HYDRO-ELECTRIC POWER PROPOSAL FOR THE IRALALARO-PAITCHAU KARST, TIMOR-LESTE

– Greg Middleton, Susan White and Nicholas White

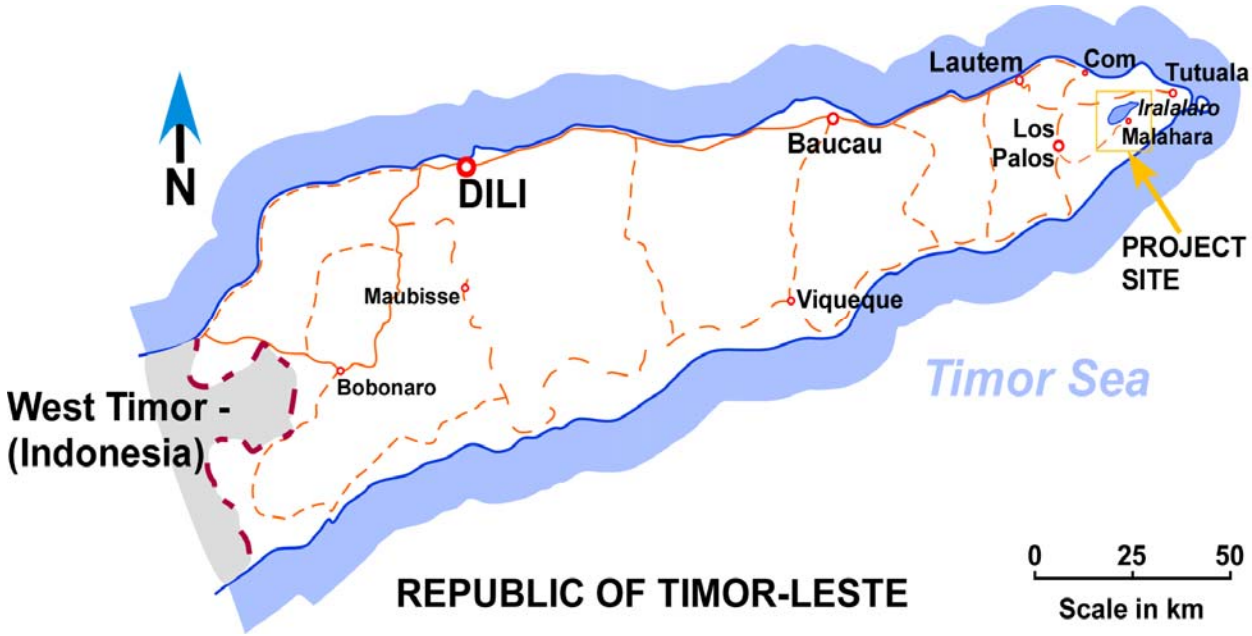

Fig. 1. The Iralalaro hydro-electric scheme would be located in a large karst area near the eastern tip of Timor-Leste.

The government of Timor-Leste (East Timor) is considering constructing a hydro-electric power scheme in the far east of the island (Fig. 1) which would have a major impact on a significant karst area.

Alerted by Senator Bob Brown and supported by the Australian Conservation Foundation and the local Haburas Foundation, Australian cavers Susan and Nicholas White and Greg Middleton travelled to the site in August 2005 to investigate the proposed scheme and its possible impacts on the region. This article is based on their report.

DEVELOPMENT OF THE HYDRO-ELECTRIC PROPOSAL

The scheme would involve the diversion of the entire flow of the Irasiquero river, the only surface outlet from Iralalaro, the country's largest lake/wetland area, away from its sinkhole at Mainina into a tunnel drilled under the Paitchau Mountains. The tunnel would feed water through the range to a powerstation at sea level on the south coast, involving a fall of about 300 metres (Fig. 2).

We were able to obtain some basic background to the proposal through ACF and Haburas, in the form of part of a 1989 'feasibility report' prepared by Italian, Swiss and Indonesian consultants (ELC-Electroconsult et. al. 1989), a 2003 update in the form of a 'mission report' by Norwegian hydro-electric consultants (Adeler et al. 2003) and a 2004 'environmental assessment scoping report' by Australian consultants (EPANZ Services 2004a).

From the start, the scheme appears to have been developed on inadequate information and with no comprehension of the consequences involved in such development on karst. Thirty years later the situation has not significantly improved.

The original 1975 proposal for a hydro scheme by Japanese consultants envisaged the building of a dam on the Irasiquero River to raise the level of Iralalaro Lake by about 3.7 m to generate 400 GWh annually. Water from the dam would flow through a short power tunnel to an underground powerstation with one large turbine and a tailrace discharging the water to the sea. About this scheme ELC-Electroconsult et al. (1989, p. 3-2) commented:

> *No site investigations, topographical, geological or hydrological, are mentioned in the report, to support the preliminary design developed; in particular, there is no mention about the karstic limestone formations in the area.*

A modified proposal prepared in 1985 by Perusahaan Umum Listrik Negara (PLN), Survey Division proposed two options:

- A run-of-river scheme – not involving any raising of the lake level; an installed capacity of 35 MW was estimated to be capable of generating up to 274 GWh/year; and
- A reservoir scheme, raising the lake level to a maximum of 333 m a.s.l. (its natural level fluctuates between ~321 and 330 m); installed capacity of 42 MW was estimated to generate up to 320 GWh/year.

