REPUBLIC OF THE PHILIPPINES

NATIONAL POWER CORPORATION

FEASIBILITY REPORT ON AGOS RIVER HYDROPOWER PROJECT

MAIN REPORT

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of the Philippines, the Japanese Government decided to conduct a feasibility survey on The AGOS RIVER HYDROPOWER DEVELOPMENT Project and entrusted the survey to the Japan Internationl Cooperation Agency (J.I.C.A.). The J.I.C.A. sent to the Philippines a survey team headed by Mr. MAKOTO TSUDA twice starting in June, 1979.

The team exchanged views with the officials concerned of the Philippine Government and conducted a field survey on the AGOS RIVER, Luzon Island. After the team returned to Japan, further studies were made and the present feasibility report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of the Philippines for their kind cooperation extended to the team.

March, 1981

Keisuke Arita
President
Japan Internaitonal Cooperation Agency

LETTER OF TRANSMITTAL

March, 1981

Mr. Keisuke Arita
President,
Japan International Cooperation Agency,
Tokyo, Japan

Dear Sir,

We have the pleasure of submitting herewith the Feasibility Report on Agos River Hydropower Project.

For preparation of this report, field investigation and studies were made for about two years starting from February, 1979. The results of the studies were compiled into the Draft Feasibility Report and submitted to your Agency at the end of November, 1980. During December 7 and December 16 of 1980, the survey team visited the Philippines again and had the meetings to discuss the Draft Report with the staffs concerned of National Power Corporation. All the findings and comments obtained have been fully incorporated in this Final Report.

The engineering and economic studies of the Report confirm that the project is technically sound and economically feasible. It is our sincere hope that the project will be proceeded to the next stage of the detailed design for the early realization of the project as soon as possible along the recommendations presented in this Report.

In submitting this report, all the members of JICA survey team express our heartfelt thanks and our sincere appreciation to the personnel of your Agency Tokyo and Manila, the Embassy of Japan and the authorities concerned of the Government of the Philippines for the courtesy and cooperation extended to us during the course of the work.

Very truly yours,

M. Tsuda

Makoto Tsuda
Team Leader
Agos River Hydropower Project

AGOS RIVER HYDROPOWER PROJECT

FEASIBILITY REPORT

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SUMMARY

Project Area

The Agos river basin having 940 km^2 of drainage area is located in the east coast of Central Luzon, about 90 km east of Manila. The Agos river basin, including two major tributaries of the Kanan and Kaliwa, is blessed with high annual rainfall exceeding 5,000 mm on an average and still covered with well-reserved thick jungle assuring abundant and clean source of water. Moreover, the shortest distance from Metro Manila makes its development most attractive for both purposes of hydropower generation and water supply to Metro Manila.

Especially, the Kanan watershed has not only rich rainfall but also very favourable seasonal distribution of rain with less district dry season, resulting in more dependable runoff available through the year.

Optimization Study

Forcussing our consideration on the above favourable conditions, a comprehensive development plan is formulated to realize the most optimum utilization of the water potential available in this river. For formulating the alternative development plans, many possible damsites, including five sites on the Kanan river, two on the Kaliwa river and two on the Agos river were reviewed.

On the other hand, the Kaliwa water supply project was already selected as the most optimum plan for water supply to Metro Manila to fulfill the demand until 1993. Furthermore, the Kanan water supply project is also proposed as the second stage to fulfill the water requirement from 1994.

Therefore, preliminary study and analysis were made for the following four alternative development plans on the Agos river system.

Plan A-1: Kaliwa Water Supply Project +
Kanan No.1 and Agos Hydropower Projects

Plan A-2: Kaliwa and Kanan No.2 W/S Projects +
Agos H/P Project

Plan A-3: Kaliwa W/S Project (with pumped storage power station between the Agos reservoir and the Kaliwa reservoir) +
Kanan No.1 and Agos H/P Projects

Plan B: Kaliwa W/S Project +
Kanan No.5 H/P Project

In formulating the alternative plans, the Kaliwa water supply project is considered as built, while the Kanan water supply project is treated as an alternative component of the proposed plan.

In the Plan A-2, required water for Metro Manila from 1994 will be diverted by gravity flow through an interbasin tunnel between the Kaliwa and the Kanan reservoirs, while the required water will be diverted by pumping through a waterway between the Kaliwa and the Agos reservoirs in the plan A-3. Both the plans A-1 and B will be materialized only when the Kanan water supply project is disqualified.

For the comparison of the alternative plans, construction cost, operation and maintenance cost, and power benefit are estimated for each plan.

Through the economic comparison, the plan A-3 is proved to be the plan with the highest net present worth out of four alternative plans. Although the plan A-3 is selected as the most optimum plan theoritically, the Kanan water supply project envisaged in plan A-2 is still considered as the second stage development in MWSS.

Under this situation, the Agos hydropower project is the only one possible plan to be implemented for hydropower development in the Agos river and is, therefore, selected among other hydropower development plans, for which detailed feasibility study is conducted. (For the study on the Agos hydropower project, it is assumed that all the water available in the Kaliwa reservoir and the Kanan reservoir will be diverted to Metro Manila from 1988 and from 1994 respectively.)

Agos Hydropower Project

The Agos project consists of construction works of Agos dam, spillway, diversion works, power tunnel, powerhouse with generating equipment of 140 MW installed capacity and 230 kV transmission line of about 43 km long with a substation at Malaya to connect with the trunk line around Metro Manila.

The damsite having a catchment area of 867 km^2 is located at the Agos river just downstream of the confluence of the Kaliwa river and the Kanan river. The annual mean discharge is estimated to be 108.2 m^3/sec. The river bed is at EL.42 m with the width of river around 120 m. Bed rocks are composed of alternating greywackes and conglomerates with occasional intercalations of thin shale layers.

The Agos reservoir has a gross storage capacity of $955 \times 10^6 m^3$ of which effective storage capacity is $570 \times 10^6 m^3$. High water level is at EL.165 m and low water level is at EL.128 m, and the drawdown is 37 m. The surface area of reservoir is 21.5 km^2 at HWL 165 m.

The dam is of rock fill with a center core and 130 m high from the river bed. The total embankment volume is 17 x $10^6 m^3$ including cofferdams. The spillway has gated crest with four numbers of radial gates and two lanes of side overflow weir. The power tunnel consists of an intake tower, one headrace tunnel of 225.8 m long with 6.8 to 9.0 m diameter and a penstock line of 350 m long with 6.1 m diameter. The powerhouse is located at downstream toe of the dam accommodating two units of each 70 MW turbine generator.

