REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION

FEASIBILITY REPORT
ON
DIDUYON
HYDROELECTRIC DEVELOPMENT PROJECT
UPPER CAGAYAN RIVER

VOLUME 2. SUPPORTING DATA

DECEMBER 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION

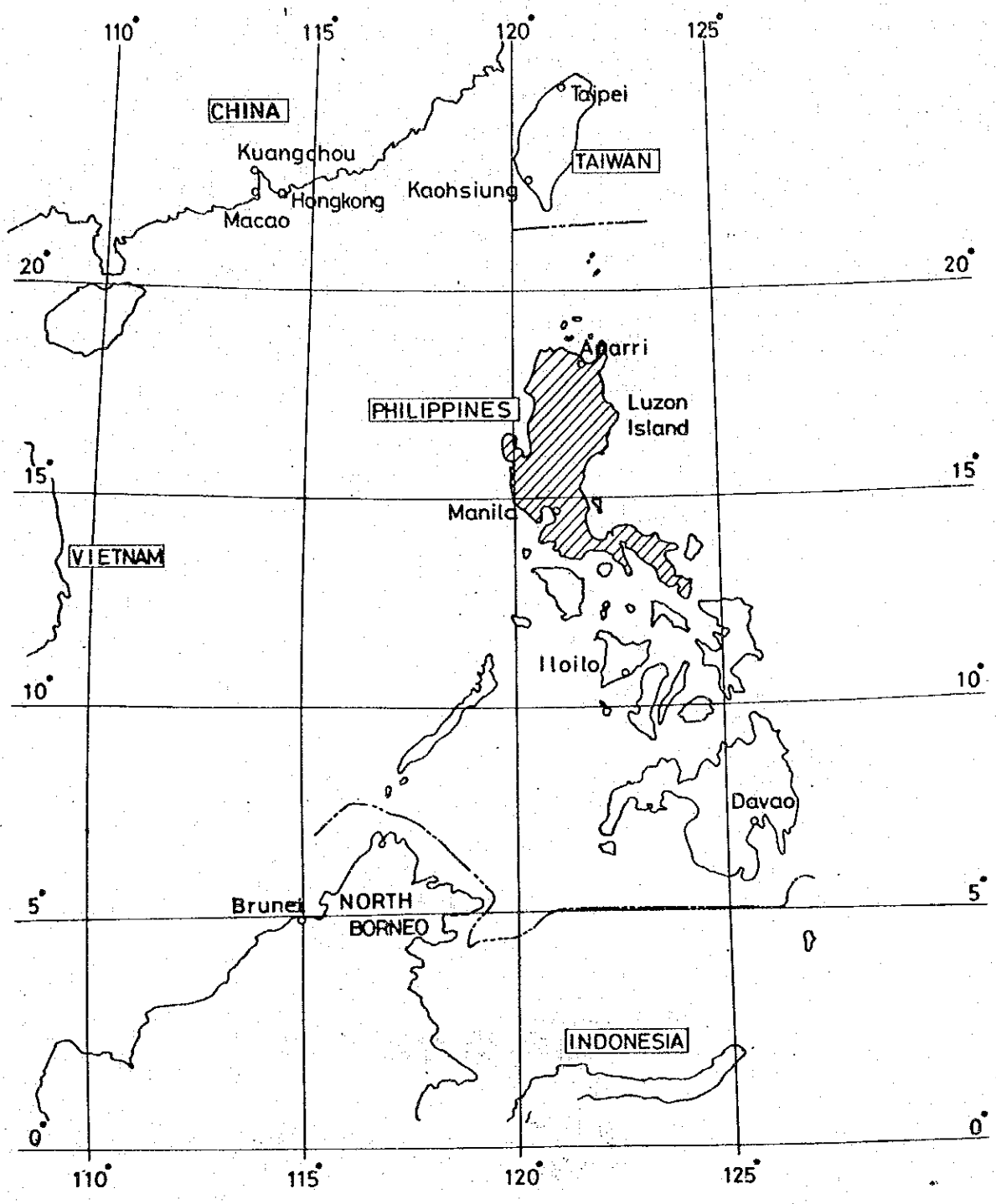
FEASIBILITY REPORT
ON
DIDUYON
HYDROELECTRIC DEVELOPMENT PROJECT
UPPER CAGAYAN RIVER

VOLUME 2. SUPPORTING DATA

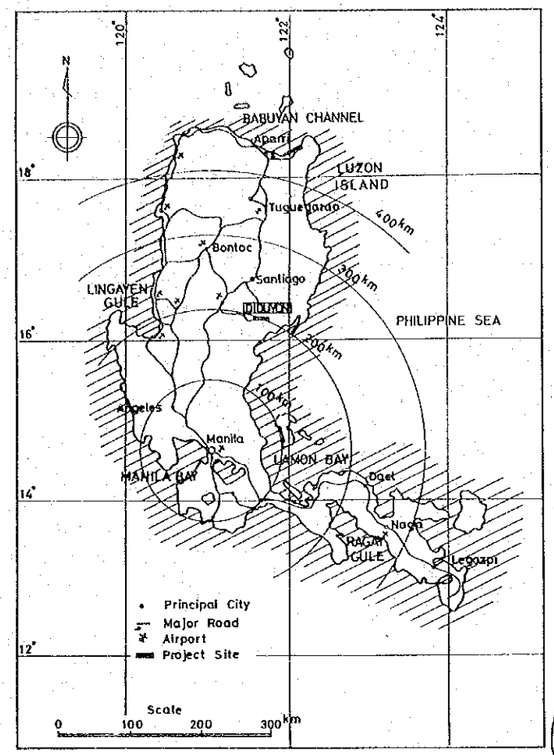
DECEMBER 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

Map of the Philippines



Diduyon Hydroelectric Project Upper Cagayan River Republic of the Philippines	
Japan International Cooperation Agency	
Map of the Philippines	
October 1980	

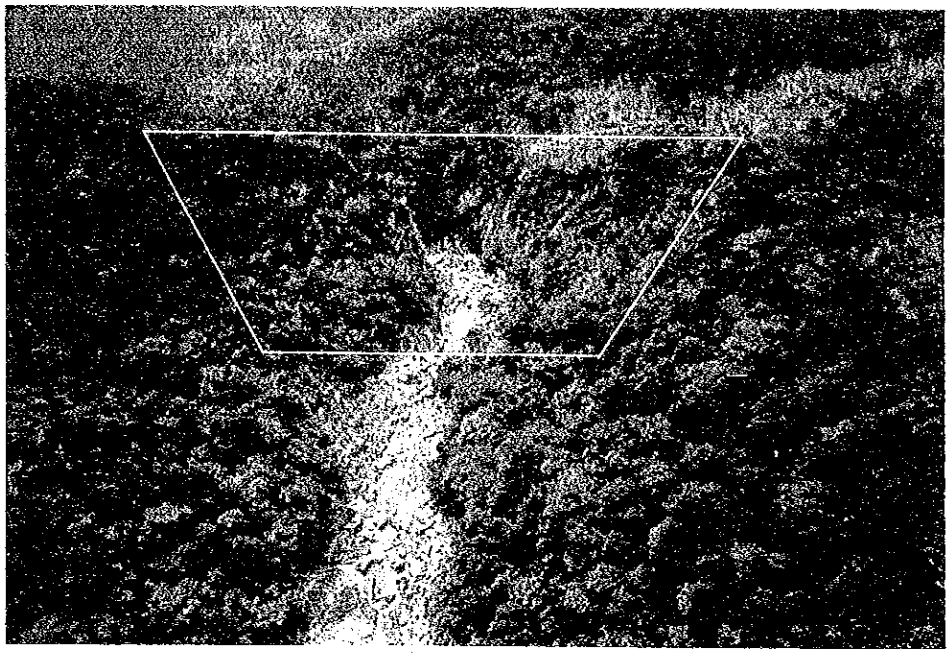


Diduyon Hydroelectric Project
Upper Cagayan River
Republic of the Philippines

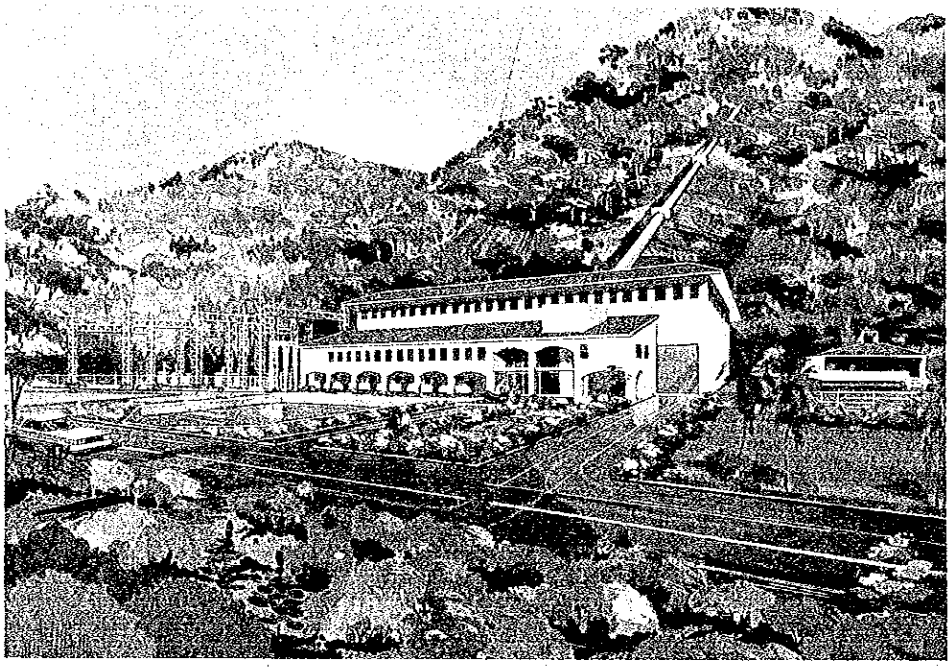
Japan International Cooperation Agency

Location Map and Site Map

October 1980



DIDUYON DAMSITE VIEWED FROM UPSTREAM



ARTIST'S CONCEPT OF POWERHOUSE

Diduyon Hydroelectric Project Upper Cagayan River Republic of the Philippines
Japan International Cooperation Agency
Dam and Powerhouse Photographs
October 1980 Fig.