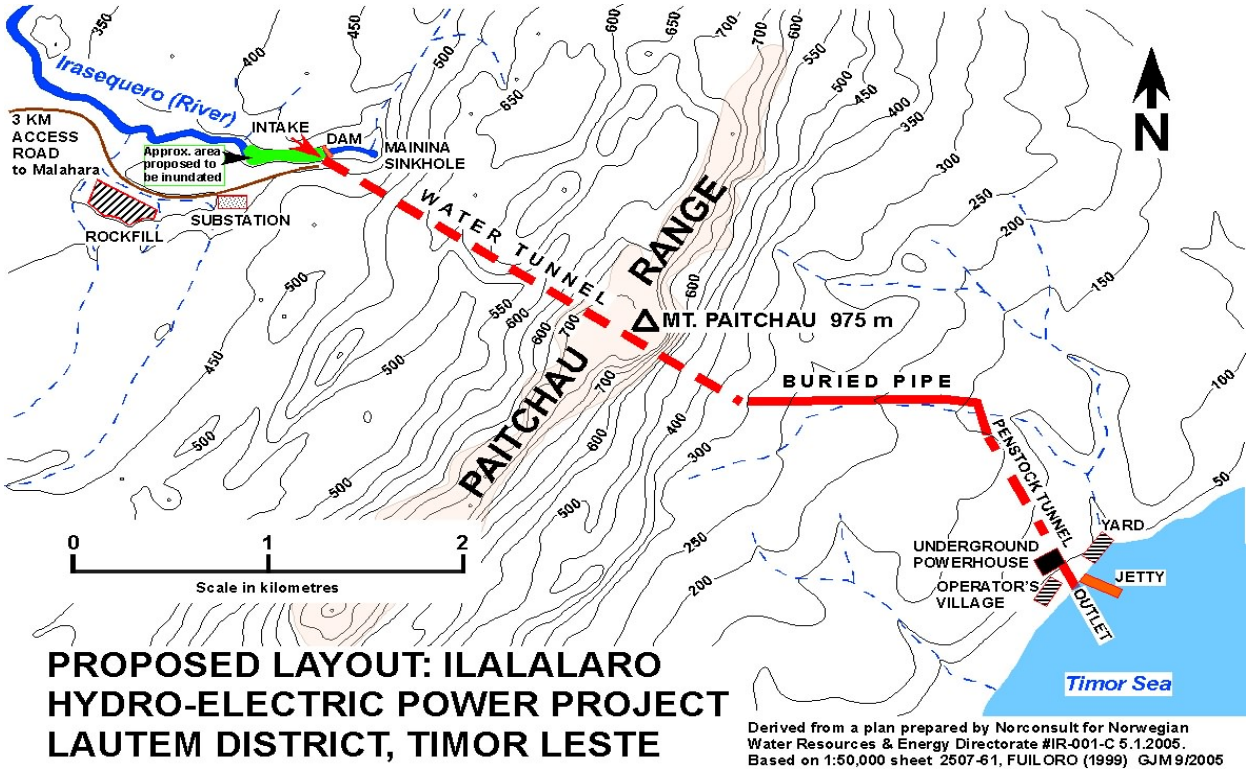

Fig. 2. Proposed layout of the Iralalaro hydro-electric scheme, involving diverting the Iralalaro river from its underground course to a powerstation.

A third version of the proposal, prepared in 1989 by ELC-Electroconsult, Motor Columbus, P.T. Arkonin and P.T. Asianenco (ELC-Electroconsult et al. 1989) conceded, for the first time, that karst was a serious issue. This was a major concession, resulting from the realisation that because of the karstic nature of the area, it is likely that any dam built on the Irasiquero River or that attempted to raise the level of the Iralalaro Lake would result in the water leaking through underground conduits. Such a dam would fail to impound water and the task of sealing all possible leakage points would be quite impractical – not to mention the costs involved. However it suggests that as a "run-of-the-river" scheme it was both technically and economically sound. The report concluded that the project did not present particularly complex technical problems and that the construction could be carried out with conventional methods and entrusted to Indonesian construction companies. The economic and financial analyses were seen to meet the profitability criteria generally accepted by international agencies for the financing of developments of this type. However it acknowledged that the hydrological data was 'scanty' and that more needed to be known about the operation of the underground drainage system; it also recommended a comprehensive geological study be carried out, including consideration of the area's 'tectonic style' (probably an admission of lack of knowledge of its structural stability).

The 1989 report formed the basis of the 'Mission Report' prepared by a Norwegian team of hydro-engineers in 2003 (Adeler et al. 2003). This report considers Timor-Leste's energy situation and alternative power sources and recommends the updating of the 1989 feasibility study for Ira Lalaro hydropower scheme with additional studies on geology and geo-hydrology. In 2004 a review by the Asian Development Bank (ADB 2004) supported the assessment that the Iralalaro scheme was the most cost-effective of 8 schemes considered.

Notably, this report had no comment to make on environmental impact, except to observe that another feasibility report was underway. The issue of extra costs in relation to expensive construction and unforseen problems likely to arise in karst terrain was neither acknowledged nor addressed. An interesting aspect of all these reports is that, while over time the potential for problems to arise in such development on karst was increasingly acknowledged, no specialised report on these aspects was commissioned.

Evidently the recommendations of the 'Mission Report' were accepted because consultants for the same Norwegian agency (NVE) went on to prepare a 'Scoping Report' for an environmental assessment of the project (EPANZ Services 2004a). This report identified "major concerns within the project", including: (a) failure to establish the fate of the water sinking at Mainina, (b) location of the project within one of the last, and probably the largest remaining, Tropical Dry forested area within Timor-Leste, proposed as a protected area covering 620 km^2, (c) that 16 bat species are present, including two undescribed specimens that may be new records for Timor. Eleven of the bat species are thought to be obligate cave roosters (EPANZ Services 2004c), (d) that the waters of Lake Iralalaro and the Irasiquero River form a closed aquatic system with unique characteristics and a new fish species, *Craterocephalus* sp. nov., was discovered in the middle section of the Irasiquero (EPANZ Services 2004b).

Subsequent to the Scoping Report, and perhaps arising out of the concerns it expressed,

particularly in relation to knowledge of geology, additional studies are reported to have been carried out (Demetrio de Carvalho pers. comm.) In particular, a seismic study has been conducted across the Paitchau Range along the line of the proposed tunnel which may have been attempting to assess the suitability of the rock for tunnelling, and some dye tracing has been undertaken to try to determine the fate of the water sinking at Mainina. It is understood that dye was detected at three springs on the southern side of the Paitchau Range, as might be expected, and at four springs towards the north coast, in the vicinity of Com, which is quite unexpected and would appear to greatly increase the potential direct impacts of the proposed hydrological diversion.

However, despite the acknowledgement in the later reports, especially the Scoping Report, of the significance of the karst and the potential vulnerabilities associated with development on karst, no detailed study of the karst appears to have been undertaken by the proponents. This leaves considerable risks in both constructional and environmental areas unexplored. The issue of the costly and risky nature of construction in intensively karstified areas continues to be ignored.

