AFULILO HYDROELECTRIC POWER PROJECT

ENVIRONMENTAL IMPACT ASSESSMENT

DECEMBER 1991

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SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME

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GLOSSARY OF TERMS AND UNITS

(Note: These explanations are provided for the lay reader. They are not intended to be scientifically precise.)

Algae	Very simple plants.
Anaerobic	Lacking in oxygen.
Bored-piles	Piles formed by pumping concrete down bored shafts.
Conductivity	The degree to which electricity will pass through water providing an indirect measurement of the concentration of dissolved ions (salts).
Crustacea	The Class of animals which includes the shrimps and crabs.
dBA	The average loudness of a noise source (measured in decibels).
EIA	Environmental Impact Assessment (may be applied to a document or to a process).
Fauna	Animals.
Flora	Plants.
GWH	Giga Watt Hour, a measure of the total power produced over a period of time, 1000 megawatt hours.
ha	Hectare, 10,000 square metres of area.
Ions	Salts
km	Kilometre, 1000 metres.
kV	KiloVolt, a measure of electric potential, 1000 volts.
m	Metre.
Macrophyte	A large higher plant (as distinct from algae).
Millimetre	One thousandth of a metre.
Mollusc	A group of animals which includes the snails and shellfish.
Montane	Occurring in mountains.
MW	Mega Watt - a unit of power, 1000 kilo watts.
Penstock	Pipes carrying water down to the power house.

pH	A measure of acidity and alkalinity, a scale from 0 (most acid) to 14 (most alkaline).
Planktonic	Small plants and animals which live floating in the water.
ppm	Parts per million, one ppm = one gram per cubic metre.
Salinity	A measure of saltiness.
Simulations	Models of the behaviour of a system.
Taxa	Groups of related plants or animals.
Turbidity	cloudiness in the water.
μ MOS	Micro Mhos/centimetre, a measure of conductivity.

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EXECUTIVE SUMMARY

The Afulilo hydroelectric power scheme will be completed in 1993. It will then provide for more than half the electricity needs of Upolu. This report examines the environmental impacts of the scheme and makes recommendations for their reduction. This summary highlights the main points. Detailed conclusions and recommendations are set out in section 8 of the report.

Environmental impact assessment needs to be completed in the design stages of a project. The Afulilo scheme is already under construction and many of the options have been decided. This has limited the value of the current assessment.

An environmental impact assessment was completed during the investigation stage of the project and that, together with technical studies, formed the basis of the decision to proceed with the scheme.

It is recommended that for major developments Western Samoa adopt the practises of:

- early environmental assessment;
- public comment; and
- technical review.

The Electric Power Corporation (EPC) has recognised the potential of vegetation in the Afulilo Reservoir to cause problems for the scheme and is going to considerable trouble and expense to clear the reservoir area. The quality of water in the reservoir is, however, still likely to be poor, particularly in the first few years of the scheme's operation. This will be because the plants growing in the reservoir will rot when it is filled, fouling the water. This process will be repeated each time the reservoir is emptied and refilled.

To reduce this effect it is recommended that:

- as much vegetation as possible is removed from the reservoir before it is filled;
- it is flushed out several times in the first years of its operation;
- pandanus, hibiscus and falaga are planted around the reservoir margins;
- people are discouraged from living near the reservoir until the water quality settles down;
- villagers at Ta'elefaga are compensated for the loss of the clean stream through their village.

The reservoir lake will range between about 250ha and 2ha in size. This fluctuation will contribute to the fouling of the water and will reduce its value for fish and birds. Maintaining the lake at a minimum of 100ha would forego only about 10% of its storage capacity but would enhance its natural and water quality values. It is recommended that the operating regime for the lake limits its draw down to keep a minimum lake size of about 100ha. The minimum lake area should be finalised after further studies.

Formation of the reservoir has destroyed the vegetation of the Punataemo'o swamp. This was the most important natural area remaining in Western Samoa. The Vaipu swamp in the Fusiluaga basin below the Afulilo falls is the only similar area remaining in Western Samoa. This area could be threatened by agricultural development and by extensions to the Afulilo hydroelectric scheme. It is recommended that the government of Western Samoa:

- close all construction roads associated with the power scheme once construction is complete;
- seriously consider the natural values of the Vaipu wetland before deciding to proceed with the proposed Vaipu extension to the Afulilo power scheme; and
- seek legal protection for the Vaipu swamp.

Effective operation of the Afulilo scheme and protection of its surrounding environment will depend on cooperation amongst a number of groups. These include the Electric Power Corporation, the local villagers, the Department of Lands and the Environment and the Department of Agriculture, Forests and Fisheries. It will be necessary, for example to control agricultural development in the catchment of the reservoir to prevent it silting up. Discussions will be required with the residents of Ta'elefaga village if poor water quality is causing problems. The cooperation of other villagers will be required to protect the Vaipu swamp.

In New Zealand, debate over the development of the Manapouri power scheme led, in 1973, to the formation of the Guardians of Lakes Manapouri and Te Anau. The Guardians were given powers under law to advise on the management of the lakes and the power scheme. Similar groups were also established elsewhere and have now been successfully operating for 18 years. It is felt that this may be a suitable model for catchment management cooperation for the Afulilo catchment.

It is recommended that a catchment management committee is established for the Afulilo scheme, including the local MP, a matai from Ta'elefaga village, a representative of the EPC, a representative of the Siosiomaga Society and chaired by the head of the Division of Environment and Conservation. The group would oversee the development and implementation of a catchment management plan. It could report annually to the Minister of Lands and the Environment.

Suggestions have been made that the reservoir be used for fish farming. Given expected changes in the size of the reservoir as the scheme is operated, the probable poor water quality and the fact the area is free of exotic fish, it is recommended that such proposals are approached cautiously.

Many of the predictions about the effects of the scheme are uncertain. It would thus be a good idea to re-examine the environmental impacts once the scheme is operating.

It is recommended that a post commissioning environmental audit be undertaken about a year after the scheme is commissioned.

1. INTRODUCTION

1.1 The Project

The proposed Afulilo Power Scheme in Western Samoa involves taking water from the headwaters of the Fagatoloa River and passing it through a 4 MW power station to discharge into Fagaloa Bay. The proposed storage in the Afulilo basin offers the only prospect for significant hydro-electric power development in Western Samoa.

1.2 E I A Brief

The Department of Conservation (NZ) responded to a request from the South Pacific Regional Environment Programme (SPREP) for assistance in preparing an Environmental Impact Assessment (EIA). The Department agreed to assist on the basis of its standing Memorandum of Agreement with SPREP. The terms of reference for this EIA are:

(1) to outline a process of environmental impact assessment for projects of this type;

(2) to assess the impact of the project on adjacent high value environment;

(3) to identify and advise on mitigation and enhancement options still open;

(4) to make recommendations on construction work in order to minimise environmental damage;

(5) to make recommendations on future development options for the hydro electric power scheme; and

(6) to assess the project's long term viability, particularly in the light of climate change.

This document is intended as an aid to decision making on the Afulilo scheme. It presents summary information in a way which allows people to better understand the effects of the scheme and makes recommendations on actions which could be taken to reduce the impacts.

It reviews both the effects of the scheme and an earlier environmental assessment carried out by Winders *et al* as part of the scheme design. The present report makes extensive use of material drawn from the tender design documents, the Winders assessment and the review of tender design by MacDonald and Partners. It also incorporates material from investigations conducted by the authors in August 1991.

2. ENVIRONMENTAL IMPACT ASSESSMENT PROCESS

2.1 EIA Process

A process of environmental impact assessment (EIA) allows those affected by a project to better understand what will happen to their surroundings and their lives. It involves communication between those:

- who are affected by the project;
- who are promoting the project; and
- who have to make decisions about it.

The EIA process differs around the world. For significant proposals, however, it always involves three essential elements:

- an EIA document;
- public comment; and
- an independent technical review.

The EIA document describes:

- the proposal and alternatives that could be considered;
- the existing environment;
- the expected effects; and
- what the proposer intends to do about those effects.

Public comment will be obtained through consultation appropriate to those involved. From scientists and government agencies written comment would be normal. For local communities, meetings and discussions with small groups is usually more useful. A written record should, however, be made, and it is usual for there to be an description of the concerns expressed.

The independent technical review examines the proposal and the concerns expressed and provides a check on the accuracy of what the proposer states.

An EIA process has benefits for all concerned. It allows those affected to better understand and react to the proposal. It usually results in positive changes to the project from the proposer's point of view. It gives decision makers a much better basis for an informed decision.

It is now accepted in many countries that between 1% and 5% of the capital cost of a large project may be spent in identifying and reducing the environmental impacts that it causes.

2.2 EIA Process for Afulilo

Environmental impact assessment was carried out for the Afulilo project. In the design of the hydroelectric scheme environmental impacts were examined and field investigations were completed by Winders *et al*(1987).

2.3 Role of the Current Assessment

The present document fits into the process at a point where construction has already begun and most of the significant design decisions have been taken. It can, at best, attempt to accurately describe the effects of the project and offer suggestions to reduce the impacts. It may also serve to identify the range of matters that should be addressed in a comprehensive environmental assessment for projects of this type.

Environmental assessment, to be useful, begins at the earliest stage of the design of a project and this was done for the Afulilo project by the design consultants. It involves communication that modifies the proposal through the design process. It should establish communication links that allow the project to incorporate new information and to deal with new factors as they arise. It would be useful for future projects if Western Samoa were to establish a formal procedure which required public consultation and technical review as part of the environmental assessment process. We understand that regulations to this effect are under consideration.

2.4 Statutory Connections

Prior to the passage of the Lands and Environment Act 1989 in March 1990, and its coming into force on 27 July 1990, there were only a few provisions scattered in a variety of statutes that related to the environmental impacts of development schemes. We were advised by Clark Peteru, Director of O Le Siosiomaga Society, that these scattered provisions had little positive effect. He says that "The lack of consolidation, specificity (or generality) and enforcement of these provisions meant in practice that development schemes were implemented with minimal or no regard to their environmental effects."

Mr Peteru advises that the 1989 Act substantially strengthens the legal situation. Although a decision was made to proceed with the Afulilo scheme prior to the passage of the Act, the Minister of Lands and Environment has power under the Act to take remedial action as the scheme progresses or after it is completed.

Under section 104 of the Lands and Environment Act the Minister may carry out monitoring and follow-up work. Section 116 would enable the Director of Lands and Environment to commission a management plan for environmental regulation of the scheme and its catchment. Such a plan could allow for mitigation of impacts, set limits on the quality of discharges, and allow for planned management of the catchment. The approval of the Minister and ratification by Cabinet is required before any such plan becomes operative.

3. DESCRIPTION OF THE AFULILO POWER PROJECT

3.1 Introduction

The proposed Afulilo Power Scheme involves a 250 hectare storage lake with around 10 million cubic metres of water storage. Its location is identified in Figures 1 & 2. This storage basin is one of two significant hydro storage areas available on Upolu. The second possible storage basin is the Fusiluaga basin below the Afulilo Falls. Earlier investigations by Hancox (NZ Geological Survey 1977) suggested a possible storage of 20 million cubic metres. The Project Engineer, Mr Clive Miller, however, believes that it would be impractical for technical reasons to utilise such storage.

The storage reservoir will be controlled by a 21 metre high concrete gravity dam. The dam will have a free overflow spillway with a crest level at 317.55 m.r.l.. The normal operating range of water in the storage basin is 310m to 317.5m.

The scheme has an effective head of over 300 metres, It will initially supply two Pelton turbines to produce 4MW (megawatts) of power with an annual output of around 23GWH (gigawatt hours). The cost of the scheme is around $US30 million. It is funded through a variety of aid agencies, with some direct funding from the government of Western Samoa.

3.2 Scheme Works

(See figure 2)

* The concrete dam structure is located on basaltic rock immediately above the Afulilo Falls (50m high).

* From the dam a headrace conduit (1.15m diameter) will carry the water through a short tunnel (382m) under the ridge dividing the Afulilo and Fusiluaga basins.

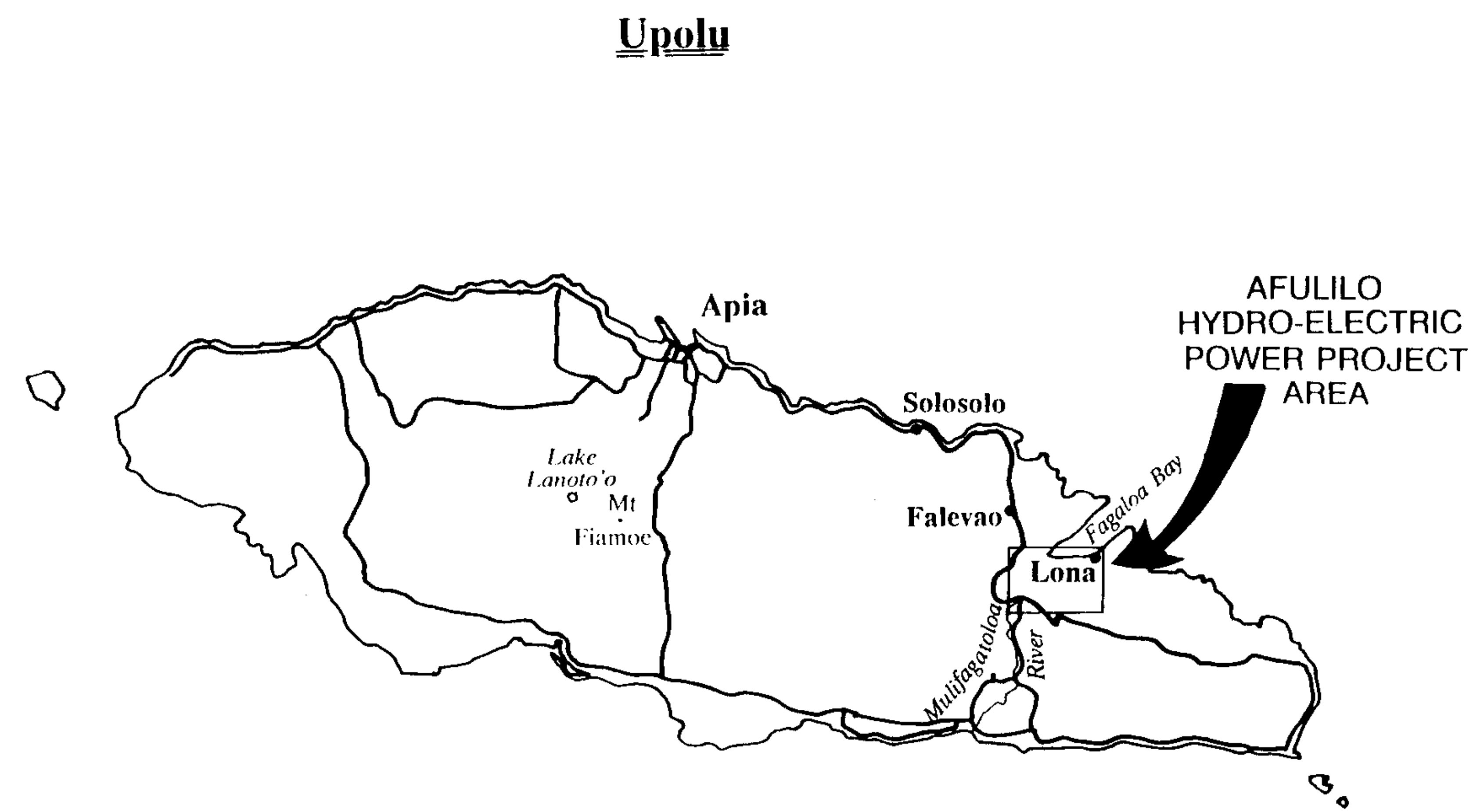
* A buried pipeline (1495m long) will then carry the water around the lower slopes above the Fusiluaga Basin.