The annual energy generation is estimated at 622.6 GWh on an average when the water at the upstream of the Kaliwa dam is fully diverted to Metro Manila. Furthermore, if the Kanan water supply project is also developed, the power generation will be reduced to 395.5 GWh per annum on an average when the water is fully diverted.

The construction time of the project requires approximately 8 years from 1981 to 1988 consisting of detailed investigation and design of 2 years and the construction works of 6 years. All the project works are to be executed by contractors to be selected by international tenders. The project will start its commercial operation from early 1989.

The total construction cost including price contingency is estimated at US$456.6 million equivalent consisting of US$374.1 million equivalent of foreign currency portion and US$82.5 million (or Peso 618.5 million) equivalent of local currency portion.

Cost Item	Cost (10^3 US$)		
	Foreign	Local	Total
1. Land Acquisition	-	2,700	2,700
2. Civil Works	177,500	30,500	208,000
- Dam & Appurtenant structures	167,800	28,600	196,400
- Power Facilities	9,700	1,900	11,600
3. Generating Equipment & Metal Works	35,600	7,200	42,800
- Generating Equipment	27,800	5,000	32,800
- Metal Works	7,800	2,200	10,000
4. Physical Contingency 10 % of (1 + 2 + 3)	21,300	4,000	25,300
5. Engineering Service & Government Administration	14,100	2,700	16,800
Sub-total (1 - 5)	248,500	47,100	295,600
6. Price Contingency	125,607	35,370	160,977
Total (1 - 6)	374,107	82,470	456,577

Project Evaluation

Most significant economic benefit of the Project is derived from electric power generation. The benefit is valued by applying capacity and energy values of the least cost alternative thermal plant. The values are estimated on the basis of construction cost of coal-fired thermal plant whose investment cost is US$790 per kW and the fuel cost is US$0.0234 per kWh at the price level of early 1980.

The present worth of benefit for 50 years operation is estimated at US$384.6 million at discount rate of 10 percent. Present worth of net benefit and benefit cost ratio are estimated at US$46.03 million and 1.14 respectively and the economic internal rate of return is estimated to be 12.5 percent for the economic life of 50 years, which indicates that the project is economically feasible. In the sensitibity analysis, though cost increase is rather sensitive to the project viability, delays of the completion of the project such as the Agos project and the Kanan water supply project do not affect the economic viability.

		EIRR (%)
I	Construction cost increase by 15 percent	9.8
II	Agos H/P project be completed in 1994	11.5
III	Kanan W/S project be completed in 2004	13.1
IV	(II + III)	12.5
V	Coal price increase by 15 percent	13.6
VI	Kanan W/S project is discarded	18.2

The financial internal rate of return is calculated at 11.4 percent, which shows that the project is financially viable. A financial cash-flow analysis shows that the internal cash generation is expected to cover the debt service and the cash surplus will reach US$336 million equivalent in 2008 when all the debt service will be repayed. The debt service ratio exceeds 1.3, which indicates the financial solidity of the project.

Other benefits to the region such as flood control, fishery, irrigation and tourism development are expected from the project. The project would not give any negative impact to the society and biology except the resettlement of less than 100 families in the reservoir area.

Conclusion and Recommendation

As outlined in "Optimization Study", the possible development plan in the Agos river consists of Agos hydropower project, and Kaliwa-Kanan water supply projects. Each project is technically and economically feasible even if developed individually. The development of the Agos hydropower project will not be affected by the Kaliwa and the Kanan water supply projects which are given the first priority among the water resources development. The power benefit derived from Agos hydropower project is sound enough even if the water is diverted for water supply to Metro Manila through the Kaliwa and the Kanan dams as proposed by PICOREM.

Besides, the power benefit of the Agos is valued by the fuel price of early 1980 which is rather low (in the report, for example, the fuel price of bunker C was estimated at US$28/barrel, but the price is already US$32/barrel). It is predicted that the price will be increased by 15 to 20 percent more in 2 or 3 years. Therefore, the project would obtain higher internal rate of return than the estimated figure hereinbefore judging from the present energy situation and the future projection.

Furthermore, the Project can be connected to the existing Malaya substation through the transmission line of only 43 km. Upon the completion of the Marcos highway between Manila and Infanta by 1981, the project site can be connected with Manila within two hours and a half by car. No difficulties are anticipated for the transportation of construction equipment and materials.

Thus, it is concluded that Agos hydropower porject is feasible in all aspects and recommended that the detailed engineering works for the project be implemented, which includes detailed investigation, design and preparation of tender documents, as early as possible.

Principal Dimensions of the Agos Hydropower Project

Hydrology	
Catchment area	867 km^2
Average annual inflow	108.2 m^3/sec
Design flood for spillway	10,600 m^3/sec
Design flood for diversion works	5,210 m^3/sec
Reservoir	
High water level	165 m
Low water level	128 m
Flood water level (P.M.F.)	169.7 m
Draw-down	37 m
Gross storage capacity	955 x 10^6 m^3
Effective storage capacity	570 x 10^6 m^3
Dead storage	385 x 10^6 m^3
Reservoir area at H.W.L.	21.5 km^2
Diversion works	
Diversion tunnels	
type	Concrete lined circular section
number	2
diameter	9 m
length	816/817 m
gates	9 m (H) x 4.5 m (W) x 2 nos.
parts of diversion tunnel No.1 used for power tunnel	
Cofferdams	
crest el. of upstream cofferdam	93 m
crest el. of downstream cofferdam	51 m
Dam	
type	Rockfill with center core
crest elevation	172 m
dam height above foundation	172 m
crest length	762 m
width of crest	12 m
upstream slope	1:2.5
downstream slope	1:1.9
embankment volume (incl. cofferdams)	
earthfill	2.2 x 10^6 m^3
sand and gravel	1.44 x 10^6 m^3
rock (incl. riprap)	12.3 x 10^6 m^3
Spillway	
type	Gated and non gated crest open chute
gated portion	
gates	14.5 m (H) x 14.0 m (W) x 4 nos.
crest el.	154 m
non gated portion	
length	210 m x 2 lanes
crest el.	165 m
length (crest to flip end)	425 m

Power tunnel	
Intake	
type	Tower of concrete rigid frame
sill elevation	114 m
Tunnel	
type	Concrete lined circular section
diameter	6.8/9.0 m
length	225.8 m
Penstock	
type	Steel lined
diameter	6.1 m
length	350 m
Powerhouse	
type	Semi-underground
width, length and height	30 m x 56 m x 39 m
max. gross head	123.4 m
min. net head	83.5 m
Generating equipment (2 units)	
Turbine	
type	Vertical shaft Francis turbine
elevation of runner center	38 m
rated head (at reservoir water el. 146.5 m)	102 m
highest net head (one unit operation)	122.6 m
rated discharge	81.5 m^3/sec
installed capacity	72,000 kW
turbine rated speed	225 rpm
average annual energy output (1994)	622.6 GWh
tailwater level at max. discharge	41.5 m
Generator	
type	Semi-umbrella & revolving, Field Type
capacity	78,000 kVA
voltage	13.8 kV
cycle	60 Hz
power factor	0.9
Main transformer	
type	3 phase forced-oil-circulation and forced air cooled outdoor use.
voltage	13.8/230 kV
capacity	78,000 kVA
Transmission line and substation	
Transmission line	Double circuit single conductor
voltage	230 kV
conductor size	ACSR 795 MCM
length	43 km
Malaya substaiton	The Agos be connected to the Luzon grid through 230 kV transmission line without transformer at Malaya substation.