Contents

List of Tables

List of Figures

U N I T S

mm	millimeter
cm	centimeter
m	meter
km	kilometer
ft	foot
m^2	square meter
km^2	square kilometer
ha	hectare
kg	kilogram
m^3	cubic meter
ft^3	cubic feet
s or sec	second
t or ton	metric ton
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
MWh	megawatt-hour
GWh	gigawatt-hour
kV	kilovolt
kVA	kilovolt-ampere
MV	megavolt
MVA	megavolt-ampere
°	degree of angle
°C	centigrade (Celsius)
mill	U.S. mill
$	U.S. dollar
₱	Philippine Peso
EL	the height above mean sea level
H.W.L.	high water level
L.W.L.	low water level
T.W.L.	tail water level
N.W.L.	normal water level
F.W.L.	flood water level
r.p.m.	revolution per minute
HP	horsepower

CHAPTER 1. DIDUYON PROJECT

1. Diduyon Project

The Diduyon Project is a hydroelectric development project with a maximum capacity of 345 MW and annual energy generation of 957 GWh, on the upper reaches of the Diduyon River, a tributary of the Cagayan River System in Northern Luzon.

The background and history of the project development are given in Vol. I, 1.1.

1.1. Study Progress

A feasibility study of the project started in July 1978. The study was carried out by technical assistance provided by the Japanese Government through Japan International Cooperation Agency (JICA) in response to a request made by the Philippine Government.

The study was carried out into three stages:

1st stage (6 months)

Field reconnaissance, gathering data and their examination, programming of field exploration works, installation of gauging stations and other preparatory works.

2nd stage (16 months)

Execution of geologic explorations, production of aerographic and ground survey maps, hydrological observations, material test and other field works.

3rd stage (8 months)

Office study of alternative plans for the project and selection of the optimum plan, design and cost estimates of the project, evaluation of the project from the viewpoints of economics, finance and environmental aspects, and preparation of the report.

Based upon the agreed Terms of Reference and Scope of Work mutually signed between National Power Corporation (NAPOCOR) and the JICA Study Team in the beginning of the study, NAPOCOR has undertaken major part of field works, such as production of aerotopographic maps and ground survey, exploration of geologic surveys including drilling, aditting and seismic prospecting, production of regional geological maps and installation of gauging station on the site with observation. JICA has been responsible for planning of the project, field investigation programming, analyses of all aspects of the project including cost estimates and economic/financial evaluations, and preparation of report. In the following table is mentioned the division of responsibilities in the study between JICA and the Philippine Government - NAPOCOR, with summary of works actually accomplished in the study.

Thus, a feasibility study of the project was carried out by complete mutual cooperation between the Philippines and Japan.

The JICA Study Team made preliminary studies of alternative plans for power development on the river basin based on reconnaissance made all over the river basin from July 1978 to February 1979. All the results were reported in the JICA Interim Report prepared in March 1979.

According to the recommendations given in the Interim Report, necessary field exploration works were carried out all over the project area, mainly by NAPOCOR and partly by the contractors employed by NAPOCOR. In the year of 1979, the weather in the Diduyon river basin was not favourable for smooth execution of field investigations due to the early coming of the rainy season. This deteriorated seriously the road condition of the logging track to and in the job sites. In early 1979, the Philippines was annoyed by another fuel crisis, which increased difficulty in transportation and procurement of necessary food, materials, and technical personnel to the site. It was anticipated in advance that the topographical ruggedness of the area would bring the surveying teams a great hardship, but combined with the bad weather conditions and difficulty

in accessibility to the job sites, the field works were all lagged behind the schedule.

In summer of the same year, there arose "the August Incident" on the site, which resulted in loss of all NAPOCOR bankhouses and warehouses on the damsite, and inevitable retreat of the NAPOCOR and JICA survey teams with a complete suspension of all field works for nearly two months.

At this juncture, NAPOCOR, in consultation with JICA, took all possible means to recover the situations, including several pacificating meetings with the inhabitants in the region, and consequently peace came again in the region. With reorganized work orders and employment of local contractors, the survey works were resumed very vigorously on all job sites. JICA also sent several times technical experts to assist NAPOCOR.

Thus, the majority of the scheduled field works was finished by May 1980. With the results of field surveys on hand, the JICA Study Team carried on the office studies of design and analysis of the project. All the results were reported in a draft final report submitted to the JICA Head-quarter and then to NAPOCOR in October 1980.

This Final Report involves all the study progress, the results of surveys as far as obtained up to now, the final optimum development plan with conclusion and recommendations as well as recommendation for necessary future works.

A feasibility study of the Diduyon Project has verified the viability of the project for development in the nearest future.

Division of Responsibilities in the Study between JICA and NAPOCOR

Item of Works	Quantity		Remarks
	Planned	Accomplished	
1. Field Reconnaissance	1	1	by JICA
2. Topographical Survey			
Aerial topo-maps			by NAPOCOR
(1/10,000)	300 km^2	300	
- " - (1/5,000)	5.9 km^2	5.9	- " -
Ground Survey (1/1,000)	5.9 km^2	6.8	- " -
Miscellaneous survey	1	1	- " -
3. Drilling			
No.3 Damsite	13 holes-880 m	14 holes-945 m	by NAPOCOR
No.2 Damsite	3 holes-140 m	3 holes-140 m	- " -
Headrace	4 holes-160 m	4 holes-160 m	- " -
Surge tank & penstock	4 holes-160 m	4 holes-162 m	- " -
Powerhouse (open type)	3 holes-120 m	3 holes-120 m	- " -
- " - (underground type)	1 hole-400 m	1 hole -400 m	- " -
Quarry	5 holes-250 m	5 holes-236 m	- " -
Total	33 holes-2,110 m	34 holes-2,163m	
4. Aditting, No.3 Damsite	6 adits-300 m	6 adits - 300 m	by NAPOCOR
5. Seismic Prospecting			
No.3 Damsite	4 lines-2.3 km	4 lines-2.1 km	by NAPOCOR
No.2 Damsite	1 line -1.0 km	1 line -1.0 km	- " -
Others	12 lines-6.7 km	12 lines-6.7 km	- " -
Total	17 lines- 10 km	17 lines-9.8 km	
6. Hydrological Observations	1	1	by NAPOCOR
7. Material test	1	1	by NAPOCOR & JICA
8. Sedimentation Test	1	1	by NAPOCOR
9. Geologic Map	1	1	by NAPOCOR & JICA
10. Preliminary Comparative Analysis of Plans	1	1	by JICA
11. Feasibility Design	1	1	by JICA
12. Reports			
Progress Report	1	1	by JICA
Interim Report	1	1	- " -
Draft Final Report	1	1	- " -
Final Report	1	1	- " -

1.2. Acknowledgement

JICA sent the Feasibility Study Team to the Philippines for the staying periods as mentioned below. The team members dispatched are as follows :

Name	Title	Staying Period
1. Mr. M. Ikeda	Team Leader	Jul. 6 - Aug. 9, 1978
	Civil Engineer	Dec. 3 - Dec. 16, 1978
		Jan. 16 - Feb. 15, 1979
2. Mr. T. Hamada	Deputy Team Leader	Aug. 11 - Sep. 13, 1979
	Planning Engineer	Nov. 6 - Dec. 20, 1979
		Jun. 8 - Jul. 5, 1980
		Oct. 20 - Oct. 27, 1980
3. Mr. S. Takemoto	Coordinator	Aug. 22 - Sep. 3, 1979
4. Mr. M. Suemori	Coordinator	Jul. 6 - Jul. 21, 1979
5. Mr. H. Kohashi	Coordinator	Oct. 20 - Oct. 26, 1980
6. Mr. Y. Chiaki	Hydrologist	Jul. 6 - Aug. 19, 1978
7. Mr. M. Doi	Civil Engineer - Planner	Jul. 6 - Aug. 19, 1978
8. Mr. T. Kochi	Civil Engineer - Designer	Jul. 6 - Aug. 19, 1978
		Jun. 17 - Jul. 5, 1980
9. Mr. H. Yugeta	Senior Geologist	Jul. 6 - Aug. 19, 1978
		Jan. 16 - Feb. 14, 1979
		Nov. 14 - Dec. 8, 1979
		Feb. 12 - Mar. 17, 1980
10. Mr. T. Shuku	Economist	Jul. 6 - Aug. 5, 1978
		Jul. 8 - Jul. 15, 1980
11. Mr. Y. Sekimura	Electrical Engineer	Jul. 6 - Aug. 5, 1978
12. Mr. N. Deguchi	Environment Engineer	Jul. 6 - Aug. 5, 1978
13. Mr. Z. Yamaguchi	Agronomist	Jul. 6 - Aug. 5, 1978

	Name	Title	Staying Period
13.	Mr. Y. Yoshino	Photogrametrist	Jul. 6-Dec. 2, 1978
14.	Mr. T. Shibata	Drilling Expert	Jan.16-Aug.24, 1979
15.	Mr. T. Murakami	Material Test Specialist	Jan.16-Mar.26, 1979
16.	Mr. S. Kawazato	Geophisical Expert	Jan.16-Jun.20, 1979

NAPOCOR assigned necessary counterpart personnel in the respective speciality to cooperate with the JICA team and to execute all the necessary field works. The NAPOCOR staff involved in this study are as follows :

Key Officers

1.	Mr. G. Y. Itchon	President, NPC
2.	Mr. J. U. Jovellanos	Sr. Vice President, NPC
3.	Mr. S. J. De Jesus	Vice President, Engineering Services
4.	Mr. E. P. Abesamis	Manager, Project Development Dept.
5.	Mr. Z. F. Baltazar	Chief, Civil Planning Div.
6.	Mr. R. A. Almero	Chief, Geology & Geotechnics Div.
7.	Mr. Z. P. Santos, Jr.	Chief, Geodesy & Carthography Div.
8.	Mr. B. E. Acuña	Manager, Materials Investigation & Test Div.
9.	Mr. G. A. Wi	Hydrology Specialist
10.	Mr. R. V. Geroso	Chief, Luzon Engineering Laboratory

Personnel Directly Assigned to the Study

11.	Mr. C. S. Guanio	Planning Specialist B
12.	Mr. E. F. Cruz, Jr.	Planning Coordinator
13.	Mr. D. A. Correa, Jr.	Field Investigation Engr.
14.	Mr. G. F. Barron	OIC, Geodesy & Carthography Unit, Diduyon
15.	Mr. B. A. Calong	Principal Hydrologist
16.	Mr. G. V. Valdez	Sr. Civil Engr. III
17.	Mr. I. A. Blanco, Jr.	Sr. Civil Engr. II

18.	Mrs. T. A. Dechavez	Sr. Civil Engr. III
19.	Mr. O. Monlinong, Jr.	OIC, Geology Unit, Diduyon
20.	Mr. E. Galleta	Geotechnical Engr.
21.	Mr. J. Fernandez	Geologist
22.	Mr. M. Gapuz, Jr.	Geologist
23.	Mr. E. Vargas	Geologist
24.	Mr. A. Albason, Jr.	Mechanical Engr.
25.	Mr. W. San Roque	Material Test Engr. II

Many other NAPOCOR engineers and technicians participated in the field works. Without their earnest cooperations and helps extended to the JICA study team, it might be almost impossible to fulfill the duties and taks assigned.