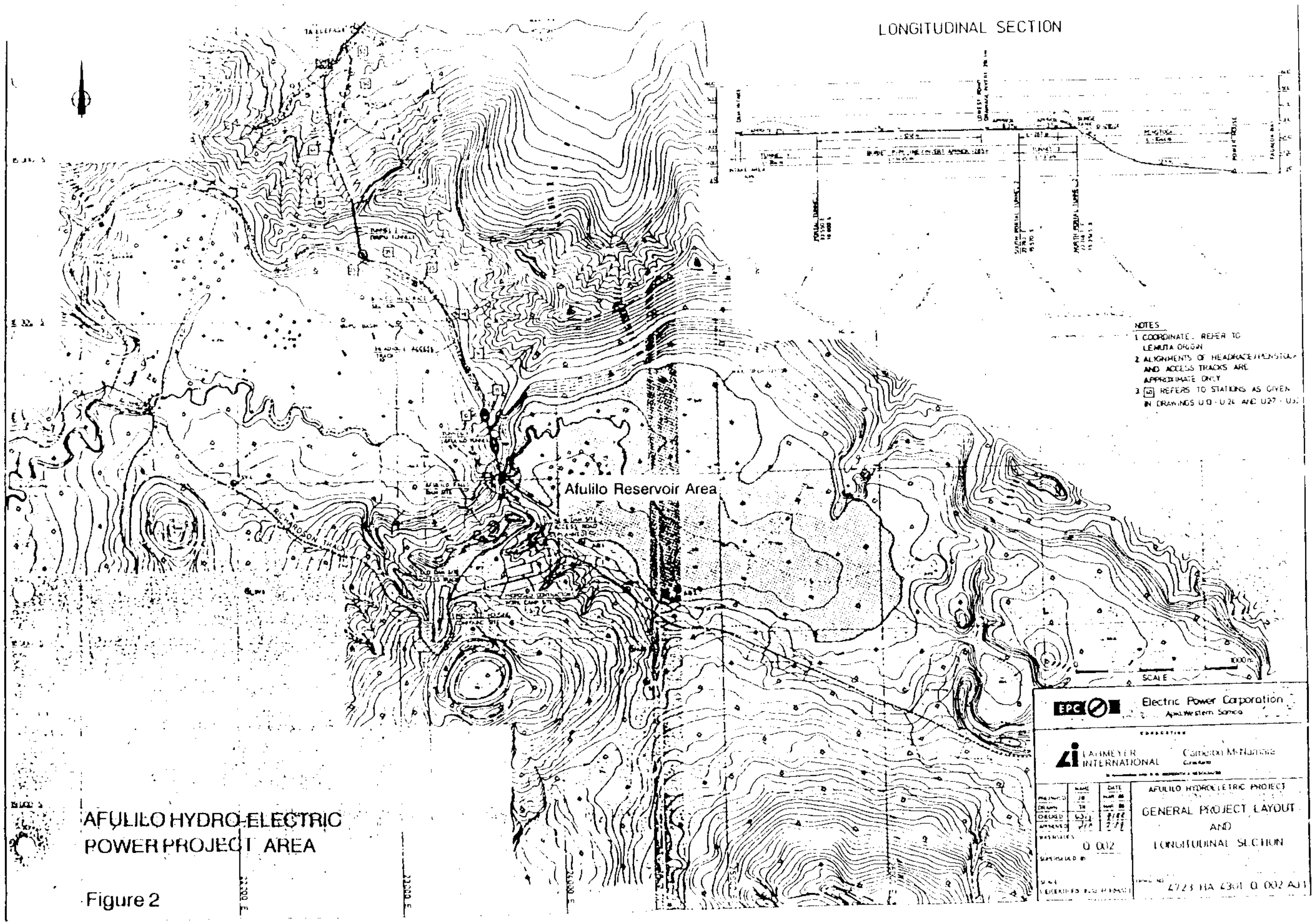
* A second tunnel (318m long) carries the pipeline (1.1m diameter) through the Fagaloa divide to a surge chamber.

* The total length of the headrace pipeline is 2195m from the dam to the Vaipu tunnel surge chamber.

* The penstock (985m of welded steel pipe) leads down the steep hill side to the powerhouse in Ta'elefaga village. The upper part of the penstock will be above ground supported by concrete pedestals. The lower portion, on easier slopes, will be a buried pipeline.

Figure 1


Upolu
Apia
Solosolo
Falevao
Lona
Fagaloa Bay
Lake
Lanoto'o
Mt
Fiamoe
Mulifagatoloa
River
AFULILO
HYDRO-ELECTRIC
POWER PROJECT
AREA



AFULILO HYDRO-ELECTRIC POWER PROJECT AREA

Figure 2

* The powerhouse will be located in an area with good foundation material which was previously the site of the primary school. The powerhouse building will be insulated to reduce noise emission. The powerhouse will discharge water via short enclosed tail races into the natural stream flowing through Ta'elefaga village.

* The normal discharge of water will be up to 1,700 litres per second.

* Two 2MW Pelton turbines will be installed to produce around 23GWH per year.

* New transmission lines (22kV) will be constructed for 4.5km from the Ta'elefaga power station to the existing Lalomauga substation. Existing transmission lines are to be upgraded by the Electric Power Corporation (EPC).

* Other new transmission lines will link the Ta'elefaga power station to the Afulilo dam (2.9km of 22kV) and on to Lotofaga (a further 10.6km).

3.3 Future Development

The pipeline, penstock (1.1m), and powerhouse have been built to allow for future possible augmentation of the water flow and power output. This future development would involve taking water from the Vaipu catchment and pumping it into the existing pipeline. An additional generator would be added in the existing power house to increase the total power output. Surplus generated power would be used to pump water up to the pipeline at times with low power demand.

4. EXISTING ENVIRONMENT

4.1 Physiographic Features

The Afulilo basin, prior to June 1991, contained a nationally significant wetland known as the Punataemo'o swamp. This flat floored natural basin would once have been a lake. Over time natural sediment in-flows have filled it in to form a wetland with a dense mixed species swamp forest and taller gallery forest along the natural levees. By 21 August 1991 this forest had been mostly felled and will, if possible, be burnt before the wet season.

Pearsall and Whistler (1991) in their Ecological survey of Western Samoa, Phase I, identified the area containing the Punataemo'o swamp as the number one priority for protected natural areas in Western Samoa. The Vaipu swamp (also known as the Fusiluaga Basin) immediately downstream was identified as the third priority. With the loss of the Punataemo'o protection of the Vaipu would probably become the number one priority.

4.2 Climate

The climate of Western Samoa is dominated by the trade winds and the South Pacific Convergence Zone. There is a dry season in April to September, and a rainy season in October to March when the convergence zone is at its most active (Burgess).

The Afulilo Basin receives a very high rainfall of over 5000mm per year, with reports of up 5800mm in some years. Annual maximum daily rainfalls recorded from Afulilo range from 145mm in 1978 to a fall of 363mm in 1982.

4.3 Geophysical Characteristics

The Afulilo Basin has a small catchment of 11.8 square kilometres bounded on the north by the steep coastal ranges eroded from the older Fagaloa volcanic series. These older Fagaloa volcanics also underlie the dam site at Afulilo Falls. On the south and east, the Afulilo Basin is bounded by the younger, less weathered Salani (Winders *et al* 1987) and the Mulifanua (Hancox 1977) basalts which overlie the older volcanics.

The Afulilo Falls formed where the head waters of the Fagatoloa River flow over a resistant barrier. This ridge acts as a "natural dam" behind which volcanic debris, sediments and swamp deposits have accumulated (Hancox 1977, p13) Investigations for the dam feasibility study revealed at least 5 metres of lake sediments in the basin upstream of the dam (Lahmeyer International, 1987). The "fine grained soft plastic organic material" described is clear evidence that a lake occupied at least part of the proposed Afulilo reservoir. The feasibility report considered that these lake sediments were "a good sealing layer"which would greatly reduce any chance of leakage from the storage reservoir.

PLATE 1

Afulilo Basin and the steep ridge of the Fagaloa Divide

The previous lake was drained by down cutting of a saddle in the older Fagaloa volcanics to form the narrow gap above the Afulilo Falls. To the north the Afulilo and Vaipu basins are bordered by precipitous ridges of Fagaloa basalt (plate 1)which rise to over 700m, and fall steeply into Fagaloa Bay on the north side (Hancox 1977, p13). The route of the buried pipeline conduit roughly follows the 285m contour running around the lower slopes of the northern divide ridges. The feasibility report (Lahmeyer International, 1987) and ground inspection (15 August 1991) indicate that the conduit route "crosses mainly colluvial and bouldery fans with slopes of 35 to 40 degrees in colluvium on the slope rib". The end of this slope rib is being cut back to improve the conduit alignment and beyond the rib steeper slopes of around 40 degrees are encountered for a short distance. The remainder of the conduit route to the second tunnel will be in bouldery fan material and colluvium on gentler slopes with several semi-permanent streams in bouldery beds. Over the entire route the alignment is well above the Vaipu swamp. Deep tropical soils weathered from the older Fagaloa basalt are found along the entire conduit route.

4.4 Plants and Animals

The Environmental Impact Assessment by Winders *et al* (1987) contains a summary of the plant and animal communities found in the Punataemo'o Swamp. Unfortunately that description contained inaccuracies. A number of the plants and freshwater species recorded do not occur in Samoa, some of the trees were incorrectly described and some of the most common plant and animal species were not recorded.

4.4.1 Terrestrial Plants

A revised species list of trees provided by Dr Arthur Whistler for the mixed swamp forest is set out in Table 1. Complete documentation was not possible in the time available, but is urgently needed as this may be the last chance to document an intact community of this type.

Numerous species of orchids and ferns grow as epiphytes but these could not be identified in the time available. A comprehensive description of flora is urgently required.

The herbaceous areas are dominated by Mikania micrantha (mile-a-minute vine), Paspalum conjugatum, and Ludwigia octovalvis and thickets of Hibiscus tiliaceus.

In addition to the omissions from Winders *et al* noted in Table 1, the following incorrect information was included in their tabulation:

- Amoora sp. does not occur in Samoa;
- Hibiscus rosasinesis and Guttarda speciosa do not occur in the Punataemo'o basin;
- Freycinctia reineckei is a vine not a tree;
- Fagraea argentus is not the name of any plant known to us; and
- Guttarda speciosa is unlikely to occur in the Punataemo'o basin.

TABLE 1

Trees of the Afulilo and Fusiluaga Basins

Scientific Name	Common Name	Status	Recorded by Winders et al
Aglaia samoensis	Laga'ali	Endemic	No
Astronidium lemafaense	-----	Endemic	No
Barringtonia samoensis	Falaga	Indigenous	No
Bischofia javanica	'o'a	Indigenous	No
Calophyllum neo-ebudicum	Tamanu	Indigenous	Mis-named
Cananca odorata	Moso'oi	Polynesian Introduction	No
Canarium harveyi	Mafoa	Indigenous	No
Canthium merrillii	Olasina	Indigenous	No
Clinostigma sp.	Niu vao	Endemic	No
Crossostylis biflora	-----	Indigenous	No
Cyathea spp.	Olioli	Endemic/Indigenous	Yes
Dysoxylum huntii	Maota mea	Endemic	Yes
Elaeocarpus ulianus	-----	Endemic	No
Fagraea berteroana	Pualulu	Indigenous	Mis-named
Ficus godeffroyi	Mati	Endemic	Yes
Ficus tinctoria	Mati	Indigenous	Yes
Flacourtia rukam	Filimoto	Indigenous	No
Gironniera celtidifolia	-----	Indigenous	No
Glochidion ramiflorum	Masame	Indigenous	No
Hedycarya denticulata	-----	Endemic	No
Hernandia moerenhoutiana	Pipi	Indigenous	No
Hibiscus tiliaceus	Fau	Indigenous	No
Inocarpus fagifer	Ifi	Polynesian Introduction	No
Macaranga stipulosa	Laufatu	Endemic	Yes
Myristica fatua	'atone	Indigenous	No
Myristica hypargyraea	'atone	Indigenous	Yes
Neonauclea forsteri	Afa	Indigenous	No
Omalanthus nutans	Fogamamla	Indigenous	No
Palaqvium stehlinii	Gasu	Endemic	No
Pandanus turritus	Pandanus	Indigenous	Yes
Planchonella torricellensis	Mamalava	Indigenous	No
Pometia pinnata	Tava	Indigenous	No
Rhus taitensis	Tavai	Indigenous	No
Sterculia fanaiho	Faga'io	Indigenous	Yes
Syzygium inophylloides	Asi toa	Indigenous	Yes
Syzygium samarangense	Nonu vao	Recent Introduction	Yes
Terminalia richii	Malili	Endemic	Yes

4.4.2 Terrestrial Animals

Table 2 listing the terrestrial animals was compiled with the assistance of Dr Rod Hay.

Dr Hay suggested that though they were not recorded in the present study the following birds could also be expected in the area: long-tailed cuckoo, barn owl, and eastern swamphen.

Winders *et al* had identified most of these species. They appear, however, to have confused the Samoan starling, which is common in the area, and the Polynesian starling which is rare. In addition, there is only one species of snake, the Pacific boa. Flying fox and bats do occur in the area, they were observed by the ecological survey team. By the time of our field inspection in late August 1991 most of the swamp forest in the Afulilo Basin had been felled. This emphasised the importance of the Vaipu, and leads to the conclusion that preservation of this area is one of the highest conservation priorities in Western Samoa. The only other comparable montane swamp forest are small areas in flat crater floors such as Mauga-o-Alii, Fogalepulu in eastern Upolu Island.

It is apparent from comments on the draft report that some people have not grasped the significance of the fact that the Punataemo'o and the Vaipu are the only large montane wetlands in Western Samoa. In protecting natural areas the importance of protecting the largest possible example of each community type is well established. Small communities are much more prone to disturbance and can easily loose their rarer species. They have more "edge" in relation to their area and are more prone to invasion by exotic weeds.

The relatively undisturbed vegetation of the Vaipu will also be a significant habitat for a range of bird and mammal species. Being less accessible to people, it will be an important centre for the spread of some species to more populated areas. It could be stressed to local villagers that the continued existence of such a refuge is important for maintaining hunting in nearby areas.

TABLE 2

Terrestrial Animals of the Afulilo and Fusiluaga Basins

Scientific Name	Common Name
Reptilia	
Candoia bibroni	Pacific boa
Cryptoblepharus boutonii	Grass skink
Lepidodactylus lugubris	Gecko
Aves	
Anas superciliosa	Pacific blue duck
Aplonis atrifuscus	Samoan starling (Fuia)
Aplonis tabuensis	Polynesian starling (Miti-ula)
Collocalia spodiopygia	White-rumped swiftlet (Pe'ape'a)
Columba vitiensis	White-throated pigeon (Fiaui)
Didunculus strigirostris	(Manumea)
Ducula pacifica	Pacific pigeon (Lupe)
Erythrura cyanovirens	Red headed parrot finch (Manu'ai pa'u la'au)
Foulehaio carunculata	Wattled honeyeater (Iao)
Halycon recurvirostris	Flat-billed kingfisher (Ti'otala)
Lalage maculosa	Polynesian triller (Miti tai)
Myiagra albiventris	Samoan broadbill (Tolai-ula)
Myzolema cardinalis	Cardinal honeyeater (Segasegamau'u)
Pachycephala flavifrons	Samoan whistler (Vasa)
Phaeton lepturus	White-tailed tropic bird (Tava'e)
Poliolimnus cinerus	White-browed rail (Vai)
Ptilinopus porphyraceus	Crimson crowned fruit
Fasciatus	Dove (Manu-tagi)
Ptilinopus perousii	Many coloured friut dove (Manu-ma)
Rallus philippensis	Banded rail (Ve'a)
Rhipidura nebulosa	Samoan fantail (Se'u)
Turdus poliocephalus	Island thrush
Vini australis	Blue-crowned lory (Sega)
Mammals	
Emballonura semicaudata	Cave bat
Pteropus samoensis	Flying fox (Pe'a)
Pteropus tonganus	Flying fox (Pe'a)
Rattus exulans	Rat (Isumu)
Rattus	Rat (Isumu)
Sus scrofa	Wild pig (Pua'a)

4.4.3 Freshwater Animals

Winders *et al* (1987) noted a relatively sparse fish and insect fauna with some very common crustacea.

Our field investigations have confirmed these observations but showed that Winders *et al* had not recorded some of the most common species including all of the molluscs, which numerically are one of the most dominant groups. It is also highly likely that the mayfly (Leptophlebidae) recorded by Winders *et al* does not occur in Western Samoa. Extensive searches, around Upolu failed to find any mayflies. This is expected given the geographical isolation of Western Samoa.

A revised species list compiled with the assistance of Dr Paddy Ryan is set out below.

The stream fauna of the Afulilo and Vaipu basins are characterised by low species diversity and abundance. A total of 15 taxa were recorded, including five crustacea, four molluscs and six insects. In numbers and biomass the fauna is dominated by crustacea and molluscs. The most common species are Atyid shrimps, Macrobranchia (prawns) and Melanoides snails (various species). Freshwater insects were rare, except for midge larvae (Chironomidae) in mossy habitats, and water skaters and backswimmers in temporary pools.

There has been little study on the animals of Samoan streams and there is limited comparative data. This makes it difficult to assess the conservation value of the freshwater environments of the Vaipu and Afulilo basins.

From limited survey work carried out, during the course of the present study (Appendix 2), most of the freshwater species found in the Afulilo and Vaipu wetlands were also found elsewhere on Upolu.

The one significant exception was a large, short clawed crayfish/prawn collected from a rocky rapid just below the Afulilo Falls. This species is like a species encountered by Dr Ryan in Fiji. Its taxonomic status and distribution are presently unknown.

The only area from which this prawn was collected has already suffered considerable damage from spoil dumped near the Afulilo Falls. This illustrates the need to take all reasonable care to avoid environmental damage when good information on the existing natural values is lacking.

