not mix with the flow from the spillway for about 60 km downstream of the dam, leading to reduced fish populations along the west bank of this stretch (Hino and others 1987, cited by Monosowski 1990, p. 31).

Cametá, the largest town downstream of Tucuruí, is one of the oldest non-indigenous settlements in the Amazon region, and has been an independent municipality since 1635 (Heinsdijk 1958, p. 48). The economic livelihood of Cametá was decimated by the effects of Tucuruí on the lower Tocantins (see Dwyer 1990, pp. 48-63). The fact that these impacts were the result of a deliberate action on the part of the national government means that the affected population views them in a way that is very different from what would result from the same level of impact caused by a natural disaster. Sensitivity to the role of the central government has its roots in the history of the Amazon region, which has for centuries been one of exploitation for the benefit of distant powers--first the Portuguese and later the <u>sulistas</u> (people from São Paulo, Rio de Janeiro, Brasilia and other locations viewed by Amazonians as part of "southern" Brazil). Needless to say, Tucuruí is viewed as primarily the work of <u>sulistas</u>. Politicians from Cametá have taken a leading role in opposing Tucuruí, for example by instituting a Parlamentary Commission of Inquiry (CPI) in the Pará state legislature in 1991.

C.) Indigenous Peoples

Impact on indigenous peoples is one of the most polemic aspects of Tucuruí, as it is in other existing and proposed dams in Amazonia. Tucuruí flooded part of three indigenous reserves (Parakanã, Pucuruí and Montanha) and its transmission lines cut through four others (Mãe Maria, Trocará, Krikati and Cana Brava) (Comissão Pró-Índio de São Paulo 1991, p. 64). In addition, the rerouting of the Transamazon Highway to skirt the western edge of the reservoir cut through the Parakanã Reserve, which was truncated to occupy only one side of the highway. The land between the highway and the reservoir was used as a resettlement area (the Gleba Parakanã), thereby denying the tribe access to the reservoir. Invasion of the reserve by non-indigenous poachers was facilitated by the arrangement. The Trocará Indigenous Area, inhabited by the Asuriní do Tocantins Indians, is located 24 km downstream from the dam, thereby suffering the effects of water pollution and loss of fish resources affecting all downstream residents.

Of the area submerged by Tucuruí, 36% belonged to the Parakanã Indians (Comissão Pró-Índio de São Paulo 1991, p. 74). Between 1971 and 1977 the tribe was moved five times by FUNAI. In 1978 (three years after construction had begun in 1975) an assistance program called "Projeto Parakanã" was set up by FUNAI and ELETRONORTE to transfer the tribe out of the submergence area, but the program was abandoned in 1979. The first portion of the tribe moved in 1981, moving on its own initiative rather than waiting for government assistance. In 1982, the remainder of the Parakanã tribe was transported by helicopter to a new village (Marudjewara) constructed by ELETRONORTE. Malaria and other diseases contributed to increased mortality in the tribe following the move (Comissão Pró-Indio de São Paulo 1991, p. 75). In 1987 ELETRONORTE and FUNAI began the "Programa Parakanã," which included building a 12-km side road to link one of the villages (Paranati) to the Transamazon Highway, purchase of a pickup truck, and building a storehouse in each of the two villages moved as a result of Tucuruí. Later activities included health services, primary education, agricultural extension and help in patrolling reserve boundaries (Comissão Pró-Índio de São Paulo 1991, p. 76).

The Krikati Indians received a truck, a tractor, some agricultural tools and a few head of cattle in compensation for the transmission line cutting their reserve (Comissão Pró-Índio de São Paulo 1991, p. 69). The Guajajara Indians (of the Cana Brava Reserve) received Cr$160 million in 1979-1980 [approximately US$6.4 million] (Comissão Pró-Índio de São Paulo 1991, p. 72). The Asuriní do Tocantins Indians downstream of the dam were never included in ELETRONORTE mitigation plans, and received no additional assistance or compensation for the impacts they suffered (Comissão Pró-Índio de São Paulo 1991, p. 78).

The Gavião-Parkatejê tribe was in the path of the transmission line to São Luís, which cuts a 19-km long swath through the Mãe Maria reserve. In April 1980, the tribe was paid Cr$40 million [approximately US$1.6 million] (Comissão Pró-Índio de São Paulo 1991, p. 68). The small amount of compensation paid in this and other cases is of much less importance than the fact that compensation was in cash rather than land. The money paid, as with virtually all cash payments of compensation to tribal peoples, serves little purpose other than freeing the electrical authorities to build the dam and transmission lines, because the tribe's lack of experience with money makes it almost inevitable that the funds are used for purposes that do not assure the tribe's continued wellbeing.

