Environmental impacts of the Rio Esti Hydroelectric Project, Panama

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Minor Field Study 115

November 2005 Uppsala

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This paper has been done as a project course of 15 ECTS points in Aquatic- and Environmental Engineering at Uppsala University, Sweden.

Photos: All photos, where not otherwise noted, are taken by the author.
Front page photo: Riders crossing the Esti River on a flooded crossing
Supervisors: Lennart Strömquist , Uppsala University
José Victoria, AES Panamá

Abstract

Hydropower projects are likely to cause severe environmental, economical and social impacts on both a local and regional level. The practice of performing Environmental Impact Assessments (EIA) when constructing big dams in order to prevent or mitigate these impacts is nowadays widespread, but the cases when these assessments are evaluated are much rarer. Evaluating impact assessments is important both for being able to better perform future EIAs and for being able to ad new mitigation efforts to the investigated project if necessary.

This study investigates the environmental effects of the Rio Esti Hydroelectric Project in Panama one year after the project entered the operational phase. The study focuses on four somewhat interlinked areas, landscape changes, changes in the water quality of the rivers, changes in the drinking water situation and the changed ability to use the rivers for eco-system services.

The changed environment is shown to negatively affect people living in the area, directly or through chain effects. There is substantial money invested in mitigating efforts, but these efforts have a tendency to be too centralised and some of the people suffering the biggest consequences are left without any mitigation.

The study shows that all negative impacts of the project were not foreseen in the EIA and that there are no working procedures to include new mitigation efforts afterwards into the project. Mitigation and monitoring efforts that are to be performed during the operational phase of the project are not always executed within the set time limits. One of the reasons for the delays is the strong intention of the owner to outsource these activities. Governmental and regional bodies are also lacking the sufficient means to exercise control over the environmental works.

Resumen

La ejecución de proyectos hidroeléctricos son causantes probables de severos impactos ambientales, económicos y sociales tanto a nivel local como regional. Actualmente, la práctica para realizar un Estudios de Impacto Ambiental (EIA), en la construcción de grandes represas para prevenir o mitigar estos impactos es altamente divulgada, pero las ocasiones en las que estos estudios se siguen monitoreando, som escasas. Seguir monitorear los estudios es importante para poder realizar mejor EIAs en el futuro y para poder añadir nuevos esfuerzos de la mitigación al proyecto investigado en caso de necesidad.

Este estudio investiga los efectos ambientales del proyecto hidroeléctrico de Esti en Panamá un año después del proyecto comenzó la fase operacional. El estudio se centra en cuatro areas con cierta interrelación: cambios en el paisaje, cambios en la calidad del agua de los ríos, cambia en la situación del agua potable y la capacidad cambiante del uso de los ríos para servicios del ecosistema.

El ambiente cambiante ha demostrado que afecta negativamente a la gente que vive en el área, directamente o por efectos en cadena. Grandes cantidades de dinero se invierten en los esfuerzos de mitigación, pero estos esfuerzos tienen una tendencia a ser demasiado centralizados y dejando a algunos de los que sufren de los mayors impactos sin ninguna mitigación.

El estudio demuestra que todos los impactos negativos del proyecto, no fueron previstos en el EIA y que no hay procedimientos de funcionamiento para incluir nuevos esfuerzos de la mitigación en el proyecto. Los esfuerzos de mitigación y supervisión que deben realizarse durante la fase operacional del proyecto no siempre se llevan a cabo dentro de los limites de tiempo estipulados. Una de las razones de los retrasos es la fuerte intensión del dueño de colocar estas actividades bajo contratos externos. Los cuerpos gubernamentalesy regionales también carecen de los medios sufecientes para ejercer el control de los trabajos ambientales del proyecto.

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1 Introduction

Energy consumption has in the last years rapidly been increasing in Panama. There are also plans to link the electricity grids of the Central American countries of Panama, Costa Rica, Honduras, Nicaragua, El Salvador, and Guatemala, connecting some 35 million consumers and thus significantly extending the energy market. The increased domestic consumption and future increase in the size of the energy market has led to a lot of money being invested in energy infrastructure projects in Panama. One of these projects is the Rio Esti Hydroelectric Project in western Panama, and several other hydroelectric projects are also at the planning stage in Panama.

Hydropower is a clean source of energy seen on a global scale. But on a local or regional scale the environmental and socioeconomic impacts can be negative and serious. The landscape and the dammed rivers often change their characteristics severely after the completion of a hydroelectric project. Sometimes the ability of people living in the area to use natural resources to improve their livelihood can be highly limited after a project. In rural areas in developing countries, using the surrounding environment for small scale farming, hunting and fishing can be equally important to an employment as means of earning a livelihood[1]. The people worst affected by such a change in the environment are often the poorest ones with the lowest safety margins. Therefore before a hydroelectric project, or any other major infrastructural project, is undertaken it is important to try to predict in what way the project is likely to affect the area and the people living in it, and to include actions in the project plan that will prevent, mitigate or compensate for negative impacts. This is normally done by performing an Environmental Impact Assessment (EIA).

This study investigates some of the environmental impacts of the Rio Esti hydroelectric project and compares these impacts with predictions made in the performed Environmental Impact Assessment. It also investigates how the different impacts on the environment are affecting the people living in the area.

There are on many occasion strong linkages between environmental, social and economical changes. People need to be seen as a part of the ecosystem in which they live. Any severe change in the system is likely to severely change the way people make their livelihood.

Hydroelectric projects are seen as greenhouse gas reducing, industrialised countries can therefore earn emission credits by investing in such projects in developing countries. It is hence likely that hydroelectric projects will be popular to cope with increased energy consumption, not only in Panama but in many developing countries. An increased understanding of how a hydroelectric project affects the local and regional environment, and thereby the people living close to the project, is therefore increasingly important

[1] Chambers (1997) p. 48

2 Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a tool "*used for reducing negative environmental consequences of development activities and for promoting sustainable development*."[2] An EIA is to look into the situation of all different stakeholders, and therefore a fundamental component of the EIA process is Public participation.[3]

EIA is a tool at the scale of individual projects but can be combined with a Strategic Environmental Assessment (SEA) which is the appraisal of policies, programmes and plans. The SEA can for example cover the development of a country's energy sector while the EIA covers the different individual energy projects.

The EIA can follow different procedures, procedures which continuously are developing and changing. The EIA as a mandatory tool in development activities originated in the early 1970s in the USA. The use of EIA has spread and today most development banks and international aid agencies use this tool when providing development assistance.[4] To be granted a loan from the World Bank for a development project, an EIA has to be included in the project.

In the first half of the 1990s, researchers emphasized the limitations of project-level EIA. A summary by Alshuwaikhat[5] includes:

- Project EIAs react to development proposals rather than anticipate them, so they cannot steer development towards environmentally "robust" areas or away from environmentally sensitive sites.
- Project EIAs do not adequately consider the cumulative impacts caused by several projects or even by one project's subcomponents or ancillary developments.
- Before preparation of the EIA, a project can be planned quite specifically, with irreversible decisions taken.
- Project EIAs often have to be carried out in a very short period of time because of financial constraints and the timing of planning applications.

Nevertheless, EIA still serves as an important tool for evaluating negative impacts of projects. Moreover, since the implication of EIA demands spatial data, the requirement for EIA to be performed provides an important mean of cost-recovery and capacity-building for agencies that are sampling spatial data to construct a national Environmental Information System (EIS), thus highly improving the sustainability of this work. This may, especially in poor countries where governmental funding may be insufficient for creating and co-ordinating an EIS, prove important.[6]

The EIA performed for the Rio Esti Hydroelectric Project estimates impacts of the project and obliges the owner, AES Panama[7], to carry out preventing, minimizing, mitigating and compensating actions in order to lessen the negative impacts.

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[2] Lee and George (2002) p. 1
[3] Hartely and Wood (2005)
[4] Lee and George (2002) p. 3
[5] Alshuwaikhat (2005)
[6] Gavin and Gyamfi-Aidoo (2001)
[7] AES Panama is a subsidiary of AES, Applied Energy Service (USA)

3 Scope and aim of the study

A 10 week field study was done between September and December 2004. At this time the Rio Esti Hydroelectric Project had been operational for approximately one year. This study aims at evaluating some of the environmental impacts of the project and the compliance with the EIA concerning mitigation of these impacts.

The severity of an environmental impact can be decided out of different perspectives such as how the biodiversity, local wildlife, global climate, water quality etc. is affected. The perspective through which the environmental impacts are mainly evaluated in this study is to what extent it affects the people living in the area. Therefore, the study can be somewhat considered to border to, and to some extent cross into, the area of social impacts.

The study is divided into four main parts. These parts concern river water quality, landscape changes, the ability to use the rivers for ecosystem services and the drinking water situation.

The study was done as a Minor Field Study (MFS) mainly financed by Sida (Swedish international development agency). This MFS is to be counted as a project course of 15 ECTS-credits in the Master of Science programme *Aquatic and Environmental Engineering* at Uppsala University.

4 Background

4.1 The Area

The Rio Esti Hydroelectric Project is located in western Panama in Chiriqui province, 425 km from the capital Panama City, in the Chiriqui River basin (Fig 4.1). 30 km to the south is David, the provincial capital. The climate is tropical humid at low grounds, i.e. most part of the project area, with a mean temperature of 27.8˚C. At higher grounds the climate is temperate very humid. Annual precipitation is between 2,400 mm and 5,600 mm with the higher values in the western part of the area.[8] There are two seasons in the area, a rainy season (May-Jan) and a dry season (Jan-May).

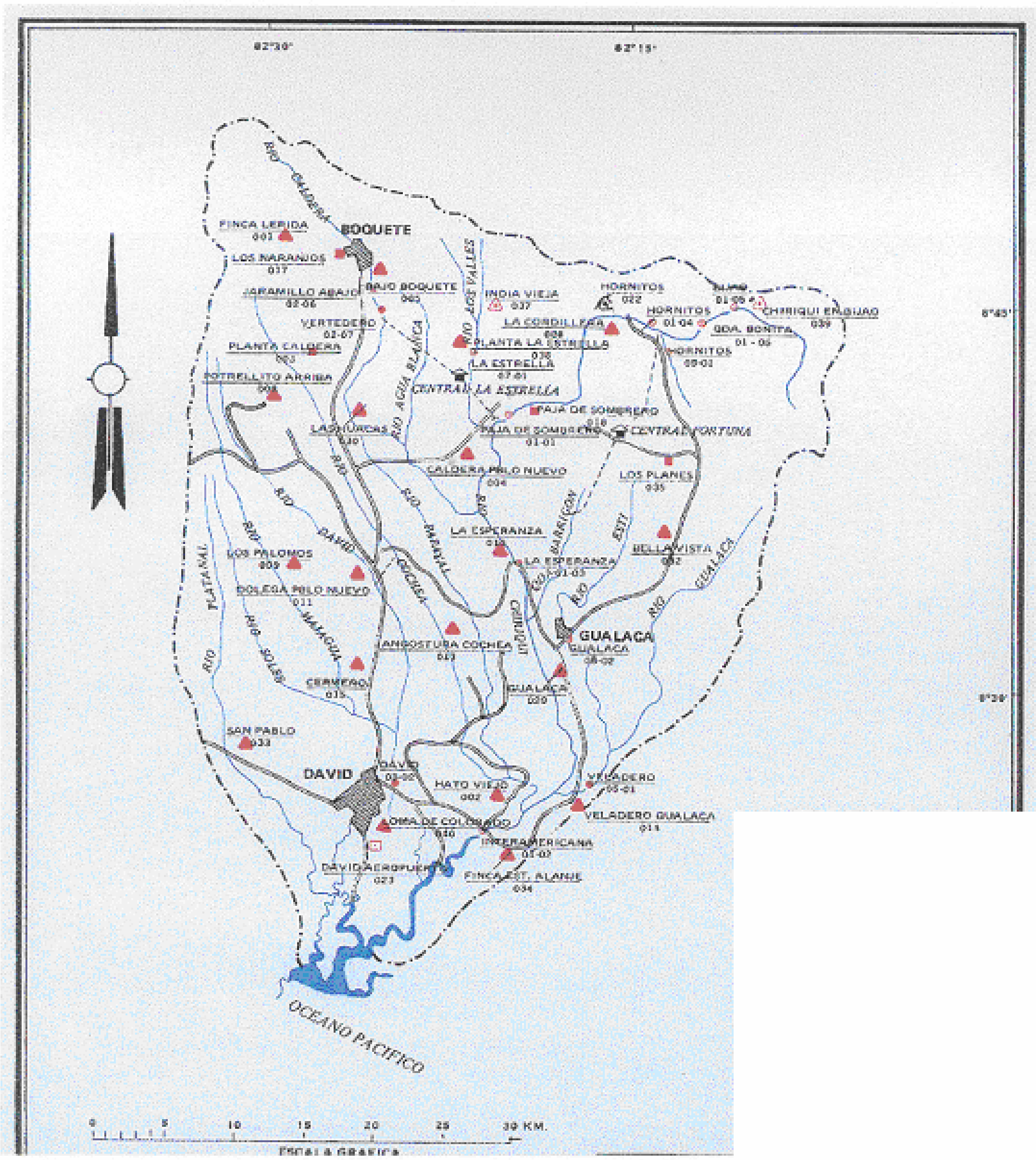

Fig 4.1 The Chiriqui River Valley.[9]

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[8]Planeta, EIA (1996) p. 5:27-5:36
[9]Map from ETESA

The area is divided into three parts regarding landscape type: old alluvial terraces, lower hills and higher hills. All of these three areas have acid soil with high extractable acidity, high aluminium saturation and low amount of exchangeable cat ions. Hence the soils in the area can be described as poor and not very well suited for agriculture. The bedrock in the area is described as highly fractured.[8]

The land in the area is mostly used for cattle. To clear land for extensive cattle herding, wide spread deforestation has occurred. As a result of this deforestation, in combination with poor land protection, high precipitation and high erosive tendency of the soils, erosion and soil degradation is a severe problem in the area (Fig 4.2).[10]

Fig. 4.2 Erosion is a problem in the area, and was so prior to the Rio Esti Project, due to poor land management.

