GOVERNMENT OF THE REPUBLIC OF THE PHILIPPINES

REPORT ON STUDY

OF

AMBUKLAO DAM REHABILITATION PROJECT

MARCH 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of the Philippines, the Japanese Government has decided to conduct a survey on the Ambuklao Dam Rehabilitation Project and entrusted the survey to the Japan International Cooperation Agency. The JICA sent to the Philippines a survey team headed by Mr. Naoaki Yamada 4 times during the period from November, 1986 to November, 1987.

The team exchanged view on the Project with the officials concerned of the Government of the Philippines and conducted a field survey in Ambuklao dam site. After the team returned to Japan, further studies were made and the present report has been prepared.

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

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

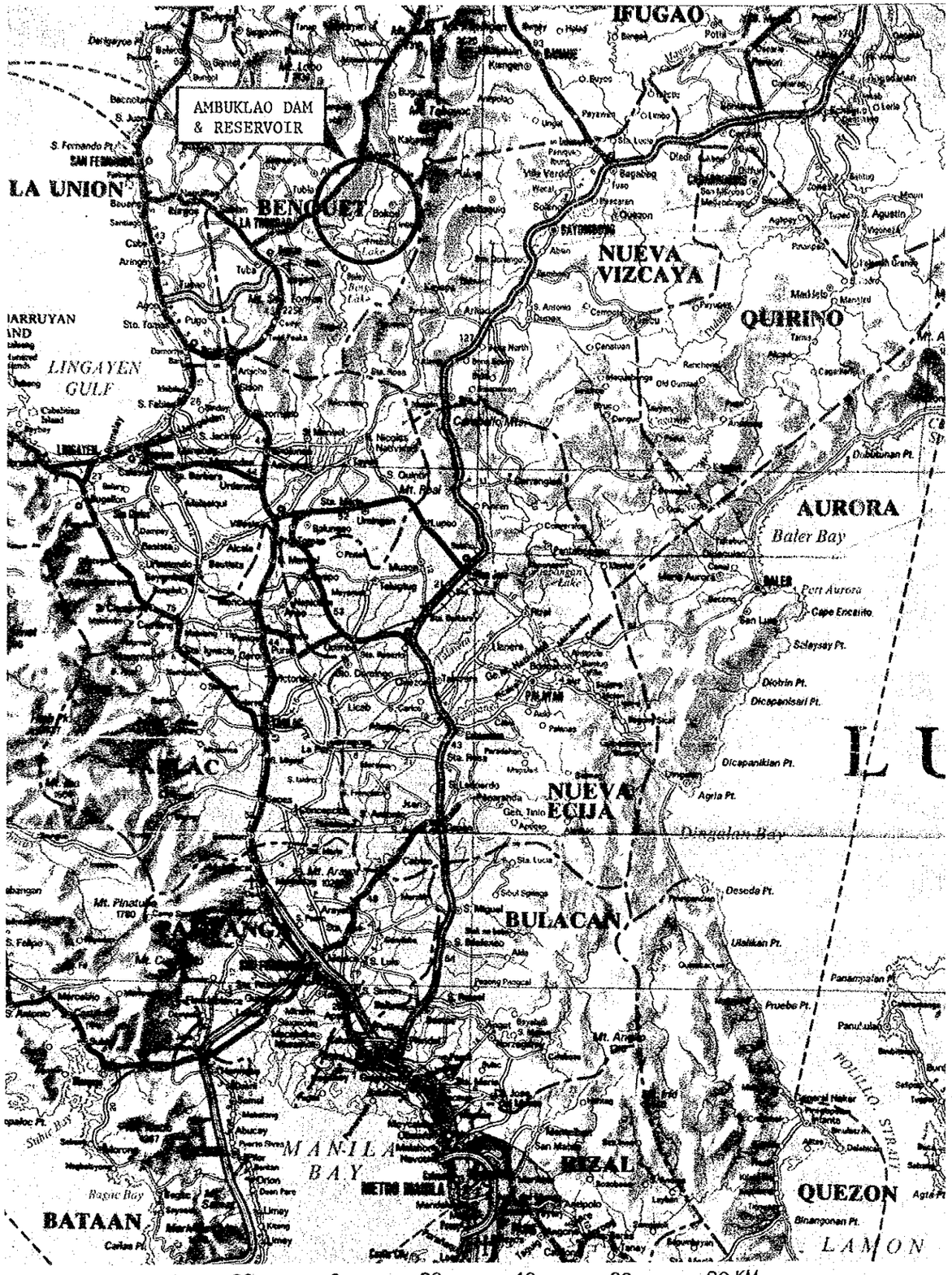
March, 1988

Kensuke Yanagiya

President
Japan International Cooperation Agency

Location Maps and Dam Typical Section,

and Site Photographs



THE AMBUKLAO DAM REHABILITATION PROJECT	
LOCATION MAP OF AMBUKLAO DAM & RESERVOIR	
SCALE AS SHOWN	DATE
THE JAPAN INTERNATIONAL COOPERATION AGENCY	