D.) Health

1.) Malaria

Anopheles mosquitos, which transmit malaria, are present throughout the Tucuruí area (Tadei and others 1983). A. darlingi, the principal vector of malaria in Amazonia, decreased in abundance after construction of the dam, although both the mosquito and the disease persist (Tadei and others 1991). A. nunez-tovari, the most common Anopheles species prior to filling the reservoir, decreased, as did A. triannulatus and A. albitarsis; A. braziliensis, which had not been found before filling, appeared in the post-filling collections. Species present both before and after filling for which there was no clear pattern of change in abundance are: A. oswaldoi, A. argyritarsis, A. mediopunctatus, A. evansae, A. intermedius and A. rangeli (Tadei and others 1991). The great increase in the human population of the area resulting from the presence of the dam, together with continued presence of an ample suite of malaria vectors, is a sure formula for severe health impacts from this disease.

2.) Mansonia mosquito plague

After filling the reservoir, populations of mosquitos of the genus Mansonia have exploded along the western shore of the lake. The mosquitos that have become a "plague" are mostly M. titillians, but also include M. pseudotitillans, M. indubitans and M. humeralis--which bite both by night and by day (Tadei and others 1991). Biting intensity was measured at 600 bites/hour on exposed human subjects (Tadei and others 1991). The swarms of these insects make life intolerable in the areas where they are concentrated, and caused a significant number of residents to leave for more hospitable locations. The explosion of mosquitos was a predictable consequence of the aquatic weeds in the reservoir, which are believed to provide breeding grounds for these mosquitos throughout Amazonia. The prevailing winds concentrate the weeds, such as water hyacinth (Eicchornia crassipes), water lettuce (Pistia spp.), and Salvinia spp. along the reservoir's left bank. The initial explosion of macrophytes (especially Salvinia auriculata), which covered much of the reservoir's surface in the first year, died back to its present level as the initial flush of nutrients was exhausted. The current level of water weed infestation, and hence the current locally intolerable level of mosquito infestation, appears to be stable.

Mansonia mosquitos do not transmit malaria, but they do transmit several arboviruses (Brazil, ELETRONORTE 1989b). It can also be a vector for filaria, the parasitic worm that causes elephantiasis. Although this disease occurs in neighboring countries such as Suriname, it has not spread to Brazilian Amazonia. The reason the disease has not spread is unknown, since Mansonia mosquitos occur throughout Amazonia (W.P. Tadei personal communication 1991).

The Mansonia mosquito plague affects the Gleba Parakanã settlement area severely. To a somewhat lesser degree it also affects the villages to which the Parakanã Indians have been relocated (about 30 km west of the reservoir).

3.) Mercury

Mercury methylation represents a major concern for hydroelectric development in Amazonia. Mercury is concentrated biologically, and concentrations increase by an order of magnitude with each step up the food chain. Humans tend to occupy the top position and can be expected to harbor the highest levels of mercury.

An estimated 50-70 t of mercury are released annually in the form of atmospheric aerosols when Amazonian gold miners amalgamate their gold (Pfeiffer and de Lacerda 1988, p.

329). It is likely that some of this is transported to hydroelectric reservoirs. The Serra Pelada gold mine lies 110 km SW of the southern tip of the reservoir, in the Itacaiunas River basin. Mining at Serra Pelada is estimated to have released 360 t of Hg into the environment between 1980 and 1986 (Porvari 1995, p. 110). Gold at the Serra Pelada mine was exhausted by the end of the 1980s, but active mines continue to be worked at a number of sites in the Tucuruí catchment, including the Rio dos Mortes and the upper Araguaia Basin.

Aerial transport of mercury over 1000 km has been found in Canada, where the increase in industrial sources in the United States immediately following World War II is registered in lake sediments in the Hudson Bay area in the extreme north of Canada (Marc Lucotte personal communication 1993). Mercury contamination in reservoirs in northern Canada is well known (Bodaly and others 1984). The Cree Indians who eat fish from the reservoirs have had serious health consequences.

Mercury concentrations in sediments and water in the Itacaiunas and Paraupebas Rivers (near Carajás and Serra Pelada) are higher than those in the Madeira River, which has become notorious for mercury contamination (Fernandes and others 1990). Since fish can migrate, it is possible that contamination comes from the mining areas, and this is stressed by ELETRONORTE officials (Paulo Edgar Dias Almeida personal communication 1991). However, the likelihood of fish migration explaining the phenomenon in a substantial number of species is small.