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ABBREVIATIONS AND UNIT

JICA	Japan International Cooperation Agency
NAPOCOR (NPC)	National Power Corporation of Philippines
NK	Nippon Koei Co., Ltd.
PICOREM	Presidencial Inter-Agency Committee for re-study of the Marikina River Multi-purpose Project
NEA	National Electrification Administration
MOE	Ministry of Energy
MERALCO (MECO).	Manila Electric Company
MWSS	Metropolitan Waterworks and Sewerage System
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
BPW	Bureau of Public Works
ECAFE	Economic Commission for Asia and the Far East
CDM	Camp, Dresser and McKee International, Inc.
M + E (M & E)	Metcalf and Eddy, Ltd.
$	United States Dollars
₱ (P)	Philippines Pesos
¥	Japanese Yen
FC	Foreign Currency
LC	Local Currency
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
O & M	Operation and Maintenance
L.F.	Load Factor
AMSL	Above mean sea level
EL.	Elevation in m AMSL
W.L. (WL)	Water level in m AMSL
H.W.L. (HWL)	High water level in m AMSL
L.W.L. (LWL)	Low water level in m AMSL
F.W.L. (FWL)	Flood water level in m AMSL
D.F.W.L. (DFWL)	Design flood water level in m AMSL
P.M.F.W.L. (PMFWL)	Probable maximum flood water level in m AMSL

mm	millimeter
cm	centimeter
m	meter
km	kilometer
m^3	cubic meter
km^2	square kilometer
ha	hectare
m^3/sec (cms)	cubic meter per second
m^3/sec.month	Water volume equivalent to the discharge of 1 m^3/sec for the duration of 1 month
kg	kilogram
t (ton)	metric ton
ℓ	liter
%	percent
°C	centigrade
°	degree
N	north
rpm	revolution per minute
Hz	Hertz (cycles per second)
kcal	kilocalorie
kV	kilovolt
kVA	kilovolt ampere
MVA	megavolt ampere
W	Watt
kW	kilowatt
MW	megawatt
kWh	kilowatt hour
MWh	megawatt hour
GWh	gigawatt hour
V	Volt
BTU	British Thermal Unit

CHAPTER 1

INTRODUCTION

1.1 Project Background

The idea of the Agos river development originated in 1915 when investigation was proposed by General de las Heras, being followed by the preliminary studies made in 1920 by Mr. G.E. Schreiber of J.G. White Engineering Co., on behalf of MERALCO. With his recommendations, the first gauging station was set up at Banugao, Infanta, Quezon Province, about 6 km upstream from the estuary. Hydrological data were collected through the stream gauging for two years, but no project formulation was made.

After establishment of the National Power Corporation (NAPOCOR) in 1936, three gauging stations and manual rain gauges were set up one each at Daraitan on the Kaliwa river, at Matatio on the Kanan river and at Bayokan on the Agos river. In 1943, NAPOCOR staff proposed six possible power stations on the basis of the data obtained. However, the Pacific War and other social disturbances in 1940s hindered even continuous river gauging. In August 1953, a project plan to construct a dam at Daraitan with 67.5 MW power station was proposed by Investigation and Planning Division of NAPOCOR. Follow-up actions were recommended in that report, but the socio-economic situation in 1950s did not permit the implementation.

High economic growth in the country during 1960s required the development of the power generation and many thermal power plants, mainly oil-fired, were constructed during this period, which occupied about 80 percent of the total generating capacity of Luzon. But, the oil crisis occurred in 1974 urged to change the future development policy emphasizing indigenous energy sources. In line with this, NAPOCOR made elaborate and comprehensive studies for power development called "Power System Luzon Generation Expansion Study". Based on this, the first 10 year development program was established, in which the Kanan hydropower development scheme was firstly included as one of the 10 urgent projects.

The proposed location is approximately 5 km upstream from the confluence with Agos, covering 357 km^2 of catchment area. According to the preliminary plan, a rockfill dam with 164 m high will be constructed with 480 million m^3 of effective storage. Water for power will be diverted through a tunnel of about 7 km to the power station to be located on the left bank of the Agos river. About 91 MW of annual average power can be generated, or 800 GWh of annual energy will be obtained. The installed capacity of 280 MW is tentatively suggested.

Following this, a proposal to make a field reconnaissance for Agos River Development Plan was submitted by Nippon Koei Co., Ltd. in February, 1978. The proposal was accepted and a reconnaissance team was sent to the project site in March, 1978. The results of the survey were compiled into a reconnaissance report, in which several alternative plans were proposed.

For facilitating this project, the Government of the Philippines requested Japanese Government to provide technical assistance for the feasibility studies for the Agos river hydropower development in mid 1978. The Government of Japan agreed with the request and sent JICA staff to negotiate the Terms of Reference with NAPOCOR in January 1979. Based upon the agreed Terms of Reference mutually signed on January 18, 1979, the JICA sent a Preparatory Survey Team consisting of 9 memebers from February 8 to March 28, 1979.

JICA Preparatory Survey Team made the preliminary studies on possible power development after the reconnaissance. Required follow-up actions and investigation program were also discussed with NAPOCOR. All the results were reported in an Inception Report submitted in March 1979. The Terms of Reference for the feasibility study works were agreed upon between JICA and NAPOCOR.

JICA sent the Feasibility Study Team for Agos River Hydropower Development Project from May 30, 1979. Detailed investigation and preliminary analysis were carried out at the site and the results and preliminary evaluation were reported in the Interim Report in December 1979. Detailed investigation and studies continued in 1980, on the basis of which an optimization study on the development of the Agos river systems was made by June 1980. All the results of the study and analysis were compiled into this Final Report.