4.2 The Project

The Rio Esti Hydroelectric Project is owned by AES Panama, and the project entered into operational phase in November 2003. National IRHE[11] had plans for a hydroelectric project in the Esti River already in the beginning of the 90´s. With the privatization in the late 1990s AES overtook the plans for a hydroelectric project in Esti. The design was changed several times before the construction started in May 2001. An updated EIA, where environmental, economical and sociological impacts of the different project proposals, in consistence with the Worldbank international environmental and social standards, had by then been approved by the Panamanian National Environmental Protection Agency, ANAM[12].

In this last updated EIA, performed by the Panamanian company Planeta, some positive and negative environmental and socioeconomic impacts for the area were estimated (Table 4.1).

The construction was performed by a consortium led by Skanska International Civil Engineering AB and also including Alstrom Power Generation AB, GE Energy (Sweden) AB and Swedpower International AB.

[10] Planeta, EIA (1996) p. 6:3
[11] Instituto de Recursos Hidrológicas y Eléctricas
[12] Autoridad Nacional del Ambiente

Table 4.1 Some possible impacts according to the last updated EIA. (Planeta, EIA(1996))

Environmental impacts		Socioeconomic impacts	
Negative	Positive	Negative	Positive
Change in landscape	Increased biodiversity	Affected archaeological sites	New economical activities
Impact on water quality		Changed production structures	Diversification of production
Increased erosion		Changes in daily routines	Stimulation of local development
Change of natural water flows		Barrier effects	Performed archaeological studies prior to construction
Loss of vegetation		Impact on road infrastructure	

Increased biodiversity is thought to be the result of a management plan for the river valley which includes the reconstruction of forest habitat in some areas.[13]

Landscape changes are considered to be a result of material extraction, filling of reservoirs and canal, movement of soil from sites of construction, turbine discharge and new building structures.[14]

Impact on water quality are supposed to stem from deforestation, extraction of construction materials from rivers, bottom releases from the reservoirs to decrease sediment level, and from movement of soil for access roads.[14]

The changes of natural water flows are assumed to originate from discharge from the electricity production, bottom releases from reservoirs to decrease sediment level and filling of the reservoirs and the canal.[14]

Loss of vegetation is believed to be due to deforestation, movement of soil and filling of reservoirs and canal.[14]

The EIA mentions both reconstruction of forest habitat and deforestation as causes for impacts. This might seem contradictory, but the reconstruction of forest habitat and the deforestation is assumed to take place at different locations.

Fig 4.3 shows the main structures of the Rio Esti project. The project consists of two dams; the Chiriqui Diversion Dam on the Chiriqui River and the Barrigon Dam on the Quebrada Barrigon. From the Chiriqui Dam water is divided through a canal to the Barrigon Reservoir. From the Barrigon Reservoir water is provided to the Canjilones Powerhouse through a conveyance tunnel, 4,800 m in length.[15] After the powerhouse the turbinated water is discharged into the Esti River close to the town of Gualaca.

[13] Planeta, EIA (1996) p. 2:18
[14] Planeta, EIA (1996) p. 8:8-8:43
[15] Env. Audit (2003) p. 3

Fig. 4.3 Schematic picture of the structures of the Rio Esti project and the bigger communities in the area[16]

Chiriqui Dam and resevoir

The Chiriqui Dam is a concrete structure located 500 meters below the confluent of the Caldera and Chiriqui Rivers. The crest is at 232.5 m a.s.l. and the reservoir is 0.05 km^2.[17]

Barrigon Dam and Reservoir

The Barrigon Dam is a concrete-faced rockfilled structure located on the Quebrada Barrigon above the junction with the Chiriqui River. Barrigon Reservoir gets water from Quebrada Barrigon, Quebrada Pan de Azucar, Quebrada Buenos Aires, the canal from the Chiriqui Reservoir, the discharge tunnel from the Fortuna Hydroelectric Project and some smaller streams. The dam has a length of 810 meters and the crest is at 225.5 m a.s.l. The maximum height over the creek is 54 meters. The area of the reservoir is 2.9 km^2. The level in the Barrgion Reservoir is to vary between 218 and 222 m a.s.l.[17]

The canal

The canal is trapezoid-shaped and has a length of five kilometres. Where the canal crosses creeks and streams, these are led under the canal through tunnels designed for 500 year flow.[17]

Canjilones Powerhouse

The powerhouse is supplied with two 60-MW turbines and is to generate around 620 GWh per year. [17]

Ecological flows

Both Chiriqui and Barrigon Dam have outlets that supply Chiriqui River and Quebrada Barrigon, respectively, with an ecological flow providing water for domestic and productive use downstream of the project. The minimum ecological flow for Chiriqui River is set to $3.5m^3/s$ in the dry season and $1.5m^3/s$ in the wet season. For Quebrada Barrigon the minimum ecological flow is set to $0.75m^3/s$ all year around. AES is obliged by to make sure that these

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[16] Modified from Env. Audit (2003)
[17] Planeta, EIA (1996) p. 2:3-2:6

minimum flows are maintained provided that the flows above the dams are not lower than the ecological flows. The natural average flows in these rivers are $50.61 m^3/s$ for Chiriqui River and $29.28 m^3/s$ for Quebrada Barrigon after the confluence with the Fortuna tailrace tunnel (Fig 4.4). The calculated average flows with spill water and ecological flows after the project completion are $7.05 m^3/s$ and $3.43 m^3/s$, respectively, giving an average flow of 14% of the normal in Chiriqui River and 12% in Quebrada Barrigon.[17]

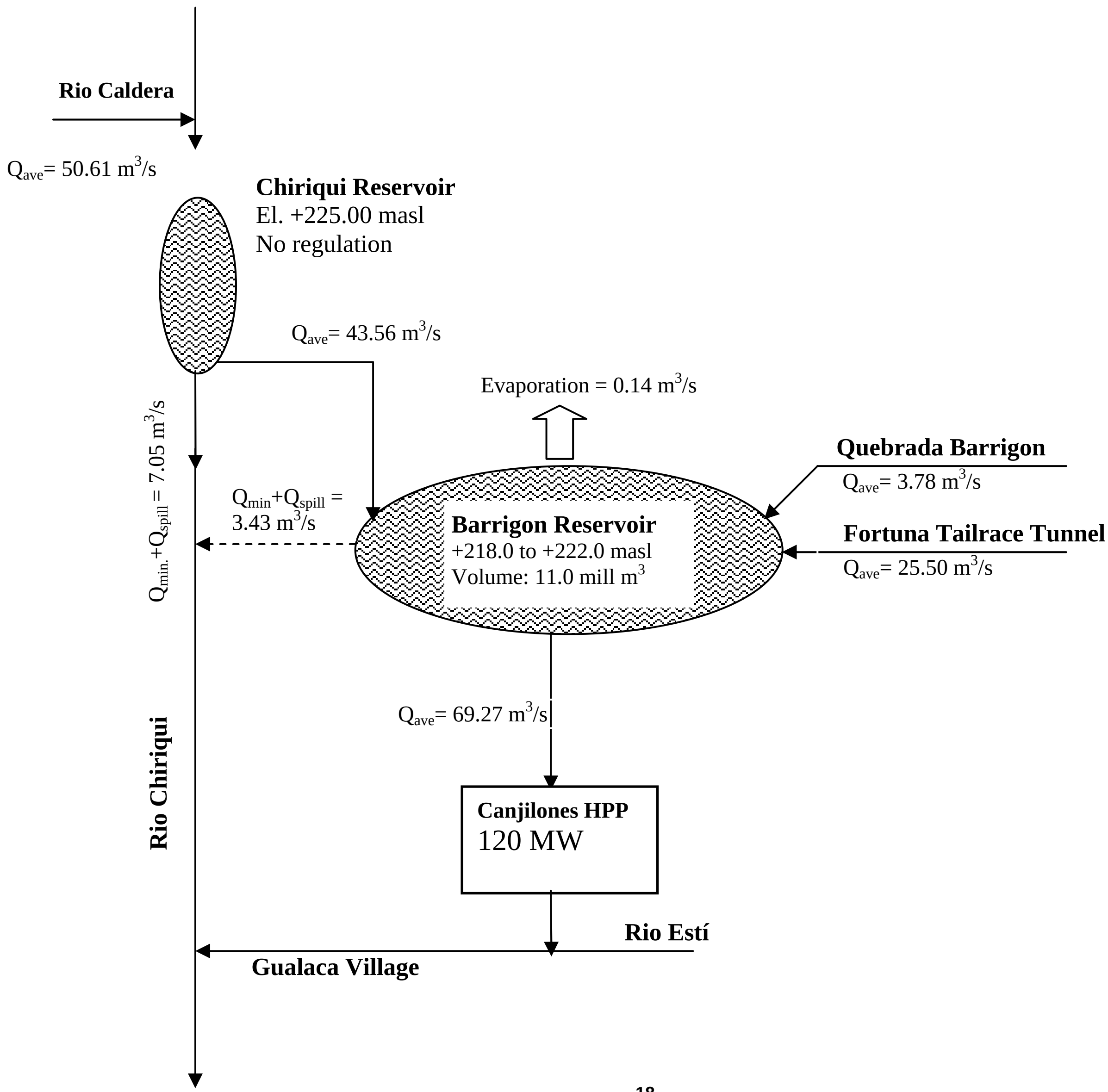

Fig. 4.4 Calculated average flows after the Project completion.[18]

[18] From Planeta, EIA (1996) p. 2:5

5 River water quality

5.1 Introduction

Beside the possible reasons for a change in the water quality listed in the EIA (see section 4.2), a change in water quality can be due to changed flows in Esti and Chiriqui Rivers (changed dilution capacity or increased river side erosion), retention in Barrigon and Chiriqui reservoirs, reaction with tunnel walls in the conveyance tunnel, increased forest cover in the area due to plantations by AES and redirection of rivers (for example discharge from Fortuna now enters the Esti River (Fig 4.4)).

5.2 Objectives and Scope of the study

The study was done from September to mid-December, which is the wet season in the area. To see if a change in the water quality can be indicated in the Chiriqui and Esti River due to the hydroelectric project, some water quality parameters were sampled and analysed.

The Chiriqui River suffers a decreased flow due to the project; possible effects are therefore likely to be most serious during the dry season. Hence, for the Chiriqui River, only a limited synoptic study of sediment content during receding flow was done, in order to see if one of the former islands now is a section of the river were particles are deposited, eroded or merely transported during a measured flow *(Table 5.2)* (Fig 5.1). The island was used as a quarry during the construction of the project

For the Esti River, with an increased flow due to the project, five main sample rounds where grab samples were taken and analysed was carried out. Sampling round 5 focused mainly on those parameters which showed different values upstream and downstream from the turbine discharge in sampling round 1 *(Table 5.1-5.3).* To see if the observed differences in the first sampling round, with a higher degree of certainty, could be said to stem from the hydroelectric project, the fifth sampling round were analysing samples taken closer upstream of, and in the turbine discharge *(Table 5.2 & 5.3)* (Fig 5.1). Sampling rounds 2-4 were only regarding turbidity and pH for some inflows to Barrigon Reservoir, the conveyance tunnel intake in the same reservoir, the powerhouse discharge water and upstream from that discharge in the Esti River *(Table 5.4)* (Fig 5.1). Not all of the parameters were tested at all of the sampling sites due to financial constraints *(Table 5.2-5.4).*

Comparison is also done with samples taken in the Esti River by IRHE between 1983 and 1993 and with values analysed in October of 2000 (*Table 5.5).*

It should be noted that this part of the study is highly limited, both concerning the number of samples taken, the amount of parameters sampled and the period of time during which the samples were taken. However, after the project entered the operational phase in the fall of 2003, no monitoring of the river water quality had yet been done, in spite of what is required in the EIA[19]. Therefore this study is the first indication on whether the river water quality in the Esti River can be said to be affected by the hydroelectric project or not.

[19] Planeta, EIA (1996) p. 11:29

Table 5. 1 Parameters tested at the different sampling rounds.

Sampling round	**1**	**2**	**3**	**4**	**5**
Date	19/10-2004	25/11-2004	27/11-2004	29/11-2004	30/11-2004
pH	Y	Y	Y	Y	Y
Temperature	Y	N	N	N	Y
Turbidity	Y	Y	Y	Y	N
Conductivity	Y	N	N	N	Y
Alkalinity tot.	Y	N	N	N	Y
Nitrates	Y	N	N	N	Y
Nitrites	Y	N	N	N	Y
Ammonium	N	N	N	N	Y
Phosphates	Y	N	N	N	N
COD	Y	N	N	N	N
Dissolved solids	Y	N	N	N	N
Total solids	Y	N	N	N	N
Coliformes (tot.) (col./100ml)	Y	N	N	N	N
Coliformes fecales (col./100ml)	Y	N	N	N	N

5.3 Methodology

5.3.1 Water sampling

For chemical and physical parameters the samples were taken in glass bottles. For bacteriological parameters sterile plastic containers were used. Chemical and physical parameters were for the first sampling round collected by using a USD 48 sediment sampler with a 3/16” inlet. For the following sampling rounds glass bottles were attached to a stone and with a rope lowered into the water. The glass bottles used were rinsed with river water 3 times at the site prior to taking the samples. One sample was obtained at each site. When possible, the samples were taken from the middle of the stream, containing water from all depths. This was achieved by in the middle of the stream lowering the sediment sampler to the bottom and raising it to the surface with a steady pace while water was let into the sample bottle.

All bacteriological and chemical samples were put on ice until reaching the laboratory. The transport time varied between one and seven hours. In the fifth sampling round, H_2SO_4 was added to the samples for nitrate, nitrite and ammonium for conservation purposes.

The analyses of the samples were performed by the IDAAN[20] laboratory in David. This same laboratory was used to analyse samples taken by the contractor during the construction of the project[21].

5.3.2 River discharge

Esti River

The flow was determined by adding the flow from the turbine discharge at the time of sampling to the flow measured upstream at one of ETESA’s[22] hydrological stations. At the hydrological station the water level is measured. From this level an empirical relationship

[20] Instituto de Acueductos y Alcantarillados Nacionales
[21] Env. Audit (2003) p. 7
[22] Empresa de Transmisión Eléctrica

curve, obtained from ETESA is used to calculate the flow. Other flows are estimated to be of comparatively minor importance and therefore neglected.