On this occasion of presentation of this Reprot, all the members of JICA herewith wish to express out heartfelt thanks to NAPOCOR and its staff, especially those who worked with us in the remote jungle area under hot and humid weather, overcoming the most rugged topographical features of the region and the difficulty in access which hampered logistic supports to the survey teams.

Our acknowledgement shall also be extended to many government organizations such as PAGASA (Weather Bureau), Bureau of Forest Development, Bureau of Fisheries and Aquatic Resources, Bureau of Land, and their local branch offices, where various information and data were provided to us.

Our deep gratitude shall also be expressed to the Municipalities of Kasibu (Nueva Vizcaya) and Cabarroguis (Quirino), and Philippine Constabulary (PC) personnel, for their kind cooperations and provision of facilities needed for our surveys.

Based on the agreement between the two Governments, JICA accepted the following three NAPOCOR engineers for the participation in the office study and discussion in Japan of the Diduyon Project.

Name	Title	Staying Period
1. Mr. E.F. Cruz, Jr.	Planning Coordinator	May 23 - Jul. 21, 1980
2. Mr. A.E. Valencerina	Principal Geotechnician	- ditto -
3. Miss P.S. Lingat	Planning Engineer	- ditto -

Their study included not only technical discussions of the Project, but also inspection and study of the similar engineering projects in Japan. Ardour and deep understanding expressed by those engineers were impressive to the JICA personnel concerned, and shall be highly praised.

1.3. Project Highlights

The salient features of the Diduyon Project are given on the following table:-

Project Highlights

Item	Unit	Description	
Catchment Area	km^2	477	
Stream Flow			
Annual average	$m^3/sec.$	30.8	for past 16 years
Drought discharge	"	10.7	
Flood	"	614	Past maximum
Plant Discharge			
Maximum discharge	$m^3/sec.$	85.2	
Firm discahrge	"	21.3	for 6 hours of daily peaking at least
Firm peak discahrge	"	85.2	
Head			
High water level	EL.	648	
Low water level	"	620	
Available drawdown	m	28	
Tailrace water level	EL.	162	
Gross head	m	486	
Effective head	"	451	
Generating Plant			
No. of units	-	2	
Rated Capacity	MW	308.5	
Peaking capability	"	345	(172.5 MW x 2)
Annual energy generation	GWh	957	
Plant factor	%	32	
Reservoir			
Gross storage	10^6m^3	579	
Live storage	"	454	
Surface area	km^2	27.3	

Item	Unit	Description
Dam		
Type	-	Concrete gravity
Height	m	111
Crest width	"	8
Crest length	"	375
Dam slope on the upstream side	-	1 : 0.1
Dam slope on the downstream side	-	1 : 0.8
Dam volume	$10^6 m^3$	1.2
Spillway		
Type	-	Chute type and tunnel spillway
Design flood discharge	$m^3/sec.$	8,900
Intake		
Type	-	Side intake, inclined tunnel
Gate	-	Steel roller gate, 1 set
Pressure Tunnel		
Type	-	Circular, pressure tunnel
Number of lines	-	1
Internal diameter	m	5.9
Length	"	11,700
Surge Tank		
Type	-	Chamber type
Number	-	1
Internal diameter (main shaft)	m	8
Height (Main shaft)	"	77
Penstock		
Type	-	Open laid type
Number of lines	-	1, bifurcating downwards
Pipe length	m	2,013
Internal diameter	"	5.0 to 2.7
Powerhouse		
Type	-	Open type
Dimensions	m	29.6 x 60 x 37

Item	Unit	Description
Tailrace		
Type	-	Free-flow tunnel, D=5.9 m
Length	m	203
Switchyard		
Type	-	Outdoor type, simple ring bus
Area	m	84 x 62
Main Electrical Equipments		
1) Hydraulic turbine		
Type	-	Vertical shaft Francis turbine
Maximum output	MW	352 (176 x 2)
Revolution	r.p.m.	360
Number of units	-	2
2) Generator		
Type	-	3-phase AC generator
Output	MVA	383.4 (191.7 x 2)
Voltage	kV	13.8
Power factor	-	0.9
Frequency	Hz	60
Revolution	r.p.m.	360
Number of units	-	2
3) Main transformer		
Type	-	Outdoor, 3-phase, forced-oil and forced-air cooled type
Capacity	MVA	383.4 (191.7 x 2)
Voltage	kV	Primary : 13.2 Secondary: 230
Frequency	Hz	60
Number of units	-	2
Transmission Line		
Size of conductor	-	ACSR 795 MCM
Line voltage	kV	230
Number of circuits	-	2
Route length from Diduyon to Santiago	km	45

Item	Unit	Description
Construction Schedule		
Powerstation	years	5
Transmission line	"	2.5
Expected commission	-	1989
Construction Cost (including interest during construction)		
Powerstation	10^6US$	461
Transmission line	"	10
Total	"	471
Economics (including transmission line)		
Benefit (B - C)	10^6US$	29.3
Benefit-cost ratio (B/C)	-	1.74
Internal economic rate of return (I.R.R.)	%	24.1

CHAPTER 2. PHYSICAL AND SOCIO-ENVIRONMENTAL STUDIES OF THE PROJECT

2.1. Topographical Surveys

2.1.1. Requirement

For the purpose of formulating alternative plans for the Project and of selecting the dimensions of various structures and approximately accurate positions, preparation of required topographical maps and profile and cross section surveys were undertaken. At the commencement of investigation, topographical maps available consisted of general maps of 1/50,000 scale and some photogrammetric maps of 1/5,000 scale of major structure sites including two alternative damsites which was prepared only to know the local topographies and the relative differences in elevation among the structure sites.

The topographies of both the No.2 and No.3 dam sites were actually surveyed, since they are very important for conducting the comparative study in which the quantities and difference in elevation estimated on the basis of the site topographies are influential factors.

2.1.2. Survey Work Items

(1) Preparation of Topographical Maps

Available topographical maps as basic data were maps of 1/50,000 scale. Topographical maps of larger scale were in urgent need for the study. Topographical maps normally needed for the feasibility design were as follows:

1) Topographical maps of the area at or near the sites of the principal structures (photogrammetric maps).

For programming field investigation works and estimating their quantity requirements as well as the initial study,

Topographical maps were prepared on the basis of available aerial photographs of 1/15,000 scale and ground control surveys.

i) Scale : 1/5,000
ii) Area : 5.92km^2 covering two alternative damsites (No.2 & No.3), a portion of proposed waterway, penstock route and powerhouse site as shown on Fig.2-1-1.

2) Topographical map for the entire project area (photogrammetry)

Topographical maps of 1/10,000 scale for the entire project area were prepared by taking aerial photographs or using already available aerial photographs of 1/15,000 scale and ground control surveys as basic data for elaborating the output studies construction work program, basic designs, studies of reservoir conditions, road construction program and resettlement program.

i) Scale : 1/10,000
ii) Area photographed: 300km^2
iii) Area mapped : 300km^2 as shown on Fig.2-1-1

3) Preparation of topographical maps at and around the principal structure sites (ground survey)

Topographical maps of 1/1,000 scale needed for layout studies and preliminary design of principal structures, and preparation of construction plan and programs for the Project were prepared. The initial plan called

for preparing maps on the basis of photogrammetry, but these maps of site topographies were actually prepared on the basis of ground surveys as delays in taking aerial photographs due to unfavorable weather conditions was caused to affect the progress of the Study.

i) Scale : 1/1,000
ii) Area : 5.92km^2 as shown on Fig. 2-1-1

(2) Profile and Cross-Section Surveys

Aside from the on-site surveys needed for preparing the topographical maps discussed above, the following profile and cross-section surveys were carried out.

1) Cross-section survey of the river in the reservoir area

A cross-section surveys across the river in the reservoir area was carried out for the purpose of upgrading the accuracy of calculations of the reservoir area and storage volume on the basis of 1/10,000 scale aerial survey maps prepared for the entire project area.

i) Location : as shown on Fig. 2-1-1
ii) Quantity : 5 traverses with a total extension of 8km.

2) Cross-section surveys at the damsite

Surveys of cross-sections at the damsite were carried out.

i) Position: as shown on Fig.2-1-1
ii) Quantity: 6 traverses with total extension of 4km.

3) Profile and cross-section surveys of the river near the damsite.

Profile and cross section surveys of the rivers course near the damsite were carried out for the purpose of calculating a relationship between the riverflow discharge and the water level at the upper and lower reaches of the dam.

i) Location: as shown on Fig.2-1-1
ii) Quantity: One profile with extending for 3km. 29 cross sections across the river, 6km in total extension.