Total mercury concentrations in plants in the forest near Tucuruí have been found to be much higher than those in Canada where mercury contamination of reservoirs is well established (Marc Lucotte personal communication 1993). The same phenomenon has been demonstrated in French Guiana (Roulet and Lucotte 1995). It is likely that high concentrations in soil and vegetation in Amazonia have built up from background deposition over millions of years, rather than from recent anthropogenic inputs (Roulet and others 1996).

The key step leading to mercury contamination of human populations is methylation of metallic mercury. Large inputs of metallic mercury (Hg), as from goldmining, are not necessary for mercury contamination to be a health risk to humans because background levels of Hg in soils and vegetation (mainly from volcanic sources, but also from long-distance transport from industrial centers) are sufficient to have serious consequences when environments that facilitate methylation are provided. Water chemistry differences among Amazonian rivers are much more important than the presence of goldmining activity in explaining differences in Hg contamination levels in riverside residents (Silva-Forsberg and others 1999).

Methylation is occurring in reservoirs, as indicated by high mercury levels in fish (Porvari 1995) and human hair (Leino and Lodenius 1995) at Tucuruí. In a sample of 230 fish taken from the reservoir, 92% of the 101 predatory fish had Hg levels higher than the 0.5 mg Hg kg^{-1} fresh weight safety limit in Brazil (Leino and Lodeius 1995, p. 109). The tucunaré (Cichla ocellaris and C. temensis)--a predatory fish that makes up over half of the commercial catch at

Tucuruí, is contaminated with high levels, averaging 1.1 mg Hg kg^{-1}, or over twice the 0.5 mg Hg kg^{-1} fresh weight safety limit. In order to stay within the recommended consumption rates, one could eat a maximum of one meal of tucunaré per week (M. Lucotte personal communication 1993). Many residents around Tucuruí eat fish every day, as do many people in Belém where much of Tucuruí's fish harvest is marketed.

Mean Hg in hair of people fishing in the reservoir was 65 mg kg^{-1} of hair (Leino and Lodenius 1995, p. 121), a value many times higher than that in goldmining areas. For example, in gold mines near Carajás, Hg concentrations in hair ranged from 0.25 to 15.7 mg kg^{-1} of hair (Fernandes and others 1990). Data from the Tapajós River have indicated measurable symptoms, such as visual field reduction, among riverside residents with hair Hg levels substantially lower than both the levels found at Tucuruí and the 50 mg kg^{-1} threshold that is currently recognized as the standard (Lebel and others 1996). The Hg concentrations in human hair at Tucuruí are already more than double those that have been found to cause fetal damage, resulting in psychomotor retardation (Leino and Lodenius 1995, p. 124).

The human health consequences of mercury poisoning can be devastating, and are not understood by most people in Amazonia. Mercury concentrates in the body throughout a person's life--it is not removed by natural cleansing processes. Cooking fish does not alter the levels or toxicity of methylmercury. The appearance of severe symptoms--even death in severe cases--can occur with great rapidity after years of apparent health. In Minamata, Japan, healthy fishermen could be stricken and die within less than a week of the onset of symptoms. Mercury is concentrated in the fetus--a healthy mother can often give birth to a deformed child (Harada 1976). The time before symptoms occur is very long. In Minamata, the Chisso Chemical Company began dumping mercury waste into Minamata Bay in 1932, yet it was not until 1956--24 years later--that the first case of contamination was recognized. Many people in Amazonia today are eating fish and feeling no ill effects, leading them to the mistaken conclusion that they are escaping the consequences of mercury poisoning.

4.) Other Potential Health Problems

Schistosomiasis could potentially affect the area. The planorbid snails (<u>Biomphalaria</u> spp.) that serve as vectors for the parasite occur in the area (de Mello 1985). Fortunately, they are not yet infected by the helminth parasite <u>Schistosoma mansoni</u>. The disease is widespread in northeastern Brazil and in the state of Minas Gerais, making it likely that the parasite will eventually reach Tucuruí (Junk and de Mello 1987).

Chagas' disease represents a potential health problem as the reduviid bugs (assassin bugs, or <u>barbeiros</u>) that transmit the disease occur in the area. The parasite (<u>Trypanosoma cruzi</u>) has been found in the area in three species of <u>barbeiros</u>: <u>Panstronglysus geniculatus</u>, <u>□hodnius pictipes</u> and <u>Lutzomaia anduzei</u> (Arias and others 1981, pp. 7-10). In general, the factor most closely associated with outbreaks of Chagas' disease is poverty: housing with mud walls and thatched roofs are especially prone to harboring the vectors. The prevalence of poverty in the area is evident. The flow of migrants attracted by the dam has resulted in much larger numbers of poor people in the area.

