4. HYDROPOWER GENERATING PLANTS AND TRANSMISSION/DISTRIBUTION SYSTEM

4.1 GENERAL

Hydropower schemes are existing in only Upolu Island they are Taelefaga, Lalomauga, Samasoni, Fale-ole-Fee and Alaoa having installed capacity of 12.2 MW in total.

The ground of Upolu is consisted of volcanic rock and coral reef having high water permeability to involve great difficult for construction of the dam-reservoir type hydropower scheme. Therefore, all existing hydroelectric power stations are of run-of-river type except Taelefaga hydropower scheme which is dam-reservoir type. The generating power of the run-of-river type is seriously affected by fluctuation of the river water flow.

There are two main power centers, Apia and Eastern Upolu. Hydropower scheme near Apia, run-of-river of the hydropower schemes are on the Vaisigano River basin and at the area 7.0 km of the main load center of Apia.

Another power center at 40 km distance east of Apia, a largest run-of-river hydropower scheme Lalomauga is located on Saunitau River basin, and Taelefaga hydropower station, dam-reservoir type, is located at the coast of Fagaloa Bay using river flow of Afuliro River basin.

The location of the hydropower schemes is illustrated in Figure 4.1.1.

4.2 EXISTING HYDROPOWER SCHEME

4.2.1 FEATURES OF THE EXISTING HYDROPOWER SCHEME

The features of the existing power scheme are shown in Table 4.2.1 and the outline of each hydropower scheme is described as below:

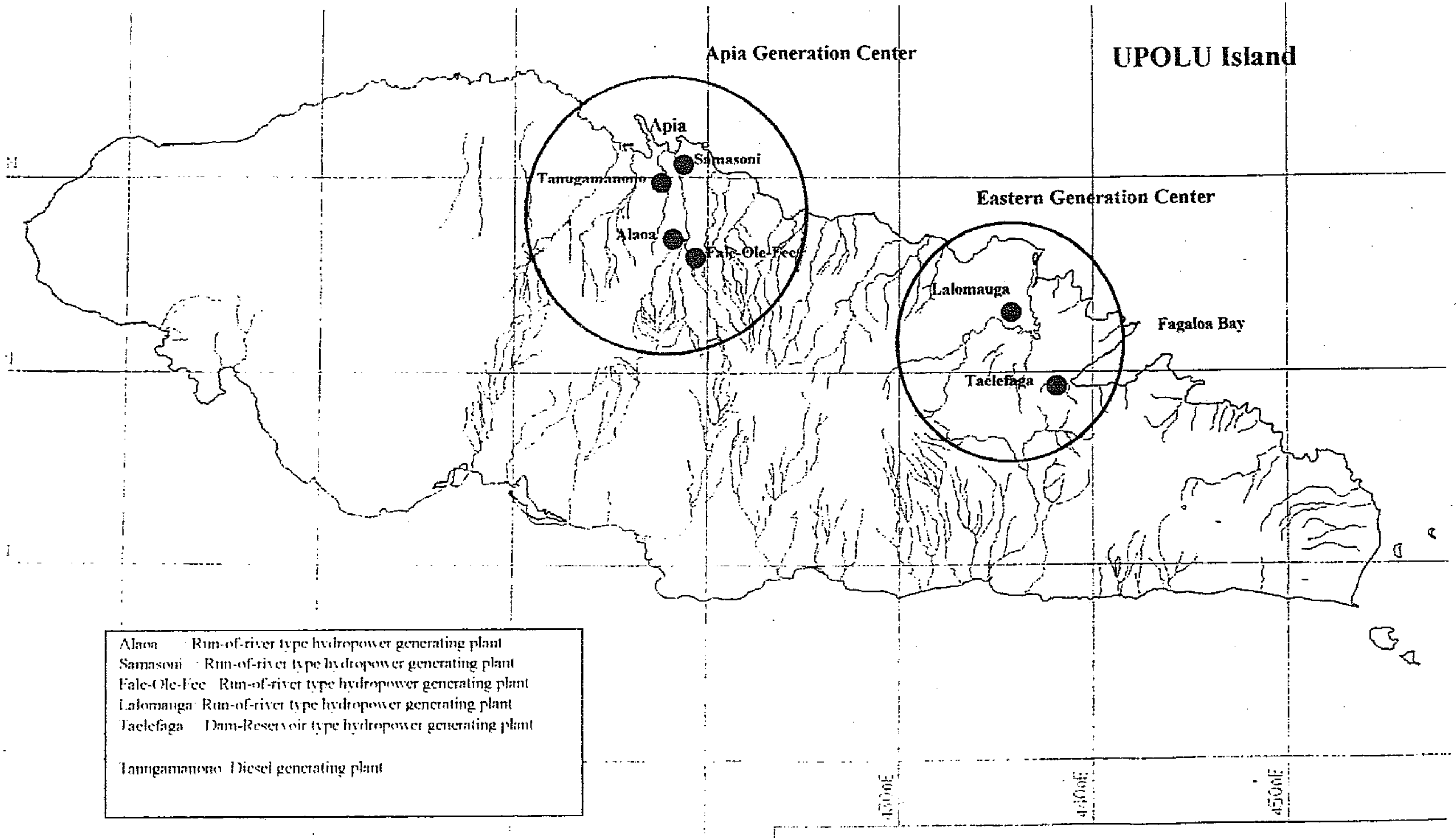


Figure 4.1.1 Location of Generating Power Plant

Table 4.2.1 Features of Hydropower Station

Items	TAELEFAGA HPS	LALOMAUGA HPS		ALAOA HPS		FALE-OLE-FEE HPS		SAMASONI HPS
1.Commissioned	1993	May 1985		1959		July 1981		February 1982
2.River Basin	-	Falefa River		Vaisigano River		Vasigaano River		Vaisigano River
3.Type of Power Plant	Dam-Reservoir	Run-of-River		Run-of-River		Run-of-River		Run-of-River
4. Dam	Concrete gravity dam	-		-		-		-
5. Reservoir Capacity	10,000,000 m3	-		-		-		-
6. Intake	Concrete, integrated in dam	East branch	West branch	East branch	West branch	Fale of Fee	Vaivase	Vaisigano
7. Headrace	2,154 m long x 1,150 and 1,100 mm dia. Steel pipe in tunnel	1,600 m long x 2.06 m dia. galvanized steel pipe	550 m long x 1.8 m dia. galvanized steel pipe	2,700 m long open channel	fully silted	2,568 m long, spiral welded steel pipe	1,434 m long, spiral welded steel pipe	-
8. Headpond	-	HDP lined, 23,000 m3 capacity for running at full load for one hour with no inflow		Concrete lined		HDP lined, 5,600 m3 capacity for running at full load for two hours with no inflow		10,000 m3, running at full load for one hour with no inflow
9. Penstock	985 m long x 400 mm dia., steel aeration pipe	339 m long tunnel and 720 m long steel pipe		steel pipe		3,462 m long spiral welded steel pipe		Bitumen coated steel pipe, 3,600 m long with 1.2 m dia.
10. Turbine								
Manufacturer	DUMONT, France	Boving & Co.LIMITED		Gibert Gilkes & Gordon Ltd.,KENDAL, England		VOITH GmbH, Germany		Gibert Gilkes & Gordon Ltd.,KENDAL, England
Year of Mfg.	1992	1983		1958		-		-
Type	Single horizontal shaft Francis turbine	Single horizontal shaft Francis turbine		Single horizontal shaft Turgo impuls turbine		Single horizonta shaft, pelton type with two jest		Two identical horizontal shaft, Turgo-impuls turbine
Number of unit	2	2		1		1		2
Net head	299 m	119.5 m		135.6 m		300 m		86 m
Water flow	0.185 m3/s	-		0.958 m3/s		0.67 m3		1.29 m3
Output	2,060 kW	1,850 kW		1,050 kW		1,740 kW		950 kW
Speed	750	1,000 rpm		600 rpm		1,000 rpm		500 rpm
Runway Speed	1,350	1,739		1,150 rpm		-		-
11.Governor								
Manufacturer	NEYPRIC	AEC PLAGE MACHINES LIMITED, UK		Gibert Gilkes & Gordon Ltd.,KENDAL, England		VOITH GmbH, Germany		WOODWARD Governor Company, USA
Year of Mfg.	1992	1983		1958		1993		-
Type	Hydraulic/Electrical	-		Mechnical/oil hydraulic		Hydraulic/Mechnical		Hydraulic/Electrical
12.Generator								
Manufacturer	ANSALDO, Itaria	AEC PLAGE MACHINE LIMITED, UK		BRUCE PEEBLES, Germany		ALSTOM		PRELIANCE, Germany
Year of Mfg	1992	1984		1958		1993		1981
Type	Synclonus Genecator	Synclonus Genecator		Synclonus Genecator		Synclonus Genecator		Synclonus Genecator
Number of unit	2	2		1		1		2
Output	2,500 kVA (2,000 kW)	2,200 kVA (1,760 kW)		1,250 kVA (1,000 kW)		2,000 kVA (1,600 kW)		1,125 kVA (900 kW)
Voltage	6,600 V	6,600 V		400 V		6,300 V		6,600 V

Items	TAELEFAGA HPS	LALOMAUGA HPS		ALAOA HPS	FALE-OLE-FEE HPS	SAMASONI HPS
Amper	218.8 A	192 A		1,805 A	183.3	99 A
Power factor	0.8 lagging	0.8 lagging		0.8 lagging	0.8 lagging	0.8 lagging
Speed	750 rpm	1,000 rpm		600 rpm	1,000 rpm	500 rpm
Frequency	50 Hz	50 Hz		50 Hz	50 Hz	50 HZ
Insulation level	F	F		-	F	
13.Main Transfomer		for No.1 unit	for No.2 unit			NA
Manufacturer	Valdagness. SRL	PAUEL. Belgium		ASEA LEPPER. Germany	ASEA LEPPER, Germany	-
Yer of Mfg.	1992	1983	1987	1981	1981	-
Capacity	2,500 kVA	2,250 kVA	5,000 kVA	1,250 kVA	2,000 kVA	-
Voltaage	6,600/23,000	6,600/22,000 V	6,600/22,001 V	400/22,000 V	6,300/20,000 V	-
Current	-	-	437.4/131.2 A	1,804/32.8 A	183/52.51	-
Coolin system	ONAN	ONAN	ONAN	ONAN	ONAN	-
Auto Transformer	NA	-		NA	NA	NA
Manufacturer	-	-		-	-	-
Yer of Mfg.	-	1992		-	-	-
Capacity	-	6,000 kVA		-	-	-
Voltaage	-	22,000/34,000 kV		-	-	-
Current	-	-		-	-	-
Coolin system	-	ONAN		-	-	-
14. Outgoing Feeder	for LALOMAUGA PS Line	for TANUGAMANONO PS Line		for FALE-OLE-FEE PS Line	for TANUGAMONONO PS	for TANUGAMANONO PS
Voltage	22 kV	34 kV		22 KV	22 kV	6.6 kV
No. of Circuit	1 cct	1 cct		1 cct	1 cct	1 cct
Outgoing Feeder	for Intake feeder	For TAELEFAGA PS Line		-	-	-
Voltage	22 kV	22 kV		-	-	-
No. of Circuit	1cct	1 cct		-	-	-
Outgoing Feeder	for Afukio feeder	for SAUNIATU feeder		-	-	-
Voltage	22 kV	22 kV		-	-	-
No. of Circuit	1 cct	1cct		-	-	-
Outgoing Feeder	for South Coast feeder	-		-	-	-
Voltage	22 kV	-		-	-	-
No. of Circuit	1 cct	-		-	-	-
Outgoing Feeder	for Lolofaga feeder	-		-	-	-
Voltage	22 kV	-		-	-	-
No. of Circuit	1 cct	-		-	-	-

(1) Alaoa Hydropower Scheme

Alaoa hydropower scheme is located on the Vaisigano river basin and upstream of both hydropower stations Samasoni and Fale-ole-Fee. The Alaoa was commissioned in 1959 and is the oldest operational hydropower station in Samoa. The station contains a horizontal shaft Turgo impulse turbine combined with a synchronous generator at 1,000 kW rated.

The generated power at the power station is transmitted from the station to Fale-ole-Fee station through a 22 kV overhead line. A bar screen intake is provided on the tailrace of the station for city water supply. The operation range of water level in the head pond is about 3 m.

(2) Fale-ole-Fee Hydropower Scheme

Fale-ole-Fee hydropower scheme is located on the Vaisigano River basin and downstream of Alaoa hydropower station. The Fale-ole-Fee was commissioned in 1981 and contains a horizontal shaft single Pelton turbine combined with a synchronous generator at 1,600 kW rated. The head pond for the station is having capacity 5,600 m^3/s of water and is capable for running of the plant at full load for two hours without any inflow into the pond. The operation range of water level in the head pond is about 4 m.

The generated power at the station is transmitted from the station to Tanugamanono Diesel power station through a 22 kV overhead line with 2.6 km line length.

(3) Samasoni Hydropower Scheme

Samasoni hydropower scheme is located on the Vaisigano River basin and downstream of Fale-ole-Fee hydropower station. The Samasoni was commissioned in 1982 and contains two Turgo impulse turbines combined with synchronous generator at 900 kW rated each. The head pond for the station is having regulating capacity 10,000 m^3 and is capable for running of the plant at full load for one hour without any inflow into the pond. The operation range of water level in the head pond is about 4.4 m.

The generated power at the station is transmitted from the station to Tanugamanono diesel power station through a 6.6 kV overhead line with about 2.6 km line length.

The water for the cooling system of Tanugamanono diesel power station is supplied from this station by mean of tapped off from the penstock.

(4) Lalomauga Hydropower Scheme

Lalomauga hydropower scheme is located on the Falefa River basin and is having the largest capacity among the power plants of run-of –river type. The station was commissioned in 1984 and contains two horizontal shaft Francis turbines combined with synchronous generator at 1,760 kW rated each. The head pond for the station is having capacity 23,000 m^3 and is capable for running of the plant at full load for one hour without any inflow into the pond. The operation range of water level in the head pond is about 5.0 m.

Lalomauga hydropower station is interconnected with Taelefaga hydropower station through a 22 kV overhead line. The generated power at this station and power received from Taelefaga station is stepped up to 33 kV by a autotransformer 22/33 kV, 6 MVA and is transmitted to Tanugamanono diesel power station through a 33 kV overhead line with 36 km line length.

(5) Taelefaga Hydropower Scheme

The Afulilo/Taelefaga hydropower scheme is the only dam-reservoir type in Samoa and was commissioned in 1993. The Taelefaga hydropower station contains two horizontal shaft Pelton turbine combined with synchronous generator of rated 2,000 kW each. The Afulilo reservoir is having a effective capacity of 10,000,000 m^3.

The generated power at this station is transmitted to Lalomauga power station through a 22 kV overhead line with 5.6 km line length.

The outline of the existing hydropower scheme is summarized in table 4.2.2 below.

Table 4.2.2 Outline of Hydropower Schemes

Power Station	Type of Station	Commissioning Year	Capacity (kW)			Year for Retirement
			No.	Installed	*1 De-rated	
Taelefaga	Dam-Reservoir	1992	1 2	2,000 2,000	2,000 2,000	2042
Lalomauga	Run-of-River	1984	1 2	1,850 1,850	1,700 1,600	2035
Samasoni	Run-of-River	1981	1 2	950 950	640 720	2032
Fale-Ole-Fee	Run-of-River	1985	1	1,600	1,400	2031
Alaoa	Run-of-River	1959	1	1,000	1,000	2009
Total	—		8	12,200	11,060	—

*1 The present available output of the aged machines
*2 A practical machine life of 50 year is adopted

The available total output capacity of hydropower scheme at present is about 11,060 kW, which is being 91 % of the total installed capacity.

4.2.2 OPERATION RECORD OF HYDROPOWER SCHEME

The annual generation and energy share of each hydropower station for the year of 2000-2002 are shown in Table 4.2.3, and a monthly generation record from 1994 to 2002 is shown in ANNEX 4.

Table 4.2.3 Operation Record of Hydropower Scheme

Name of Scheme	2002		2001		2000	
	Generated Energy		Generated Energy		Generated Energy	
	MWh	%	MWh	%	MWh	%
Alaoa	3,395.5	8.0	3,414.4	9.8	4,232.6	10.2
Samasoni	5,960.2	13.8	5,013.3	14.4	6,184.3	14.9
Fale-ole-Fee	2,861.2	6.8	3,312.5	9.5	4,287.1	10.3
Lalomauga	9,886.6	22.9	8,983.7	25.9	9,393.9	22.5
Taelefaga	20,462.3	47.5	14,035.2	40.4	17,556.3	42.1
Total	42,565.7	100.0	34,759.1	100.0	41,654.2	100.0

In the year of 2002, the hydropower schemes produced the power energy of 43.0 GWh in total, and about 48 % out of the total hydro generation was produced by Taelefaga hydropower scheme.

The plant factors (a ratio of annual generated energy against the possible annual generation at the full operation of the plant) of the hydropower schemes in the last 9 years are shown in Table 4.2.4.