4) Profile and cross-section surveys of the river near the powerhouse site (the tailrace outlet).

Profile and cross-section surveys along the river were carried out for the purpose of calculating a relationship between the riverflow discharge and the river water level at the upper and lower reaches of the tailrace outlet.

i) Location: as shown on Fig.2-1-1
ii) Quantity: One profile with extending for 3km. 29 cross sections, 6km in total extension.

(3) Other Surveys

Other surveys necessary for the following field investigations were carried out.

1) Survey of drilling holes.
2) Survey of test adit portals.
3) Survey of seismic prospecting lines.
4) Survey of test pits for construction materials.

2.1.3. Summary of Topographical Survey Works

The following is the survey works done by the Survey Division of NAPOCOR.

(1) Technical Summary of Survey Works

1) General

Location Base Camp: Town of Kasibu, Province of Nueva Vizcaya

Area Surveyed: The Diduyon River Area

Purpose of Survey: The purpose of the survey is to provide topographic maps which will give field data and basic information for the feasibility study, geological investigation and preliminary design.

2) Phases of Work Undertaken

Ground Topographic Mapping:

(i) Reconnaissance

A reconnaissance group composed of survey personnel was formed and reconnoitered the project area to examine the general terrain of the surrounding area, accessibility of roads, weather conditions, vegetation and problems of clearing. Also the group selected the Kasibu town as the best site for its office and living quarters in order to maximize manpower efficiency. Field camps were also set-up at the damsite No.2 & No.3, and the powerhouse site for personnel undertaking survey works.

(ii) Topographic Survey

To secure data from which the location of the damsite, powerhouse site, penstock and surge tank will be determined both in plan and elevation and which are necessary for the production of topographic maps, ground controls (horizontal and vertical) were established.

Classification and standard of accuracy for control points:

Horizontal Control

System	:	Triangulation (Primary)
Accuracy	:	Third Order
Spacing of Arc./ Dist.bet.sta.	:	As required
Base Measurement	:	Actual error not to exceed - 1/75,000
		Probable error not to exceed - 1/250,000
Triangle Closure	:	10 sec. (maximum)
Length Closure	:	1/5,000 m.
Method of Angular Measurement	:	Repetition Method
Instruments used	:	One-sec. direct reading theodolite

The degree of precision of all horizontal control data correspond approximately to that prescribed by the Bureau of Lands for all control stations used in the project. The rectangular coordinates or origin of coordinates for the base line were determined by astronomical/solar observation works.

Vertical Control

System	:	Spirit levelling in loop closures
Accuracy	:	Third order
Max. Distance bet. staffs & levelling instrument:		50 m.
Check bet. forward & backward running or loop closures	:	12 mm $\sqrt{K}$ where K - dis. in kms.
Instruments used:		NK-10 (Wild) level NI-21 (CARL ZEIS) automatic level

All elevations of vertical controls, referred to mean sea level, are based from BM NV-33 at EL.307.231m of P. C. and G. S. first order levelling, located along the National High-way #5, about 250m, N.E. of Km Post #256 in the town of Bambang, Province of Nueva Vizcaya.

In the establishment of bench marks for the Project, levelling in loop closure was carried along the existing road from the town of Bambang to the Kasibu town enroute to the location of various structure sites for the alternative damsites, powerhouse site and waterway.

Method of indication of control stations:

Horizontal Control

- A general lay-out of the primary triangulation scheme was planned on an existing 1:50,000 scale military map.

- Two survey groups equipped with instruments such as walkie-talkies, compass, altimeters, etc. were organized on both banks of the river to select the location of triangulation stations.

- For strength of figure, a scheme of quadrilaterals for triangulation stations was adopted wherein no angle less than 30° occurs.

- To facilitate easy identification and relocation, all stations were marked with a nail in the center of a 30cm equilaterally triangular concrete monument, 60cm long and set 55 cm underground with the inscription "D-, NPC, 1979"
- Prior to actual angular measurement, the surrounding area of each station was cleared of all obstruction. Since each point is to be used frequently, wooden poles with black & white cloth, braced and held vertically by several guy wires were used to facilitate observations.

Vertical control

- From the P.C. and G.S. control emanated the levelling survey of vertical controls from which bench marks were established over the area.

- All bench marks were painted on stones or pegs with corresponding descriptions were driven into the ground, nailed on trees and pavements or chisel marked and painted on street curbs.

- During the course of levelling works, immediate computation and calculation of results was made in accordance which the accuracy adopted.

- Bench marks established in or near the damsite, powerhouse and penstock area were monumented for ready and immediate reference.

Photogrammetric Mapping

The aerial photogrammetric mapping of the Project structure sites was undertaken by Certeza Surveying Aerophoto Systems, Inc., a contractor of NPC for this particular scope of work.

Attached herewith is a brief summary of photogrammetric mapping works submitted by Certeza Surveying Aerophoto Systems, Inc.

Instruments

Survey instruments used:

Horizontal	-	Wild T-2 theodolites Wild DI 3S
Vertical	-	Wilk NK-2 levels

Instruments used for stereo plotting and aerial triangulation:

For aerial triangulation	-	Wild universal A-7 autograph
For stereo mapping	-	Wild B8S

Procedures

Structure sites (Blocks I, II, III and IV) were first surveyed independently using assumed data for both horizontal and vertical survey works. These sites were later tied in to the NAPOCOR established basic control stations and bench marks using survey methods of third order accuracy for the horizontal work. For elevations, a combination of spirit levelling and trigonometric levelling was employed.

The overall area photogrammetric mapping was undertaken utilizing existing aerial photography of 2970-1972. Picture point controls for stereomapping were established in the field to cover major portion of the area, and this was supplemented by aerial triangulation points established with the use of our Wild A-7 autograph. Stereo plotting of maps was done on Wild B8S stereoplotters.

All the above work was done in accordance with the NAPOCOR terms of reference prepared for this photogrammetric mapping.

Accuracy

The final map accuracy is entirely dependent on the accuracy of the NAPOCOR basic control net. From these NAPOCOR control stations emanated the surveys used in establishing photo points that were the basis of the stereo mapping work.

Maps were compiled in conformity with international photogrammetric mapping standards. If the basic NAPOCOR control net is correct and up to standard, 90% of the elevations should be within 1/2 of the contour interval and maximum error in elevation should not be more than one contour interval.

For densely wooded areas where heavy brush or trees cover fully obscures the ground, the contours are shown as dash lines (form lines) and follow roughly only the form of the ground as far as can be discerned from the stereoscopic model.

Miscellaneous survey works

A) Relocation of and laying out seismic lines, drill holes and adits for geologic investigation

Locations of all seismic lines, drill holes, and adits for geologic investigation purposes, relocated and laid-out in the field were tied to the established horizontal and vertical controls. The rectangular coordinates for these lines, drill holes and adits were based on the adjusted true values, while elevations were referred to mean sea level datum (true elevations).

B) River cross-section at the damsite and powerhouse site

The cross-section of the river is measured during low water period to obtain as accurate as possible profile data. Starting above high water level, a traverse levelling on both

banks was secured by the spirit levelling method. As per Consultants requirements, the length of cross-section is about 1.5 km upstream and downstream of the dam axis at 100m intervals and about 150m up from both banks of the river.

The coordinates and elevation (true) of these cross-sections were based from the nearest control stations in the area.

Computation/Plotting

The computation of survey results for subsequent plotting was expedited at the various field camps. Each field camp had an assigned computer plotter to immediately calculate results and check if data obtained fell within the standard classification and accuracy adopted for this project.

Records of control points

All ground controls (primary to tertiary) and survey points with their location and description are given in Tables 2-1-1 to 2-1-2.

3) Delays/Problems encountered

Since the start of survey works the following have always been the major problems encountered, which caused us much delays and set-backs:

- Impassable roads and bridges;
- Unpredictable weather conditions prevailing in the area;
- Difficulty in hauling of equipment and food supplies;
- Lack of serviceable vehicle most suited for the existing road conditions;
- Threat to NAPOCOR personnel by outside elements and indifference of local inhabitants who are against the project;
- Problem in local hiring of emergency personnel for the project;

- Sudden breakdown of survey instruments and vehicles;

- Lost and burned field notes and data due to burning incident at the Damsite No.3.

Table 2-1-1 Location of Control Points (1)

Station Designation	Coordinates		Elevation	Remarks
	Northing	Easting		
BLIM - 7	17,973.390	20,596.170		
LINE	18,644.448	19,858.142	750.909	
CERTEZA BASE	19,453.320	19,739.675	753.130	
NPC BASE	19,642.925	19,862.005	737.384	
D - 1	18,305.272	21,016.507	744.920	
D - 2	17,204.619	20,362.527	750.633	
D - 3	17,298.763	21,733.417	802.499	
D - 4	16,229.619	21,401.502	802.620	
D - 5	15,853.896	23,356.824	743.829	
D - 6	14,931.649	21.984.566	774.481	
D - 7	15,797.992	24,909.785	729.829	
D - 8	14,523.304	23,737.250	725.364	
D - 9	16,242.000	26,725.059	687.831	
D - 10	15,062.488	26,237.738	779.568	
D - 11	17,213.979	28,846.856	756.909	TER
D - 12	15,141.001	27,346.137	778.283	ROOSE
D - 13	16,449.971	30,843.381	737.705	
D - 14	14,279.673	28,808.192	804.236	KATAR
D - 15	14,156.679	32,008.353	801.203	
D - 16	12,012.410	31,398.777	769.671	BIYOY
D - 17	15,199.624	36,380.561	981.540	
D - 18	11,892.510	36,670.663	1,218.184	
D - 19	16,763.669	37,314.762	996.539	
D - 20	13,927.712	38,907.392	853.618	
D - 21	20,914.633	40,613.724	1,018.907	
D - 22	16,367.452	41,115.045	949.164	
D - 23	25,579.757	42,948.598	449.674	
D - 24	18,472.961	42,965.341	804,946	
D - 25	26,513.110	45,700.541	448,707	
D - 26	21,877.605	45,395.217	537.942	

Location of Control Points (2)