E.) Economic Distortion

Brazil has committed itself to supplying subsidized cheap power to foreign aluminum firms in Barcarena (Pará) and São Luís (Maranhão). This distorts the entire Brazilian energy economy, inflicting wide-ranging social costs. ALBRÁS (the consortium that smelts aluminum in Barcarena) alone received US$395.5 million in subsidies from the Brazilian government over the period from January 1985 to May 1994, and in 1993 the total paid to this consortium was US$97.9 million (Brazil, Conselho Nacional da Amazônia Legal 1994, p. 41). Almost two-thirds of the power generated by the Tucuruí Dam is supplied at heavily subsidized rates to the aluminum industry in Barcarena and São Luís. Tucuruí's 4000-MW installed capacity generates 2059 MW (18.03 tWh) annually (Brazil, ELETRONORTE nd [1992], p. 3); the 1985 energy use for aluminum manufacture was 625 MW in São Luis and 630 MW in Barcarena (Gitlitz 1993). Expansion of the mill's capacity at Barcarena (CVRD 1997) implies an energy use of 677 MW by 1996. Assuming 2.5% transmission loss (see Fearnside 1997), 65% of the available output is used for aluminum.

Brazil loses astronomical sums with the subsidy given to the aluminum industry. The root of the problem is Portaria No. 1654 of the Ministry of Mines and Energy, dated 13 August 1979 (published in the Diário Oficial da União of 16 August 1979), which concedes electricity for a period of 20 years at a rate linked to the international price of aluminum, the energy used in the smelting not being allowed to exceed 20% of the international price of the product. When aluminum is cheap, as it is now, the companies pay almost nothing.

International financiers of dams in Brazil, such as the World Bank, are essentially channeling money to Japan instead of to Brazil. The funds build dams to supply electricity to Brazilian cities that could be supplied from existing dams, such as Tucuruí, but are not because the Brazilian government is effectively giving away Tucuruí's power to Japan in the form of subsidized aluminum ingots.

The entire Brazilian economy has been distorted by the price concessions negotiated as part of the agreement to allow construction of Tucuruí. By 1991 the two aluminum smelters supplied by Tucuruí were using 5% of all of the electrical energy in Brazil (Pinto 1991a). The percentage of energy use represented by "energy-intensive industries," of which aluminum is the most important but which also include steel, iron alloys, chlorine and paper pulp, rose from 33% of industrial energy use in 1975 to 41% in 1987 (Lobo 1989). Brazil's heavy subsidy of electricity rates explains the growth, especially in the export sector. Brazil's export products had an average energy content of 674.9 kWh per US$1000 exported in 1975, rising to approximately 1000 kWh per US$1000 in 1989 (Lobo 1989). In 1985, Brazil charged aluminum manufacturers US$0.010 per kWh, while Japan charged US$0.069 (Lobo 1989).

On a global scale, the subsidy of energy for aluminum permits wasteful use of this metal. Aluminum is used, for example, for cans for soft drinks and beer; even if recycled several times these eventually wind up in the trash. An aluminum can without recycling uses 7000 British thermal units (BTU) of energy, a recycled can uses 2500 BTU per use, while a reusable bottle refilled 10 times consumes an average of only 500 BTU per use (Young 1991, p. 24). If the true cost of aluminum were charged for the product, including the cost of building hydroelectric dams and compensating for their environmental and social impacts, aluminum would be much more expensive and would only be used for purposes that have no substitute. The principal aluminum-consuming countries are not building more large dams, having found that the financial, social and environmental costs of dams are too heavy. They would much prefer to export these impacts to countries like Brazil, while continuing to enjoy the benefits in the form of cheap aluminum.

Subsidies were revoked for new projects in August 1985, but continued for existing projects; the ALBRÁS and ALUMAR contracts run to 2004 (Lobo 1989). In March 1990, soon after Brazil's former President Fernando Collor de Mello took office, deep cuts in incentives were announced, with the goal of eliminating all government subsidies from the Brazilian economy. Soon afterwards, however, exceptions began to open up. The most important was the smelting of aluminum, for which continued subsidies were guaranteed. The subsidy for aluminum narrowly missed being abolished by the National Congress in April 1990 (<u>Gazeta Mercantil</u> 7 April 1990).