CLIMATE

The eastern end of East Timor has a wet tropical monsoonal climate characterised by a hot summer, distinct monsoonal wet and dry seasons and relatively small temperature variation. The Lautem district is the wettest in East Timor. The limited data available is from Los Palos (Fig. 1) where there is mean annual rainfall of 1,921mm concentrated in the wet season (Nov.-July), monthly average temperatures range from 28.9°C (Nov.) to 18.8°C (Aug.), humidity ranges from 82.2% (May) to 73.2% (Oct.) and estimated evaporation at Los Palos is 1,033 mm p.a. Evaporation exceeds rainfall from August to November. Rainfall records cover an even shorter term for Malahara and Maupitine, east of Los Palos and south of the lake, but show ~37% less rainfall than Los Palos, with similar evaporation (EPANZ Services 2004a). With such limited data any lake and aquifer recharge calculations have severe limitations.

REGIONAL GEOLOGY

The geology of the eastern end of Timor Leste is predominantly limestone: only the Permian 'Cribas Formation' and the Recent 'Suai Formation' are significantly non-carbonate. There are several theories attempting to explain the tectonic and formational history of the island and discussion on the geological history continues. However all theories agree that the island is composed of contributions from the Australian continental plate and the highly deformed rocks from the Banda Terrane. This suggests that Palaeozoic conditions similar to that shown in the Bonaparte Gulf Basin (Northern Australia) should be present although the carbonate sedimentary rocks deposited since the Permian indicate that the area has been an island for a long time as little non-carbonate material is present (Audley-Charles 1968).

The Permian Cribas Formation is amongst the oldest rocks recorded from Timor-Leste and comprises fossiliferous shallow water non-carbonate sediments derived from elsewhere, possibly from the erosion of northern Australia (Audley-Charles 1968). Limestone occurs commonly at the top of the unit. Its contact with the overlying Triassic Aitutu Formation is not clear. The Cribas Formation is insoluble and is likely to form an aquiclude where it underlies limestones and is present as upthrust sections in the Paitchau Mountains south of the Iralalaro polje and along the north coast.

Overlying the Cribas Formation is the 1000m thick Triassic Aitutu Formation which is a marine, calcite or aragonite mud, probably deposited by precipitation from sea-water by the activity of plankton or bacteria, in a shallow marine environment under low-energy conditions. This is a highly soluble lithology; less than 5% of the material is insoluble. The Aitutu Formation is present as uplifted sections in the Paitchau Mountains (UNESCAP 2002).

The Aitutu Formation is followed by a very large time gap (over 200Ma) in the geological sequence, from about 210 Ma (late Triassic) to about 1.6 Ma (early Pleistocene) when the Baucau and Poros Limestones formed. Further west there are Jurassic, Upper Cretaceous and Palaeogene deposits but none are reported east of Los Palos. Lack of data seriously constrains the geological understanding of the eastern end of the island and the understanding of the lithologies and structures underlying the Iralalaro polje and is a serious problem for development in the area (UNESCAP 2002).

The area was subjected to tectonic activity including folding up until the Pliocene. Except for the upthrust Permian and Triassic sediments of the Paitchau Mountains, the post-Pliocene sediments, e.g. the Baucau Formation, blanket the eastern end of the island and are assumed to unconformably overlie older folded and/or faulted sedimentary rocks (UNESCAP 2002).

The Baucau Formation is a hard, vuggy, cavernous, massive, white fossiliferous reef limestone (Audley-Charles 1968) occurring as a series of terraces (representing raised beaches) and has a maximum thickness of ~100 m. The raised beaches indicate the continued uplift history of the area to recent times, and are currently being studied by geologists from the University of Melbourne. It is widespread in the eastern part of the island and controls the topography of the Baucau and Lautem plateaux. The lacustrine Poros Formation occurs only east of Los Palos on the Lautem Plateau and must have been deposited after the Baucau Limestone on which it rests had been elevated above sea-level. The bed of the Iralalaro polje is in Quaternary alluvium, which here appears to be a heavy black clay. It may be the relative impermeability of this clay, which allows the lake to hold water.

Fig. 3. View north across the flat-floored Iralalaro polje from foothills of Paitchau Range.

LANDFORM GEODIVERSITY AND GEOMORPHOLOGY

The Iralalaro-Paitchau Mountains area contains a wide range of karst-related landforms, including a large polje, collapse dolines, sinkholes, blind valleys, karren and caves. An indication of the paucity of the earth science studies so far carried out in connection with the proposed project is the fact that prior to our visit (in August 2005) no one had recognised that the feature marked on some maps as the "Fuiloro Plateau" and referred to by some consultants as "the Ira Lalaro depression" (ELC-Electroconsult et al. 1989, p. S-2) and by others as "a large karstic plateau" (EPANZ Services 2004a, p. 8) is, in fact, a huge *baselevel polje*.

Surficial karst landforms

This polje is the most outstanding single landform of the region and the widely fluctuating Iralalaro Lake occurs in it. It is clearly evident in a digital terrain model of the region and is also quite obvious at ground level (Fig. 3). Except for the limited description in our reports, it is completely undescribed.

We estimate the area of the Iralalaro polje to be around 100 km^2. which makes it large by international standards. Its catchment is virtually entirely within the karst, and has an area of 406 km^2. It is reported that the surface area of the Iralalaro lake fluctuates from 10 to 55 km^2.

Associated with the polje are a number of small dolines, some of which had water at their lowest points at the time of inspection (August 2005) but most of which were dry. A small number had vertical sides and were filled with water to within a metre or so of the surface (Fig. 4). While much smaller in scale, in form and appearance they mimic *cenotes* and they provide an indication of the level of the watertable below the polje floor during dry conditions. The principal drainage from the polje is via the Irasiquero River which runs for about 3.5 km south to the Mainina *sinkhole* or *swallet* (Fig. 5). The sink lies in a *blind valley* cut into the foothills of the Paitchau Range.

The Mainina sinkhole is a large and impressive feature at the southern end of the valley. The water sinks into a restricted swallet around a metre in diameter in the river bed. The water actually drains through holes only about 10 cm in diameter. Investigation of the swallet is difficult due to high velocities of flow, even in the dry season.

The *blind valley* has a high head wall composed of a large boulder slide. The boulders reach over 5m in diameter and are angular, indicating limited solutional modification. Small boulder caves are present in the boulder slide. It is unclear as to whether the slide is due to the collapse of a previous swallet and cave or just undermining of the head wall. Investigation failed to find any access to abandoned (dry) passages connecting with the present underground flow. The valley periodically floods up to a level of ~20m above dry season river level, as indicated by the absence of forest below that level. The swallet is unable to easily drain the high discharge of the Irasiquero River during the wet season, and the water dams back.