TABLE 3

**Freshwater Fauna
of Afulilo Basin (A), Vaipu Swamp (V)
and Ta'elefaga Stream (T)**

Scientific Name		Common Name	Site	Recorded by Winders
Fish				
Anguilla unidentified sp.		Eel	A,V,T (anecdotal)	Yes
Syngnathidae		Pipefish	T	*
Kuhlia sp.		Jungle perch	T	*
Sicyopterus "micrurus"		Large gobi	T	*
Stiphodon elgeans		Small gobi	T	*
Insects				
Notonectidae		Backswimmer	A,V	Yes
Anisoptera unidentified sp.		Dragonfly	A	Yes
Chironomidae unidentified sp.		Midge	A,V,T	Yes
Ischnura aurora		Damselfly	A,V	No
Hydrometridae?		Waterskaters	A	Yes
Worms				
Oligochaeta unidentified sp.			V	No
Molluscs				
Clithon costanea			T	*
Melanoides lutosa			A,V	No
Melanoides tuberculata			A	No
Melanoides peregina			A,V	No
Nerita porcata			V	No
Septaria barbonica			T	*
Septaria porcellana depressa			T	*
Septaria suffreni			T	*
Crustacea				
Atyidae	species 1	Cascade shrimp	V	Yes
	species 2	Redbanded shrimp	A,V,T	Yes
	species 3	White shrimp	A,V,T	Yes
Macrobrachium lar		Prawn	A,V,T	Yes
Unidentified sp.		Claw prawn	A	No

(* note Winders *et al* did not examine the fauna of the Ta'elefaga Stream.)

The Afulilo and Vaipu basins may be quite important in the long term conservation of the native freshwater fauna of Western Samoa. These basins appear to lack fish, other than eels, and importantly seem to be free of exotic fish (such as Tilapia and Gambusia) that are conspicuous species elsewhere. These are also the only large swamp/river habitats in Western Samoa. A more detailed examination of the freshwater fauna of Western Samoa as a whole, could show these areas to be quite unusual.

Our investigations on the Afulilo and Vaipu basins were very limited due to the short time available for the work. There may well be other species present that we did not observe.

Similarly the headwaters of the Fagatoloa River may be one of the few substantial areas in Western Samoa that have freshwater communities in a relatively natural state. The importance of preserving such communities should not be underestimated.

The animals found in the stream at Ta'elefaga village, below the proposed outfall, were typical of other streams within Fagaloa Bay. There was a diverse range of fish together with limited numbers of crustacea and molluscs. The habitat had been somewhat damaged by culvert construction and pollution. Stream faunas with higher diversity were found elsewhere in Fagaloa Bay.

4.4.4 Coastal Plants and Animals

The coastal plants and animals at the head of Fagaloa Bay are described in Winders *et al.* This description has been not been checked by field observations in the present study, but the area may have changed as a result of cyclone Ofa.

4.5 **Water**

The water running from the Afulilo Basin is brown stained from dissolved material. It is otherwise relatively clear at low flows but carries a load of sediment in freshes. The water is slightly acid to neutral (pH 6.7 to 7.1). When measured, the oxygen concentration was slightly depressed (64-73% of full saturation). This can be attributed to the high biological oxygen demand of material rotting in the swamp. There are low levels of dissolved ions (salts) (conductivity 75 μMOS)

At Ta'elefaga village the stream is clear but brown stained at low flows. The waters of this stream were typical of those sampled around Upolu (Appendix 3). The water is alkaline, probably as a result of its passage through the basalt (pH 7.7 - 9.0), and is fully oxygenated by its turbulent flow down the rocky stream bed. There is a moderate concentration of dissolved ions (salts) as the stream approaches the sea (conductivity 110 - 140μMOS). The stream mixes rapidly with the salt water when it reaches the mouth and its influence is lost within a few metres.

Immediately offshore of the village the water is typical of close inshore coastal seawater with minor freshwater influence (salinities of 31% to 32.5%). On the day of our first visit civil works in the stream had discoloured the water in the head of the bay and the cloud of sediment had drifted to the true left of the stream mouth.

4.6 Social

The Afulilo area is within the traditional boundaries of Fagaloa and Aleipata districts. The land has been taken under the Taking of Lands Act for the construction of the hydro scheme.

The residents of this area have traditionally used the area for wild pig and pigeon hunting.

Ta'elefaga village has a resident population of approximately 500 people. These people support themselves with plantations, fishing and employment in Apia. The other villages in Fagaloa Bay have a similar life style.

4.7 Historic

There appears to have been no serious attempt to identify the presence of any historic or archaeological sites that may be affected by the project.

Green and Davidson (1974) report an important sequence of sites around the outflow from the Vaipu swamp and a range of other sites adjacent to Richardson's Track. Their account is included as Appendix 4. It is understood that later investigations were undertaken in the area, but it was not possible to obtain information on this within the short term of the study.

It is recommended that:

- all existing information is collated to identify any significant sites in the project area; and

- if earth works for the project uncover any evidence of archaeological sites that these are properly documented by a competent archaeologist.

5. ENVIRONMENTAL EFFECTS OF THE SCHEME

5.1 Introduction

Construction of the Afulilo hydroelectric power scheme has already begun and some the effects can be readily seen. Other effects will only become apparent after the scheme is commissioned. Earlier reports made predictions about environmental effects of the scheme. The present report reviews that work and makes a more comprehensive assessment of the possible immediate and secondary effects of the scheme. Earlier reporting did not consider secondary effects such as power transmission, transportation of materials. This is rectified in the present report. With much of the scheme now under construction and most design details finalised, it is now easier to assess environmental impacts.

The principal previous assessment was that completed by Winders, Barlow and Morrison Pty Ltd (Report No. 3469, October 1987) who reported to Cameron McNamara. The present report draws on that work and on field inspections completed in August 1991.

5.2 Afulilo Dam

The 21m high concrete gravity dam at Afulilo Falls has a crest width of 25m which includes a non-gated free overflow spillway. The invert of the intake is at 306.5 m.r.l., but the normal minimum operating level is 310 m.r.l. and the maximum operating level is at 317.5 m.r.l.. The design flood is 163 cubic metres per second (1000 year return event) and this would be discharged over the spillway.

The major effect of the dam will be to impound most of the flow at Afulilo Falls. Flood flows will still discharge over the spillway when the reservoir is full. The reservoir will hold 10 million cubic metres of water when it is full, forming a lake of 250ha.

The old river channel immediately below the Afulilo Falls will carry no flow of water, or only a small residual flow, most of the time. During floods, substantial volumes of water will be discharged over the spillway to flow down the river channel. Further into the Vaipu basin the river will begin to flow more strongly again, drawing water from rain falling in the basin and on the hills of Fagaloa basalt to the north.

The dam will add a further physical barrier to the upstream movement of fish and shrimps in addition to that already provided by the Afulilo Falls. This could to some extent be overcome by the installation of a fish pass for young eels (elvers) and gobies. To be effective, a small flow (a minimum of 20 litres per second) of water would be required in the river bed below the Afulilo Falls. Effective designs are available from the Ministry of Agriculture and Fisheries in New Zealand. A working example can be seen at the Patea Dam, which at about 50m is similar to the height of the Afulilo Dam and Falls.

The dam will remove the scenic beauty of the 48m (170 feet) high Afulilo Falls. Only in flood flows will they reappear at their new height of 59.5m.

The dam will include a bottom sluice for emptying the lake. Set at 306.5 m.r.l., the sluice will allow flushing of accumulated sediment. Any such flushing should be done during a flood event. This will ensure that:

(a) the sediment is flushed down the lower river system as part of a natural flood event; and

(b) the ecological effects of anaerobic (deoxygenated) water on the Fagatoloa River are minimised.

The Electric Power Corporation should set down clear operating instructions to this effect.

During the first two or three years of operating the scheme it may be advisable to completely drain the reservoir to flush out as much of the rotting plant material and contaminated water as possible. It would be best to do this during a flood at the beginning of the wet season.

The Afulilo dam structure is being extended into the surrounding volcanic ridge by a wall of bored-piles which form lateral cut-off walls. These are extended at depth by a double grout curtain. This elaborate structure should ensure that there is very little leakage past the dam. This will stop water being lost through the ground to the Fusiluaga basin.

Construction debris (rock and soil) was dumped over the steep slopes adjacent to the Afulilo Falls. These slopes should be revegetated after construction is complete to prevent unwanted erosion close to the dam structure. Spoil debris have already accumulated in the river channel.

Rubbish is also being dumped over the Falls. It is a specific requirement of the "Civil Contract" that this is not to be done. We have been assured by the Resident Engineer that the contract is being enforced. The Contractor has cleaned up the area several times and will be required to do so again under the contract.

5.3 Afulilo Reservoir

The Afulilo dam will impound up to 10 million cubic metres of water at the maximum normal operating level of 317.50 m.r.l.. The lake surface at this level will be approximately 250ha (figure 3). When the lake is empty (e.g. at the end of the dry season) its level will be around 310 m.r.l.. At this level the water will form a small elongated pond (see figure 3) little larger than the present incised river channel.

5.3.1 Forest Clearance

The major environmental effect of creating the Afulilo storage reservoir is the complete destruction of the Punataemo'o swamp forest ecosystem. Protection of this forest was identified by Pearsall and Whistler (1991) as the number one conservation priority for Western Samoa.

The EPC has contracted local villagers to clear the forest to 317.5 m.r.l. and all vegetation is to be burnt or removed from the storage area. To date some of the felled trees have been piled up for burning. Felling of the forest was completed by the end of September 1991.

PLATE 2

Forest Clearance in the Afulilo Basin

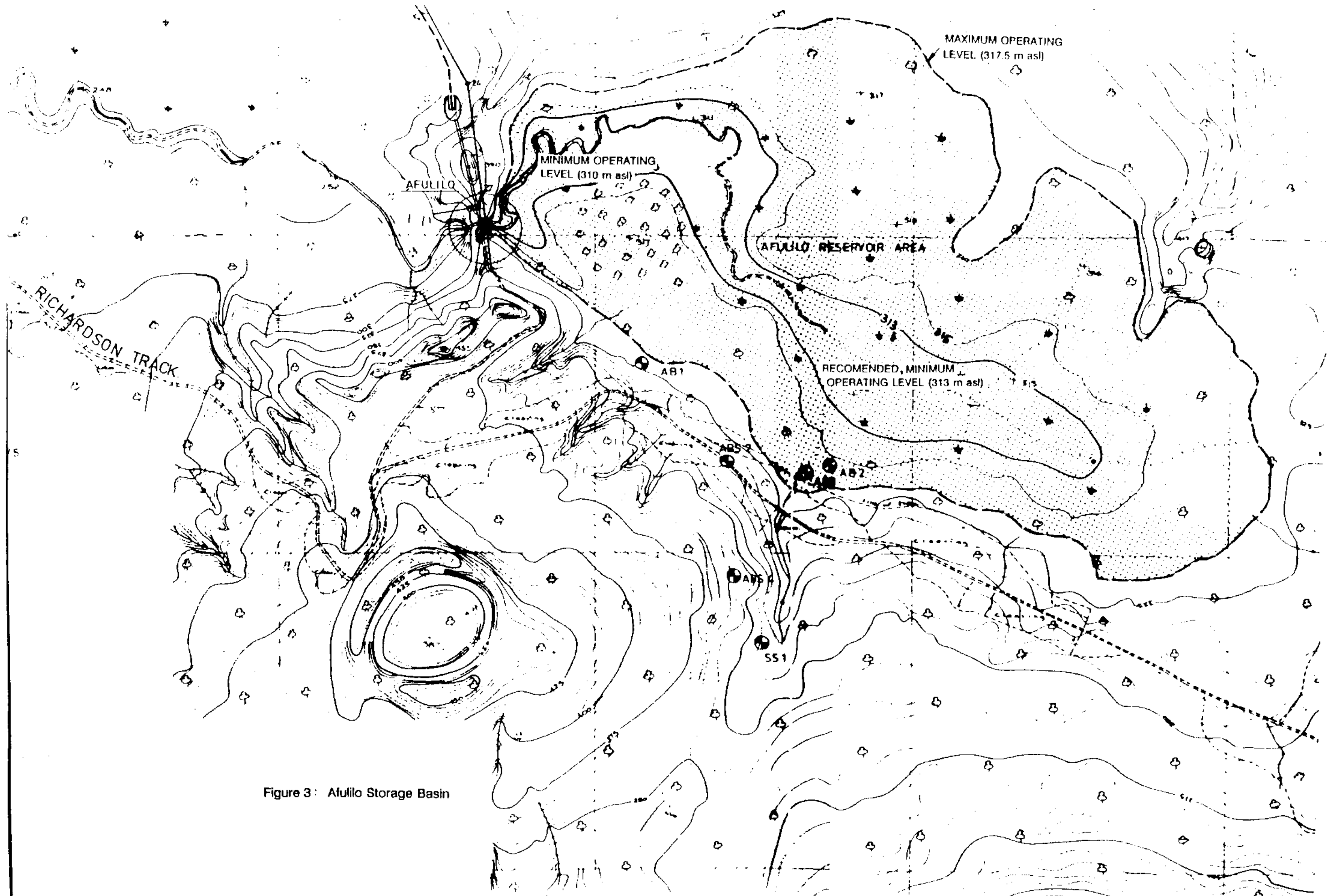


Figure 3 : Afulilo Storage Basin

5.3.2 Lake Level Fluctuations

When full, the Afulilo reservoir will be a very shallow lake, with a maximum depth of 11m close to the dam and extensive areas having water depths of less than 3m.

Simulations of reservoir water storage are available in Study of Energy Outputs of the Afulilo and Vaipu Extension Schemes for Various System Demands reported by Lahmeyer International, March 1990. The simulation graphs for variant C represent the most advanced stage of development and a predicted demand of 55GWH. The simulations are useful in that they provide an indication of the general behaviour of the Afulilo reservoir for given historic rainfall years. It should be noted that these graphs do not represent a quantitative picture of how the Afulilo development will behave in any particular future year. This will depend on the weather and how the scheme is operated.

Simulations of the reservoir water storage (Lahmeyer International, March 1990) show that in wet years, like 1980 and 1981 (figure 4), the lake would have been almost full for most of the year. In dry periods, however, such as 1982, 1983, and 1984 (figure 5) the reservoir would have held relatively little water (less than 4 million cubic metres) for most of the time. In this period lake levels would not have exceeded 314 m.r.l. and the lake would at all times have been less than 100ha (for the particular simulation being presented).

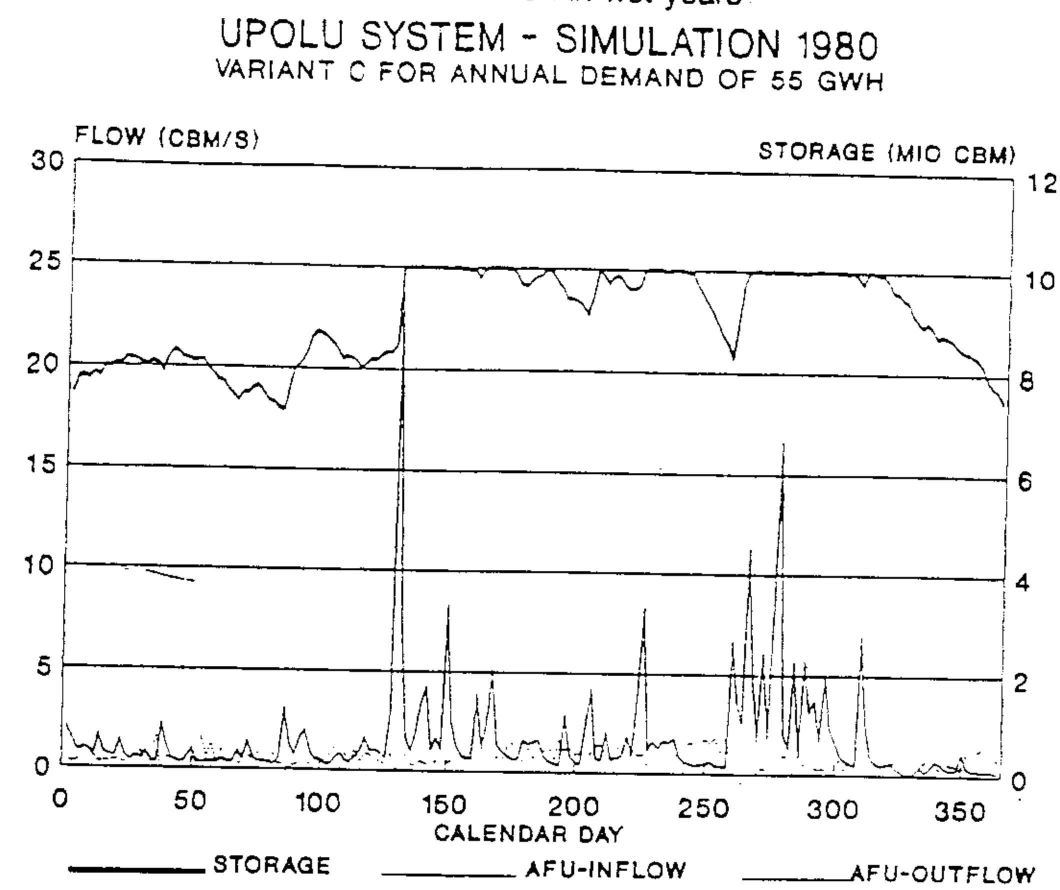
The 1975 year (figure 6) could be regarded as a representative average year. It has nearly 150 days (5 months) with the lake close to full during the wet season. The stored water then falls as it is used for power generation. The storage lake is at very low levels for 10 weeks at the end of the dry season.

5.3.3 Water Quality

The lake will take on the average daily air temperature, ranging from about 23 to 30 degrees Celsius. The shallow margins may at times reach higher temperatures. During the day the surface water will, at times, be a degree or two warmer than the water at a depth of three metres.