Power generated by Tucuruí does little to improve the lot of those who live in the area: a fact dramatized by high-tension lines passing over hut after hut lit only by the flickering of kerosene lamps (<u>lamparinhas</u>). Most of the power from Tucuruí supplies subsidized energy for multinational aluminum plants in Barcarena (ALBRÁS-ALUNORTE, of Nippon Amazon Aluminum Co. Ltd. or NAAC, a consortium of 33 Japanese firms) and in São Luís (ALUMAR, of the U.S. firm Alcoa, and the British and Dutch firm Billiton). Companhia Vale do Rio Doce (CVRD) maintains 51% and 61% interests in ALBRÁS and ALUNORTE, respectively (CVRD 1983). The power sold to the aluminum companies is at only one-third to one-half the cost of generation: according to Aureliano Chaves, then-Minister of Mines and Energy, power generated at Tucuruí at a cost of US$38 per MW was being sold for US$10.5-16.5 (Silva 1991). According to the National Department of Water and Electrical Energy (DNAEE) the cost of generation is US$50 per MWh at Tucuruí, as compared to the mean for Brazil of US$20 per MWh (Monosowski 1990). The power sold to ALBRÁS in 1989 was paid at less than one-sixth of the rate paid by residential consumers in Brazil (Brazil, ELETRONORTE 1989b). In 1990 ALBRÁS paid 22 mils per KWh and ALUMAR 26 mils per KWh, while a residential consumer paid 64 mils per KWh--three times more than ALBRÁS (<u>Jornal do Brasil</u> 17 April 1990). The difference between the price charged the aluminum smelters and the cost of generation is subsidized by the Brazilian populace through their taxes and home electricity bills.

III.) BENEFITS OF TUCURUÍ

A.) Power Generation

Power generation is normally the primary source of social benefits from hydroelectric dams, as the employment created and goods produced are usually proportional to the electrical power generated. Tucuruí-I has an installed capacity of 4000 MW (12 generators of 330 MW each and two of 20 MW each). No dam produces as much power as its installed capacity, as the amount of water in Amazonian rivers varies on an annual cycle and is inevitably insufficient during part of the year to run all of a dam's turbines. The firm power, or that which can be counted on with a high probability, is 2115 MW for Tucuruí-I (Monosowski 1990).

Tucuruí-II would double the installed capacity from 4000 to 8000 MW, but this does not mean that the power output of the dam would be doubled. Additional power would be generated only during the season of high water flow, since during a substantial part of the year the output is limited by insufficient water in the Tocantins River rather than by the number of turbines. Additional dams providing storage and flow regulation upstream of Tucuruí would increase the output from Tucuruí-II, but would not alter its function as a supplier of additional power only during periods of peak flow. The ambitious plans for additional dams in the Tocantins/Araguaia Basin (Figure 2) illustrate the need for consideration of impacts of related projects.

B.) Employment

Financial loss is only a part of the impact of the subsidy to the aluminum industry. The quantity of employment generated by aluminum processing is minimal: there are 1200 jobs in Barcarena and 750 in São Luís. In 1986, ALBRÁS used 49.5% of all of the electricity consumed in the state of Pará (Brazil, ELETRONORTE 1987, pp. Amazonas-32 and Pará-12). The "workers town" at Barcarena, including dependents, shopkeepers, etc., has a population of only 5000 people; this town consumes more energy than Belém, Santarém, and all of the other cities of Pará together. Virtually any other use of electricity would bring greater benefits to Brazil (see Fearnside 1989).

The construction of Tucuruí cost a total of US$8 billion when the interest on the debt is included, according to the calculations of Lúcio Flávio Pinto (1991b). Considering the percentage of power used for aluminum, Tucuruí alone (which is only a part of the infrastructure supplied by the Brazilian government) cost US$2.7 million per job created.

IV.) BRAZIL'S SYSTEM FOR ASSESSING SOCIAL IMPACTS

Social impacts played little if any role in the initial decision to build the Tucuruí Dam. This decision was largely based on financial benefits to distant actors, particularly in Japan and France, and to Brazilian beneficiaries of the construction contracts (see Teixeira 1996, Pinto 1991a,b). Since Tucuruí was planned and built during Brazil's military regime, it is perhaps unsurprising that little importance was attached to negative effects on local residents in Amazonia. Since then, requirements have been implemented for a Report on Impact on the Environment (RIMA), an Environmental Impact Study (EIA), and a public hearing (<u>audiência</u>

pública). These cover social as well as environmental impacts. One might hope that these advances will lead to a decision-making process whereby the benefits and the costs (including social benefits and costs) of proposed developments are estimated in a thorough and objective way and are publicly debated prior to taking decisions on development projects such as hydroelectric dams. However, recent experience with these safeguards in the case of Amazonian dams indicates the ease with which their intended protections can be thwarted when political interests make project approval and construction a priority (Fearnside and Barbosa 1996a,b). Strengthening these procedures should be a top priority if the worst impacts of unfettered development are to be avoided. Evaluating future development proposals can be greatly improved if lessons are learned from past experiences, such as the case of Tucuruí.

