THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT
OF
FEASIBILITY STUDY
ON
KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

NOVEMBER, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of the Philippines, the Government of Japan decided to conduct a feasibility study on Kalayaan Pumped Storage Plant Development Project Stage II and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a study team headed by Mr. Morihiro Sato of Electric Power Development Co., Ltd. three times during the period from January 1990 to September 1990.

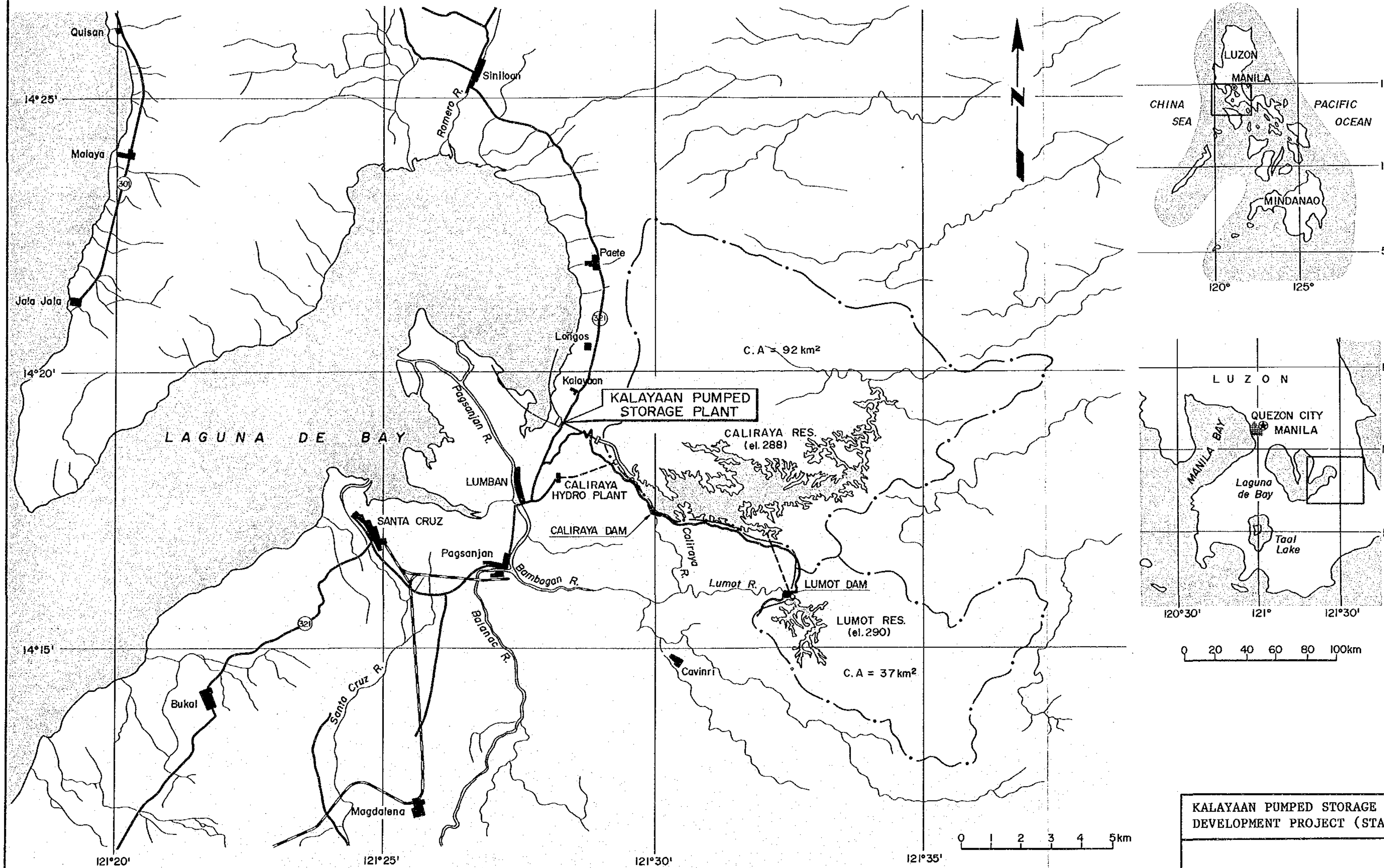
The team held discussions on the project with officials concerned of the Government of the Philippines and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my sincere appreciation to officials concerned of the Government of the Philippines for their close cooperation extended to the team.

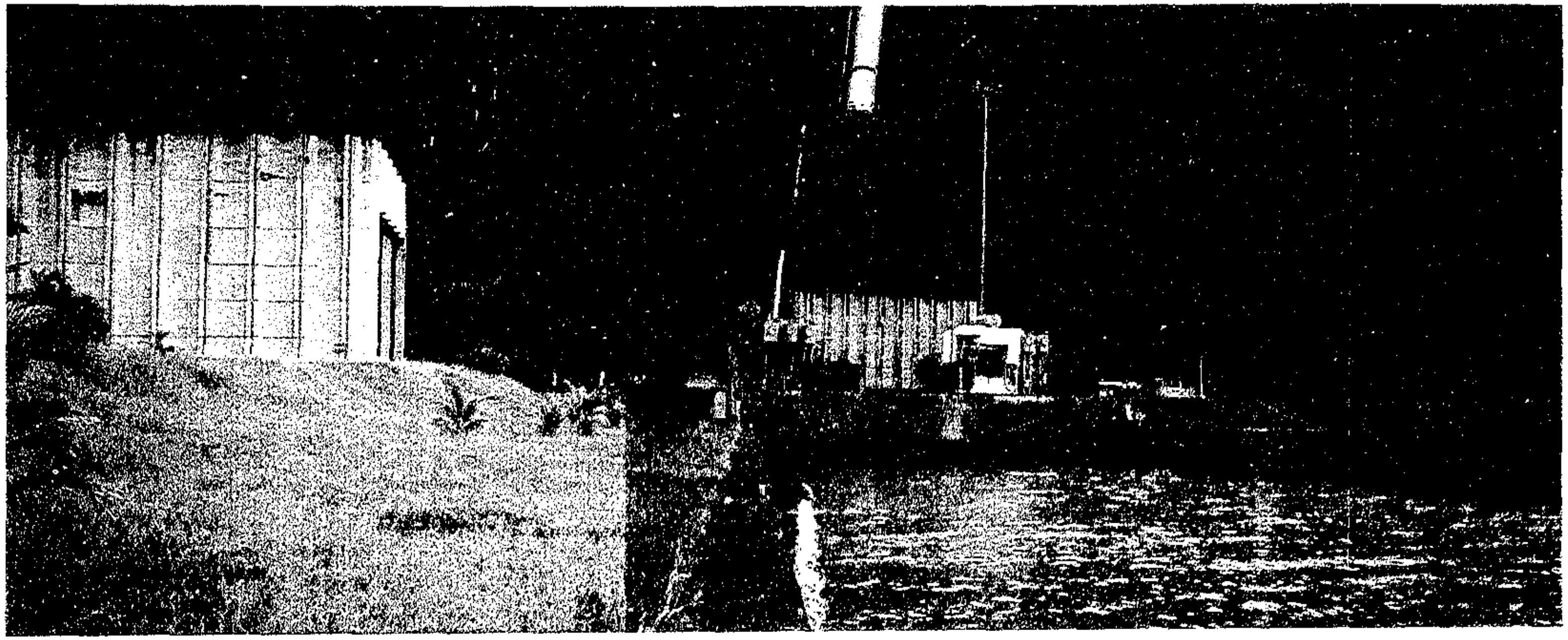
November 1990

Kensuke Yanagiya
President
Japan International Cooperation Agency

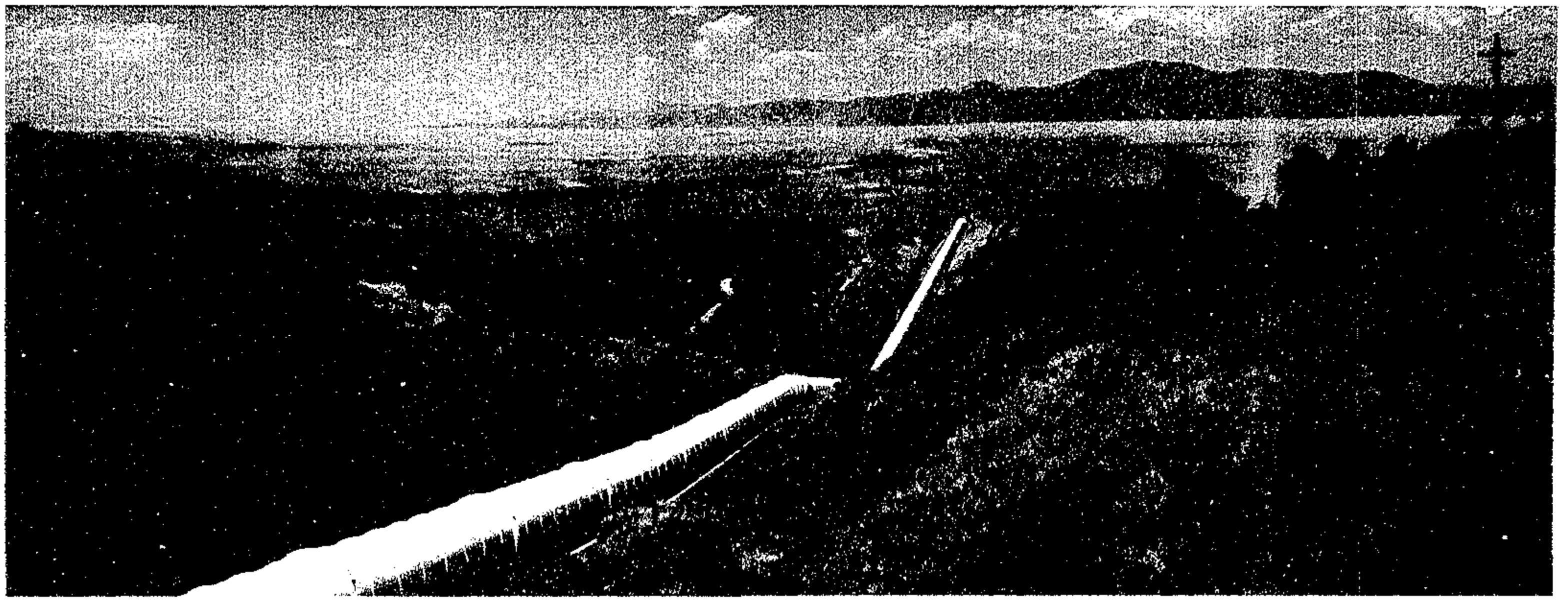


KALAYAAN PUMPED STORAGE PLANT
DEVELOPMENT PROJECT (STAGE II)

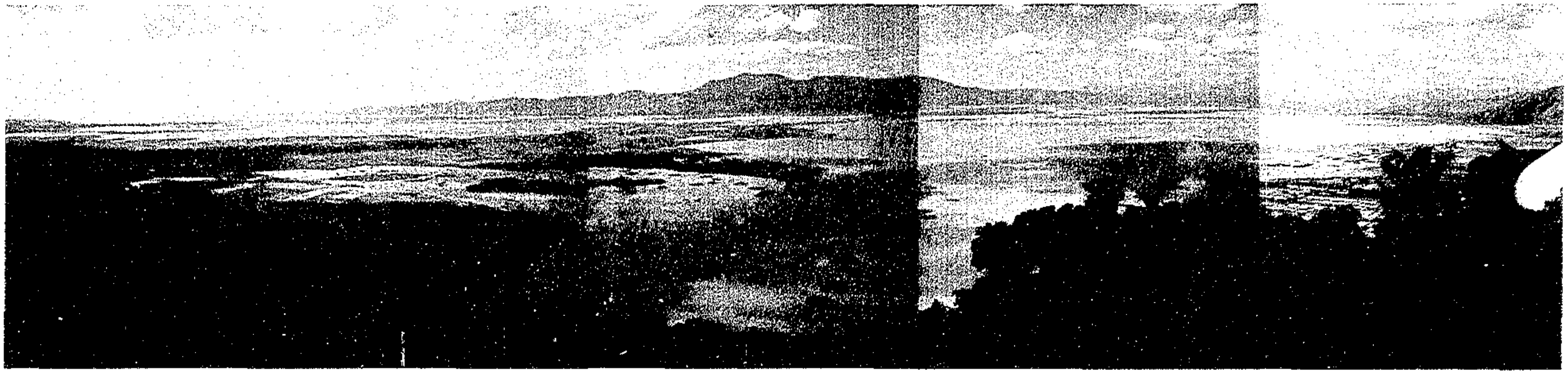
REGIONAL MAP & ROADS



Kalayaan Pumped Storage Power Plant and Tailrace



Existing Penstock for Stage I Project



Grown Floating Aquatic Plants in the Tailrace

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UNITS

m	-	meter, unit of length
km	-	kilometer (1,000 m)
m^2	-	square meter
m^3	-	cubic meter
m^3/s	-	cubic meter per second
V	-	volt, unit of voltage
kV	-	1,000 volts
W	-	watt, unit of active power
kW	-	1,000 W
MW	-	megawatt (1,000 kW)
VA	-	volt-ampere
MVA	-	megavolt-ampere (1,000 kVA)
Wh	-	watt-hour, unit of energy
kWh	-	1,000 Wh
MWh	-	megawatt-hour (1,000 kWh)
GWh	-	million kWh
rpm	-	revolutions per minute
Hz	-	hertz, unit of frequency
hr, (hrs)	-	hour
m-kW	-	unit of specific speed
g	-	gram, unit of weight
kg	-	1,000 g
t	-	ton (1,000 kg)
MT	-	metric ton
l	-	liter
BTU	-	British Thermal Unit
LB	-	pound
cal	-	calorie, thermal unit
Kcal	-	kilocalorie (1,000 cal)

CURRENCY

P	-	Philippine Peso
US$	-	U.S. Dollar
US$M	-	million dollars

Foreign Exchange Rate

P22.50 = $1.00
P 1.00 = $0.0444

ABBREVIATIONS

Stage I Project	-	Existing Kalayaan Pumped Storage Power Plant
Stage II Project	-	Extension of Kalayaan Pumped Storage Power Plant
NAPOCOR	-	National Power Corporation
JICA	-	Japan International Cooperation Agency
KPSPP	-	Kalayaan Pumped Storage Power Plant
AC	-	Alternating Current
AV	-	Average
AVR	-	Automatic Voltage Regulator
A.E.G.	-	Annual Energy Generation
BOD	-	Biochemical Oxygen Demand
B/C	-	Benefit Cost Ratio
CB	-	Circuit Breaker
CIF	-	Cost, Insurance and Freight
CL	-	Caliraya Lake
Comm	-	Commissioning
C&F	-	Cost and Freight
Dep Enr	-	Dependable Energy
Dia	-	Diameter
DO	-	Dissolved Oxygen
EDCOP	-	Engineering & Development Corporation
EIA	-	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
EL	-	Elevation
ELC	-	Electroconsult
EPA	-	Environmental Protection Agency
Ex Rate	-	Exchange Rate
FC	-	Foreign Currency
FWS	-	Free Water System
GDP	-	Gross Domestic Product
Gen	-	Generation
GOV	-	Speed Governor for Water Turbine
HWL	-	High Water Level
Hyd	-	Hydro
IDC	-	Interest During Construction
Ins Cap	-	Installed Capacity
LC	-	Local Currency
LEI	-	Lake Evaluation Index
Lf	-	Load Factor
LL	-	Laguna Lake
LLDA	-	Laguna Lake Development Authority
LOLP	-	Loss Of Load Probability
LWL	-	Low Water Level
Max	-	Maximum
MELARCO	-	
Min	-	Minimum
NEDA	-	National Economic Development Authority
NE-SW	-	Northeast-Southwest
ph	-	Phase

PLC	-	Programmable Logic Controller
Pow	-	Power
puMW	-	per unit MW
r	-	Discount Rate
SFS	-	Subsurface Flow System
St.s	-	Station Service
Thr	-	Thermal power
Tot	-	Total
TSI	-	Trophic State Index
VAT	-	Value Added Tax

Conclusions and Recommendations

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

(1) Introduction

The Kalayaan Pumped Storage Stage II Project has been studied in terms of its necessity, engineering problems, environmental impacts and its economic feasibility, and the conclusion as described below have been obtained.

(a) In meeting the rapid economic growth of the Republic of the Philippines, in particular Metro Manila, a large number of electric power supply facilities are needed in future. As these power sources are required urgently, and must be provided economically, the focus of power development will be placed on coal-fired thermal power plants in near future.

(b) The Stage II Project of Kalayaan Pumped Storage Power Plant should be implemented as soon as practicable in order to economically operate the thermal power plants referred to above, to have the supply capability respond quickly to load variation by means of hydroelectric power plants, and to assure stable and high quality supply of electric power.

(c) This Project is favorably situated for electricity supply as it is located only 60 km to the southeast of Metro Manila, which is the largest load center of the Republic. In addition, as certain civil structures, such as dam, intake, and penstock route have been provided in construction works of Stage I, they can be utilized for the Stage II Project. With these provisions, the construction period can be reduced and the construction cost of the Stage II Project will be low.

(2) Size and Timing of Development

(a) Size of the Project

The size of the Stage II Project shall be 300 MW, with two 150 MW units.

(b) Timing of Development

The following development schedule is proposed based on the projection of power supply and demand balance.

First Unit (Unit No. 3): January 1997
Second Unit (Unit No. 4): July 1997

(c) Transmission System

It is not necessary to prepare a new transmission line for the Stage II Project, because the existing transmission line of 230 kV can be utilized for the Project.

(3) Basic Design Parameters of the Project

The basic design parameters of the Stage II Project are presented in Table-1.

Table-1 Specifications of the Stage II Project

		Caliraya Reservoir	Lumot Reservoir
1. Upper Reservoir			
Catchment area	km^2	92	37
High Water Level	m	EL. 288.00	EL. 290.00
Low Water Level	m	EL. 286.00	EL. 286.00
Effective storage capacity	10^6 m^3	22.09	22.00
Total storage capacity	10^6 m^3	79.01	43.8

2. Dam (Existing)			
Type		Upstream side concrete-protected earth-fill	Upstream side concrete-protected earth-fill
Crest elevation	m	EL. 292.00	EL. 294.00
3. Spillway (Existing)			
Normal-use spillway type		Vertical shaft with gate	Overflow vertical shaft
Dia. x length	m	4.2 x 320	4.0 x 214
Emergency spillway type		Overflow	
Overflow crest EL	m	EL. 291.30	
Overflow crest length	m	160	
4. Lower Reservoir (Natural lake)		<u>Laguna de Bay</u>	
HWL	m	EL 3.24	
Av. water level	m	EL. 0.60	
LWL	m	EL.-0.36	
Total storage	10^6 m^3	4,000	
5. Upper Canal (Existing)			
Water surface width	m	100.00	
Bed width	m	45.00	
Bed elevation	m	EL. 281.50	
6. Penstock			
Surface portion Dia. x length x lines	m	6.00-5.00 x 1,200 x 1	
Tunnel portion Dia. x length x lines	m	3.30 x 100 x 2	

7. Power Generation Scheme

		Generating	Pump-up
Gross head (Normal water level)	m	286.40	286.40
Normal effective head	m	282.00	-
Max. effective head (Max. total pump head)	m	287.20	291.40
Min. effective head (Min. total pump head)	m	278.40	283.80
Max. power discharge (Max. total pump head)	m^3/s	62.0 x 2	49.9 x 2
Max. output/input	MW	152 x 2	159 x 2
Pump-Turbine			
Type		Reversible vertical type Francis pump-turbine	
Number	Unit	2	2
Rated output	MW	154	
Input (Min. total pump head)	MW		155
Rated speed	rpm	360	360
Motor-Generator			
Type		3-ph, AC, synchronous generator-motor	
Number	Unit	2	2
Output	(MVA, MW)	167	155
Frequency	Hz	60	60
Pump-up starting system		Pony motor start and back to back start	
Main transformer			
Type		Outdoor, 3-ph forced oil, air-cooled	
Number	Unit	2	2
Capacity	MVA	170	170

Frequency	Hz	60	60
Voltage	kV	230/13.8	
Outdoor Switchyard			
Bus bar system		1 - 1/2 CB system, transmission line outgoing 6 cct	

(4) Construction Cost

The total construction cost of the Project, including interest during construction, is estimated at US$ 170.97 millions. The major items of the construction cost are presented in Table-2.