Station Designation	Coordinates		Elevation	Remarks
	Northing	Easting		
*BASE	13,795.709	33,771.943	646.389	Check Base at
*CHECK	14,148.406	33,971.698	619.637	Damsite #2
S - 1	13,691.340	34,432.696	683.219	Secondary
S - 2	14,675.695	34,975.510	720.909	Station
*BM 64B	13,987.710	35,928.757	572.978	Bench Mark at
*BM 65	13,950.334	36,640.337	627.297	Damsite #3
SY - 2	14,171.912	36,416.322	571.875	
SY - 3	14,338.952	36,542.941	679.004	
SY - 4	14,086.831	36,351.828	667.857	
*DR - 1	14,076.426	36,343.941	672.670	Bore Holes
DR - 2	14,138.714	36,391.156	601.312	Damsite #3
DR - 5	14,032.668	36,310.771	652.777	
DR - 6	13,959.232	36,276.019	648.965	
DR - 7	13,880.379	36,247.065	653.150	
DR - 8	13,793.233	36,215.066	669.135	
DR - 9	13,699.362	36,181.227	688.375	
*DH - 1	14,202.732	36,439.682	553.769	
*DH - 2	14,184.902	36,420.167	556.473	
DL - 3	14,272.321	36,492.432	578.778	
DL - 4	14,259.595	36,482.786	567.081	
PH	24,077.882	43,858.832		Check Base at
CB (-CIA)	25,022.934	43,627.825		Powerhouse
ALI	24,378.339	44,528.007		
*PH - 1	24,052.164	44,131.764	164,876	
*PH - 3	24,020.827	44,072.139	171.466	

Legend : *Levelled

Location of Control Points (3)

Station Designation	Coordinates		Elevation	Remarks
	Northing	Easting		
BASE	13,795.709	33,771.943	646.389	Check Base at
CHECK	14,148.406	33,971.698	619.637	Damsite #2
T - 30	14,034.170	34,305.845	584.280	
T - 31	14,304.484	33,941.498		
T - 32	14,273.849	34,210.705	583,763	
T - 33	14,530.909	34,079.183	585.250	
T - 34	14,380.624	34,390.517	610.180	
T - 35	14,644.239	34,375.902	580.891	
T - 36	14,306.943	34,582.361	600.043	
T - 37	14,585.209	34,603.247	579.658	
T - 38	14,273.830	34,789.396	584.156	
T - 39	14,465.852	34,696.205	578.149	
T - 40	14,299.312	34,873.410	583.019	
T - 41	14,355.490	34,828.822	577.713	
T - 42	14,271.634	35,022.008	575.818	
T - 43	14,346.488	35,012.177	577.613	
T - 44	14,276.872	35,108.612	571.813	
T - 45	14,342.073	35,088.771	577.741	
T - 46	14,215.751	35,262.557	571.555	
T - 47	14,300.386	35,204.703	574.928	
T - 48	14,139.475	35,379.440	569.739	
T - 49	14,218.194	35,387.107	974.178	
T - 50	14,067.466	35,541.388	571.187	
T - 51	14,144.876	35,540.152	572.134	
T - 52	14,015.676	35,645.865	568.717	
T - 53	14,079.234	35,687.850	572.942	
T 54	13,966.274	35,732.389	571.653	

Location of Control Points (4)

Station Designation	Coordinates		Elevation	Remarks
	Northing	Easting		
T - 55	14,046.454	35,732.138	569.734	
T - 56	13,968.321	35,892.481	570.741	
T - 57	14,026.077	35,834.483	568.066	
T - 58	14,108.206	35,956.712	568.523	
T - 59	14,096.258	35,872.643	571.443	
T - 60	14,177.063	36,014.767	571.986	
T - 61	14,205.699	35,939.435	573.147	
T - 62	14,244.432	36,084.935	568.761	
T - 63	14,293.175	36,029.456	569.703	
T - 64	14,267.047	36,155.746	564.623	
T - 65	14,326.516	36,161.245	569.913	
T - 66	14,263.157	36,224.264	566.536	
T - 67	14,322.665	36,251.972	563.226	
T - 68	14,236.200	36,312.338	562.904	
T - 69	14,315.942	36,354.689	562.020	
T - 70	14,220.098	36,387.475	562.980	
T - 71	14,260.484	36,483.557	569.463	
T - 72	14,183.310	36,477.297	557.505	

Table 2-1-2 Location of Benchmarks (1)

Station/ Description	Elevation	Location/Description
PC & GS NV - 33	307.231	PC & GS NV - 33, located at Barrio Abian, Bambang, Nueva Vizcaya, inside the property of Maneses Magbual.
BM - 1	313.043	National Highway, located at Barrio Abian, opposite Km. 254.
BM - 2	315.602	National Highway, located at Barrio Abian, opposite Km. 253.
BM - 2A	320.005	
BM - 3	320.004	National Highway, located at Km. 252 Banbang, Nueva Vizcaya.
BM - 3A	320.858	
BM - 4	320.300	Located in front of Bambang Market, Mark BM - 4 at big concrete monument.
BM - 5	316.055	Mark - X, at trunk of Caymito tree rightside going to Kasibu.
BM - 6	314.948	Mark - X, at rightside of Km. Post 252 going to Kasibu.
BM - 7	318.040	Mark - X, at the root of Caymito tree, Left-side of the road going to Kasibu.
BM - 8	326.101	Mark - X, at rightside of the road going to Kasibu, Barrio San Fernando, Bambang, Nueva Vizcaya.
BM - 9	333.597	Mark on top of Km. Post 255 going to Kasibu.
BM - 10	335.525	Mark - X, on top of big boulder near Km. Post 256 to Kasibu.
BM - 11	351.028	Mark - X, of Km. Post 257 going to Kasibu.
BM - 12	345.145	Mark - X, on root of mango tree about 7 meters right of Km. 258.
BM - 13	365.417	Mark - X, on top of boulder opposite Km. 259 at Barrio Labni.
BM - 14	385.466	Mark on top of boulder about 2 meters from Km. 260 going to Kasibu.
BM - 15	432.117	Hub near Km. 261 going to Kasibu, rightside of the road.
BM - 16	455.796	Mark on top of boulder opposite Km. 262, right-side of small house.
BM - 17	530.837	Mark on top of boulder leftside of Km. 263.

Location of Benchmarks (2)

Station/ Description	Elevation	Location/Description
BM - 18	615.212	Mark on top of boulder rightside of road going to Kasibu
BM - 19	715.291	Mark on top of boulder about 10 meters, the Km. Post 265, rightside to Kasibu.
BM - 20	849.140	Mark - X, at the huge boulder opposite of Km. 266, leftside going to Kasibu.
BM - 21	936.793	Mark - X, at the BM 21 big boulder, leftside going to Kasibu.
BM - 22	863.343	Mark - X, at the top of Km. 268 going to Kasibu.
BM - 23	819.542	Mark - X, at the big boulder leftside of the road at about 5 meters after Km. 269 going to Kasibu.
BM - 24	817.182	Mark - X, at huge boulder leftside 16 meters before Km. 270 at Kasibu.
BM - 25	795.640	Mark - X, at the boulder at the flower garden in-front of Landicho's Party occupied house owned by Mr. Maor.
BM - 26	776.867	Rightside going to Kasibu Mark - X, at big boulder near the Jackfruit tree.
BM - 27	768.416	Mark at big boulder rightside of the road going to Kasibu.
BM - 28	774.787	Mark at big boulder near the Km. Post #274, leftside to Kasibu.
BM - 29	756.198	Mark - X, at big boulder near Km. Post #275, rightside to Kasibu.
BM - 30	745.723	Mark - X, at the big boulder rightside of road near the Km. Post #276 going to Kasibu.
BM - 31	763.175	Mark on top of the boulder near to Km. Post #277 about 25 meters rightside of the road going to Kasibu.
BM - 32	756.340	Mark on top of big boulder near Km. Post #278 rightside going to Kasibu.
BM - 33	761.674	Mark - X, at big boulder rightside of the road going to Kasibu, Km. Post #279.
BM - 34	756.787	Mark - X, at the concrete guide of the culvert at about 10 meters after Km. Post #279 going to Kasibu.
BM - 35	727.525	Mark - X. at big boulder right of the road going to Kasibu.
BM - 36	697.562	Mark - X, at the cemented reprop of the garden opposite of Km. 0, Kasibu (leftside) opposite of Vice Mayor's house.

Location of Benchmarks (3)