The quality of water in the lake will vary over time. As the lake is filled, the vegetation left in the basin will die. As it rots the action of the bacteria will rapidly use up the oxygen at the bottom of the lake. Anaerobic decomposition will take over in the absence of oxygen and will then generate methane and hydrogen sulphide. Anaerobic decomposition is very slow so the process will continue for a considerable period of time. In still weather the anaerobic water will form a layer at the bottom of the lake. Given the shallow depth of the lake, however, it will never thermally stratify, although there will at times be marked stratifications in oxygen concentrations.

Figure 4 : Examples of Reservoir simulation in wet years



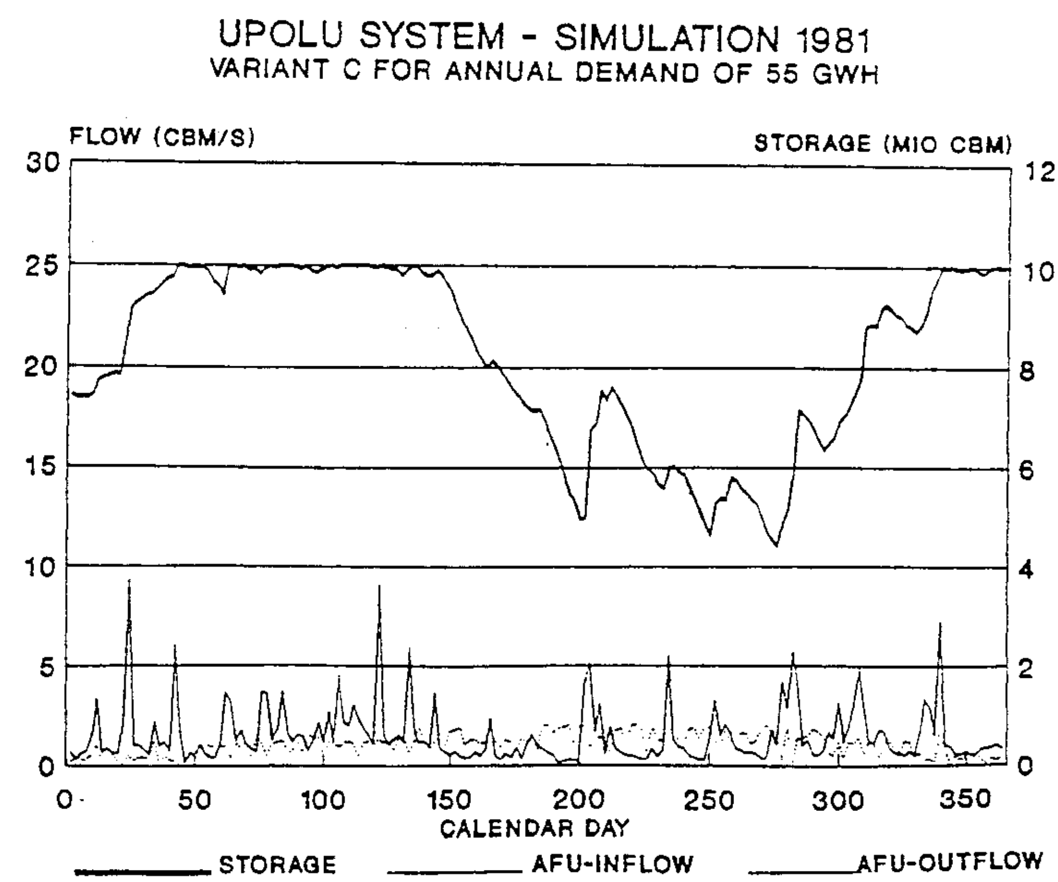
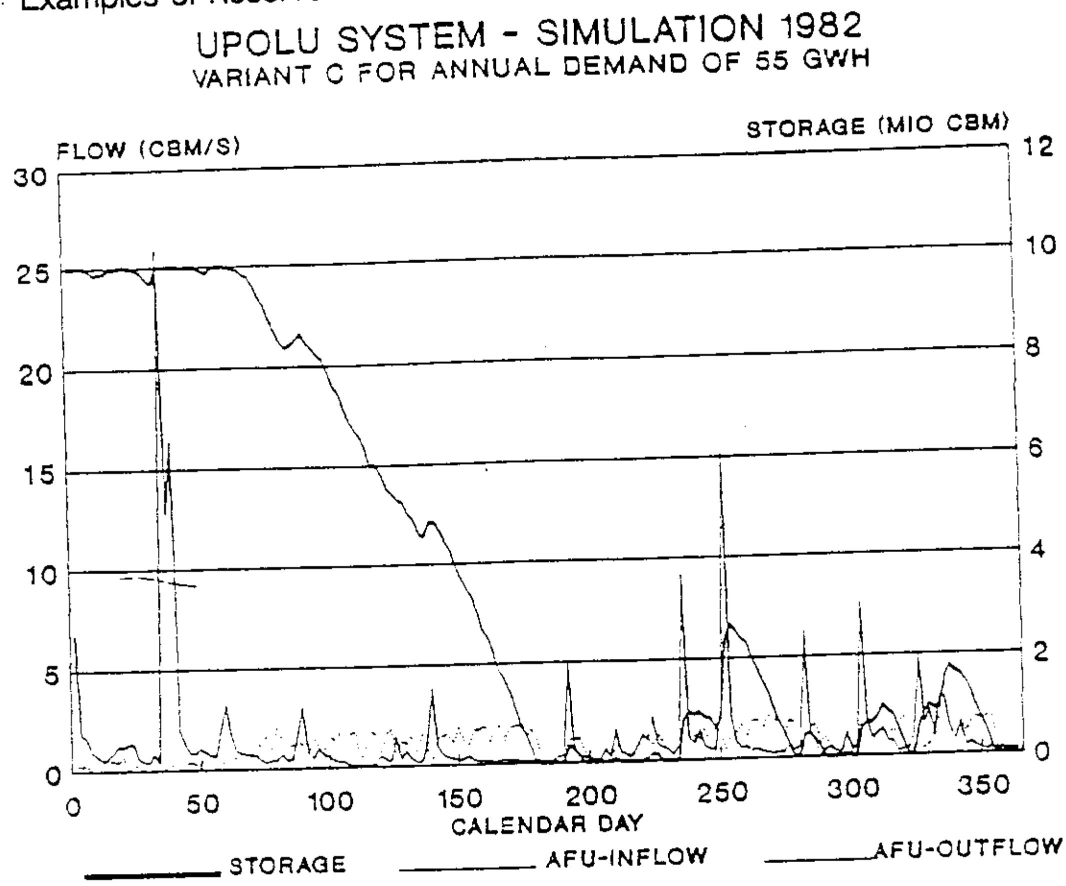


Figure 5 : Examples of Reservoir simulation in dry years



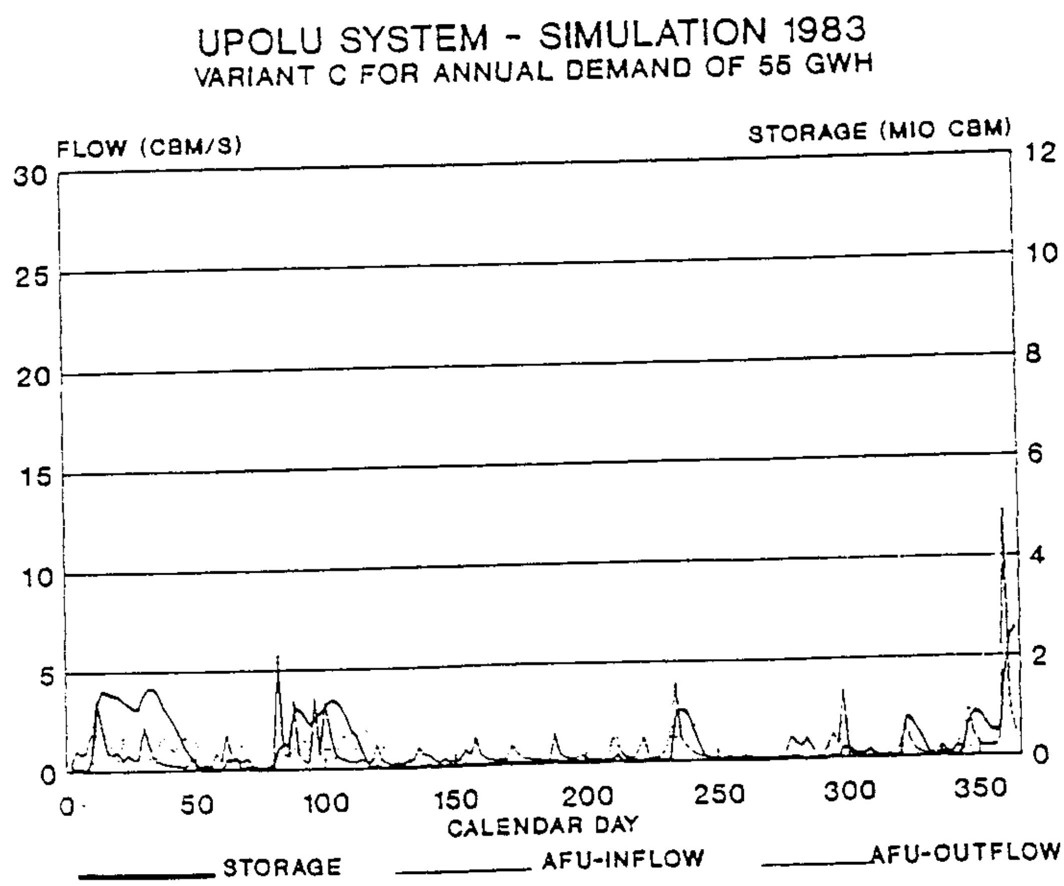
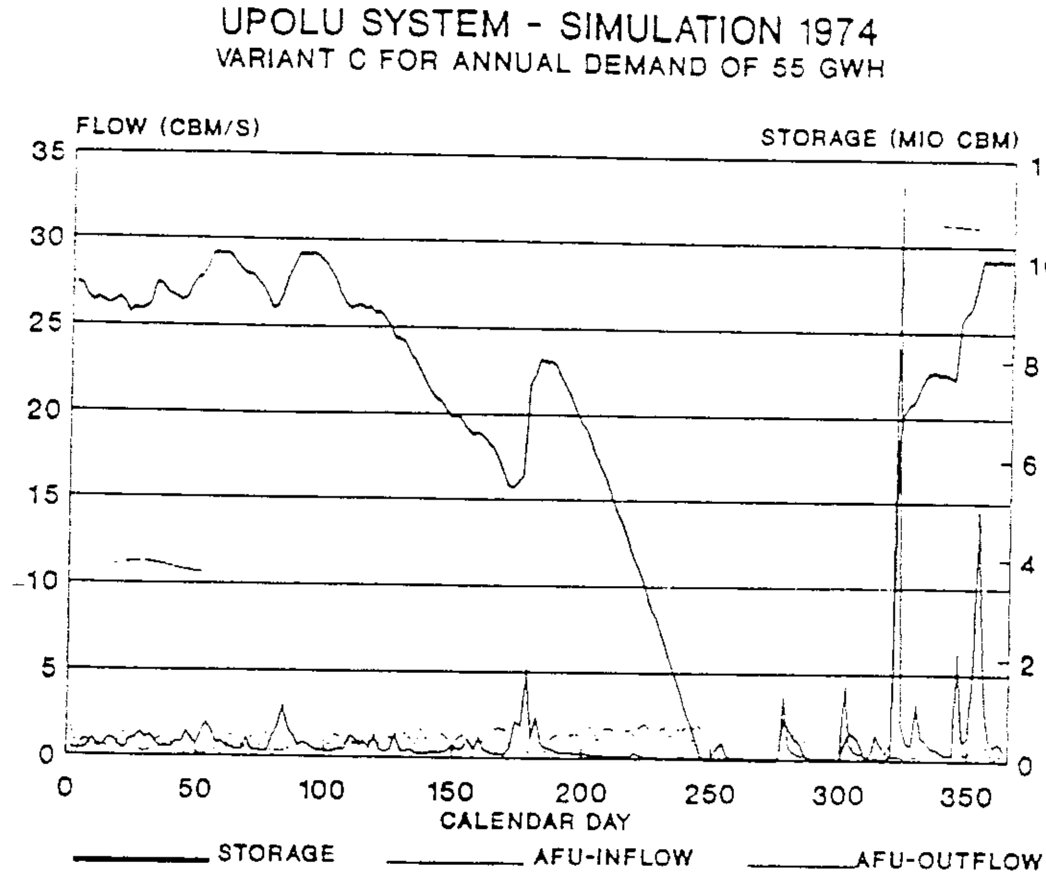
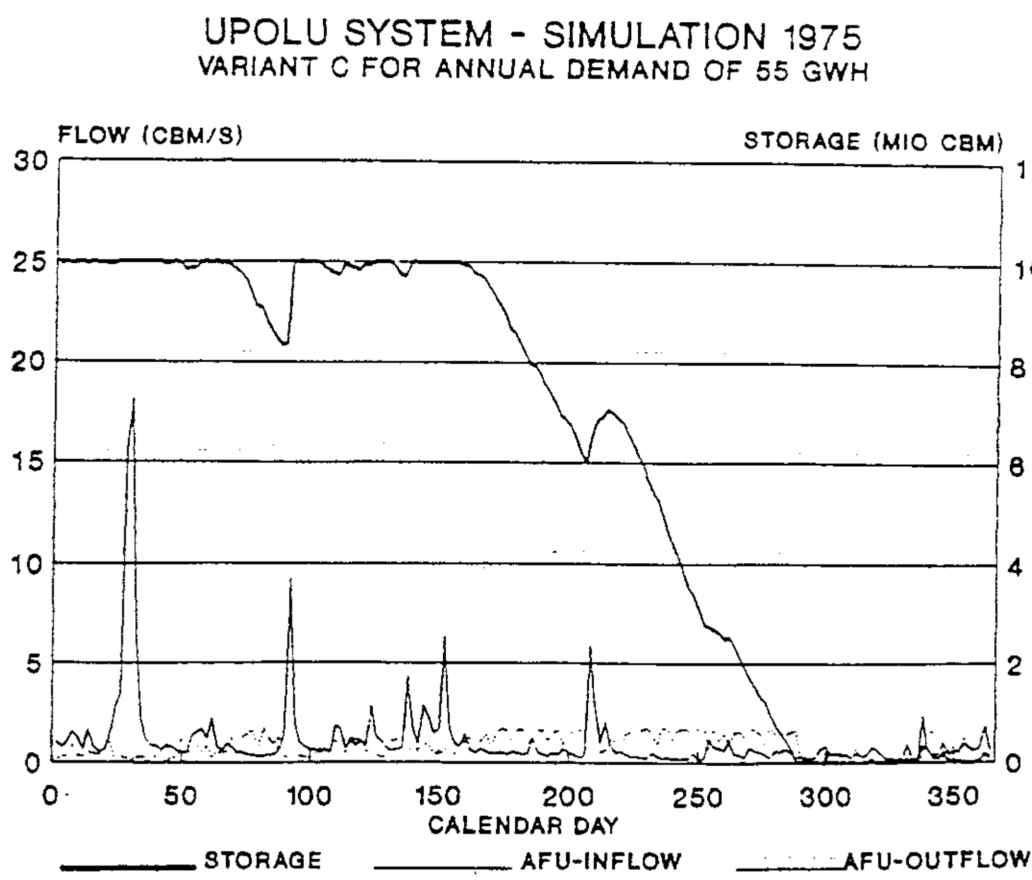


Figure 6 : Examples of Reservoir simulation in an average year





We examined the oxygen temperature profile of Lake Lanoto'o and this is reported in Appendix 3. Clearly, in this much deeper lake, there is no sign of true thermal stratification, even at depths twice that which occur in the reservoir at its fullest. There is a thermal gradient at the surface to 2m - 3m depth, but there is no sign of significant deoxygenation in the water below this as would occur in true thermally stratified lake. Given the other characteristics of Lake Lanoto'o and the reservoir, the reservoir will not thermally stratify.

Nevertheless the amount of decomposition should be sufficient to reduce oxygen levels at the bottom of the reservoir, and this effect may at times extend throughout the water column. The degree to which this condition persists will depend on the amount of plant material that can be cleared from the basin before the reservoir is filled. The local people felling the forest believe that it will be almost impossible to burn the fallen timber. The area receives around 5m of rain a year and the felled timber is quickly covered by a prodigious growth of vines. The local workers are talking of using oil and old tires to facilitate the burning. This would cause some air pollution and quite serious water pollution problems.

The fallen timber needs to be moved to the edges of the swamp if burning is to have a real chance of succeeding. The area appears too soft to operate any conventional earth moving machinery and something in the nature of a dragline or winch system would appear to be required.

If the fallen timber is not removed, the dam may need a net and boom system to keep floating material out of the intake. That material which does not float down to the dam would add considerably to the mass of material decomposing, and greatly lengthen the period of very poor water quality.