The area on the south side of the polje has a disrupted drainage pattern as seen on satellite photos of the area. Superficial runoff in the wet season probably drains underground through a range of small sinks, which are obscured by the forest cover. Except for the Irasiquero River and the polje, there is very limited surface water in the dry season.

Subterranean landforms, primarily caves

Very little documentation of caves has yet been carried out in the area. Prior to 2005, the only known records were of archaeological sites to the east of the polje, between Tutuala and the coast, and to the west around Baucau. The only significant cave survey seems to have been one by O'Connor and Veth (2005) of the outer part of Lene Hara Cave. There are locals in Tutuala who are happy to show visitors this cave (presumably normally for a fee). We are not aware that they provide any interpretation though it appears such caves are regarded with a certain reverence.

Lene Hara Cave has a very large entrance (Fig. 6) and a number of large, dry speleothems. It barely possesses a dark zone, and shows no strong tendency to follow any particular orientation, so appears not to be joint-controlled. However, near horizontal bedding is strongly displayed in the northern wall of the main chamber. There is evidence of surface flow from the rear of the cave in the wet season but no well-developed streamway and no evident connection to a subterranean watercourse. The floor is generally rocky or dusty and has been heavily trafficked.

Fig. 4. Small water-filled doline of cenote form in floor of Iralalaro polje.

The only area of flowstone in a near-natural state is adjacent to the southern wall towards the back of the chamber. The cave has a number of panels of ancient art in the entrance (Fig. 7) and excavation has established occupation back as far as 35,000 BP (O'Connor, Spriggs and Veth 2002).

Other caves in the vicinity of Tutuala have also been the subject of archaeological study in recent years. Ile Kéré Kéré is a high but narrow overhang on the Tutuala Scarp, overlooking the sea. It has large stalactites and flowstone deposits and wild bees build hives in its shelter; its art was recorded at least as early as 1967 (Almeida 1967, cited in O'Connor 2003).

This site is recognised for its spiritual values though, again, locals were happy to guide us there. Indeed, during the Indonesian period a concrete path was constructed for about 800 m from the road to the rockshelter, evidently to facilitate tourism. O'Connor (2003) lists nine other 'new' rock-art sites in the eastern part of Timor-Leste, at least 6 of which appear to be within the Iralalaro karst. Their speleological significance has not been assessed.

Lene Hara and other caves/rockshelters in the district contain a wealth of rock art documented by Glover (1986) and O'Connor (2003). There is potential for the caves of this region to have high archaeological significance, especially as Timor is seen as a likely stepping-stone on the route taken by humans to Australia more than 55,000 years ago (Mulvaney & Kamminga 1999). With the recent discovery of a new small-bodied human from cave deposits on the nearby island of Flores, interest in cave occupation sites on Timor is likely to increase.

In August 2005, the authors were shown a cave, known as Noi Noi Kuru, on a raised terrace of Baucau Limestone near the village of Malahara. Inspection revealed this to be a cave of significant extent and as it had not previously been documented, a survey was undertaken. The cave was found to be about 320 m in length, almost flat-floored and with chambers generally over 4 m high.

The cave is remarkable for the strength of its passage orientation, NE-SW, clearly the result of very pronounced joint-control of solutional enlargement. There is abundant evidence, in the form of significant areas of roof spongework, of the cave having been primarily formed by phreatic waters. There is no evidence of vadose stream action. The cave has abundant speleothems (Figs 8 & 9), large chambers and, with its almost flat floor throughout, is easily traversed.

Noi Noi Kuru could be opened as an 'adventure' show cave with a minimum of effort and could make a significant contribution to local ecotourism. However, it has served as a refuge for local villagers at times of invasion and civil strife. Sixty families were said to have sheltered in it for two months in 1975 when the Indonesians took over. There seems to be a feeling that it could be needed again someday.

It is clear that there is considerable karst, including cave, development of the Baucau Limestone. Although no large caves were observed in the limestones of the Aitutu Formation in the Paitchau Range, there were abundant surface karst features (karren) and one small cave was noted. Less than half a day was spent in this area and no deliberate search for caves was made. The lack of knowledge of caves in the Aitutu Formation is no indication that significant karst features are absent, as no exploration has occurred. Other caves on the southern slopes of the Paitchau Mountains were reported to have been used by Fretilin during the guerrilla campaign against the Indonesians. There is evidently potential for significant cave development in the area.

Hydrogeology

No detailed information is available on the groundwater and hydrogeology of the area. Substantial development is being planned in the absence of detailed hydrogeological data and the assumptions on which the water volumes have been based are at best unproven. If incorrect they would have serious consequences for the viability of the planned hydroelectric scheme.

The description of the hydrology in the Scoping Report cannot be accepted with any confidence as it is clear that the writes did not understand the karst. The failure to identify the polje and thus understand its close relationship with the groundwater, absence of any hydrogeological data and the failure to initiate its collection, and the lack of clarity as to the fate of water disappearing into the Mainina Sinkhole, both in geographical terms and as to quantities at different seasons show that the proponents seriously misunderstand the nature of the area. The failure to attempt a water budget is the result of this.

Fig. 5. The blind valley of the Irasiquero river ends at the Mainina sinkhole.

Surface and underground biodiversity

Studies such as that carried out for UNDP in 2001 (Sandlund et al. 2001) drew attention to the great natural values of the Iralalaro-Paitchau area. In particular the lake and the associated wetland ecosystem, the presence of saltwater crocodiles and the relatively undisturbed forest surrounding the lake itself.

The Iralaloro/Paitchau area contains the single largest area of tropical forest remaining in Timor-Leste and is considered to contain the single best representation of natural dry tropical habitats for the islands of Timor, Wetar, Atauro, Roti and Semau. Lake Iralaloro has the largest and most biologically significant wetland area in Timor-Leste.

While Tropical Dry forest and Tropical Semi evergreen forest habitats occur elsewhere in Timor-Leste, the only occurrence of Tropical Evergreen forest is restricted to a small area above the Mainina [sink]hole on the north side of the Paitchau range, which makes this area of particular significance (EPANZ Services 2004a, p. 18)

In relation to avifauna, a survey in 2003-04 by BirdLife International (Trainor 2004) found that 'Paitchau-Iralalora' and Jaco Island constitute two of nine 'Important Bird Areas' of Timor-Leste in that they possess "one or more species of global conservation concern, or one or more globally restricted-range bird species" and that Paitchau-Iralalaro had the highest number of 'key' bird species (16). There is no information or discussion on the importance of the polje to bird life.