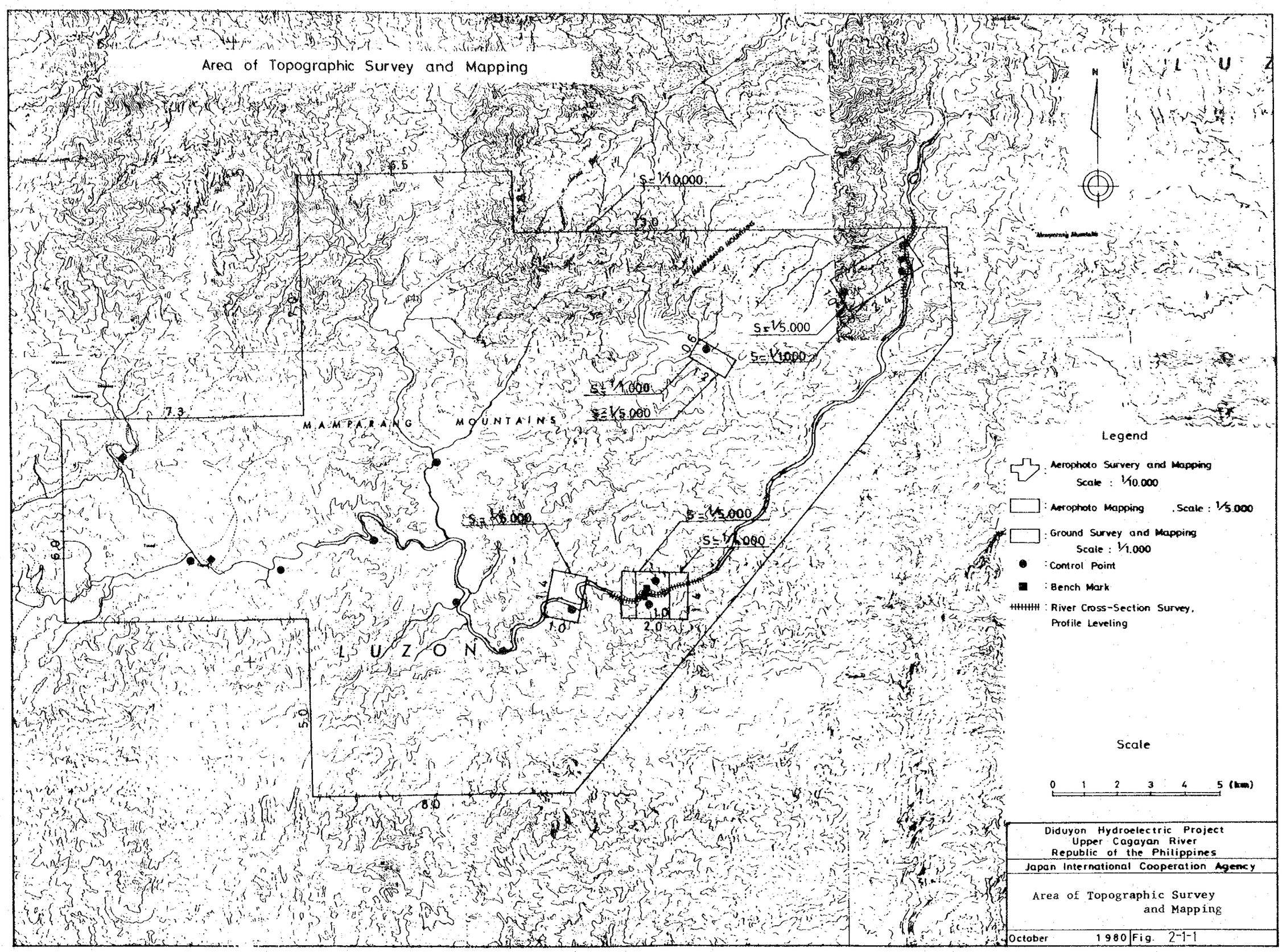
Station/ Description	Elevation	Location/Description
BM - 37	688.416	Mark on top of big boulder rightside going to Kasibu.
BM - 38	721.806	Mark on top of boulder leftside of the road going to Kasibu.
BM - 39	685.233	Mark - X, of boulder at about 25 meters from place and about 70 meters from the house of Fonbuena at Barrio Pudi.
BM - 40	714.282	Mark on top of boulder right of the road going to Kasibu.
BM - 41	706.575	Mark on top of the boulder right of the road going to Katarawan.
BM - 42	707.605	
BM - 43	659.942	Mark - X, at big boulder leftside of the road going to Katarawan.
BM - 44	664.971	Mark on top of the boulder rightside of the road going to Katarawan.
BM - 45	664.811	Mark - X, trunk of a tree leftside of the road at Sitio Paxquet civinities.
BM - 46	654.386	Mark - X, at the root of the trunk of the tree at about 300 meters of Pacquet Barrio school, leftside of the road at about 50 meters of the store.
BM - 47	658.952	Mark on top of the boulder rightside of the road going to Katarawan.
BM - 48	640.807	Mark on top of boulder rightside of road going to Katarawan.
BM - 49	645.748	Mark - X, at a planted boulder at Sitio Poliguen at leftside of the road.
BM - 50	625.875	Mark - X, at a planted boulder at rightside of the road at about 7 meters, road going to Katarawan.
BM - 51	640.620	Mark at boulder rightside of the road going to Katarawan.
BM - 52	659.487	Mark at leftside of the road going to Katarawan.
BM - 53	639.747	Mark - X, at the trunk of the tree leftside of the road going to Katarawan Camp at about 1.1 km.
BM - 53A	642.199	Mark - X, at the cut of huge tree at about 7 meters in-front of the store and 25 meters in front of Katarawan bunkhouse office leftside of the road.

Location of Benchmarks (4)

Station/ Description	Elevation	Location/Description
BM - 54	656.350	Mark - X, at the half-burried boulder at about 618 meters from camp site Katarawan, leftside of the road
BM - 55	619.490	Mark on top of boulder leftside of the road going to Biyoy.
BM - 56	612.181	Mark on top of boulder rightside of the road going to Biyoy.
BM - 57	600.176	Mark at boulder rightside of the road going to Kumamasi
TBM - 57	600.176	Mark - X, at rice paddies at 2 huge hubs.
BM - 58	650.941	Mark - X, at a planted boulder beside the big tree, leftside of the road going to Kamamasi.
BM - 59	597.967	Mark at boulder leftside going to Papalongan.
BM - 60	660.137	Mark - X, at a big tree rightside of the road to Damsite #2.
BM - 60A	685.649	Mark at store leftside of the road going to Papalongan.
BM - 60B	677.840	Side shot only and preparation for levelling primary control.
TBM - L	669.726	
A -	586.685	Mark - X, at the half-burried boulder R. abutment of Diduyon River Dam #2.
BM - 61	710.481	Mark on top of boulder leftside going to Damsite #3.
BM - 62	677.852	Mark on top of boulder rightside of road going to Damsite #3.
BM - 63	645.339	Mark - X, at the cut of the big tree leftside of the road at Sitio Papalongan.
BM - 64	661.011	Mark - X, at the bed rock rightside of the road going to Japanese Consultants.
BM - 64A	614.803	
BM - 64B	572.978	Mark on top of big boulder near the NPC Consultant house at Damsite #3.
E -	568.284	
BM - 65	627.297	Mark - X, at the huge boulder leftside of the road at about 250 meters after the Consultants' house.
BM - 65A	635.494	
A 03	625.704	

Location of Benchmarks (5)

Station/ Description	Elevation	Location/Description
BM - 66	566.736	Mark on top of big boulder rightside of the road going to Alicia.
BM - 67	564.979	Mark - X, at huge boulder between two crecks at about 200 meters.
BM - 68	540.633	Mark on top of big boulder rightside of the road going to Powerhouse.
BM - 69	516.032	Mark on top of big boulder.
BM - 69A	455.613	Mark on top of big boulder rightside of the river near the Baliti tree.
BM - 70	423.420	Mark on top of big boulder rightside of the river near the Narra tree, near the house of Mr. Padawa.
BM - 71	380.892	Leftside of river - Mark Stone.
BM - 72	340.874	
BM - 73	299.046	Mark on top of big boulder rightside of the river.
BM - 74	259.622	Mark - X, at the top of huge boulder left abutment.
BM - 75	236.706	Mark on top of boulder leftside of the river.
BM - 76	209.894	Mark - X, at the bedrock right abutment of the river.
BM - 77	191.439	
BM - 78	174.873	Mark on top of the big boulder rightside of the river.
BM - 79	163.378	Mark - X, at the boulder at the center of peanut plantation at about 1 km. before Alicia.
PH - 1	164.876	


Area of Topographic Survey and Mapping
N
S=1/10,000
S=1/5,000
S=1/1,000
MAMPARANG MOUNTAINS
LUZON
5.5
7.3
3.0
0.6
1.3
1.0
2.0
8.0
5.0
Legend
: Aerophoto Survery and Mapping
Scale : 1/10,000
: Aerophoto Mapping , Scale : 1/5,000
: Ground Survey and Mapping
Scale : 1/1,000
: Control Point
: Bench Mark
: River Cross-Section Survey, Profile Leveling
Scale
0 1 2 3 4 5 (km)
Diduyon Hydroelectric Project
Upper Cagayan River
Republic of the Philippines
Japan International Cooperation Agency
Area of Topographic Survey and Mapping
October 1980 Fig. 2-1-1

2.2. Geologic Survey

2.2.1. With regard to the geological survey of the Project area the governments of the Philippines and Japan agreed that JICA will carry out investigation programming, supervision and preparation of the report and NAPOCOR will carry out the field investigation work.

2.2.2. Summary of Geologic Report on the Project Area

The following is a summary of the results of investigation compiled by E. P. Vargas, Sr. Geologist III, Geology & Geotechnics, NAPOCOR, who undertook the field investigation.

(1) Introduction

Purpose and Scope - This report was written to present and discuss the results of the geological investigation, particularly regional and detailed geological survey of the feasibility studies at the Project. These studies were conducted to identify geologic hazards which may or may not exist in the project area.

Project Description - The project area, approximately 300 km in size, is situated in the municipality of Kasibu, Nueva Viscaya and Cabarroguls, Quirine Province. The major appurtenant structures, particularly the proposed damsite, headrace tunnel route are within the municipal jurisdiction of Kasibu. The powerhouse, penstock and surge tank are in Burangay Dibiowan, Cabbarroguis, Quirino.

The proposed damsite, located at latitude 16°15' and longtitude 121°27', will have a proposed height of 111 m, a high water level at EL 648m. The power plant will have a maximum capacity of 345 MW. They will be built across the Diduyon River.

Previous Studies - Prior to studies conducted by JICA and NAPOCOR, which commenced during the first half of 1978, other government agencies conducted geological survey and watershed inventory of the Diduyon River Basin. In 1965, the US Bureau of Reclamation (USBR) in cooperation with different government agencies of the Philippines had made a study on the power generating potential of the Cagayan River Basin, which includes the Diduyon River. It mentioned in its report that a dam, with a height of 110 meters and a watershed area of 484 km^2 located at latitude 16°16' and longtitude 121°27' can be constructed. It is surprising to note that the present location of the dam axis is very close to that proposed by the USBR. Other studies were conducted by the Philippine Bureau of Mines in cooperation with JICA in conjunction with its mineral inventory of Nueva Vizcaya Province, which commenced in 1975 and ended in 1978.

Method of Investigation - The geological survey of the Project consisted of regional and detailed geological mapping of the reservoir area and appurtenant structures, diamond drilling, seismic prospecting at proposed damsite No.2 and No.3, surge tank, penstock route and headrace tunnel route. Aditting was confined at the proposed damsite No.3.