Table 4.2.4 Plant Factor in the Last 9 Years

(Unit: %)

Year	Alaoa	Samasoni			Fale-Ole-Fee	Lalomauga			Taelefaga			Hydro Total
		No.1	No.2	Total		No.1	No.2	Total	No.1	No.2	Total	
2002	38.8	21.4	54.2	37.8	24.2	28.2	36.0	32.0	67.3	49.5	58.4	41.3
2001	39.0	30.1	33.5	31.8	23.6	25.1	13.1	19.1	50.6	29.5	40.1	33.3
2000	48.3	31.3	47.1	39.2	30.6	29.5	31.4	30.5	64.4	35.8	50.1	39.9
1999	43.8	31.0	46.1	38.5	30.6	21.9	32.4	27.1	50.4	39.6	45.0	36.7
1998	36.6	31.2	26.7	29.0	25.9	31.7	34.7	33.2	49.2	47.8	48.5	37.0
1997	51.3	48.4	36.9	42.6	34.7	33.2	34.7	34.0	79.5	76.6	78.1	51.6
1996	48.6	46.6	34.2	40.4	33.3	32.6	30.1	31.4	59.0	42.1	50.6	41.0
1995	50.4	46.8	38.5	42.7	35.6	22.3	44.0	33.2	63.6	71.2	67.4	47.6
1994	59.6	46.0	51.6	48.8	27.0	36.6	50.9	43.8	62.1	62.8	62.5	49.9
Average	42.3	37.0	41.0	39.0	29.5	29.0	34.2	31.6	60.7	50.6	55.6	42.1

From this, the plant factor of hydropower schemes of run-of-river type, in the average of the last 9 years, are being for 29.0 % of Lalomauga No.1 to 42.3 % of Alaoa and is 55.6 % for Taelefaga hydropower station of dam-reservoir type.

The monthly generation of the hydropower scheme in 2002 is shown in Table 4.2.5.

In 2002, outage of Samasoni No.1 and Taelefaga No.2 is caused by insulation fault of generator stator coil and generator bearing fault, respectively. Samasoni No.1 has commenced its service on January 30, 2003. For Taelefaga No.2 generator is still being. EPC dose not take necessary action for early repairing and the damaged generator is still in the power station.

The monthly generation by the run-of-river type hydropower scheme produced 42,566 MWh in total, 7,820 MWh (35 %) in dry season and 14,284 MWh (65%) in wet season out of the total generation.

Table 4.2.5 Monthly Generation in 2002

Mon.	Alaoa	Samasoni			F.O.F	Lalomauga			Taelefaga			Total (MWh)
		No.1	No.2	Total		No.1	No.2	Total	No.1	No.2	Total	
Jan.	324	453	442	895	380	554	541	1,095	742	634	1,375	4,069
Feb.	351	301	357	658	306	396	259	655	678	590	1,268	3,238
Mar.	366	342	390	732	325	75	234	309	933	889	1,822	3,555
Apr.	300	327	313	640	252	261	263	523	907	869	1,776	3,491
May	327	262	376	638	183	635	597	1,232	819	786	1,605	3,985
Jun.	250	0	380	380	177	165	358	523	807	777	1,585	2,915
Jul.	258	0	379	379	202	447	525	972	1,084	1,071	2,155	3,966
Aug.	257	0	346	346	206	336	637	973	1,195	1,259	2,453	4,235
Sep.	207	0	255	255	168	372	331	703	1,151	1,198	2,349	3,682
Oct.	264	0	373	373	240	576	747	1,323	1,123	598	1,721	3,921
Nov.	196	0	220	220	145	143	356	499	1,222	0	1,222	2,282
Dec.	295	0	445	445	276	381	698	1,079	1,132	0	1,132	3,228
Total	3,396	1,685	4,275	5,960	2,861	4,341	5,546	9,887	11,793	8,670	20,462	42,566

4.3 PRESENT SITUATION OF POWER STATIONS

Effective water depth of the head pond for the generation purpose is a 3 m for Alaoa scheme and 5 m for Lalomauga scheme. The monitoring of the water level of head pond is a most essential matter for safety and continuously operation of the generating plants. However, due to damages of monitoring and telecom facilities for all run-of-river type power plants, the water level is observed by maintenance staff of the head pond and informed to power station in one hour interval.

Cooling water for the Tanugamanono diesel plant is supplied from the penstock line for Samasoni power station. Therefore, water level down of the head pond of Alaoa means not only outage of Alaoa power station, but also outage of Tanugamanono diesel power plant and will much effected to the power supply in Upolu.

4.3.1 ALAOA HYDROPOWER STATION

Since 1959, this station has been operated over for 43 years, it is reflected in the general appearance of the station. The power station has a single Turgo impulse turbine which is having fairly high efficiency in the partial load operation and less extent wear of the turbine runner caused by earth and sand contained in the flow water compared with other turbine type. The governor is an old mechanical/oil hydraulic type by belt driven from the main shaft of the turbine.

The main transformer for step up the generating voltage was replaced in 1981 as well as the generator was served for rewinding of the stator coil in several times and the exciter of generator was replaced in 1990s.

The station has been operated quite stable at present. To ensure such stable operation in longer time, the plants including turbine-generator and control and protection facilities are recommended to be overhaul as soon as possible.

The major maintenance history of the station is summarized below:

Year		Major maintenance history
1981	:	Main transformer was replaced
1990's	:	Generator coil was repaired with rewinding in several times
1990's	:	Generator exciter was replaced

The followings are observed at the station:

(i) Defect of the monitoring system for water level of the head pond

(ii) Oozing out of oil from the top cover of governor

(iii) Leakage of water from the needle servo motor

(iv) Gathered rust on the penstock

(v) Gathered rust on the main transformer tank

4.3.2 SAMASONI HYDROPOWER STATION

Since 1981, this station has been operated over for 22 years, and the available plant output is to be 72 % of rated output.

In 1993, the penstock (steel pipe of 1,250 mm in diameter) of the station was damaged in 24 m long of the pipe by a fallen giant tree during cyclone. The damaged section of the line has been repaired with different two size of pipes 1,200 mm in diameter, 12 m in length and 1,165 mm x 12.m. This repairer causes increase of head losses, but negligibly small in comparison with the length of penstock line of 3,600 m.

In 1996, No.1 generator was repaired with rewinding of the stator coil due to insulation failure, and caused the similar circumstances on No.2 generator in 2002. At present, AVR of the No.2 generator is not operated properly to establishment the exciting voltage and is operated by manual. There are many defect instruments for measuring pressure, speed and temperature, etc.

The generator circuits at 6.6 kV are connected directly to the Apia power distribution system without transformer. This electrical arrangement will cause the damage of the generator and facilities on their circuit by the inversion force of the switching surge and/or the lighting surge from the distribution system. To protect the plant from the surge voltage, tie-transformer (6.6/6.6 kV) or step up transformer (6.6/22 kV) and surge absorber (capacitor and arrester) should be installed as normal practice.

The major maintenance history at the station is summarized below:

Year		Major maintenance history
1993	:	Damaged part of penstock pipe was repaired with smaller size in diameter
1996	:	No1. generator repaired with rewinding of stator coil
2002	:	No.2 generator, same as above

The followings are observed at the station:

(i) Defect of the monitoring system of water level of the head pond

(ii) Defect of the water level meter of the tailrace

(iii) Oozing out of the oil from the oil cooler of oil pressure facility for No.1 unit

(iv) Defect of the pressure meter for lubricating oil system for No.1 unit

(v) Defect of the speed meter of turbine for No.1 and No.2 unit

(vi) Oozing out of oil from the oil pump of oil pressure facility for No.2 unit

(vii) Defect of the oil pressure meter of oil pressure facilities for No.2 unit

(viii) Defect of the position indicator of deflector and spear on the control panel, for No.1 and No.2 units

4.3.3 FALE-OLE-FEE HYDROPOWER STATION

The operation of this station was suspended in May 1990. The main transformer, turbine-generator and their ancillary facilities was severely damaged when shut down devices failed to isolate a 22 kV feeder fault occurred. In 1994, the station has been put into operation with refurbishment of the damaged equipment and facilities.

The major maintenance history at the station is summarized below:

Year		Major maintenance history
1994	:	Main transformer, turbine-generator and their ancillary facilities were refurbished

The followings are observed at the station:

(i) Leakage of water from the water supply pipe for the city water treatment plant

(ii) Defect of the fault indicator on the control panel

(iii) Defect of the monitoring system of water level of the head pond

(iv) Gathered rust on the main transformer tank

4.3.4 LALOMAUGA HYDROPOWER STATION

Since 1984, this station has been operated over for 19 years and operated in quite stable at present.

The main transformer for No.2 generator was replaced in 1995, and No.1 turbine-generator had overhauled with replacement of the turbine runner, upgrading of governor and maintenance of generator in 1995.

The major maintenance history at the station is summarized below:

Year		Major maintenance history
1995		Main transformer for No.2 generator was replaced
1995	:	No.1 turbine-generator was overhauled with replacement of the runner

The followings are observed at the station:

(i) Leakage of oil from the No.2 governor servo motor

(ii) Leakage of oil from No.2 guide vane servo motor

(iii) Defect of the seal of inlet valve

4.3.5 TAELEFAGA HYDROPOWER STATION

The power plant is still new and of modern design and is operated satisfactorily except No.2 generator. The operation of No.2 generator has been stopped since November 2002 due to the trouble of its bearing and caused the similar circumstances several times before. It is urgently necessary to find the cause and to take measure.

4.3.6 CONTROL CENTER

The operation of the Upolu power system is managed by control center located at Tanugamanono diesel power station.

The hydropower stations were designed to be remotely controlled and/or supervised of operation states from the control center, through PLC or UHF radio transmitting system. However, at present, these facilities were not functioned in cause of fault of data transmitting system, power line carrier and radio system, and also some part of system had bee destroyed at the end of 1990s. It is necessary to renovate at least the data monitoring system of operation of the power system in safety and smoothly.

At present, the operation data, water level of the head pond, kWh and KVar, are reported by the operators of power station and head pond at each station every one hour, through UHF telephone system.

4.4 ORGANIZATION OF HYDROPOWER GENERATION SECTION

The organization for the hydropower generation section is presented in Table 4.4.1. Under the Manager Generation, two cores teams, i.e. hydro team is organized maintenance of the hydropower stations and operation team for operation of power station.

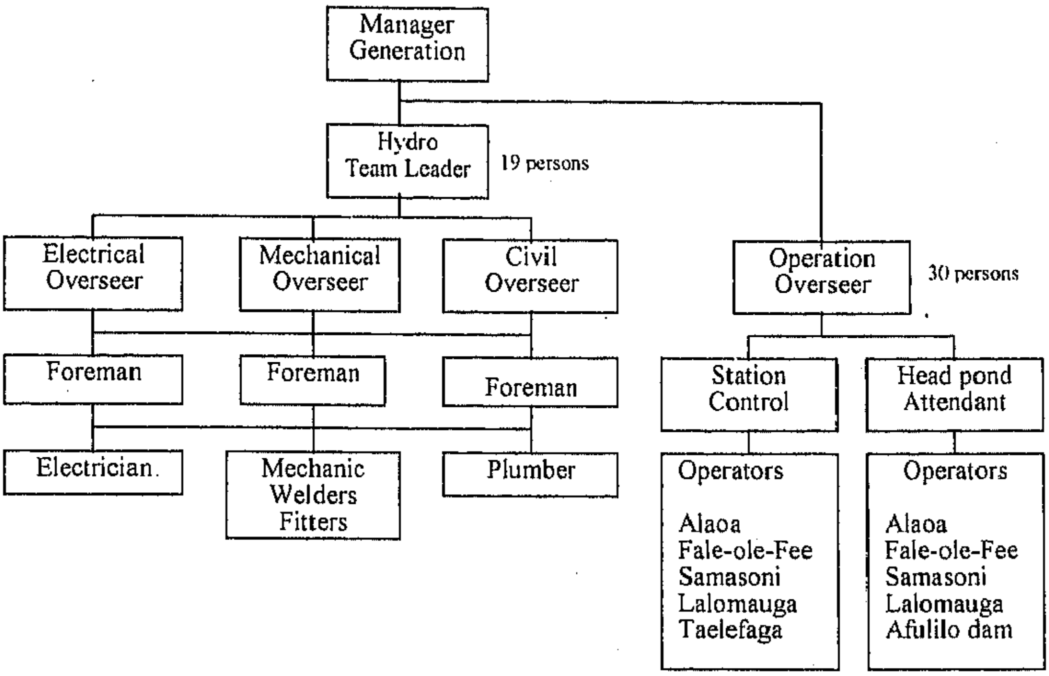


Figure 4.4.1 Organization of the Hydropower Generation Section

4.4.1 OPERATION TEAM

Arrangement of station operators. Lalomauga station is operated by three shift with 2-operators each and other stations by three shift with one operator each. The major operation data are recorded on the operation log sheet by the operator every one hour and simultaneously being reported to the control center. For operation of head pond, an operator is arranged for each station for during the daytime and peak demand hour (am. 19:00 to 20:00)

The operator's room at each power station is in a corner of the power house, which is at the blind side for monitoring the running situation of turbine-generators and control panel. Daily routine inspection by the operator should be carried out in the methodical manner and various mechanical/electrical protection relays and alarm should be maintained to secure their performance.

4.4.2 MAINTENANCE TEAM

The maintenance works of the hydropower plants are performed by the Hydro Team, which is constituted from the staff of electrical, mechanical and civil.

The hydro team conducts only the ordinary maintenance and repair of the plant equipment and facilities including civil structures. Visual inspection of turbine-generators is conducted by the team at each 250 operation hours.

The maintenance regulation into particulars for the daily inspection, periodical inspection and overhaul is not established as yet. Therefore, some turbine-generators, ancillary equipment and control and protection system are not served for periodical inspection and overhaul extend over a long period of time.

4.4.3 MAINTENANCE WORK

As normal practice, the periodical inspection and overhaul of the plant should be carried out with the interval shown in Table 4.4.1.

Table 4.4.1 Maintenance Work

Item	Interval	Purpose
Daily inspection	daily	To determine overall conditions of the equipment at ordinary time
Periodical inspection	6-12 months	Inspection and test for confirming and maintain of the equipment function
Overhaul	5-7 years	For function recovery. Equipment is disassembled and inspected precisely. Damaged or worn parts or other abnormal parts are replaced or repaired and detailed inspection and performance test are conducted

For the operation and safety control of a hydropower station, the basic safety items related to maintenance and operation as well as for safety management shall be predetermined. For this purpose, it is necessary to establish on the basis of these basic items, the rule and the operation, inspection and measurement by which the operation and maintenance must be carried out.

Operation should be carried out in accordance with the operation procedure rule prescribing on the operation sequence at ordinary time and the procedure of taking measures during abnormal state, but the following items must be observed at ordinary time in order to take proper measures quickly and after the occurrence of an accident:

(i) The full knowledge of the power system inside and outside the power station

(ii) The full knowledge of provisions for operation rule

(iii) The full knowledge of the performance and characteristics of equipment

(iv) The full knowledge of control, protection circuits, oil pipe and water pipe systems

(v) The study by using operation and maintenance manuals at ordinary times.

Main precautionary items in daily operation are listed below

- Situation of trash at intake screen
- Temperature conditions at bearing, winding, and elsewhere
- Presence of vibration or abnormal sound at rotating machines
- Volume and temperature situation of lubricating oil and cooling water

- Load conditions such as voltage, current, output and power factor of generator
- Presence of abnormal state at equipment inside and outside the power station and at other structures

In addition to the above, low load operation which causes a low efficiency and adverse effects upon a water turbine should be avoided as much as possible.

4.5 POWER TRANSMISSION AND DISTRIBUTION SYSTEM

The power transmission and distribution system in Samoa, there are four independent power system, namely Upolu, Savaii, Manono (installed capacity, diesel engine generator 84 kW), and Apolima (installed capacity, diesel engine generator 25 kW)

4.5.1 RURAL ELECTRIFICATION PROJECT

In 1993 and 1994, the Rural Electrification Project had been implemented under the Grant Aid scheme of the Government of Japan. The project composed the expansion of the distribution system in the Upolu and Savaii islands. The project composed the construction of distribution lines shown in Table 4.5.1.

Table 4.5.1 Distribution Lines Constructed under the Project

Island	22 kV Line	22 kV/LV Line	LV line
Upolu island	41 km	37 km	30 km
Savaii island	80 km	73 km	40 km
Total	121 km	110 km	70 km

For construction above lines, the following materials and construction equipment were also supplied under the Project.

Table 4.5.2 Materials and Construction Equipment Supplied under the Project

Items	Unit	Upolu	Savaii	Total
Distribution line materials				
22 kV Line	km	41	39	80 km
22 kV + 440/230 V Line	km	37	36	73 km
440/230 V Line	km	30	10	40 km
Distribution transformers				
Single phase, 15 kVA	unit	27	38	25 (975 kVA)
Three phase, 25 kVA	unit	22	1	23 (575 kVA)
Three phase, 350 kVA	unit	10	0	10 (500 kVA)
Air break switches	unit	39	38	77
Drop out switches	unit	128	78	206
Lightning arresters	unit	254		254
WH Meters				
Single phase	unit	950		950
Three phase	unit	50		50

Items	Unit	Upolu	Savaii	Total
Construction equipment				
Working truck with excavator	unit	1	1	2
Working truck with crane	unit	3		3
Truck with hoist	unit	3		3
Rock drill	unit	3		3

Upon the completion of the Project, whole area on both islands has been placed in the service. The electrification ratio has much been improved from 75 % to 92 % in Upolu and 70 % to 84 % in Savaii.