Brazil's impact assessment requirements for dams and other development projects are vague with respect to the degree to which social impacts must be assessed. This stems from Law No. 6938 of 31 August 1981 and Decree No. 8835 of 10 June 1983, creating the National Council of the Environment (CONAMA), and the "regulamentation" of this law on 21 January 1986 (CONAMA Resolution 001/86). ELETRONORTE consistently takes advantage of the vague language to interpret minimal inclusion of social aspects (Sigaud 1990, p. 100, see also Teixeira 1996, pp. 118-120). In 1986 (i.e., after Brazil's political system had become more democratic) ELETROBRÁS produced a set of guidelines for impact studies that include some additional requirements for social evaluations (Brazil, ELETROBRÁS 1986).

A fundamental problem is that the EIA and RIMA are produced by consulting firms that are completely beholden to the project proponent, in this case ELETRONORTE. The proponent prepares the terms of reference, chooses the winning firm, and pays for the work. In addition, the final parcel of payment is not released until after the document has passed through a series of revisions in which the proponent can request changes in the content of the report (see Fearnside and Barbosa 1996b). The firms are therefore induced to prepare reports indicating a minimum of impacts, both by means of direct pressure and by their interest in being chosen for future consulting contracts.

Rosa and others (1995, p. 7) have proposed a redefinition of the hydropower "potential" of Amazonia that would eliminate sites from the list where social impacts would be clearly excessive. At present, official calculations indicate a total potential of 97,800 MW, which, if fully tapped, would flood 100,000 km^2 (Brazil, ELETROBRÁS 1987, p. 150). This would represent 2% of the Legal Amazon, or about 3% of the forested area. Just as potential sites are eliminated from the list where engineering factors such as topography and stream flow are inappropriate, sites with obvious social and environmental limitations could be eliminated early in the decision process--before pressures for dam construction become so strong that the projects are "irreversible." At present, calculations of hydropower potential include the assumption that all sites identified by physical criteria will be developed. The most urgent case is the estimated power output for the Belo Monte Dam, a calculation which apparently counts on regulation of the flow of the Xingu River by upstream dams that would have disastrous social impacts (Fearnside 1996).

V.) CONCLUSIONS

The social costs of the Tucuruí Dam were and continue to be heavy. These include displacement of the population in the submergence area and their subsequent relocation due to a plague of Mansonia mosquitoes, collapse of the fishery that traditionally had supported the population downstream of the dam, health effects including malaria and mercury contamination, and displacement and disruption of indigenous groups. The high financial cost and minimal employment produced by Tucuruí, which primarily supplies power for aluminum smelting, cause economic distortions with wide-ranging social impacts, including the opportunity cost of not having used the nation's financial and natural resources in ways more beneficial to the local inhabitants. In the case of Tucuruí, authorities systematically underestimated impacts and overestimated benefits.

ACKNOWLEDGMENTS

I thank the following people for valuable discussions about Tucuruí: Lúcia Andrade and Leonide dos Santos (Comissão Pró-Índio de São Paulo); Deputada Aída Maria Silva (Assembléia Legislativa, Belém); J. Revilla Cardenas, E.G. Ferreira, R. Leite, J.A.S.N. de Mello, and W.P. Tadei, (INPA); J. Carvalho (Projeto Parakanã, Tucuruí); E. Monosowski (Monosowski Consultants); I thank the staff of ELETRONORTE and Camargo Corrêa at Tucuruí for their patience with my questions, and the INPA staff at Tucuruí and the Sindicato dos Trabalhadores Rurais de Tucuruí for logistical assistance and information. The colonists of the Gleba Parakanã deserve special thanks for their time and warm welcome during my visit. Bruce Forsberg and Marc Lucotte provided valuable insights on mercury contamination. P.L.M.A. Graça, N. Hamada, S.V. Wilson and two reviewers commented on the manuscript. I thank the Pew Scholars Program in Conservation and the Environment, the National Council of Scientific and Technological Development (CNPq AI 350230/97-98) and the National Institute for Research in the Amazon (INPA PPI 5-3150) for financial support. This paper was presented at the "Simpósio sobre Ecologia de Reservatórios: Estrutura, Função e Aspectos Sociais", Instituto de Biociências, Universidade Estadual Paulista (UNESP), Botucatu, São Paulo, Brazil, 25-28 May 1998.