GOOSENECK INTAKE
INTAKE TOWER
ROAD
TUNNEL A
TUNNEL B
BULKHEAD PLUG
TUNNEL C
LOW LEVEL OUTLET WORKS
ACCESS TUNNEL
ACCESS ROAD TUNNEL
UNDERGROUND POWERSTATION
CABLE & VENTILATION TUNNEL
TRANSMISSION TOWER NO.1
SWITCHYARD
TAILRACE TUNNEL
PARAPET
ROCKFILL DAM
CREST EL. 756.0
AXIS OF DAM
SLOPE 1 ON 2
SLOPE 1 ON 1.75
SLOPE 1 ON 2.5
SLOPE 1 ON 2
ROCK QUARRY NO.1-A
RIPRAP
APPROACH SLAB EL. 735
RIPRAP 1 ON 1.5
CONC. SLOPE PAVING
1 ON 1
SPILLWAY
GRAVITY WALL
BUCKET
ROAD TO BORROW
N
0 100 200 m
1 / 2000

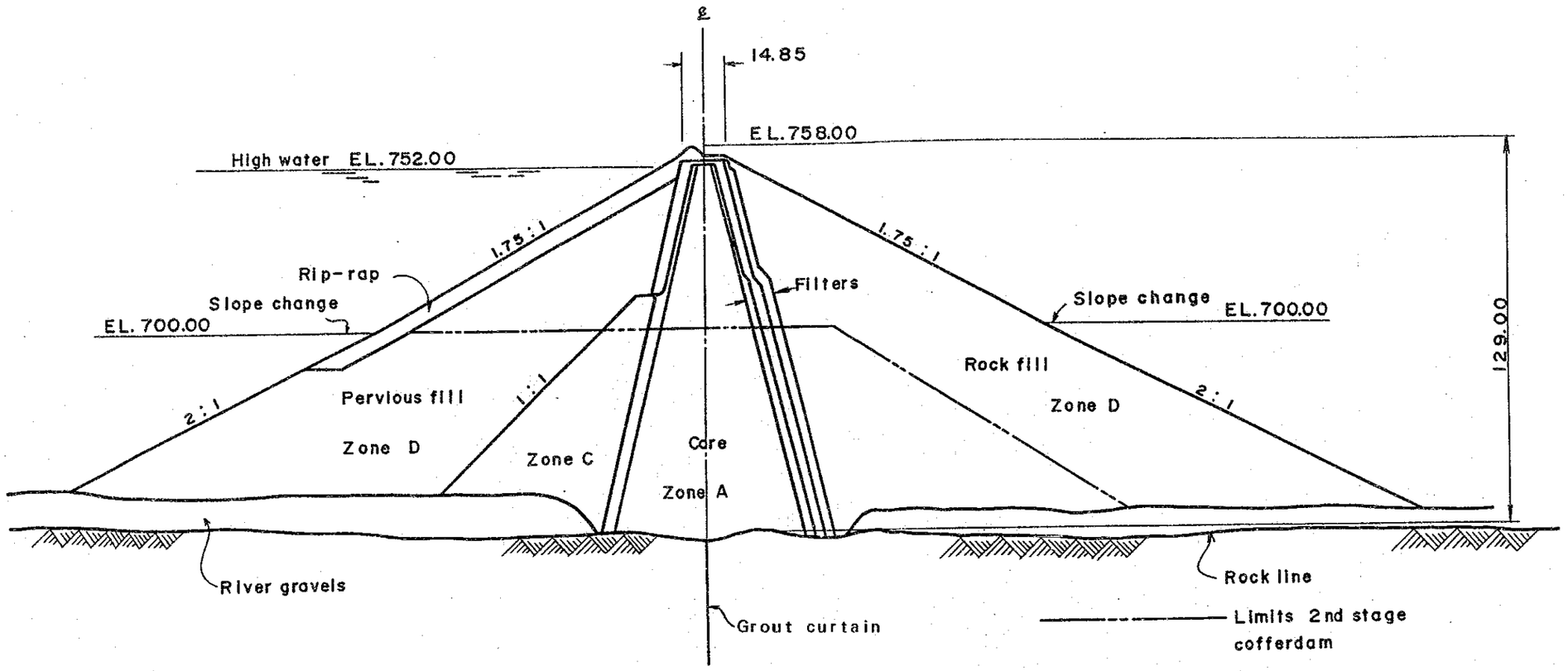
THE AMBUKLAO DAM REHABILITATION PROJECT

GENERAL PLAN

(DAM & POWER STATION)