4.5.2 PRESENT STATE OF POWER SYSTEM

(1) Power System in Upolu

The power transmission and distribution system and the features of distribution lines in Upolu are as shown in Figure 4.5.1 and Table 4.5.3.

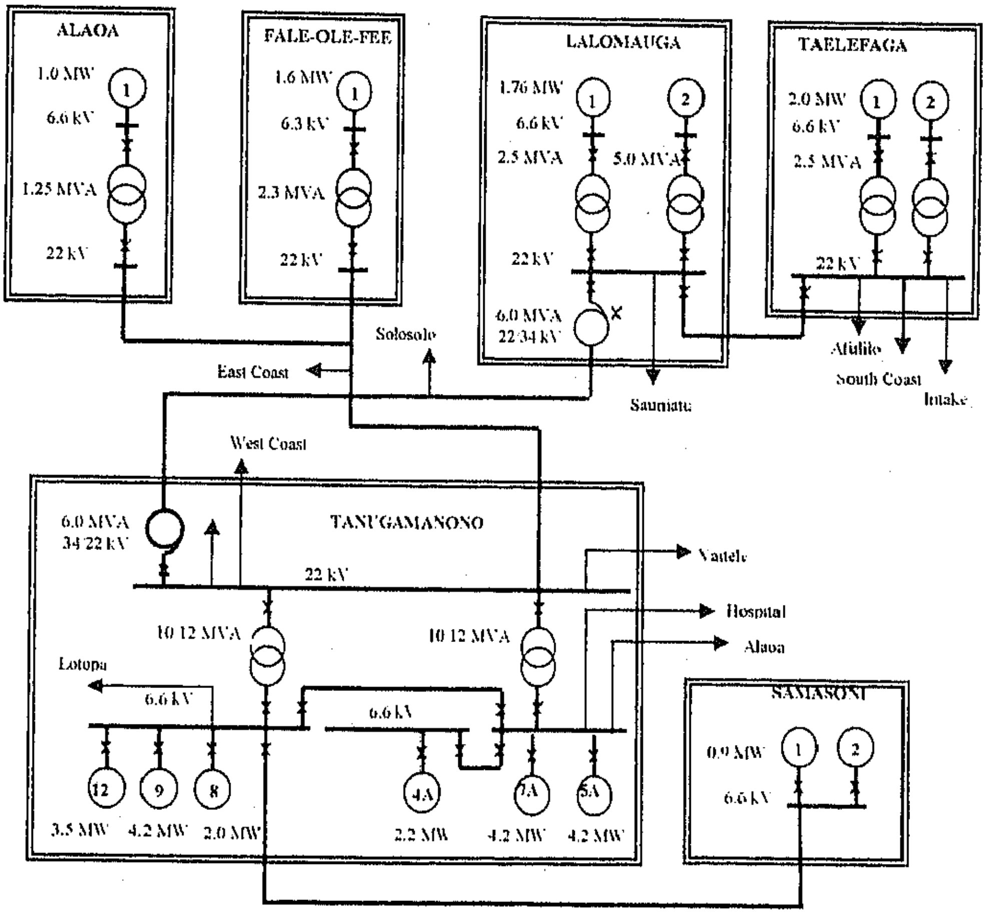


Figure 4.5.1 Power System in Upolu

Table 4.5.3 Features of Distribution Lines in Upolu

Description	Unit	Q'ty
33 kV high-tension line	km	33
22 kV high-tension line	km	287
6.6 kV high-tension line	km	38
440/230 V low-tension line	km	800
Number of distribution transformer	sets	422
Total capacity of distribution transformers	kVA	38,915

The electric power in the Upolu island is supplied from the main distribution center at Tanugamanono Power Station through 33 kV, 22 kV and 6.6 kV high-tension lines with low-tension lines at 430/240 V for consumer's service.

In the Upolu power system, there are two main power generation centers, at near Apia and Eastern part of Upolu. Tanugamanono Diesel power station is located in Apia close to the major load center. Hydropower stations at near Apia, they are Alaoa, Fale-ole-Fee, and Samasoni run-of river hydro schemes on the Vaisigano River.

The second generation center is in the east part of the island where the Lalomauga of another run-of river scheme and Taelefaga of dam-reservoir hydropower schemes are located.

The two generation centers are connected with interconnection line of a single circuit 33 kV. This interconnection line is connected to the 22 kV distribution systems through 6 MVA autotransformer at Tanugamanono and Lalomauga stations.

The autotransformer capacity of 6 MVA is capable of the power transmitting about 4.8 MW at the power factor 0.8, compared to the installed generating capacity 7.52 MW at both stations Lalomauga and Taelefaga. The power transfer will be limited to the maximum power demand required for the north coast and Solosolo feeders.

A large number of distribution transfers are installed on the interconnection lines between the Lalomauga – Tanugamanono power station. and Fale-ole-Fee - Tanugamanono power stations, to supply electricity for the consumers along the lines. It means that the fault of the distribution facilities on the interconnection lines will give an undesirable effect to the power stations directory.

(2) Power System in Savaii

The power transmission and distribution system and the features of distribution lines in Savaii are shown in Figure 4.5.2 and Table 4.5.4.

Savaii is served by two diesel power stations of Salelologa and Vaipouli, however, two power stations are presently operated independently as shown in Figure 4.5.2.

The data such as fault record in Savaii power system are not available at present

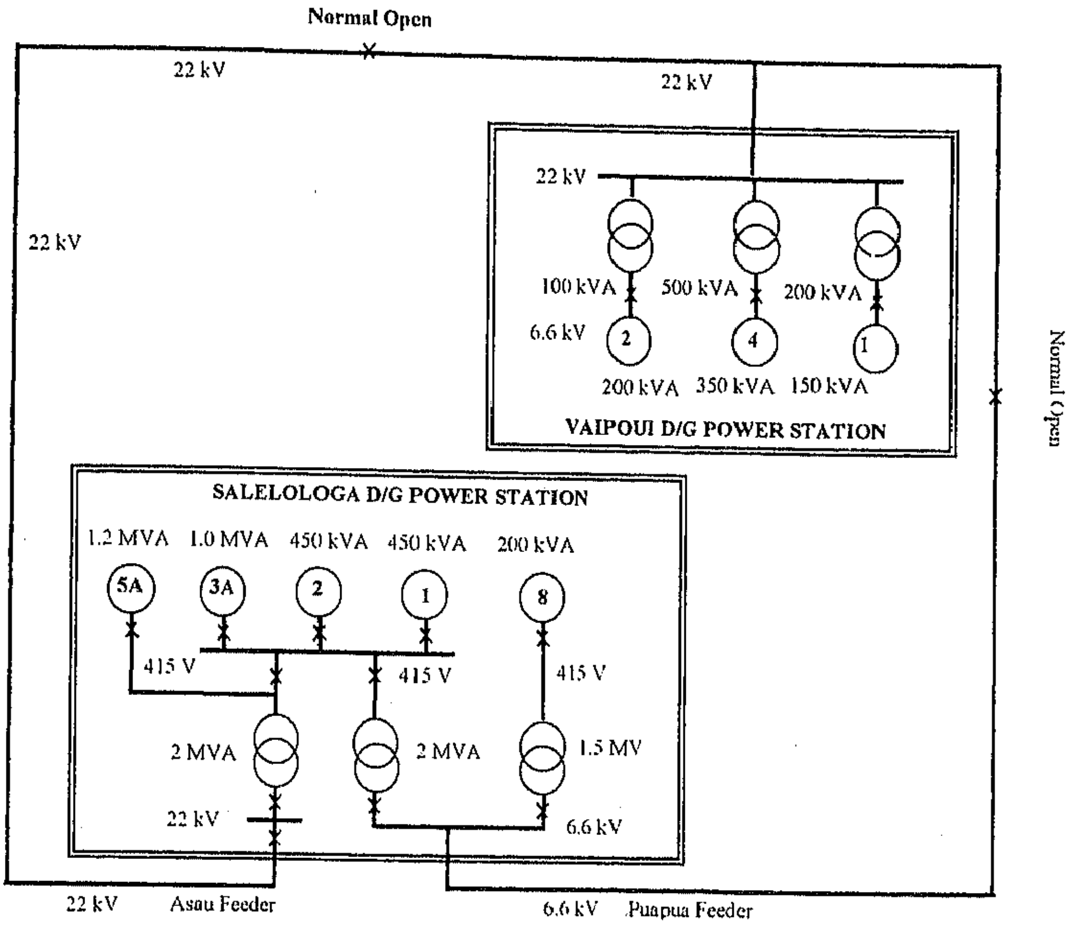


Figure 4.5.2 Power System in Savaii

Table 4.5.4 Features of Distribution Lines in Savaii

Description	Unit	Q'ty
22 kV high-tension line	km	50 in estimated
6.6 kV high-tension line	km	20 in estimated
440/230 V low-tension line	km	n.a
Number of distribution transformer	sets	116
Total capacity of distribution transformers	kVA	2,340

4.6 FAULT RECORD ON THE UPOLU POWER SYSTEM

The fault records on the system in the last three years based of monthly report of EPC are shown in Table 4.5.5. The present performance of the Upolu power system is considered to be unreliable with frequent power interruption.

Table 4.6.1 Monthly Fault Record from 2000 to 2002

Year/ Month		Number of power Interruption/Fault	Number of System Black Out and Brown Out	Number of Feeder Interruption
2002	January	8	3	5
	February	13	5	8
	March	7	1	6
	April	5	3	2
	May	4	2	2
	June	14	2	12
	July	7	4	3
	August	3	2	1
	September	5	5	0
	October	8	2	6
	November	4	0	4
	December	9	1	8
Total		87	30	57
2001	January			
	February	8	4	4
	March	12	5	7
	April	3	0	3
	May	10	1	9
	June	8	3	5
	July	1	0	1
	August	15	4	11
	September	5	2	3
	October	7	4	3
	November	7	4	3
	December	12	8	4
Total		88	35	53
2000	January	11	5	6
	February	6	3	3
	March	14	2	12
	April	6	2	4
	May	16	2	14
	June	3	1	2
	July	5	1	4
	August	0	0	0
	September	3	2	1
	October	2	1	1
	November	7	2	5
	December	10	2	8
Total		83	23	60

Table 4.6.2 Annual Fault Record in Upolu

Year	Number of Power Interruptions/Fault	Number of System Black Out and Brown Out	Number of Feeder Interruption
1995	88	14	74
2000	78	20	47
2001	88	35	53
2002	87	30	57

The Monthly Reports are not available for information about the duration time of power interruption. However, another available study data for "Fault Cost Estimate Analysis' on the some cases of interruptions in 2000 prepared by EPC, from this that the average duration for system black and brown out is estimated about 1.8 hour and lost revenue WST 1,743 per hour, and for feeder interruption 1.4 hour and WST 212 per hour, respectively.

It is suspected from the fault record of the monthly report in 2002 that the interruption of 60 % out of total was caused by the feeder fault and 40 % by the generating plants.

To improve the reliability of the power system, the following items should be reviewed and studied:

(i) Coordination between the existing protection system for power stations and distribution lines including grounding system

(ii) Study of the coordination the existing setting values of relays

(iii) Study the introduction of auto re-closer relay

(iv) Study of the construction of distribution switching station

(v) Study of the installation of automatic fault breaker on the line

4.7 CONCLUSION AND RECOMMENDATION

To maintain the safe operation of the plant, to improve the performance of the power system and to avoid the unforeseen accident on the plants, the following countermeasure are recommended:

(i) To renovate the water level monitoring system at each hydropower generating plant

The range of available water level of the head pond for the generation purpose, it is a 3 meter for Alaoa scheme to 5 meter for Lalomauga scheme. The monitoring of the water level of head pond, for operation of the run-of-river type is a most essential matter for safety and continuously operation of the generating plants.

(ii) To install the tie-transformer (6.6/6.6 kV) or step up transformer (6.6/22 kV) and surge absorber (capacitor and arrester) to protect the plant from the surge voltage, for protection plant equipment and facilities from the inversion force of the switching surge and/or the lightning surge at the Samasoni hydropower station

(iii) To improve the reliability of the power system, it needs more consideration on the followings:

- Coordination between the existing protection system for power stations and distribution lines including grounding system
- Coordination the existing setting values of protection relays
- Introduction of auto re-closer relay on feeders
- Construction of distribution switching station
- Installation of automatic fault breaker on the distribution lines

- Isolate the domestic supply from the interconnection lines between the Lalomauga – Tanugamanono and Fale-ole-Fee – Tanugamanono stations.

(iv) To establish the maintenance regulation into particulars for the Daily Inspection, Periodical Inspection and Overhaul works, the works should be executed certainly to maintain the present performance of the plant and to avoid the unforeseen accident on the plants, as scheduled below.

Item	Interval	Purpose
Daily inspection	daily	determine overall conditions of the equipment at ordinary time
Periodical inspection	6-12 months	Inspection and test for confirming and maintain the equipment function
Overhaul	5-7 years	For the function recovery. Equipment is disassembled and inspected precisely. Damaged or worn parts or other abnormal parts are replaced or repaired and detailed inspection and performance test are conducted

(v) To establish the failing and recording system of data on the operation and maintenance by the data base program of computer.

(vi) To renovate at least the remote data monitoring system at the control center to operation of the Upolu power system in safety and smoothly.