In parallel to our study on the Agos river, water resources for the Kanan and Kaliwa rivers, tributaries of the Agos, were studied by MWSS for water supply to Metro Manila. The results of the study are carefully reviewed and are taken into account in this report.

1.2 Objectives and Scope of Study

The objectives of the feasibility study are to investigate the technical soundness and to determine the economic and financial feasibility of the project through field investigation and detailed analysis. The study is divided into two parts; Phase I Study for overall development study for hydropower development of the Agos river, in which optimum combination of the development plans is formulated; and Phase II Study for detailed feasibility study on the selected priority scheme.

Necessary investigation and study for the Phase I Study include the following items:

a) Review of all the existing data, reports and informations

b) Topographic survey

c) Aerographic survey and mapping

d) Geological investigation

e) Construction material survey

f) Meteorological and hydrological investigation

g) Power survey

h) Construction cost survey

i) Economic and environmental surveys including resettlement study

j) Comparative studies on the alternative development schemes and pre-selection of the optimum development plan

Necessary investigation and study for the Phase II Study include the following works:

a) Additional geological investigation and analysis

b) Additional construction materials survey, test and analysis

c) Meteorological and hydrological analysis

d) Reservoir operation study

e) Power study

f) Feasibility grade design of dam(s), power station and related structures on the proposed power scheme

g) Construction planning and cost estimate

h) Economic and financial analysis of the project

1.3 Feasibility Study and Report

JICA despatched the survey team headed by Mr. M. Tsuda from May 1979 and conducted the feasibility study under the close cooperation with NAPOCOR staff. (Name of the JICA experts and NAPOCOR counterpart staffs are listed in Table 1-1.)

All the results of the study and analysis were summarized into the Feasibility Report, which comprises:

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CHAPTER 2

THE PROJECT AREA

2.1 National Socio-economy

The Philippines is located between latitude 5° and 21° north and between longitude 117° and 127° east with an area of 300 thousand square kilometers. The natural conditions of the Philippines are very favorable for agricultural production. Total population of the country was about 42.1 million on 1975 with the population density of about 140 persons per square kilometer, which increased at an average rate of 2.8 percent per annum during the period of 1970 - 1975. The working population in 1975 is estimated at about 14.5 million, more than 50 percent of which is engaged in agricultural sector.

The gross domestic product (GDP) in 1978 was ₱171.1 billion or the equivalent of US$23.0 billion, and per-capita GDP was approximately ₱3,700 (US$500). About 39 percent of GDP is occupied by service sector followed by 35 percent of industrial sector. The agricultural sector has relatively lower share in GDP compared with other non-agricultural sectors, which accounts for 26 percent of GDP. During the past five years from 1974 to 1978, GDP in real terms increased by 6.3 percent per annum.

The government of the Philippines has embarked on the five-year plan (1978 - 1982) under the framework of the ten-year plan (1978 - 1987). The plan envisages to raise GNP at an average annual growth rate of 7.7 percent for the five-year plan period and 8.0 percent for the ten-year plan period in real terms. In order to attain this high target, massive public and private investment towards industrialization, agricultural modernization and human resources efficiency is planned.

2.2 The Project Area

2.2.1 General

The Agos river basin having 940 km^2 of drainage area is located in the east coast of Central Luzon, between the latitudes of 14°32'N and 15°N and the longitudes of 121°18'E and 121°40'E. The name of Agos is given to the utmost downstream reaches of about 23 km from the confluence of two principal tributaries, Kanan and Kaliwa, to its estuary to the Pacific Ocean between the towns of General Nakar and Infanta, Quezon Province.

Out of the total drainage area, 393 km^2 belong to the Kanan river, 473 km^2 to the Kaliwa and the rest of 74 km^2 to the basin along the main stream of Agos. The Kanan, the eastern tributary, orginates in latitude 15°N and flows from north to south between the two mountain ranges, one separating it from the Pacific coast on the east, and another separating it from the adjoining two river basins of Kaliwa and Umiray on the west. The heights of surrounding mountains range from 800 to 1,500 meters in elevation AMSL. The Kaliwa, another tributary of Agos, has a V-shaped watershed located in the west of Kanan basin, separated by a north-south mountain range on the west between the altitudes of 400 and 1,300 meters, beyond which the Marikina river drains further west area up to Manila Plain. On the southern divide, a series of hills ranging from 400 to 700 meters separates the Kaliwa basin from the Laguna de Bay watershed.

The Kanan river basin is sparsely populated and still covered with thick virgin forest and fairly thick top soils. The rainfall in the basin is more than 6,000 mm per annum. Only one rugged logging road extends through the jungle up to near the confluence of the Mayabiga river with Kanan with the total length of approximately 50 km. One rough air strip is available at Lagmac, a small hamlet located about 6 km upstream from the above confluence. Major transportation means for the mountain people is, therefore, limited to the navigation by small canoes. However, the boat transportation is not easy due to numerous rapids in the river and the navigation become almost impossible during flood season.

On the contrary, the Kaliwa river basin has been comparatively developed through the past logging operations and by many settlers. The Kaliwa river has two major branch streams of Lenatin and Limutan. The Lenatin river basin, located adjacent to the Marikina river watershed, is more developed with many small farms for coconuts, bananas and other cereal crops cultivated after logging or burning the forest. The Limutan river basin has been less developed due to difficult access. As for the main stream of the Kaliwa after the confluence of Limutan, the southern hill area has been developed for farms and plantations. The northern forest is under logging operation. Many jeepable logging roads are developed in the Kaliwa watershed, but no bridge exists. Therefore, all transportations are suspended during high flood season.

All three major towns, Infanta, Real and General Nakar, are located on the alluvial plain developed along the utmost downstream reaches of the Agos. Infanta and Real are connected with Famy by a gravel road crossing over the mountain and a paved highway to Manila. Total road length between Manila and Infanta is 143 km, out of which mountain road of about 34 km is closed from time to time due to land slide during heavy monsoon season.

For development of the region, the Ministry of Public Highways planned construction of a new highway of two lanes, connecting Marikina and Infanta with about 110 km length. The construction started from 1977 and is expected to be completed by the end of 1980. Upon completion of this highway, Infanta town will be connected with Metro Manila by two hours drive. The highway passes along the hillside near the proposed Agos damsite, so that the implementation of the project will have no difficulty for transportation of many heavy equipment and construction materials.

No town in this area is equipped with telephone except one wireless available between Infant and Manila. Therefore, for the smooth and efficient operation of the future construction works, an exclusive wireless equipment is required to be installed.