Chiriqui River

Close to the sampling sites there is a hydrological station. The level in this station was used together with an empirical relationship curve from ETESA in the same manner as for the Esti River to calculate the flow.

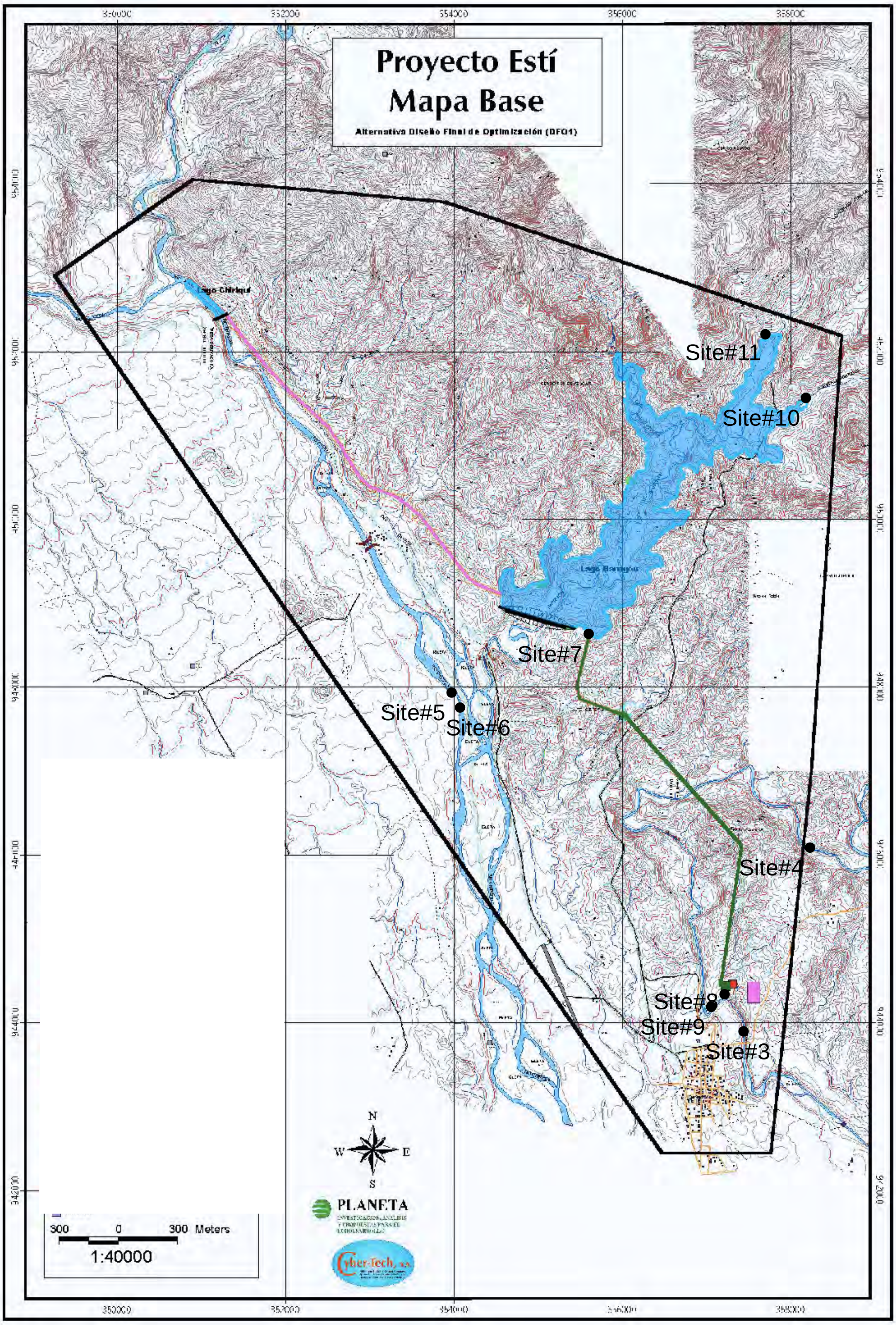

Fig. 5.1 The project area. The polygon marks the area considered as the project area in the EIA. The water sampling sites are marked on the map. Site#1 and Site#2 are located southeast of the map further downstream the Esti River.[23]

[23] Modified map from Planeta Consultores Panama

5.4 Results

Table 5.2 Water quality parameters, sampling round 1, conducted 19/10-2004

	Esti River				Chiriqui River	
	Downstream discharge			*Upstream discharge*	*Upstream quarry*	*Downstream quarry*
	Site#1	*Site#2*	*Site#3*	*Site#4*	*Site#5*	*Site#6*
Time	08:05	08:41	09:31	10:21	11:48	12:32
Weather observation	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny
Flow (m^3/s)	140	140	140	14,5	6	5
Chemical parameters						
Temperature (°C)	24.0	23.4	23.3	24.6	24.1	26.4
pH						
field sampling	8,1	8	7,5	7,6	7,7	8
laboratory analyses			7,5	7,5		
Conductivity (µS/cm)			56,9	71,6		
Alkalinity (mg/l)			36	42		
Nitrate (mg/l)			2,24	3,15		
Nitrite (mg/l)			0,86	0,23		
Phosphates (mg/l)			0	0		
COD (mg/l)			0	0		
Physical parameters						
Turbidity (NTU)			5	2,5		
Total solids (mg/l)	43,8	52,1	43,8	43,3	42,3	46,1
Dissolved solids (mg/l)	38,2	49,6	38,7	37,4	39,5	43,7
Suspended solids*(mg/l)	5,6	2,5	5,1	5,9	2,8	2,4
Biological parameters						
Coliformes (tot.) (col./100 ml)			>200.5	>100.8		
Coliformes fecales (col./100ml)			118	64		

*Obtained through calculation (Susp. solids =Tot. solids –Dis. solids)

Site#1 is located the furthest downstream from the turbine discharge, followed by Site#2 and Site#3 in mentioned order. Site#4 is taken upstream of the discharge (Fig 5.1). For Site#3 the sample was only taken some 2 meters from the shore and for Site#2 only water down to a depth of approximately 0.5 meters was sampled due to sampling difficulties.

It can be seen that water quality for the Esti River downstream the turbine discharge compared to upstream the discharge differs concerning some parameters. The turbidity, nitrite and *Coliformes* increase, whereas the conductivity, alkalinity and nitrate decrease. pH, COD, phosphates and solids do not show any clear difference between samples taken up- and downstream of the turbine discharge.

For the Chiriqui River it can be seen that pH and total solids are lower upstream the quarry compared to downstream that same quarry.

The 14.5 m^3/s flow at the upstream site in the Esti River corresponds to a water level of 116 cm. The river was in a receding state from a maximum at 157 cm, corresponding to 57 m^3/s reached some 14 hours earlier. The turbine discharge had been steady at 125 m^3/s during, and from approximately one hour prior to, the time of sampling, and with minor fluctuations from eight hours prior to the sampling (Appendix A).

The Chiriqui River was also in a receding state from a maximum of 241 cm reached 18 hours prior to the sampling. The flow of 5-6 m^3/s at the time of sampling corresponds to water levels of 17-19 cm. (Appendix A)

Table 5.3 Water quality parameters, sampling round 5, conducted 30/11- 2004

	Conveyance tunnel		**Esti River**			
	Tunnel intake	Turbine discharge	Downstream discharge		Upstream discharge	
	Site#7	Site#8	Site#3	Site#3	Site#9	Site#9
Time	12:35	13:24	10:25	10:25	10:50	10:55
Weather observation	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny
pH	8.45	8.28				
Temperature (°C)	23.0	23.7	22.5	22.5	24.6	24.6
Conductivity (µS/cm)	112.2	66.5	95	105.2	120,4	115,8
Alcalinity (mg/l)	44	48				
Nitrite (mg/l)			0.19	0.02	0.14	0.13
Nitrate (mg/l)			1.08	2.12	1.18	1.87
Ammonia (mg/l)			0.01	0.023	0.014	0.054

In sampling round 5, samples were obtained from four different sites: at the beginning and at the end of the conveyance tunnel and also in the Esti River, both up- and downstream of the turbine discharge outlet (Fig 5.1). For the sample sites in the Esti River duplicate samples were taken for accuracy control.

The values in *Table 5.3* show that the conductivity decreases considerably when led through the conveyance tunnel. This concurs with *Table 5.2* where the conductivity of the Esti River is less downstream from the turbine discharge than upstream from that discharge. The ammonium, nitrate and nitrite concentrations show discrepancies in the duplicated samples. If the second sample for the downstream site is excluded it looks like Nitrite levels increase whereas Nitrate levels decrease after the turbine water enters the river.

Table 5.4 Turbidity and pH levels, sampling rounds 2-4, conducted 25/11-2004 – 29/11-2004

Turbiditysampling 29-11-04

Sampling site	**time of sample**	**pH**	**Turbidity (NTU)**
Quebrada Barrigon (site#10)	10:55	7,7	0,4
Creek Plan de Azucar (site#11)	10:45		0,3
Fortuna discharge (site#11)	10:42	6,8	5,1
Tunnel intake (site#7)	11:50	7,4	5,1
Turbine discharge (site# 8)	13:00	7,2	1,7
River Esti, upstream discharge (site# 9)	13:30		0,1

Turbiditysampling 27-11-04 *Tunnel from Fortuna closed, very little water exiting.*

Sampling site	**time of sample**	**pH**	**Turbidity (NTU)**
Quebrada Barrigon (site#10)	09:00		0
Creek Plan de Azucar (site# 11)	08:45		0
Fortuna discharge (site# 11)	08:42	7,5	0,9
Tunnel intake (site#7)	11:00	7,8	1,8
Turbine discharge (site# 8)	13:45		1,9
River Esti, upstream discharge (site#9)	14:10	7,7	0,2

Turbiditysampling 25-11-04

Sampling site	**time of sample**	**pH**	**Turbidity (NTU)**
Turbin Discharge (site# 8)	09:05	7,2	3
River Esti, upstream discharge (site# 9)	09:25	7,6	0,3

Quebrada Barrigon, Creek Plan de Azucar and the Fortuna discharge all flow into the Barrigon Reservoir (Fig 5.1).

All the turbidity samplings show that the turbidity is significantly higher in the turbine discharge than in the Esti River upstream from that discharge. The discharge water from the Fortuna hydroelectric plant has a relatively high turbidity level and the turbidity level at the tunnel intake increases when this discharge water is entering the reservoir *(Table 5.4)*.

Table 5.5 Water quality indicators measured in the study compared to earlier measured indicators for the Esti River

	Esti, 83-93		**Esti,Oct-00**	**Esti, Oct/Nov-04**		**IDDAN levels**
	Min-Max	Median		downstream discharge	upstream discharge	
Chemical parameters						
pH	6,4-9,07	7,61	7,6	7,5	7,5	6,5-8,5
Conductivity	60-170	103,1	70	56,9-105,2	71,6-120,4	--
Alcalinity(mg/L)	18-70	40	24	36	42	120
Nitrate(mg/L)	0,004-2,38	0,195	--	1,08-2,24	1,18-3,15	10
Nitrite(mg/L)	0,001-0,171	0,011	0,003	0,02-0,86	0,13-0,23	1,0
Phosphates(mg/L)	0,018-0,159	0,08	0,87	0	0	--
COD(mg/L)	0,19-2,51	0,7	8.0	0	0	10
Physical parameters						
Turbidity (NTU)	--	--	43.0	5	0,1-2,5	1,0
Total solids (mg/L)	15-208	86,96	92	43,8-52,1	43,3	--
Disolved solids (mg/L)	--	--	90	38,2-49,6	37,4	500
Suspended solids*(mg/L)	0,78-44,9	6,95	2	2,5-5,6	5,9	--
Biological parameters						
Tot. coliformes (col./100 ml)	--	--	1100	>200.5	>100.8	--
Fec. coliformes (col./100ml)	--	--	60	118	64	--

The levels of the indicators are well within the levels set by IDAAN, with the exception of the turbidity. The turbidity was however even higher when measured in 2000. The only parameters with significantly lower or higher levels than earlier measures are nitrate and nitrite. However, as seen in the duplicate samples in *Table 5.3*, the nitrate and nitrite measurements are not very reliable. Phosphates and COD show zero-levels and are thus lower then earlier measured levels. However, the zero-levels can be due to low measure capability of the analysing method used in the laboratory.

The Esti River has a greenish colour upstream from the turbine discharge. The discharge water has, however, a strong brown colour and when mixed with the Esti River, the colour of the river water changes substantially. Further downstream from the discharge, the river regains most of its natural colour.

Fig 5.1 The greenish water of the Esti river mixes with the brownish water from the turbine discharge. Picture taken just downstream of Canjilones power house (z17 E- 357385 N- 944866).

5.5 Discussion

The decrease of conductivity in the Esti River after the turbine discharge shown in *Table 5.2* indicates that the turbinated water has a lower conductivity than the Esti River. An explanation for the decreased conductivity might be that the water upstream the discharge in the Esti river mainly consists of groundwater base flow and hence has a relatively high conductivity, whereas the turbinated water that comes from the reservoir consist of a higher amount of low-conductivity rainwater, or of groundwater with a lower conductivity due to different soil and bedrock characteristics.

However, *Table 5.3* shows that the conductivity in the turbine discharge is roughly two times lower than the water at the conveyance tunnel intake. According to this result, the water needs to have reacted with the gates; the tunnel walls or the turbines to cause the documented decrease in conductivity.

Since oils and other organic compounds do not conduct electricity well and therefore have a low conductivity in water, an oil spill would lower the conductivity.[24] This decrease in conductivity doesn't only need to refer to diluting effects. It has been shown that droplets in an oil-water micro emulsion carry electric charges. [25, 26]

Charged ions in the water may then be adsorbed to the surface of these charged droplets, and by doing so they will become less mobile in the water. This decreased mobility of ions in the water will lead to a decreased conductivity.