Bats dominate the native terrestrial mammal fauna of Timor, comprising more than 90% of all species. A study of bats in the Iralalaro-Paitchau area by specialists from the NT Department of Infrastructure, Planning and Environment in 2004 (EPANZ Services 2004c) found 12 of the 24 species known from the Lesser Sunda islands (including Timor) to be present and added 3 or 4 new species.

The most abundant bat was found to be the cave-roosting fruit bat *Rousettus amplexicaudatus* (Geoffroy's rousette), followed by *Rhinolophus canuti* (Canut's horseshoe bat) and two yet to be identified *Murina* species; *Hipposideros sumbae* (Sumba leaf-nosed bat) and *Rhinolophus celebensis* (Sulawesi horseshoe bat) also appear to be abundant in the area.

The study found that many species of bat were likely to be obligate cave roosters. The only other native mammals recorded by the consultants are the Long-tailed Macaque *(Macaca fascicularis)*, Common Spotted Cuscus *(Phalanger orientalis)* and deer *(Cervus timorensis)* – are all introduced to Timor. Glover (1986) adds the civet 'cat', *Paradoxurus hermaphroditus.*

The lake and Irasiquero River contain a population (estimated at 200-500) of the estuarine crocodile, *Crocodylus porosus.* The crocodile is revered as a totem animal by the local communities and is not hunted by them – however it has been hunted by others in the past. McCord's Long-necked Turtle *Chelodina mccordii* is found in the lake and river. Formerly thought to be restricted and critically endangered, it now appears to be common in the area, up to 30/day being caught by the people of Malahara village alone (EPANZ Services 2004a).

A study of the aquatic ecology of the area by the Environmental Research Institute of the Supervising Scientist, Darwin (EPANZ Services 2004b) found:

- an unusually high diversity of aquatic plants in the Irasiquero river;
- a diverse macroinvertebrate fauna (57 families recorded) but no decapod crustaceans in the Iralalaro lake or Irasiquero river, presumably because they have no continuous surface water connection to the sea;
- "Spring sites on the Irasiquero contained commonly found amphipod and isopod crustaceans – groups typical of groundwater ecosystems. Thus groundwater below the Mainina sinkhole may harbour a specialist fauna - so-termed 'stygofauna'."
- 28 species of fish (of which 21 were in freshwater habitats and eight were in the Vero River estuary), most of which are widespread in the region, but two of which "are new to science and possibly endemic to Timor (*Craterocephalus* sp. nov. found in Irasiquero River and *Lentipes* sp. nov. found in Vero River)."

Very little is known of the subsurface fauna of the study area. The only study carried out to date to deliberately investigate part of this fauna is that on bats, mentioned above. During the authors' survey of Noi Noi Kuru, a number of invertebrates were observed, including spiders, cave crickets and a whip-scorpion or scorpion-spider.

Environmental consultants (EPANZ Services) to the Norwegian group promoting the hydro-electric development have drawn attention to the need, if the project proceeds to the environmental assessment stage, for "*Possible* assessment of stygofauna and flora within the karstic cave below the Mainina sink hole" and for further bat studies (EPANZ Services 2004a, p. 48). Elsewhere in their report the consultants concede (EPANZ Services 2004a, p. 35) that the dewatering of the karst below the Mainina sinkhole would have "an unknown effect on the so-called stygofauna, which is fauna, that is associated with underground karstic caverns. The extent and nature of such fauna has not been established." In considering possible mitigation measures, the consultants note:

> *It would appear that any assessment of stygofauna would be an extremely specialised task and this would be difficult and probably extremely hazardous if entry to the hole is required. It is possible that this may not be able to be realistically assessed.*

It does not seem to have occurred to the consultants that it may be possible to access the underground aquatic habitat through other, non-waterfilled entrances or to study the stygofauna where the karst drainage rises to the surface. They have not even suggested that any effort be made to locate such points.

POTENTIAL ENVIRONMENTAL PROBLEMS INADEQUATELY ADDRESSED BY THE PLANNERS

Potential problems for tunnelling in karst

The 1989 report barely mentions the possibility of problems for this major tunnelling project arising from the nature of the karstified rocks through which it must pass. In considering geology, ELC-Electroconsult et al. (1989) stated:

> *... the following geological features are of paramount importance for the project, namely:*
> - *As a negative effect, the high karstification of the Ira Lalaro depression and its surrounding limestones, which practically impedes a water storage, and limits the civil design to a run of river scheme;*
> - *As a positive effect, the presence of impervious shale which protects the mountain ranges from karstic groundwater intrusions and a competent crystalline limestone which if, as assumed, is not karstified, represents probably a good rock to cross with a power tunnel.*

There seem to be some rather large leaps of faith here, based on little evidence. There is a relatively impervious shale, the Cribas Formation (see Figs 4 and 14) but there appears to be no reliable information as to its precise interface with the Aitutu Formation (which is largely carbonate rock) deep under the Paitchau Range. The 1:250,000 geological map of the area indicates significant faulting. The major tunnel would run from the sinkhole and pass under the range at a very low gradient. As Fig. 10 shows, what it passes through depends on the position of the interface between the Cribas and Aitutu formations. As to whether the Aitutu Formation is karstified or not in this area remains to be discovered.

It is also clear that while the Cribas Formation appears to be impervious, water from the Mainina sinkhole *crosses* it to reach the south coast (Fig. 10) as indicated by the limited water tracing information. Either the Cribas Formation is not impervious or there are hydrological routes through it or around it.

Fig. 6. Entrance to Lene Hara Cave, near Tutuala.

Recognising the lack of detailed information, the 1989 report did recommend the carrying out of a comprehensive geological study as a base for new engineering geology investigations but to the best of the authors' knowledge such investigations have still not been carried out (though there are reports of some seismic investigations). The 1989 study (ELC-Electroconsult et al. 1989) nevertheless concluded that the project did not present any "specially complex technical problems" and that the civil construction could be carried out with conventional methods. This appears to totally dismiss the very real difficulties which tend to be the norm, rather than the exception, when undertaking engineering projects on, and especially under, karst terrain.