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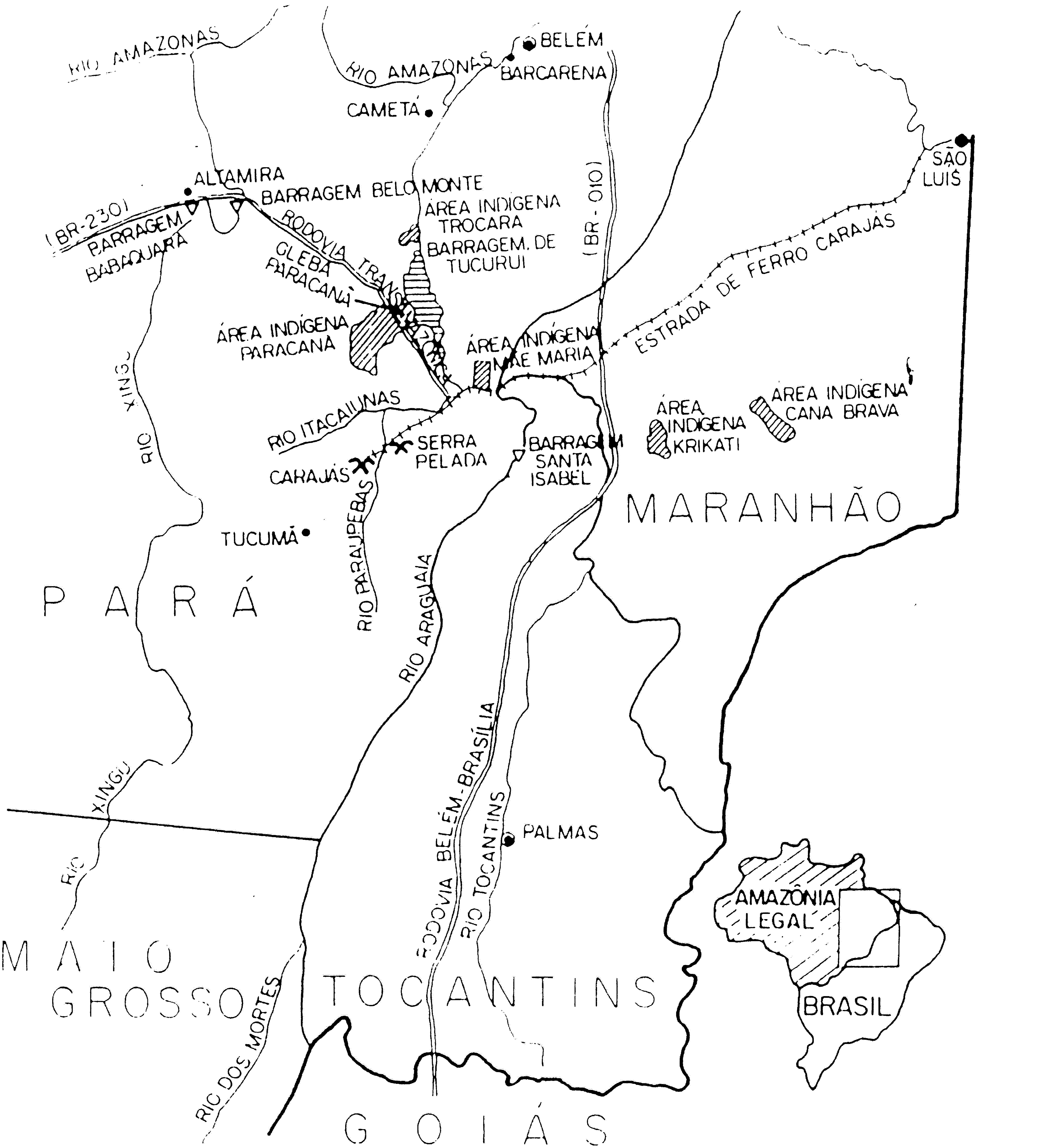
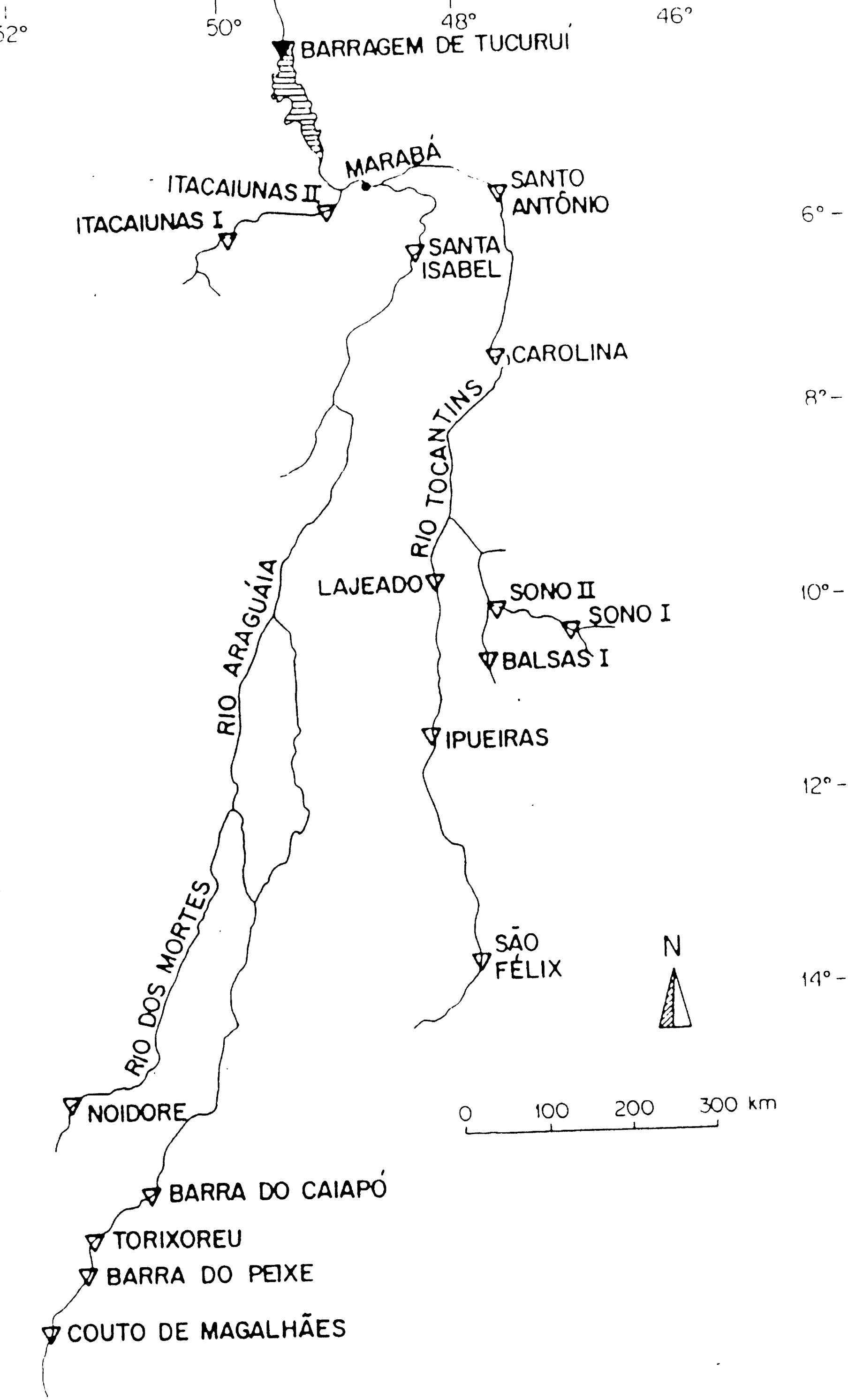
FIGURE CAPTIONS