Both old and new hydroelectric plants can have problems with hydrocarbon leaks. Oil can escape from turbine bearings and hydrodynamic seals, wicket gate bushings, insulators and the hydraulic valve system found in horizontal Francis turbines[27]. Hydraulic oil can escape from dam gates.[27]

Hence, it is not unrealistic that the measured decrease in conductivity indicates a problem with oil leaks from the powerhouse in Canjilones. Oil can severely affect aquatic life. Therefore future water monitoring programs should include analyses of oil and hydrocarbon

[24] U.S. EPA (2003)
[25] Eicke et. al. (1989)
[26] Bumajadad and Eastoe (2004)
[27] Inbar (1999)

content in the Esti River. If these samples indicate problems with leaking oil, actions need to be taken to stop this leakage.

Even though the flow was receding in the Chiriqui river at the time of sampling, the particle content increased downstream of an old quarry. This indicates that the sites in the Chiriqui River where building materials were excavated during the construction phase now are eroding and that the particle content in the river therefore is increasing.

The data for nitrate and nitrite are somewhat unreliable as seen in the big inconsistency between duplicate samples (*Table 5.3*). However, it seems like the nitrate level is lower downstream from the discharge and the nitrite level higher compared to upstream from the discharge. Empirically, areas in Panama with tropical forest cover have shown to have high levels of nitrite.[28] The likely effect of the increase in nitrite in the Esti River is that discharge water from the Fortuna Hydroelectric project enters the Barrigon reservoir and thereafter the Esti River. Fortuna is located in a densely forested area why this water can be suspected to have high nitrite levels. The simultaneous decrease in nitrate level can indicate that the cause for high nitrite levels in areas with tropical forest cover is a high presence of denitrifying bacteria. These bacteria can, if oxygen levels are low, reduce nitrate (NO_3) into nitrite (NO_2) when oxidising organic carbon to get energy.

Since the particle content doesn't rise notably after the discharge of the turbinated water (*Table5.2*), the change in colour of the river water is most likely due to an increased content of organic material in the water. This increase is probably due to the Fortuna discharge water that as stated above comes from a densely forested area and thus can be assumed to contain a high level of organic matter.

The higher level of turbidity downstream of the Esti turbine discharge compared to upstream in the Esti River is concurred by all of the turbidity measures (*Tables 5.2* & *5.4*). The one of the inflows to the Barrigon reservoir with the highest measured turbidity is the discharge water from the Fortuna hydroelectric project. However, since no turbidity data are available from the main inflow to the reservoir, the conveyance canal from the Chiriqui reservoir, it is not possible to say whether the turbidity level in the reservoir is affected by the observed erosion from the sides of the reservoir or only comes from the Fortuna discharge.

Even if there seems to be some changes in water quality due to the discharge of turbinated water into the Esti River, most notably a decrease in conductivity and an increase of turbidity, the levels for these parameters are, with the exception of the turbidity, within the limits set by the IDAAN. For turbidity, the IDAAN levels are exceeded also by water upstream from the turbine discharge in the sample analysed in 2000, prior to the project.

Hence this study doesn't show any severe negative impact on the river water quality of the Esti River as predicted in the EIA. However, the decrease in conductivity possibly indicates oil leakage from the powerhouse which then would have to be considered as a negative impact on the water quality. It should also be emphasised, that this is a synoptic study, only testing some parameters and at a receding flow. The strongly eroding river sides downstream of the turbine discharge indicate that during an increasing flow the particle content of the water is likely to be higher downstream the turbine discharge than it would have been without the Rio Esti project, even if this could not be documented in this study. How an increased

[28] Zarete (2004-11-23)

turbidity and particle content affects the aquatic environment downstream the project area and where the river empties in the sea is not evaluated, neither in the EIA nor in this study.

The calculated flows in the Rivers of Esti and Chiriqui are somehow uncertain. It is normal for the river beds of rivers in this area to change shape substantially due to rolling and sliding rocks and stones. The empirical relationship between water level and flow varies and therefore the value of the flow at the hydrological station is not exact. Moreover, smaller streams emptying in those rivers between the site of the hydrological stations and the sites where the sampling was done had to be neglected. However, the trend of decreasing water level is very strong for both rivers, and there is no doubt that they were in a receding state at the time of sampling (Appendix A).

6 Landscape changes

6.1 Introduction

A big hydroelectric project will without doubt cause substantial landscape changes. The most obvious landscape changes after the Rio Esti project are the creation of the artificial reservoirs in the area. Other traces in the landscape are the occurrence of waste dumps, quarries, machinery parks, offices, power lines, a transformation station, a power house, access roads, the diversion canal, audits and pressure shaft for the conveyance tunnel and tree plantations. Moreover the Rio Esti hydroelectric project has led to highly altered flows in the Esti and Chiriqui Rivers and in Quebrada Barrigon, resulting in eroding riversides in the Esti River and a dry old river bed in the Chiriqui River and the Quebrada Barrigon. This landscape change is tightly connected to the possibility to use the rivers for ecosystem services.

Some of the problems in the area prior to the Rio Esti project were erosion causing land degradation and the drying out of springs and creeks during the dry period. The rate of soil erosion depends mainly on five factors: climate, topography, vegetation, soil characteristics and anthropogenic activities. Climate and topography can be seen as the causes of erosion, vegetation and soil characteristic can to different extent reduce the erosion and human activity can either accelerate or decelerate erosion depending on land management.[29] In the project area, land management, or more accurate the lack of land management, has accelerated land degradation. [30]

AES has been planting trees at some 400 ha in the project area, mainly as an erosion protection measure (Fig 6.1). A forest works to avoid erosion in mainly four ways. First, vegetation decreases the amount of water to reach the ground during precipitation, since a number of raindrops are caught in the canopy and evaporates from the leaves, without ever reaching the ground. Secondly, water drops that don't evaporate from the canopy have a lower impact speed when reaching the ground, since a number of the falling drops are slowed down, or split into smaller drops, by leafs (The kinetic energy of the precipitation is generally considered to be the main factor causing erosion.[31]). Thirdly, the roots of trees reinforce the soil which will therefore not be eroded as easily even if run off occurs. Fourthly, trees act as windbreakers decreasing wind velocity at the ground and hence lessening wind erosion.

Fig 6.1 A 4-5 year old teak plantation closely east of the Canjilones powerhouse.

[29] Toy (1977) p.14
[30] Planeta, EIA (1996) p. 9:7
[31] Zachar (1982) p. 207

Land degradation stemming from loss of a vegetative cover is common in many parts of the world's tropical/subtropical regions. Since soil-surface temperature increases significantly following the loss of vegetative cover, the water holding capacity of the soils will decrease. The increased forest cover in the area due to the AES plantations could therefore to some amount decrease the water scarcity in creeks and waterholes in the dry season and break the trend of land degradation. [32, 33]

6.2 Objectives and Scope of the study

The purpose of the study was to, by doing some spot checks, document how the re-vegetation was succeeding at different sites and to what extent debris has been removed from abandoned areas. Moreover, the impacts of the tree plantations are evaluated, and an assessment of whether erosion problems are taking place at different sites or not, without in any way trying to quantify these problems, is performed.

6.3 Methodology

After excursions in the area some tree plantations and abandoned sites were simply visually investigated and photo documented.

At some of these sites the vegetative cover was quantified. This was done by dividing the area investigated in squares of 20 m^2 with the help of a portable GPS. For every one of these, an area of 1 m^2 that seemed representative for the 20 m^2 square was chosen, marked out with a 1 m^2 wooden frame and photographed from the height of approximately 1.5 meters with a digital camera. In a photo edition program a transparent checked pattern was overlaid each picture. The checked pattern was sized so that 10x10 squares covered the framed and photographed 1 m^2 (Fig 6.2). The amount of checked pattern intersections that covered vegetation then responded to the vegetative cover in percent for the 1 m^2, since for every m^2 there are 100 overlaid intersections. This vegetative cover in percent was assumed to represent the vegetative cover for the entire 20 m^2 square.

The photos were taken from the height of 1.5 meters with the photographer standing on one side of the 1 m^2 square, so the photograph is not taken totally perpendicular to the ground but in some angel. Therefore it will look as if a plant situated in the square close to the photographer covers more soil then if it was to be situated on the remote side of the square from the photographer.

To decide the level of uncertainty for the method because of non-perpendicular projections photographs of one square were taken from the four different sides of the square. For this square the calculated vegetation cover differed between 62% and 74%. This uncertainty is however likely to be minor to the uncertainty that lies in picking a 1m^2 square that perfectly represents the 20m^2 parcel of land it is located in. The percentages of vegetation cover given below should therefore be seen more as relative then as absolute figures.

[32] FAS (2005)
[33] Mahe (2005)

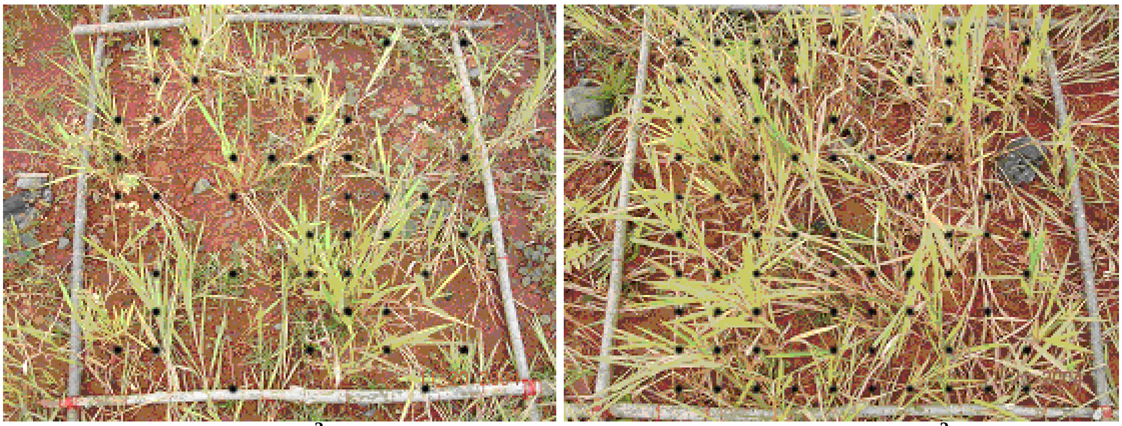

Fig 6.2 To the left, a 1 m^2 with a 44% vegetative cover. To the right, a 1 m^2 with 74% vegetative cover. Black dots show where grid intersections were located over vegetation. The grid used is not shown in the photos.

6.4 Results and discussion

6.4.1 Reforestation programme

With the Rio Esti project, AES Panama bought some 3160 ha from farmers in the area. Most of this land was not necessary for the project.[34] AES Panama has planted trees on some 400 ha of these lands for erosion protection. This could serve as an incentive for others to plant trees on their lands and thereby break or slow down the trend of land degradation in the area. At the time of the study, however, this could not be observed.

AES Panama will be trying to sell off the lands not needed for the project, including the forest plantations. If these lands are sold, it will, according to AES, be done under a contract that regulates the management of the plantations.[35] This should introduce some plantation management knowledge to the area and even if there up to date have not been any observable changes in private land use due to the forest plantations of AES, this could occur when or if local people are making money from the existing tree plantations.

The trees planted in the area by AES Panama are mostly teak; other trees planted in the area by the company are acacia and pine trees. Teak is a valuable and disease resistant tree that grows well in Panama.[36] It drops its leaves during dry periods, thus the capacity to lessen the kinetic energy of raindrops and consequently the positive effect on erosion prevention is lower during the dry season and in the beginning of the wet season than during other times of the year. Even if erosion could occur in teak-plantations during the beginning of the rainy season, no substantial erosion was seen in the plantations investigated during the study. The plantations therefore seem to fill their purpose as erosion protection.

Even if the area can be assumed as able to contain more water during dry periods due to the increased forest cover, the fact that the majority of the planted trees are teak, with no leaves during the dry period, makes it likely that this impact is somewhat limited. Moreover, the tree plantations are not placed in the vicinity of the wells supplying the area with drinking water and the drinking water situation therefore, does not seem to be affected at all. If the

[34] Bergsten (2005)
[35] Victoria (2004-09-10)
[36] United Nature (2005)

waterholes and creeks in the area contained water longer into the dry season compared to before the plantations could not be estimated due to the lack of background data.

The plantations are organised as monocultures where one type of tree (most commonly teak) dominates each plantation. The plantations are not connected to each other and furthermore some of the plantations are now being fenced, giving the plantations a low level of connectivity.

The lack of connectivity between plantations and their poor heterogeneity makes them less suited for wildlife than would otherwise have been the case. The positive impact on biodiversity that in the EIA are supposed to stem from an increased forest cover would have been bigger with more heterogeneity and higher level of connectivity.

6.4.2 Recuperation of abandoned areas

The EIA states that quarries, service areas, machinery parks, workshops and other temporary structures should be removed immediately after the completion of the construction phase. It also states that the land should be replanted or allowed for natural re-vegetation to occur. Exceptions can be made if the structures can be re-utilized as offices, tourist centres etc.[37] [38]

At the time of the study there still remained debris, buildings and hard structures at a number of these sites (Fig 6.3). At some sites topsoil had been added and grass planted, whereas other sites had no debris or structures but have been left to natural re-colonization (Fig 6.4).

Fig 6.3 To the left (z17 E- 357250 N- 945165), hard structures and debris remain at some sites in the area. To the right (z17 E- 351752 N- 949623), the highly affected area just south of the Barrigon dam, big parts without any land preparation or vegetative cover.

[37] Planeta, EIA (1996) p. 9:28
[38] Env. Audit (2003) p. 18

Fig 6.4 To the left, the site where *vegetative_cover* was mapped (z17 E-357197 N-944787), top soil has been added and grass planted. To the right, the site where *vegetative_cover_2* was mapped (Fig 6.6) (z17 E-357292 N-945397), excavated material from the conveyance tunnel has been placed at this site. The site is left to natural re-vegetation.

Where topsoil have been added and grass planted the vegetative cover is higher than at similar nearby areas left to natural re-colonization (Fig 6.6). The cover is however uneven also at actively re-vegetated sites. As a result, the added topsoil is eroding to some extent (Fig 6.5). The problems with erosion seems, maybe a bit contradictory, to be bigger at areas where topsoil has been added and active re-plantation performed than at areas left to natural re-vegetation. The ground at abandoned sites with no added topsoil is often very compact and consists mainly of gravel or stones, material resistant to erosion because of their size and weight. Erosion that is observed at these sites is almost solely occurring as gullies forming in slopes. (Fig 6.5)

Fig 6.5 To the left, gullies are forming at an abandoned site (south of Barrigon dam) left to natural re-colonization without any land preparation actions. To the right, erosion at a site where topsoil has been added and grass planted (z17 E-357197 N-944787).