The 2004 report does not consider any possible problems relating to tunnelling or carrying out major excavations in karst. The only issue it addresses relating to tunnelling is the disposal of spoil. While spoil disposal problems are real enough, consideration needs to be given to problems that may arise in creating the spoil, i.e. during tunnelling and excavation.

The glib dismissal of any likely problems in the 1989 study and failure to address it in the 2004 report is in stark contrast to the attitudes of those with experience in karst engineering. Milanović (2000, p. 79) summarises the risks:

> *The nature of karst presents a great variety of risks associated with any kind of human activities. The risk component is unavoidable in spite of very serious and complex investigation programs, including all available investigation methods. Moreover, the risk can not be totally eliminated by increasing the investigative programs. Perhaps it can be minimized to an acceptable level, but never absolutely eliminated.*

Difficulties and failures in the development of karst terranes generally can be classified as technical and ecological. The technical difficulties and failures are connected with various man-made structures: dams, reservoirs, tunnels and intake structures. The ecological failures are a consequence of various human activities which deteriorate the environment and water quality, deplete water quantity and endanger underground fauna..

Fig. 7. Geometric art in the entrance to Lene Hara Cave.

Specifically, in relation to the boring of tunnels, Milanović (2000, p. 84) warns:

In underground structures such as tunnel excavation the risk aspect is emphasized, since the evaluation of engineering-geological characteristics of the media is based on expensive investigation works and difficult interpretation where reliability is hard to achieve. In the long and deep tunnels the risk is increased due to limited scope of "point" investigation works (boreholes), while conclusions are mostly based on surface investigations (geological mapping, geophysical works). The presence of large caverns at depths below 100 m is impossible to determine by existing methods from the surface. Moreover, it may present an important problem if tunnel boring machine (TBM) is to be used, particularly if the cavern is filled with clay.

Further, Marinos (2001) concludes:

Tunnelling and mining in karst require a thorough hydrogeological knowledge over a broader area. Lack of this knowledge may result in a design which will not be able to face problems or hazards that may occur during construction with probably dramatic consequences on the completion of the operation.

Common investigations which should be undertaken to minimise potential problems with drilling in karst are outlined by Milanović (2004):

- *detailed geological mapping at the surface,*
- *drilling,*
- *water level monitoring,*
- *geophysical surveys (from the surface and from within the tunnel), and*
- *speleological exploration.*

To the best of our knowledge in the present case none of these has been initiated (though there are verbal reports of some seismic investigations) and no plan appears to have been drawn up although Adeler et al. (2003, p. 16) did recommend "additional studies on geology and geo-hydrology" – without spelling out what aspects these should concentrate on beyond referring back to similar recommendations in the 1989 study.

Karst drainage – the fate of the Mainina water

One of the first points conceded in the 2004 'Environmental Assessment' (EPANZ Services 2004a, p. 1) is that "The fate of this water [that entering the Mainina sinkhole] has not been established". It seems remarkable that any environmental assessment of this project did not rate the answering of this question as a top priority. The 2004 report admits that "much of the information in this [hydrology] section is derived from the ELC-Electroconsult report (1989)"[!] Inconclusive and conflicting results were reported for some earlier tracing attempts.

Some dye tracing experiments were subsequently carried out and risings towards the south coast were identified, together with at least two towards the *north* coast. The southerly springs (which would have been expected) may cause the proponents little concern in the social context because this coastal area is almost unpopulated, however it is another matter to the north. Information from a more recent water trace indicates that the water from the Mainina sinkhole reappears in two resurgences to the north near Com as well as springs along the south coast.

Interestingly, the two northern springs show higher levels of the trace than the southern ones. Unfortunately, the consultants and the Government have been tardy in releasing details of the dye tracing tests and it is not known if any flow times were determined or if there is any real quantitative data on flows. We have seen some limited data but it is difficult to comment further without details of the tracing methodology. Without such details and the construction of a fully documented water budget for the drainage basin any decision to divert this water to another use would be irresponsible.

Potential problems resulting from dewatering karst

The 2004 report acknowledges that the project would have –

Possible effects on the structural stability of the karstic system should the flows diminish. Any subsequent collapses that may occur within the system could have other compounding effects with regard to the ability of floodwaters to be carried away via the Mainina karstic route.

This concern is presumably founded on the well-documented problem of collapse induced by dewatering resulting in removal of buoyant support. Ford and Williams (1989, p. 409) observe:

In a fully saturated medium, the buoyant force of water is 1 tonne m^{-3} and if the water table is lowered 30 m, the increase in effective stress on the rocks is 30 tonnes m^{-3}. If unconsolidated overlying materials are affected by such de-watering, compression occurs and the surface subsides.

Vermeulen and Whitten (1999, p. 68) warn:

Excessive extraction of water may cause the drying up of aboveground and underground systems in limestone areas, leading to possible collapse as flooded cavities become filled with air. Small water bodies, which may be inhabited by small, site-endemic fish species and snails, will disappear, and with them the species.

Alterations of flow patterns by the construction of dams, water extraction and flood control in and around limestone areas will profoundly change the limestone environment and lead to the extinction of whole communities. The quantity of water and the availability of nutrients change, … aquatic habitats are destroyed, …

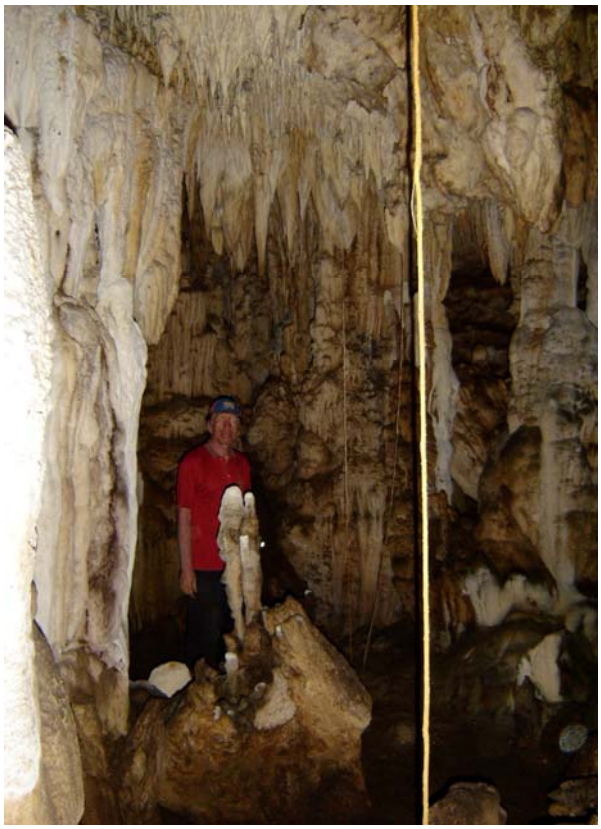

Fig. 8. Ignacio, our guide, with speleothems and roots, Noi Noi Kuru.