Aside from the field work, other useful geological data such as regional trend analysis, drainage pattern, and other regional geologic topographic features were analyzed by the use of topographic army maps of 1:50,000 scale and aereal photographs of 1:15,000 scale thru statistical analysis of joints, lineaments and faults.

Petrographic analysis of rock samples from the project area was another tool used in identifying different rock units.

Duration of Investigation - Preliminary studies at the proposed damsite and appurtenant structures were conducted for a short duration by the team of Japanese consultants from JICA and their counterparts from NAPOCOR. These studies were conducted during the months of July to August 1978 and January to February 1979, to which the JICA team formulated guidelines in undertaking feasibility studies of the Project.

Geological survey, drilling, aditting and seismic prospecting covered the space of one and a half years, from the start of the mobilization of drill rigs and geologic mapping to the completion and demobilization.

(2) Geography

Location and Accessibility - The Project situated in the province of Nueva Vizcaya and Quirino Province is geographically bounded by the coordinates 16°13' to 16°23' east latitute and 121°15' to 121°32' North longitude. It is approximately 315 km from Manila and can be reached by land vehicles through concrete roads up to Bambang then through logging reads to the project site. These logging roads leading to the different appurtenant structure sites are impossible to reach during the rainy season.

Topography and Drainage: The project area is situated in the Mamparang Mountain Range. It is characterized by a mountainous to hilly terrain with patches of flat lands in the meanders of the major rivers. The mountains, which have an average height of 900 meters, have pointed to rounded summits. Highest elevation in the project area is 1,200 m, and the lowest is about 280m above mean sea level at Barangay Alicia.

Other topographic features found in the area are karst

topography, hanging valleys, and saddle areas. Caves, sinkholes, and underground rivers are found in the limestone belt. Saddle areas which are sometimes indicative of shear zones are numerous. Most of the saddle areas investigated did not reveal any shear zone, but are mostly products of differential erosion of hard and soft rocks. Hanging valleys were generally observed downstream of damsite No.3.

The area which is in its early geomorphic maturing has a well integrated drainage pattern characterized by numerous creeks, waterfalls, rapids and gullies. The Diduyon River, the major river dissecting the project area and on which the dam will be built, has a wide V-shaped valley with a meandering course.

Studies by the JICA Team classified Addalam-Diduyon River system into three distinct sections namely: (1) section with a riverbed gradient of 1/370 upstream of the riverbed EL 600, (2) section with steepest gradient of 1/30 and (3) 1/530 gradient downstream of the riverbed EL 200. It is worthwhile mentioning here that in the second section creeks and minor river join the Diduyon River in hanging valleys.

According to the JICA Team, features mentioned above provide the best conditions for hydropower development.

Vegetation and Climate - Approximately 40% to 60% of the area is covered by virgin forest. Numerous "Kaingins" were observed along the hill sides which are planted with camote, upland rice, ginger, bananas and corn. Flat lands and river terraces are planted with rice, corn, peanuts and beans.

A dry period occurs only during the months of February to June while the wet period occurs during the rest of the year.

(3) General Geology

Lithology - Rock types distributed in the project area consist of pyroclastic rocks intruded by dike volcanic flows, sedimentary rocks and alluvial deposits.

Two types of pyroclastic rocks are found at the Diduyon River basin, namely agglomerate and tuff. The agglomerate is gray to dark gray, hard and sound, and contains large quantities of sub-angular to subrounded boulders of andesitic composition. The matrix is andesitic.

Low grade metamorphism on this rock type has changed the matrix into hornfels, but relict textures of the volcanic character are still recognizable as determined from petrographic analysis.

Outcrops of this agglomerate are found along the Diduyon River and at the damsite area, Barangay Katarawan reservoir area and underground powerhouse area at Didipio River.

The second type of pyroclastic rock found in the reservoir area is the tuff formation. It is buff to red in color and contains andesites, glass fragments, feldspar, pyroxene, quartz and minor opaque minerals. Three types of tuff were observed. The first type found along the riverbed at sitio Pacquet, which seems to be the base, is agglomeratic with greater than 32 mm sub-angular to subrounded fragments of andesite in the tuff matrix. The second type, reddish in color, has pebble size fragments of tuff and glass in the tuff matrix. The third type was identified as vitric tuff.

Fresh outcrops of this tuff are moderately cemented while weathered portions are soft.

Two types of volcanic flow were observed in the Diduyon River Basin. The first type is andesite. It is dark gray to black, fine grained porphyritic and very hard. Phenocrysts consists of 20-50 percent oligoclase-andesine feldspar, 10-30 percent pyroxene and minor amphibole on the majority of the rock samples analyzed by micro-petrography. The ground mass is made up of brown to black glass and microlites of feldspar and ferromagnesian minerals.

Outcrops of this rock type are found distributed along river banks, creeks, logging road cuts and precopiis of ridges, from the reservoir area up to the powerhouse area.

Andesites from Kasibu to Maglan interbed with tuff and overlie the agglomerate, while andesites near the damsite areas are intercalated with agglomerate.

The second type of volcanic flow is the porphyritic trachyte. This is found in the Malabing-Alayan reservoir area and along Dibiowan creek at the powerhouse area. The trachyte at the reservoir area is light to dark greenish gray, fine-grained and porphyritic. Phenocrysts consist of pink dedecahedral analcite crystals ranging in size from 3 mm to 50 mm in diameter set in a groundmass of glass, feldspar (oligoclase-andesite and orthoclase) microlites, chlorite and opaque minerals. It is worth-while mentioning here that this trachyte consists of three types of volcanic effusion. The first one, a lava flow, has large analcite crystals with a maximum diameter of 50 mm. Pyroclastics (lapilli tuff to lighic tuff) with trachytic composition, of explosive volcanism, is the second episode. Analcite crystals are still present here. Small analcite phenocrysts having a minimum of five mm diameter constitute the third type of lava effusion. The groundmass is almost identical to the first type. This overlies the andesite

and agglomerate.

The trachyte in the powerhouse area, on the other hand, also a volcanic flow, is slight to fresh in color, fine-grained and porphyritic. Phenocrysts consist of euhedral orthoclase, pliagioclase, nepheline and ferromagnesians set in a groundmass of brown to pinkish glass, feld-spar microlites and sericite. This is overlain by andesite. However, this andesite may be younger than the andesites in the reservoir area.

The segmentary rock sequence in the project area consists of coralline limestone, sandstones and conglomerate. The limestone is white to cream, very hard and gives out a metallic sound when struck by a hammer. It is distributed in an elongated belt trending North-North westerly to North-South from the Barangay of Malabing down to Katarawan. An advanced stage of karst topographic development is evident. Sinkholes, pepine hills and caverns with underground rivers dot this limestone belt.

Approximate thickness of this limestone is 100 m. The base is exposed at Alayan around EL 625 m. No calcareous sandstone or siltstone was observed in this particular area. Only a small outcrop of what seems to be a basal conglomerate of limestone with rounded to sub-rounded pebbles of volcanics and limestone was observed. This limestone is hypothesized as a capping, unconformably overlies the porphyritic trachyte.

The sandstone and conglomerates are exposed along the Diduyon River and Dibiowan creek at the powerhouse area. This formation, 10-20 m thick, unconformably overlies the volcanic rocks. The base is conglomerate grading to pebbly sandstone. The top portion is silty sandstone.

The conglomerate is dark gray, well cemented and contains sub-angular to sub-rounded pebbles and cobbles of limestone andesite, trachyte and reworked fossils. Matrix is sandy with considerable amounts of clay and silt. Quartz was not identified in the petrographic analysis. The angularity of the fragments and the considerable amount of clay mineral suggest that provenance is very close. The top portion, i.e. silty sandstone, is buff to dark greenish gray, bedded, poorly sorted and poorly indurated. It contains angular fragments of plagioclase, ferromagnesians, carbonates and reworked microfossils. Cementation is calcium carbonate and clay. This formation is probably younger than the limestone.

Dikes intruding the agglomerate are hornblende andesites. Outcrops were observed about 1 km from the proposed dam axis, along the Didipio River, and at the Diduyon River. The general trend is N 20° W. A dike was also observed from drill cores recovered at the proposed underground powerhouse area.

Alluvial deposits and terrace gravels are preponderous along river banks and terraces. These contain angular, subrounded to rounded pebbles, cobbles and boulders of sandstone, agglomerate, andesites and trachyte. Thickness of these deposits range from 2 m to 20 m. The base of some terrace deposits was observed at two localities, namely sitio Siguem near the junction of the Diduyon and Campote Rivers and at Biyoy near the junction of the Biyoy and Diduyon Rivers.

Terrace near river valleys amply uplift in the area.

Geologic Structures - Field observations as well as aereal photo/topographic map analysis of 630 faults, joints,

lineament traces and linear features transecting the rocks in the Diduyon River basin indicate two prominent tectonic trends. These are the NE-SW set and the NW-SE set. Statistical data shows that the NEW-SW trend is dominant over the NW-SE set. Relative ages of these two trends are hard to determine.

Structures of tectonic origin existing in the project areas include faults, joints, anticlines and synclines. Structures of non-tectonic origin consist of bedding planes and flow layers.

Faults are either strike-slip (dextral and sinistral) or gravity faults. Most of the strike-slip faults have thickness ranging from 2 mm to 0.5 m, while the shear zone of gravity faults have as much as 15 m thickness.

Intersitices of these faults consist of mylonite, breccia, and gauge. Oxidation is not common. Strike-slip faults are generally cemented by calcite, rhodochrosite and silica. Gravity faults are gaugy.

Joints are tight to open. Some have calcite, rhodochrosite and silica filling. Thickness ranges from 2 mm to 10 cm.

Three fold trends were inferred from the project area:- a Northwest-Southeast and a North-South trend at the reservoir area, and an East-Northeasterly trend at the powerhouse area. Dips measured from bedding planes in limestone, tuff and sandstone range from 5° to 30° indicating that folding of the rocks in the area concerned was not too intense.