This construction cost is estimated based on the prices of January 1990. The annual interest rate is assumed to be 6.33% for foreign currency and 20.0% for domestic currency.

The construction cost items in the table are indicated in U.S. dollars, and the exchange rate is assumed to be 1 US$ = 22.5 pesos.

Table-2 Estimated Construction Cost

(Unit: US$M)

	Foreign Currency	Domestic Currency	Total	Note
Preparation Works	0.48	1.57	2.05	
Civil Works	9.26	17.17	26.44	
Hydraulic Equipment	16.75	14.45	31.20	including dredger
Electromechanical Equipment	60.40	5.80	66.20	
Administration Cost	4.00	3.55	7.55	6% of total
Physical Contingency	5.23	3.34	8.57	
Net Construction Cost	96.12	45.89	142.01	
Interest during Construction	11.23	17.73	28.96	Foreign; 6.33% Domestic;20.0%
Construction Cost	107.35	63.62	170.97	
Cost for Rehabilitation Works	4.82	5.60	10.42	Caliraya Dam
Total Construction Cost	112.17	69.22	181.39	

(5) Economic Evaluation

In terms of the Benefit (B) to Cost (C) ratio, the economics of the Stage II Project is favorable being higher than 1.0 as shown below. Therefore, this Project is sufficiently feasible in terms of economics.

The discount rate was assumed to be 15%.

Benefit (B) = US$111.06 million

Cost (C) = US$100.70 million

B - C = US$10.36 million

B/C = 1.10

Equalized Discount Rate = 21.15%

(6) Environmental Assessment

The major environmental impact created by the Stage II Project will be the transfer of contaminated water in the lower reservoir of Laguna de Bay to the upper reservoir of Caliraya. This effect has already occurred by operation of the Stage I Project. Considering that no serious environmental issue has occurred by operation of the existing power plant, it is expected that the effect of expanding the power plant would be minor.

Recommendations

(1) Construction Schedule

Considering the construction schedule of the Stage II Project, it is expected that commissioning of the No. 3 Unit will take 39 months, and that of the No. 4 Unit 45 months. Therefore, the construction schedule presented below must be kept in proceeding with the construction in order to meet the increasing power demand.

1990-11 -- 1991-3:	Provision and Award of Definite Design
1991- 4 -- 1992-9:	Definite Design
1992-10 -- 1993-3:	Financing Formalities
1993- 4 -- 1993-9:	Bidding and Award of Contract for Construction
1993-10 :	Start of Construction
1997-1 & 7 :	Commissioning

(2) Mitigation Measures for Environmental Impact

Although the implementation of the Stage II Project will not create an environmental problem caused by the Project itself, the contamination of Laguna de Bay, which is the lower reservoir of the Project, will progress inevitably due to household and industrial waste water drained from the surrounding area. It is a matter of natural course that, as the contamination of the lower reservoir is intensified, the upper reservoir of Caliraya Lake will also be contaminated. Although it is impossible to stop the contamination of the lower reservoir, it should be possible to retard this process.

In order to retard this contamination, it is recommended, as a matter of general environmental protection, to take the following actions:

(a) Providing a coffer dam to separate a part of Laguna de Bay.

(b) Providing a "Wetland" in the lower reservoir to reduce contamination.

The cost of these provisions is approximately estimated at US$ 6 Million. It should be added that in implementing these retarding measures, a study of possible environmental problems by construction of the coffer dam, and a review of this construction cost will be necessary.

As previously mentioned, it is considered that the environmental impact concerning Laguna de Bay should be separated from the Kalayaan Stage II Project and be taken up as a national project.

The reason is that if the elimination of contamination of Laguna de Bay were to be considered in this Project, it would require a cost far greater than the Kalayaan Stage II Project itself, and as a consequence, the original objective of the Pumped Storage Power Generation Project itself will not be justifiable.

Incidentally, if the marginal cost that could be borne by the Project were to be tentatively examined, it would be as given below. That is, it would be the break-even point of the Project for B/C = 1.0, and the amount would be about US$ 20 Millions.

Chapter 1 Introduction

Chapter 1 Introduction

1.1 Background and Role of the Project

NAPOCOR (National Power Corporation) projects that the power demand of the Luzon Grid, which accounts for 87% of the total power demand of the Republic of the Philippines, will grow to approximately 7,000 MW in the year 2000 from the current maximum demand of 2,938 MW (as of June 1989), going ahead with electric power development projects to meet this growth of electric demand. As the reserve margin capacity in the power system of Luzon is expected to fall to 4% from 1994 to 1996, NAPOCOR intends to overcome this supply crisis by installing 600 MW of new gas turbine plants, thereby providing a reserve margin rate of around 17%. However, considering the fact that the fuel cost of gas turbine is high, and the service life is generally short, these gas turbine plants can not be regarded as a permanent measure of dealing with the power supply shortage, and NAPOCOR is compelled to work out more permanent measures as soon as possible. As one of such permanent measures, NAPOCOR had been studying a plan of expanding the existing Kalayaan Pumped Storage Power Plant (called Stage I Project hereafter) by installing an additional plant (called Stage II Project hereafter) adjacent to the existing one, and through the Government of Republic of the Philippines, requested the Government of Japan to conduct a feasibility study for this Stage II Project.

Stage II Project is expected to play the important role of dealing with the peak demand in the later half of the 1990s when the geothermal and coal-fired thermal power plants become the major power supply sources in the Luzon grid. Therefore, the this Project will have the following roles when developed.

* Currently, the spinning reserve of the power system is provided by gas turbine plants. By replacing this role with hydroelectric power sources, the disadvantages with the gas turbine plants, such as high operating cost, short service life, and unstable output affected by air temperature changes, can be eliminated, to improve the reliability of power system operation.

* As the proportion of coal fired thermal power plants in the power supply capacity increases in future, it will be required to make up for the difference of the size of load between peak and off-peak periods. Therefore, the pumped storage power plants, which pump up during off-peak period and generates power at peak period, will be required. At the same time, the pumped storage power plants can regulate power system frequency, control system voltage, and regulate reactive power flow in the power system when they are operated in power generation mode, thereby substantially contributing to the power system operational performance.

* A feasibility study has been completed for this project site in 1978 by cooperation offered by an Italian team, and two 150-MW pump turbines are in operation today.

  Therefore, the construction cost can be saved substantially by utilizing the existing dam and a part of civil structures, and the least cost priority in the overall development program would be very high.

1.2 Objective and Scope of the Study

1.2.1 Objective

Upon the abovementioned request of the Philippine Government, the Japanese Government caused its agency implementing studies, the Japan International Cooperation Agency (JICA), to dispatch a Preliminary Study Team to the Philippines in September, 1989 and the Team held discussions with NAPOCOR, the Philippine agency in charge of this Project. JICA then organized the Study Mission for Feasibility Study of the Stage II Project, and the Mission conducted the necessary study with the members and according to the itinerary which are presented in Section 1.3.

The objective of the Study was to conduct field surveys and studies in Japan, to formulate the technically, economically and financially optimal development plan, and to produce a feasibility report on the Kalayaan Pumped Storage Power Plant Stage II Project, as well as to transfer technologies to its Philippine counterpart through the process of the Study.

1.2.2 Scope of the Study

The Study has been conducted in three stages

* Preliminary Investigation Stage
* Detailed Investigation Stage
* Feasibility-grade Design Stage

The contents of studies in each stage are as described below.

(1) Preliminary Investigation Stage

(a) Collection and review of all existing data, reports and other relevant information on this Project.

(b) Site reconnaissance.

(c) Power survey

* Review and analysis of relevant information on growth of power consumption, forecasts of energy and peak demand, characteristics of power consumption pattern, etc.

* Review and analysis of power supply expansion program including those of transmission line and substation

(d) Review of existing development schemes

(e) Formulation of alternative development schemes and their comparative studies to select the optimum development scheme

(2) Detailed Investigation Stage

Based on the result of the Preliminary Investigation Stage, the Detailed Investigation was carried out for the selected site as follows.

(a) Topographic surveys (by NAPOCOR)

(b) Geological investigation and material tests (by NAPOCOR)

(c) Hydrological survey

(3) Feasibility-grade Design Stage

Based on the result of the Preliminary and the Detailed Investigation Stages, the Study was carried out for the selected site as follows.

(a) Optimization studies of Project size

(b) Review and study of the optimum power generation program including relevant transmission line

(c) Establishment of dam operation program

(d) Environmental assessment

(e) Compensation survey

(f) Feasibility-grade design of structure components

(g) Construction program

(h) Cost estimation

(i) Economic and financial analyses

1.2.3 Confirmed Items

Based on the results of the first field investigation (from January 17 to February 6, 1990), the Mission discussed with NAPOCOR on the major items which should be reflected in the design works to be carried out in Japan, and the following items and premises were mutually confirmed.

(1) Concerning the output of the Stage II Project, 300 MW, or the same output as that of Stage I, would be suitable, considering the water intake facility and penstock route which had already been constructed.

(2) Concerning the number of units and unit output, two-150 MW units would be appropriate, considering the capacity of the power system to which the Stage II Project is to be connected.

(3) Concerning the operating water level of Caliraya Dam, it is currently utilized up to a water level of EL 289.15 m (in dry season). In Stage II Project, the design criteria shall be the same as those of the existing facilities, and the high water level shall be EL 288.00 and the low water level 286.00.

(4) The alternatives to be adopted for the purpose of a comparative study shall be the three Alternatives (Alternative A, B and C), as described in Chapter 10.

(5) The construction costs shall be estimated with the prices as of January, 1990, and both the domestic currency portion and the foreign currency portion shall be expressed in terms of U.S. dollars.

(6) The advance investment already sunk for the Stage II Project at the time of construction of the Stage I, shall not be counted in the construction cost of the Stage II Project.

(7) The cost of rehabilitation of Caliraya Dam shall be added to the total construction cost of the Stage II Project according to the request of NAPOCOR, but this rehabilitation cost shall not be included in the study of economic feasibility of the Stage II Project.

1.3 Field Investigation Tasks and List of Participating Personnel

1.3.1 Field Investigation Tasks

The Mission studied the following items, in addition to the items listed in Paragraph 1.2.2 of this chapter, when it conducted the field survey in January and March of this year.

(1) Survey on conditions of the existing facilities

(2) Survey on load dispatching operations

(3) Survey on operating performance of the power plant.

(4) Geological survey at Project site and its surrounding areas.

(5) Guidance of boring works

(6) Study of materials related to seismic design

(7) Investigation on under-water portions of intake facility by divers

(8) Survey on candidate quarries for aggrigates

(9) Survey on unloading facilities and transportation routes

(10) Meetings and discussions with organizations concerned to environmental regulations

(11) Meetings and discussions on blasting tests

(12) Water quality survey by collecting water of Laguna de Bay

1.3.2 Investigation Itinerary

The itinerary of field investigation is presented in Table 1-1 through Table 1-4.

1.3.3 List of Participating Personnel

The following engineers were directly engaged in the Study of this time.

(1) NAPOCOR

Mr. Marciano C. Avendano	- Vice-President, Engineering
Mr. Pancho C. Dino	- Manager, Hydro Power Eng. Dept.
Mr. Rodolfo C. Dela Cruz	- Manager, Hydro Planning Div. HPED
Mr. Reynoldo I. Evangelista	- Manager, Hydro Design Div. HPED
Mr. Edgar C. Portante	- Luzon Grid Manager, SPD
Mr. R. M. Pulanco	- Manager, Geology & Geotec. Div. TRSD
Ms. P. L. Lopez	- PE A, Hydro Planning Div. HPED

Mr. Petronilo Pana	- PE II, Geology and Geotech. Div. TRSD
Mr. Andy B. Arvesu	- PE II, Hydro Design Div. HPED
Mr. Francisco A. San Pablo	- PE II, Hydro Planning Div. HPED
Ms. Ma. Juliet E. Herrera	- Project Economist, HPED
Ms. Nilda P. Santiago	- Supervising Engineer, HPED
Mr. Bienvenido Babilonia	- Principal Engineer A, TPED
Mr. Rolando B. Dugeno	- Corplan Specialist, SPD
Mr. G. C. Quejada	- Supervising Engineer, HPED
Mr. D. V. Politico	- Senior Engineer, HPED
Mr. B. Balugo	- Senior Geologist, TRSD
Mr. H. B. Alba	- ERSD
Ms. Humbelina M. Castro	- Chief, Phys-Chemi. Envi. Sec. EMD

(2) JICA Mission

Morihiro Sato	- Mission Leader
Katsue Iino	- Hydrology, Planning
Kazuo Kaneko	- Civil Facilities Design
G. Stevanella	- Civil Facilities Design
Kazuhiko Fushimi	- Construction Work Planning
Miyoshi Kishida	- Geology
Tadahisa Udo	- Geology
Taketoshi Murata	- Geology
Akio Suzuki	- Power System Planning
Ryouji Sugawara	- Electric Facilities
Kazuhiko Watanabe	- Electric Facilities
G. A. Crema	- Environment
Tetsuya Fukuda	- Economy and Finance

Table 1-1 JICA Mission Schedule (Preliminary Investigation)
Jan. 17 - Feb. 6, 1990

DATE	SCHEDULE	CONTENTS	AT
Jan 17 (Wed)	Tokyo-Manila	BY PR431 Lv 13:15 Ar 16:50	
18 (Thu)	Meeting	Discussion on QUESTIONNAIRE	NAPOCOR
19 (Fri)	Meeting	Discussion on QUESTIONNAIRE and Field Survey	NAPOCOR
20 (Sat)	Field Survey	Realization of the outline of the site condition	Kalayaan
21 (Sun)		Collection of the materials for Field Survey	Hotel
22 (Mon)	Meeting	Discussion ON INCEPTION REPORT Collection of Data	NAPOCOR
23 (Tue) 24 (Wed) 25 (Thu)	Field Survey	See INCEPTION REPORT 4.1 (3) Field Survey Additionary, Execution of simple environmental investigation (Water quality investigation)	Kalayaan
26 (Fri)	Meeting	Discussion on Field Survey Collection of Data	NAPOCOR
27 (Sat)	Desk Work	Arrangement of collected data	Hotel
28 (Sun)		Arrangement of collected data	Hotel
29 (Mon) 30 (Tue)	Meeting	Discussion of development plan Collection of Data	NAPOCOR
31 (Wed) Feb 1 (Thu)	Meeting and Field Survey	Discussion of Detailed investigation, Field Survey Mr. Kaneko, Mr. Kisida and Mr. Stevanella go to Field Survey	NAPOCOR & Kalayaan
2 (Fri)	Meeting	Discussion on Detailed investigation and Feasibility Design Collection of data	NAPOCOR
3 (Thu)	Desk Work	Arrangement of collected data Drawing of meeting document	Hotel
4 (Sun)		Arrangement of collected data Drawing of meeting document	Hotel
5 (Mon)	Meeting	Discussion of pending problems	NAPOCOR
6 (Tue)	Manila-Tokyo	BY PR432 Lv 14:25 Ar 19:15	

Table 1-2 JICA Mission Schedule (Submission of Interim Report)
Mar. 22 - Mar. 30, 1990

DATE	SCHEDULE	CONTENTS	AT
Mar 22 (Thu)	Tokyo-Manila	By JL 741 Lv 10:00, Ar 13:30 Meeting with JICA Phil. Office	
23 (Fri)	Meeting	Discussion on Interim Report with Embassy of Japan	EOJ
		Discussion on Interim Report	NAPOCOR
24 (Sat)	Site Visiting	Field Investigation, Collection of Data	Kalayaan
25 (Sun)	Preparation	Preparation of Discussion	Hotel
26 (Mon)	Meeting Site Visiting	Discussion on Interim Report Collection Data	NAPOCOR Kalayaan
27 (Tue)	Meeting	Discussion on Interim Report	NAPOCOR
28 (Wed)	Meeting	Discussion on Interim Report	NAPOCOR
29 (Thu)	Meeting	Report to JICA and EOJ on results of Discussion W/NPC	JICA, EOJ
30 (Fri)	Manila-Tokyo	By JL 742 Lv 14:50, Ar 19:50	

Table 1-3 JICA Mission Schedule (Submission of Draft Final Report)
Aug. 25 - Sep. 8, 1990

DATE	SCHEDULE	CONTENTS	AT
Aug 25 (Sat)	Tokyo-Manila	By PR 431 Lv 10:15, Ar 13:30	
26 (Sun)	Visiting	Site Visiting	Kalayaan
27 (Mon)	Meeting	Submission and Explanation of Draft Final Report to JICA and NAPOCOR	JICA NAPOCOR
28 (Tue)	Meeting	Explanation on Draft Final Report	NAPOCOR
29 (Wed)	Meeting	Explanation on Draft Final Report	NAPOCOR, EOJ
30 (Tue)	Meeting	Explanation on Draft Final Report	NAPOCOR
31 (Fri)	Meeting	Explanation on Draft Final Report	NAPOCOR
Sep 1 (Sat)	Preparation	Preparation for Discussion	Hotel
2 (Sun)	Preparation	Preparation for Discussion	Hotel
3 (Mon)	Meeting	Discussion on Draft Final Report	NAPOCOR
4 (Tue)	Meeting	Discussion on Draft Final Report	NAPOCOR
5 (Wed)	Meeting	Discussion on Draft Final Report	NAPOCOR
6 (Thu)	Meeting	Discussion on Draft Final Report	NAPOCOR
7 (Fri)	Meeting	Internal Meeting	Hotel
8 (Sat)	Manila-Tokyo	By PR 432 Lv 14:25, Ar 19:15	

Table 1-4 JICA Mission Schedule (Blasting Test)
Aug. 25 - Sep. 14, 1990

DATE	SCHEDULE	CONTENTS	AT
Aug 25 (Sat)	Tokyo-Manila	By PR 431 Lv 10:15, Ar 13:30	
26 (Sun)	Preparation	Site Visiting	Kalayaan
27 (Mon)	Meeting	Explanation of Blasting Test to JICA	JICA
		Explanation of Blasting Test, Discussion of Test Schedule	NAPOCOR
28 (Tue)	Meeting	Preparation	NAPOCOR
29 (Wed)	Preparation	Preparation	Kalayaan
30 (Thu)	Preparation	Excavation	Kalayaan
31 (Fri)	Preparation	Excavation	Kalayaan
Sep 1 (Sat)	Preparation	Installation of Measuring Devices	Kalayaan
2 (Sun)	Preparation	Installation of Measuring Devices	Kalayaan
3 (Mon)	Meeting	Discussion of Test Schedule	NAPOCOR
4 (Tue)	Preparation	Drilling	Kalayaan
5 (Wed)	Meeting	Discussion of Test Schedule	NAPOCOR
6 (Thu)	Preparation	Drilling	Kalayaan
7 (Fri)	Preparation	Drilling	Kalayaan
8 (Sat)	Test	Test (Case I & J)	Kalayaan
9 (Sun)	Test	Blasting Test (Case A,B,E,F)	Kalayaan
10 (Mon)	Meeting	Report to JICA on Test	JICA
		Report to NAPOCOR on Test & Discussion of Test Schedule	NAPOCOR
11 (Tue)	Preparation	Transportation of CCR	Manila
12 (Wed)	Preparation	Preparation for Transportation of Testing Equipments	Kalayaan
13 (Thu)	Meeting	Report to JICA on Test	JICA
		Report to NAPOCOR on Test	NAPOCOR
14 (Fri)	Manila-Tokyo	By PR 432 Lv 14:20, Ar 19:15	

Chapter 2 General Description of the Republic of the Philippines

Chapter 2 General Description of the Republic of the Philippines

2.1 General Description

(1) Land

The Republic of the Philippines is constituted by 7107 islands which are scattered over 1,851 km from north to south to the southeast of Asian continent and to the northeast of Malaysian Islands. In spite of the large number of islands, 96% of the total national land area, which is 299,000 km^2 are made up of the eleven largest islands, which are Luzon, Mindoro, Samar, Leyte, Cebu, Masbate, Bohol, Negros, Panay, Palawan and Mindanao. The total national population is approximately 58 millions, of which about 8 millions people inhabit in Metro Manila.