2.2.2 Administrative Structure

The Agos river basin, including the Kanan and Kaliwa basins extends over the Provinces of Quezon and Rizal. More than 80 percent of the catchment area of the Agos river belongs to the Province of Quezon, while the rest of the area belongs to the Province of Rizal. The catchment area in the Province of Quezon consists of the municipalities of General Nakar, Infanta and Real. The catchment area of the Lenatin river almost belongs to Rizal Province while that of the Limutan river, the Kanan river and the left bank of Kaliwa river belongs to the municipality of General Nakar. The catchment area of the right bank of Kaliwa river belongs to Infanta. The basin along the main stream of Agos belongs to the municipalities of General Nakar, Infata and Real. The municipality of General Nakar has the largest catchment area in the Agos river basin.

2.2.3 Population and Land Use

Total population of the three municipalities relating to the drainage area of the Kanan, Kaliwa and Agos rivers was estimated at about 57,600 in 1978, which consists of 14,220 of General Nakar, 27,800 of Infanta and 15,600 of Real. During the period of 1970 - 1978, the total population increased with a relatively high growth rate of 4.6 percent annually on an average. The highest population increase was recorded in General Nakar with the average growth rate of 6.5 percent per annum being followed by Real with 5.6 percent and Infanta with 3.1 percent.

Average population density is 30.6 persons per km^2 in the three municipalities, in which Infanta and Real have the relatively higher density of 114 persons and 53 persons per km^2, respectively. The population density of General Nakar is very low with only 10 persons per km^2 due to the limited available flat land.

Most of the people in the three municipalities live in the east coast. In the relatively well developed Kaliwa river basin, about 4,000 to 5,000 people inhabit while less than 1,000 people live in the Kanan river basin. A major native tribe called Dumagat inhabits both in the Kanan and Kaliwa river basins with an estimated total number of around 1,000.

Total land area of the three municipalities is about 1,900 km^2. More than 80 percent of the total lands are forest land. As explained in the preceding section, the forest in the Kanan river basin is mostly virgin forest, while that in the Kaliwa river basin is the secondary one mainly planted for coconut trees. Available agriculture land is quite limited with only a total of 180 km^2 or 9 percent of the total land area. About 15 km^2 or 0.8 percent of the total land area is now being used for fish ponds, most of which are located in Infanta and Real, while around 8 km^2 of the lands are for pasture. The residual area is allocated for cultivated lands, residential, commercial and others.

2.2.4 Regional Economy

Most important economic activities in the region are agriculture, fishery and forestry. In the agricultural activity, palay (paddy), coconut and banana are the three major crops. According to the agricultural census conducted in 1971, about 3,270 tons of palay, 10 million of coconuts and 1,720 tons of banana were produced in the three municipalities. Other minor crops cultivated in the region are corn, sugar cane, beans and coffee. Livestock breeding is not a main line of the region's agriculture and a limited number of animals such as carabaos, hogs, cattles, horses, goats, chickens and ducks are being raised partly for animal power and partly for self-consumption. Fishery is another important economic activity in the region. From offshore or coastal fishing, about 66 tons of fish are produced annually. Species of fish caught in Lamon Bay and Polillo Strait are round scad, skipjack, anchovies, mackerel, sardines, shipmouth, moonfish, pogy, cavalla and nemipteried. Fresh water fish and brackish fish are cultivated in the fish ponds. Annual production in the fishponds is estimated at 750 tons in the region. Species of fish cultivated are freshwater fish like bangus, shrimp and prawn. Although the quantity is very limited, fishing of such fresh water fish such as milkfish, mudfish, eel, carp and crab is being practised in the Agos river mainly for self-consumption.

There are three logging companies located in the region, which are De Dios Enterprise Logging Corporation, Infanta Logging Corporation and Eastern Plywood Corporation. At present, only the Infanta Logging Corporation is under operation. Maximum production of logs is set at 22,000 m^3 per year. Major type of the logs is lauan.

2.2.5 Infrastructure

The Agos river irrigation system was completed in 1959 by the National Irrigation Administration (NIA). The irrigation system consists of an intake structure at Banugao, 8.1 km of main canals, 39.7 km of lateral canals and 15.7 km of farm ditches. The intake structure is located at the right bank of the Agos river about 6 km upstream from the estuary. Irrigable area is about 1,000 ha at present, which is expected to expand up to 1,200 ha in the near future. Beside the Agos river irrigation system, a communal irrigation system is installed in General Nakar. The system also takes the irrigation water from the Agos river using pump and commands the area of about 250 ha.

Electricity is being supplied only to Infanta town proper in the region by the Infanta Light and Power Service Cooperative which was established in the Poblacion of Infanta in October 1964. At present, two units of 100 kVA diesel generators and one 30 kVA generator are being operated to produce about 37,000 kWh of the electricity per month. Average power tariff is estimated at ₱1.2 per kWh in 1979. Consumers now benefitted by the cooperative consist of 621 residential, 129 commercial, 75 street lights and one industrial. Electric power is not yet available both in General Nakar and Real, where kerosene lamp is mainly used for lighting.

Municipal water supply systems are available for the towns of Infanta, Real and General Nakar. But the percentage of the benefitted household by the systems is still low. Water charge is ₱5.00 to ₱10.00 a month at present. Wells and springs are the major water source for the system. In the rural areas in the region, there is no water supply system and the people takes water from river, streams, springs, wells and rainwater.

CHAPTER 3

THE POWER SECTOR

3.1 Power System in the Philippines

Electric power generation in the Philippines is now being made by National Power Corporation (NAPOCOR), Manila Electric Company (MERALCO) and private-owned cooperatives. By the Presidential Decree/1, the Ministry of the Energy (MOE) was created, under which NAPOCOR has become the solely responsible organization for generation by larger power stations and transmission.

Electricity distribution and sales in the rural areas is the responsibility of individual area cooperative operating under the auspices of the National Electrification Administration (NEA). These co-operatives either generate electricity using diesel driven units or buy from the grid if they are connected.

Total installed capacity in the Philippines is around 3,600 MW/2 in 1979. About 3,000 MW of the installed capacity or 83 percent is located in Luzon grid, while 152 MW or 4 percent is in the Visayas grid and 455 MW or 13 percent in Mindanao grid. With respect to power grid, steam power is predominant with its share of 62 percent of the total capacity followed by hydropower with 26 percent share. The geothermal power of 223 MW capaicty was developed in 1979, and its share occupies 6 percent. The diesel power is limited to the isolated islands or places with its share of only 6 percent. Before 1978, most of the steam power generating facilities were owned by MERALCO particularly in Metro Manila. After NAPOCOR's acquisition of MERALCO steam power plants with the installed capacity of about 1,700 MW in 1978 - 79, about 85 percent of the total generating facilities are now owned by NAPOCOR.