(vii) To make an overhaul of the Alaoa generating plant as soon as possible

Chapter - 4 ANNEX Monthly Generation Record from 1994 to 2002

Scheme	Alaoa			Samasoni	Fale-Ole-			Lalomauga			Taelefaga	Hydro
		No.1	No.2	Total	Fee	No.1	No.2	Total	No.1	No.2	Total	Total
Year: 2002												
Jan.	324.19	452.88	441.81	894.69	324.19	553.60	541.40	1,095.00	741.75	633.60	1,375.35	4,013.4
Feb.	350.97	301.28	357.01	658.29	350.97	395.60	259.40	655.00	678.00	589.65	1,267.65	3,282.8
Mar.	366.42	342.23	389.82	732.05	366.42	74.60	234.30	308.90	933.45	888.60	1,822.05	3,595.8
Apr.	300.18	326.70	313.35	640.05	300.18	260.90	262.50	523.40	906.90	868.80	1,775.70	3,539.5
May	327.06	261.84	376.00	637.84	327.06	635.30	596.70	1,232.00	819.30	785.55	1,604.85	4,128.8
Jun.	249.60	0.00	380.23	380.23	249.60	165.30	358.00	523.30	807.45	777.45	1,584.90	2,987.
Jul.	257.59	0.00	378.56	378.56	257.59	447.30	524.80	972.10	1,083.90	1,071.15	2,155.05	4,020.8
Aug.	256.97	0.00	345.76	345.76	256.97	335.80	637.10	972.90	1,194.75	1,258.50	2,453.25	4,285.8
Sep.	207.24	0.00	254.56	254.56	207.24	372.30	331.00	703.30	1,150.65	1,198.35	2,349.00	3,721.3
Oct.	263.63	0.00	372.86	372.86	263.63	575.60	747.30	1,322.90	1,123.05	597.90	1,720.95	3,943.
Nov.	196.34	0.00	219.80	219.80	196.34	143.20	355.80	499.00	1,221.60	0.00	1,221.60	2,333.
Dec.	295.32	0.00	445.47	445.47	295.32	381.30	697.50	1,078.80	1,131.90	0.00	1,131.90	3,246.8
Total	3,395.51	1,684.93	4,275.23	5,960.16	2,861.15	4,340.80	5,545.80	9,886.60	11,792.70	8,669.55	20,462.25	43,100.
Plant Factor (%)	38.76	21.37	54.22	37.79	24.23	28.15	35.97	32.02	67.31	49.48	58.40	41.2
Year: 2001												
Jan.	353.92	137.65	308.37	446.02	353.92	432.70	126.00	558.70	985.50	966.45	1,951.95	3,664.
Feb.	295.12	41.44	355.36	396.80	295.12	102.90	217.20	320.10	709.35	610.20	1,319.55	2,626.
Mar.	359.86	429.83	374.57	804.40	359.86	531.90	574.20	1,106.10	527.70	354.60	882.30	3,512.
Apr.	346.17	366.19	185.37	551.56	365.52	425.90	499.90	925.80	643.05	407.85	1,050.90	3,239.
May	372.87	232.83	419.03	651.86	252.11	443.60	317.00	760.60	572.85	391.65	964.50	3,001.
Jun.	319.35	29.77	364.52	394.29	319.35	293.30	468.90	762.20	689.70	568.20	1,257.90	3,053.
Jul.	254.37	157.97	117.65	275.62	254.37	227.90	404.60	632.50	703.20	576.45	1,279.65	2,696.
Aug.	205.53	143.32	33.02	176.34	205.53	84.80	317.30	402.10	1,088.55	0.00	1,088.55	2,078.
Sep.	138.33	102.22	6.24	108.46	138.33	68.40	360.60	429.00	757.65	185.70	943.35	1,757.
Oct.	219.13	190.46	27.76	218.22	219.13	453.80	495.60	949.40	697.05	472.65	1,169.70	2,775.
Nov.	186.94	121.30	66.47	187.77	186.49	230.10	570.50	800.60	761.55	441.15	1,202.70	2,564.
Dec.	362.81	420.53	381.40	801.93	362.81	578.90	757.70	1,336.60	728.25	195.90	924.15	3,788.
Total	3,414.40	2,373.51	2,639.76	5,013.27	3,312.54	3,874.20	5,109.50	8,983.70	8,864.40	5,170.80	14,035.20	34,759.
Plant Factor (%)	38.98	30.11	33.48	31.79	23.63	25.13	13.14	19.13	50.60	29.51	40.05	33.2
Year: 2000												
Jan.	445.83	301.13	446.63	747.76	512.52	408.80	538.60	947.40	1,029.15	0.00	1,029.15	3,682.
Feb.	487.66	416.85	397.43	814.28	609.57	400.00	561.30	961.30	1,075.65	42.60	1,118.25	3,991.
Mar.	575.12	520.20	499.05	1,019.25	753.47	303.60	648.70	952.30	1,181.40	0.00	1,181.40	4,481.
Apr.	473.88	249.78	426.30	676.08	444.76	231.10	138.90	370.00	1,170.30	0.00	1,170.30	3,135.
May	418.27	173.49	391.40	564.89	275.87	437.10	496.90	934.00	1,112.55	485.25	1,597.80	3,790.
Jun.	304.09	235.74	183.12	418.86	228.33	565.10	127.60	692.70	1,135.50	1,086.60	2,222.10	3,866.
Jul.	219.89	75.15	344.87	420.02	234.72	521.00	215.20	736.20	1,122.00	1,073.55	2,195.55	3,806.
Aug.	213.88	123.64	137.33	260.97	136.40	132.00	142.40	274.40	1,101.00	1,073.70	2,174.70	3,060.
Sep.	153.96	86.34	101.52	187.86	97.42	45.50	255.30	300.80	798.60	839.70	1,638.30	2,378.
Oct.	229.10	32.28	267.41	299.69	260.18	464.90	583.40	1,048.30	104.85	276.60	381.45	2,218.
Nov.	324.55	108.33	370.41	478.74	347.56	604.50	593.90	1,198.40	426.60	524.40	951.00	3,300.
Dec.	386.34	146.18	149.76	295.94	386.34	433.80	544.30	978.10	1,018.95	877.35	1,896.30	3,943.
Total	4,232.57	2,469.11	3,715.23	6,184.34	4,287.14	4,547.40	4,846.50	9,393.90	11,276.55	6,279.75	17,556.30	41,654.
Plant Factor (%)	48.32	31.32	47.12	39.22	30.59	29.49	31.43	30.46	64.36	35.84	50.10	39.8
Year: 1999												
Jan.	537.13	421.49	479.14	900.63	698.19	672.30	752.40	1,424.70	371.85	478.20	850.05	4,410.
Feb.	492.77	428.79	438.21	867.00	652.79	643.00	688.60	1,331.60	582.60	709.50	1,292.10	4,636.
Mar.	551.40	408.65	416.49	825.14	505.93	193.80	503.10	696.90	950.10	1,009.05	1,959.15	4,538.
Apr.	362.98	137.66	364.36	502.02	265.55	71.00	446.90	517.90	914.85	834.90	1,749.75	3,398.
May	334.32	278.87	296.33	575.20	399.90	299.20	514.70	813.90	687.30	656.10	1,343.40	3,466.
Jun.	383.79	182.43	474.63	657.06	451.52	253.30	412.00	665.30	1,185.30	575.55	1,760.85	3,918.
Jul.	255.33	204.10	83.45	287.56	116.02	25.30	72.80	98.1-	1,252.05	1,207.80	2,459.85	3,216.
Aug.	176.98	182.64	3.26	185.90	47.36	0.00	60.30	80.30	1,008.90	961.95	1,970.85	2,441.
Sep.	238.75	163.71	178.05	341.76	278.59	437.60	516.50	954.10	932.40	880.50	1,812.90	3,626.
Oct.	315.90	146.26	337.86	484.12	451.81	495.80	627.90	1,123.70	1,017.15	972.60	1,989.75	4,365.
Nov.	308.86	155.32	342.78	498.10	329.40	244.00	297.90	541.90	1,048.20	823.35	1,871.55	3,549.
Dec.	314.03	116.67	306.29	422.96	249.35	62.30	228.70	291.00	1,138.65	0.00	1,138.65	2,415.
Total	4,272.24	2,826.59	3,720.66	6,547.45	4,464.40	3,397.60	5,121.80	8,519.40	11,089.35	9,109.50	20,198.85	43,984.
Plant Factor (%)	43.83	30.95	46.10	38.52	30.56	21.87	32.36	27.12	50.39	39.61	45.00	36.7
Year: 1998												
Jan.	395.41	317.33	410.38	727.71	601.58	586.90	577.20	1,164.10	970.80	924.15	1,894.95	4,783.
Feb.	389.77	316.65	346.58	663.23	521.95	680.30	595.20	1,275.50	905.40	912.90	1,818.30	4,668.
Mar.	437.35	374.94	315.53	690.47	471.07	604.70	373.70	978.40	1,072.35	957.60	2,029.95	4,607.2
Apr.	326.80	337.66	58.10	395.76	223.31	254.20	266.10	520.30	912.60	887.25	1,799.85	3,266.0
May	236.91	124.81	128.03	252.84	95.44	163.00	199.00	362.00	688.80	619.50	1,308.30	2,255.4
Jun.	243.31	218.01	42.12	260.13	194.94	519.40	548.10	1,067.50	549.15	526.65	1,075.80	2,841.6
Jul.	170.97	83.85	68.99	152.84	97.45	122.50	244.70	367.20	703.05	825.15	1,528.20	2,316.6

Scheme	Alaoa	Samasoni			Fale-Ole-Fee	Lalomauga			Taelefaga			Hydro
		No.1	No.2	Total		No.1	No.2	Total	No.1	No.2	Total	Total
Aug.	170.67	97.49	65.56	163.05	151.64	294.90	464.10	759.00	528.75	523.05	1,051.80	2,296.16
Sep.	148.82	82.89	40.17	123.06	116.27	494.90	540.90	1,035.80	378.45	325.80	704.25	2,128.20
Oct.	127.32	71.42	59.12	130.54	129.45	262.00	288.70	550.70	747.60	692.10	1,439.70	2,377.71
Nov.	247.56	121.00	228.44	349.44	425.22	418.20	624.80	1,043.00	798.90	847.80	1,646.70	3,711.92
Dec.	309.17	315.83	341.01	656.84	602.16	490.30	622.70	1,113.00	364.50	336.90	701.40	3,382.57
Total	3,204.06	2,461.88	2,104.03	4,565.91	3,630.48	4,891.30	5,345.20	10,236.50	8,620.35	8,378.85	16,999.20	38,636.15
Plant Factor (%)	36.58	31.23	26.69	28.96	25.90	31.73	34.67	33.20	49.20	47.82	48.51	37.00
Year: 1997												
Jan.	501.85	489.59	446.19	935.78	501.09	666.10	631.30	1,297.40	1,051.35	987.30	2,038.65	5,274.77
Feb.	460.66	416.97	437.14	854.11	654.27	429.50	381.40	810.90	1,060.65	1,051.35	2,112.00	4,891.94
Mar.	567.41	475.46	541.58	1,017.04	887.15	577.30	567.30	1,144.60	1,052.55	1,006.05	2,058.60	5,674.80
Apr.	488.41	398.54	385.63	784.17	447.21	199.80	84.60	284.40	1,255.95	1,211.55	2,467.50	4,471.69
May	486.85	450.88	277.45	728.33	475.45	372.30	382.00	754.30	1,045.50	1,009.80	2,055.30	4,500.23
Jun.	366.01	296.84	152.82	449.66	324.02	332.00	312.40	644.40	999.00	960.00	1,959.00	3,743.09
Jul.	281.59	271.19	61.34	332.53	160.38	207.30	316.30	523.60	1,132.05	1,075.80	2,207.85	3,505.95
Aug.	279.78	215.39	126.75	342.14	261.71	634.90	601.70	1,236.60	1,283.40	1,244.70	2,528.10	4,648.33
Sep.	244.18	282.48	19.95	302.43	232.62	402.80	538.90	941.70	1,286.10	1,255.95	2,542.05	4,262.98
Oct.	235.29	172.23	118.89	291.12	217.43	318.20	505.50	823.70	1,315.05	1,247.85	2,562.90	4,130.44
Nov.	234.19	145.79	133.16	278.95	260.93	440.10	451.70	891.80	1,225.80	1,185.90	2,411.70	4,077.57
Dec.	346.51	199.54	203.51	403.05	441.77	542.00	582.40	1,124.40	1,222.20	1,191.30	2,413.50	4,729.23
Total	4,492.73	3,814.90	2,904.41	6,719.31	4,864.03	5,122.30	5,355.50	10,477.80	13,929.60	13,427.55	27,357.15	53,911.02
Plant Factor (%)	51.29	48.39	36.84	42.61	34.70	33.22	34.74	33.98	79.51	76.64	78.07	51.63
Year: 1996												
Jan.	510.60	467.58	450.55	918.13	750.38	656.60	520.10	1,176.70	614.70	197.85	812.55	4,168.36
Feb.	515.27	411.76	418.10	829.86	620.74	424.50	436.20	860.70	577.65	79.65	657.30	3,483.87
Mar.	558.79	514.87	509.58	1,024.45	898.25	675.00	465.40	1,140.40	972.90	55.05	1,027.95	4,649.84
Apr.	442.98	303.73	288.82	592.55	346.68	669.10	249.20	918.30	1,226.25	372.75	1,599.00	3,899.51
May	423.37	239.64	352.79	592.43	331.27	546.80	622.10	1,168.90	1,181.10	1,068.00	2,249.10	4,765.07
Jun.	290.31	277.21	65.19	342.40	156.52	178.50	452.50	631.00	1,274.85	1,246.80	2,521.65	3,941.88
Jul.	203.55	214.28	5.21	219.49	83.92	24.20	113.90	138.10	1,278.45	1,200.60	2,479.05	3,124.11
Aug.	154.47	141.60	11.79	153.39	60.10	114.20	131.50	245.70	670.35	664.95	1,335.30	1,948.96
Sep.	176.06	152.13	48.22	200.35	134.05	282.70	258.90	541.60	540.60	507.60	1,048.20	2,100.26
Oct.	299.09	300.64	109.93	410.57	357.16	543.40	480.40	1,023.80	407.55	391.50	799.05	2,889.67
Nov.	215.41	215.48	68.80	284.28	232.26	230.40	231.50	461.90	790.20	721.80	1,512.00	2,705.85
Dec.	470.16	432.00	364.02	796.02	694.35	678.10	683.60	1,361.70	914.85	861.00	1,775.85	5,098.08
Total	4,260.06	3,670.92	2,693.00	6,363.92	4,665.68	5,023.50	4,645.30	9,668.80	10,449.45	7,367.55	17.817.00	42,775.46
Plant Factor (%)	48.63	46.56	34.16	40.36	33.29	32.58	30.13	31.36	59.64	42.1	50.85	40.97
Year: 1995												
Jan.	475.66	385.77	414.91	800.68	636.01	693.10	782.90	1,476.00	652.35	804.75	1,457.10	4,845.45
Feb.	459.89	399.60	388.45	788.05	581.37	266.90	804.50	1,071.40	769.05	826.80	1,595.85	4,496.56
Mar.	523.81	444.61	431.02	875.63	669.22	244.60	783.50	1,028.10	930.60	975.30	1,905.90	5,002.66
Apr.	530.52	442.06	411.43	853.49	611.79	180.10	654.20	834.30	884.85	971.10	1,855.95	4,686.05
May	504.80	432.12	428.87	860.99	643.36	284.80	716.90	1,001.70	889.35	1,150.20	2,039.55	5,050.40
Jun.	407.26	185.74	364.71	550.45	353.39	17.00	594.00	611.00	1,227.30	1,152.75	2,380.05	4,302.15
Jul.	329.91	306.07	113.58	419.65	248.85	0.00	544.80	544.80	1,402.50	1,388.85	2,791.35	4,334.56
Aug.	276.56	271.54	106.78	378.32	277.72	0.00	765.30	765.30	1,305.90	1,382.10	2,688.00	4,385.90
Sep.	263.11	330.64	21.50	352.14	353.84	182.40	670.70	853.10	1,226.55	1,303.35	2,529.90	4,352.09
Oct.	172.18	192.94	9.52	202.46	138.11	577.80	53.20	631.00	1,115.25	1,277.55	2,392.80	3,536.55
Nov.	252.91	218.49	89.14	307.63	250.42	489.70	337.40	827.10	335.25	634.80	970.05	2,608.11
Dec.	215.72	79.25	257.05	336.30	228.38	504.70	82.10	586.80	399.30	598.80	998.10	2,365.30
Total	4,412.33	3,688.83	3,036.96	6,725.79	4,992.47	3,441.10	6,789.50	10,230.60	11,138.25	12,466.35	23,604.60	49,965.79
Plant Factor (%)	50.37	46.79	38.52	42.65	35.62	22.32	44.04	33.18	63.57	71.16	67.36	47.85
Year: 1994												
Jan.	411.47	82.85	527.37	610.22	0.00	355.90	791.10	1,147.00	1,061.55	1,072.35	2,133.90	4,302.59
Feb.	410.36	300.06	350.36	650.42	0.00	458.10	133.90	592.00	1,095.00	1,114.80	2,209.80	3,862.58
Mar.	550.07	307.55	493.92	801.47	0.00	599.80	425.40	1,025.20	1,020.90	1,044.60	2,065.50	4,442.24
Apr.	588.95	431.53	476.40	907.93	62.42	464.60	678.90	1,143.50	662.10	783.45	1,445.55	4,148.35
May	563.22	424.22	443.25	867.47	601.40	584.70	813.20	1,397.90	752.55	485.85	1,238.40	4,668.39
Jun.	459.20	325.00	304.60	629.60	503.10	491.10	671.70	1,162.80	811.35	822.45	1,633.80	4,388.50
Jul.	390.14	289.60	228.75	518.35	376.99	295.60	726.40	1,022.00	1,085.20	1,070.85	2,156.05	4,463.53
Aug.	369.55	300.44	240.39	540.83	518.38	517.66	715.20	1,232.86	898.95	874.50	1,773.45	4,435.07
Sep.	314.10	219.75	165.29	385.04	305.51	227.40	627.30	854.70	1,069.35	1,109.70	2,179.05	4,038.40
Oct.	371.96	404.49	97.18	501.67	403.86	481.40	793.30	1,274.70	802.20	868.65	1,670.85	4,223.04
Nov.	371.70	230.16	292.92	523.08	425.50	494.10	673.10	1,167.20	930.60	984.00	1,914.60	4,402.08
Dec.	416.87	311.65	444.02	755.67	590.49	677.30	793.20	1,470.50	692.40	773.50	1,465.90	4,699.43
Total	5,217.59	3,627.30	4,064.45	7,691.75	3,787.64	5,647.66	7,842.70	13,490.36	10,882.15	11,004.70	21,886.85	52,074.19
Plant Factor (%)	59.56	46.01	51.55	48.78	27.02	36.63	50.87	43.75	62.11	62.81	62.46	49.87

5. HYDROPOWER DEVELOPMENT PLAN

5.1 RECOMMENDATION OF HYDROPOWER DEVELOPMENT

Since 1959, a hydropower generation has been supplying the electric power to Apia in the Upolu island, Samoa. After completion of a power national grid around the Upolu, all generated power from hydropower plants are available anywhere as well as all power from diesel power plants.

Under the current worldwide circumstance between the electric power and the environment, a power generation system by sustainable natural resources moves into popular even their adverse economy. Among several renewable energy sources; such as a small hydropower, a wind power, a solar power, a geothermal power and a biomass power, a small hydropower is the most viable energy in Samoa obviously owing to the annual precipitation more than 5,000mm at the highest area and rapid river flows with steep slope about 1:10.

The following Table 5.1.1 summarizes its main advantages and disadvantages of hydropower projects briefly. The table is quoted from the issues of International Hydropower Association (IHA) to be shown at the World Water Forum in Osaka/Kyoto, Japan in March 16-23, 2003.

Table 5.1.1 Advantages and Disadvantages of Hydropower Projects

ADVANTAGES	DISADVANTAGES
Economic Aspects	
• Low operating and maintenance costs • Long life span (50 to 100 years and more) • Flexible to meet load (for hydro with reservoir) • Reliable Service • Proven technology • Instigates and fosters regional development • Highest energy efficiency rate (pay-back ration and conversion process) • Generates revenues to sustain other water uses • Creates employment opportunities • Fuel Saver • Provides energy independence by exploiting national resources • Optimizes power supply of other generating options (thermal and intermittent renewables)	• High upfront investment • Precipitation dependent
Social Aspects	
• Leaves water available for other uses • Provides flood protection - in many cases • Enhances navigation conditions -in some cases	• In many cases -inundation of land requiring involuntary displacement • In many cases -river passage restrictions

ADVANTAGES	DISADVANTAGES
• Enhances recreational facilities -in many cases • Enhances accessibility of the territory and its resources (access roads and ramps, bridges) • Built and operated with a high percentage of local manpower • Improves living conditions • Sustains livelihoods (freshwater, food supply)	• Modification of land use patterns • In some cases -may facilitate propagation of waterborne disease vectors • Requires management of competing water usages • Affects livelihoods of impacted people
Environmental Aspects	
• No atmospheric pollutants and only very few GHG emissions • No waste • No depletion of non renewable resources (i.e. coal, gas, oil) • Creates in many cases new freshwater ecosystems with increased productivity • Study results enhance knowledge and improve management of valued species • Helps to slow down climate changes • Enhances air quality	• In many cases -inundation of habitats, loss or modification of biodiversity • In many cases -loss or modification of fish habitat • In some cases -changes in reservoir and stream water quality • In some cases -temporary introduction of methyl-mercury into the food chain • In many cases -modification of hydrological regimes • Barriers for fish migration, fish entrainment • In some cases -reservoir sedimentation requires control measures

In Samoa, a small hydropower scheme has advantages in economic, social and environmental aspects as shown in the above table. A hydropower can save consumption of diesel oil supplied from Singapore through Mobil Oil, which prices are depend on the strategic world market. A run-of-river type of hydropower can keep adverse affects on social and natural environmental aspects at the minimum. And, introduction of a hydropower to Samoa instead of diesel power will have a potential of application for CDM (Clean Development Mechanism), which was adopted at the Kyoto conference as Kyoto Mechanisms in December 1997.