Windy weather will stir oxygen into the water but will also stir up material from the bottom. In the first years of operation this is likely to cause sudden oxygen drops in the water as the fine rotted material, the anaerobic water and the associated bacteria are stirred in. These bottom sediments will at all times be the major source of nutrients for the growth of algae. The catchment is very small relative to the size of the full reservoir and mostly forested. There will thus be little nutrient entering the reservoir from the catchment.

In the warm shallow lake there may be high standing crop of both filamentous and planktonic algae, unless there are animals to eat them. The total production may, however, be low except after windy weather has stirred up the bottom sediment.

As the lake is drawn down the exposed muddy bottom and shores may erode rapidly in high rainfall to release large quantities of suspended sediment into the water. This would cloud the water and make it brown.

In the warm moist climate the lake shores, and the bottom when it is exposed, will be rapidly colonised by grasses, herbs and vines. These will die as lake levels rise again depleting the oxygen as they rot and generating hydrogen sulphide and methane.

When the lake level falls filamentous algae will be exposed and rot (there do not appear to be any rooted aquatic macrophytes in Western Samoa capable of living in the reservoir). The rotting can be expected to be a smelly process.

The rotting of plant material can be expected to depress the pH of the lake and it could be expected to be somewhat acid with a pH of 5 to 7. If the existing plant material were largely removed and regrowth prevented the pH could be expected to remain closer to 7.

5.3.4 The Reservoir as Habitat

The reservoir, when full, will be the largest standing body of freshwater in Western Samoa. Lake Lanoto'o, the largest natural lake is only about 16ha. Because of the downstream barriers to fish migration, the poor water quality and large lake level fluctuations, however, the reservoir cannot be expected to sustain a large natural population of fish.

The reservoir could be good habitat for eels, but the dam will prevent the elvers from reaching the lake in their migration from the sea. An elver pass would help, but the major waterfalls downstream are already limiting the number of elvers that can reach the Punataemo'o swamp.

The simplest way of stocking the lake with eels would be to collect elvers where they mass below the first major waterfall and transport them by road to the reservoir. This could be done in summer when greater numbers of elvers migrate (although there are no strong seasonal runs as occur in temperate countries). Dr Don Jellyman of MAFFISH, NZ, advises that the simplest method for collecting elvers is to place brush in a pool below an obstruction overnight. When the brush is retrieved the elvers can be shaken onto a sheet and then transported to the reservoir in buckets or bags of water.

The lake level fluctuations can be expected to have a major effect on the eel populations in dry years. Reduction of a 250ha habitat to a 2ha habitat will not leave them space to live. Given that eels are slow to mature, the reservoir population could be expected to contain few large individual eels. This would, however, be overcome if the lake was held from falling below a minimum size of, say, 100ha.

The reservoir will become a good habitat in wet years for the common shrimps and they could be found in large numbers. Their numbers would also be enhanced by maintaining a minimum lake level.

Around the margins of the lake hardy plants that survive periodic inundation will gradually come to dominate. There are likely to be three main species pandanus (Pandanus turritus), hibiscus (Hibiscus tiliaceus) and falaga (Barringtonia samoensis). Given that the swamp forest has been felled, these species will need to be replanted on the reservoir margins (Whistler pers. comm.).

The reservoir will be good habitat for ducks and herons in wet years.

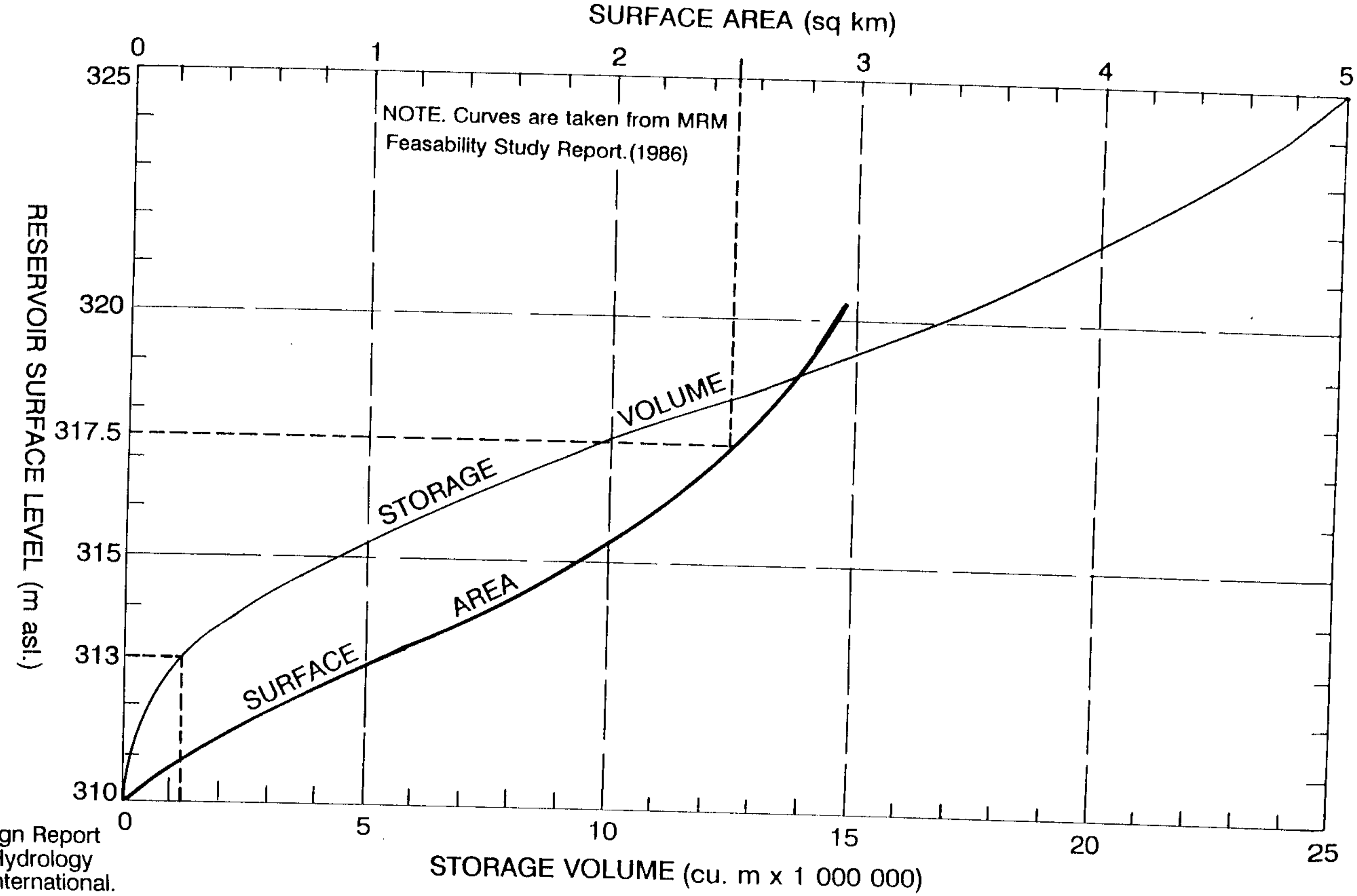
5.3.5 Limitation of Lake Drawdown

Limiting the drawdown of the reservoir to a minimum of around 313 m.r.l. after most of the rotting material has been flushed from the lake should be seriously considered. This would retain a lake with a surface area of around 100ha and a volume of one million cubic metres of water (see figure 7).

It is assumed that the reservoir will be operated to maximise generation when lake levels are high. This mode of operation would draw the reservoir down and thus ensure the maximum capture of storm in-flows and rainfall.

Retention of a minimum lake level would greatly enhance the value of the reservoir as habitat for plants and animals. It would improve the water quality and would offer the possibility of a substantial population of eels and shrimps developing, or using the lake to establish fish farming.

STAGE Vs. SURFACE AREA and STORAGE VOLUME for AFULILO RESERVOIR.



Limiting the draw down of the reservoir to 313 m.r.l. would involve forgoing one million cubic metres of storage and the generation of some electricity. Fine tuning of the system's operating rules and experience with the Afulilo reservoir may well show that this is a good option.

5.3.6 Monitoring Reservoir Performance

It is recommended that the performance of the Afulilo reservoir is monitored for at least five years (1993 - 1997 inclusive). This monitoring should include rainfall, lake water level, tail-water level below the power station, and power output from the scheme. Collection of this actual performance data would allow a simulation model to be calibrated with the objective of optimising lake operation and power output.

It would also be highly desirable to monitor the water quality in the lake. This would include regular field measurements of dissolved oxygen, temperature, pH, colour, odour and transparency (or turbidity). This would enable informed decisions to be made about the effect of the operating regime on the lake and its value for activities such as fish farming.

5.3.7 Storage Basin Sedimentation

As only a few small streams flow into the Afulilo reservoir there is unlikely to be sediment accumulation at the lake margins. Landslides or debris avalanches off the very steep ridges on the northern catchment boundary (Fagaloa volcanics) appear to be trapped in dense vegetation on the lower slopes where the slope angle eases. Where debris is deposited in natural stream channels some sediment could be transported into the reservoir during the wet season storm events. Sediment from such sources is unlikely to be a problem in operating the reservoir and power station.

Turbid water containing fine sediment particles and organic matter stirred by wind and wave action around shallow lake shores can remain in suspension for very long periods. High turbidity may affect plants and animals in the lake. It would also make the discharged water from the powerhouse less acceptable for other purposes (e.g. for washing clothes). The EPC and the local people have already agreed to move the washing place upstream of the powerhouse, where a pool has been formed on the east side of the road (pers. comm. Resident Engineer). This area could easily be landscaped and the banks formed to make it into a pleasant washing area.

Proposals by people from the villages around Fagaloa Bay to clear land around the reservoir should be discouraged by the EPC. Extensive agriculture, especially on the steeper slopes could lead to increased soil erosion and deposition of sediment in the reservoir. As a minimum, an extensive buffer of undisturbed land around the reservoir margin will be required.

5.3.8 Aquaculture

The Department of Agriculture, Forests and Fisheries has through its fisheries advisor , Dr Leon Zann, expressed interest in using the Afulilo Reservoir for aquaculture (fish farming). Local villagers have also indicated interest in the capacity of the reservoir to support an enhanced population of eels and prawns. Dr Zann believes that freshwater aquaculture offers an opportunity to relieve pressure on over used coastal reef areas.

Our findings on the probable quality of the water in the lake, and the low levels that it would be drawn down to, indicate that it would be unwise to commit resources to aquaculture in the Afulilo Reservoir in at least the first three years of the scheme's operation.

There is concern, however, that private individuals may introduce exotic fish for their own reasons. If these fish became established subsequent aquaculture development in the reservoir may be compromised. It may therefore be necessary to attempt pilot stocking with sterile fish. Monitoring of growth and survival of sterile stocks would provide valuable information on the aquaculture potential of the reservoir.

Over the first three years the water quality could be monitored to give an indication of its suitability for aquaculture. Data on water temperature, oxygen concentration, pH and turbidity could be collected at the face of the dam. Observations should be made at the top, middle and bottom of the water column. An assessment would also be required of the plant productivity in the lake.

The reservoir is likely to have a relatively low annual biological productivity as nutrient inflows are small. The primary productivity will be expressed as algal phytoplankton and filamentous algae. Samoan freshwater systems, from our limited observations, appear to be lacking in significant native aquatic macrophytes. Secondary productivity will appear in the form of zooplankton (both cladocera and copepods were recorded from Lake Lanoto'o), molluscs, shrimps and mosquito larvae.

Any fish species introduced would need to be able to utilise these resources and be able to cope with the sometimes low oxygen concentrations expected. If a residual lake of substantial size is not retained it would also be wise to use fish species that mature in less than 12 months.

Dr Bob Wear of Victoria University (Wellington, NZ) suggested that the prawn Macrobrachium rosenbergii and the milkfish Chanos chanos would be worth considering for the conditions expected in the lake. He suggested that the best advice on tropical aquaculture is from Hawaii. We understand that staff of the Department of Agriculture, Forestry and Fisheries are already in contact with their counterparts there.

The Afulilo and Fusiluaga basins, and the reaches of the Fagataloa River above the first major falls, appear to be free of introduced fish. Any breeding fish populations introduced into the Afulilo Reservoir can be expected to escape to most parts of the Mulivaifagatoloa river system.

It is unlikely that any native species introduced into the reservoir would form a breeding population, as they probably have marine stages in their life histories which could not be completed with a return to Afulilo. Only eels seem able to pass all the falls on the Mulivaifagatoloa River, and even they will be excluded by the Afulilo Dam. Native fish could, however, be artificially stocked into the reservoir on a regular basis if the cost can be kept low.

The earlier environmental assessment expressed concern about the growth of mosquitos in the reservoir and suggested fish introductions to avoid this. We believe that it would be wise to wait and see whether the problem in fact develops. The pools of the Punataemo'o already contain some natural insect predators such as backswimmers (Notonectidae) and dragon fly larvae (Anisoptera) that eat mosquito larvae.

The problem of contaminating the Mulivaifagatoloa river system with exotic fish could be overcome by using sterile fish stocks. There may be difficulties in establishing breeding facilities to produce sterile fish in Samoa. This approach, therefore, has its own problems in cost, quarantine issues, certainty that the stock is fully sterile and finding or developing an ongoing source of stock.

How important it is to keep the Mulivaifagatoloa system free of exotic fish will depend on how widespread these fish are now. It would be desirable to complete a comprehensive survey of the freshwater fauna of Western Samoa including investigation of the locations of exotic fishes to enable decisions on this and other introductions to be made.

We would recommend that aquaculture with breeding stocks of exotic fish in the Afulilo reservoir is only contemplated after:

(a) a comprehensive assessment of the freshwater fauna of Western Samoa;

(b) assessment of water quality;

(c) identification of suitable species; and

(d) trials with sterile stocks.

5.4 Supply Conduit and Tunnels

5.4.1 Tunnels

The only possible immediate environmental impact of the two tunnels which are to be excavated to carry the pipeline is that caused by the disposal of the tunnelling material.

The Resident Engineer for the project confirmed that:

(a) topsoil and highly weathered material from the tunnels will be dumped in spoil disposal areas;

(b) weathered rock is to be used for roading purposes; and

(c) good quality rock will be transported to the aggregate plant for crushing and use in concrete production.

The two tunnels of 382m and 318m will produce a moderate volume of material (approximately 4200 cubic metres, Resident Engineer pers. comm.). On completion of the tunnelling the spoil dump areas are to be smoothed off and revegetated (with local plants) and planted with local tree species such as laupata Macaranga spp. to stabilise/retain the dumped material. Spoil dumps will be kept clear of natural stream channels to avoid unnecessary sediment in the Fusiluaga basin. It was pleasing to learn that the Civil Contract contains provisions covering these matters.

5.4.2 Supply Conduit

The route of the buried pipeline lies across the lower slopes of the ridges above the Vaipu swamp at approximately the 285m contour. The invert level of this buried pipeline is 282 m.r.l..

The site engineer has instructed the contractors to limit the working zone to a 40m width over this 1495m long route. Vegetation is being cleared along the conduit route. A permanent access road is being formed with adequate culverting of stream channels.

Over most of the route the road is being formed by side casting material onto the relatively gentle down hill slopes (20 - 30 degrees of slope). The trench for the pipeline has yet to be excavated. It is planned that this trench will be on the down hill side of the access road. It will be of variable depth depending on the topography.

Where the pipeline crosses permanent streams and drop structures are installed, debris from the road and pipeline trench will be dumped well clear of the stream channel to prevent storm flows washing sediment into the Vaipu swamp as specified in the Civil Contract.

As the access road and pipeline trench are completed all areas of bare spoil and batters will be revegetated to prevent erosion as specified in the Civil Contract.

In view of the very high annual rainfall (over 5000mm concentrated in the wet season), and the potential for high daily rainfall (100mm to 400mm) this revegetation work should proceed as early as possible as the pipeline installation takes place.