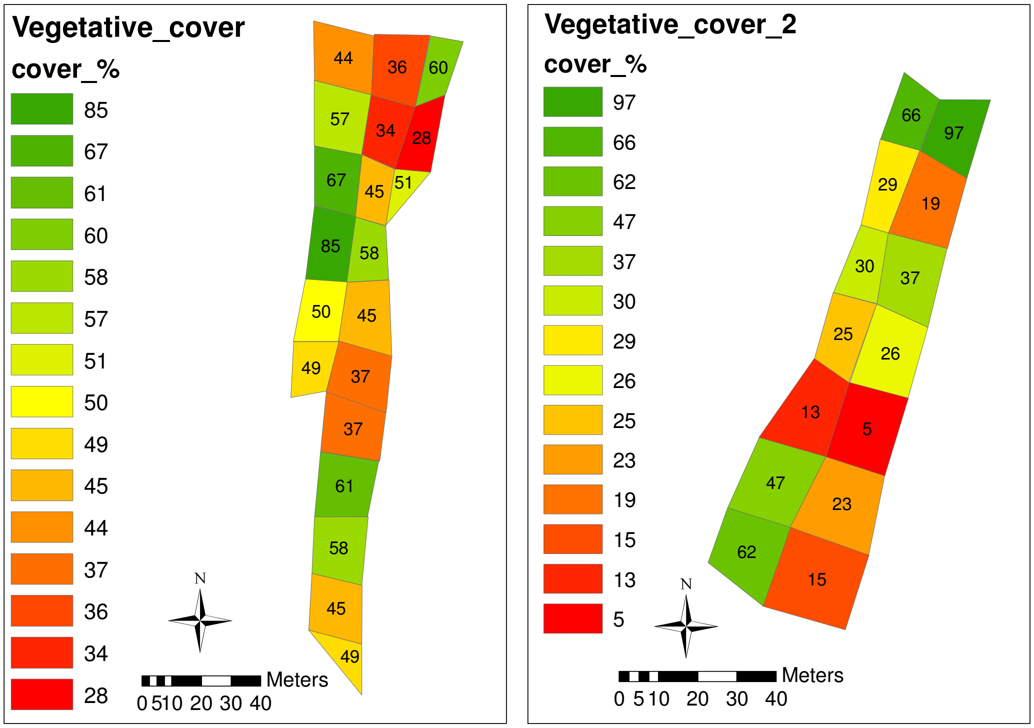

Fig. 6.6 To the left the vegetative cover in percent for an area with top-soil added and grass planted (southern point at z17 E-357197 N-944787). To the right, the vegetative cover for a nearby area that has been left to natural re-colonization (southern point at z17 E-357292 N-945397).

Areas left to natural re-colonization show a very wide range in how far plant re-colonization has reached at this stage, even though they have been left abandoned for approximately the same amount of time. The reason for this could be differences in the ground materials, or differences in how compacted different areas have been. The more compact the ground is, the harder it is for plants to colonize.

It is not likely that contamination is the reason for the comparatively low vegetative cover at some sites. The most likely contaminant of these areas is oil, originating from leaking machines or containers. Contamination of oil would be seen as smaller bare areas since oil is likely to be concentrated to the place where the leakage occurred and not to cover vast areas.

The vegetative cover is recovering at two investigated old quarries in the Chiriqui River. The type of vegetation at different sites in the quarries depends greatly on how high over the river they are growing. There are also parts consisting of big boulders with no vegetation. The vegetation is mainly consisting of bushes, grass and, closer to the river, reed. The quarries were islets in the river prior to the project, used for cattle grazing. Nor the present vegetation neither the terrain makes these sites suitable for cattle grazing nowadays.

Water is sipping through the old quarries and forming small ponds (Fig 6.7). Fry and algae can be seen in these ponds and there are some species of wading birds seen around the sites. However ponds of stagnant water can in tropical areas be the ground for malaria mosquitoes, other disease carriers and bacteria. Not enough time has elapsed since the abandonment of the quarries to see if the health situation has been affected for cattle or humans in the proximity to them.

 

Fig 6.7 To the left, small ponds with stagnant water are forming in the old quarries in the Chiriqui River (z17 E- 354593 N- 948341). To the right, old water holes in cattle pasture showing that stagnant water is not a new occurrence in the area.

It should be noted that the presence of small ponds with stagnant water has existed in the area before the project and the forming of the quarries. In the enclosed pastures for cattle, creeks dry out in the dry season forming small stagnant ponds; water holes are also dug at some sites. Therefore any infectious disease obtained by cattle drinking stagnant water, as well as remedies, should be well known by cattle farmers in the area. Moreover, the quarries are not located in the immediate vicinity to any big groups of households, and neither malaria nor dengue fever is a problem in the area.

The stagnant or slow flowing water at the old islets in the Chiriqui River is therefore not likely to impose any severe health implications in the area. Instead they might act as areas for fish reproduction and as food sources for birds.

6.4.3 Effects of altered river flows

The effect of the altered flow in the Esti River is substantial river side erosion (Fig 6.8). How the people in the area are affected by this altered flow is discussed in section 7.

Fig 6.8 The sides of the Esti river is eroding due to the increased flow.

The decreased flow in the Chiriqui River leaves big portions of the old river bed, consisting of boulders and rocks, dry. It is, however, during peak flows again covered with water.

This old river bottom shows in most places no sign of any re-vegetation. Since deposited soil and plants which are starting to colonize the river bottom are frequently swept away by the high flows that are flooding the river bed, no re-colonization is likely to ever occur. Re-vegetation can only be seen at places with higher altitude or just upstream from the small islands that exist. These are areas that are not flooded with the same frequency and where the water velocity can be assumed to be lower than at other sites in the river during peak flows (Fig 6.9).

Fig 6.9 The old river bottom of the Chiriqui River. At some higher grounds some plants have managed to grow (left picture, z17 E- 355566 N- 943311). The majority of the old river bottom however, is completely without vegetation (right picture, z17 E- 355468 N- 943082).

If plants are to re-colonize the old river bottom, a significant deepening of the main channel has to be made, so that the water does not flood the entire river bottom and sweep away newly colonized plants when the flow is increasing.

Riparian forests along rivers are agreed upon by ecologists to play an important role to mitigate flooding, filter nutrients from run-off, prevent bank erosion and preserve habitat for plant and animal species.[39] And according to the EIA; the most valuable areas in the region from a biodiversity perspective, concerning both fauna and flora, are the riparian forests adjacent to the rivers.[40]

With the changed flow in these rivers the riparian forests are negatively affected. In the case of the Esti River these forests are simply eroding away. In the case of the Chiriqui River, these forests are no longer adjacent to the river water and the necessary interaction with the river is therefore lost.

6.4.4 Erosion protection measures

A lot of effort has been put into replanting slopes where erosion is most likely to occur. The method most widely used is that of vegetative terraces with *Brachiaria humidicola* grass (Fig 6.10). The vegetative terraces are normally combined with the earth being moved into terrace structures. At most places these methods work fine to protect erosion. However, at some sites, namely around the pressure chimney, below Barrigon Dam and on the southern slope of the canal there are signs of gullies starting to form even though vegetative terraces have been planted (Fig 6.10). These gullies are likely to widen with more rain if action is not taken to restore the erosion protection.

Many old abandoned access roads are left without any preparation for re-vegetation. These roads are now eroding and so are adjacent areas since run-off water gains high velocities over the bare pieces of land (Fig 6.11).

Moreover, there are bare slopes on the north side of the diversion canal where erosion can be observed (Fig 6.11). Below the Barrigon dam and along some of the roads there are also slopes without vegetative cover where erosion can be seen or are likely to occur. These sites need to be planted to avoid erosion and possible damages on project structures.

During low water level (117 m a.s.l.) in the Barrigon reservoir a belt of muddier water close to the shores can be observed. This shows that wave erosion is taking place, at least when the water levels in the Barrigon reservoir are low. No vegetation to prevent or decrease erosion around the reservoir has been planted.

No quantifying of the erosion has been done at any of the sites.

According to AES, a survey will be carried out and where needed, improvement of the erosion measures will be performed in 2005.[41]

[39] Amigues et. al. (2002)
[40] Planeta, EIA (1996) p. 5:60, 5:76
[41] Victoria (2004-12-02)

Fig 6.10 Vegetative terraces with *Brachiaria humidicola* to prevent erosion. Even though the vegetative terraces at most places are successful in preventing erosion there are places where eroding gullies are starting to form. Reconstruction of some terraces is needed. (z17 E- 357355 N- 946260)

Fig 6.11 Left, a number of no longer used roads are left un-restored and erosion is occurring. To the right, terraces adjacent to the canal without sufficient vegetative cover are showing traces of erosion (z17 E-354002 N-950221).

7 The ability to use the rivers for ecosystem services

7.1 Introduction

Ecosystem services represent the benefits human populations derives directly or indirectly from an ecological system. Examples of ecosystem services can be food production, water supply, soil formation, recreation etc. These services are often claimed to be given too little weight in policy decisions. [42]

Using ecosystem services for small scale farming, hunting and fishing may be equally important as paid employment as means of earning a livelihood in rural areas in so called developing countries.[43] Where employment opportunities are poor, persons rely more on using the surrounding nature to survive. In an area with rivers nearby, these rivers are normally important to supply the population with different needs, from being a source of food and water to being a place for recreational activities.

If the characteristics of the rivers are changing, the people's possibilities to use the rivers might deteriorate. A change in the possibility to benefit from the rivers in the Esti area can be due to altered flows, deteriorating water quality and a river pattern change (the river runs in a different place from before).

7.2 Objectives and scope of the study

In the area around the Rio Esti project, the rivers of Chiriqui and Esti and Quebrada Barrigon have changed their characteristics considerably. This part of the study aims at investigating in which way the populations in the communities adjacent to the rivers, La Esperanza, El Carillo and Higuerón, have changed their way to use the rivers since the completion of the Rio Esti project.

7.3 Methodology

To achieve the objects of this part of the study, interviews and group meetings were held in the communities of La Esperanza and Higuerón. In the communities of El Carrillo semi structured interviews were held. The interviews were held in Spanish by the author. The group hearings, also in Spanish, were held by the author together with Peter Bergsten who did a simultaneous study on socioeconomic impacts. To inform about the group hearings, posters were placed at natural gathering places in the villages, approximately one week in advance, information about the meeting was also spread by word of mouth. In Higuerón only men attended to the meeting, in La Esperanza there were some women as well even if the majority was men. At both meetings there was unfortunately a complete lack of young persons.

River level readings from the hydrological station La Esperanza in Chiriqui River were obtained from ETESA to complement observations on the changed river characteristics made by people living close to the river.

[42] Costanza et. al (1997)
[43] Chambers (1997) p. 48

7.4 Results and discussion

7.4.1 Changed characteristics of the Chiriqui River

The average flow of the Chiriqui River at the location of the diversion dam was prior to the project 51 m^3/s, the calculated average flow from the diversion dam is 7 m^3/s (Fig 4.4). The minimum flow releases from the diversion dam to assure the supply for downstream users and to maintain aquatic life is set to 1.5 m^3/s and 3.5 m^3/s during the rainy and dry season respectively. [44]

Hence, the average flow of the river has decreased significantly. However, occasionally due to intense rains, excess water is released from the Chiriqui Reservoir through overflow weirs. This causes a very rapid increase in the river level of up to three meters within minutes. This is observed by the people in the area and corroborated by water level graphs. During the months of October and November 2004, such an increase occurred 30 times.

Fig 7.1 The Chiriqui River under the bridge between La Esperanza and El Carrillo. The left picture shows a low flow situation and the right a high flow situation. Both pictures are taken during October 2004, (right picture taken by a villager in La Esperanza) (z17 E-353159 N-950229).

The Chiriqui River has been a regulated river since the construction of the Fortuna hydroelectric plant in 1984 and heavy rains are normal in the mountainous part of the catchment area. Rapid increases of the water level have therefore occurred earlier, but these water level changes are since the construction of the Rio Esti project both more frequent and more rapid than earlier. They are also more unpredictable than before the project according to some of the people living close to the river. No warning system, similar to the one constructed on the Esti River downstream from the powerhouse, exists to alert people prior to dam releases.

The new reduced flow in the Chiriqui River leaves a big part of the old river bed dry. At the sections where the remaining water flows in a narrow stream in the middle or at either side of the old river bed, accessibility to the river can be a problem since people or animals have to walk over the old river bottom consisting of boulders and rocks. At other sections the water trickles down more or less using the entire width of the old river bed. At these sections the water depth is so shallow that it is very hard using the water.

[44] Planeta, EIA (1996) p. 2:5

7.4.2 La Esperanza

The community of La Esperanza, located on the eastern shore of the Chiriqui River, some 1.5 km downstream from the diversion dam is home to some 70 persons. The information on actions and opinions of the population in La Esperanza stated in this section comes, when not mentioned otherwise, from a group hearing held the 17th of October in 2004.

Before the construction of the diversion dam in the Chiriqui River, people from La Esperanza used the river for fishing, swimming, washing and doing dishes. Those having horses or cattle used the river to give their animals water. Fishing was listed to be the most important of these activities on the group hearing.

The changed river characteristics have according to the people of La Esperanza decreased the possibilities for fishing. Even if people can be seen along the river with fishing rods they catch less and smaller fishes than they did before the project.

The water level is too low for swimming and the river is too dirty and inaccessible for washing clothes or doing dishes. Moreover, all activities in or close to the river are now dangerous due to the rapid and unpredictable increase of the water level.

This decreased possibility to use the river increases the demand for the potable water supplied to La Esperanza by the aqueduct, water that during the dry period already is scarce. (See section 8).

7.4.3 El Carrillo

El Carrillo is located on the opposite side of the Chiriqui River from La Esperanza and is inhabited by some 25 persons. Four out of the five households were interviewed.