(2) Meteorology

The Philippines have tropical climate. The annual average temperature is 27.5°C, and temperature changes relatively little throughout the year, with the monthly average temperature being a little higher than the annual average, or approximately 29°C, in April and May.

In Luzon Island, the rainy season is experienced from June to October, and the dry season from November to May. In certain other islands, there is no distinctive rainy or dry seasons.

The temperature, humidity and precipitation of each month in the Philippines are presented in the table below.

	Jan.	Feb.	Mar.	Apr.	May	June
Temperature (°C)						
Average	25.7	26.2	27.5	29.0	29.4	28.6
Maximum	29.5	30.2	31.8	33.1	33.4	32.1
Minimum	22.2	22.4	23.5	24.9	25.7	25.3
Humidity (%)	73	69	63	65	69	76
Precipitation (mm)	13.3	5.4	11.7	22.6	116.3	290.4

	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature (°C)						
Average	27.9	27.3	27.4	27.6	27.5	26.2
Maximum	31.2	30.4	30.6	31.0	30.5	29.0
Minimum	24.8	24.4	24.4	24.4	23.7	22.9
Humidity (%)	79	82	81	77	76	75
Precipitation (mm)	394.1	489.4	350.7	197.8	130.1	65.5

2.2 Current Status of National Economy

The national economic activity of the Philippines declined through 1984 and 1985, with her GNP exhibiting negative growth rates of -7.1% and -4.1% respectively. However, as the interest rate became stabilized, domestic demands such as consumption expenditure and investment in the private sector grew in 1986, 1987 and 1988, with GNP recovering rapidly with growth rates of 1.9, 5.9 and 6.7%, respectively.

From viewpoint of Philippine economic structure in terms of the gross domestic products (GDP), the service sector accounts for 44% of GDP, followed by 39% of industrial sector, and 23% of agricultural, forestry and fishing sector. The international trade balance is in deficit by approximately 1.1 billion U.S. dollars as of 1988. Export commodities are mainly agricultural products, such as coconuts, banana and timber.

Import of capital goods from the U.S. accounts for a large weight in the total import, and the burden of payment on oil import is still heavy. Reimbursing the accumulated liabilities in international trade is the important subject in promoting economic growth.

The ratio of external debt outstanding to GNP once marked 95% in 1986, and exceeds 80% even today. The ratio of external debt service to the export of goods and services (TDS/XGS) was 35.4% in 1987, and 33.7% in 1988, which can be termed a grim situation.

In recent years, the economy of the Philippines started to recover rapidly, and seems to maintain high economic growth. However, the actual situation can not be considered too optimistically due to the accumulating external debts and shortage of foreign currency reserves which are needed for economic growth.

Current Status of Philippine Economy

(in %)

	1985	1986	1987	1988
Real GNP Growth Rate	-4.1	1.9	5.9	6.7
Consumer Price Inflation Rate	23.1	0.8	3.8	8.8
Balance of Current Account/GNP	-0.3	3.3	-1.6	-1.1
Export/GNP	25.4	24.7	26.8	29.4
Foreign Reserves including Gold*	10.9	26.1	23.1	-
External Debt Outstanding/GNP	81.9	95.0	86.5	-

*unit: US$ x 10^8

The Medium-Term Economic Plan (1989 to 1992) of the Philippine Government has been formulated in consultation with IMF under such a economic situation. In this new Medium-Term Economic Plan, it is attempted to maintain a relatively high annual growth rate of 6.5% by means of a policy combining with aggressive governmental finance, promotion of privatization, and intensified taxation.

Outline of Medium-Term Economic Plan of Government (1989 - 1992)

(1) Economic Development Target: Elimination of poverty, creation of employment, realization of social equity.

(2) Basic Task: Attaining continued economic growth.

(3) Main Targets in Socio-Economic Development

i) To attain an average GNP growth rate of 6.5%.

ii) To increase the ratio of investment to GNP from 18% in 1988 to 24.5% in 1992.

iii) In particular, to increase the ratio of government investment to GNP from 3% in 1988 to over 5.5% in 1991 - 1992.

iv) This will create a shortage of funds of 3 billion US$ during the period from 1989 to 1992. To deal with this, new loans will be secured from foreign commercial banks and the Paris Club (Public Debtors' Council) will be requested to reschedule loans again.

v) The tax revenue of the government is to be secured by the new taxation system introduced in 1988 which features a value-added tax, and at the same time streamlines government structures. This will reduce the current governmental expenditures of 13.9% in 1988 to 12% by 1992.

Major Targets in Medium-Term Economic Plan of Philippines
(1989 -- 1992)

(in %)

	1987	1988	1989	1990	1991	1992
GNP Growth Rate	5.9	6.7	6.5	6.5	6.5	6.5
Consumer Price Inflation Rate	3.8	3.8	8.0	6-7	5-6	5-6
Public Investment/GNP	3.6	3.4	4.2	4.7	5.6	5.8
Debt Service Ratio *	35.4	33.7	33.8	32.2	31.0	29.4

* Debt Service Ratio (TDS/XGS): Total debt service relative to export of goods and services.

2.3 Economy and Electric Power Indices

(1) Economic conditions in the Philippines have recovered rapidly since 1987, and the GDP growth rate of 1988 marked a 6.7% growth over the previous year.

Generally speaking, there is a strong correlation between GDP and electricity demand. The electricity consumption of 1988 was 22,944 GWh reflecting the growth of GDP, and this was a 9.3% growth over the previous year. This growing trend of demand will continue, even if the growth rate may be reduced a little.

Past Trend of Energy Demand

(in 10^6 kWh)

	1983	1984	1985	1986	1987	1988	1989
Philippines	18,682 (7.3)	18,666 (0)	18,757 (0.5)	19,263 (2.7)	20,995 (9.0)	22,944 (9.3)	24,076 (4.9)
Luzon Grid	15,294 (6.2)	14,655 (-4.2)	14,449 (-1.4)	14,756 (2.1)	16,030 (8.6)	17,439 (8.8)	18,215 (4.4)
Visayas Grid	1,057 (36)	1,177 (11.4)	1,343 (14.1)	1,467 (9.2)	1,693 (15.4)	1,876 (10.8)	1,998 (6.5)
Mindanao Grid	2,331 (4.2)	2,835 (21.6)	2,965 (4.6)	3,040 (2.5)	3,272 (7.6)	3,629 (10.9)	3,863 (6.4)

Figures in parentheses are growth rates over previous years (%).

Past Trend of Maximum Power Demand

(in MW)

	1983	1984	1985	1986	1987	1988	1989
Luzon	2,478 (4.8)	2,374 (-4.2)	2,311 (-2.7)	2,435 (5.4)	2,582 (6.4)	2,780 (7.3)	2,938 (5.7)
Visayas	229 (41.9)	242 (5.7)	256 (5.8)	284 (10.9)	307 (8.1)	333 (8.5)	350 (6.3)
Mindanao	410 (5.9)	433 (5.6)	470 (8.5)	484 (3.0)	533 (10.1)	571 (7.1)	617 (8.1)

Figures in parentheses are growth rates over previous years (%).

The total installed generating capacity of the Philippines was 5,782.4 MW as of 1988 (composed of 40.9% oil-fired thermals, 15.4% geothermals, 7.0% coal fired thermals, and 36.7% hydroelectric). However, unavailability of thermal power generating facilities due to aging, failure and repair/inspection, and the reduced generation of hydroelectric plants due to reduced reservoir water level created periodical power supply failures in power systems of Luzon Island.

In particular, the power supply capability to Metro Manila is in severe shortage this year, due to reduced hydroelectric output caused by the dry weather of last year and concurrent failure of thermal power plants. Since late April, shortage is so serious that large consumers in this area are requested to shut down their operations on Mondays, in addition to Saturdays and Sundays until the wet season arrives in June.

(2) The Government of the Philippiens ordered NAPOCOR to make efficient use of domestic energy resources except imported oil.

Although the decision to mothball of nuclear power plant construction by Aquino Administration in 1986 was based on safety and political considerations, this became one of the big causes of power supply shortage as demand grew rapidly. In order to deal with such power shortage, NAPOCOR is being forced to install 600 MW gas turbine plants as an emergency measure.

However, gas turbine plants are not favorable in generating economy. Considering the current situation, it would be indispensable to promptly promote the development of coal-fired thermal power plants, hydroelectric power plants including pumped storage, and geothermal power plants.

(3) The policy and strategy of electric power development in the Philippines are as described below.

i) *Completion of each project within the scheduled construction* period.

ii) Implementation of rehabilitation programs for existing oil-fired thermal power plants in order to reinforce generating capacities and improve supply reliability.

iii) Reviews and adjustments designed to improve the efficiency of energy utilization at various stages and facets.

(a) Improvement of plant factor and load factor.

(b) Reduction of facility investment cost and suppression of generating cost.

iv) Implementing energy conservation programs.

v) Rationalization and improvement of power system operation for reduction of power transmission loss.

vi) Inviting private industries into power development investment by BOT scheme and curtailment of public investment.

vii) Assessment of environmental protection measures and their implementation in relation with all types of energy development programs.

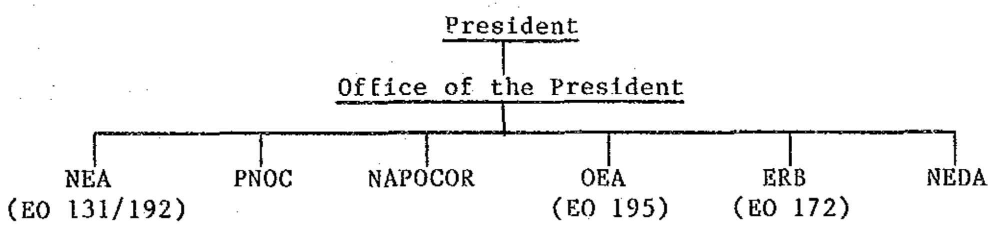
Chapter 3 Current Structure of Electric Utility

Chapter 3 Current Structure of Electric Utility

3.1 Structure of Electric Power Sector

3.1.1 Government and Governmental Organizations Concerned

In 1987, Aquino Administration abolished the Department of Energy, and reformed governmental organizations related to energy. The jurisdiction of the Department of Energy has been transferred to the Office of Energy Affairs (OEA) and the Energy Regulatory Board (ERB). Establishment of OEA was implemented based on the Executive Order No. 195. OEA is in charge of formulation of energy policies and plans, and general coordination. The organizational chart is given in Fig. 3-1.



Note: NEA : National Electrification Administration
PNOC : Philippine National Oil Company
OEA : Office of Energy Affairs
NEDA : National Economic and Development Authority

The NEDA co-ordinates energy policies and energy-related projects from the point of view of the Philippine economy as a whole.

Fig. 3-1 Government Organization Responsible for Energy

3.1.2 Electric Utility of the Philippines

The electric utility of the Philippines is operated by both public and private sector organizations. In the public sector, the National Power Corporation (NAPOCOR) surveys and develops all electric power resources, including such indigenous resources as geothermal and hydroelectric, and supplies electric power, which is generated by hydroelectric and thermal power plants developed by NAPOCOR, through its nation-wide transmission networks to electric cooperatives, Manila Electric Company, etc. In the private sector, Manila Electric Company (MERALCO) supplies power to Metro Manila. The power supply in remote areas where NAPOCOR has no transmission system is carried out by electric cooperatives.

(1) NAPOCOR

NAPOCOR was established in 1936 under full governmental subsidization with the objective of operating an electric utility using hydroelectric power and other natural resources. This was based on Commonwealth Act No. 120 of 1935. In 1972, the scope of business of NAPOCOR was expanded according to the NPC Charter and Presidential Decree 40, and today, NAPOCOR is engaged in all surveys and development of power resources, construction and operation of transmission networks, and supply of power to electric cooperatives all over the country, Manila Electric Company, and other corporations in accordance with the economic and social development policy of the nation.

All deliberations and decisions of utility policies of NAPOCOR is done by the Board. The board members are assigned by the President of the country. The organization chart of NAPOCOR is given in Fig. 3-2.

The total capacity of the generating facilities owned by NAPOCOR as of the end of 1988 was 5,782 MW, with the number of employees 11,294 persons.

(2) Manila Electric Company (MERALCO)

Manila Electric Company was founded in 1919 by merging three companies, Manila Electric Railroad & Lighting Co., Manila Suburban Railway Co., and La Electricista. Later, a bus transport division was separated, segregated, and the part of the company related the to electric utility was gradually expanded as the power demand increased. All stocks of Manila Electric Company were held by an U.S. holding company named General Public Utilities Corporation, but they were bought by MERALCO Securities Corp. in 1962.

Therefore, MERALCO is engaged in the distribution of power, purchased wholesale from NAPOCOR, to Manila City and its surrounding area, which covers 8,813 km^2 (approximately 3% of the national land area). According to the record for in 1986, NAPOCOR supplied 10,260 GWh of electricity to MERALCO, and this corresponded to 58% of the total wholesale power of NAPOCOR which was 17,645 GWh.

(3) National Electrification Administration and Electric Cooperatives

In the Philippines, rural electrification has been one of the important government policies, and the National Electrification Administration (NEA) was established in 1969 for promotion of rural electrification. NEA arranges financing, prepares bidding documents and purchases equipment/materials for rural electrification, and the distribution facilities thereby completed are sold to electric cooperatives. Therefore, NEA does not possess power facilities of its own, but organizes nation-wide electric cooperatives, and promotes rural electrification through these cooperatives.

Up to the present time 118 electric cooperatives have been established in 73 states and 2 substates of the nation. The electric cooperatives distribute power, which is supplied by NAPOCOR, to consumers in their territories.

3.2 Power Supply Facilities

The compositions of power supply facilities of Luzon, Visayas and Mindanao regions, as of 1989, are illustrated in Fig. 3-3. The outline (installed capacity, commissioning date) of each power plant in Luzon Island is given in Table 3-1.

Approximately one half of capacity of oil-fired thermal power plants, which account for 45% of the total installed capacity of the Luzon Grid, is almost 20 years old, and these facilities may not be operated at full power due to aging. It is being planned to rehabilitate these aged thermal power plants during the period from 1990 to 1992, starting with the Sucat No. 1 Unit.

3.3 Power Demand and Supply

The total installed capacity of the Luzon Grid as of 1989 was 4,322 MW. The peak demand (at generation end) was 2,938 MW, and there was ostensibly sufficient supply capability.

In reality, however, 41 blackouts and 97 GWh of power supply shortage occurred in the entire Philippines in 1989 (Table 3-2). It can be surmised that the major reasons for this situation were frequent natural hazards such as typhoons, and the low reliability of aged thermal power plants. It is expected that the power supply shortage in 1990 will be severer because of reduced hydroelectric output due to less rain in the year.

NAPOCOR is planning to introduce gas turbine plants and repair the old thermal power plants to tentatively deal with this situation.

Table 3-2 Energy Deficiency in the Philippines

Year	Number of Blackouts	Duration	ENS *
1988	12	64 hrs.	5.5 GWh
1989	41	438 hrs.	97.4 GWh

* ENS: Energy Not Served

3.4 Classification of Energy Generation by Fuel

In Fig. 3-3, the ratios of installed generating capacities and the amounts of energy generated in Luzon, Visayas and Mindanao regions are presented.

The Mindanao region is almost self sufficient with energy supplied by hydroelectric power plants, and it is noted that dependence on oil is outstanding in the Luzon Grid.

With the objective of improving self-sufficiency in energy of the Luzon Grid, it is being planned to develop hydroelectric power in the northern area of Luzon Island, and utilize the hydroelectric and geothermal power developed in the southern areas by means of a Luzon-Visayas-Mindanao interconnection.

3.5 Patterns and Characteristics of Power Consumption

A typical weekday load cycle of Luzon Island is presented in Fig. 3-4.

The total demand pattern is strongly influenced by the urban type pattern of loads in Manila City and its surrounding areas, which account for 70% of the total demand of Luzon. The total load curve pattern is composed of this urban pattern and the flat load curve of rural area, plus the pumping load of pumped storage plants.

On weekdays, there are three peaks on the daily load curve, occurring at 11 a.m., 2 p.m. and 7 to 8 p.m., with the highest peak occurring in the evening. This peak is caused by the lighting load peak in rural areas superimposed on the urban loads.

These characteristics of daily load curve are analyzed and presented in Table 3-3. Speaking of the annual load factor, the load factor of 71.5% in 1988 was reduced a little in 1989 to 70.8%.

Table 3-3 Daily Load Characteristics in 1988 and 1989

	Weekday	Saturday	Sunday
Load Factor *	82.6%	81.9%	78.7%
Off Peak Rate	64.0%	65.0%	68.6%

* Without pumping.