Figure 1. The Tucuruí reservoir and locations mentioned in the text.

Figure 2. Planned hydroelectric development in the Tocantins/Araguaia Basin.


RIO AMAZONAS
BELÉM
BARCARENA
RIO AMAZONAS
CAMETÁ
SÃO LUÍS
ALTAMIRA
BARRAGEM BELO MONTE
(BR-230)
BARRAGEM BABAQUARA
RODOVIA TRANS
ÁREA INDÍGENA TROCARA
BARRAGEM DE TUCURUÍ
(BR-010)
GLEBA PARACANÃ
ESTRADA DE FERRO CARAJÁS
ÁREA INDÍGENA PARACANÃ
ÁREA INDÍGENA MÃE MARIA
ÁREA INDÍGENA CANA BRAVA
RIO ITACAIUNAS
ÁREA INDÍGENA KRIKATI
SERRA PELADA
BARRAGEM SANTA ISABEL
CARAJÁS
RIO XINGU
MARANHÃO
TUCUMÃ
RIO PARAUPEBAS
PARÁ
RIO ARAGUAIA
RODOVIA BELÉM-BRASÍLIA
RIO TOCANTINS
RIO XINGU
PALMAS
AMAZÔNIA LEGAL
MATO GROSSO
TOCANTINS
BRASIL
RIO DOS MORTES
GOIÁS



52°
50°
48°
46°
BARRAGEM DE TUCURUÍ
MARABÁ
ITACAIUNAS II
ITACAIUNAS I
SANTO ANTÔNIO
SANTA ISABEL
6°
CAROLINA
8°
RIO TOCANTINS
RIO ARAGUÁIA
LAJEADO
SONO II
SONO I
BALSAS I
10°
IPUEIRAS
12°
RIO DOS MORTES
SÃO FÉLIX
N
14°
0
100
200
300 km
NOIDORE
BARRA DO CAIAPÓ
TORIXOREU
BARRA DO PEIXE
COUTO DE MAGALHÃES