Total length of the transmission line is 9,800 circuit km/3 in the whole country, which includes 1,525 km of 230 kV, 824 km of 138 kV, 1,087 km of 115 kV and 6,363 km of 69 kV and below. About 82 percent of the transmission line is located in Luzon grid, while around 13 percent is in Mindanao grid and only 5 percent in the Visayas grid.

Total electric power generation and consumption in the country amounted to 12,488 GWh and 10,887 GWh, respectively in 1978/4. About

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/1 Presidential Decree No.1206 dated 6 October, 1977.

/2 NAPOCOR Plants plus MERALCO Plants.

/3 Circuit km = Nos. of circuit x route length (km).

/4 NAPOCOR and MERALCO only.

89 percent of the electric power was consumed in Luzon grid, 9 percent in Mindanao grid, while only 2 percent was consumed in the Visayas grid. Per capita consumption of electric power in the Philippines was 235 kWh in 1978.

Electrification ratio is still in low level of 32 percent in the whole country. About two million households have been benefitted from the electrification. (Details of the national electric power supply system, consumption and electrification are presented in Appendix C Power Study.)

3.2 Electric Power in Luzon

3.2.1 Power Station and Transmission Line System

Electric power in Luzon is being supplied mainly by NAPOCOR and MERALCO supplemented by small private generation utilities. Total installed capacity of the system was around 3,000 MW in 1979 which consists of 540 MW of hydropower plants and 2,450 MW of thermal power plants including 220 MW of geothermal plant. As indicated in these figures, Luzon grid still relies heavily on thermal power plants particularly on oil-fired thermal plants.

In line with the national policy for saving fuel oil consumption, NAPOCOR has emphasized exploitation of non-fuel oil energy sources such as hydropower and geothermal power. Total generating capacity now under construction amounts to 1,510 MW, of which 670 MW for hydro plants, 620 MW for nuclear and 220 MW for geothermal plants. Existing power stations in Luzon are summarized in Table 3-1.

In parallel with the expansion of the generation facilities, NAPOCOR has expanded the transmission line system in Luzon grid. Total length of transmission line in Luzon grid was 8,060 km, higher than 13.8 kV, which includes 1,525 km of 230 kV line, 1,087 km of 115 kV line and 5,450 km of 69 kV line and below. By the end of 1981, about 2,511 km of the transmission line will be added to the present system to catch up with the expansion program of the generating facilities and to extend electric power to unelectrified areas. Included in the expansion program are 1,513 km of 230 kV line, 35 km of 115 kV line and 961 km of 69 kV line.

The location map of the existing power stations, transmission lines and substations are presented in Dwg.1 of Appendix C.

3.2.2 Electric Power Generation and Consumption

Total net power generation in Luzon attained 11,239 GWh in 1978, which consisted of 3,641 GWh produced by NAPOCOR, 7,145 GWh produced by MERALCO and 453 GWh by self-generating cooperatives and industries. About 80 percent of the total power generation, or 9,041 GWh, was made by thermal power which is mainly oil-fired and steam power plants while 16 percent or 1,745 GWh was made by hydropower plants and 4 percent or 453 GWh by self-generation. These figures indicate that the power sector in Luzon highly depends on the imported oil.

Total electric power consumption in Luzon was 10,217 GWh in 1978. About 23 percent of the energy sold or 2,354 GWh was supplied by NAPOCOR. About 73 percent or 7,433 GWh by MERALCO and the residual 4 percent or 430 GWh by self-generation. By sector, the industrial sector consumed the largest portion of the energy with 38 percent share followed by residential use with 34 percent. The commercial sector consumed 23 percent while the miscellaneous consumed 5 percent/1.

Both the power generation and power consumption have increased with relatively high growth rate of 10 percent per annum. During the period of 1960 - 1969, the highest annual growth rate of over 13 percent was recorded. The rate of growth slowed down to around 8 percent per annum from 1969 to 1973 and stagnated during 1973 - 1974 due to the oil crisis and the following economic disturbance. From 1974 to 1978 the growth rate started to increase again with an average annual growth of about 7 percent. Annual growth rates for the power generation and power consumption are summarized as shown below (Historical growth of the power consumption is presented in Table 3-2).

Period	Power Generation	Power Consumption
1960 - 69	13.5 % p.a.	13.8 % p.a.
1969 - 73	8.2 % p.a.	8.5 % p.a.
1973 - 74	0.7 % p.a.	0.9 % p.a.
1974 - 78	7.9 % p.a.	7.4 % p.a.
(1960 - 78)	(10.4 % p.a.)	(10.6 % p.a.)

Maximum demand in Luzon was recorded at 1,860 MW in 1978. During the past 18 years, it expanded at an average annual rate of 9.3 percent. The annual expansion of the peak demand was very high (11.7 percent) during 1960 - 1969, which decreased gradually at 9.3 percent and 6.4 percent in 1969 - 1972 and 1973 - 1978, respectively.

/1 including, miscellaneous of NAPOCOR and street light of MERALCO.

The load factor of the generating facilities has been gradually increasing since early 1960s and attained 69 percent in 1978. The system loss has been decreased from early 1960s and was estimated at 9 percent in 1978.

Typical daily load curve of the Luzon grid is presented in histogram form in Fig.3-1. This curve shows that peak load time is 8 to 10 hours during 10 AM to 8 PM. During this period the curve is relatively flat and there is no extreme heavy load. Under this condition peaking hours required for hydropower stations are estimated at 8 to 10 hours.

3.2.3 Tariff and Revenue

Different tariff rates are set applicable to defferent grids in the Philippines by NAPOCOR. Tariff of Cebu and Panay grids is the highest in the three girds, while Mindanao is the lowest which is determined by taking into account their developmental stage and energy cost.

Tariff set by NAPOCOR consists of demand charge which is proportional to billing demand and basic energy charge which is proportional to energy consumption. In addition, fuel cost adjustment has been made when the weighted average cost of fuel burned in thermal power plants during any month is either higher or lower than the basic price and the basic energy charge shall be proportionately increased or decreased.

Total sales revenue of NAPOCOR was ₱921.6 million/1 in 1978. About 80 percent or ₱738.7 million of the total sales revenue was raised in Luzon. From 1972 to 1978, sales revenue in Luzon increased at an average rate of 45 percent per annum. Average revenue per kWh in Luzon was ₱0.2/2 in 1978, which was slightly higher than that of the whole country. Historical sales revenue of electric power is shown in Table 3-3.