Under CDM, all nations present, including the developing world, agreed that a portion of the developed world's obligation could be met by reducing equivalent emissions in developing countries as shown in the following example of Figure 5.1.1 for Japan and Samoa:

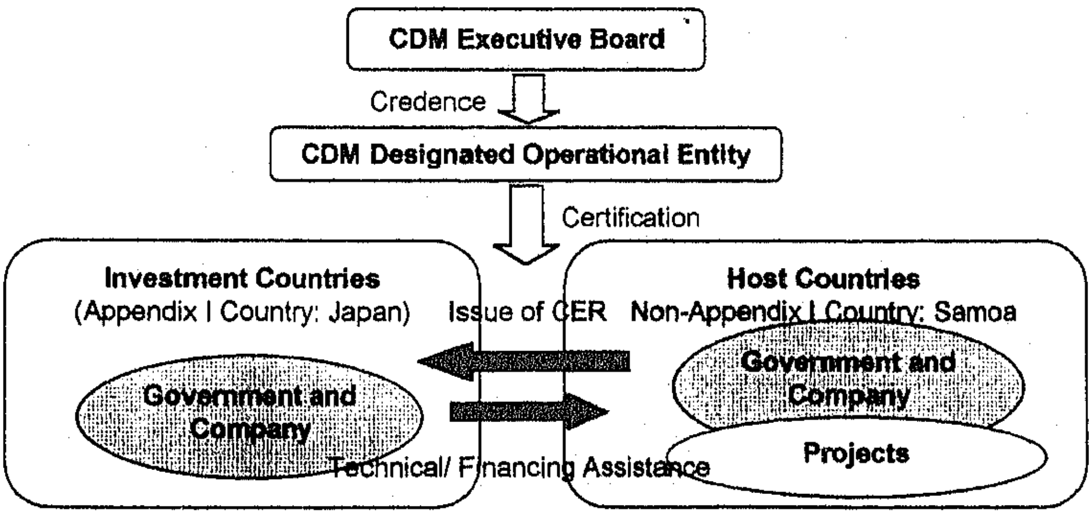


Figure 5.1.1 Flow Chart of CDM Procedure

Hydropower is well suited to CDM as most of the new capacity is expected to be in the developing world using expertise and significant capital investment from the developed world. In the case of hydropower, there are no risks associated with unproven or unfamiliar technologies, and the emission reductions can often be measured in relation to those of diesel engine electricity. The least emissive source of electricity is hydropower, as shown in Figure 5.1.2 below:

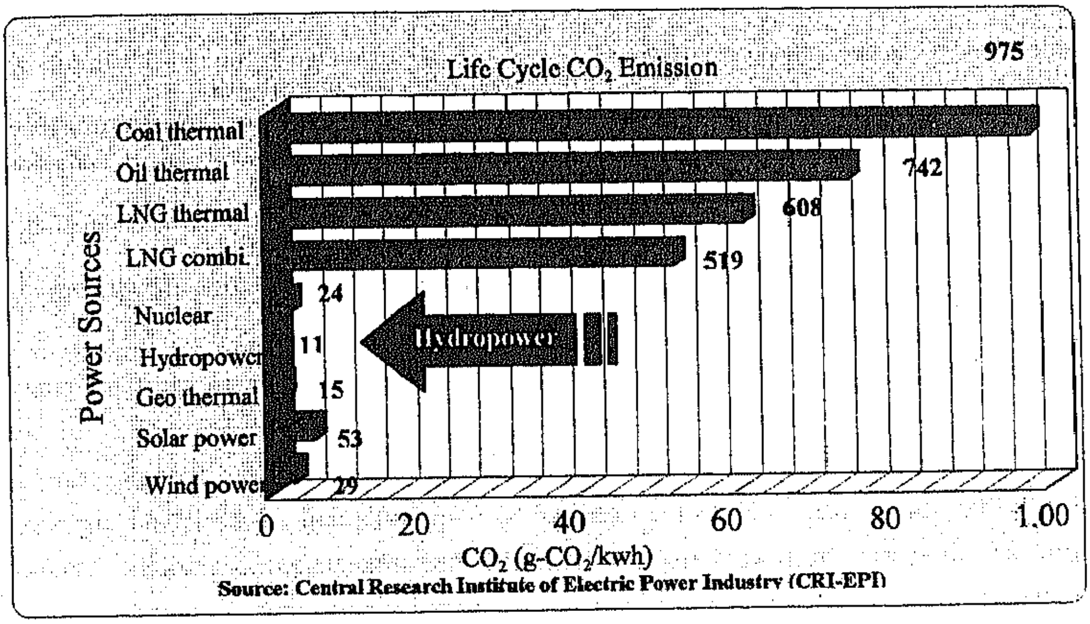


Figure 5.1.2 Life Cycle CO_2 Emission by Power Sources

Our JICA Study Team would recommend to EPC to develop the following hydropower schemes as the results of the Study in Samoa at the period from February 2 to March 14, 2003. In this Study, five (5) river basins had been studied as potential sites for a small hydropower scheme under the JICA's TOR, such as (i) Faleaseela scheme, (ii) Lotofaga scheme, (iii) Tafitoala scheme, (iv) Namo cascade scheme and (v) Sili cascade scheme. The detailed study results are shown in the following chapter:

Table 5.1.2 Recommended Hydropower Schemes in Samoa

No.	Name of Scheme	Location	Install Capacity (kW)	Annual Generation (GWh/Year)	Plant Factor (%)	Catchment Area (km^2)	Maximum Discharge (m^3/s)	Gross Head (m)
1	Faleaseela	Upolu-South	390	1.74	50.9	4.47	0.4	125
2	Lotofaga	Upolu-South	910	4.58	57.4	15.59	2.0	60
3	Tafitoala	Upolu-South	1,450	7.38	58.0	14.41	1.8	100
4	Namo No.1	Upolu-North	860	4.37	58.1	16.49	2.0	60
5	Namo No.2	Upolu-North	550	2.82	58.6	15.08	1.8	42
6	Namo No.3	Upolu-North	880	4.47	57.9	13.38	1.6	71
7	Namo No.4	Upolu-North	500	2.61	59.6	7.49	0.8	80
Sub-total		Upolu	5,540	27.97	-	86.91	-	-
8	Sili No.1(1st)	Savaii-South	1,180	5.97	57.7	9.45	0.9	160
9	Sili No.1(2nd)	Savaii-South	1,800	9.38	59.4	15.32	1.4	168
10	Sili No.2	Savaii-South	1,600	8.29	59.0	12.80	1.2	168
Sub-total		Savaii	4,580	23.64	-	37.57	-	-

5.2 GENERAL CONDITION OF HYDROPOWER PLANNING

5.2.1 PREVIOUS STUDY ON HYDROPOWER SCHEME

Several hydropower schemes had been studied since 1970's. The Study Team confirmed the following study reports as shown in Table 5.2.1. Potential sites for hydropower are referred to the reports No.2 and No.3 below during this JICA Study, which layouts are as shown in Annex 5.1 (1) for Faleaseela and Lotofaga Schemes and Annex 5.1 (2) for Tafitoala and Namo Schemes.

Table 5.2.1 Previous Study Reports related to Hydropower

No.	Title	Firm	Sponsor	Date	Remarks
1	Project formulation study on Renewable Energy	TEPCO	JICA	Mar.2001	-
2	Institutional Strengthening & Power Development of EPC	HECHEC	ADB	Oct.1997	-
3	Study of Sili No.1 Hydropower Project	EPDC	EPC	Nov.1996	-
4	National Water Resources Master Plan Study (Stage I)	RKL	-	Dec.1995	Missing of Main report in EPC.
5	Pre-Feasibility Study of Sili River Hydropower Project	HECHEC	-	Oct.1995	
6	Watershed Management in Western Samoa, Review of Current Programes & Recommendations for future Work with particular reference to the Vaiola & Faleata Watersheds in Savaii	L.K.Rowe	MFAT	May 1994	Study on Hydrology only
7	Sili River Multi-Purpose Project Pre-Feasibility Study Up-Date	Mosely	USAID	May 1991	-
8	Western Samoa Power System Planning Study	GIBB	ADB	Apr.1991	-
9	Feasibility Study for Potential for the development of the Water Supply on the Sili River Basin	Bechtel	-	Oct.1985	Missing of all in EPC.
10	Namo Hydro Electric Scheme, Pre-Feasibility Study	GMM	-	Nov.1982	-
11	Electrical Resistivity Investigations of Hydrological Problems in Western Samoa	G.F.Risk	NZBA	Oct.1979	Study on Hydrology only
12	Hydro-Electric Power Development Master planning & Feasibility Study	MRM	-	1979	Missing of all in EPC.
13	Western Samoa Hydropower Project, Hydrological Survey	K.R.Jones	ADB	Apr.1977	Study on Hydrology only
14	Feasibility Study of Western Samoa Electric Service Development	ELC	-	Apr.1972	-
15	Geology and Hydrology of Western Samoa	NZGS	-	1952	Study on Geology & Hydrology only

5.2.2 GEOGRAPHIC DATA

(1) Geology

The Samoa islands are aligned approximately southeast-northwest along a chain of volcanic vents of which the oldest are in the southeast and the youngest in the northwest as shown in Annex 5.2 (1). The islands are built primarily of basalt rock and debris and the weathered material produced from it, with small areas of coralline sand in some coastal locations.

Because of the water retaining capacity of relatively deeply weathered material of the Fagaloa formations, most of the country's permanent stream and rivers are founded in these area. South and west of the Fagaloa formations of Upolu, and in central Savaii, the most recent basalts of the Salani Volcanics have more gentle slopes, although they are dissected by some steep-sided river gorges.

From the central ridges, these deposits slope relatively gentle down to the north and south coasts and are less weathered than the older formations. Soils are often fewer than 30cm deep and are frequently very stony although relatively fertile. There is little surface water as rainfall quickly seeps through the porous rock.

(2) Geography

A significant part of central Savaii is above EL.1,200m with the highest peak, Mauga Silisili, reaching EL.1,858m. Upolu's central ridge, craters and peaks are lower with the maximum height EL.1,100m.

From a distance the land seems to slope relatively evenly down towards the coasts, but this impression obscures a considerable amount of local relief. The general slope of land is shown in Annex 5.2 (2) with four (4) categories.

(3) Topographic Maps

The following six (6) kinds of topographic maps and aerial photographs are available at Mapping Section, Ministry of Natural Resources and Environment as of March 2003. As the topographic maps published in 2000 are made by digital terrain model, their digital data also are available with EPC's official application to Mapping Section.

As the Study Team had found out the accuracy of 1:50,000 scaled map better than 1:20,000 during the site reconnaissance for hydro potential sites, the preliminary hydropower plans were made on the 1:50,000 scaled map, even 20m counter line in 1:50,000 scaled map is larger than 50ft (15.24m) counter line in 1:20,000 scaled map. However, all previous studies including the study in 2001 were made on the 1:20,000 map.

Table 5.2.2 Available Maps and Aerial Photos

No.	Scale	Map / Aerial Photo	Remarks	Sheet No.	Location	Published Year
1	1:20,000	Topo-map	50 ft (15.24m) contour	No.01-No.16 (16 sheets)	Savaii	1977
2				No.17-No.28 (12 sheets)	Upolu	
3	1:50,000	Topo-map	20 m contour	No.S1-No.S4 (4 sheets)	Savaii	2000
4				No.U1-No.U2 (2 sheets)	Upolu	
5	1:5,000	Aerial-Photograph	along coast only	No.001-No.045 (80 sheets)	Savaii	
6				No.100-No.221 (122 sheets)	Upolu	

The catchement areas of each intake structure for the potential river basin are measured by a digital Planimeter (PLANIX 7, Tamaya). Measurement results are shown in Annex 5.3 (1).

5.2.3 HYDROLOGICAL DATA

(1) Climate in Samoa

Almost all of Samoa has a mean annual rainfall of over 2,500mm and rain fall increase rapidly with elevation to exceed 6,000mm in the highest parts of Savaii as shown in Isohyetal Map of Annex 5.2 (3). In coastal southern Upolu and parts of southern Savaii and at higher elevation, monthly rainfall in both islands has relatively little seasonal variation. However, the coastal parts of northern and western Upolu, and of all Savaii except the south coast, do have a seasonal dry period from May to October.

The annual range of mean temperature at sea level at Apia is very small, with a mean monthly temperature of 25°C in July and 26°C in January to March. Mean maximum temperature also vary by less than 1°C during the year and minimum by only 1.5°C. The daily temperature ranges vary from 5.5°C in January to 6.3°C in July.

(2) Meteorological/Hydrological Data

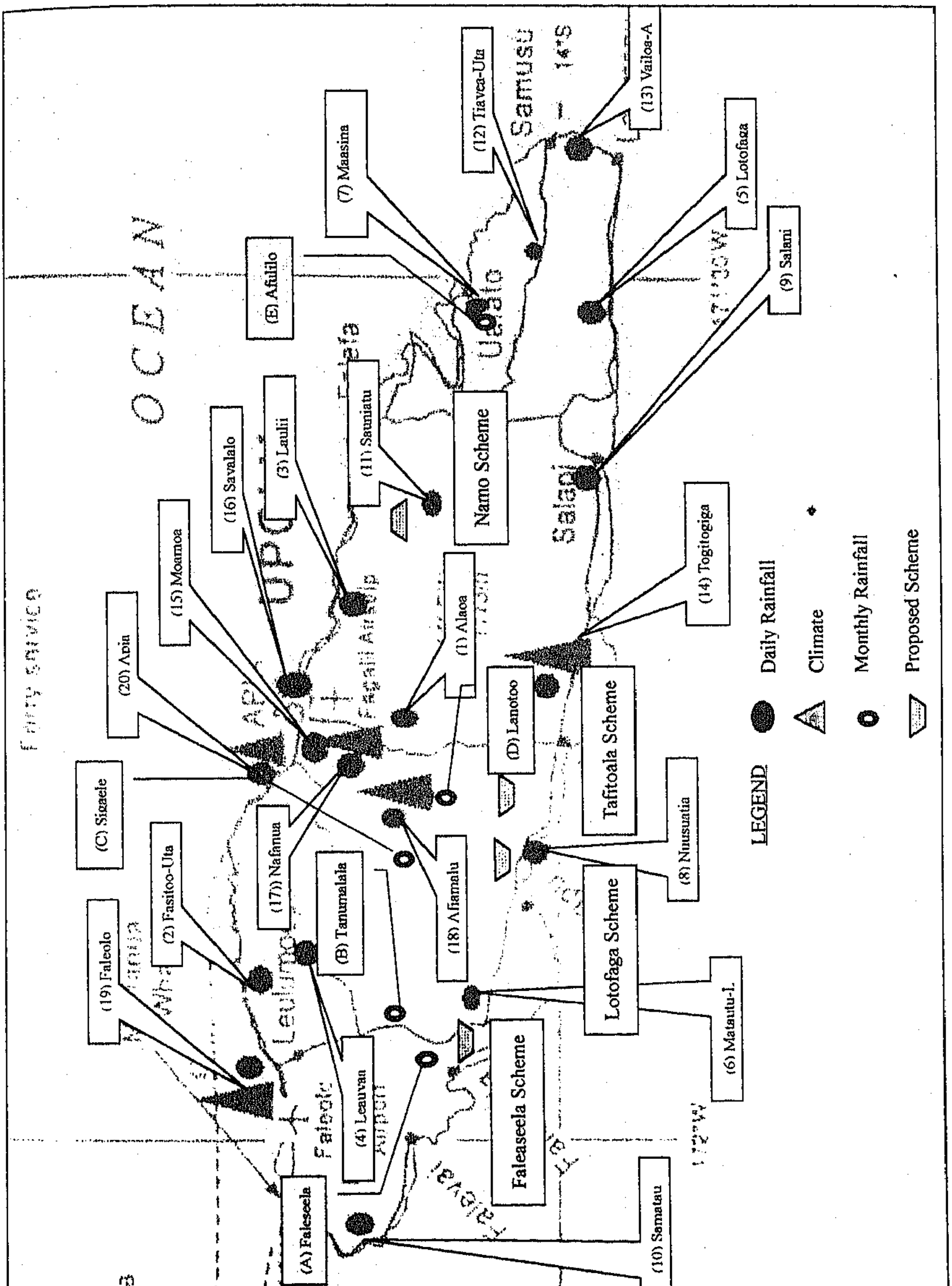
The daily rainfall data at 34 stations in both Upolu and Savaii are obtained at the Climate Unit of Meteorology Division, Ministry of Agriculture, Fishery, Forestry and Meteorology as shown in Figure 5.2.1, Figure 5.2.2 and Table 5.2.3. As all of the data are compiled in the computer, the monthly data also available from the daily basis at expense. Apart from the Climate Unit, the Hydrology Unit is measuring the monthly rainfall at five (5) stations since 1975.