Table 3-1 Existing Power Plants in Luzon grid (as of Dec. 1989)

(a) Pondage Hydro

Plant Name	Unit No.	Unit Capacity (MW)	Firm Out put (MW)	Comm. Year	Year of Retirement
1. Caliraya	1	8.00	15	10/45	1992
	2	8.00		11/45	1992
	3	8.00		10/47	1997
	4	8.00		2/57	2000
2. Ambuklao	1	25.00	36	12/56	2006
	2	25.00		12/56	2006
	3	25.00		9/57	2007
3. Binga	1	25.00	79	1/60	2010
	2	25.00		1/60	2010
	3	25.00		3/60	2010
	4	25.00		3/60	2010
4. Angat (main)	1	50.00		10/67	2017
	2	50.00		10/67	2017
	3	50.00		8/68	2018
	4	50.00	total 142	8/68	2018
5. Angat (aux.)	1	6.00		7/67	2017
	2	6.00		7/67	2017
	3	6.00		10/78	2028
	4	10.00		5/86	2036
6. Pantabangan	1	50.00	26	4/77	2027
	2	50.00		5/77	2027
7. Magat	1	90.00	180	8/83	2033
	2	90.00		9/83	2033
	3	90.00		11/83	2032
	4	90.00		8/84	2034
Sub-total		895	478		——

(b) Pumped Hydro

Plant Name	Unit No.	Unit Capacity (MW)	Firm Out put (MW)	Comm. Year	Year of Retirement
1. Kalayaan	1	150.00	300	5/82	2032
	2	150.00		8/82	2032
Sub-total		300	300		——

(c) Run-of-River Hydro

Plant Name	Unit No.	Unit Capacity (MW)	Firm Out put (MW)	Comm. Year	Year of Retirement
1. Botocan	1	8.00	0	1946	1998
	2	8.00		1948	1998
	3	0.96		1945	1995
2. Buhi-Barit	1	1.80	0	9/57	2007
3. Cawayan	1	0.40	0	10/59	2009
4. Masiway	1	12.00	0	12/80	2030
Sub-total		31.2	0		———

(d) Oil Thermal

Plant Name	Unit No.	Unit Capacity	Minimum Out put	Comm. Year	Year of Retirement
1. Manila	1	100.00	30.0	9/65	1995
	2	100.00	30.0	10/65	1995
2. Sucat 1&2 (Garoner)	1	150.00	50.0	10/68	1998
	2	200.00	120.0	1/70	2000
Sucat 3&4 (Snyder)	3	200.00	120.0	7/71	2001
	4	300.00	120.0	9/72	2002
3. Bataan	1	75.00	50.0	9/72	2002
	2	150.00	80.0	2/77	2007
4. Malaya	1	300.00	120.0	9/75	2005
	2	350.00	150.0	3/79	2009
Sub-total		1,952	870.0		———

(e) Gas turbine

Plant Name	Unit No.	Unit Cap.	Dependable Out put	Comm. Year	Year of Retirement
1. Malaya	1	30.0	30.0	9/89	2004
	2	30.0	30.0	9/89	2004
	3	30.0	30.0	9/89	2004
2. Bataan	1	30.0	30.0	9/89	2004
		30.0	30.0	9/89	2004
	1	30.0	30.0	9/89	2004
		30.0	30.0	9/89	2004
Sub-total		210	210.0		———

(f) Geothemal

Plant Name	Unit No.	Unit Capacity (MW)	Minimum Out put (MW)	Comm. Year	Year of Retirement
1. Tiwi	1	55.00	30.0	1/79	2009
	2	55.00	30.0	5 79	2009
	3	55.00	30.0	1 80	2010
	4	55.00	30.0	4/80	2010
	5	55.00	30.0	12/81	2011
	6	55.00	30.0	3 82	2012
2. Mak-Ban	1	55.00	30.0	4/79	2009
	2	55.00	30.0	7 79	2009
	3	55.00	30.0	4/80	2010
	4	55.00	30.0	6/80	2010
3. Mak-Ban	5	55.00	30.0	7/84	2014
	6	55.00	30.0	9/84	2014
Sub-total		660	360		———

(g) Coal fired Thermal

Plant Name	Unit No.	Unit Capacity (MW)	Minimum Out put (MW)	Comm. Year	Year of Retirement
1. Calacal	1	300.0	230.0	9/84	2014
Sub-total		300	230		———
GRAND TOTAL (MW)		4,321			

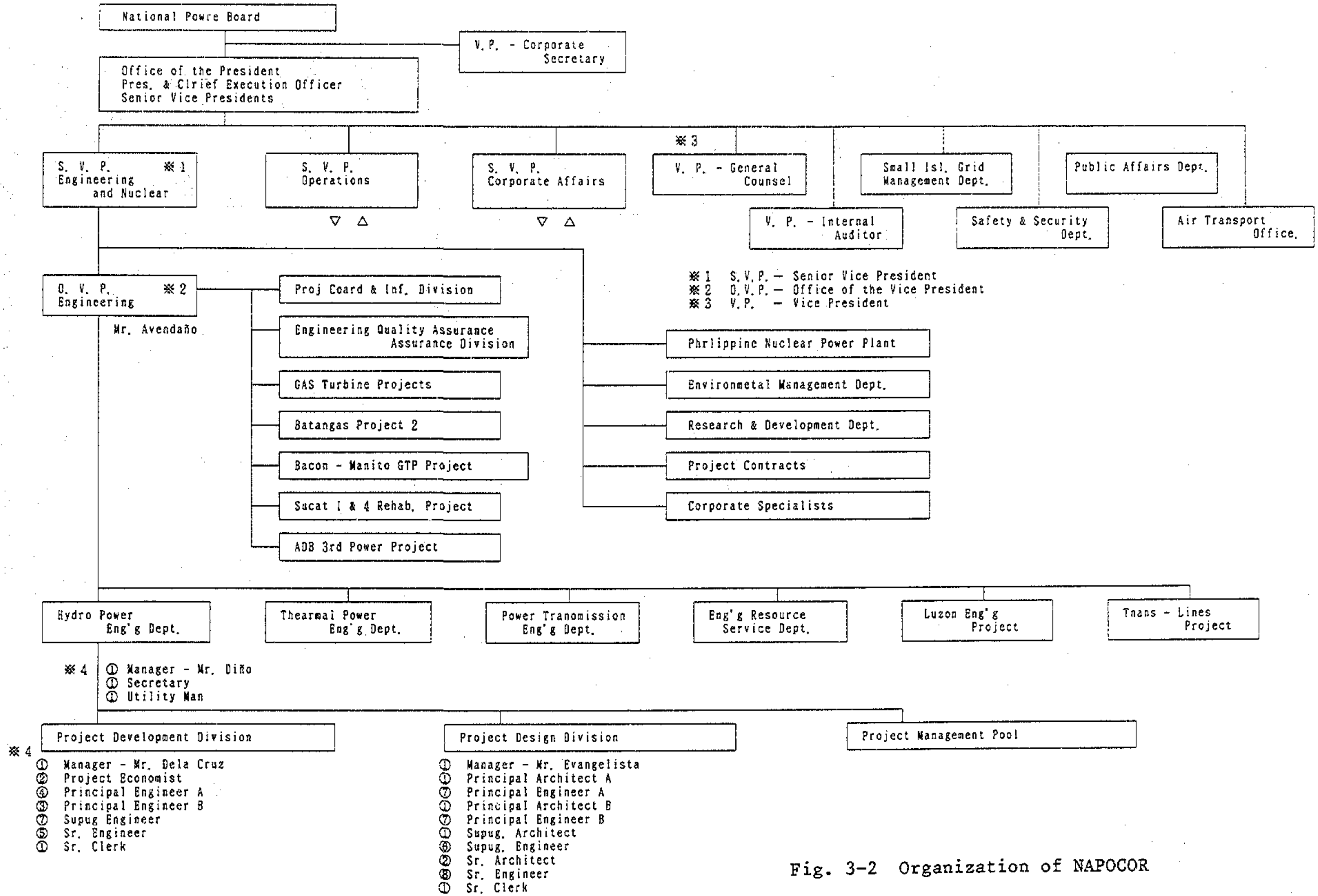


Fig. 3-2 Organization of NAPOCOR

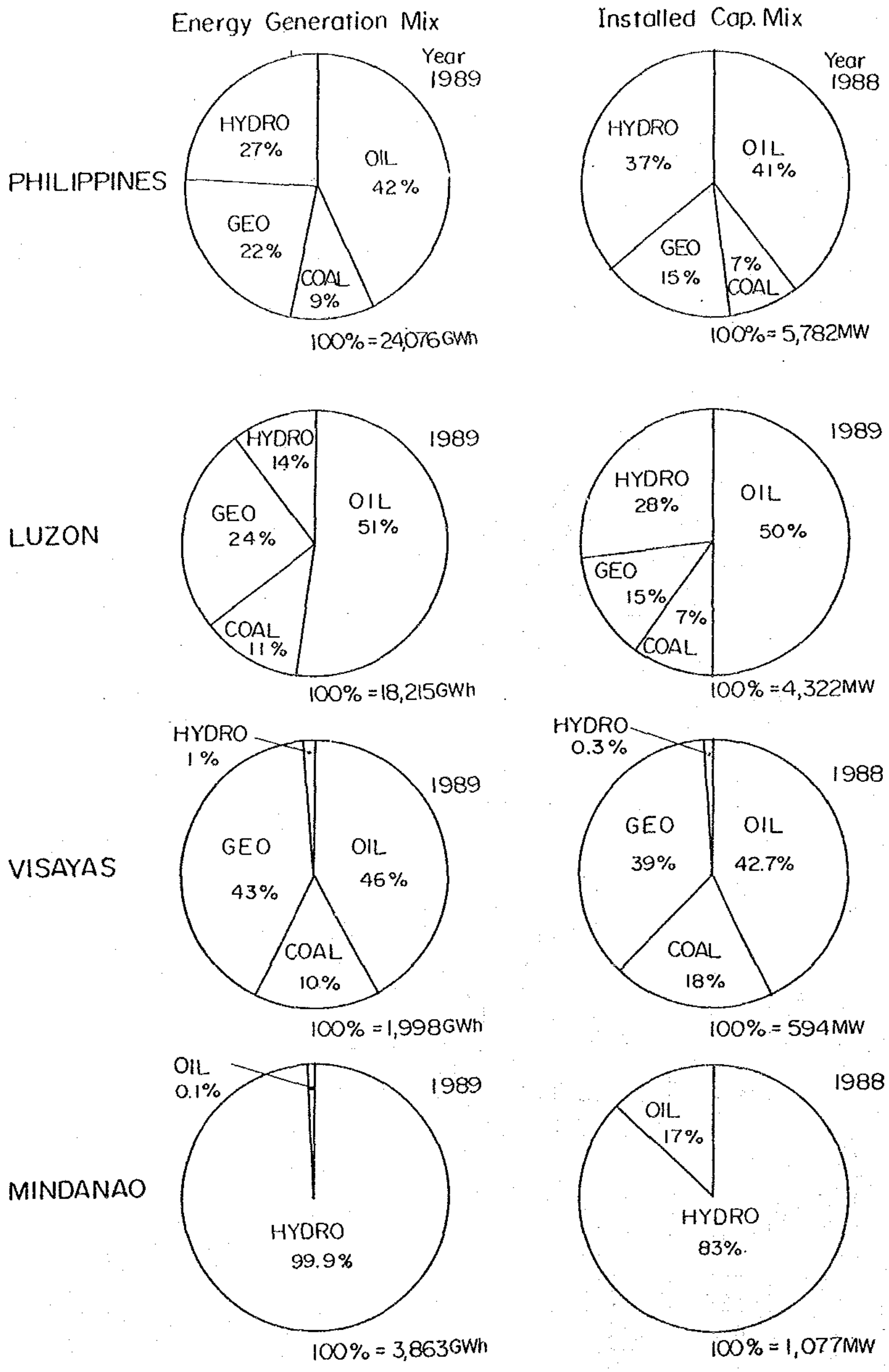


Fig. 3-3 Installed and Energy Generation Mix of the Philippines

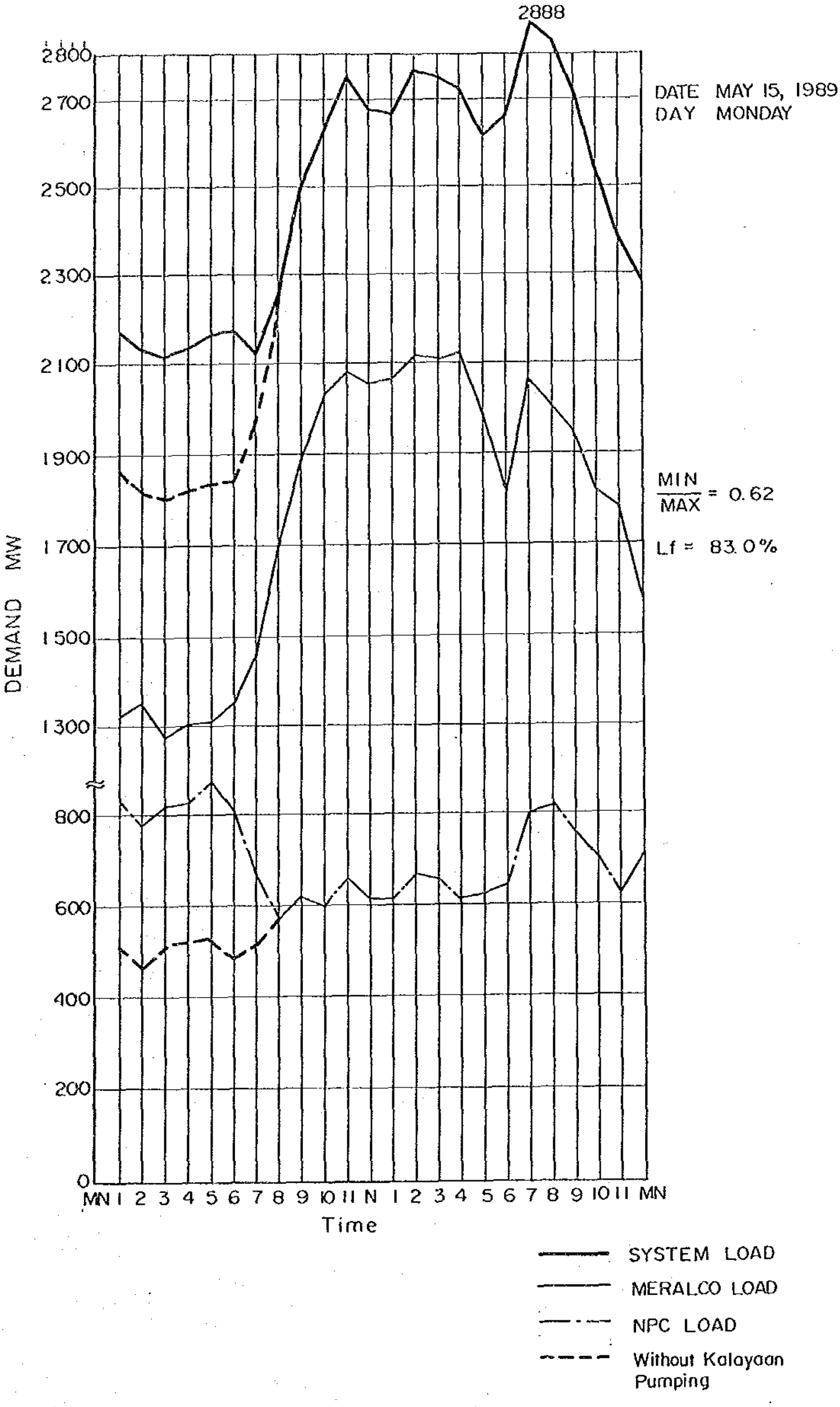


Fig. 3-4 Typical Daily Load Curve in Luzon grid

Chapter 4 Load Projections

Chapter 4 Load Projections

4.1 Present State

The transitions in power demand of the Luzon Grid from 1980 to 1989 are shown in Table 4-1. According to this figure, electric power demand stagnated at one time due to the political insecurity of 1984, but since the establishment of the Aquino Administration in February 1986, there has been a smooth expansion with an annual growth rate at the 6 percent level in average.

The breakdown of power demand in the Luzon Grid is 89 percent residential, 8 percent industrial and 3 percent other.

NAPOCOR forecasts medium and long-range energy demand using by piling up scheme according to each industrial demand. This time, a load forecast to year 2005 was made by a macro-scopic technique using the correlation between GDP and energy demand, and this was compared with the results obtained by NAPOCOR.

4.1.1 Load Forecast by Macroscopic Method

The expression of the local GDP (x) and energy sales (y) of Luzon Island from 1985 to 1989, when the economy was comparatively stable according to Fig 4-1, obtained by a primary regression technique is as follows:

$$y = 0.36624x - 7579.7$$

where, y: Energy sales of Luzon Grid (GWh)
x: Local GDP of Luzon Region (million pesos at 1972 level)

The correlation coefficient in this case is 0.97844, and it may be said that a fairly good linear characteristic is indicated.

Load forecasts for the period of 1990 to 2005 were made using this expression for the two cases below.

(a) Mid Case (GDP growth rate: 6.4%)
(b) Steady Case (GDP growth rate: 5.5%)

Tables 4-2 and 4-3 give the respective forecast results. The difference between the two as seen from the power demands for the year 2000 is about 1 and a half years.

4.1.2 Load Forecast Results to be Adopted

The load forecast made by NAPOCOR in November 1989 is on the slightly high side as shown in Table 4-4, and is close to the Mid Case (GDP annual rate: 6.4%) by the macroscopic method.

However, according to the Medium-term Economic Outlook of NEDA (National Economic and Development Authority), the dominant view is that growth at 6 percent will be difficult to achieve for some time to come. Further, taking the actual performance of 1989 which was slightly poorer than originally forecast into consideration, it was decided to adopt the results of the Steady Case (GDP annual rate: 5.5%) which is more realistic.

4.1.3 Future Load Characteristics

Considering the substantial latent peak loads which is currently existing, as described in Section 3.5 of Chapter 3, it has been predicted that the difference between the peak and off-peak demands will expand in future and this tendency is added to the current load characteristics, thereby reducing the future load factor.

Specifically, it has been projected that the average annual load factor for the period from 1990 to 2000 will be 70%, and the daily load factor has been projected as illustrated in Table 4-5, and the daily load curve as given in Fig. 8-3 in Chapter 8. These projected characteristics were taken into account in studying the operating pattern of pumped storage power plant.

Table 4-5 Future Daily Load Characteristics

(%)

	Weekday	Saturday	Sunday
Daily Load Factor	82	81	78
Off Peak Rate	60	63	65

4.2 Electric Power Development Program

As described in Table 3-1, the oil-fired thermal power plants account for 45% of the total installed generating capacity in Luzon Grid of 4,320 MW.

With the policy of energy self-sufficiency, the Government of the Philippines is exercising efforts for development of indigenous energy resources such as hydroelectric power and geothermal power. Speaking of hydroelectric power, there is a potential resources of 4,000 to 5,000 MW in Luzon Island only, and it is being planned to develop Casecnan (268 MW) in late 1990s and San Roque (390 MW) in early 2000s. As the geothermal power can have steady output throughout the year, in contrast to hydroelectric power, their development plans are actively being studied, with emphasis on the resources in the southern Luzon Island and Leyte Island.

An Electric Power Development Plan for the period from 1990 to 2000 has been formulated based on the Power Development Program of NAPOCOR, as presented in Table 4-6.

In this plan, the Power Development Program after 1996 has been modified in such a manner that the demand of each year can be met even if aged thermal power plants are retired and gas turbine plant output is reduced.

4.3 Demand and Supply Balance

The peak demand of the Luzon Grid in 1989 was 2,938 MW, and seen simply in terms of installed capacity, there was a reserve capacity of 47 percent. Despite this, however, in reality, there was a considerable shortage in supply due to decline in output of thermal power plants, forced outage, droughts, etc.