Since no aqueduct is supplying El Carrillo with water, the Chiriqui River has played an important role for the people, especially during the dry season when the creeks in the areas dry out. The people of El Carrillo have used the river to swim, to wash clothes and dishes, to cook, to give water to animals and also, in the dry season, as a source of drinking water. Fishing is not mentioned to have been of any great importance.

With the decreased flow the water is said to have become dirtier than earlier. The river is also more inaccessible since the remains of the river floats some 30 metres away from the old shore, a distance covered with boulders and rocks very hard to cross for old people. Even for young people it takes time to cross the old river bottom, especially if loaded with dishes or washed clothes. This increases the dangerous situation with the rapid water level changes since it takes some time to reach higher ground when the flow increases. Another disadvantage mentioned with the situation nowadays during the dry period is that tasks like washing and doing dishes have to be performed in the middle of the sun without any possibility for shade.

With the changed situation the people are using the creeks in the area to a wider extent, and are doing so longer into the dry season than they used to. When water bodies start to dry out in the summer, snakes become abundant around the creeks that still have water, the same creeks that the people without a well have to use to wash, to do dishes and to get water for drinking and cooking. These tasks are therefore said to have become increasingly dangerous.

When the last creeks dry out in the summer the families without a well use the river in spite of the dangers the river poses and the bad quality its water is said to have, they find themselves with no other options. For drinking water they have to rely on their neighbours with a well.

7.4.4 Changed characteristics of the Esti River

The natural flow for the Esti River has increased from 6 m^3/s to 75.4 m^3/s with the construction of the Rio Esti hydroelectric project.[45]

The flow is also to a larger extent irregular due to opening and closing of the turbine gates in correspondence to energy demand.

7.4.5 Higuerón

Higuerón is located a few hundred metres west of the Esti River and consists of some 130 households or slightly over 500 persons. The information on actions and opinions of the population in Higuerón stated in this section comes, when not mentioned otherwise, from a group hearing held the 14th of November in 2004.

During the group hearing people claimed that before the project they used the river to fish, to do laundry, to wash themselves and to swim. The river thus served as an area to perform household tasks, to complement the daily aliment and also as a recreational area. Since the project completion the water has a brownish colour and a manifold increased flow. Due to this change in river characteristics and to the danger imposed by rapid changes in the water level, the people no longer does laundry or swims in the river. To fish has become less fruitful.

Instead of using the Esti River, the creeks in the area are used to a bigger extent for laundering, but because of their small size they have limited values for swimming. Moreover, in the dry season they often dry out, and the people are therefore using the potable water for washing to a bigger extent than they did earlier. This increases the demand for potable water, especially in the dry season when, for one part of the community, scarcity was already a problem prior to the project (See section 8).

The statement that fishing has become less fruitful may depend on either that there are less fish as a result of the changed river characteristics or simply that they have become more difficult to catch with the old fishing methods. When interviewed, an experienced rafting and kayaking guide with long experience of the river claimed that the changes he had observed in the river, beside an increased river side erosion, were an increased abundance of birds and a greener riparian zone. No test fishing was done to document if the aquatic fauna had changed in any way.

For the population of Higuerón the most severe effect from the amplified flow of the Esti River is the increased difficulties to cross the river. Earlier the river could be crossed on foot year around, even if one might had to wait some hours for the flow to decrease at rainy season peak flows. Many people in Higuerón have plantations or work on farms on the eastern side of the river and therefore need to cross the river to make their livelihood. People living on the eastern side need to cross the river to sell the harvest at the market. To render crossing the river possible even after the project, AES was obliged to construct four Irish crossings for

[45] Planeta, EIA (1996) p. 8:39

humans, cattle and light vehicles. These crossings were after construction transmitted to the Panamanian Ministry of Public Works (MOP)[46].

The crossings were inadequately constructed. At the time of this study, around a year after the project completion, two of the crossings were completely destroyed due to high flows, trees floating in the river and river side erosion (Fig 7.2). One of the crossings was severely inundated and caused great danger for people needing to cross (Fig 7.3). The forth crossing was still intact at the time of the study.

Fig 7.2 Two of the ineptly constructed Irish crossings over the Esti River, destroyed by the high flows (left z17 E-359863 N-939991, right z17 E-359841 N-939053)

Fig 7.3 The inundated crossing used by people in Higuerón to get to and from their fields or works (z17 E. 360772 N-937458).

Since the Irish crossings had been approved by the MOP and were transferred to their management when they collapsed, AES was not legally obliged to do any reconstruction. However, since the crossings were obviously badly constructed, AES accepted a moral obligation for the situation and commenced the construction of three new bridges in November 2004, two hanging bridges for humans and cattle and one bridge allowing vehicles of up to seven tonnes to cross the river.

It was said at the group hearing that when these new bridges are in place, the situation concerning crossing the river will become better then it was before the project since the possibilities to cross the river with vehicles gives the potential to further develop the plantations east of the river.

[46] Ministerio de Obras Publicos

The severe river side erosion shows that the Esti River is still not wide enough for the present flow. The river is very likely to continue erode the shores quickly until reaching a width that is more suited for its flow. How wide the river will become within 10 or 20 years is hard to say.

The eroding force of the water and the difficulties to construct sustainable structures in the river are seen on the shores close to the former Irish crossings. Here river side protection in the form of stone cages was applied to protect the footings of the crossings. Nevertheless, the river has started to erode around these stone cages (Fig 7.4)

It remains to be seen if the new bridges are to last for any substantial time or if they will follow the faith of the old ones. To assure the future possibilities for people to cross the river proper guarantees should be demanded before management and responsibility is transferred to governmental institutions.

Fig 7.4 The river side adjacent to the Irish crossings shows proof of severe erosion (left z17 E-359863 N-939991, right z17 E. 360772 N-937458).

8 Drinking water situation

8.1 Introduction

Causes for impacts related to drinking water can be the altered flows in the Esti and Chiriqui Rivers, the decrease of cattle herding in the area due to farmers selling of farmland to AES, the increased forest cover in the area due to plantations by AES, the construction of a water plant for the town of Gualaca as a mitigation action included in the project, changed hydrological situation with the creation of two reservoirs in the area, affected streams due to construction of the diversion canal and access roads.

8.2 Objectives and Scope of the study

This part of the study served to see if the drinking water situation has been altered in any way for the people in the area because of the hydroelectrical project and if so to what extent. The area is here considered to be the communities of Gualaca, La Esperanza, El Carrillo and Higuerón.

8.3 Methodology

To achieve the objectives of this part of the study, the same interviews and group hearings as described in section 7 were used. In Gualaca interviews were also held with the *consejo municipal,* a municipal body responsible for supplying the town of Gualaca with drinking water and running the water treatment plant. The water plant was visited together with plant operators and the districts sanitation engineer at the local hospital was interviewed.

8.4 Results

8.4.1Gualaca

Gualaca is the regional centre in the district with the same name. There are some 700 households or some 3000 people.

Before the Esti hydroelectric project, the town of Gualaca was using an aqueduct consisting of 6” plastic tubes and using gravity. The water was disinfected using chlorine granules. In these years there were problems with scarcity of water during the dry season, and a circulation system where parts of the community were closed off at different times to keep the pressure in the pipes had to be utilized. In the wet season, parts of the aqueduct were sometimes swept away by the Esti River during high flows. The water bill was sometimes lowered to half the normal fee for the households due to the unreliable service.

A canal (Canal Casa Blanca) running through Gualaca also provides water for different needs, such as bathing, washing clothes, fish farms, water for animals and irrigation.

As one mitigation effort included in the Rio Esti Project, a water treatment plant for the town of Gualaca was constructed. This water treatment plant is using water from the conveyance tunnel, leading water from the Barrigon reservoir to the turbines in the Canjilones power house.

With the water station in operation, the running costs for the consejo municipal are higher then earlier; they are therefore planning to raise the water fee from $ 2.5 to $ 4 a month per household.

The water treatment plant
The plant uses $AlSO_4$ as flocculent and chlorine gas as disinfectant. The water also passes through a sand filter which is cleaned by back flushing 2-3 times/day. The plant has two storage tanks of 40 000 gallons each. The flow through the plant is normally 16 l/s.

The plant is attended seven days a week and the water quality concerning turbidity, chlorine content, alkalinity, pH and temperature on both incoming and outgoing water is checked more or less regularly, depending on if there are reactants available at the moment or not. IDAAN is also performing monthly analyses, as they did before the completion of the water treatment plant.

8.4.2 La Esperanza

Water is supplied to La Esperanza through an aqueduct consisting of 1.5" plastic pipes, using gravity. Water is taken from the lands of a former farm, now owned by the AES. In La Esperanza there are problems with water scarcity in the dry season. They are using a circulation system closing off different parts of the pipe system during periods of low pressure.

The opinion is that there since long is a downgoing trend in the availability of water in the summer. Therefore the people are trying to construct a new aqueduct to use a different water source; however they are still lacking some 100 metres of tubes to complete the new aqueduct.

During the construction phase of the Esti Project some people were running restaurants serving food to people working in the project. Problems occurred with project workers getting ill. Even though the responsible persons for water issues in La Esperanza considered their water to be of good quality, to not risk a forced closing down of the restaurants, the people of La Esperanza bought equipment for adding chlorine to the drinking water. This equipment is still being used even if not sufficiently to reach the level of residual chlorine (0.8 mg/l) in the distribution system recommended by MINSA. There is also a need to clean the storage tank more frequently than what is done.[47]

8.4.3 El Carrillo

El Carrillo is not part of the district of Gualaca but belongs to the district of David. El Carillo does not have any aqueduct supplying drinking water. During interviews two of the households claimed that before the project, they were using the Chiriqui River as a source of drinking water in the dry season, when the small streams that are used in the wet season dries out. Two families have dug wells. One of these is equipped with a pump and a diesel engine, the other well is newly constructed and the family has not started using it since it is not yet complete. Instead they used a small stream running close to the house. However, they planned to finish the well before the peak of the dry season.

Since the water in the Chiriqui River is said to be too dirty to drink, some families are dependent on one neighbour with a well for getting drinking water during the dry months, a

[47] MINSA (2004)

situation which they find highly unsatisfactory since they are not sure they will get water from their neighbour in the future. Especially not if the well starts to dry out. The well did not dry out last summer, when the hydroelectric project was already operational, but the people are afraid that this might happen if next summers get drier. No attempts to deepen the well have been made.

One of the interviewed claimed that people were getting water from a small waterhole close to the river. This was disputed by the other families and when the water hole was visited it seemed very small and was surrounded with a yellowish slime.

8.4.4 Higuerón

Higuerón can from a drinking water point of view, be divided into three parts. One part (around 50 households) gets their drinking water from an aqueduct consisting of 1.5” - 3” plastic pipes and using gravity. The other two parts get their drinking water from two separate wells. The different distributing systems are not connected. The part supplied by the aqueduct has equipment to disinfect the water with chlorine. Water analyses made by MINSA (19/10-2004) show that this equipment is not in use, this is confirmed by the president of the water committee. The part supplied by the aqueduct sometimes experience scarcity of water during the dry period and utilizes a circulatory system when needed to keep water pressure.[48]

The spring supplying the aqueduct with water is located some distance away from the community. The aqueduct passes over both the Gualaca and the Esti Rivers before reaching Higuerón. Occasionally, during the rainy season, the aqueduct has been destroyed by high flows in the Gualaca River. Prior to the project this never occurred due to peak flows in the Esti River. However the Esti River has today, due to the discharge water from the Canjilones power station, a flow some 12 times higher then it had prior to the project. And since the finalisation of the project, the aqueduct has been destroyed several (2-3) times where it crosses over the Esti River.[48, 49]

Fig 8.1 The Higuerón aqueduct passing over the Esti river. Since the project completion it has been swept a way by high flows 2-3 times. There is a risk that the footing on the eastern (right) river side will erode away in time. This would significantly worsen the situation in Higuerón. (Picture taken from z17 E-359841 N-939053, direction N)

[48] Delgado (2004-10-14)
[49] Group hearing (2004-11-14)

8.5 Discussion

Generally speaking, water analyses performed by MINSA show that the quality of the drinking water in the district is improving year by year, mostly due to increased sealing of the water sources, and to the fact that more communities have the possibility to disinfect the water with chlorine. On the other hand, the quantity of drinking water available in the dry season seems to be deteriorating in the area. However, none of these trends originate from the Rio Esti hydroelectric project; they would have been the same in a no project scenario.

8.5.1 Gualaca

The drinking water situation in Gualaca has improved substantially with the completion of the water treatment plant. Most importantly, the water supply is now a lot more reliable than before the project. The conveyance tunnel has to be assumed as a reliable water source year around and the storage capacity of 80 000 gallons assures that there very rarely will be situations of water scarcity in the town of Gualaca. During the time of the study this was only noticed once and this was due to damages in the pipe system. The pipes between the water plant and the community are crossing the Esti River, but at a higher altitude than earlier. Therefore, even if the flow in the Esti River has increased, the risk of the aqueduct being damaged by high flows has decreased significantly.

The ability to assure a good quality of the drinking water has also increased with the increased water quality sampling and the improved ways of water treatment. However, when tested, the levels of residual chlorine in the pipe system in Gualaca were under the recommended level at 0.8 mg/l set by MINSA. This result concurred with what had been noticed in earlier tests. This could easily be helped by adding more chlorine to the water.

During the dry period the temperature is higher in the area, and because of this more chlorine will vaporize from the water and it will be even more important to raise the amount of chlorine added. One other slight problem that can be expected during the dry period is increased organic material in the flocculation and sedimentation tanks. The treatment plant is surrounded with teak plantations. Teak is a tree that drops its leaves during the dry period. Since the flocculation and sedimentation tanks are not covered, dead leaves are likely to fall into them. This increase of organic material in the tanks will probably increase the frequency with which the tanks have to be cleaned.

The increase in monthly water fee is a negative effect caused by the construction of the water station.

8.5.2 La Esperanza

Since buying chlorinating equipment was more or less forced upon the community it is not surprising that the equipment is not used to the extent required to reach levels of chlorine in the distribution system set by MINSA. For the population, including the responsible for the water issues, the quality of the drinking water is not considered to be a problem. This is also the reason why not even a comparatively quick, cheap and easy measure as cleaning the storage tank is performed with sufficient frequency.