3.3 Demand Projection

3.3.1 Previous Studies

The overall electric power development in Luzon from 1976 to 1977 was studied/3 to review the past accomplishment and to program future development plan up to year 2000. In this study, expected power consumption was forecasted using elaborated exponential demand function

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/1 Including fuel cost adjustment.

/2 From September 1980, the average power rate becomes ₱0.40/kWh.

/3 Power system Luzon Expansion Study, Lahmeyer International GmbH.

incorporating four (4) variables: (i) population, (ii) proportion of population actually served, (iii) oil price, and (iv) gross regional product per capita. The estimated overall growth rate from 1977 to year 2000 is 9.2 percent per annum with the following breakdown:

Period	Average Annual Growth Rate
1977 - 1980	11.7 %
1981 - 1985	10.7 %
1986 - 1990	9.3 %
1991 - 1995	8.1 %
1996 - 2000	7.2 %

This estimated growth rate was applied to the Luzon Grid Expansion Program prepared by NAPOCOR in early 1978. In the expansion program, electric power consumption in Luzon is estimated to reach 34,960 GWh in 1990 with an average annual growth rate of 10.6 percent.

Following the above projections, NAPOCOR revised the expansion program two times in June 1979 and in 1980 according to the recent trend of consumption increase and relatively modest economic expansion prospect during the next decade. In the latest revised program, electric power consumption is expected to grow by 7.0 percent until 1990, which is relatively lower than the estimated figure in the previous program. The revised expansion program is given in Table 3-4.

3.3.2 Future Demand Estimate

For estimating future power demand in Luzon, historical power consumption and peak demand were reviewed again. As explained in the preceding section, both the power consumption and the peak power demand showed higher growth trend during 1960 - 1969 period. After 1969, the trend of growth was relatively lower with an increase rate of 7 - 9 percent per annum excluding 1972 - 73 period. The change in trend after 1969 indicated that the power consumption in Luzon entered into a lower growth stage corresponding to the *socio-economic structural* change.

<table>
<tr><th>Period</th><th>Energy Consumption</th><th>Peak Power Demand</th></tr>
<tr><td>1960 - 1969</td><td>13.8 % p.a.</td><td>11.7 % p.a.</td></tr>
<tr><td>1969 - 1972</td><td rowspan="2">8.5 % p.a.</td><td>9.3 % p.a.</td></tr>
<tr><td>1972 - 1973</td><td>0.3 % p.a.</td></tr>
<tr><td>1973 - 1974</td><td>0.9 % p.a.</td><td rowspan="2">6.5 % p.a.</td></tr>
<tr><td>1974 - 1978</td><td>7.4 % p.a.</td></tr>
</table>

After reviewing the trend of power consumption, correlation between the power consumption growth and the national economic growth was reviewed and checked. Since the correlation between per capita power consumption and per capita income has already been established in many countries and well applied for future projection, these two indicative figures are used for our projection. The most beneficial point for this approach is that it can incorporate the factors of the different stages of development in the country and makes it possible to estimate relatively long-range projection.

On the basis of the available data, per capita consumption in Luzon Mainland/1 and per capita GNP are calculated during the period of 1960 - 1978. In order to check the income elasticity of power demand, relation between power consumption in Luzon grid and per capita GNP is plotted on logarithm scale section paper as shown in Appendix C, Power Study. The curve is produced by linear regression method to remove random element. From this, it is identified that there are three major changes in trend of income elasticity of power demand. During the period of 1960 - 1963 *and 1964 - 1970, higher income elasticities 3.60 and 5.13, respectively,* were recorded. But the elasticity slowed down to 1.01 during the period of 1970 - 1978.

(1) Projection of Electricity Consumption

Future electricity consumption is estimated by applying the estimated recent trend of the income elasticity of power demand on the following assumptions:

a) The low income elasticity of 1.01 will be maintained during the period of 1979 - 1995.

b) Population increase in Luzon Mainland/2 will be:

1978 - 1980	3.09 % p.a.
1981 - 1985	2.90 % "
1986 - 1990	2.76 % "
1991 - 1995	2.43 % "

c) Per capita income growth/3 will be:

1978 - 1983	4.05 % p.a.
1983 - 1987	5.25 % "
1988 - 1995	5.10 % "

/1 Luzon Mainland: Region I to IV excluding the Provinces of Marenduque, Occidental and Oriental Mindoro, Palawan Catanduanes and Masbate.

/2 NEDA Projection.

/3 Ibid.

The projected power consumption is 17,140 GWh in 1985 and 25,350 GWh in 1990 and 36,900 GWh in 1995 as presented in Table 3-5.

(2) Peak Power Demand

Peak power demand in the future is estimated on the following assumptions:

a) System loss excluding station use is 7.5 percent during 1979 - 1982, which will decrease to 7.0 percent from 1983 to 1987 and 6.5 percent from 1988 to 1995.

b) Load factor is 69 percent during 1979 - 1982, which will increase to 70 percent during 1983 - 1995.

Projected peak power demand is 3,000 MW in 1985, 4,420 MW in 1990 and 6,430 MW in 1995. Details of the estimated figures on power consumption and peak power demand are presented in Table 3-5.

The estimated power consumption and peak power demand in the future are plotted in Fig.3-2 and 3-3 respectively, together with NAPOCOR projection. As shown in the figures there are no major difference between our estimate and NAPOCOR projection both for the projected peak demand and power consumption although our projected figures are slightly higher than that of NAPOCOR in the later stage. The projections of NAPOCOR seems to be reliable one for the study of future expansion program at present.

3.4 Expansion Program and Agos Project

To cope with the expected power demand increase, a long term expansion plan is formaulated by NAPOCOR for the period of 1980 - 1990. The plan envisages to generate 28,033 GWh with the installed capacity of 5,571 MW in Luzon by 1990. The average annual increase rate for the energy generation and installed capacity during the planned peirod are set at 6.4 percent and 4.8 percent respectively.

The most predominant characteristic of the plan is to reduce heavy dependence on imported oil during the projected period by utilizing indigenous energy sources such as hydropower, geothermal and coal thermal. Hydropower development is emphasized and it is expected to dominate 46 percent of the total installed capacity at the end of the planned period. The shares of geothermal plant and coal-fired thermal plant are also expected to grow considerably with the planned target of 10 percent and 5 percent, respectively. The oil-fired thermal plant, on the contrary, will reduce its share from present 72 percent to 27 percent.