5.5 Penstock

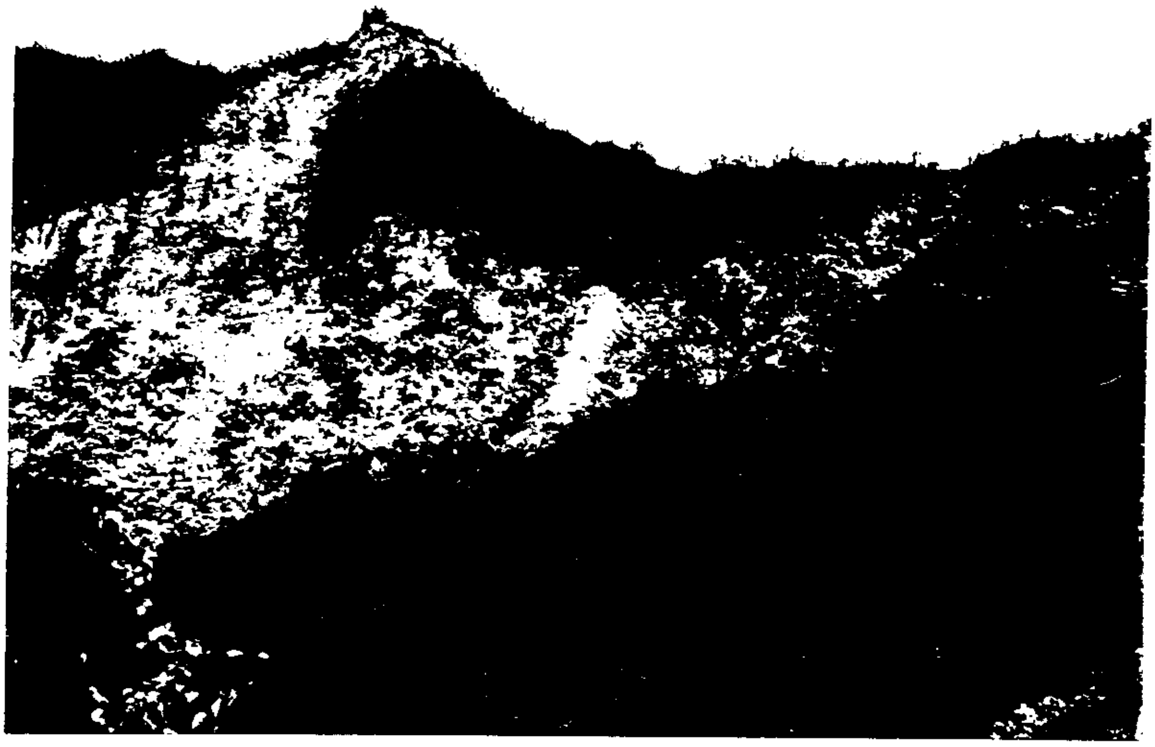
5.5.1 Upper Portion

For the upper exposed portion of the penstock, material excavated from the pedestal footings should not be dumped into the stream channels. We appreciate that the very steep slopes in the area make this part of the construction a very difficult task.

If any access roading is constructed up these slopes above Fagaloa Bay, a great deal of care should be taken to ensure that the road works do not initiate major erosion. Adequate control of storm water runoff and good culverting will help to minimise the problem.

PLATE 3

Upper Penstock Line Clearance



5.5.2 Lower Portion

The lower portion of the penstock will be buried. It should be treated as recommended above for the supply conduit around the Vaipu Swamp. All exposed soil and spoil deposits should be revegetated as soon as possible after the penstock has been installed.

5.6 Powerhouse

5.6.1 Noise Emission

The powerhouse is now under construction on a site between the road and the stream which flows through Ta'elefaga village. A new primary school has been built across the road opposite the powerhouse.

The Tender Design Report (Lahmeyer Consortium, 1989) and the Review of Tender Design (November 1988) recognise that noise arising from the generators could be a problem. It is understood that "appropriate noise protection measures will be taken".

The project engineer has stated that noise at the face of the powerhouse will not exceed 60dBA. This should not produce a noise problem at the school.

An commonly accepted standard in New Zealand is for industrial concerns to produce no more than 60dBA at the boundary of an adjacent residential property. For continuous noise, production 45dBA is the accepted standard at the boundary for noise produced at night. There is insufficient information available to say definitely whether this standard would be met at the nearest fale. In comments on the draft of this report the project consultants suggested that 54dBA could be expected 100m from the power house. This indicates that the effects of night time noise production require further investigation.

5.6.2 <u>Tailrace</u>

The tailrace channels carrying the spent water from powerhouse will discharge directly into the stream flowing through Ta'elefaga village. The three tailrace channels of 10m and 20m length are to be buried (i.e. fully enclosed) and will have gratings at their outlets to prevent children entering the tailrace outlets.

5.6.3 <u>Outfall to Stream</u>

The discharge of up to 1.7 cubic metres of water per second into the stream of Ta'elefaga village will give flow equivalent to a small fresh in the present stream. The average annual flood for this stream is 15 cubic metres per second (Resident Engineer, pers. comm.).

The Tender Design Report (Lahmeyer Consortium, June 1989) acknowledges that "leading the tailrace into the creek will affect to a certain degree the village life (safety, odour, bathing and washing habits)". The stream is used for washing clothes and children play in the area. An alternative piped water supply is available for drinking and washing also, although we did not establish its capacity or reliability.

The Review of Tender Design (E.H. Taylor <u>et</u> <u>al</u>, November 1988) notes that "hydrogen sulphide originating from rotting vegetation in the reservoir may be released by aeration of the flow in the discharge channel". This smell factor together with turbidity clouding the water will probably make the discharge undesirable for the first few years of the operation of the dam.

When the water is anaerobic, lacking in oxygen, this will combine with the hydrogen sulphide to exclude fish from the 150m of stream channel between the powerhouse and the sea. The discharge will also have a lower pH (be more acid) than the existing water in the stream and this may have some effect on life in the stream. Given that water is taken from the bottom of the deeper portion of the reservoir where the water is anaerobic, it can be expected to have significant concentrations of dissolved iron and manganese. These will precipitate out as floc when the water is re-oxygenated in the stream channel. The floc will fill in spaces in and around stones excluding shrimps and snails, but will not otherwise be harmful.

The discharge quality is likely to be sufficiently variable, however, to provide sufficient clean water to allow fish (described in section 4.4) which spend part of the time in the sea to move between the sea and the upper parts of the stream.

We examined the option of a separate discharge channel to the sea to avoid discharge to the stream. Such a channel could be designed to assist in re-aeration of the water in the discharge. Given the location of the powerhouse, however, this would be technically difficult to achieve. The new channel would need to be on the true left bank of the stream. Its construction in this location would destroy two fale and it would physically divide the village.

The channel would also function little better than the existing stream channel at re-aerating the discharge. This stream bed is well armoured over a portion of its course with large basaltic boulders, providing good riffles to get oxygen into the water. Adding cobbles to the shingly parts of the course would further assist re-oxygenation.

Consequently we would recommend against the construction of a separate discharge channel.

Given the use made of the stream by villagers for washing clothes and use made of the area by children an alternative facility is required. The Resident Engineer has stated that a pool which has been excavated upstream of the powerhouse on the eastern side of the road could be used for this purpose.

PLATE 4

Stream through Ta'elefaga Village

5.6.4 Discharge to the Sea

The effect of discharging a relatively constant flow of up to 1.7 cubic metres per second of freshwater (of doubtful quality) into the head of Fagaloa Bay is difficult to assess.

The Environmental Impact Assessment by Winders *et al* (October 1987) discusses this potential problem in some detail. The consultants examined current patterns in Fagaloa Bay and reported on temperature, conductivity and salinity measurements made in this area. The stream flow is, however, small relative to the discharge and hence "the influence of a more significant stream flow was not determined".

The toxic material will have little effect, as the hydrogen sulphide should break down before the discharge reaches the sea. Similarly, acidity is not a concern as the buffering capacity of the seawater will neutralise any acidity immediately on mixing. The only possible issues are therefore the effects of lowered salinities due to the addition of freshwater, and sediment suspended in the discharge.

Post cyclone recovery of the marine communities at the head of the bay adjacent to Ta'elefaga village could possibly be inhibited by the discharge from the powerhouse. It would, however, be expensive and not very reliable to try to model these effects in advance of commissioning.

It could be useful to map the marine communities adjacent to the village now, repeat just before commissioning to assess the post cyclone recovery and then again a year after the scheme was commissioned. A control area in the bay away from the discharge should be similarly examined. This would give controls both in space and time and allow any impacts to be readily assessed. It may be, however, that other influences such as sedimentation resulting from land clearance around the bay would mask any effects of the power scheme.

On balance we think that the risk is low and that further work in this area is not justified.

5.7 Modification of Flows Downstream of the Dam

5.7.1 Existing Condition

River flows were monitored at Afulilo Falls, Vaipu and at Sopoaga from 1971 to 1984. Rainfall data was also collected from several sites. The mean annual discharge for Afulilo is 1.2 cubic metres per second from a nominal catchment area of 11.8 square kilometres. At Vaipu the mean annual discharge is 1.98 cubic metres per second from a catchment of 18.8 square kilometres.

Table 5.1 from the MRM-Feasibility Study sets out the annual rainfall and runoff data. An alternative estimation approach gives a mean annual rainfall of 5700mm.

TABLE 4

Annual Water Balance For Afulilo Catchment

(Source: MRM - Feasibility Study)

Water Year (Nov-Oct)	Rainfall (mm)	Runoff (mm)	Losses Evapotranspiration (mm)	Seepage (mm)	Seepage Rate (l/s)
1971-72	5 100	3 000	1 280	820	307
1972-73	5 580	3 660	1 280	640	240
1973-74	4 720	2 820	1 280	620	232
1974-75	6 150	4 140	1 280	730	274
1975-76	4 480	2 340	1 280	860	322
1976-77	4 560	2 380	1 280	900	337
1977-78	5 470	3 710	1 280	480	180
1978-79	5 220	3 330	1 280	610	229
1979-80	6 790	5 000	1 280	510	191
1980-81	5 670	3 850	1 280	540	202
1981-82	4 960	3 430	1 280	250	94
1982-83	3 500	2 000	1 280	220	83
1983-84*	3 320	1 930	1 170	220	83
Mean	5 180	3 310	1 280	600	224

* Balance excludes October 1984 for which runoff data are not available. Means are calculated from results for 1971-72 to 1982-83.

The relatively short period of record includes a wet period in 1980 - 1981 and a very dry period in 1982 - 1984. In 1982 - 1984 a very strong El Nino condition prevailed in the South Pacific.

5.7.2 Post Dam Condition

The Afulilo Falls dam will trap a large part of the flow in the 10 million cubic metre storage basin. There is no provision for the passage of a small residual flow. Groundwater seepage from the volcanic rock, and drainage off the steep slopes, around the Fusiluaga basin, however, is likely to produce a small flow of water in the upper portion of the old river channel.

Once the storage in the reservoir reaches 317.50 m.r.l. flood flows will be discharged over the free overflow weir. These flood events should resemble previous floods in the Fusiluaga basin and will mainly affect the incised river channel.

The existence of the storage reservoir will reduce the volume and frequency of occurrence of flood flows in the Vaipu channel. In dry years (e.g. 1982 - 1984) little flow would pass the Afulilo dam; but in wet years like 1980 - 1981 when the reservoir would have been full, numerous flood events would have been discharged over the spillway to flow though the Fusiluaga basin.

5.7.3 Effects on Wetlands

The Vaipu swamp in the Fusiluaga basin will have a greatly reduced river flowing through it. In major storms discharges over the spillway will produce sizeable flood flows below the Afulilo Falls. Perennial streams flowing into the swamp from the northern part of the basin should continue to supply water.

The major water input into the swamp complex is clearly the 5000mm of rainfall that it receives annually. It is thus concluded that the construction of the Afulilo dam is likely to have little hydrological effect on the Vaipu swamp outside of the main river channel.

The plant habitat should be changed only slightly. The swamp will be a little drier around the levees as the effect of many flood flows over topping the banks will be lost. The communities at the toes of the slopes should not be affected.

5.7.4 Effects on Freshwater Fauna

The freshwater animals of the rocky reaches of the Fagatoloa river in the upper reaches of the Vaipu swamp directly below the Afulilo falls will lose all of their habitat. The fact that flood flows will spill over the dam will not in any way restore any habitat in this area. The cascade shrimp and claw prawn will vanish from this area.

The slow flowing, swampy river habitat through the Vaipu will be reduced and the animals there will decrease in numbers as a consequence. The size of the river in low flows during dry periods will be significantly reduced as far as the Fuipisia Falls. Oxygen concentrations will also be somewhat reduced. Without a wider survey of the freshwater fauna of Western Samoa, however, the significance of these effects cannot be assessed.

5.7.5 Effects on Wildlife

The Vaipu swamp wildlife should not be affected in any major way by the change in flows caused by the construction of the Afulilo dam. It is the proposed Vaipu extension that is the concern for this area.

5.7.6 Effects on Marine Environment

The river at Afulilo Falls and through the Vaipu is one tributary of the much larger Mulivaifagatola river which discharges to the sea at Salani. The loss of water from the river should cause no noticeable effects at its point of discharge to the sea.

5.7.7 Effects on River Channel Stability

Reduction in river flows between Afulilo Falls and Vaipu may create somewhat drier conditions in the natural levees along the channel. The lower levels may allow the gallery forests to expand. There will be some growth of terrestrial plants into the river channel and this will ensure that the river banks remain stable. Such growth could impede the occasional flood discharges from the Afulilo dam, but this should not cause any problems.

5.7.8 Residual Flows

In many parts of the world it is normal practise to allow a small continuous release of water past a dam to maintain a residual stream flow in the old river channel. The Afulilo dam has been designed with no such provision and the matter was not addressed in the EIA by Winders *et al* (1987).

To be at all effective a residual flow would need to be at least 20 - 30 litres per second. Given that there are no fish other than eels in the area, and that eels would be better hand stocked into the reservoir, a residual flow is not recommended for the Afulilo.

5.8 Construction Effects

Construction of the Afulilo hydroelectric scheme is expected to take two years and three months from the beginning of construction in late 1990. The first electricity should be generated in 1993. Over this period heavy trucks will haul all the components from Apia to various sites.

In the order of 400 truck movements (a return trip equals two movements) would appear to be required over 6 to 9 months. As the work intensifies it can thus be expected that the number of return trips will rise from the 12 experienced in July to around one or two return trips per day. This should not cause significant disruption to the villages along the coast road from Apia as long as the trucks keep their speed down through the villages.

5.9 Power Transmission Lines

Commissioning of Afulilo will require the construction of new transmission lines and the upgrading of existing lines.

New transmission lines are to be built from:

(a) Ta'elefaga powerhouse to Lalomauga substation (4.5km of 22kV line);

(b) Ta'elefaga powerhouse to Afulilo Dam (2.9km of 22kV double line);

(c) Afulilo Dam to Lotofaga (10.6km of 22kV line).

Care should be taken to ensure that any access roading to the transmission lines is properly formed and culverted to minimise future erosion problems. Clearing of existing forest along new transmission lines should be kept to an absolute minimum, particularly on the steep slopes above Fagaloa Bay.

5.10 Social Effects

Only limited comment can be made in this report on the social effects of the power scheme. The team has no special training in this area and is not familiar with the social structure of Western Samoa. Social impact assessment is, however, an important part of modern environmental impact assessment and should be considered for future projects.

A few general observations are possible at this stage

Construction of the dam has already had an obvious effect on local villagers. Men are resident at the dam and reservoir sites assisting with construction (approximately 140) and clearing the swamp (about 100). There has been a significant injection of cash in the local community, although it appears that this has not fallen equally to all villages in the area.

In the longer term the power scheme may bring limited direct benefits to the local community. The EPC plans to reticulate electricity to villages in Fagaloa Bay following construction of the scheme.

It will be the local people in Ta'elefaga village that will experience the environmental impacts of the scheme. There will probably be unpleasant discharges of water in their village as noted by Winders *et al* in the original environmental impact assessment.

The Resident Engineer has stated that for 24 hour a day operation, there could be 10 people directly employed with some additional maintenance and casual staff. It would be desirable for as many of these workers as possible to be drawn from the immediate local community with appropriate training provided.

The power generated will have significant benefits at the national level. It will provide a more reliable electricity supply. It will, either reduce pollution from diesel generation, or allow further electricity use depending on the development of total demand. In the medium term it will reduce dependence on imported diesel.

6. FUTURE DEVELOPMENT OPTIONS - THE PROPOSED VAIPU EXTENSION

6.1 Vaipu Extension

The present Afulilo scheme is being built with pipeline, penstock, powerhouse and tailraces all designed to allow for a future increased flow of water. At the powerhouse it would merely be necessary to install a third turbine and generator.

The proposed Vaipu extension would add to the water available to the Afulilo hydroelectric power scheme. It would thereby increase annual power output by up to 4GWH. This would represent 5.7% of the estimated annual Upolu consumption (Lahmeyer International, March 1990).

The present augmentation proposal appears to envisage a small headpond (say 50,000 cubic metres), a pump station and a pipeline to connect with the existing Afulilo conduit.

PLATE 5

Vaipu Swamp - Fusiluaga Basin

6.2 Environmental Impact

6.2.1 Head Pond

Provided the head pond was kept small, for example 50,000 cubic metres, this should not have any great effect on the Vaipu swamp forest. The dam or weir involved would present another barrier to the passage of fish, although this would be small in comparison to the large waterfalls downstream.

6.2.2 Abstraction

Loss of water would destroy the freshwater habitat immediately downstream unless a significant residual flow was allowed to bypass the Vaipu intake.

6.2.3 Pipeline

The most probable pipeline route would be around the margins of the Vaipu swamp. According to the Resident Engineer the existing access track around the north side of the Vaipu swamp would be the probable route of the pipeline to the south portal of tunnel 2.

It is vital that any future development not include works in the main body of the Vaipu swamp and that works on its margins are minimised. Opening access into the heart of the wetland would ensure its long-term destruction.

6.3 Conclusion

Loss of the last large montane wetland in Western Samoa would be a very heavy price to pay for the relatively small gain in extra generating capacity.

It is recommended:

(a) That the Government of Western Samoa seriously consider all factors, including the conservation value of the Vaipu swamp, before a decision is made on the Vaipu extension.

(b) That the operation of the Afulilo hydro scheme be studied in detail to optimise the use of the reservoir and power production. This monitoring would include five years of recording rainfall, lake level, tail-water level, and power production. This data could then be used to calibrate a simulation model to create an operating regime that would optimise power production. Works Project Services, PO Box 12-447, Wellington, New Zealand is one of a number of organisations capable of routinely carrying out such modelling and power optimisation.