While the surface consequences of any collapse deep within the Paitchau Range seem unlikely to be significant, the nature of karst drainage is such that it should not be assumed that effects would only be felt along a straight line between the Mainina sinkhole and the springs towards the south coast.

If the water also drains to the north, as suggested by the limited water tracing, the watertable underlying the whole region would potentially be affected.

On the other hand, it is documented that the existing flow into the Mainina sinkhole varies significantly throughout the year, from about 5 m^3/sec to 33 m^3/sec, and there is no evidence of this having led to collapse within the karst (although there has been no effort put into finding any).

The possibility exists, however, that removing all, or most, of the last 5 m^3/sec and the permanent lowering of water levels could be the trigger which destabilises the system.

Impact of dewatering on dependent fauna

While groundwater dependant fauna were not even hinted at in the 1989 study, they are at least mentioned in the 2004 one:

Spring sites on the Irasiquero contained commonly found amphipod and isopod crustaceans – groups typical of groundwater ecosystems. Thus groundwater below the Mainina sinkhole may harbour a specialist fauna - so-termed 'stygofauna' (EPANZ Services 2004a, p. 16).

In considering impacts and possible mitigation measures, the report notes that diversion of the Mainina water away from the karst may have impacts including:

An unknown effect on the so-called stygofauna, which is fauna, that is associated with underground karstic caverns. The extent and nature of such fauna has not been established.

It then goes on to cast doubt on the feasibility of even investigating this fauna:

It would appear that any assessment of stygofauna would be an extremely specialised task and this would be difficult and probably extremely hazardous if entry to the hole is required. It is possible that this may not be able to be realistically assessed. (EPANZ Services 2004a, p. 35)

As a means of mitigating the impacts of dewatering, the report suggests only "the provision of a downstream release that would be sufficient to maintain the health of the systems but at a lower level" without offering any suggestion as to how the 'downstream release' might be quantified or timed.

Any study purporting to responsibly consider the environmental impacts of the proposed scheme must properly investigate the stygofauna, assess its extent and significance and propose adequate measures to protect it, or at least to minimise adverse impacts on it.

MANAGEMENT OF THE KARST

Protected Area issues

Proposals to provide protection to the special environmental values of the Iralalaro-Paitchau area are long-standing. The situation is well summarised by McWilliam (2003):

The district of Lautem contains one of the finest contiguous blocks of dense lowland tropical and monsoon forest on the island of Timor. Covering an area of some 300 sq. km and incorporating the heavily forested Paichao range of low mountains, this forest zone extends from the eastern extremity of East Timor (Jaco Island) in a narrow band (7-10 km) westwards following the unpopulated southern coastal hinterland. As a region with great ecological value and complex biodiversity, the area has long been accorded special significance. During the period of Indonesian rule (1975-99), much of the forested zone was classified as a natural conservation reserve. This category of protection, on paper at least, prohibited logging and other forms of extractive activity within its boundaries. Subsequently, under the United Nations Transitional Administration in East Timor (UNTAET) from 1999, the area was re-classified and declared as one of 15 so-called, 'Protected Wild Areas' (UNTAET Regulation 19/2000). This sentiment and commitment to recognize and conserve the heritage and resources of the Tutuala-Paichao Reserve, has continued under the new government of an independent East Timor. In 2002, through its Directorate of Forestry, the government initiated a program to formally demarcate and legislate the area as the country's first 'National Park'.

It appears that more recently, particularly in view of established rights within the area, the Government has sought to establish a mutually agreed framework for management with local communities bordering the forest area and is now considering a reserve category more in accord with IUCN's Category V (IUCN 1994) which would permit a range of traditional practices to continue (McWilliam 2003) or Category VI which allows even greater development of resources.

This is not to say that the whole area should be actively managed to encourage or facilitate practices which would degrade natural qualities and certainly does not to imply that development of the hydro-electric scheme elsewhere in the proposed reserve would be a compatible use. On the contrary, the proposed scheme is incompatible with the maintenance of many of the natural and cultural values which give the area its special significance, particularly the karst values.

The best natural features within any Category V or VI reserve could be declared as separate, more highly protected areas (e.g. Category 1a Strict Nature Reserve) or, more simply, some parts of the reserve could be zoned for a limited range of uses so as to favour nature conservation. This might apply in the present case to the mountains and the south coast that have not been inhabited for many years.

In keeping with the intent of this type of protected area, management should be shared with the local community, not simply imposed by a government agency. This is particularly so, given the history of this place and the experiences its inhabitants have suffered at the hands of 'government'. Nevertheless, a concerted program to inform the local community with regard to aspects of environmental management which may not be adequately addressed by traditional practices, (and karst will probably be one of these), will no doubt be necessary if the sustainable management of this outstanding area is to be assured.

Specific karst management issues

A full inventory of the caves and other karst features of the region (especially pits, dolines, sinks, springs and dry stream courses) should be undertaken without delay as a first step in analysing the karst networks and connections – and their habitat, ecological, archaeological, palaeontological and other values. Such an inventory would serve as the basis on which plans could be developed for the proper management of these resources.

The lack of information in these areas is a serious problem and at the very least expert consultants should be engaged immediately to investigate and evaluate the stygofauna and its ecosystem, to provide baseline data for later assessment. There is a sizeable local human population, which derives its livelihood from agriculture in and around the lake. There is a serious concern that if the hydro-electric power scheme is built, over time the groundwater level in the polje may be systematically and permanently lowered.

If this were to occur the livelihood of the Malahara community and other communities dependent on the lake, the groundwater as well as the associated ecosystem, would be jeopardized. A groundwater system such as that which exists in this polje and the surrounding catchments, and downstream areas, can be subject to pollution problems that can affect beneficial uses of the groundwater. Faecal pollution at the present time is probably the main risk but indiscriminate use of agricultural chemicals or fertilizers could have detrimental effects also.

Fig. 9. Nicholas and white column, Noi Noi Kuru.