In parallel to the expansion of the power generation, expansion of transmission line and substation capacity are also planned. The target total length of the transmission line in 1990 is 4,625 km in Luzon grid including 503 km EHV 500 kV transmission line connecting the Abulog and Chico hydropower stations to Manila. The target sub-station capacity is set at 5,055 MVA in the Luzon grid.

The Agos Hydropower Project is included in the power expansion plan with the installed capacity of 140 MW. The project construction is expected to start from 1983 and the hydropwoer station is planned to commission in 1989. Fig.3-3 presents the relation between planned power plant expansion program and projected peak demand. From this figure it is proven that the expansion power plan considers enough allowance for the capacity even if the peak power demand grows with relatively higher increase ratio than the estimated one in the preceding section.

Fig.3-2 shows the relation between available energy and projected energy demand. According to this, surplus energy will not be sufficient enough in 1985 and 1990, considering the yearly stop of thermal power station for maintenance.

CHAPTER 4

RESULTS OF SURVEY AND INVESTIGATION

4.1 Topography

The available maps for planning of the Agos Hydropower Project were the national maps of 1 to 50,000 scale with 20 meter contours, which cover whole the project area. For the detailed study, the following survey works were required to be conducted.

a) Preparation of aero-photo maps covering the proposed reservoir area (1 to 5,000 scale with 5 meter contours),

b) Ground control survey by staking points for horizontal and vertical control

c) Setting bench marks from the estuary of the Agos river to the Agos damsite

d) River profile and cross-section survey from the estuary of the Agos river to the Agos damsite

e) Preparation of detailed topographical maps of 1 to 1,000 scale with 1 meter contours covering the following areas

i) Agos damsite (1.92 km^2)

ii) Afterbay weir site (0.32 km^2)

iii) Kanan No.1 damsite (0.83 km^2)

Out of the survey works listed above the aerial-photo maps for the reservoir area along the Kanan river were prepared by PICOREM. The copy of which was given to us in October 1979. The aerial-photo maps for the remaining reservoir area mainly along the Kaliwa river were prepared by NAPOCOR and were given to us in July 1980. All other topographic surveys were carried out by JICA experts and NAPOCOR surveyors.

Besides the above, the survey works required for the geological and construction material investigations including the line survey of seismic exploration were conducted. Longitudinal cross section survey for the Kanan No.5 damsite (previously selected by Lahmeyer Consult Co.) was also made for reference. All the survey works were almost completed by the end of August 1980. The survey works conducted during the whole study period for the Project are summarized in Dwg.2.

4.2 Meteorology

Located between the latitudes of 12°N and 19°N, the Luzon has a tropical climate, predominatly affected by the North-East Monsoon prevailing from November to February and the South-West Monsoon from July to September. The trade winds come from the east during the rest of the year and whenever the monsoon is weak. The mountain ranges in Luzon, generally running from north to south, cause the rising of humid air mass inflow bringing heavy showers on the slope facing the inflow direction, and on the other hand function as the mountain barriers against the humid air mass inflow into inland area.

As the Kanan river basin is located near the east coast of Central Luzon, the rainy season of this area is mainly affected by the North-East Monsoon resulting the much rain from October to January. While the Kaliwa river basin is affected by both the North-East and the South-West Monsoons due to its location resulting the two peak months of rainfall in August and November. Further, the Kanan river basin has average monthly rainfalls not less than 160 mm even in the dry season being affected by the trade winds, while the Kaliwa river basin has distinct dry season spanning over four months from January to April.

There were four rainfall gauging stations operated by NAPOCOR in the Agos river basin from 1937 to 1950. In addition, PAGASA has operated one meteorological station at Infanta from 1926 to present. The average monthly rainfalls recorded at the five stations are listed as follows.

The rainfall characteristics mentioned above are clearly shown in the following table. The average annual rainfall of 6,170 mm recorded at Matatio suggests that very heavy rain and large flood occur in the Kanan river basin.

The number of days less than 10 mm rainfall per day in Infanta is about 265 in a year or about 173 in the dry season from February to August. Since most of rains in the Agos river basin are not brought by daily tropical showers but by monsoon, tradewinds and typhoons, there is no clear difference in rainfall between the morning and the afternoon on an average in the long-run.

To resume the rainfall observation after the stopage of 28 years, NAPOCOR hydrology team set up five manual rain gauges in June and July 1978. Six new automatic rain gauges, effective for three months' operation were set up in August and September 1979 by NAPOCOR-JICA joint hydrology team at the higher and the upper reaches as far as accessible at present as shown in Fig.4-1.

An isohyetal map of the average annual rainfall in the Agos river basin is prepared based on the past rainfall records and those records obtained by newly established rain guages. The isohyetal map is shown in Fig.4-2. The heavy rainfall in the Kanan river basin is clearly seen

Average Monthly Rainfall in the Agos River Basin

Station	Infanta	Bayokan	Matatio	Daraitan	Sta. Ines
Basin	Agos	Agos	Kanan	Kaliwa	Kaliwa
Record Length in Year	44	5	7	5	3
Period	1927 - 1979	1939, 1947 - 1950	1937 - 1939 1947 - 1950	1937 - 1939 1947 - 1948	1937 - 1939
Jan.	367	424	682	124	63
Feb.	232	281	364	61	15
Mar.	184	213	326	62	54
Apr.	191	186	289	93	84
May	227	180	237	165	249
June	220	195	164	206	325
July	240	250	275	352	607
Aug.	203	314	326	482	616
Sep.	304	348	354	341	316
Oct.	511	605	658	382	346
Nov.	598	801	1,342	531	566
Dec.	561	872	1,153	418	359
Total	3,838	4,669	6,170	3,217	3,600

in the figure. The map gives the average annual rainfall of 5,890 mm and 3,550 mm for the Kanan and Kaliwa river basins respectively.

From the above studies, it can be said that the Agos river basin abounds with rich rain partly exceeding 6,000 mm per annum but its areal distribution is quite different between the Kanan and Kaliwa river basins due to their locations and topographic conditions.

The average air temperature and relative humidity at Infanta are 26.8°C and 83.1 percent respectively. As the Agos river basin is located between the latitude of 14°32'N and 15°00'N, the air temperature does not vary so much through a year. The lowest temperature normally occurs in January, while the highest in June. However, the difference of the monthly average temperature between January and June is only as small as 4°C.

Strong wind having the highest momentary velocity of 52.5 m/sec equivalent to 189 km/hour is recorded at Infanta.

The average evaporation of 1,420 mm per annum is recorded at Cuyambay, about 8 km south-west of the proposed Kaliwa damsite.