(c) That the Afulilo-Vaipu area be subject to a catchment management plan produced with suitable consultation with local landowners. This would prescribe appropriate land uses and identify how natural areas were to be protected.

7. EFFECTS OF CLIMATE CHANGE

The consultant group sought advice from the New Zealand Meterological Service on the possible influence of climate change in Western Samoa.

The extremely dry period experienced in 1984 - 1984 was associated with a major El Nino event which affected a large area of the South Pacific.

The most likely effect of climate change is to make conditions more variable. This would probably include:

(a) major storm events with very high rainfalls will tend to occur more frequently than in the past. These may cause erosion on the steep slopes of the Fagaloa Divide, but will ensure that the reservoir fills rapidly with water;

(b) drought periods are likely to be more severe than in the past and may well occur more frequently. For example a dry period like that recorded in 1983 - 1984 represents a one in 30 year event from present records. With climate change, however, such events may occur at more frequent intervals than in the past.

Conclusions

1. Climate change is unlikely to affect the long-term viability of the Afulilo hydroelectric power scheme.

2. It may be necessary to utilise more expensive diesel generation during drought periods, say once a decade.

3. Spillway design at Afulilo dam is more than adequate to cope with the frequency and severity of major storm events.

8. CONCLUSIONS AND RECOMMENDATIONS

This report examines the environmental impacts of the Afulilo hydro power project presently being constructed on Upolu, Western Samoa. It makes extensive use of material reported in the earlier EIA carried out for the project by Winders *et al* (1987). It reviews that work and advances further conclusions based on new information.

This section sets out the principal findings and recommendations of the report. The recommendations are addressed to the Government of Western Samoa which commissioned the report. Where possible, the specific agencies of the Government are identified.

It is suggested that the Cabinet of the Western Samoan Government is briefed on these recommendations and, where it agrees, endorses the recommendations as instructions to its departments.

Preparation of this report has highlighted the value of comprehensive environmental impact assessment and wide consultation early in the design of major projects. The environmental assessment work that was done had positive influences on the scheme design, although it could have gone further both in detail and in setting the project in the context of the Western Samoa environment.

(1) The Afulilo dam will create a ponding area of 250 hectares. This area is being cleared of all standing vegetation. Such clearing is necessary, both to protect the quality of water in the reservoir, and for the operation of the dam. The felled trees should be burnt or dragged from the pond area.

   (a) **Recommendation:** That all possible vegetation is removed from the dam storage area by the Electric Power Corporation (EPC) to reduce the amount of rotting material.

   (b) **Recommendation:** That, if possible, useable timber is recovered from the swamp by the EPC and back-loaded to Apia on the trucks bringing materials to the site.

   (c) **Recommendation:** That if timber cannot be recovered, it be burnt or dragged from the reservoir area by the EPC. If trees are burnt, oil and old tyres should not be used to assist burning. The option of hauling the logs to the swamp margins should be examined instead or, if this is not possible, then only light spirits such as petrol be used.

   (d) **Recommendation:** That consideration is given by the EPC to fully draining the lake several times in the first three years of its operation to flush out rotting plant material.

   (e) **Recommendation:** That lake draining is only done during natural flood events to protect the river downstream.

(2) Formation of the ponding area is destroying the Punataemo'o swamp, which was one of the most important natural areas remaining on Upolu. The only other such area in Western Samoa is the Vaipu (Fusiluaga) swamp immediately downstream. Future extension of the Afulilo hydro-electric power scheme has been suggested by pumping water from the outflow of the Vaipu into the headrace conduit. Considering the relatively small amount of additional power generated, 4GWH or 5.7% of the total Upolu demand of 70GWH, disruption of the Vaipu swamp forest ecosystem would seem an overly heavy price to pay.

(a) **Recommendation:** That serious consideration be given by the Government of Western Samoa to the natural values of the Vaipu swamp before a decision is made on the Vaipu extension.

(b) **Recommendation:** That no works are permitted in the Vaipu swamp and that land clearance is prevented in the swamp margins.

(c) **Recommendation:** That discussions are initiated by the Division of Environment and Conservation (DEC), of the Department of Lands and Environment, with landowners to secure the long-term protection of the Vaipu swamp.

(d) **Recommendation:** That the plant and animal species of the Punataemo'o basin are recorded by the DEC before these populations are destroyed.

(3) The ponding area behind the dam will at times contain a shallow lake of up to 250 hectares. During dry years, however, the lake will disappear. As the lake rises and falls in the course of a normal year's operation, there will be large areas of rotting vegetation on the exposed lake bed and in the water. This may cause bad smells and foul the water.

(a) **Recommendation:** That local people are discouraged by the DEC from establishing permanent settlements adjacent to the lake until the consequences of the fluctuating levels have been established by observation.

(4) The only lake weed in Western Samoa capable of seriously affecting the operation of the hydro scheme is water hyacinth. This exotic weed appears to be found only in a few drains around Apia.

(a) **Recommendation:** That EPC consider eradicating water hyacinth to remove any threat to the Afulilo power scheme.

(5) In wet years the reservoir behind the dam will remain full of water for most of the year. In such years it may prove substantial habitat for prawns. It is unlikely that a population of eels will naturally persist. The upstream migration of the young eels will be stopped by the dam. Retention of a minimum lake level and stocking the reservoir with young eels (elvers) from lower in the Fagatoloa River could partly overcome this problem. Without a minimum lake level the eel population will be small. Prawns and eels are valued by locals as food.

(a) **Recommendation:** That stocking of the lake with elvers is carried out by local villagers under the guidance of the Department of Agriculture, Forestry and Fisheries.

(6) In wet years the reservoir could be a valuable habitat for birds, such as ducks and herons. Its value for both birds and fish will depend on the water quality and the sorts of plants that grow on the lake edges. These will both be improved if local plants which can grow both in and out of water are present. This will reduce the amount of rotting vegetation and improve the habitat for animals.

(a) **Recommendation:** That pandanus, hibiscus, and falaga be planted at the site by the EPC around the margins before the reservoir is filled.

(7) It has been suggested that the reservoir be used for aquaculture. It would seem valuable to have a fish species in the reservoir which would graze down the growth of plants and algae to reduce the amount of rotting vegetation. This has to be weighed against the possibility that the Punataemo'o and Vaipu swamps may be among the few areas remaining in Western Samoa which are free of introduced fish. This makes them very valuable as areas where some of the native freshwater invertebrates might remain undisturbed.

→ (a) **Recommendation:** That Department of Agriculture, Forests and Fisheries (DAFF) ensure that exotic fish not be introduced into the Punataemo'o or Vaipu basins.

OR

(b) **Recommendation:** That fish species be introduced to the reservoir only after careful consideration by DAFF and DEC of the possible impact on native species in the Vaipu swamp and the river system downstream.

AND

(c) **Recommendation:** That any trials be carried out only with sterile fish.

AND

(d) **Recommendation:** That any fish species introduced be able to mature to harvestable size in less than 12 months and tolerate poor water quality should a minimum reservoir size of around 100 hectares not be maintained.

(8) It would be desirable for water quality, habitat for birds and fish, and for future aquaculture potential for a lake of no smaller than 100 hectares to be maintained at all times. This could be done by limiting drawdown to about 313 m.r.l. This would involve foregoing about 10% of the storage capacity of the reservoir for electricity generation.

(a) **Recommendation:** That a minimum lake level be maintained by EPC to retain a lake area of no less than 100 hectares at all times after the first three years.

(9) Construction of the dam has involved the development of substantial roading in previously undisturbed areas. This has made areas available for agriculture with consequent effects on natural communities.

(a) **Recommendation:** That agricultural development be prevented in the Vaipu swamp or its margins by EPC closing all construction roads and limiting public access into the dam and quarry sites.

(b) **Recommendation:** That a catchment management plan be prepared by DEC for the Afulilo basin to determine appropriate land uses and thereby safeguard the water quality of the water storage reservoir.

(10) Management of the Afulilo and Vaipu basins and the hydro-electric scheme will be improved by good communication between the principal parties involved. Establishment of a group to oversee environmental management of the area and the scheme would be one way to achieve this. Such a group could be serviced by the Division of Environment and Conservation and report directly to the Minister of Lands and the Environment.

(a) **Recommendation:** That the Minister of Lands and the Environment consider establishing a group, perhaps made up of the local MP (representing the villagers associated with the Afulilo and Vaipu basins), a matai of Ta'elefaga village, a representative of the EPC, the President of the Siosiomaga Society, and chaired by the head of the Division of Environment and Conservation. Such a group could provide for regular communication, oversee the production of a catchment management plan, deal with environmental and other problems that arise. It would report annually through its Chairman to the Minister of Lands and the Environment.

(11) Dam construction is leading to exposed areas of soil and spoil below the dam, adjacent to the headrace conduit road, and in the area of the penstock construction. In addition, spoil and rubbish have occasionally been dumped over an area adjacent to the Afulilo Falls.

(a) **Recommendation:** That the EPC keep spoil away from watercourses and the exposed soil be revegetated with local species and replanted with local trees as soon as possible. It is noted that the existing contracts require these actions.

(12) The road around the Vaipu swamp crosses several significant streams. It is important that these crossings have adequate culverts or carefully constructed drop structures. Failure of the road and the pipeline due to washouts would entail repair works which would cause substantial on-going impacts. It is understood that all significant stream crossings will include substantial culverts or drop structures to avoid this problem.

(13) The generators for the power scheme will be located in Ta'elefaga village. The local school has already been moved to allow this to happen. The generators will produce some noise and it is not yet clear whether this may be above acceptable standards on still nights.

(a) **Recommendation:** That noise production of the generators is assessed by the EPC and that the effect of night-time noise is further investigated.

(14) Water from the powerhouse will be discharged into the stream which flows through Ta'elefaga village. The amount involved will be substantially more than the natural low flow of the stream. At times the water will be clean, but much of the time it may be discoloured, and at least in the early years will probably have an unpleasant smell. It is inappropriate for this water to be discharged to the stream immediately upstream of the village, but it is now not technically feasible to correct this situation.

(a) **Recommendation:** That the villagers are made aware of the probable state of the stream and that all possible steps are taken by the EPC to improve the water quality (eg. vegetation clearance, reservoir flushing, armouring the stream and retention of a minimum lake level).

(15) It has been suggested that the water from the powerhouse could be used for fish ponds at the village. The probable poor water quality makes it unwise to pursue such a venture until the power scheme has been in operation for some time. This will give the water quality a chance to settle down.

(a) **Recommendation:** That aquaculture using the power station discharge is not pursued by DAFF for some years after commissioning the scheme.

(16) The extra constant flow of fresh water carrying sediment into Fagaloa Bay could possibly have negative environmental effects, but these are difficult to predict in advance, and are not expected to be significant. It would be worthwhile re-examining the area in a post commissioning audit of the project.

(17) Transport of the pipeline, concrete, and generator parts, will involve around 400 truck trips along the road between Apia and Ta'elefaga over a period of six to nine months. This is unlikely to pose a significant disruption to villages along the route, as long as the trucks keep their speed down. There will be an average of only two truck movements per day between Apia and Ta'elefaga.

(18) Construction of the dam has already had significant social effects on local villagers. About 140 men are resident at the dam site assisting with the construction and another 100 clearing the swamp. There has been a significant injection of cash into the local community. In the long-term, however, the power scheme will bring limited direct benefits to the local community. The power generated will have benefits principally at the national level. It will be locals at Ta'elefaga village that will experience the impacts of the scheme with a probably unpleasant discharge of water in their village.

(a) **Recommendation:** That employment opportunities for local villagers are maximised in the operation of the scheme, with training being provided as required.

(19) There will be some impacts from the upgrading of the power reticulation system. This will involve, as a minimum, some forest clearance between Ta'elefaga and Lalomauga. This should be minimised by techniques such as using taller poles to improve ground clearance.

(a) **Recommendation:** That the EPC set out clearly for DEC its intentions for the reticulation upgrading so that the environmental effects can be assessed.

(b) **Recommendation:** That any access roading required for the upgrading of the power reticulation be properly formed and culverted to avoid future erosion problems.

(c) **Recommendation:** That the EPC keep associated vegetation clearance to an absolute minimum and taller poles be used where necessary to improve ground clearance.

(20) Diversion of water from the Afulilo Falls will reduce the flow of water leaving the Vaipu swamp. The downstream effects of this change have not been determined authoritatively. There will certainly be a reduction in river habitat through the Vaipu and flushing of this system will be reduced. Given the size of the catchment of the Mulivaifagatoloa River, there are unlikely to be significant effects downstream of the Fuipisia Falls.

(21) On the basis of evidence currently available on climate change caused by the build-up of carbon dioxide in the atmosphere, the climate pattern may become more extreme and variable with larger storms and floods happening more often. Droughts of greater severity could also be expected more frequently, eg. once a decade. The Afulilo scheme could cope with both problems, although electricity generation could be reduced in some years. Long-term viability of the scheme, however, would not be threatened.

(22) Monitoring of the operation of the scheme and its effects will assist in reviewing its management. This would help to run the scheme more efficiently, to deal with any environmental affects that occur, and to identify opportunities for other beneficial uses of the facility. Details on monitoring are included in the main text of the report.

(a) **Recommendation:** That the EPC monitor performance of the Afulilo Reservoir for at least five years after commissioning.

(b) **Recommendation:** That the water quality in the reservoir is monitored for at least three years after commissioning.

(c) **Recommendation:** That a post commissioning environmental audit of the functioning of the scheme is conducted by DEC one or two years after commissioning.

(23) To allow adequate assessment of future hydro and aquaculture projects, a comprehensive assessment of the freshwater fauna of Western Samoa is urgently required. This should examine the distribution of both native and introduced species.

(a) **Recommendation:** That the Division of Environment and Conservation consider commissioning a comprehensive survey of the distribution of fresh water animals in Western Samoa.

(24) There may be a number of significant archaeological sites in the area. No assessment has yet been made of their presence, nor of the effects of the scheme on these sites.

(a) **Recommendation:** That such an assessment is carried out by the Division of Environment and Conservation funded by the EPC.

(b) **Recommendation:** That if archaeological sites are revealed by earthworks associated with the project, they are properly recorded by a competent archaeologist employed by the EPC.

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APPENDIX ONE

Record of Consultation and Inspections

Monday	12 August 1991	John Waugh begins work to set up project.
Tuesday	13 August 1991	Works with Clive Miller in project office reading tender documents.
Wednesday	14 August 1991	Peter Lawless and Lindsay Chadderton arrive and begin work. Discussion with NZ High Commission. Arrange hire vehicle. Meet with Leon Zann FAO advisor to the Department of Agriculture, Forests and Fisheries.
Thursday	15 August 1991	Site visit with Robert Dorr of the Lahmeyer Consortium acting on behalf of the EPC. Visit includes Ta'elefaga village and the construction site at Afulilo.
Friday	16 August 1991	Set up and approve programme of investigation with DEC. Lindsay Chadderton in field withecological survey team.
Saturday	17 August 1991	Examined hydro pond for comparative data.
Sunday	18 August 1991	Day off.
Monday	19 August 1991	Field work at Afulilo with ecological survey team. Met with matai of surrounding villages at Afulilo. Lindsay Chadderton and survey team stay with local workers.
Tuesday	20 August 1991	Field work at Afulilo, Lindsay Chadderton only. Lawless and Waugh writing up report.
Wednesday	21 August 1991	Meeting with Clive Miller to clarify technical points. Field work at Lake Lanoto'o to gather comparative data.
Thursday	22 August 1991	Field work at Afulilo. Meeting with matai at Afulilo.
Friday	23 August 1991	Field work at Fagaloa Bay assisted by Tupuola Sami and Limu Filia.
Saturday	24 August 1991	John Waugh returns home. Sampling small streams for comparative data.
Sunday	25 August 1991	Day off.

Monday	26 August 1991	Lindsay Chadderton sorting and classifying samples. Peter Lawless writing up. Meeting with Apia Observatory staff.
Tuesday	27 August 1991	Peter Lawless writing up. Lindsay Chadderton sorting samples.
Wednesday	28 August 1991	Writing up and further sampling in the Vaipu.
Thursday	29 August 1991	Interview with Feti Tuluono, General Manager of EPC. Interview with John Worrall. Writing up. Draft report available and discussed with Pati Liu.
Friday	30 August 1991	Meeting with matai of Ta'elefaga Village. Public meeting sponsored by Siosiomaga Society.
Saturday	31 August 1991	Peter Lawless and Lindsay Chadderton leave.

APPENDIX 2

Freshwater Fauna

Introduction

There have been relatively few investigations of the freshwater fauna of Western Samoa. To our knowledge the only published works have been taxonomic papers (e.g. Haynes 1984), fish species checklists (see Wass 1984 for a review and updated lists) and an ecological account of mollusca (Starmuhlner 1986). There do not appear to have been any comprehensive studies of the biota and no accounts of distribution patterns, abundance or community descriptions.