Even if not from initiative of the population, parts of the income generated from the increased commerce during the construction phase of the project has been invested into a possibility to improve the water quality. This gives an increased security for the population against deteriorating water quality.

The biggest problem concerning drinking water in La Esperanza is the scarcity suffered during the dry season. The lands surrounding the spring which is supplying La Esperanza with water, now owned by AES, have not had any trees planted. An increased forest cover in an area may improve water containing capacity of the soil, and if forest would have been planted on these lands, the problem with a decreased water level in the spring during the summer might have declined gradually.

The people of La Esperanza consider a new aqueduct to be the best way to get around the problem of insufficient water supply. They have acquired means for buying all but the last 100 meters of pipe to complete a new aqueduct. This showes that there exists capacity for organisation in the community and that the lack to achieve water quality standards set by MINSA, depends, if not only so at least principally, on the fact that the drinking water quality is not looked upon as a problem.

During the construction phase, there were wells around the community, used in the project. The population of La Esperanza did not want to keep these after the project since it would be necessary to use pumps in order to distribute the water. The increased cost that this would have implied for the water users was said to be the reason for the denial of using the wells.

With a decreased flow in the Chiriqui River, the people of La Esperanza claims that the river isn't used for bathing or washing clothes as it was before the project (see section 7). Drinking water thus has to be used not only for drinking but, to a larger extent than before the Rio Esti project, also for dishes, washing clothes and bathing. This has increased the demand on, and the competition for, the water supplied by the aqueduct. Since the supply has not increased but continues to follow a deteriorating trend, the situation concerning drinking water in La Esperanza has worsened as a result of the Rio Esti Hydroelectric Project.

8.5.3 El Carillo

The drinking water situation in El Carillo is for some of the families extremely precarious, and it has worsened because of the Rio Esti Hydroelectric Project. No water samples concerning the bacteriological or chemical quality of the water in the Chiriqui River were analysed to support or dispute the claim made that the water is now too dirty to serve for drinking or even cooking. However, it is likely that with the substantial decrease of flow in the river, the water quality will be affected in a negative way since pollutants aren't diluted to the same extent. For this reason it is also likely that the water quality will be worst in the dry period when the water is most needed.

Remarkably, El Carillo was never even mentioned in the EIA, even though concerning the drinking water situation, the persons most severely affected are found here.

To alleviate the worsened drinking water situation, an aqueduct can be constructed, wells can be dug or El Carillo can be included in the water distributing system of La Esperanza without any major technical difficulties. However, between the population of El Carillo and the population of La Esperanza there are strong antagonistic feelings. The people of El Carillo claim that they helped building the aqueduct to La Esperanza and that the distribution system should therefore be extended to also include the households on their side of the river. In La Esperanza it is on the other hand claimed that the aqueduct was constructed without any help from people in El Carillo and that they therefore do not want to share the already limited supply of drinking water.

The situation in El Carillo is likely worsened since it belongs to the district of David instead of the district of Gualaca. Thus the administration bodies for El Carillo and La Esperanza are not the same, which makes cooperation concerning water issues more difficult.

The people that are worst off concerning drinking water in El Carillo strongly argue about their precarious situation. They also feel that the AES should be obliged to compensate them for their worsened situation by building an aqueduct to the community. Except for the one household that has dug a new well, no one of the interviewed persons in El Carillo have done anything to improve their situation themselves, nor did anyone express any specific plans to do so. If this depends on their disempowered situation or an exaggeration of the problems is difficult to say without actually observing the situation during the dry period. Willingness to take part constructing an aqueduct if they were to be provided with pipes was expressed.

8.5.4 Higuerón

No issues concerning the quality aspect of the drinking water were mentioned during the group meeting or the interview. The fact that existing equipment for disinfection is not used is also a clear indication that water quality isn't considered a problem.

Scarcity of water during the dry season for the part served by the aqueduct (some 50 houses) is the only problem experienced in Higuerón concerning drinking water. This situation is worsened by the Rio Esti Hydroelectric Project since the increased flow in the river erodes the river sides and tumbles trees that are then carried downstream, destroying the aqueduct. The drinking water situation for the other parts of the community is not affected by the project.

There are some possibilities to raise the aqueduct so that it will cross the Esti River at a higher elevation, but because of the lack of trees high enough on one river side this is not likely to solve the problem entirely.

Furthermore, with the increased flow of the Estí River the river pattern is now likely to change into having a less meandering characteristic. When travelling downstream on the river from the discharge at the Canjilones powerhouse, river side erosion can be seen along almost the entire length of the river down to its confluence with the Gualaca River, also where the aqueduct crosses the Esti River, and even if the aqueduct is elevated, it is likely that the tree that serves as footing on one side of the river will erode away in some years. Moreover, the aqueduct crosses over the Esti River where the river bends around a low promontory (Fig 8.2). With the increased flow there are signs that the river will erode and transform this promontory into an islet. The difficulties and costs for having the aqueduct cross the river will then be multiplied.

Fig 8.2 Left, the Esti river is eating into the low promontory (right) where the aqueduct for Higuerón crosses the Esti River.

9 Conclusions and reflections

This study has looked into the situation one year after the project entered the operational phase. Hence no concern is given to any environmental problems during the construction phase. This study is also limited geographically and has omitted those communities and areas further downstream from the project area. Moreover, this study took place entirely during the wet season. The situation during the dry season can therefore not be properly estimated.

9.1 General Conclusions

The suitability to use the Chiriqui and Esti rivers for ecosystem services, such as recreation, fishing, washing clothes, bathing and doing dishes has decreased. The populations suffering from this decrease are those in the communities close to these rivers, namely La Esperanza, El Carrillo and Higuerón.

The main reason for the decreased use of the Chiriqui River is that the water is said to have become dirtier with the lower flow, that it is harder to access the water when the water edge is further away from the communities, that the river at some places is too shallow to use, that there is less fish and that it is dangerous to get near the river due to the rapid increases of the water level.

Along the Esti River the decreased use of the river is said to be due to less catch of fish and an increased danger using the river. Even though there is a warning system along the Esti River the people still thinks of the river with its manifold flow increase as too dangerous for swimming or washing clothes as they used to.

With the exception of putting a warning system along the Chiriqui river (This work was planned but had not started at the time of this study), no work is planned to mitigate any of the causes for the decreased ecosystem service value of the Esti and Chiriqui Rivers.

This decreased use of the Rivers increases the demand for potable water which now has to be used for washing and dishing to a greater extent than earlier. Scarcity is considered to be the one big water problem in the area, and this problem has increased in the communities situated close to the rivers. In Higuerón the situation has not worsened only because of increased demand for drinking water but also because of more frequent collapses of the aqueduct due to the higher flows in the Esti River. The situation will worsen significantly for parts of this community if the footing for the aqueduct where it crosses the Esti River is eroded away.

The town of Gualaca is not situated in the immediate vicinity of the Esti River but is suffering from a decreased flow in the Casa Blanca Canal, running through the community. This canal is used for washing, dishing, bathing, fish-farming and for watering cattle. The increased pressure on potable water due to the decreased water in the canal is more than compensated by the newly constructed water plant. Because of this plant, there is an improvement in water access and quality in Gualaca town. However, the water plant has increased the running costs and the tariffs for water are planned to be increased with over 60%. To what extent this affects the poorer part of the population remains to be seen.

No mitigation efforts for the increased pressure on drinking water except for in Gualaca have been done, nor are any recommended in the EIA. The most severe situation is in El Carrillo, where the Chiriqui River earlier was used as a source of drinking water during the dry period. This community was strangely not even mentioned in the EIA and no mitigation efforts have been done nor are there any planned in this community.

The most severe effect from the changed river flows is the increased difficulties to cross the Esti River for people living in and around the community of Higuerón. Many people have their fields or their work on the opposite side of the river from where they are living. These problems were foreseen in the EIA and four crossings where constructed as mitigation efforts. These crossings were, however, inaptly constructed and at the time of the study, two were completely destroyed and one was severely flooded. New crossings are to be constructed but before they are finished there is no compensation for the suffered loss of income for the people of both sides of the Esti River.

The effect on the water quality in the Esti River has not proved significant in this study, but this part of the study has been limited.

The vegetative terraces constructed to avoid erosion are mostly working. Some do need to be repaired since erosion has started and is likely to increase. An inventory of where repairs of the terraces are needed should be performed in the close future. This is also the intention of AES Panama. However, not at all erosion susceptible slopes have been planted. Thus there is a need for an extension of erosion protection measures.

Many places are left for natural re-vegetation. The pace of re-vegetation differs widely between sites. No complete inventory has been made to see if special land farming measurements are needed to promote re-vegetation. Even though there are sites where vegetation rapidly is gaining ground, with the present strategy scars will be left in the nature for a long time to come. Some sites still have concrete structures remaining, totally preventing any re-vegetation

The tree plantations seem to work fine to prevent erosion, but their benefits as wildlife habitats are limited due to the monocultural character of the plantations and the low level of connectivity between them. The plantations have not yet shown any signs of promoting a diversified land management among the people in the area.

9.2 Compliance with the EIA

The EIA states a number of measurements needed to be carried out in order to prevent or mitigate negative impacts from the project. Some of these measurements are still to be realised. The project fails to comply with the EIA in mainly two aspects, namely those of removing debris and preparing surfaces for re-vegetation, and monitoring the river water quality.

As has been noted in earlier studies, there is still debris lying around at some sites and old abandoned access roads are left unprepared for re-vegetation[50]. No activity to change this situation was observed even though the EIA states that it should.

At the time of this study there was yet no monitoring of the river water quality. Negotiations with universities to perform the sampling and analysing were underway but not showing any

[50] Env. Audit (2003)

quick results. No monitoring was done prior to this study even though the EIA states that these monitoring efforts should be performed once a month during the first year.

The mitigation of just paying for lost land to erosion along the Esti River due to the increased flow is only justified if there are to be new hydroelectric plants constructed on the river within a five year period. That this will happen seems more and more unlikely due to unfavourable bedrock characteristics. If there within five years are no additional hydroelectric plants in the Esti River, according to the EIA erosion protection constructions need to be built. But concerning the way the river is eroding its margins it seems unlikely that these will succeed in preventing erosion. Moreover, it would be an expensive measure and it is more likely that AES will appeal this part of the EIA.

There are no signs of the extensive River Management Plan, worked out in the EIA, to be followed up.

9.3 Reflections

Mitigation efforts seem to be focused on a few big projects. People living in the periphery, both geographically and socially, are mostly left out. The least empowered persons seem to gain the least and suffer the most from the Rio Esti project.

The presence of a big company in an area can often have some positive side effects on that area. To improve public relations, companies have been known to spend money on activities ranging from sponsoring the local football team to carrying out extensive social work (For example EGE Fortuna, owner of the Fortuna Hydroelectric plant, located in the district, is planning to build new aqueducts and supply more disinfection equipment in the area during 2005. They have also donated an ambulance and helped equip Gualaca hospital). AES has yet not started any activities of this kind but the general belief and expectation is that when the Rio Esti Project has been running for a bit longer, AES will also contribute to improve the situation for the people in the area.

However, there is of course no obligation for companies to supply social services to people living in the region where the company is operating. Still, it seems that in Panama, where governmental services can be insufficient in many rural areas, the population, the rural municipalities and also the central government often count on big companies in the region to supply help with different social services. The ministry of health (MINSA) is now said to redirect funds away from the Gualaca district to other parts of the province and country since they consider it likely that a certain amount of social services will be supplied for by EGE Fortuna, and now also by AES Panama. To rely on the benevolence of private companies for social services to be provided to the population is of course highly uncertain, but nevertheless, this seems to be the case in Panama. If a central agency is overestimating the total inputs to social services from a private company the effects for the district will be a decline of social services instead of the expected improvement. The inputs made by the company will not be additional and the planned mitigating effect for people affected by a project will be diminished by the redirection of governmental or provincial funds.

The owner of a hydroelectric plant is obviously interested in focusing on producing and selling electricity. Maintenance of structures not directly affecting the productivity and of continuous mitigating activities are rather sold, put on contract or transferred to governmental agencies or municipalities. There is nothing bad or strange with this transfer, but it is very important that the body overtaking responsibilities has the capacity to do so in a proper way.

With the transfer of structures or responsibilities the plant owner should still have obligations if there shows to be problems later on stemming from, for example, inadequate construction.

It appears to be no or very weak intentions to follow the EIA where recommendations are given instead of obligations. The extensive River Valley Management Plan on how to promote environmental, social and economical development in the area presented in the EIA seems to be work performed in vain, especially where there are ambiguities concerning the body responsible for the action. When mitigation efforts are not directly referring to the project and therefore not included in the construction or operating costs, the body responsible for executing and paying for the actions needs to be explicitly stated. Otherwise there is much work put on recommending ambitious actions that are very unlikely to ever be carried out. This work then only serves to increase the cost of the EIA.

Also, there seems to be no intentions of introducing mitigation efforts for negative impacts that have not been foreseen in the EIA. The agency to evaluate the situation, and where needed demand new mitigation efforts, is the Panamanian national environment protection agency, ANAM. ANAM has not been given any extended resources to oversee the project wherefore their ability to do so must be considered limited. Any activity dealing with the Rio Rio Esti project also draws attention away from other environmental issues in the district.

A possible approach to get around the weak following up of projects is to lessen focus on vague recommendations in the EIA and instead earmark this part of the budget for audits following up both how well the owner is complying with the EIA during the operational phase and to what extent new actions need to be carried out by the owner in order to mitigate unforeseen negative impacts of the project. This following up should take place at some occasions during a certain number of years and should favourably be part of the EIA contract. Therefore, it should be undertaken by the same company that did the EIA, but now together with the district or regional office of the agency with the authority to exercise legal measures, e.g. the environment protection agency. In this way the comprehensive knowledge about the project that the company who performed the EIA already has, will be transferred to local responsible authorities. The continuous screening of the monitoring plan, and of new impacts stemming from the project, should then be taken care of by the agency with the legal authority. To assure that a continuous screening can be performed, part of the tax on the companies' earnings from the project can be earmarked for the regional office of the screening responsible agency.