However, the river discharge data are not measured anywhere since the mid/1980 due to political and budgetary reasons. As even the measured discharge are not computerized and measurement intervals and locations are not regular, the Study Team judged that the discharge data would not useful for the Study. During the site reconnaissance, the Hydrology Unit staff measured the river discharge for our reference.

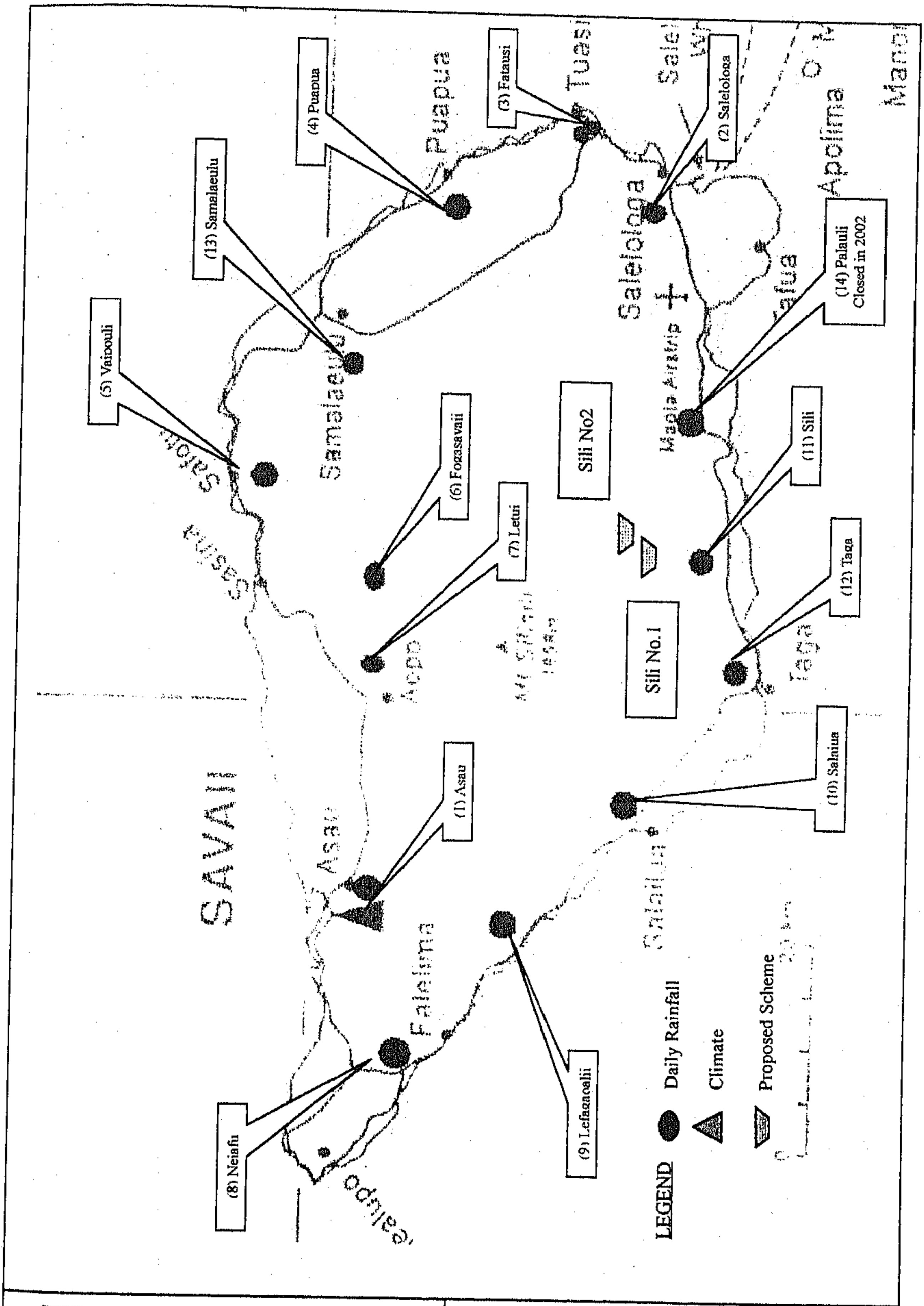
(3) River Discharge Data

Periodical discharge mesurement works had been carried out by the staff of Hydrology Unit of Meteorology Division at major river and stream since Mid/1970s as shown in Annex 5.2 (4), however all works were discontinued at Mid/ 1980s with not only budgetary reasons but also some troubles due to Samoan land tenure.

Some water level gauge stations had been installed under the contract between government and village. But, the water level data had not been collected due to demolition of facilities by villagers. Accordingly, the river discharge data are not used in this Study.



STUDY OF ELECTRIC POWER DEMAND & SUPPLY IN SAMOA	Figure 5.2.1
JAPAN INTERNATIONAL COOPERATION AGENCY	National Climate and Rainfall Network (Upolu)



STUDY OF ELECTRIC POWER DEMAND & SUPPLY IN SAMOA	Figure 5.2.2
JAPAN INTERNATIONAL COOPERATION AGENCY	National Climate and Rainfall Network (Savaii)

Table 5.2.3 National Climate and Rainfall Network

Island	No.	Address	Districts	Date Started	Luck of Data	Remarks	Latitude	Longitude	Elevation	Applicable Scheme
Upolu	1.	Alaoa	Vaimauga West	1957	-	-	13°55' 00" S	171° 45' 00" W	896 m	-
	2.	Fasitoo-Uta	Aana # .1	Jan.3. 1994	-	-	13°48' 41" S	171°56' 22" W	270 m	-
	3.	Laulii	Vaimauga East	May 1. 1970	-	-	13°51' 28" S	171° 42' 11" W	12 m	-
	4.	Leauvaa	Gagaemauga # 1	Mar.1. 1996	-	-	13°50' 00" S	171° 55' 00" W	210 m	-
	5.	Lotofaga	Aleipata	Oct. 1934	-	-	14°02' 25" S	171°33' 27" W	334 m	-
	6.	Matautu- L	Lefaga	Aug.17. 1993	-	-	13°57' 37" S	171°55' 38" W	65 m	Faleseela
	7.	Maasina	Fagaloa	May 6. 1995	-	-	13°55' 00" S	171°35' 00" W	2 m	-
	8.	Nuusuatia	Safata	Feb.2. 1992	-	-	13°59' 02" S	171° 50' 18" W	45 m	Lotofaga, Tafitoala
	9.	Salani	Falealili	Apr.6. 1995	-	-	14°05' 00" S	171°35' 00" W	56 m	-
	10.	Samatau	Falelatai	1992	-	-	13° 54' 13" S	172°03' 04" W	8 m	-
	11.	Sauniatu	Anoamaa East	Apr.6. 1995	-	-	13°55' 00" S	171°37' 00" W	60 m	Namo
	12.	Tiavea-Uta	Aleipata Itu Pa I Lalo	1980	-	-	14°00' 00" S	171° 29' 00" W	270 m	-
	13.	Vailoa- A	Aleipata	Apr.6. 1995	-	-	13°55' 00" S	171°40' 00" W	32 m	-
	14.	Togitogiga.	-	1978	1983-1989	Climate Station	14°01' 03" S	171° 43' 17" W	148 m	-
	15.	Moamoa	-	Mar.4. 1962	1971-1972	-	13°52' 12" S	171°47' 13" W	380 m	-
	16.	Savalalo	-	Apr.2. 1994	-	-	13° 39' 53" S	171° 46' 18" W	6 m	-
	17.	Nafanua	-	1965	-	Climate Station	13°51' 25" S	171°45' 46" W	45 m	-
	18.	Afiamalu	-	1903	1907-1948	Climate Station	13° 54' 31" S	171°46' 55" W	688 m	-
	19.	Faleolo	Aana Alofi #.1	Jul. 1956	1996-1999	Climate Station	13°49' 55" S	171° 59' 54" W	3 m	-
	20.	Apia	-	-	-	Climate Station	13°48' 54" S	171°46' 50" W	1 m	-
Upolu	A	Faleaseela	Monthly Rainfall	1975	-	Closed in Dec.'99	-	-	-	Faleseela
	B	Tanumalala	Monthly Rainfall	1975	-	-	-	-	-	-
	C	Sigaele	Monthly Rainfall	1975	-	-	-	-	-	-
	D	Lanotoo	Monthly Rainfall	1975	-	-	-	-	-	-
	E	Afulilo	Monthly Rainfall	1975	-	-	-	-	-	Namo
Island	No.	Address	Districts	Date Started	Luck of Data	Remarks	Latitude	Longitude	Elevation	Applicable Scheme
Savaii	1.	Asau	Vaisigano #1	May 15. 1984	1988-1993	Climate Station	13°32' 56" S	172°39' 37" W	386 m	-
	2.	Salelologa	Faasaleleaga #.1	Mar.28. 1994	-	-	13°45' 00" S	172° 15' 00" W	2 m	-
	3.	Fatausi	Faasaleleaga #.2	Mar.29. 1994	-	-	13°35' 43" S	172° 12' 55" W	3 m	-
	4.	Puapua	Faasaleleaga #.4	Nov.4. 1996	-	-	13° 26' 00" S	172° 21' 07" W	3 m	-
	5.	Vaipouli	Gagaa'emauga #.3	1927	1952-1974	-	13°27' 52" S	172°22' 04" W	62 m	-
	6.	Fogasavaii	Salega	Nov.4. 1996	-	-	13° 29' 11" S	172° 28' 46" W	44 m	-
	7.	Letui	Gagaifomauga #.3	Nov.4. 1996	-	-	13°34' 21" S	172° 45' 20" W	80 m	-
	8.	Neiafu	Alataua-Sisifo	Mar.20. 1994	-	-	13°34' 14" S	172° 44' 46" W	6 m	-
	9.	Lefagaoalii	Gagaaemauga #.2	Oct.1. 1992	Mar.30. 1994	-	13° 42' 89" S	172° 35' 64" W	55 m	-
	10.	Salailua	Palauli Sisifo	Jan.5. 1977	1984-1987	-	13° 47' 64" S	172° 30' 63" W	22 m	-
	11.	Sili	Palauli Le Falefa	Jul.27. 1995	-	-	13° 45' 00" S	172° 25' 00" W	25 m	Sili
	12.	Taga	Palauli Sisifo	Jan.10. 1990	-	-	13° 47' 36" S	172° 30' 38" W	25 m	-
	13.	Samalaeulu	Gagaaemauga #.1	Jul.27. 1995	1996-2002	-	-	-	-	-
	14.	Palauli	Palauli Sasae	Jan.1. 1933	1934-1967	Closed in Jul.'02	13°45' 28" S	172° 18' 06" W	12 m	-

(4) Estimation of River Flow from Rainfall Data

A series of river flow discharge are one of the most important data for hydropower planning as well as geography. As runoff data are not available at any river basin in Samoa as mentioned above, runoff data shall be prepared by using the water balance at river basin, even though their accuracy are poor.

A water balance of river basin is shown by the following formula:

$$P = L + Rd + Rb + E$$

Where, P : Annual Rainfall

L : Annual direct loss to sea through ground

Rd : Annual direct runoff

Rb : Annual base runoff

E : Annual evapotranspiration

Annual rainfall data are applied for each hydro potential river basin as shown in Table 5.2.4:

Table 5.2.4 Applied Rainfall Data at River Basin

No.	Name of Scheme	Station No.	Name of Station	Available Period	
				From	To
1	Faleaseela	Upolu No.6	Matautu-L	Sep.1993	Jan.2003
2	Lotofaga	Upolu No.8	Nuusuatia	Mar.1992	
3	Tafitoala				
4	Namo	Upolu No.11	Sauniatu	May 1995	
5	Sili	Savaii No.11	Sili	Aug.1995	

Although a direct loss is not considered and ratio of direct runoff is 64% - 74% usually, under the consideration of (i) short distance of river stretch and (ii) plateau of lava in Samoa, the ratio of both direct loss and direct runoff are applied at the value shown below with subsequent runoff coefficient.

Table 5.2.5 Runoff Coefficient at River Basin

No.	Name of Scheme	Ratio of Direct Loss	Ratio of Direct Runoff	Runoff Coefficient (for reference)		
				This Report	2001 JICA	1996 EPDC
1	Faleaseela	15 %	80 %	0.46	0.42	0.40
2	Lotofaga	10 %	80 %	0.54	0.42	0.66
3	Tafitoala	10 %	80 %	0.54	0.42	-
4	Namo	10 %	80 %	0.55	0.42	-
5	Sili	10 %	80 %	0.53	0.42	-

Potential evapotranspiration is calculated by using the Blaney-Criddle equation as shown below:

$$E = K \times P \times (45.5 \times T + 813)/100$$

Where, E : Evapotranspiration by month (mm)

K : Coefficient of monthly consumption by vegetation (=0.6)

P : Monthly percent of daytime hours of year (%), at South Latitude 14 °, South Hemisphere

Mon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P	8.97	7.97	8.54	8.03	8.07	7.70	7.08	8.19	8.16	8.69	8.65	9.01

T : Monthly mean temperature at Togitogiga Climate Station, refer to Annex 5.3 (2)

The calculation results of river flow at each hydropower potential site are summarize by flow duration curve as shown in Annex 5.3 (5).

5.2.4 ENVIRONMENTAL ISSUES

(1) Environmental Impact Assessment

Environmental awareness has pervaded through many sectors of Samoa' economic. As results, both Government agencies and the public at large have started to design and to construct suitable residential accommodation, buildings, seawalls, roads, power generation, etc., to accommodate adverse impacts. Samoa is requesting the adaptation and mitigation campaign against Climate Change (CC) and Sea Level Rise (SLR) through legislation, projects and education. Consequently, much attention should be paid for source of power generation. The best mix proportion of power generated both by diesel plants and hydropower plants shall be studied under the comprehensive environmental impact assessment.

However, Samoa does not have an Environmental Impact Assessment (EIA) legislation. A draft regulation has been developed and is now being incorporated to the draft Environment Bill which is under Cabinet consideration. This EIA process will incorporate the need to assess the potential impacts of development activities on the country's biodiversity.

(2) Environmental Conservation

The increasing world-wide concern about the need to conserve the environment is reflected in a number of studies of Samoa's vegetation and ecology and proposals to establish conservation areas as shown in Annex 5.2 (5) to protect watersheds or particular ecological formations. However, the formal declaration of these proposed conservation area is complicated by the nature of Samoan land tenure.

(3) Land Capability

In addition to the computer data produced the detailed GIS database for the country in 1990, the maps at a scale of 1:50,000 portray the soil, elevation, land tenure, land use, settlements, roads and land capability in terms of potential value for agriculture and forestry. Such data can be invaluable for development planning, and Samoa is relatively unusual in having such good coverage. Annex 5.2 (6) draw on the land capability information.

(4) Forest Cover

In the mid/1950s, 74 % of Samoa's land area was under forest, but by the late 1980s the proportion had fallen to 55% as shown in Table 5.2.6. Annex 5.2 (5) shows a forest area distribution as of 1990.

Table 5.2.6 Percentage of Land Area under Forest

Year	Upolu	Savaii	Total
1954	65 %	79 %	74 %
1987	43 %	63 %	55 %
1990	25 %	50 %	40 %

The Forestry Policy (GWS 1994) has been developed which stressed the need for balance utilization of forests and forest lands as indispensable component of an integrated land-use system. This emphasis can provide an enabling environment with potential to raise economic growth, to meet the socio-economic needs of an increasing population and to ensure that the cultural aspirations are accommodated. The emphasis also guarantees a long term vision that benefits both the present and the future generations through ecologically sustainable development.

Accordingly, even at the beginning stage of a hydropower planning and even for the small scaled and run-of-river type scheme, much attention should be paid for the forest conservation.

(5) Clean Development Mechanism (CDM)

The Kyoto Protocol under Article 12 also provides for the Clean Development Mechanism (CDM) which could be employed by the least developed countries like Samoa to accommodate the transfer of necessary technology through a voluntary partnership with an Annex I country. Although the procedures involved are not yet finalized, CDM can be a useful tool for technology transfer which may eventually achieve some of Samoa's needs for adapting to Climate Change (CC) and Sea Level Rise (SLR).

(6) Collected Data

The following documents/reports are collected at Division of Environment & Conservation, Department of Lands, Surveys and Environment, Ministry of Natural Resources and Environment in Samoa.