NAPOCOR, in setting up long-term electric power development plans, has employed a programming technique called WIGPLAN and has planned power development in a manner to satisfy a given degree of supply reliability (LOLP: 1-3 day/yr). According to the results of the recent study using WIGPLAN, it is estimated that goal of supply reliability will be achieved after Tongonan geothermal resources are further developed in 1995. In this chapter, studies are made from both the aspects of annual energy balance and power balance of peak days seen from reserve supply capability and considering performances such as forced outage of power sources.

(1) Power Balance

Peak demands on Luzon System are seen around May and November. Here, the daily kW peak balance of a weekday in May which is close to the dry season for hydro is considered. The output conditions for the various types of generating facilities are as given below.

a) Coal, Oil, Geothermal

Repair works are not to be made during peak months. It is hypothesized that there is outage of the maximum unit (Malaya 2G, 350 MW) due to faulting.

(Dependable Output)

Coal, geothermal: 95% of rated capacity
Oil : 60% of rated capacity

(Retiring Schedule)

Manila	100 MW x 2	retirement 1995
Sucat	1 G, 150 MW	retirement 1998
Sucat	2 G, 200 MW	retirement 2000

Gas turbines are hurried substitutes to fill the void resulting from mothball on a nuclear power plant, and since it is expected there will be early deterioration due to a high rate of operation, it was considered that output would decline to one half in 5 years with retirement to be in 10 years.

b) Hydro

(Firm Output)

Based on past performance in operation, the firm outputs were set as follows.

Firm Outputs of Hydro Power Stations

(Unit: MW)

Power Plant	Magat	Ambuklao	Binga	Angat	Caliraya	Casecnan
Firm Output	180	36	79	142	15	94*

Power Plant	Pantabam	Botocan	Masiway	Kalayaan	Total
Firm Output	26	0	0	300	872

* assumed value

(Retiring Schedule)

Botocan	3G	0.96 MW	1995
Botocan	1G, 2G	2 x 8 MW	1998
Caliraya	1G, 2G	2 x 8 MW	1992
Caliraya	3G	1 x 8 MW	1997
Caliraya	4G	1 x 8 MW	2000

(2) Energy Balance

The plant factors of the various types of power plants were set as given below, based on which annual energy production amounts were determined.

Oil-fired thermal	:	50%
Coal-fired thermal, geothermal	:	75%
Gas turbine	:	10%
Pumped Storage	:	15%

Reservoir type hydro : 25%

Run-of-river type hydro : 20%

It was considered that forced outages of thermal units would not affect the annual energy balance.

(3) Results of Study

As shown in Table 4-7 and Figs. 4-3 and 4-4, there will be a condition of both peak and energy supply capability being short for the time being, and this is seen in the present situation of frequent supply shortages.

The kW peak balance will be recovered once in 1993 with commissioning of the Coal 3 Power Plant, but true recovery including energy balance will not be achieved until after 1997.

Particularly, in the latter half of the 1990s, the peak supply capability will decline with aging of gas turbines commissioned in the period from 1989 to 1992, but on the other hand, it will be a period when pumping-up power sources will be created through development of large-scale coal-fired thermal plants. Accordingly, it is judged that the latter half of the 1990s will be a favorable time for the Stage II Project.

The concrete timing of commissioning of the Stage II Project and the scale of development will be discussed in Chapter 8.

Table 4-1 Trend of Power Demand and GDP in Luzon Grid

Year	GDP Mil P at 1972	Demand (GWh)		Loss+St.s Load (%)	Peak Pow. in (MW)	Annual Lf (%)	Demand Rate (%)
		Sales Lev	Gen. Lev.				
1980	59,306	12,164	13,126	7.9	2,074.0	72.2	-
1981	61,896	12,690	13,647	7.5	2,225.0	70.0	4.0
1982	63,272	13,125	14,199	8.2	2,364.0	68.6	4.0
1983	64,558	13,908	15,312	10.1	2,478.0	70.5	7.8
1984	60,021	13,245	14,143	6.8	2,374.0	68.0	-7.6
1985	57,328	13,135	14,449	10.0	2,311.0	71.4	2.2
1986	57,730	13,461	14,756	9.6	2,435.0	69.2	2.1
1987	60,001	14,720	16,030	8.9	2,592.0	70.6	8.6
1988	63,576	16,078	17,439	8.5	2,776.0	71.7	8.8
1989	67,391	16,788	18,215	8.5	2,938.0	70.8	4.4

Table 4-2 Demand Forecast in Luzon Grid (Mid-case GDP: 6.4%)

Year	GDP Mil P at 1972	Demand (GWh)		Loss+St.s Load (%)	Peak Pow. in (MW)	Annual Lf (%)	Demand Rate (%)
		Sales Lev	Gen. Lev.				
1989	67,391	16,788	18,215	8.5	2,938.0	70.8	-
1990	71,704	18,681	20,269	8.5	3,305.5	70.0	11.3
1991	76,293	20,362	22,093	8.5	3,602.8	70.0	9.0
1992	81,176	22,150	24,033	8.5	3,919.3	70.0	8.8
1993	86,371	24,053	26,097	8.5	4,255.9	70.0	8.6
1994	91,899	26,077	28,294	8.5	4,614.1	70.0	8.4
1995	97,780	28,231	30,631	8.5	4,995.3	70.0	8.3
1996	104,038	30,523	33,118	8.5	5,400.8	70.0	8.1
1997	110,697	32,962	35,764	8.5	5,832.3	70.0	8.0
1998	117,781	35,557	38,579	8.5	6,291.4	70.0	7.9
1999	125,319	38,317	41,574	8.5	6,779.9	70.0	7.8
2000	133,340	41,255	44,761	8.5	7,299.6	70.0	7.7
2001	141,874	44,380	48,152	8.5	7,852.6	70.0	7.6
2002	150,953	47,705	51,760	8.5	8,441.0	70.0	7.5
2003	160,614	51,244	55,599	8.5	9,067.1	70.0	7.4
2004	170,894	55,008	59,684	8.5	9,733.2	70.0	7.3
2005	181,831	59,014	64,030	8.5	10,442.0	70.0	7.3

Table 4-3 Demand Forecast in Luzon Grid (Steady case GDP: 5.5%)

Year	GDP Mil P at 1972	Demand (GWh)		Loss+St.s Load (%)	Peak Pow. in (MW)	Annual Lf (%)	Demand Rate (%)
		Sales Lev	Gen. Lev.				
1989	67,391	16,788	18,215	8.5	2,938.0	70.8	-
1990	71,098	18,460	20,029	8.5	3,266.3	70.0	10.0
1991	75,008	19,892	21,583	8.5	3,519.7	70.0	7.8
1992	79,133	21,402	23,221	8.5	3,786.9	70.0	7.6
1993	83,486	22,997	24,952	8.5	4,069.1	70.0	7.5
1994	88,077	24,678	26,776	8.5	4,366.5	70.0	7.3
1995	92,922	26,452	28,700	8.5	4,680.4	70.0	7.2
1996	98,032	28,324	30,732	8.5	5,011.7	70.0	7.1
1997	103,424	30,299	32,874	8.5	5,361.1	70.0	7.0
1998	109,112	32,382	35,134	8.5	5,729.7	70.0	6.9
1999	115,114	34,580	37,519	8.5	6,118.6	70.0	6.8
2000	121,445	36,899	40,035	8.5	6,528.9	70.0	6.7
2001	128,124	39,345	42,689	8.5	6,961.7	70.0	6.6
2002	135,171	41,926	45,490	8.5	7,418.4	70.0	6.6
2003	142,606	44,649	48,444	8.5	7,900.2	70.0	6.5
2004	150,449	47,521	51,560	8.5	8,408.4	70.0	6.4
2005	158,724	50,552	54,849	8.5	8,944.7	70.0	6.4

Table 4-4 Demand Forecast by NAPOCOR (PDP Nov. 1989)

Year	Demand (GWh)		Peak Pow. (MW)	Annual Lf (%)
	Sales Lev.	Gen. Level		
1989	17,317	18,782	2,978	72.0
1990	18,733	20,373	3,230	72.0
1991	20,325	22,116	3,506	72.0
1992	21.951	23,886	3,787	72.0
1993	23,707	25,797	4,090	72.0
1994	25,604	27,860	4,417	72.0
1995	27,652	30,089	4,771	72.0
1996	29,864	32,496	5,152	72.0
1997	32,235	35,096	5,564	72.0
1998	34,833	37,904	6,010	72.0
1999	37,620	40,936	6,490	72.0
2000	40,630	44,211	7,010	72.0
2001	43,880	47,748	7,570	72.0
2002	47,391	51,568	8,176	72.0
2003	51,182	55,693	8,830	72.0
2004	55,276	60,148	9,536	72.0
2005	59,698	64,960	10,299	72.0

Table 4-6 Power Development Program by the Mission

YEAR	New Power Plants (MW)		Retirement(MW)	Installed Cap.
1,989	———		———	Total:4,322MW
1,990	Hopwell GT Power Barge GT	4×50 4×30	none	4,642
1,991	Sucat Land Barge GT New GT	1×30 6×50	none	4,972
1,992	Power Barge GT Bac-Man Geo Combined Cycle	1×27.5 2×55 1×200	Carilaya #1,2 -16	5,293.5
1,993	Power Barge GT Bulusan Geo Coal Ⅲ Maibarara Geo Bac-Man Geo Ⅱ Calaca Ⅱ	1×27.5 3×20 1×300 1×10 2×20 1×300	none	6,031
1,994	Balog-Balog Hyd. Pinatubo Geo	2×11 3×20	none	6,113
1,995	Cagua Geo Tongonan Geo-A Del Gallego Geo	2×20 8×55 6×20	Botocan #3 -1 Manila#1,2 -200	6,512
1,996	Tongonan Geo-B Coal A-1 *	8×55 1×300	none	7,252
1,997	Coal A-2 * Kalayaan Ⅱ	1×300 2×150	Carilaya #3 -8	7,844
1,998	Coal B-1 Casecnan	1×300 268	Botocan#1,2 -16 Sucat #1 -150	8,246
1,999	Coal B-2 Combined Cycle	1×300 1×300	none	8,846
2,000	Combined Cycle	1×600	Carilaya #4 -8 Sucat #2 -200	9,238

* Coal A : Masinloc

Table 4-7 Demand and supply Balance in MW and GWh

YEAR	1989	1990	1991	1992	1993	1994
Demand(Gwh) Gen.Lev	18,215	20,029	21,582	23,221	24,952	26,776
Peak pow. (MW)	2,938	3,266	3,520	3,787	4,069	4,367
Pondage Hyd. (MW)	895	895	895	879	879	901
Run-of-river	32	32	32	32	32	32
Pumped Hyd. (MW)	300	300	300	300	300	300
Hyd.Tot.Ins.Cap(MW)	1,227	1,227	1,227	1,211	1,211	1,233
Hyd.Tot.Firm Cap.	778	778	778	770	770	777
Hyd.Dep.Enr(GWh/yr)	2,410	2,410	2,410	2,375	2,375	2,423
Gas Turbine(MW)	210	530	860	888	915	810
Oil Thermal(MW)	1,925	1,925	1,925	1,925	1,925	1,925
Geo.Thermal	660	660	660	770	880	940
Coal	300	300	300	300	900	900
Combined cyc.	0	0	0	200	200	200
Thr.Tot.Ins.Cap(MW)	3,095	3,415	3,745	4,083	4,820	4,775
Thr.Tot.Firm Cap.	2,067	2,387	2,717	3,039	3,741	3,693
Thr.Dep.Enr(GWh/yr)	14,923	15,203	15,492	17,553	22,242	22,544
Tot.Ins.Cap(MW)	4,322	4,642	4,972	5,294	6,031	6,008
Ins.Cap.Margin(%)	47	42	41	40	48	38
Tot.Firm Cap(MW)	2,845	3,165	3,495	3,809	4,511	4,470
Firm Cap.Margin(%)	-3	-3	-1	1	11	2
Tot.Dep.Enr(GWh/yr)	17,333	17,613	17,902	19,928	24,617	24,967
Dep.Enr.Margin(%)	-5	-12	-17	-14	-1	-7

YEAR	1995	1996	1997	1998	1999	2,000
Demand(Gwh) Gen.Lev	28,700	30,732	32,874	35,134	37,519	40,035
Peak pow. (MW)	4,680	5,012	5,361	5,730	6,119	6,529
Pondage Hyd. (MW)	901	901	893	1,161	1,161	1,153
Run-of-river	31	31	31	15	15	15
Pumped Hyd. (MW)	300	300	600	600	600	600
Hyd.Tot.Ins.Cap(MW)	1,232	1,232	1,524	1,776	1,776	1,768
Hyd.Tot.Firm Cap.	777	777	1,073	1,167	1,167	1,163
Hyd.Dep.Enr(GWh/yr)	2,422	2,422	2,798	3,357	3,357	3,340
Gas Turbine(MW)	650	485	471	457	352	192
Oil Thermal(MW)	1,725	1,725	1,725	1,575	1,575	1,375
Geo.Thermal	1,540	1,980	1,980	1,980	1,980	1,980
Coal	900	1,200	1,500	1,800	2,100	2,100
Combined cyc.	200	200	200	200	500	1,100
Thr.Tot.Ins.Cap(MW)	5,015	5,590	5,876	6,012	6,507	6,747
Thr.Tot.Firm Cap.	3,983	4,521	4,792	4,973	5,438	5,728
Thr.Dep.Enr(GWh/yr)	25,470	30,187	32,146	33,447	37,297	40,223
Tot.Ins.Cap(MW)	6,247	6,822	7,400	7,788	8,283	8,515
Ins.Cap.Margin(%)	33	36	38	36	35	30
Tot.Firm Cap(MW)	4,760	5,298	5,865	6,140	6,605	6,891
Firm Cap.Margin(%)	2	6	9	7	8	6
Tot.Dep.Enr(GWh/yr)	27,891	32,609	34,944	36,805	40,655	43,563
Dep.Enr.Margin(%)	-3	6	6	5	8	9