In undertaking an environmental impact assessment of the Afulilo project we were faced with little background material upon which the affected areas fauna could be compared. Therefore, the survey work undertaken became a compromise between assessing the faunas of the Afulilo falls, Punataemo'o and Vaipu swamps (likely areas of impact) and the rest of Upolu. This appendix outlines the results of freshwater survey work undertaken on Upolu between August 14 and 28 (1991), and gives some discussion of communities encountered.

Methods

Samples were collected from 17 sites (Fig. 8), including one sample from Lake Lanoto'o (site 7), three sites in Punataemo'o Swamp (sites 1, 4, & 5), and two sites in the Vaipu Swamp below the Dam site (sites 2 & 3). Benthic invertebrates were collected with a hand held net (mesh 0.25 mm) held downstream of stony substrata which were disturbed by foot or turned over and scrubbed by hand. One three minute kick sample was collected at most sites, stored in 80 % methanol or 10 % formalin and sorted later in laboratory. In addition because of the low abundance of invertebrates, 10 - 100 metre reaches of stream were worked (as above disturbing substrate) at most sites using a push net (see below) or hand net. These samples were picked through in the field for macroinvertebrates and specimens retained.

Fish were collected using gee minnow traps (wire fish traps produced in Canada see Main et al. 1985), hand nets and push nets. Records were also supplemented with observations. Ten to 100 metre reaches of stream were worked. The push net was a 1.5 m wide (1m high) 1mm mesh net strung between two bamboo poles and weighted at the bottom end by a chain. While one person holds the net the other disturbed substrate upstream working towards and flushing fish into the net which is scooped up. This technique is widely used in New Zealand and proved successful in Samoa. Fish, prawns, shrimps mollusca and insects were all caught using this technique.

Identifications follow Haynes (1984) and Starmuhlner (1986) mollusca, and Winterbourn and Gregson (1990) for insects. Fish were generally identified by Dr Paddy Ryan previously of University of South Pacific). Eels were identified using a key from Fiji, but names assigned follow those listed in Wass (1984). Shrimps were differentiated by rostrum shape, and separation into operational taxonomic units was on gross differences only.

Results and Discussion

Invertebrates

Stream invertebrate communities were characterised by a low species diversity and the virtual absence of macro-insect larvae. The 30 operational taxonomic units (OTUs) recorded (Table 5.), included ten mollusca, nine crustacea and nine insecta. Numerically and in biomass the fauna was dominated by molluscs and crustaceans, especially Aytid shrimps and Melanoides snails. Neritina spp. and Septaria spp. were commonly recorded in coastal streams, but usually in low numbers. The large freshwater prawn Macrobrachium ?lar was present at most sites and although a conspicuous component of the fauna it was never abundant.

Freshwater insects were generally rare, however, in mossy stretches and among filamentous algae chironomidae larvae were at times common. Moderate numbers of Notonectidea and Hydrometridae were observed in or on the surface of pools and slow flowing stretches of river in the Punataemo'o Swamp.

Trichoptera, Plecoptera and Ephemeroptera all appear to be absent on Upolu. Given Samoa's geographic isolation this is probably not surprising. It seems likely that the Leptophlebiid recorded by Winders et.al. was the damselfly Ischnura aurora. Despite extensive searching no mayflies were encountered, whereas, I. aurora was relatively widespread but uncommon. I. aurora was recorded by Starmuhlner (1986) and in the current survey it was present at the out flows of the Vaipu and Punataemo'o swamp, upper reaches of the Vaipu, and a small stream at base of Mt Fiamoe.
Melanoides lutosa, M. perigrina, an unidentified dragonfly larvae and the claw shrimp/prawn were only recorded in streams or swamp likely to be affected by the Afulilo dam. However, both species of Melanoides were recorded by Starmhuhlner (1986) from streams elsewhere on Upolu and therefore it seems unlikely they are restricted to this catchment. The distributional status of these other two taxa cannot be determined.

Fish

A total of nine fish taxa were collected from 10 sites around Upolu (Table 6). Anguillids and Poeciliidae appear to be the most widespread whereas goldfish (Carassius auratus) were only recorded from Lake Lanato'o. Tilapia are also probably much more widespread than this survey indicates as like the Poeciliidae they appear to have been actively dispersed.

Wass (1984) noted that Poecilia mexicana was introduced to American Samoa by the Department of Public Health to control mosquitos, and it is probable that Western Samoan stocks originate from these. There is however, unconfirmed reports of P. reticulata (Wass 1984) from Samoa.

The Afulilo basin and Vaipu swamps are characterised by the absence of fishes. There were numerous local accounts of eels with the Punataemo'o swamp but these have apparently been fished heavily (recently) and none were caught during our survey.

Coastal streams in Fagaloa Bay contained a diverse and interesting fish fauna. No introduced fishes were recorded, and this may be due to the ephemeral nature of these streams (Zann pers. comm.). Observations of other streams in Fagaloa bay suggest they all contain similar fish communities.

Introduced fishes can reduce or eliminate native fishes through competition, predation, disease and hybridisation. They can also drastically alter invertebrate communities (Hurlbert et.al 1972). Both Tilapia and Poeciliids are commonly accused of ecosystem alterations. Among fisheries staff there is a perception that these fish are widespread on Upolu. Therefore there is a strong possibility that many of the stream faunas of Upolu have been modified by introduced fishes. If this is so, then both the streams of Fagaloa Bay and Afulilo Basin are significant as some of few remaining examples of natural pristine freshwater systems. The streams assemblages present, although generally containing taxa found elsewhere, are important because of their pristine status. Furthermore until a comprehensive study of the freshwater fauna is undertaken a most conservative approach should be followed, and all possible steps taken to minimise impacts on remaining habitats.

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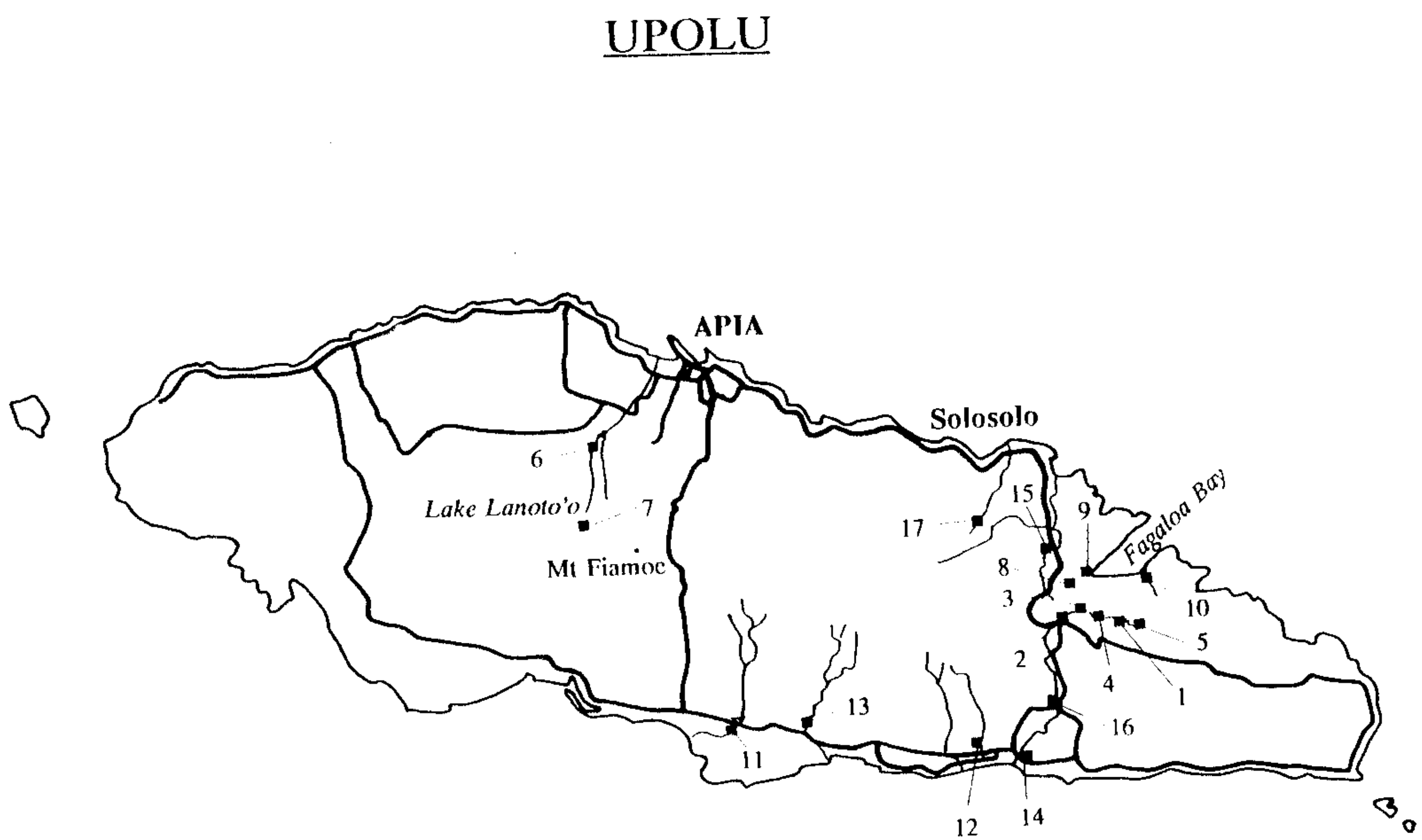

Figure 8 Location of sampling sites

TABLE 5

Distribution of freshwater invertebrate OTU's (operational taxonomic units) collected from survey of various sites on Upolu, Western Samoan, August 1991. Site numbers relate to Fig. 8. Presence/absence data only.

SITES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17
Dragonfly larvae	•															
Chironominae					•	•		•	•	•		•	•			
Tanypodinae											•		•			
Oligocheata		•									•	•				
?Polycheate					•											
Notonectidae	•	•				•										
?Ischnura aurora (damselfly)		•	•		•	•										
Limonia sp.										•		•				
Aphrophila sp.					•											
Macrobrachium ?lar.	•	•	•					•	•		•	•	•		•	•
Aytidae sp1 (one spine on rostrum)	•	•	•		•	•					•					
Aytidae sp2 (multi-spined rostrum)		•				•					•					
Aytidae sp3 (Cascade species)		•	•										•			
?Macrobrachium sp. (striped orange and green)								•	•	•						
Aytidae sp4 (red/white sp.)			•						•							
Claw shrimp/prawn			•													
Varuna litterata												•				
Melanoides lutosa		•		•	•											
Melanoides perigrina		•	•													
Melanoides tuberculata				•	•	•										
Neritina tartoni										•						
Neritina porcata								?	•	•						
Neritina ?rubida (type)												•				
Septaria porcellana depressa								•								
Septaria suffreni									•	•						
Septaria barbonica								•		•						
Clithon costanea								•		•						
Hydrometridae	•				•	•										
Homeodytes sp.							•									
Shrimp sp5							•									

TABLE 6

Distribution of freshwater fishes collected from survey of various sites on Upolu, Western Samoa, August 1991. Site numbers relate to Figure 8. Presence/absence data only.

SITES	1	6	7	8	9	10	12	13	14	15	16	17
Anguilla celebesensis (Kaup 1856)						•					•	
Anguilla mauritiana (Bennett 1831)							•					
Anguilla sp. (unidentified)	*			•								
Syngnathidae				•	•	•			•			
Kuhlia sp.				•	•	•						
?Sicyopterus sp.				•	•	•		•				
Stiphodon 'elegans'						•						
Carassius auratus			•									
Tilapia mossambica			•									•
Poeciliidae		•					•		•	•		

* None caught, however, numerous local reports of eel stocks in the swamp.

APPENDIX 3

Physiochemical Water Quality Measurements

SITE NO. (REFER MAP)	SITE NAME	DESCRIPTION	SAMPLING DATE	TIME (h)	TEMPERATURE (°C)	OXYGEN (ppm)	OXYGEN (%Sat)	pH	CONDUCTIVITY (μ MHOS)	ALTITUDE (metres a.s.l.)
1	Punataemo'o Swamp	Small pool.	24/8/91	1030	27	5.7	75%	4.7	-	310 m
		Small stream.	24/8/91	1050	25	4.0	51%	5.2	-	410 m
		Main branch stream.	24/8/91	1105	25	4.8	61%	6.3	-	410 m
2	Vaipu outflow	Above weir at road.	22/8/91		25	6.2	77%	7.3	70	230 m
			23/8/91		25.2	6.4	81%	7.5	78	230 m
4	Punataemo'o Outlet	Above Afulilo Falls.	20/8/91		25	5.0	64%	6.7	130	310 m
			23/8/91		25	5.7	73%	7.1	70	310 m
7	Lake Lanato'o	Profile Depth								
		(1) Surface	21/8/91	1400	24.8	6.7	87%	6.8	-	806 m
		(2) Surface			24.0	7.1	93%			
		(2) 1.0 m			24.0	6.9	90%			
		(2) 2.0 m			23.8	6.7	88%			
		(2) 3.0 m			23.5	6.7	88%			
		(2) 4.0 m			23.5	6.7	88%			
		(2) 5.0 m			23.5	6.7	88%			
		(1) 5.0 m			23.5	6.7	88%			
		(2) 6.0 m			23.5	6.6	87%			
		(2) 7.0 m			23.4	6.6	87%			
		(2) 8.0 m			23.4	6.6	86%			
		(2) 9.0 m			23.2	6.4	83%			
		(2) 10.0 m			23.5	6.3	82%			
		(1) 10.0 m			23.2	6.5	84%			

SITE NO. (REFER MAP)	SITE NAME	DESCRIPTION	SAMPLING DATE	TIME (h)	TEMPERATURE (°C)	OXYGEN (ppm)	OXYGEN (% Sat)	pH	CONDUCTIVITY (μ MHOS)	ALTITUDE (metres a.s.l.)
		(2) 11.0			23.2	6.5	84%	-	-	
		(2) 12.0			23.2	6.5	84%	-	-	
		(1) 13.0			23.5	6.4	83%	-	-	
		(2) 13.0			23.2	6.4	83%	-	-	
		(2) 14.0			23.2	6.4	83%	-	-	
		(1) 15.0			23.5	6.5	84%	-	-	
		(2) 15.0			23.2	6.1	80%	-	-	
		(1) 17.0*			23.2	0.2	3%	-	-	
		(2) 17.0			23.5	6.2	81%	-	-	
		(1) 18.0*			23.5	0.1	1%	-	-	
		(1) 19.0*			23.5	0.1	1%	-	-	
		(2) 20.0			23.2	3.8	50%	-	-	
		(1) 25.0*			23.5	0.1	1%	-	-	
		(1) 30.0*			23.5	0.1	1%	-	-	
		(1) 40.0*			23.5	0.1	1%	-	-	
		(1) 46.0*			23.5	0.1	1%	-	-	
		(Note: * = probe on bottom)								
8	Upper Ta'elefaga	(a) 2km upstream of village.	22/8/91	1500	26.5	-	-	8.2	120	100 m
		(b) 2km upstream of village.	22/8/91	1500	26.0	-	-	8.0	115	100 m
		(c) 1km upstream of village.	22/8/91	1440	28.0	-	-	7.7	110	50 m
9	Lower Ta'elefaga Stream	(a) 30m above new culvert on true left branch.	22/8/91	1220	28.0	-	-	8.3	-	10 m
		(b) 30m above new culvert on true right branch.	22/8/91	1210	28.0	-	-	8.6	-	10 m

SITE NO. (REFER MAP)	SITE NAME	DESCRIPTION	SAMPLING DATE	TIME (h)	TEMPERATURE (°C)	OXYGEN (ppm)	OXYGEN (%Sat)	pH	CONDUCTIVITY (μ MHOS)	ALTITUDE (metres a.s.l.)
9		(c) 50m above powerhouse.	22/8/91	1200	28.0	-	-	8.5	-	8 m
		(d) 100m above ford and 100m below powerhouse.	22/8/91	1150	28.0	7.8	100%	8.6	140	4 m
		(e) Above ford.	22/8/91	1110	30.0	-	-	9.0	-	1 m
		(f) 50m downstream of ford on estuarine flats.	22/8/91	1100	28.0	8.5	109%	-	140	0 m
		(g) 70m downstream of ford.	22/8/91	1120	30.5	-	-	-	8% Salinity	0
		(h) 100m downstream of ford (10m into sea).	22/8/91	1125	30.0	-	-	-	31.0% Salinity	0
		(i) 110m downstream of ford (20m into sea).	22/8/91	1130	29.0	-	-	-	32.0% Salinity	0
		(j) 115m downstream of ford (25m into sea).	22/8/91	1135	29.0	-	-	-	32.5% Salinity	0
		(k) Ditto, but in plume from stream.	22/8/91	1140	29.5	-	-	-	32.0% Salinity	0

APPENDIX 3 (CONTINUED)

Measurements were taken with:

Oxygen/Temperature	-	YSI Model 57 Oxygen Meter
Conductivity	-	YSI Model 33 Conductivity Meter
pH	-	Kane-May Model 7000 pH Meter

APPENDIX 3 (CONTINUED)

Measurements were taken with:

Oxygen/Temperature	-	YSI Model 57 Oxygen Meter
Conductivity	-	YSI Model 33 Conductivity Meter
pH	-	Kane-May Model 7000 pH Meter