(i) World Summit on Sustainable Development Assessment Report, Government of Samoa, 2002

(ii) First National Communication to the UNFCC, A PICCAP-GEF Funded Project, Oct.1999

(iii) Samoa's First Report to the Convention on Biological Diversity, Div.of Environment & Conservation, Dec.2000

(iv) Samoa's Biodiversity Strategy and Action Plan, GEF/UNDP, 2001

(v) The Conservation of Biological Diversity in Upland Ecosystem of Samoa, MOFA of NZ, 1997

(vi) Samoan Environment Forum No1, Division of Environment & Conservation, April 2000

(vii) Samoan Environment Forum No2, Division of Environment & Conservation, 2000

(viii) Samoan Environment Forum No3, Division of Environment & Conservation, 2001

(ix) Mapping the Diversity of Samoa, Institute of Pacific Studies, University of the South Pacific and National University of Samoa, 1998

(x) Environmental Assessment Report, Afulilo Hydropower Project, South Pacific Regional Environment Programme (SPREP), December 1991

(xi) Environmental Assessment Report, Augmentation Phase of Afulilo Hydropower Scheme, South Pacific Regional Environment Programme (SPREP), November 1997

5.2.5 EXISTING HYDROPOWER CIVIL STRUCTURES

JICA Study Team visited five (5) existing hydropower plants as shown below:

Table 5.2.7 Existing Hydropower Plants owned by EPC

No.	Power Station	Generator Designation	Name-plate Capacity (kW)	Rated Capacity (kW)	Year Installed	Manufacturer
1	Taelefaga (Afulilo Dam)	No.1	2,000	2,000	1993	GEC Alsthom
		No.2	2,000	2,000	1993	
		Sub-total	4,000	4,000	-	
2	Lalomauga	No.1	1,850	1,700	1985	-
		No.2	1,850	1,600	1985	
		Sub-total	3,700	3,300	-	
3	Fale-Ole-Fee	No.1	1,740	1,700	1994	Voith(Turbine), GEC Alsthom (Generator)
4	Alaoa	No.1	1,045	1,000	1959	Turgo Gilkes
5	Samasoni	No.1	950	700	1982	Gilbert Gilkes & Gordon
		No.2	950	700	1982	
		Sub-total	1,900	1,400	-	
Total of Hydropower			12,385	11,400		

Inspection results on each civil structure are shown in the following table:

Table 5.2.8 Inspection Results on Existing Hydropower Civil Structures

No.	Structures	Taelefaga (Afulilo Dam)	Lalomauga	Fale-Ole-Fee	Alaoa	Samasoni
1	Intake	No problem.	Not inspected.	Not well maintained. Difficult to access.	No structure at Western intake. Easy come sedimentation. Not inspected (Eastern).	Skimmer walls are broken.
2	Headrace canal/Tunnel	No problem.	Not inspected.	Water leakage at Vaivase line (used by villagers)	Difficult maintenance of open/long canal	Direct intake.
3	Reservoir/ Head pond	No problem.	Sealing rubber was damaged at few points.	Sedimentation unknown.	Much sedimentation even periodical dredge.	Provision of access for dredge works
4	Penstock Line	No problem.	No problem.	Along access road. Easy to inspect.	No problem.	Along access road. Easy to inspect.
5	Powerhouse	No problem.	No problem.	No problem.	No problem.	No problem.
6	Tailrace	No problem.	No problem.	Interrupted to water supply system.	No problem.	Possible damaged by flood.

No.	Structures	Taelefaga (Afulilo Dam)	Lalomauga	Fale-Ole-Fee	Alaoa	Samasoni
7	Access road	Covered by grass.	No problem. To intake unknown.	No maintenance to both intakes.	No access by cat to Eastern intake.	Well maintained.
8	Others	EIA for Afulilo Dam was carried out in 1991 and 1997.				

5.2.6 EXISTING HYDROPOWER DEVELOPMENT PLAN

EPC has plans to proceed an extension and a new hydropower development under ADB's technical and budgetary assistance.

(1) Extension of Taelefaga Hydropower Plant and Dam Height Rise of Afulilo Dam

ADB will start the augmentation phase of the Afulilo Hydropower Scheme. The project consists of (i) extension of 2MW generator at Taelefaga power station, (ii) dam height rising on the spillway crest of Afulilo Dam at 1.7 m, and (iii) increment of the catchment area by diversion of run-off discharge from the neighboring basin to the Afulilo reservoir through open canal. The commission date of the project is scheduled at the end of 2004.

(2) Sili Hydropower Development Study

ADB has provided assistance for energy sector development, power sub-sector in particular, since 1971. The purpose of the project will see the development of water resources of the Sili River basinin order to provide adequate hydroelectric generation on the island of Savaii. The project will reduce the need to run diesel power stations in Savaii, with considerable savings to the EPC in imported fuel costs.

ADB will engage the technical assistance at a feasibility study level by selecting the Consultants within March 2003. The Study will start in April and be expected to finish at the end of September 2003.

5.3 HYDROPOWER PLANNING

5.3.1 SITE RECONNAISSANCE OF HYDRO POTENTIAL SITE

After the preliminary study on the both 1:20,000 and 1:50:000 scaled maps, the Study Team made site reconnaissance to the proposed hydropower potential sites at the following manners. JICA senior volunteer and EPS's counterparts were also accompanied to the reconnaissance party. Two staff of Hydrology Unit (Mr. Mafutaga & Mr. Iosefatu) joined us to the Upolu-South area not only for the river discharge measurement but action as guide. Meanwhile, in spite of EPC's efforts to discuss with villagers at downstream of Namo hydro scheme, the Study Team could not access to the potential site due to no villager's permission to access during S/Team's stay in Samoa. The photographs during site reconnaissance for each new hydro scheme are shown in Annex 5.4.

Table 5.3.1 Site Reconnaissance to Hydro Potential Sites

No.	Name of Scheme	Location	Date (in 2003)	Visited Engineers
1	Faleaseela	Upolu-South	February 14	S/Team, JICA, EPC, Hydrology Unit
2	Lotofaga	Upolu-South	February 15	S/Team, JICA, EPC, Hydrology Unit
3	Tafitoala	Upolu-South	February 15	S/Team, JICA, EPC, Hydrology Unit
4	Namo	Upolu-North	March 2	S/Team, JICA, EPC (Mouth only)
5	Sili	Savaii-South	February 27-28	S/Team, JICA, EPC

The river discharge measured by the staff of Hydrology Unit using a current meter are shown in the following table: The measurement locations are shown in figures of site reconnaissance.

Table 5.3.2 Discharge Measurement Data during Site Reconnaissance

No.	Name of Scheme	Location	Discharge (m^3/s)	Estimated Catchment Area (km^2)	Specific Discharge ($m^3/s/km^2$)
1	Faleaseela	Intake site(U/S)	0.345	4.8	0.0719
2		Measure point(D/S)	0.265	5.5	0.0482
3	Lotofaga	Middle reach	1.890	16.6	0.1139
4	Tafitoala	After confluence	0.941	13.0	0.0724
5		Before confluence	0.643	8.5	0.0756

5.3.2 METHODOLOGY OF HYDROPOWER PLAN

(1) Study of Waterway Layout

The potential sites are studied by the 1:50,000 scaled map. Based on the map study, site conditions of major structures and their accessibility are confirmed by site reconnaissance. In order to increase catchment area for intake, several intakes shall be considered for collecting discharge to the head pond. The catchment area is measured by a digital planimeter for each intake. A length of headrace canal is also measured on the map. A length of penstock line is calculated by both measured horizontal distance and each elevation deference. General Layouts of each new hydro scheme are shown in Annex 5.4.

(2) Headloss Calculation and Decision of Install Capacity

A headloss between a head pond and a tailrace is calculated at (i) screen, (ii) inlet, (iii) pipe friction, (iv) bend, (v) transition, (vi) branch, (v) inlet valve of Penstock Line and (vi) tailrace exit. After calculation of effective head against the maximum power discharge, possible power output is obtained with a fixed value 0.85, combined efficiency of turbine and generator. Annex 5.3 (6) shows a calculation sheet in case of Namo No.3 Hydropower Scheme.

(3) Selection of Turbine

Generally, a type of turbines from 10MW to 1kW shall be selected by the relationship between an effective head and a maximum power discharge as shown in the diagram of Annex 5.3 (8). Among the hydropower potential sites in Samoa, the gross heads are distributed from 40m to 120m and the power discharge from 0.4m^3/s to 2.0m^3/s. According to the diagram, the Turgo Impulse type turbine was selected as the most suitable one by a large range of available discharge (0.2m^3/s to 8.0m^3/s) and a high efficiency as shown in Table 5.3.3 and Figure 5.3.1.

Table 5.3.3 Efficiency of Turgo Impulse Type Turbine

No.	Capacity	100%	90%	80%	70%	60%	50%
1	100kW	83.5	84.0	84.0	83.5	82.0	80.0
2	1,000kW	84.5	85.0	85.0	84.5	83.0	81.5
No.	Capacity	50%	40%	30%	20%	10%	-
1	100kW	82.5	83.0	81.0	72.5	61.5	-
2	1,000kW	84.0	85.0	82.5	76.0	66.0	-

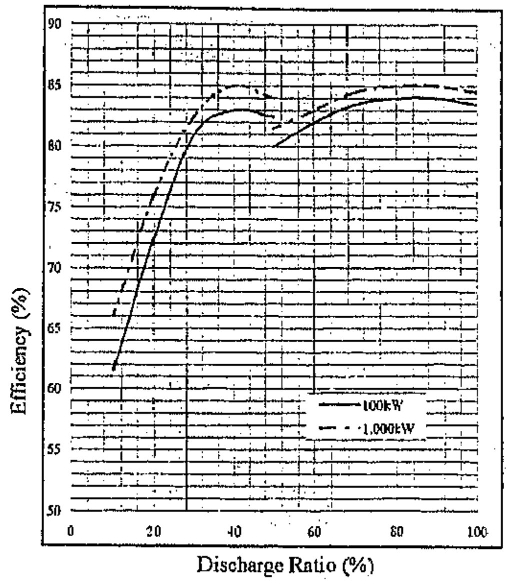


Figure 5.3.1 Efficiency Curve

Also that has the following good reasons:

(i) available capacity between 100kW and 10,000kW,

(ii) available head between 25m to 300m,

(iii) low price including generator due to high rotating speed,

(iv) high durability due to less friction at turbine.

(4) Maximum/Minimum Power Discharge

The maximum power discharge is obtained by error and trial at 55-60 % plant utilization factor depend on plant maximum discharge, which gives about 20% runoff discharge. The minimum power discharge is fixed by mechanical requirement of the Turgo Impulse type, which is the highest discharge between 10% of the maximum discharge and 0.2 m^3/s.

(5) Simulation for Power Generation

Depend on the available monthly discharge, an operation mode divided into 7 modes is selected automatically subject to the head pond water depth. Based on effective head, available discharge after spillout and efficiency of turbine, monthly mean output is calculated. The simulation results in case of Namo No.3 Hydropower Scheme are shown in Figure 5.3.2, Figure 5.3.3 and Table 5.3.4.

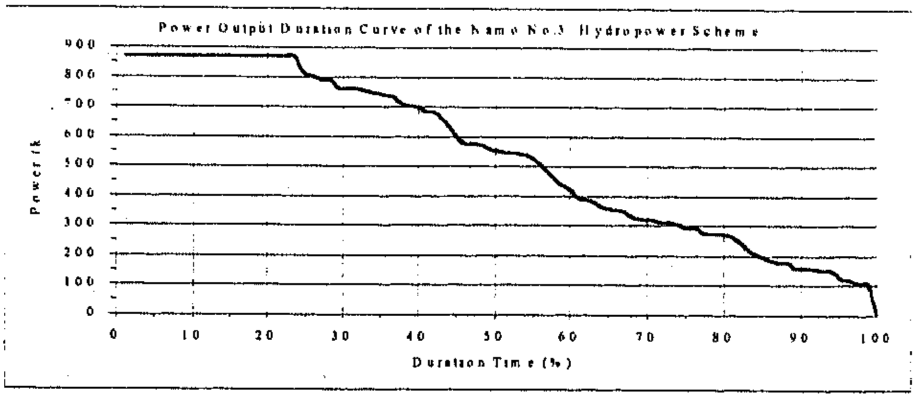


Figure 5.3.2 Power Output Duration in case of Namo Hydropower No.3 Scheme

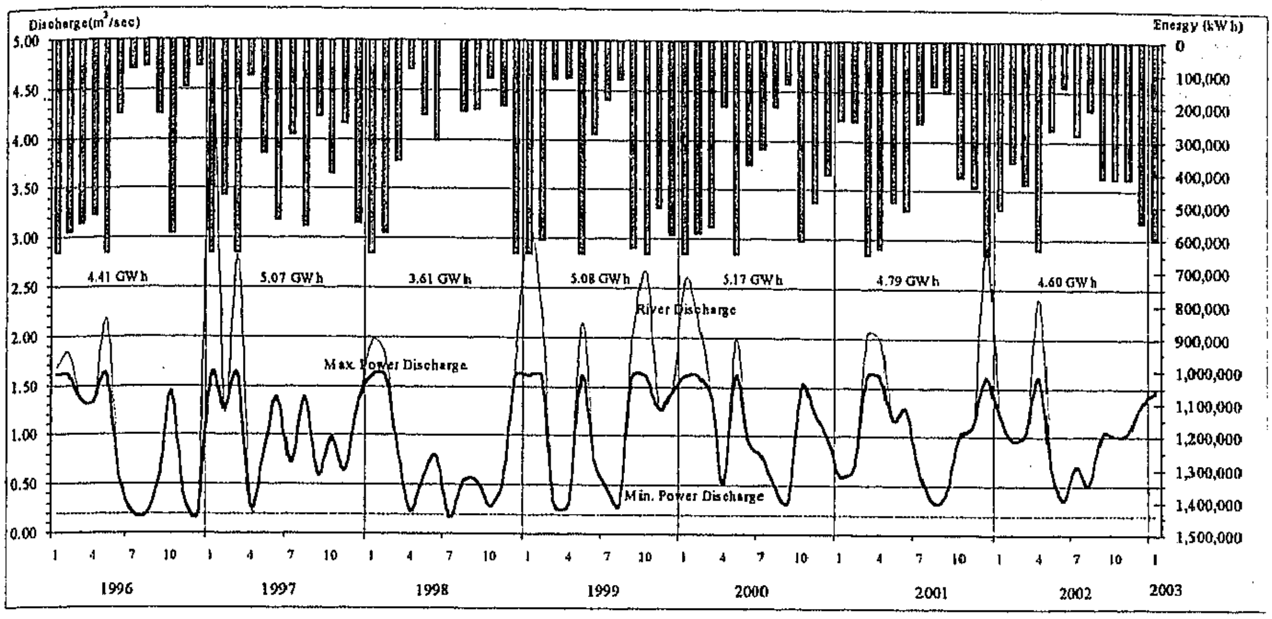


Figure 5.3.3 Simulation Results in case of Namo Hydropower No.3 Scheme

Table 5.3.4 Simulation Results for Power Generation

No.	Name of Scheme	Install Capacity (kW)	Average Output (kW)	Annual Power Generation (GWh/Year)	Seasonal Power Generation (*1) (GWh/Dry)	(GWh/Wet)	Plant Factor (%)
1	Faleaseela	390	209	1.74	0.77	0.98	50.9
2	Lotofaga	910	550	4.58	2.41 (*2)	2.19	57.4
3	Tafitoala	1,450	886	7.38	3.88 (*2)	3.52	58.0
4	Namo No.1	860	526	4.37	1.83	2.52	58.1
5	Namo No.2	550	339	2.82	1.19	1.62	58.6
6	Namo No.3	880	537	4.47	1.87	2.58	57.9
7	Namo No.4	500	314	2.61	1.09	1.50	59.6
8	Sili No.1(1st)	1,180	717	5.97	2.55	3.23	57.7
9	Sili No.1(2nd)	1,800	1,126	9.38	4.02	5.09	59.4
10	Sili No.2	1,600	994	8.29	3.53	4.50	59.0

Note : (1) Dry season : May to October, Wet season : November to April
(2) Generation in dry is larger than wet.

(6) Firm Energy

Firm energy is defined as the power output generated by power discharge with 90% dependability at each discharge duration curve as shown in Annex 5.3 (4) after multiplied by utilization coefficient (0.95). Secondary energy are obtained by deduction of the firm from total energy. The calculation results are shown in Table 5.3.5.

Table 5.3.5 Firm Energy for Power Generation

Scheme	Discharge 90% Runoff (m^3/s)	Head Gross head (m)	Head loss (m)	Efficiency	Output (kW)	Annual Energy Firm (GWh)	Secondary (GWh)	Total (GWh)
Faleaseela	0.06	125	0.5	0.70	51	0.42	1.31	1.74
Lotofaga	0.26	60	1.0	0.80	120	1.00	3.58	4.58
Tafitoala	0.24	100	1.0	0.80	186	1.55	5.83	7.38
Namo-1	0.35	60	1.0	0.80	162	1.35	3.03	4.37
Namo-2	0.32	42	1.0	0.80	103	0.86	1.97	2.82

Scheme	Discharge 90% Runoff (m^3/s)	Head: Gross head (m)	Head: Head loss (m)	Efficiency	Output (kW)	Annual Energy: Firm (GWh)	Annual Energy: Secondary (GWh)	Annual Energy: Total (GWh)
Namo-3	0.29	71	1.0	0.80	159	1.32	3.14	4.47
Namo-4	0.16	80	0.5	0.75	93	0.77	1.84	2.61
Sili-1 (1)	0.14	160	0.5	0.75	164	1.37	4.61	5.97
Sili-1 (2)	0.22	168	1.0	0.80	288	2.40	6.99	9.38
Sili-2	0.32	168	1.0	0.80	419	3.49	4.80	8.29

5.3.3 METHODOLOGY OF COST ESTIMATE

Cost estimates for each new hydropower scheme in this report are carried out for not only budget arrangement but also economic analysis with ranking of development priority. As the hydropower plan had been made on the 1:50,000 scaled map by applying the river discharge data obtained from the daily rainfall data for several years, a cost estimate based on unit prices and construction volumes subject to its civil design is judged having no accuracy. Accordingly, the preliminary cost estimate by using several forms of diagrams in each civil structure and Electric/Mechanical equipment was applied on "Cost Estimate Guideline for Potential Study, Bureau of energy resources, METI/GOJ, March 2000". Accordingly, all cost shall be estimated in Japanese Yen. Equivalent US$ is calculated with exchange rate JP.Yen120/US$1.00 without separation of foreign and domestic cost allocation. A construction period is considered 2 years for each hydropower scheme.