(4) Engineering Implications

Damsite No.3

Rocks underlying this particular damsite are composed of agglomerate intruded by andesite dikes. This agglomerate forms a monoclinic structure trending N 35°- 50° E; 25-35° E. Three prominent sets of structures (faults and joints) exist in this area. These trend N 50-55W, N30-35E and N65-70E. Dips of these structures are steeply dipping to the vertical. Calcite, rhodochrosite and silica occupy or cement the interstices of these structures.

The important geologic problem at this site lies on the saddle part on the right bank. Drill core data, particularly DR-06, 06 A, 07, 07 A and DR-08 indicate that a weak zone exists in the area. The thickness of this zone is more or less 70 m while the extent is approximately 200 m. Several small scale faults and slips with 60° to vertical dips were actually measured in the recovered cores. The cores are brecciated, mylonitized and slightly altered. Rhodochrosite fill the interstices of the structures. Other structures with clay filling expand when water is doused over the cores.

All low angle fault which exist at the feet of the right bank at the proposed dam axis may cause some problems on the stability of the foundation. This fault trending NS 4°E and dipping 32° NW was followed for 8m at adit DR-1. The shear zone is 34 cm.

Powerhouse, Penstock and Surgetank Area

The bedrock in these areas is andesite, sandstone and conglomerate intercalated with andesite and porphyritic trachyte. The proposed powerhouse site overlies a wide river terrace which consists of boulders, cobbles and pebbles of andesite with silt, sand, and clay matrix. The thickness

of this terrace has an average of 10m. The bedrock is andesite. Referrence should be made to 2.2.4 in respect of the underground powerhouse site.

The penstock and surgetank area is underlain by andesite. The andesite at the surgetank is highly jointed while that at the penstock is blocky. Overburden in the penstock route has an average or 10 m.

The most prominent fault observed in the area is a gravity fault tending N30°E and dipping 64°SE. It has a 15 m shear zone with sulphuric emanations. This large scale fault which is inferred to be several kilometers long may not affect the stability of the foundation in the area as no recent movements were observed.

Limestone Belt (Refer to 2.2.3)

The limestone belt in the reservoir area at the Malabing river is distributed in the Barangays of Malabing, Kapisaan, Alayan and Belet. Approximate area is 10 km^2.

The main problem concerning this belt is leakage as this limestone may extend to the eastern rim of projected reservoir limit. Investigations on the eastern rim, however, did not reveal any extension. Moreover, the limestone-volcanics contact is confined at EL 650 based on the Certeza topographic map of 1:10,000 scale. Mountains bordering this eastern rim are biotite bearing porphyritic andesite.

Landslide Areas

Most of the landslide areas investigated were in the vicinity of damsite No.3 to Biyoy. These slides have an extent of more or less 20-50m. These contain angular

fragments of pyroclastics and clay. The slides are mostly on the steep slopes and river banks of the Diduyon River. They are often aggravated by bulldozing of logging roads.

Landslides in other parts of the reservoir area are minimal. These are often confined to near logging roads.

The regional geological map made in the study is presented in Fig. 2-2-1, and all graphical geologic logs, geologic development maps and geologic sections are shown in Figs. 2-2-2 to 2-2-46.

2.2.3. Special Comment on Geologic Appraisal of the Limestone at Malabing-Alayan Reservoir Area

The following are preliminary findings on the occurrence of limestone and its lithologic/topographic relationship with other rock types at the Alayan-Malabing Reservoir Area. Attached herewith are maps and profile sections of 1:10,000 scale. The comment was also prepared by Mr. Vargas, NAPOCOR Geologist.

(1) Physiography

Location and Topographic/Drainage Characteristics

The limestone belt is situated at the Baragays of Malabing, Kapisaan, Alayan and Belet on a North-South trending synclinal valley. This valley is surrounded by 1,000 m class mountains, in the north by the Palali Mountain range, while to the east and west by the Mamparang Mountains. Karst topography is evident here; hills, knolls, sinkholes dot the valley. The highest elevation of the above mentioned hills attain a maximum of 750 m, with steep to almost vertical slopes.

Two caves and underground rivers were explored at Alayan and Malabing, respectively. The portal of the cave at Alayan is about EL 650, while the underground river is approximately 15 m below, with a discharge greater than 150 liters per second, flowing in an easterly direction.

The second cave at Malabing is 4 km North-northwest of Alayan cave. The portal and mouth of the cave and river respectively are at an approximate EL 630 m. The flow of this underground river is westerly. Both of these underground rivers contain pebbles and cobbles of volcanic origin in their channels.

The southernly flowing Malabing River and its tributaries are the main drainage system in this reservoir area. It is interesting to note that most of the creeks transecting the volcanic rocks in this particular area flow in an East-Northeast to East-West direction on the Eastern side, while these on the western side flow vice versa. Creeks near the contact of the limestone and volcanics flow North to South.

(2) General Geology

Lithology Alluvial deposits, coralline limestone, and volcanic rocks of andesitic to alkali trachytic composition constitute the Malabing-Alayan Reservoir Area. A thin veneer of alluvial deposits, approximately 2 m thick, covers a vast expanse of the valley. Topographic expression of these deposits are plain lands. These deposits are commonly composed of subrounded to rounded pebbles and cobbles of volcanic rock and limestone at its lower portion, and gravel and silt at its upper portion. These deposits overlie both limestone and volcanics.

As mentioned earlier in the preceding discussion, hills, knolls, sink-holes and caverns with underground rivers are preponderous. These physiographic features are characteristic of the coralline limestone. Approximate thickness of this formation is 100 m. The base is exposed at Alayan at around EL 625 m.

Unconformably overlain by the limestone are the volcanic rocks. The eastern rim of the reservoir is composed mostly of biotite-andesite porphyry, while the western and northern portion by analcite-trachyte porphyry.

The biotite bearing andesite porphyry is fine-grained, light to dark gray in color and porphyritic on fresh outcrops. Phenocrysts consist of subhedral crystals of feldspar with distinct lineation, and secondary biotite flakes. Outcrops are mostly found along creeks and logging roads.

Preponderous along the Malabing River and Alayan Creek is the analcite-trachyte porphyry. This rock consists of volcanic flow, agglomerate, and tuff. The base and the top portion of this formation are volcanic flows, while the intermediate part is agglomerate and tuff. It is worthwhile to note here, that the base of the flow has larger analcite crystals, 3 cm in diameter, than the top layer which has only a maximum diameter of 7 mm.

Structures

The area investigated is inferred to be an assymetrical syncline with a North-South trend. The dips on the eastern rim of the fold range from 5° to 8°, whereas those at the western rim range from 10° - 12°. Flow layers from the volcanics trend N 15-35 E and dips range from 20° to 35°. This implies that the limestone has an angular unconformable contact over the volcanics. The contact observed at the Alayan Creek is quite short in extent to be a mappable unit, about 3 m long. In any case, round pebbles of volcanics and limestone was observed and sampled at this outcrop.

Due to thick overburden and high weathering rate in the area concerned, contacts of the rock units were inferred by: (1)-changes in the topography and (2)-changes in the stream pattern.

A 5 m shear zone, inferred to be a normal fault, trending N 28 S with a dip of 60° easterly, was observed at Alayan.

Joint pattern in the limestone was not directly observed, however, Northeast-Southwest and Northwest-Southeast patterns were inferred from lineaments or linear features of ridges, gullies, and creeks from aereal photos and 1:50,000 topographic map.

(3) Conclusion

The limestone in the reservoir area of the Diduyon River Project is distributed in the barangays of Malabing, Kapisaan, Alayan, and Belet with an approximate area of 10 km^2 in total. This limestone, probably a capping, has no indication of interbedding or interlayering with the volcanics. Neither calcareous sandstone-siltstone interface nor indications of it were observed in the limestone-volcanics contact. Only a small outcrop of what seems to be a basal conglomerate of limestone with rounded to subrounded pebbles of volcanic rocks and limestone fragements was observed.

As mentioned earlier, rock fragments on the margins of the reservoir, consist of volcanic rocks, i.e. analcite-trachyte porphyry and biotite bearing andesite porphyry. This therefore implies that water from creeks on the eastern and western rims of the reservoir oozes out from volcanic rocks. In addition to this, the highest elevation of run-off at creeks has an average of EL 700 m, high above

the reservoir high water level of 648 m, implying the water tightness of this particular reservoir area.

2.2.4. Special Comment on the Geologic Log of UPH - 01
(Underground Powerhouse Site)

Hereunder is presented special comment on the geologic log of UPH-01 obtained by drilling explorations carried out thereupon. The report was prepared by Mr. C.G. Monlinong, Jr., Geotechnical Engineer, NAPOCOR.

(1) Introduction

Purpose

The geological and geotechnical investigations for feasibility studies of the Project brought up two major schemes for the proposed power tunnel ways. One scheme of a single stage development has its power tunnel routes directed at Didipio and its end terminating at a proposed open type powerhouse at Dibiowan, Cabarroguis, Quirino province. The second scheme is of a single stage development, with its tunnel route taken nearer to the Diduyon River and the underground powerhouse to be situated just before reaching the Didipio Creek, and the discharged water from the powerhouse with be guided to a tailrace outlet located at Dibiowan.

The purpose of this drilling is to determine the viability of the latter scheme through interpretation of the geologic conditions of the underlying rocks represented by cores recovered from the drill hole UPH-01.

Location and Accessibility

The drill hole UPH-01 is located at Barrio Alimit within the jurisdiction of the Municipality of Kasibu, Nueva Vizcaya, and approximately 30 km road distance from Debibie, Quirino province, the nearest source of provisions and food supplies. It is accessible via logging roads by any four wheeled axle vehicle. These roads can be passed through with difficulty during rainy seasons and are most often unpassable during adverse weather conditions.

Topography

The terrain above the proposed underground powerhouse site is very rugged and mountainous with few rolling hills and plains along the meander of the Didipio creek, located below and east collar of drill hole UPH-01.

The area is forested with noticeable patches of Kaingins created by the local inhabitants.

(2) General Geologic Descriptive Log

Borehole Data:

Inclination	Vertical
Depth of Hole	400 m
Depth of Bedrock	9 m
Date Started	Jan. 26, 1980
Date Completed	April 7, 1980
Driller	EGI