10 Abbreviations

Here follows an explanation of abbreviations used in the paper:

AES	Applied Energy Services *An American Energy Company*
ANAM	Autoridad de Nacional del Ambiente *Panama’s National Environment Authority*
ECTS	European Credits Transfer System *A scale to transfer credits for university studies*
EIA	Environmental Impact Assessment *See section 2*
ETESA	Empresa de Transmisión Eléctrica SA *Panama’s Transmission Company*
IDAAN	Instituto de Acueductos y Alcantarillados Nacionales *Panama’s Institute for National Water Supply and Sewage Systems*
IRHE	Instituto de Recursos Hidrológicas y Eléctricas *Former state owned Electricity Company*
MINSA	Ministerio de Salud *Panama’s Ministry of Health*
MOP	Ministerio de Obras Públicas *Panama’s Ministry of Public Works*

11 Acknowledgments

The main financial means for this study was issued by the Swedish International Development Agency (Sida) through the committee of Tropical Ecology of Uppsala University

The personnel at AES Panama were most helpful during the study. Special thanks to José Victoria for supervising my work in Panama and for giving the permission for this study to be carried out. Also to Randolpho Guerra for arranging with accommodation and helping out whenever needed.

Appreciation also goes to my supervisor in Sweden Lennart Strömquist for coming up with the idea of the study, for lending equipment and for giving useful advices during and prior to the study.

I would also like to express my deep gratitude to:

ETESA and their staff, for aiding me with the water sampling and generously sharing their time, information and resources with me.

Manuel Zarete at Planeta Panama, for allowing me to use their maps and giving me valuable insight information about the work with the EIA.

The staff at the Consejo Municipal in Gualaca, for letting me use their laboratory at the water treatment plant and taking lots of time answering my questions.

Peter Bergsten with whom I shared housing during the study, for the cooperation, the good times and the views given on my work. He conducted at the same time a study about the social and economical impacts of the Rio Esti project, for more information consult his work "*Audit of social and economic impacts, Estí hydroelectric project, Panama*"

Anders Carlsson and Mats Stenmark at SwedPower AB, for letting me share the information in the Basic Design and sending me an excellent map of the area.

Finally, a big thank you and good luck to all other persons in Gualaca who in different ways have been helping me with the study and been showing me their hospitality. May all go well!

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Delgado Delgado Dennis, Water Committee President, Higuerón

Victoria Victoria José, Engineer, Environmental Manager, AES Panama, Caldera office

Zarete Zarete Manuel , Engineer, Planeta Consultores, Panama

Appendix A

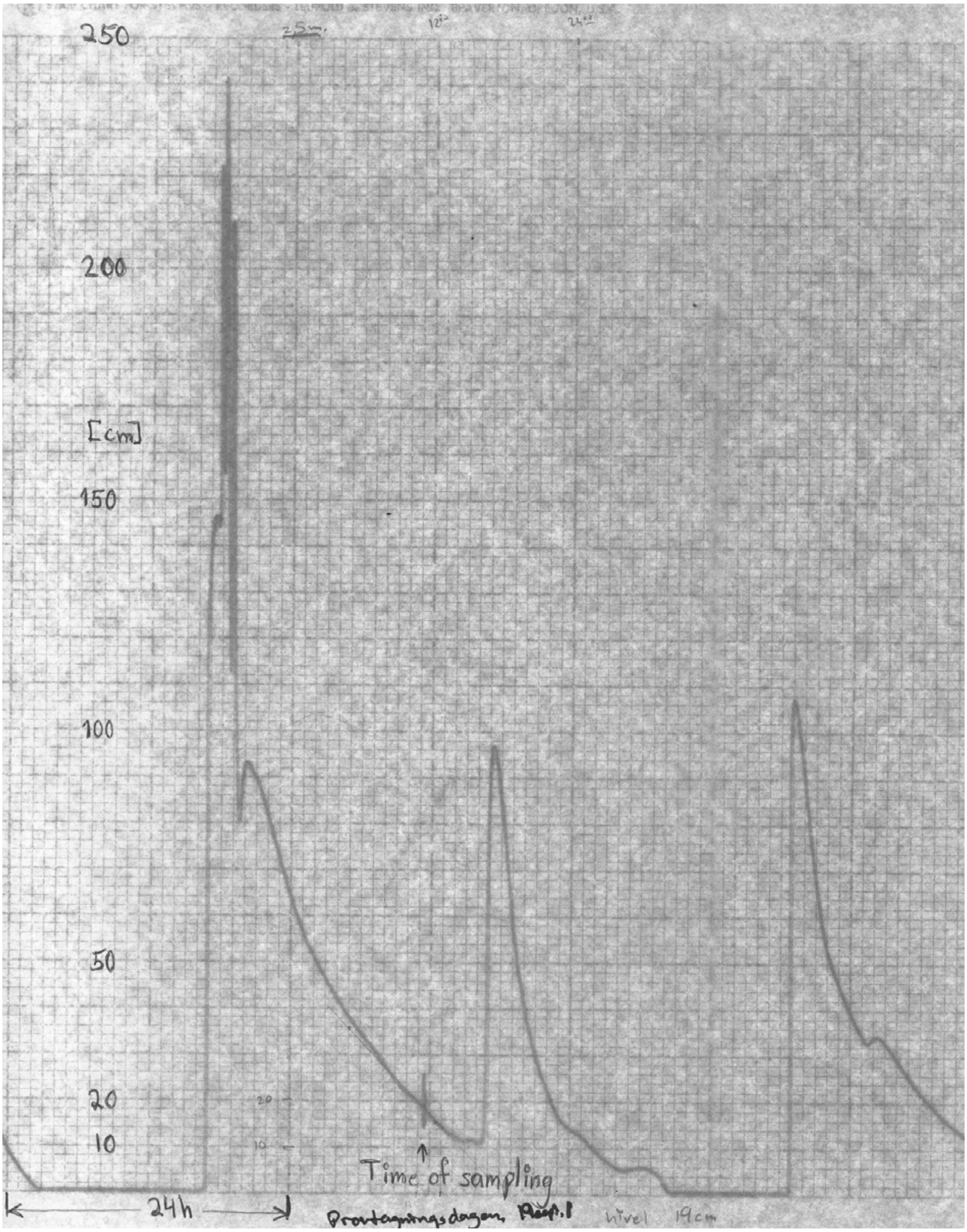

Fig A.1 River water level of Rio Chiriqui around the time of sampling round 1. The time of sampling is noted on the graph.

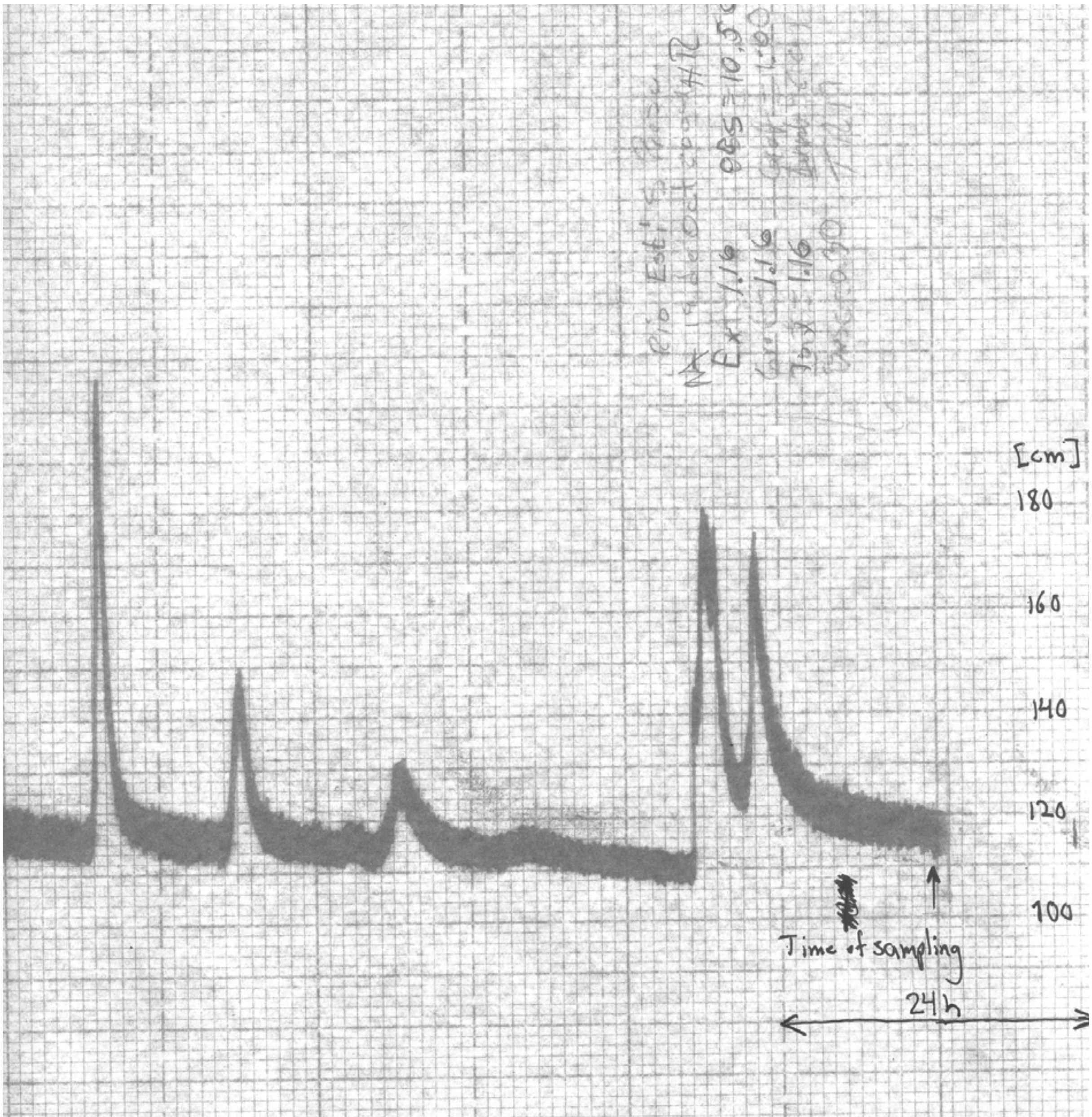

Fig A.2 River water level of Rio Esti (Site#4) around the time of sampling round 1.

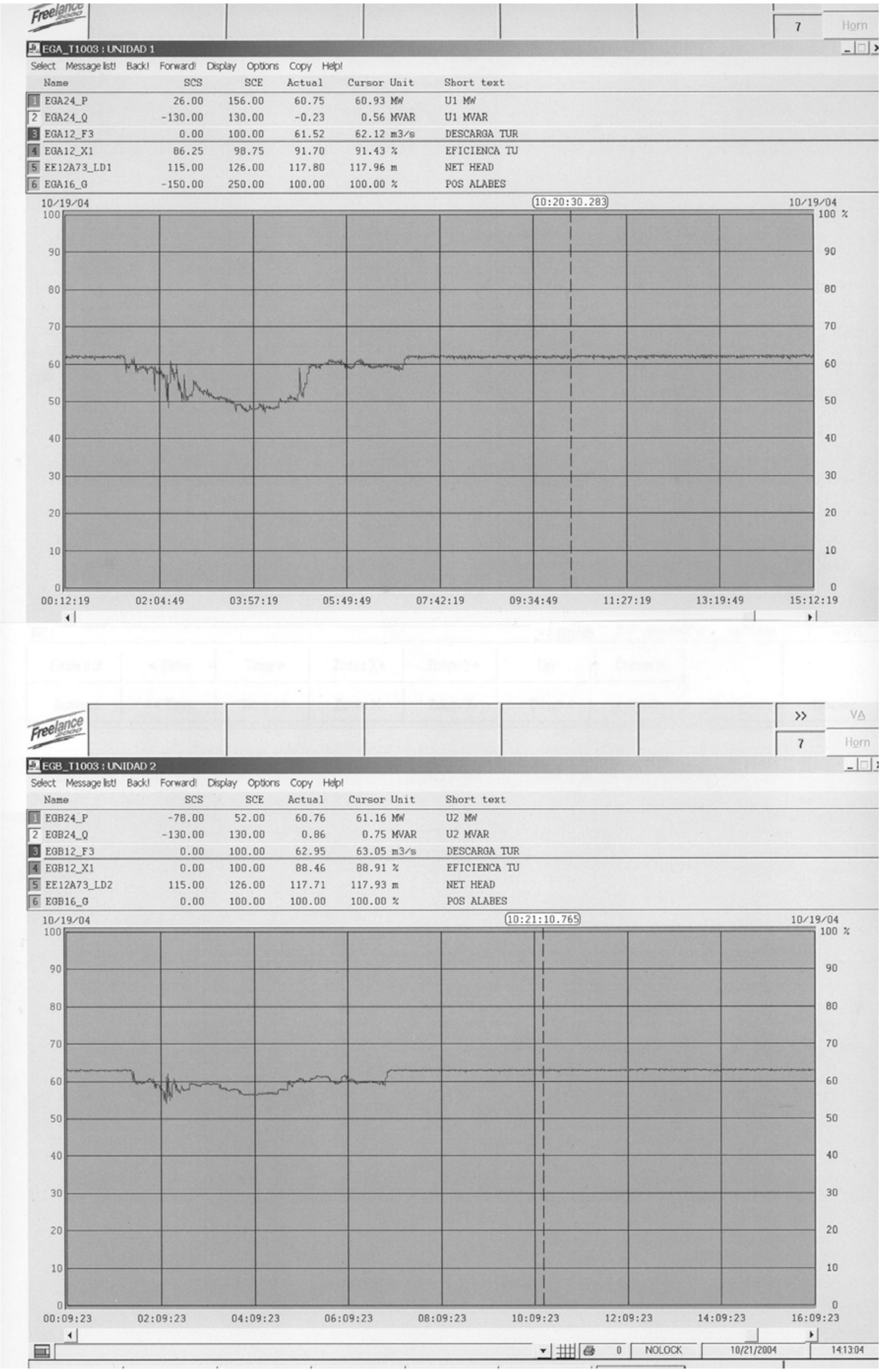

Fig A.3 Flow in turbine 1 & 2 in the powerhouse (Site#8) around the time of sampling round 1.