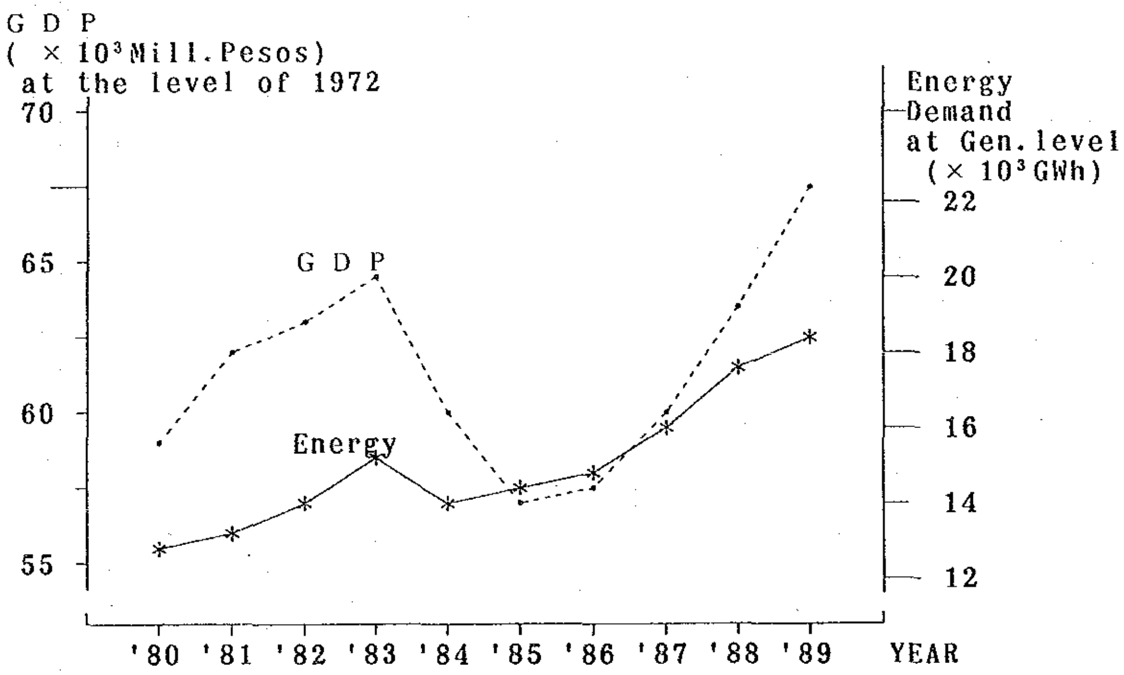


Fig. 4-1 Correlation between GDP and Electric Energy

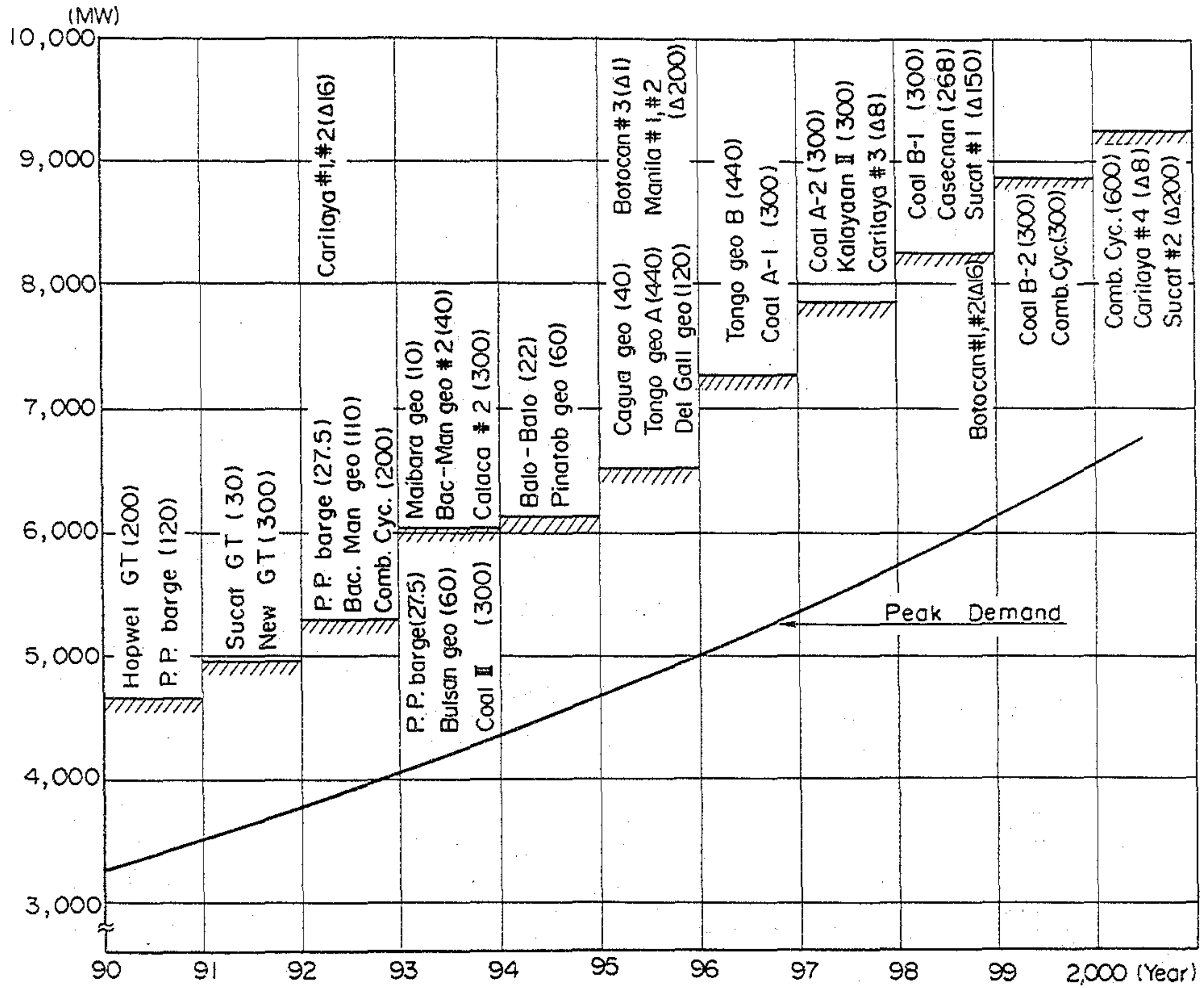


Fig. 4-2 Installed Power Balance in Luzon Grid

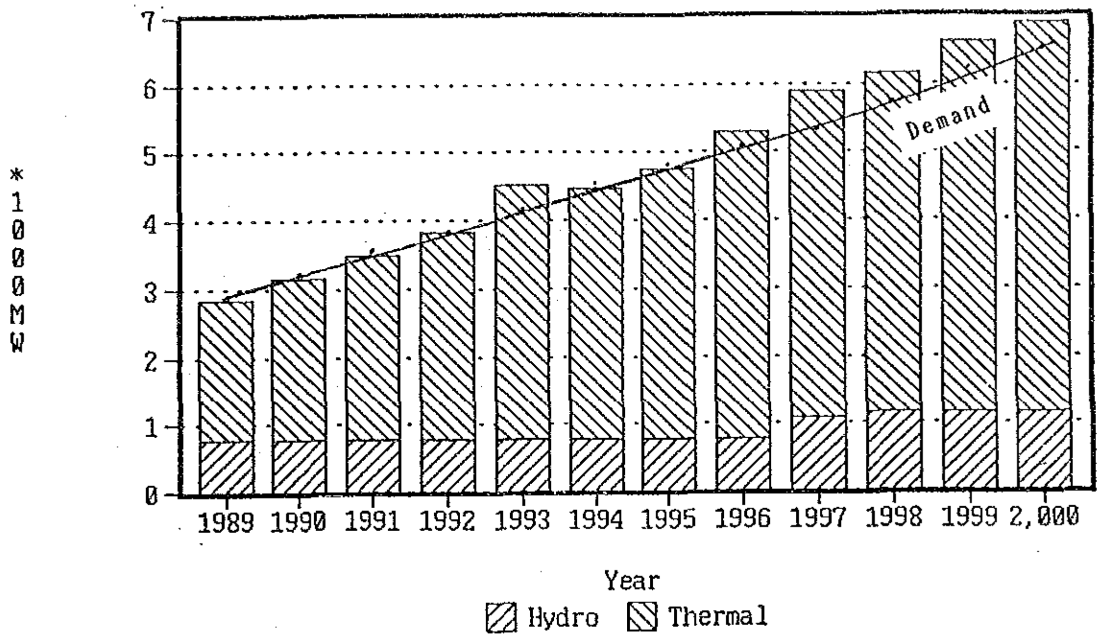


Fig. 4-3 Firm Power Balance in Luzon Grid

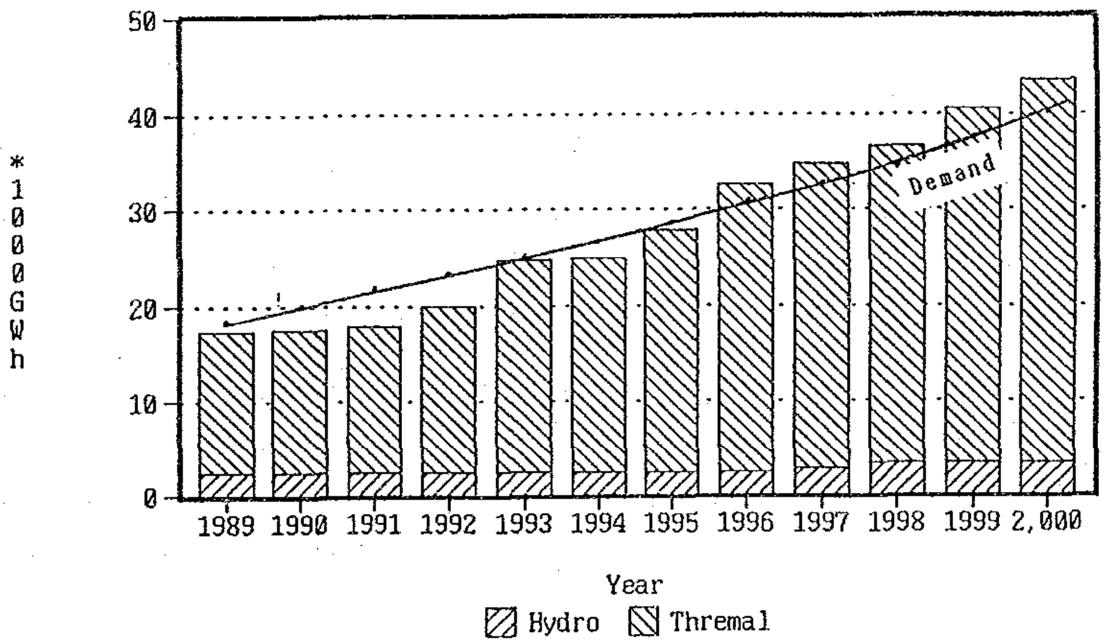


Fig. 4-4 Firm Energy Balance in Luzon Grid

Chapter 5 Hydrology

Chapter 5 Hydrology

5.1 General Meteorology

The Republic of the Philippines is located in the tropics and has more than 7,000 islands, large and small, scattered between 5° and 21° north latitude. Broadly speaking, the territory may be divided into a region in the north of the large island of Luzon, a region in the south of the large island of Mindanao, and the Visayas Islands Region where is located between these two large islands.

The climate is oceanic and strongly influenced by the monsoons developed in the Indian Ocean and the north Pacific Ocean. There is little temperature variation throughout the year except in mountainous areas. Rainfall is generally heavy and humidity is high.

The southwest monsoon due to Indian Ocean trade winds causes mostly southwest winds to begin blowing from around June, which become strongest in August and continue into September and October, bringing rain all over the western coasts of the Philippines.

The northeast monsoon is a cold air current system developed due to high atmospheric pressures in the north Pacific Ocean causing mostly northeast winds to blow from around October, becoming strongest around January, and continuing to around April, and at times bringing heavy rains all over the eastern coasts of the Philippines.

The average precipitation of the entire Philippines is 2,400 mm. However, the influences of location and topography are great, and in general, the difference between dry and wet seasons is distinct on the South China Sea side, which includes Manila, whereas the Pacific Ocean side has abundant rainfall throughout the year.

The Philippines are situated along the path of typhoons and heavy damage is sustained from these storms. Typhoons are generated in the ocean to the east of the Philippines and move to the west or toward Indochina and strike the Philippines from July to December.

5.2 Caliraya and Lumot Reservoirs

The Caliraya and Lumot reservoirs are provided by earthfill dams on the upstream stratches of the Caliraya and Lumot rivers which are tributaries of the Pagsanjan River, and the two reservoirs are connected by a tunnel with diameter of 2.0 m and length of 1,850 m.

5.2.1 Meteorology

(1) Geographical Conditions

Caliraya Reservoir is located approximately 60 km east-southeast of Manila, in the central area of Luzon Island. Geographically, the vicinity of the central region of Luzon is sandwiched by Manila Bay on the west side and by Lamon Bay on the east side, and the greater part of the central region is taken up by Laguna de Bay. Caliraya Reservoir is located at the west half of the approximately 30 km between the northeast part of Laguna de Bay and Lamon Bay. The area of Central Luzon has Mt. Banahao towering to an elevation of more than 2,000 m approximately 25 km south of Caliraya Reservoir, but mostly, the land on the Lamon Bay side is a tableland of elevation 400 to 500 m, while the land on the Manila Bay side has low-elevation topography.

(2) Precipitation

The meteorology of the vicinity of Caliraya tends to be affected by the two monsoons because of its geography. There is precipitation of more than 200 mm monthly from June to December, and the annual precipitation is around 3,000 mm. The maximum daily rainfall of the year occurs mostly in November or December, and in 1964, as much as 457.2 mm was recorded.

(3) Temperature

The temperature is about the same as at Manila, the minimum being from 20°C to 24°C, and the maximum being from 24°C to 33°C. It is the hottest in May and it is generally about 4°C cooler than Manila.

(4) Evaporation

Evaporation is about 1,200 mm annually.

5.2.2 Hydrology

(1) Inflow

The catchment areas of the Caliraya and Lumot reservoirs are 92 km^2 and 37 km^2, respectively, comprising plateau-like hill areas of elevation from 400 to 500 m.

The areas of the reservoirs are 12 km^2 and 6.4 km^2, and make up large proportions of the respective catchment areas, and rainfall enters the reservoirs in short periods of time.

Gauging stations for inflows had not been provided yet. Therefore, inflow had been calculated by using the water level of Caliraya Reservoir, the energy productions of Caliraya and Kalayaan Power Plants, and pump-up energy of Kalayaan Power Plant.

Caliraya Reservoir is connected with Lumot Reservoir by a tunnel 2.0 m in diameter so that the inflow to Lumot Reservoir is regulated naturally and flows into Caliraya Reservoir to be included as part of the inflow to Caliraya Reservoir.

The past average annual inflow was 200 x 10^6 m^3. Table 5-1 gives the actual inflow at Caliraya Reservoir.

The peak flood discharge at Caliraya Reservoir has been analyzed in "Feasibility Report of Caliraya Dam Rehabilitation Project" by JICA in Sept. 1986, as shown below.

Return Period (yr)	Peak Flood Discharge (m^3/s)
1,000	2,632
200	2,173
100	1,968
50	1,770
10	1,300

(2) Runoff Regulation by Reservoir

The effective storage capacities of Caliraya and Lumot reservoirs are 22.1 x 10^6 m^3 (see Fig. 5-1) and 22.0 x 10^6 m^3, which are large in comparison with the annual inflow of 200 x 10^6 m^3.

The Caliraya and Lumot reservoirs are tied together by a connecting waterway as mentioned previously, and through the water level difference between the two reservoirs, inflows and outflows (1 m = 2.37 m^3/s, 2 m = 3.37 m^3/s, 3 m = 4.10 m^3/s, 4 m = 4.76 m^3/s) are small capacity-wise. However, the two reservoirs possess regulating functions which act organically with each other. (See Fig. 5-2)

The stream inflow to Lumot Reservoir is naturally regulated annually by the discharge through the connecting waterway and runs into Carilara Reservoir.

Water above the high water level is discharged by a morning glory type spillway 4 m in diameter.

The inflow of Caliraya Reservoir consists of stream inflow pumped water by the Stage I Plant (maximum: 90.8 m^3/s) and discharge from Lumot Reservoir. The outflow consists of generation discharge of Caliraya Power Plant (maximum: 14.74 m^3/s), Kalayaan power generation discharge (Stage I, maximum: 124.0 m^3/s), and outflow to Lumot Reservoir. The reservoirs are operated for these outflows and inflows to be optimum in using the effective storage capacity of 22.1 x 10^6 m^3 for power generating operation on a weekly basis.

Water rising above EL.289.2m during flood is discharged by a spillway tunnel 4.2 m in diameter with a cylinder gate and an emergency spillway. (In the previously-mentioned "Feasibility Report of Caliraya Dam Rehabilitation Project", rehabilitation of the normal-use spillway, addition of a spillway, and rehabilitation of the dam are recommended).

(3) Water Level of Caliraya Reservoir

Caliraya Reservoir, since its construction until March 1982, had been operated solely for Caliraya Power Station with maximum output of 32 MW, using maximum discharge of 14.74 m^3/s. During that time it was operated with maximum water level of EL. 289.15 m and minimum water level of EL. 276.00 m, for a reservoir operation pattern of water stored in the reservoir in the wet season and supplemented from the reservoir in the dry season. Since August 1982, the operation of Stage I Project had been on the basis of a weekly pattern of peak power generation of maximum output of 300 MW with maximum discharge of 124.0 m^3/s, between maximum water level of EL. 289.15 m and minimum water level EL. 286.00 m, and of off-peak time pump-up. Recently, however, since there has come up the matter of rehabilitation of Caliraya Dam, the maximum water levels in operation have been made EL. 289.15 m in the dry season and EL. 288.0 m in the wet season to cope with water level rises during floods.

(4) Sedimentation in Caliraya Reservoir

The particulars of Caliraya Dam are height of 42 m, total storage capacity of 79.0 x 10^6 m^3, and reservoir area of 12 km^2. Fifty years have passed since start of construction on the dam in 1939.

Sedimentation in the reservoir is not considered to be very great as much landsliding and erosion are not found in the surrounding topography, even though 50 years have passed since start of construction. The Pagsanjan River of the same river system is transporting large amounts of sediment to Laguna de

Bay annually, and the source of sediment supply is thought to be midstream and downstream stretches of the river as described in 5.3.3 of Chapter 5.

5.3 Laguna de Bay

5.3.1 Geographical Conditions

Laguna de Bay is located to the southeast of Manila and takes up the greater part of Central Luzon sandwiched by Manila Bay and Lamon Bay. It extends approximately 45 km east-west and 40 km north-south, and the area is approximately 900 km^2 with two peninsulas sticking out more than 20 km into the lake from the north. Laguna de Bay empties into Manila Bay by means of the Pasig River which starts out from the northwest part of the lake, goes northwest for approximately 20 km, and passes finally through Metro Manila.

5.3.2 Water Level of Laguna de Bay

The water level of Laguna de Bay fluctuates in a range between EL. -0.2 m and EL. 2.0 m in proportion to rainfall. Broadly divided seasonally, March to June make up the period of lowest water with water levels between EL. -0.2 m and EL. 0.4 m, January to February, and July to August are intermediate periods with water levels from EL. 0.2 m to EL. 0.9 m, while September to December correspond to a period of high water at EL. 0.8 m to EL. 2.0 m. On August 3, 1972, a water level of EL. 3.53 m was recorded.

5.3.3 Sediment Carried by Pagsanjan River

The Pagsanjan River collects the waters of the upstream plateau-like tablelands (tuff, agglomerate, etc.) including Caliraya and Lumot reservoirs and 250 km^2 of river terrace areas at its midstream and downstream stretches in a dendritic pattern, and empties into Laguna de Bay protruding about 6 km into the northeast part of the lake, south of Kalayaan, due to deposition of sediment.

According to "Feasibility Study Report of Kalayaan Pumped Storage Plant" in May 1973 by ELC, the sediment discharged into Laguna de

Bay by this river has been at a rate of extension of 10 m a year from 1919 to 1969.

The largest source of the sediment transported in is considered to be silt scoured from river terraces at the midstream and downstream stretches of the river due to rising water levels during floods.

5.4 Establishment of Meteorology Observation Station and Guaging Station

The meteorology and river flows must be observed to support operation and maintenance of facilities including dam, power plant and switch yard, and to grasp information related to the power generation based on the amount of reservoir inflow.

5.4.1 Establishment of Meteorological Observation Station

For Caliraya and Lumot Reservoirs, the meteorological stations will be established near the dams, because these reservoirs have large storage capacities as compared to their catchment areas, and installation of stations near the dams will facilitate operation maintenance of the stations.

The variables to be observed will be the air temperature, humidity, precipitation and wind velocity, and it is desirable to transmit these data to the control room of Kalayaan Power Plant for automatic recording.

5.4.2 Establishment of Guaging Station

To monitor the inflows into Caliraya and Lumot Reservoirs, the water level meters in the reservoirs will be installed at the dams or near the intake structures. It is desirable to install water level meter in tailrace of the normal-use spillway, in order to measure the inflow loss (spilled water) which is discharged through the normal-use spillway of Caliraya Reservoir.

The measured data will be transmitted to the control room of Kalayaan Power Plant Kalayaan Control Station for automatic recording, similarly to the meteorological data.

The inflows to Caliraya and Lumot Reservoirs will be calculated based on the reservoir water levels, discharge for power generation (generated energy) and the reservoir water losses.

Table 5-1 Actual Inflow at Caliraya Reservoir (MCM)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	Sub-total	JUL	AUG	SEP	OCT	NOV	DEC	Sub-total	TOTAL
1960	16.88	12.70	7.60	3.14	13.11	18.80	70.23	9.58	14.98	10.84	24.87	10.55	9.14	79.96	150.19
1961	8.01	5.39	4.34	2.64	9.19	9.00	38.57	8.77	6.35	13.24	12.21	28.32	9.79	78.68	117.25
1962	5.27	6.66	5.61	4.51	4.44	6.81	33.30	10.82	7.62	21.96	7.45	16.13	15.06	79.04	112.34
1963	5.39	6.61	3.61	3.95	3.21	5.84	28.61	6.58	15.03	12.35	9.96	8.81	12.70	65.43	94.04
1964	9.31	8.57	9.32	7.56	6.18	16.11	57.05	14.34	8.87	12.66	23.65	29.59	23.94	113.05	170.10
1965	9.99	5.96	7.44	5.69	6.57	2.45	38.10	9.55	7.51	9.59	8.74	19.39	25.26	80.04	118.14
1966	8.50	3.94	4.14	3.31	8.13	6.27	34.29	10.29	5.70	7.21	9.33	9.64	14.81	56.98	91.27
1967	13.08	2.55	4.64	5.58	3.55	4.32	33.72	4.82	12.15	8.56	10.44	22.23	8.93	67.13	100.85
1968	7.52	3.72	3.65	1.60	3.02	4.36	23.87	5.10	7.19	7.51	14.79	5.61	4.70	44.90	68.77
1969	6.73	0.46	0.97	0.83	0.51	1.09	10.59	8.52	4.64	8.01	4.01	8.55	21.07	54.80	65.39
1970	13.29	3.38	1.79	4.62	1.21	4.31	28.60	9.61	3.64	10.76	24.91	33.67	20.08	102.67	131.27
1971	8.54	19.25	16.96	10.95	18.17	37.91	111.78	49.32	16.69	15.41	72.79	49.85	69.53	273.59	385.37
1972	9.89	16.05	5.08	10.37	10.11	18.18	69.68	55.37	25.75	26.09	21.12	56.53	60.58	245.44	315.12
1973	15.56	8.28	5.18	9.67	4.58	5.75	49.02	11.82	8.31	27.15	44.69	76.59	84.49	253.05	302.07
1974	13.13	9.63	10.56	4.19	13.45	13.25	64.21	6.31	32.24	14.86	64.71	52.42	57.38	227.92	292.13
1975	26.22	10.69	14.28	38.37	13.63	11.86	115.05	2.04	15.87	24.64	26.08	33.15	86.78	188.56	303.61
1976	16.59	7.38	2.11	30.23	31.77	46.46	106.54	3.56	25.45	5.35	34.26	42.93	48.69	160.24	266.78
1977	19.94	13.08	5.95	2.45	26.64	9.94	78.00	12.21	16.46	19.74	16.14	40.82	46.01	151.38	229.38
1978	15.77	6.32	3.76	7.85	5.26	4.76	44.72	4.21	15.45	26.49	100.84	16.84	13.69	177.52	222.24
1979	4.21	0.29	0.28	5.96	15.81	22.02	48.57	7.53	20.37	15.79	24.91	35.03	16.46	120.09	168.66
1980	9.57	10.71	25.48	12.58	13.62	46.85	118.81	28.29	15.57	26.84	54.58	58.21	29.31	212.80	331.61
1981	18.12	8.16	12.78	11.93	15.28	15.62	92.09	29.34	18.71	32.01	37.90	65.89	45.00	228.85	310.94
1982	16.27	10.66	5.45	9.74	6.43	6.79	55.34	18.85	9.56	35.10	12.43	33.53	27.58	137.05	192.39
1983	28.57	10.14	8.15	6.01	4.54	2.76	60.17	29.16	16.02	20.38	58.62	19.19	21.60	164.97	225.14
1984	19.33	8.86	14.64	5.02	7.59	6.78	62.22	5.95	13.95	16.54	63.84	21.36	16.28	137.92	200.44
1985	6.15	8.02	5.52	3.98	8.67	26.95	39.29	30.01	6.86	27.86	75.21	39.42	30.05	209.41	268.70
1986	23.62	9.19	9.19	9.33	4.07	6.59	61.99	41.33	38.50	18.34	79.64	53.62	44.27	275.70	337.69
1987	18.70	7.68	6.62	4.50	2.03	5.55	45.08	4.01	14.08	9.79	16.58	54.00	62.19	160.65	205.73
1988	42.94	15.11	6.32	26.81	9.93	19.14	120.25	16.45	10.93	8.46	81.37	67.12	15.48	199.81	320.06
1989	17.38	21.03	18.93	9.49	29.90	32.10	128.83	26.73	13.99	16.67	26.92	17.71	21.52	123.53	252.36
TOTAL	434.47	260.47	230.35	262.86	301.60	388.82	1878.57	480.47	428.44	510.20	1062.99	1026.70	962.37	4471.16	6349.73
AVERAGE	14.48	8.68	7.68	8.76	10.05	12.96	62.62	16.02	14.28	17.01	35.43	34.22	32.08	149.04	211.66 (6.71 m^3/s)
MAXIMUM	42.94	21.03	25.48	38.37	31.77	46.85	128.83	55.37	38.50	35.10	100.84	76.59	86.78	275.70	385.37
MINIMUM	4.21	0.29	0.28	0.83	0.51	1.09	10.59	2.04	3.64	5.35	4.01	5.61	4.70	44.90	65.39