Under consideration of the considerable labour cost difference between Japan and Samoa, only for the civil work items are deducted 40% from original calculation value. The conditions and results of cost estimate are as shown in Table 5.3.6 and Table 5.3.7. Annex 5.3 (7) shows a calculation sheet in case of Namo No.3 Hydropower Scheme.

Table 5.3.6 Conditions of Cost Estimate by Forms of Diagrams

No.	Items	Assumed Conditions	Parameter	Applied Condition
1	Used map	1:25,000	-	1:50,000
2	Max. Capacity	50,000kW	-	1,800kW
3	Civil Works	Powerhouse	Installed capacity	Surface type
4		Intake weir	Height, Length, Conc. volume	excld. Fishway
5		Inlet structure (No pressure type)	Radius of canal, Discharge	excld. Settling basin
6		Headrace canal (Open/culvert type)	Discharge, Length, Section area	excld. tunnel
7		Head pond	Discharge	excld. surge tank
8		Spillway Works (Exposed type)	Discharge, Slope, Length	excld. pipe
9		Penstock Works (Exposed type)	Discharge, Length, Head	-
10		Tailrace (No pressure type)	Discharge, Length, Section area	incl. gate
11		Miscellaneous for waterway	5% of waterway works	-
12		Equipment foundation	Discharge, Head, Nos of unit	-
13		Miscellaneous works	3% of civil works	-
14		Permanent Access road	Length	New & improvement
15	Metal works	Spillway Pipe	Discharge, Slope, Length, weight	Exposed type
16		Penstock Pipe	Discharge, Length, Head, Weight	Exposed type
17	Electrical works	Turbine & Generator	Capacity, Head, Nos of unit	-
18	Temporary facilities	Temporary access road, building, water/ electric supply	10% of civil, metal and electrical works	-
19	Administration cost	Survey, Study, Design, Labour cost	13% of civil, metal, electrical and temporary works	-
20	IDC	Interest during Construction	Const. period, Interest, Cashflow factor	2 years, 0.8%, 0.4

Table 5.3.7 Estimated Construction Cost (Unit : US$)

Structure	Faleaseela	Lotofaga	Tafitoala	Namo(1)	Namo(2)	Namo(3)	Namo(4)	Sili-1(1)	Sili-1(2)	Sili-2
Powerhouse	92,000	186,000	273,000	178,000	123,000	181,000	113,000	231,000	328,000	297,0
Intake weir	101,000	335,000	436,000	184,000	184,000	198,000	143,000	143,000	244,000	172,0
Inlet structure	81,000	239,000	173,000	268,000	253,000	194,000	97,000	103,000	128,000	118,0
Headrace canal No.1	158,000	98,000	1,371,000	2,016,000	952,000	611,000	399,000	682,000	1,413,000	631,0
Headrace canal No.2	1,193,000	1,638,000	848,000	0	0	473,000	641,000	916,000	305,000	536,0
Head pond	76,000	222,000	207,000	222,000	207,000	191,000	120,000	130,000	175,000	158,
Spillway (Civil)	54,000	120,000	120,000	120,000	120,000	113,000	82,000	82,000	152,000	134,
Spillway (Pipe)	54,000	93,000	93,000	93,000	93,000	90,000	72,000	72,000	109,000	101,
Penstock (Civil)	278,000	285,000	4,358,000	344,000	328,000	281,000	364,000	1,846,000	2,214,000	2,406,
Penstock (Pipe)	211,000	238,000	2,127,000	276,000	178,000	189,000	173,000	906,000	1,626,000	1,864,
Tailrace	17,000	58,000	54,000	58,000	54,000	39,000	26,000	28,000	46,000	42,
Sub-Total (A)	2,313,000	3,512,000	10,058,000	3,758,000	2,492,000	2,559,000	2,229,000	5,136,000	6,740,000	6,458.
Miscellaneous (Civil)	116,000	176,000	503,000	188,000	125,000	128,000	112,000	257,000	337,000	323,
Foundation of unit	13,000	69,000	104,000	66,000	39,000	60,000	24,000	60,000	192,000	157,
Sub-Total (B)	2,327,000	3,581,000	10,163,000	3,823,000	2,531,000	2,619,000	2,253,000	5,196,000	6,932,000	6,614,
Miscellaneous (Mecha.)	70,000	108,000	305,000	115,000	76,000	78,000	68,000	156,000	208,000	198,
Generating Equipment	1,005,000	2,449,000	2,795,000	2,399,000	1,983,000	2,238,000	1,418,000	2,022,000	2,758,000	2,509,
Transmission line	25,000	75,000	100,000	15,000	50,000	50,000	50,000	125,000	0	125,
Sub-Total (C)	3,543,000	6,388,000	13,866,000	6,540,000	4,764,000	5,113,000	3,900,000	7,755,000	10,235,000	9,769,
Temporary facilities	354,000	639,000	1,387,000	654,000	477,000	512,000	390,000	776,000	1,023,000	977,
Access road	142,000	237,000	189,000	94,000	165,000	378,000	378,000	188,000	188,000	188,
Sub-Total (D)	4,038,000	7,264,000	15,442,000	7,288,000	5,406,000	6,003,000	4,668,000	8,719,000	11,447,000	10,934,
Other expenses	525,000	944,000	2,008,000	948,000	703,000	781,000	607,000	1,133,000	1,488,000	1,422,
Ground-total	4,563,000	8,208,000	17,449,000	8,236,000	6,108,000	6,784,000	5,275,000	9,853,000	12,935,000	12,356.
Unit cost per kW	11,700	9,020	12,034	9,577	11,105	7,709	10,550	8,350	7,186	7.
Unit cost per kWh	2.62	1.79	2.36	1.88	2.17	1.52	2.02	1.65	1.38	
Ranking	7	2	6	3	5	1	4	3	1	2

5.3.4 METHODOLOGY/RESULTS OF ECONOMIC EVALUATION

(1) Benefit-Cost Method

An economic analysis of the hydropower project is made by a comparison method between its benefit (B) and cost (C). The benefit (B) of a hydropower project shall be applied for the alternative cost by thermal plant to supply the power equivalent to the hydropower. The cost (C) is derived from the construction cost estimate of the hydropower project. In the case of benefit cost ratio (B/C) is larger than 0.5, the project is judged as prospective project to recommend to start the basic/detailed design.

(2) Benefit as Annual Cost of Alternative Thermal Plant

An alternative thermal plant is a diesel plant in Samoa. Annual benefit is obtained based on the fixed cost (equipment cost) and variable cost (fuel cost) of a diesel plant as shown below:

$$B = B1 + B2 = \text{kW benefit } (Ph \times b1) + \text{kWh benefit } (E \times b2)$$

where, B: Annual benefit of hydropower (US$)

Ph : Average output of hydropower (kW)

E : Annual Energy generation of hydropower (kWh)

b1 : kW value (Capacity value) = $Ct \times \beta \times \alpha$

b2 : kWh value (Energy value) = $H \times P$

Ct : Unit construction cost of diesel plant (US$/kW)

β : kW adjustment factor (= 1.1)

α : Annual cost factor of diesel plant (= 15%)

H : Heat rate (= Energy value / Efficiency / Calorific value /Specific gravity)

P : Fuel price (= S$1.48 = US$0.4918, as of February 2003)

(3) Cost as Annual Cost of Hydropower Scheme

Annual cost of hydropower is obtained from its construction cost.

$C = Ch \times \alpha$

where, C : Annual cost of hydropower project

Ch : Construction cost including IDC

α : Annual cost factor (= 11%)

Calculation results are shown below:

Table 5.3.8 Input Data for Economic Calculation

No.	Input Items	Unit	Value
1	Construction period	Year	2
2	Interest	%	8%
3	Annual cost factor (hydro)	%	11%
4	Unit const.cost of Diesel	US$/kW	1,500
5	kW adjustment factor	Ratio	1.1
6	Annual cost factor (Diesel)	%	15%
7	Diesel fuel unit price	US$/litre	0.4918
8	Thermal efficiency	Ratio	0.35
9	Calorific value	kcal/kg	10,200
10	Specific gravity	kg/litre	0.85
11	Energy value	Kcal/kWh	860
12	Cashflow factor	Ratio	0.4

Table 5.3.9 (1) Economic Evaluation Results

No.	Name of Scheme	(1)	(2)	(3)	(4)	(5)
		Annual Benefit for Hydropower (Cost of Diesel)				
		Average Output	Annual Power Generation	kW Benefit	kWh Benefit	Annual Benefit (=3 +4)
		(kW)	(GWh/Year)	(US$/kW)	(US$/kWh)	(US$)
1	Faleaseela	209	1.737	51,728	242,105	293,832
2	Lotofaga	550	4.578	136,125	638,086	774,211
3	Tafitoala	886	7.379	219,285	1,028,492	1,247,777
4	Namo No.1	526	4.374	130,185	609,652	739,837
5	Namo No.2	339	2.824	83,903	393,612	477,514
6	Namo No.3	537	4.467	132,908	622,615	755,522
7	Namo No.4	314	2.611	77,715	363,924	441,639
8	Sili No.1(1st)	717	5.973	177,458	832,522	1,009,980
9	Sili No.1(2nd)	1,126	9.384	278,685	1,307,951	1,586,636
10	Sili No.2	994	8.289	246,015	1,155,329	1,401,344

Table 5.3.9 (2) Economic Evaluation Results

No.	Name of Scheme	(6) Annual Cost for Hydropower: Base Const. Cost (US$1,000)	(7) Interest during Const.(IDC) (US$1,000)	(8) Total Cost (=6 + 7) (US$1,000)	(9) Annual Cost (US$)	(10) B/C (=5/9)	(11) Priority by B/C
1	Faleaseela	4,563	292	4,855	534,050	0.55	N/F
2	Lotofaga	8,208	525	8,733	960,630	0.81	2
3	Tafitoala	17,449	1,117	18,566	2,042,260	0.61	6
4	Namo No.1	8,236	527	8,763	963,930	0.77	3
5	Namo No.2	6,108	391	6,499	714,890	0.67	5
6	Namo No.3	6,784	434	7,218	793,980	0.95	1
7	Namo No.4	5,275	338	5,613	617,430	0.72	4
8	Sili No.1(1st)	9,853	631	10,484	1,153,240	0.88	3
9	Sili No.1(2nd)	12,935	828	13,763	1,513,930	1.05	1
10	Sili No.2	12,356	791	13,147	1,446,170	0.97	2

Note; (3)=kW x Unit cost of diesel x kW Factor x Cost factor
(4)=kWh x Energy value / Efficiency / Calorific value /Specific gravity x Fuel cost
(7)=Cost x Time x Interest x Cashflow factor, (9)=Total Cost x Annual cost factor (hydro), (11)N/F: Not feasible.

5.3.5 RECOMMENDATION AND CONCLUSION OF HYDROPOWER SCHEMES

(1) Summary of New Hydropower Scheme

Our study results on hydropower development plan are summarized as shown below:

Table 5.3.10 Summary of New Hydropower Scheme

No.	Name of Scheme	Location	Install Capacity (kW)	Average Output (kW)	Firm Output (kW)	Nos. of Unit (Nos)	Annual Power Generation (GWh/Year) Total	Firm	Secondary	Plant Factor (%)
1	Faelaseela	Upolu -South	390	209	51	1	1.74	0.42	1.32	50.9
2	Lotofaga		910	550	120	1	4.58	1.00	3.58	57.4
3	Tafitoala		1,450	886	186	1	7.38	1.55	5.83	58.0
4	Namo No.1	Upolu -North	860	526	162	1	4.37	1.35	3.02	58.1
5	Namo No.2		550	339	103	1	2.82	0.86	1.96	58.6
6	Namo No.3		880	537	159	1	4.47	1.32	3.15	57.9
7	Namo No.4		500	314	93	1	2.61	0.77	1.84	59.6
8	Sili No.1(1st)	Savaii -South	1,180	717	164	1	5.97	1.36	4.61	57.7
9	Sili No.1(2nd)		1,800	1,126	288	2	9.38	2.40	6.98	59.4
10	Sili No.2		1,600	994	419	2	8.29	3.49	4.80	59.0

No.	Name of Scheme	Location	Install Capacity (kW)	Power Generation (GWh/Year) Total	Construction Cost Total (US$1,000)	/kW (US$)	/kWh (US$)	Catch. Area (km²)	Max. Power Discharge (m³/s)	Gross Head (m)
1	Faelaseela	Upolu -South	390	1.74	4,563	11,700	2.63	4.47	0.4	125
2	Lotofaga		910	4.58	8,208	9,020	1.79	15.59	2.0	60
3	Tafitoala		1,450	7.38	17,449	12,030	2.36	14.41	1.8	100
4	Namo No.1	Upolu -North	860	4.37	8,236	9,580	1.88	16.49	2.0	60
5	Namo No.2		550	2.82	6,108	11,110	2.16	15.08	1.8	42
6	Namo No.3		880	4.47	6,784	7,710	1.52	13.38	1.6	71
7	Namo No.4		500	2.61	5,275	10,550	2.02	7.49	0.8	80
8	Sili No.1(1st)	Savaii -South	1,180	5.97	9,853	8,350	1.65	9.45	0.9	160
9	Sili No.1(2nd)		1,800	9.38	12,935	7,190	1.38	15.32	1.4	168
10	Sili No.2		1,600	8.29	12,356	7,720	1.49	12.80	1.2	168

(2) Project Evaluation

According to the project priority evaluated by B/C, the Namo No.3 scheme has the first priority, and the Faleaseela lowest in Upolu. And also, the Sili No.1 (2nd stage) scheme is the highest and the Sili No.1 (1st stage) lowest in Savaii.

As the project site of Faleaseela scheme is easy to access, it is slightly developed by villagers compared with other potential areas. Water gushing out from spring at the upstream of the proposed intake site is used for water supply to the villages, and the river at the proposed power station site are occupied by village house as well as using as a water pool for villager's accommodation. Consequently, it is recommended to withdraw this scheme from the alternative hydropower schemes.

For the Namo scheme, the cascade development would be applied in order to use a total head effectively and to divide the scheme to small ones with advantage for budget arrangement.

Even if the Sili No.1 (1st stage) is ranked low, as the value of B/C is high compared with schemes in Upolu, the cascade development of Sili river basin is recommendable to proceed. As the proposed intakes of Sili No.2 are to be constructed at the upstream of the intake for Sili No.1 (2nd stage), a revised plan to construct No.2 following No.1 (1st stage) without No.1 (2nd stage) has also possibility. The results of the feasibility study of the Sili hydropower by ADB would reveal the most recommendable development scheme by the end of September 2003.

Table 5.3.11 Particular Site Condition of each Scheme

No.	Scheme	Faleaseela	Lotofaga	Tafitoala	Namo	Sili
1	Accessibility	Easy	Slightly hard	Slightly hard	-	Slightly hard
2	Permanent bridge	Not necessary	Not necessary	Not necessary	-	Necessary
3	Gorge slope	Gentle	Slightly steep	Steep	-	Steep
4	Problems due to Land Tenure	None	None	None	Strong	Strong
5	Existing river use	W/supply at U/S, Pool at D/S	Not use	Pool at D/S	-	
6	Conservation area	Faleaseela catchment	Identified by Forestry Div.	Identified by Forestry Div.	Falefa catchment	Vaiola catchment
7	Habitats	Few at P/S site	None	None	None	None

With assumption of the design and procurement stage for one (1) year and the construction stage for two (2) years, the first project could start a commercial operation in 2007 at the earliest. Each three-year interval, new scheme could be commenced technically not financially. We would propose to develop the hydropower scheme as shown below:

Table 5.3.12 Development Priority and Prospective Commission Year

No.	Name of Scheme	Location	B/C	Priority by B/C	Evaluated Priority	Commission Year
1	Faelaseela	Upolu-South	0.55	7	N/F	-
2	Lotofaga		0.81	2	2	2010
3	Tafitoala		0.61	6	6	2022
4	Namo No.1	Upolu-North	0.77	3	3	2013
5	Namo No.2		0.67	5	5	2019
6	Namo No.3		0.95	1	1	2007
7	Namo No.4		0.72	4	4	2016
8	Sili No.1(1st)	Savaii-South	0.88	3	1	2007
9	Sili No.1(2nd)		1.05	1	2	2010
10	Sili No.2		0.97	2	3	2013