SCALE 1 : 4000 | DATE

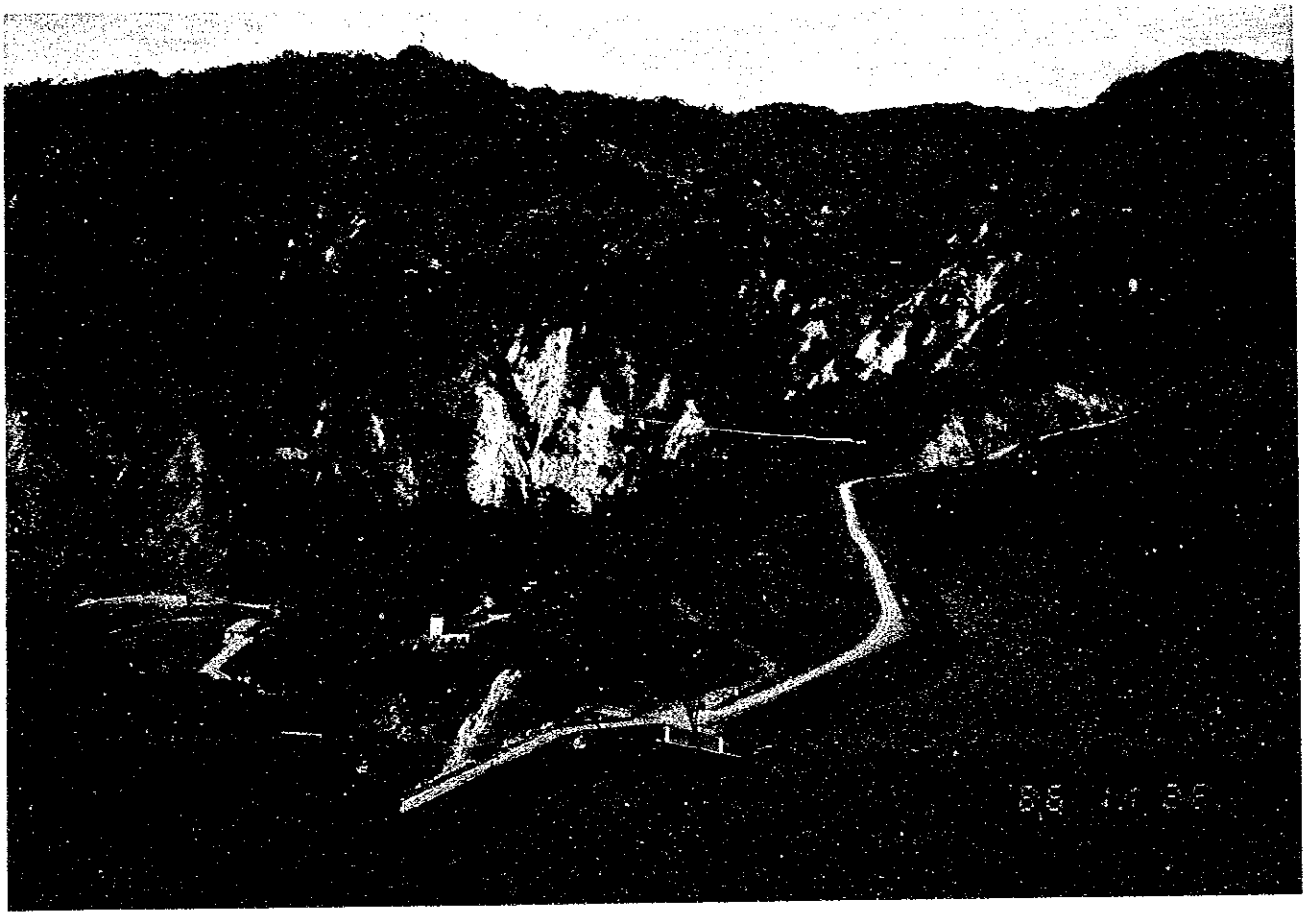
THE JAPAN INTERNATIONAL COOPERATION AGENCY



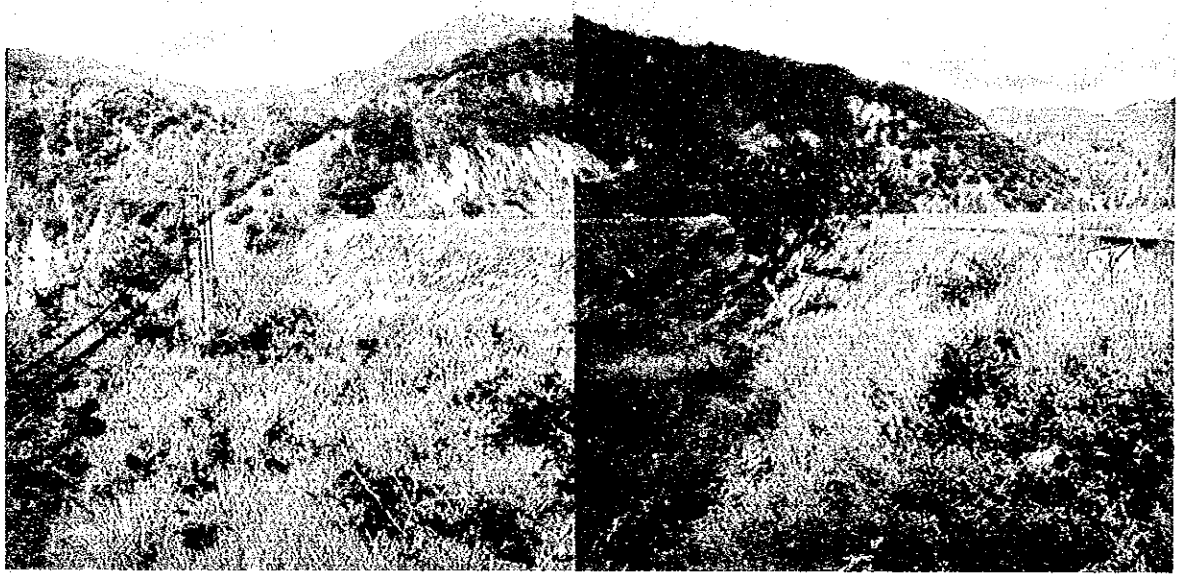
THE AMBUKLAO DAM REHABILITATION PROJECT	
TYPICAL SECTION OF DAM	
SCALE As shown	DATE
THE JAPAN INTERNATIONAL COOPERATION AGENCY	