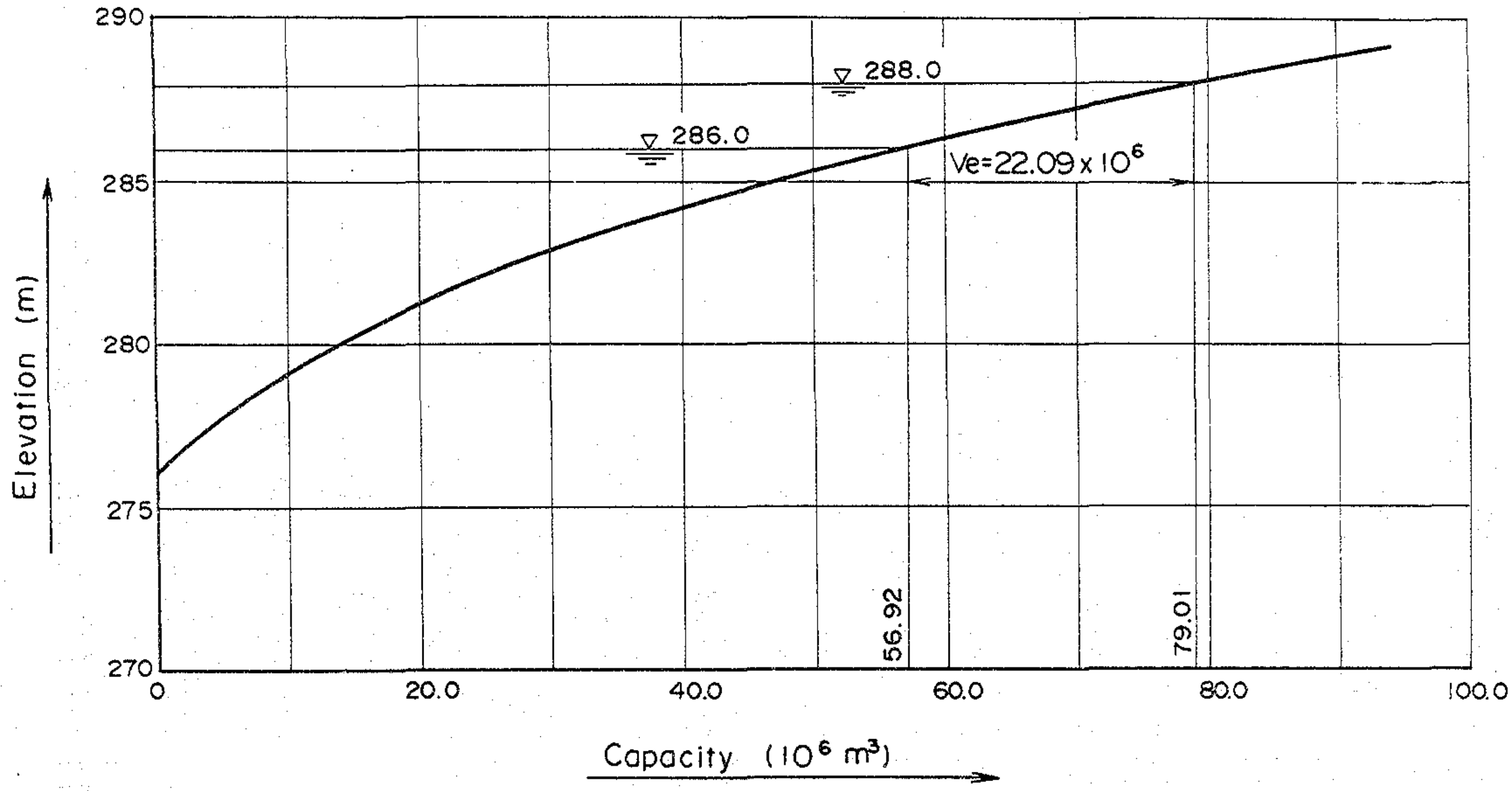


Fig. 5-1 Caliraya Reservoir Capacity

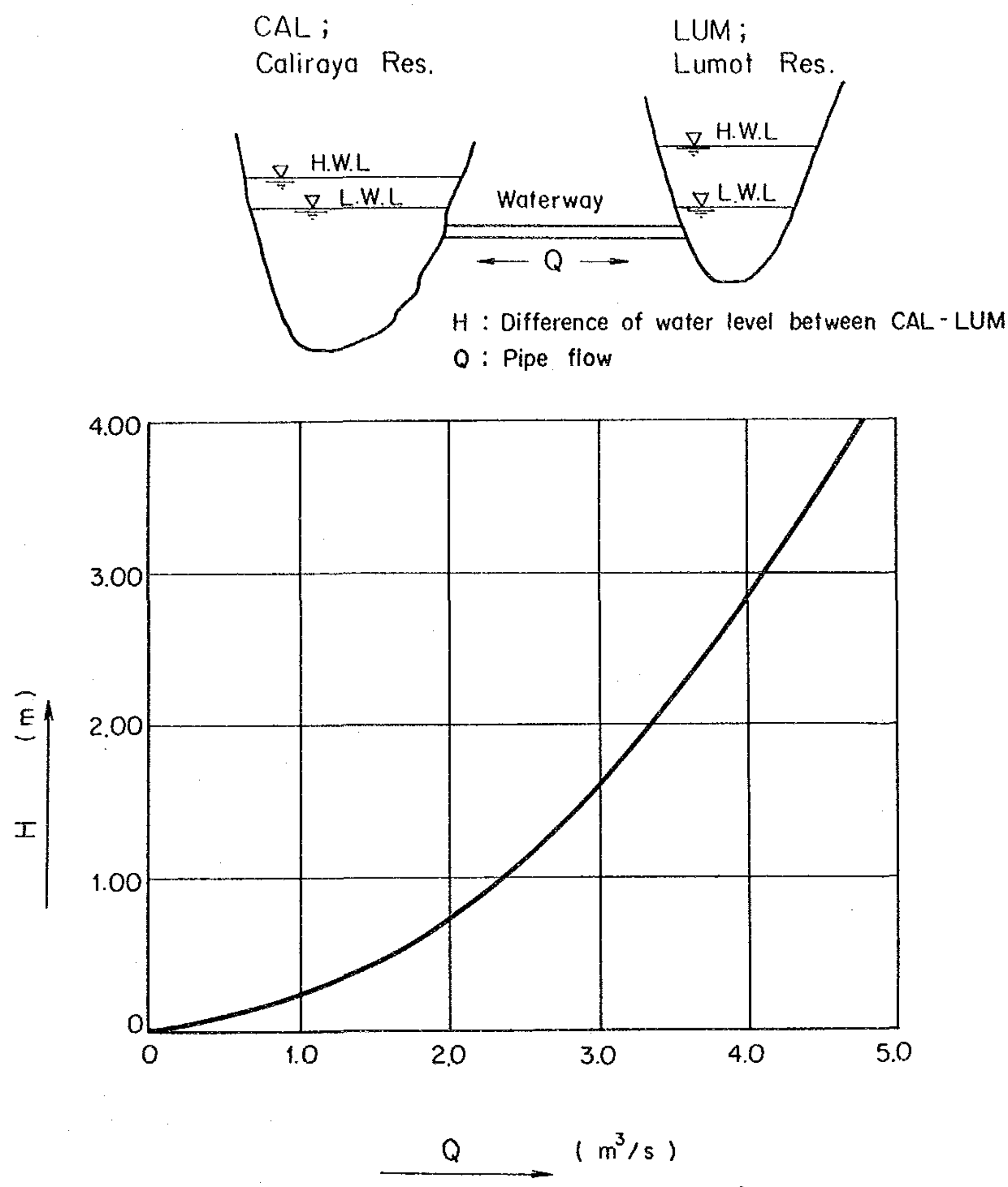


Fig. 5-2 Connecting Tunnel Discharge

Chapter 6 Geology

Chapter 6 Geology

6.1 Topography and Geology around the Project Site

The topography of the area around the Project site, located to the eastern end of Laguna de Bay, is featured by lava plateau, 200 to 400 m in altitude, which form steep cliffs at the shore of Laguna de Bay, as illustrated in Fig. 6-1.

The tops of the lava plateaus are flat lands having relatively large numbers of small undulations, and Caliraya Reservoir and Lumot Reservoir, which form the upper reservoirs for the plant, are located on these plateaus. The western sides of these plateaus are steep slopes, from 200 to 300 m in relative height and having 50° to 60° gradients, which faces Laguna de Bay. The national road runs at elevation of 40 to 50 m along these steep slopes. The delta formed by the Pagsanjan River, flowing to the northwest, spreads to the south of the power plant site.

The geology of the area around the Project site, as shown in Fig. 6-2, is featured by a wide cover of volcanic products which originated from Banohao Volcano located about 25 km south of the site and, were ejected from the Neogene Pliocene Epoch to the Quarternary Period.

These volcanic products consist of pyroclastic rocks of basalt-andesite lava, tuff, agglomerate, etc., which are widely distributed from the northern side to the eastern side of Laguna de Bay and centered at Banohao Volcano.

In Fig. 6-2, remarkable faults are indicated in three directions, N-S, NW-SE and NE-SW.

6.2 Geology around Each Structure Site

The materials collected during the investigation and the results of the field survey indicate the following geological features (Refer to Fig. 6-3).

(1) Upper Canal

The upper canal already exists, having been constructed in the Stage I.

The ground surface consists of tuff and basalt, and tuff is widely distributed overlying basalt. The weathering of tuff has progressed to change the color to red-brown, and soften the tuff. The foundation bases of the upper canal are mostly weathered basalt.

A landslide is observed on the right bank at about 500 m to the upstream of the intake. The landslide seems to have affected an area of 250 to 300 m along the stream, 50 to 60 m in height. The affected area contains several slides of horseshoe shape, and there is no sign that they are moving now. If movement is found in future, some measures will be required, including the removal of sliding deposits.

(2) Intake

The intake was constructed together with the upper canal during construction works of the Stage I. There is a transition boundary near the intake from agglomerate to basalt, and the foundation of the intake is weathered basalt.

No abnormal condition is found at the intake and its surrounding area, and it is deemed that there is no geological problem in terms of civil engineering.

(3) Penstock Route

The route of the penstock of Stage II has been planned 10 m to the west of the existing penstock of Stage I, and the area of the penstock route was mostly excavated during construction works of the Stage I.

The geological properties along the penstock route consist of the following three kinds.

(a) Upper Inclined Section

In this section, basalt of the same nature as that around the intake is distributed. The surface is mostly covered with sand and soil with little foundation rock exposed, but some exposure of hard and massive basalt rocks are observed in some places.

(b) Central, Sub-Horizontal Section

In this section, tuff is widely distributed with thickness of approximately 40 m (according to DDH-PT-C boring) over the basalt base rock. On the slope (1:1.7) constructed to the west of the penstock route of this plan, medium-soft tuff are exposed from place to place. The slope of these rocks are stable, and there seems to be no risk that the slope collapses.

(c) Lower, Sub-Vertical Section

This section forms a steep gradient of 45° to 65°, where fresh and hard basalt rocks are distributed. Basalt is exposed all over the cliff along the road at elevation of 50 m. The basalt rocks in this area have relatively developed joints and cracks, which will be turned to rock lumps of 20 to 50 cm diameters by excavation.

In this survey, a boring (DDH-STII-3) was done vertically from the surface of national road down to 30 m to confirm the rock quality. The results indicated that there are hard, fresh and massive basalt from surface down to 9.5 m. From the depth of 9.5 m to the boring bottom of 30 m, there are developed cracks in some zones, but medium hard and massive agglomerate is generally distributed.

From the above survey results, it can be concluded that there will be no particular problem concerning bearing force and stability in the foundation of the penstock route, its surrounding areas and the slope which has been already constructed.

(4) Power Plant

The land area for the power plant of Stage II work and its surrounding areas have been prepared in Stage I. Agglomerate is exposed all over the steep slope of the mountain side. The agglomerate has various lithofacies, such as soft component containing matrix of tuff materials, generally hard component containing many basalt gravels, as well as parts containing thin layers or lenses of tuff and basalt. The rocks are generally massive, but some parts are weathered and embrittled.

According to the boring survey materials of Stage I, there is a fault with large base rock displacement in the NE-SW direction at about 30 m to the west of the power plant site, and a strong water gush was encountered at the power plant site.

In this survey, boring (DDH-STII-1, DDH-STII-2) was performed on 2 holes at the power plant site to confirm the fault mentioned above, and the properties of foundation rocks and permeability of the power plant site were studied.

According to this study, it is deemed that the fault exists at the boundary between talus deposit and agglomerate at the depth of 23.3 m of DDH-STII-1, but it property is not clear as the core recovery rate is not good, being around 50%. It was confirmed that the foundation rock is medium-hard, and consists of generally massive agglomerate. Concerning the permeability of foundation rock, there were many zones where high permeabilities of 20 Lugeon or more were observed. In particular, with DDH-STII-2, water gush of $P = 0.08$ kgf/cm^2, $Q = 12$ l/min., and $P = 1$ kgf/cm^2, $Q = 30$ l/min. was observed at two points respectively.

Based on the above survey result, it can be regarded that the foundation rock at the power plant site involves no problem concerning bearing force and slope stability during excavation. However, as high permeability is observed, and pressurized ground water exists, the measures of stopping this water must be studied carefully.

(5) Tailrace

According to the boring survey record of Stage I, the foundation of the tailrace is agglomerate for a distance of approximately 50 m from the power plant. On the west side of fault located there, it probably consists of talus deposits made up of basalt boulders and cobbles, and deposits from Laguna de Bay consisting of clay, silt, and sand.

There appears to be no problem as a structural foundation, but thorough study will have to be made to stop water from Laguna de Bay during the construction work.

6.3 Geological Investigation Works

Boring were conducted as described below at the power plant site and the sub-vertical section of the penstock route. The water permeability test using the bored holes were conducted at the same time.

Hole Number	Direction	Boring Length	Location
DDH-STII-1	S50° E45°	70	power plant site
DDH-STII-2	vertical	50	power plant site
DDH-STII-3	vertical	30	penstock route
Total of 3 Holes	---	150	----

The results of boring are given in Fig. 6-4, and the details are presented in the boring logs in Appendix 1. The outline of results are presented below.

(1) DDH-STII-1

0 -- 23.33 m: Talus deposit

* The core mainly consists of gravels and debris of basalt. The core recovery rate is not good, being generally below 50%.

23.33 -- 70.00 m: Agglomerate

* Mainly consists of relatively hard, bar shaped cores, 20 to 50 cm long. The core recovery rate was good, generally being 100%.

* The boundary between the talus deposite and agglomerate at 23.33 m is deemed a fault based on past survey results. As the core recovery rate of this core is not good, being approximately 50%, it is not conclusive. However, it can be judged that there is a fault at 23.33 m considering the conditions of surrounding areas.

* In the Lugeon test, many zones were 30 Lugeons or more, and it was confirmed that permeability is high.

(2) DDH-STII-2

0 -- 1.00 m: Alluvium

* Consists of sands and gravels.

1.00 -- 50.00 m: Agglomerate

* Mostly consists of relatively hard, bar-shaped cores which are 20 - 50 cm long. The core recovery rate is good, generally being 100%.

* According to the result of Lugeon test, the following three regions had high permeability, and two of them bred water.

  . Depth 14.45 to 17.45 m: 25 Lugeon.
  Water spring; $P = 0.08$ kgf/cm^2, $Q \doteq 12$ l/min

- Depth 32.50 to 33.55 m: 30 Lugeon.
  Water breeding; P = 1 kgf/cm^2, Q ≑ 30 l/min

- Depth 44.70 to 47.75 m: 25 Lugeon.

Regions other than the above three indicated 10 Lugeons or less. Therefore, it seems that high permeability exists only in locations where there are open fractures.

(3) DDH-STII-3

0 -- 9.46 m: Basalt

* Mainly consists of fresh, hard cores which are from 15 to 20 cm bars.

9.46 -- 30.00 m: Agglomerate

* In some places, fractures developed and turned to rock pieces. However, cores are mostly relatively hard, and 20 to 40 cm long bars.

* The results of Lugeon test were 5 Lugeons or less for basalt, indicating low permeability. Agglomerates indicated relatively high permeability, being generally 15 Lugeons or more down to the depth of 23.35 m. From 23.35 m to the bottom of 30.00 m, very low permeability of 0 Lugeon was measured.

6.4 Blasting Test

6.4.1 Objective and Schedule of Blasting Test

The location of the Stage II Project is near the existing power plant, and in excavation of the power plant shaft for Stage II, there is a possibility that adverse effects will be exerted on the existing power plant.

Many studies have been conducted in the past concerning actual conditions and control methods with regard to blasting vibrations, and various suggestions have been made about the effects of blasting and limitation on structures built on base rock or unconsolidated ground.

Concerning the allowable limit on structures, Langefors, Crandell, Koheeler, Edwards, Bumines and Suzuki et al. claim that, as indicated in Fig. 6-5, the vibration velocity should be 5 kine or less. However, as there are differences in conditions of structures and foundations, it is questionable whether this limit should be directly applied. Therefore, blasting tests must be conducted at the site in question to develop an experimental equation that is most suitable for the ground condition of the site, and the blasting control measures should be established based on specific conditions of the site.