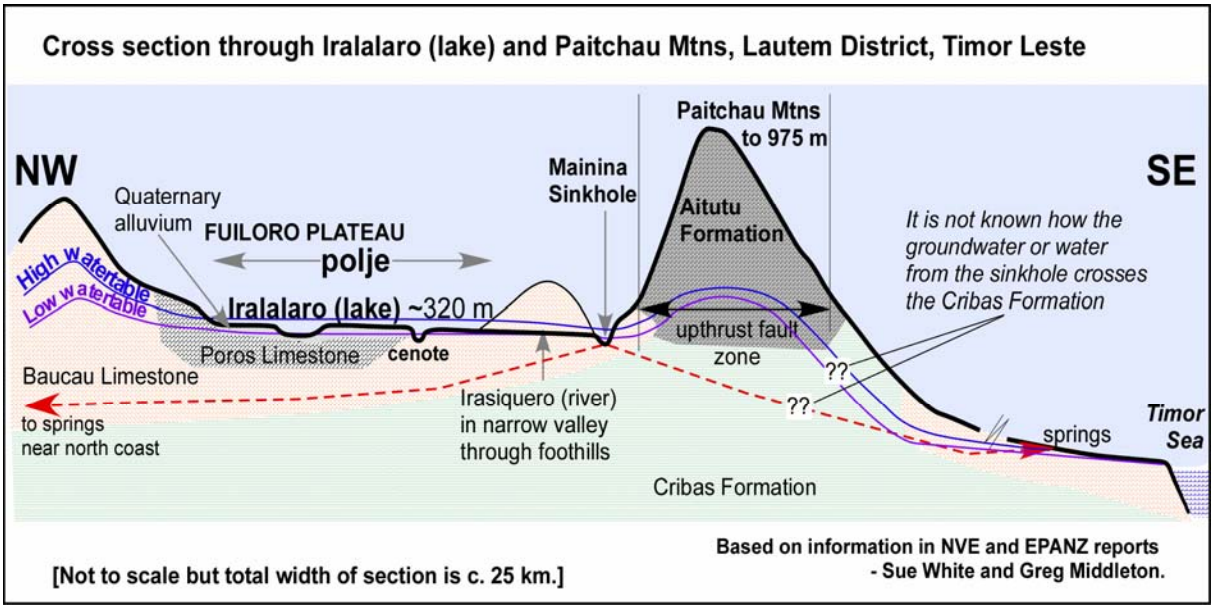

Fig. 10. Schematic section through Timor-Leste in vicinity of Malahara village, showing Iralalaro Lake and polje, Paitchau Mountains, inferred geology and presumed routes taken by underground water.

Ecotourism

The communities at the eastern end of Timor-Leste have only very recently begun to experience tourism pressures. There is some potential here but current facilities are very limited. Many villages, eg Malahara, have no public accommodation or eating premises, or even small shops.

There are many possibilities for activities such as birdwatching, walking, horseriding, adventure caving and more serious trekking, but the servicing of even small numbers of visitors is currently problematic. Planning for ecotourism needs to encompass the infrastructure facilities and further adventure tourism assessment to support such tourism in and around Malahara and Tutuala.

Some caves in the area would no doubt be suitable for adventure caving. At least some of these have known associations with Fretilin activities as caves were used during the guerrilla campaign directed at the Indonesian occupiers.

The Australian "Sparrow Force" activities in 1942 during World War II used a route from the coast over the Paitchau Mountains. This history is known locally and needs further research. This is important because it is the sort of history which can greatly enrich tourist activities.

Reservations exist in the Malahara community about both the hydro-electric proposal and developments which tourism might bring. Only by community involvement in these developments will benefits be spread.

At the present time the Malahara community would struggle to sustain and benefit from a hydro-electric scheme development and is equally ill-prepared to provide for an ecotourism "boom". There is interest in the revenue and jobs but understandably ambivalence and uncertainty about the intrusion that such developments would bring.

Research

The Iralalaro area has excellent potential for interesting and significant research. The area has experienced little research except perhaps archaeological work and the biological surveys associated with the hydro-electric proposal. There is potential for significant research in the earth science area such as research into understanding karst in tropical areas of Australasia and the role karst has in landscape evolution in recently uplifted areas.

The understanding of karst and its relation to groundwater is fundamental to the future management and appropriate development of this part of Timor-Leste.

A thorough understanding of the hydrological relationships of the system would assist in ensuring the sustainability of existing communities and in assessing impacts of proposed developments.

CONCLUSIONS

The authors have grave concerns about the viability and the impacts of the proposed Iralalaro hydro-electric scheme. Based on the available reports, a brief site visit, their understanding of karst and research of the literature, it appears that there are serious gaps in the site studies and serious limitations on the understanding of the area by the consultants designing the scheme.

In conclusion, the scheme, in so far as the authors have been able to understand it, appears to have a number of serious limitations which, unless they are addressed, could seriously undermine the scheme's viability, or at least cause significant cost overruns.

Additional studies may address some of these concerns but there appears to be a reluctance to undertake studies on the fundamental nature of the area, i.e. the karst.

Concerns include:

1. The karst has not been subjected to a thorough and detailed study by experts in this specialised field and the implications of the karstic nature of the terrain appear not to have been adequately appreciated.
2. The cost of the scheme may have been seriously underestimated.
3. The risks and costs of drilling and tunnelling in karstic terrain are probably underestimated and have not been given the detailed consideration they deserve.
4. Risks and costs of dewatering the karst have neither been fully understood nor properly addressed.
5. The lack of even a simple water budget brings into question the basis for assuming the viability of the scheme over time.
6. The area's ecotourism potential relies on the mountains, forests, karst, caves, wildlife and the history/prehistory of the area. The hydro scheme could damage precisely those features most likely to attract adventure tourists, and would put at risk the development of tourism in the region.
7. The proposed hydro scheme is incompatible with the maintenance of many of the natural and cultural values, which give the area its special significance. There is a case for protection of the Iralalaro polje, the subterranean wetlands and their associated ecosystems. Further investigation is needed into the possibility of having the area protected under the Ramsar convention.
8. The proponents demonstrate a lack of understanding of local infrastructure whilst selling the scheme as a potential employer. There are serious questions as to the ability of the proposed scheme to provide the claimed electricity output in perpetuity at the currently estimated costs and with the suggested low levels of environmental impact.

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