Accordingly, blasting tests using conventional dynamite and static cracker (Calmmite), were conducted for 19 days from August 26 to September 13, 1990 (See Table 1-4 in Chapter 1), in order to identify the basic vibration characteristics of the foundation near the existing power plant, and so that the blasting method, the type of explosive, size of charge and the excavation method in the real construction work could be studied.

The special explosives (Calmmite) and measuring instruments were procured by the Japanese side, and two experts on this subject were dispatched from Japan to plan, provide guidance, and evaluate the blasting tests.

6.4.2 Test Site

The blasting tests were conducted on the foundation rock of the proposed site of the Stage II Project, as illustrated in Fig. 6-6.

6.4.3 Blasting Pattern

Prior to the main tests, preliminary tests, Cases-A and B, were conducted at a location farthest away from the existing power plant inside the site of the Stage II, in order to confirm the effect of blasting on the existing plant. Then, the main tests, Cases-E, F, I and J were conducted at the center of the Stage II site.

(1) Preliminary Blasting Test

The preliminary blasting tests, Cases A and B illustrated in Fig. 6-7 with blasting patterns, were conducted at a point farthest from the Stage I power plant and using conventional dynamite and CCR, to confirm the extent of the effect on the existing power plant, and to measure the vibration velocity (V) and K-value.

(2) Main Blasting Test

The blasting patterns, charges, etc. for the main test were studied based on the results of preliminary tests, and the effect on the existing power plant was re-examined. The main tests were conducted according to patterns illustrated in Fig. 6-8 and Fig. 6-9, and at the center of the Stage II power plant site.

The tests were conducted for cracking of rock having one free surface (Cases C, D, E, F) and two free surfaces (Cases I, J) in order to simulate the actual situation as much as possible.

6.4.4 Measurement Items and Method

For measurement of vibration velocity, measurement points nearest to the point of explosion and easily affected by vibration were selected. There were three of these points, the concrete structure of the Stage I power plant (the side wall of the power plant), the center of the concrete foundation of the generator, and the control room.

The measurement items were the vibration velocity (kine) and acceleration (gal), so that they could be compared with past measurement results, and the measurement data can be analyzed easily with high accuracy after the test.

The configuration of measuring instruments were such that, as illustrated in Fig. 6-10, the two components of pickups installed at measuring point (in orthogonal arrangement), and 6 measurement components were recorded simultaneously on the data recorder through an

Real-time analysis was also carried out on part of the records at the time recording was done for use as references in the next blasting tests.

6.4.5 Measurement Results

The vibration measurement results of each blasting test were collected in a data recorder.

The data were analyzed by FFT analyzer to identify maximum acceleration amplitude and predominant vibration period for each blasting test, these were transformed into vibration velocities, and correlations with explosive charges were obtained.

The results are given in Table 6-1, Fig. 6-11, and Fig. 6-12.

According to the abovementioned measurement results, in all tests performed using conventional dynamite, vibration velocities were all less than 1 kine as shown in Table 6-1, and no effect at all was seen on the existing power plant.

In examples of past measurement results, it was reported that the vibration velocities at which there were no effects at all on structures were less than 1 kine while at 3 kine or higher, there were cases when some kinds of effects were seen, and these test results indicated similar trends.

However, regarding breaking effects, explosive charges were insufficient except in Case-F, breaking of the whole did not occur, and the degree was only that of peripheries of the various hole mouths being broken. In the data of measurement results, vibration waveforms specific to blasting were seen in Case-F and favorable records were obtained, whereas in other cases, waveforms close to stationary waves were seen.

As seen in Fig. 6-11, although there is great scatter as a whole, the larger the explosive charge in a case, a trend of higher vibration velocity being indicated is recognized. In Fig. 6-12, the distances from the blasting site to the measuring points and vibration velocities are shown, and although scattering is great, and not distinct, a trend of attenuation with distance is seen.

In Cases I and J when the static cracker (Calmmite) was used, no noise, vibration, or flying of rock occurred as expansive force created by hydration reaction is taken advantage of. In the instance of Case J, a blow-out phenomenon began to occur 30 minutes after charging Calmmite, and the effect was smaller compared with Case I. Case I had adequate effect and rock was broken into small pieces. However, a long time was required for the effect to appear.

Tests of Cases-C and D employing low detonation-velocity explosive (CCR) had been planned, but since it was found during drilling that the foundation rock was highly permeable and there would be a fairly great amount of springing of water, effects could not be expected even if tests were to be performed and, since it was already known that the vibration value would be about 1/5 to 1/10 of that of dynamite, testing was dropped.

The measurement data of the individual blasting tests are given in Appendix 2.

6.4.6 Analysis and Evaluation of Measuring Results

In general, there is the relationship of the following equation between the vibration velocity generated by blasting and the amount of explosive used.

$$V = K \times W^m \times D^n$$

where:
- V: vibration velocity (kine = cm/s)
- W: amount of explosive (kg)
- D: distance (m)
- K: Coefficient determined by rock quality, explosive type, and blasting method

It was decided to use the above equation for analysis of the velocity measurement results obtained in these tests. Regarding the indices m and n, they were considered to be in the ranges of m = 0.5 to 1.0 (2/3, 3/4) and n = -1 to -2 (-1.5, -2). Since measuring points were extremely close by, it could be expected that attenuation due to distance would be great. Therefore, very-near-distance data of the past were referred to, and the indices m = 2/3 and n = -2 generally employed were adopted.

The basic equation concerning blasting vibrations in this case was the following:

$$V = K \times W^{2/3} \times D^{-2}$$

Applying the value of Case-F in which the maximum vibration velocity was recorded in actual measurements to this equation to obtain the value of the constant K, K = 974 was obtained, and rounding out to be on the conservative side, it came out as given below, although, incidentally, the simple average K-value for all data was 355.

Conventional dynamite K = 1000

Further, obtaining the maximum vibration velocity of the various measuring points by reverse operations applying the dynamite charges (kg) and distances d (m) of these cases using the above K-value, 1.28 kine was calculated for No. 1-V of Case-E, but the actual measurement was 0.28 kine and low, and it may be judged that this was a K-value amply on the conservative side.

Considering the results of these blasting tests, it is desirable for excavation to be done with controlled blasting at least holding vibration velocity to 2 kine in excavation for the main structure of the stage II Project in order that there will not be any adverse effects on the existing plant. In such case, it will be necessary for explosive charges and blasting vibrations to be controlled, monitoring blasting vibrations every time blasting is done. As reference, the relationships of explosive charges and distances with vibration velocities calculated employing the basic equation are shown in Fig. 6-13.

In particular, as vibration velocity is higher in case of one-free-surface blasting than in case of two-free-surface blasting with the same amounts of explosive, it is thought advisable for a sequential blasting device to be used.

The low detonation-velocity explosive (CCR), and the static breaker (Calmmite) cannot be expected to have very much breaking effect at ground of high permeability as at this site, but it is conceivable for these low detonation-velocity explosives and static breakers to be used for supplemental rock excavation in the area close to the existing plant.

However, in excavation by such blasting, the amounts of explosives would be limited so that there will be cases when the bedrock cannot be adequately broken, and consideration should be given to parallel use of giant breakers for secondary breaking.

Table 6-1 Measuring Results of Blasting Tests

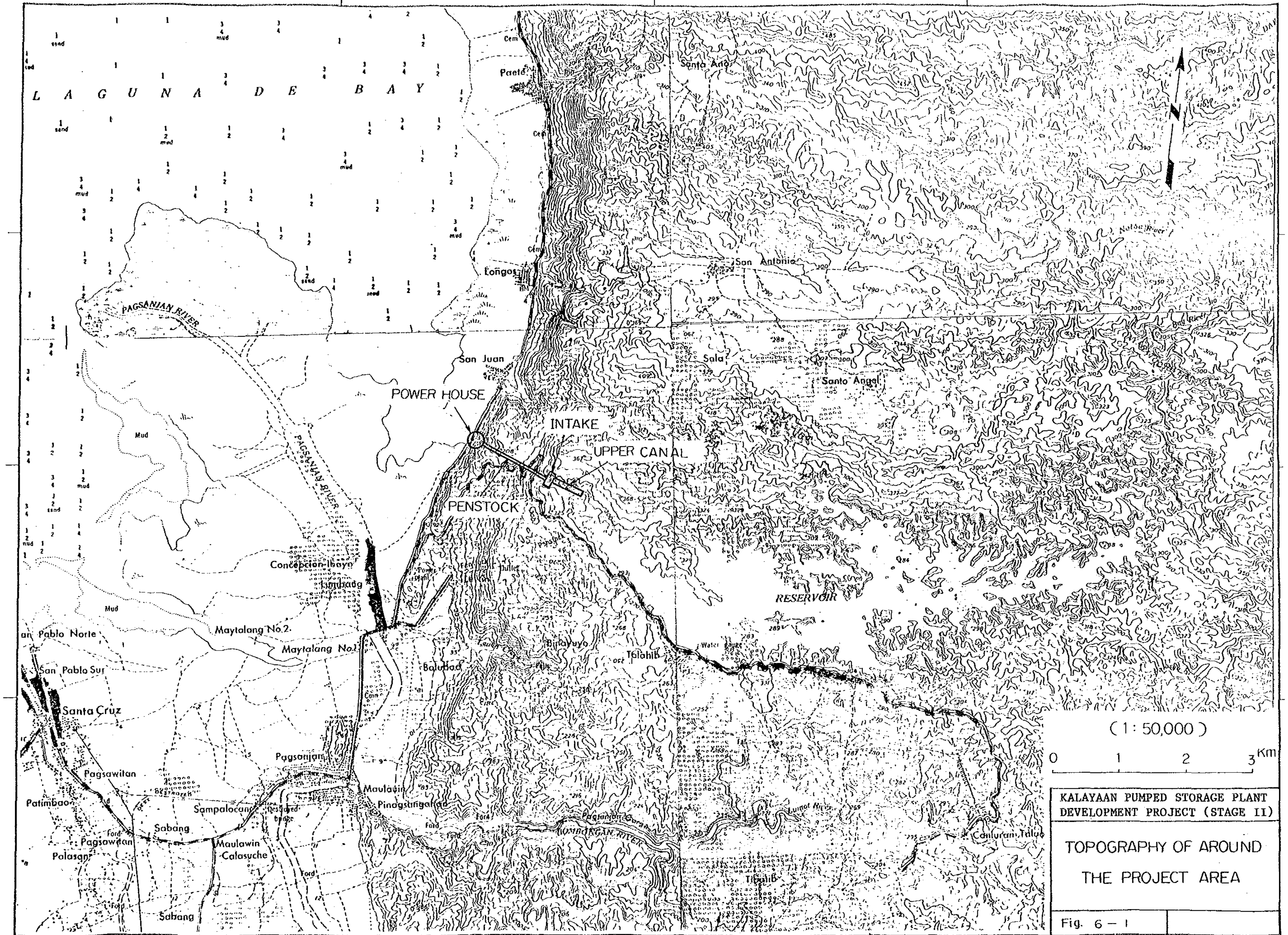
Case-No.	Weight (g)	Drill Depth (m)	Dis. (m)	Meas. Point No.	Accelera-tion(α) (gal=cm/s2)	Frequen-cies(f) (Hertz)	Velocity ($V=\alpha/2\pi f$) (kine=cm/s)	K
Case-A (Explosive)	750	1.30	54	No.1-H	43	120	0.06	201.5
			54	No.1-V	22	120	0.03	103.1
			67	No.2-H	32	120	0.04	230.8
			63	No.3-H	35	120	0.05	223.2
			63	No.3-V	15	120	0.02	95.7
Case-B (Explosive)	1,200	1.30	56	No.1-H	220	120	0.29	810.3
			56	No.1-V	49	120	0.06	180.5
			69	No.2-H	52	120	0.07	290.8
			64	No.3-H	55	120	0.07	264.6
			64	No.3-V	55	120	0.07	264.6
Case-E (Explosive)	1,800	1.30	34	No.1-H	59	120	0.08	61.1
			34	No.1-V	209	120	0.28	216.6
			48	No.2-H	205	120	0.27	423.3
			46	No.3-H	220	120	0.29	417.2
			46	No.3-V	272	120	0.36	515.9
Case-F (Explosive)	2,100	1.50	43	No.1-H	70	80	0.14	157.0
			43	No.1-V	67	25	0.43	480.9
			56	No.2-H	80	25	0.51	973.9
			53	No.3-H	251	110	0.36	622.1
			53	No.3-V	164	80	0.33	558.9
Case-I (Calmmite)	25,560	1.50			More effectively			
Case-J (Calmmite)	64,440	1.50			Effectively			

Generating	No.1-H	43	60	0.11
	No.1-V	40	60	0.11
	No.2-H	36	30	0.19
	No.3-H	33	105	0.05
	No.3-V	61	105	0.09

Non Generating	No.1-H	7	120	0.01
	No.1-V	21	120	0.03
	No.2-H	21	120	0.03
	No.3-H	22	120	0.03
	No.3-V	23	120	0.03

Measuring point No.1 ; Power house's wall
No.2 ; Switch contorol box
No.3 ; Generator room

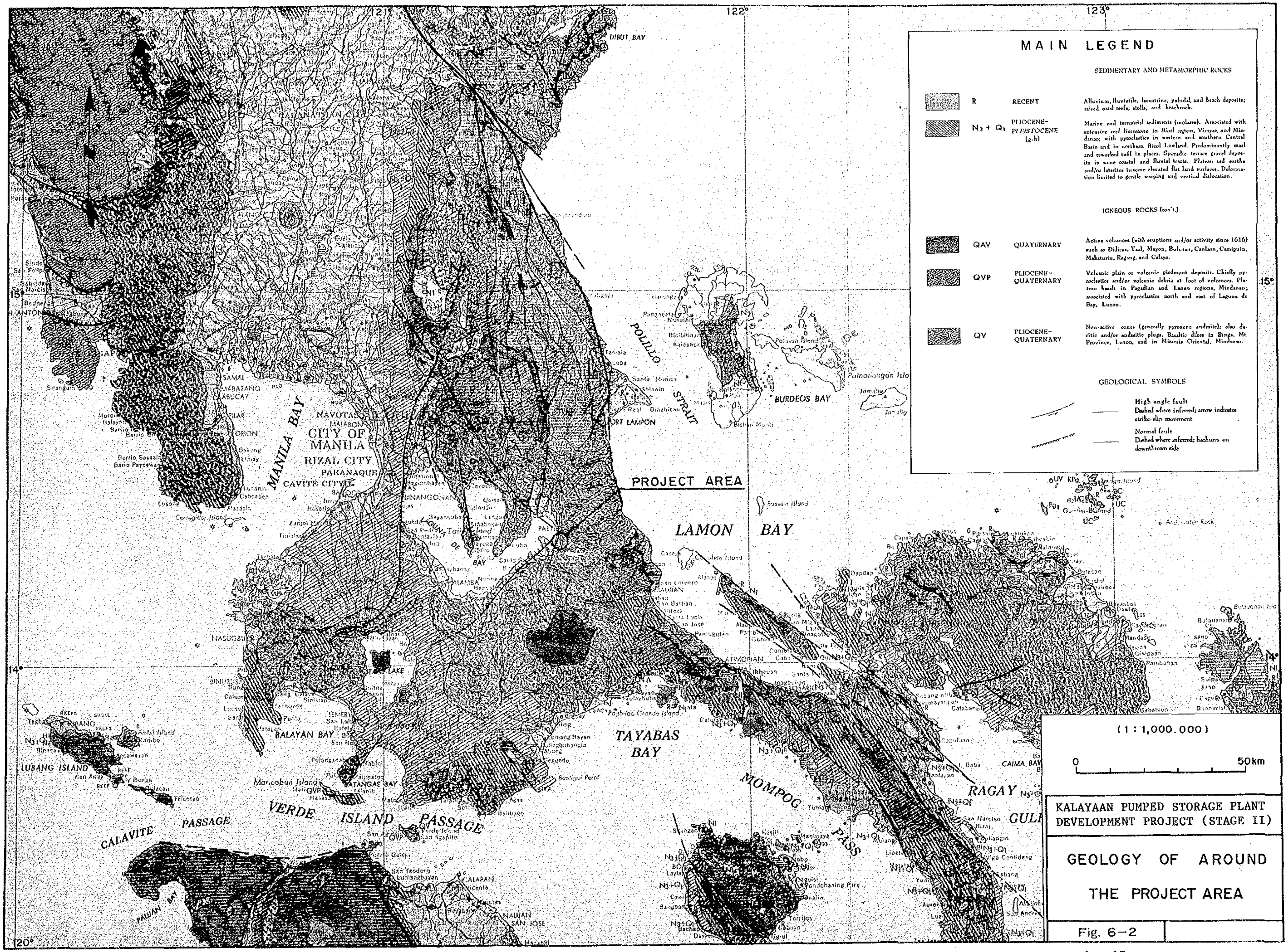
-H ; Horizontal component
-V ; Vertical component



KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

TOPOGRAPHY OF AROUND THE PROJECT AREA

Fig. 6 – 1



MAIN LEGEND
SEDIMENTARY AND METAMORPHIC ROCKS
R RECENT
Alluvium, fluviatile, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beachrock.
N3 + Q1 PLIOCENE-PLEISTOCENE (g-h)
Marine and terrestrial sediments (molasse). Associated with extensive reef limestone in Bicol region, Visayas, and Mindanao; with pyroclastics in western and southern Central Basin and in northern Bicol Lowland. Predominantly marl and reworked tuff in places. Sporadic terrace gravel deposits in some coastal and fluvial tracts. Plateau red earths and/or laterites in some elevated flat land surfaces. Deformation limited to gentle warping and vertical dislocation.
IGNEOUS ROCKS (con't.)
QAV QUATERNARY
Active volcanoes (with eruptions and/or activity since 1616) such as Didicas, Taal, Mayon, Bulusan, Canlaon, Camiguin, Makaturin, Ragang, and Calayo.
QVP PLIOCENE-QUATERNARY
Volcanic plain or volcanic piedmont deposits. Chiefly pyroclastics and/or volcanic debris at foot of volcanoes. Plateau basalt in Pagadian and Lanao regions, Mindanao; associated with pyroclastics north and east of Laguna de Bay, Luzon.
QV PLIOCENE-QUATERNARY
Non-active cones (generally pyroxene andesite); also dacitic and/or andesitic plugs. Basaltic dikes in Binga, Mt. Province, Luzon, and in Misamis Oriental, Mindanao.
GEOLOGICAL SYMBOLS
High angle fault
Dashed where inferred; arrow indicates strike-slip movement
Normal fault
Dashed where inferred; hachures on downthrown side
PROJECT AREA
MANILA BAY
CITY OF MANILA
RIZAL CITY
LAMON BAY
TAYABAS BAY
POLILLO STRAIT
BURDEOS BAY
VERDE ISLAND PASSAGE
CALAVITE PASSAGE
MOMPOG PASS
RAGAY GULF
BALAYAN BAY
LUBANG ISLAND
DIBUT BAY
121°
122°
123°
15°
14°
120°
(1 : 1,000,000)
0 50km
KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)
GEOLOGY OF AROUND THE PROJECT AREA

Fig. 6-2