General view of the Ambuklao Dam

from the Left Bank

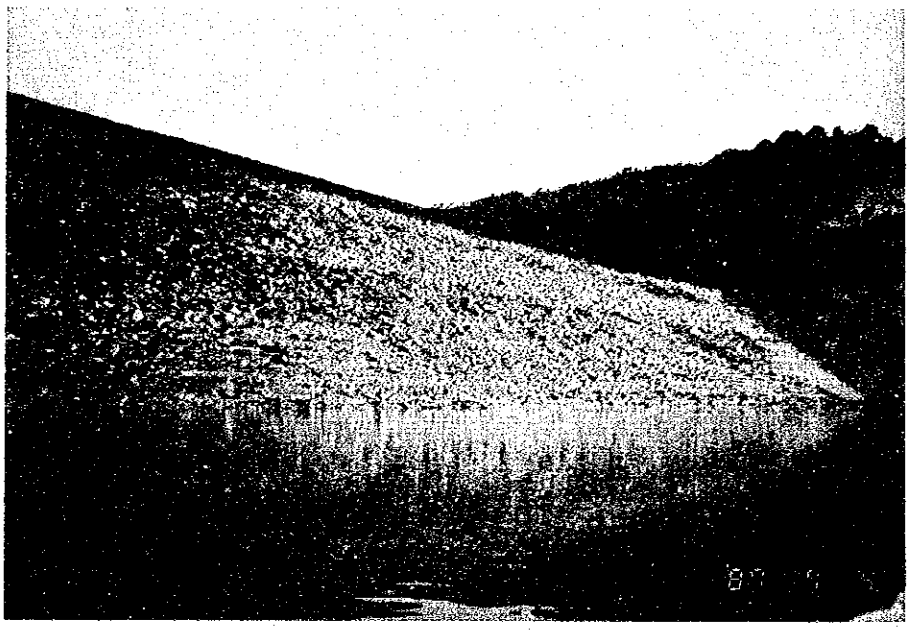


Downstream Face of the Dam

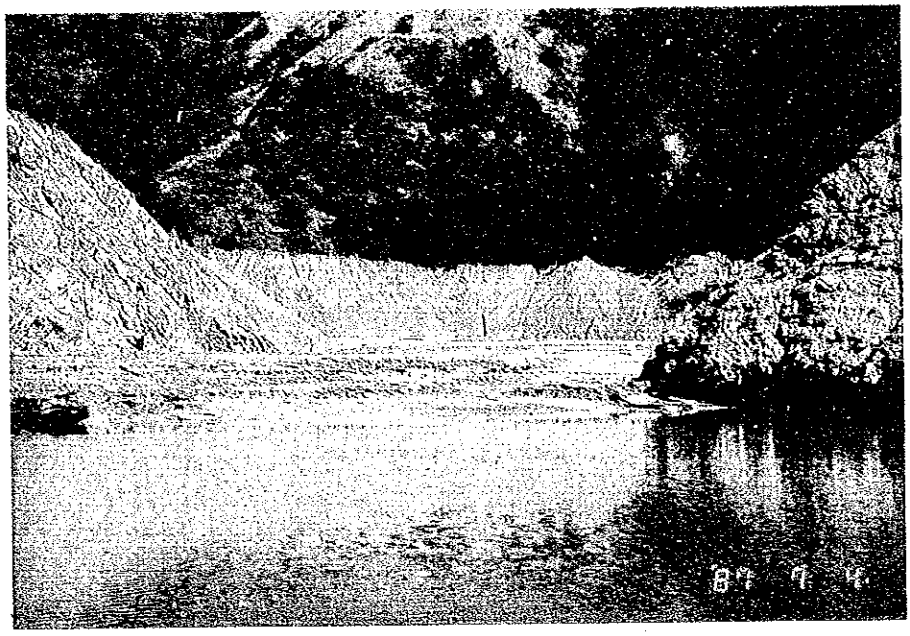


Upstream Face of the Dam

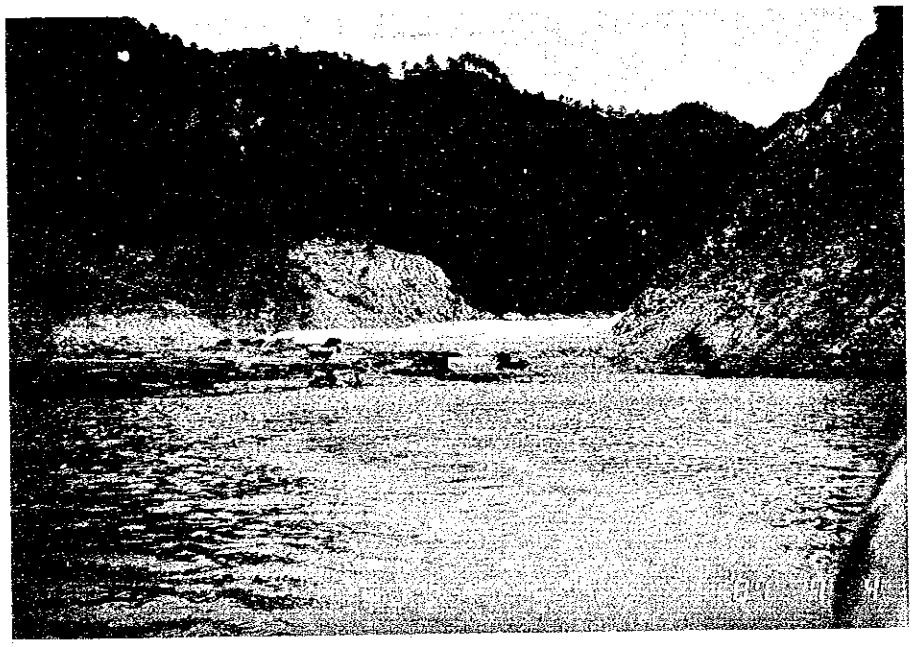
(W.L. 717.00m)



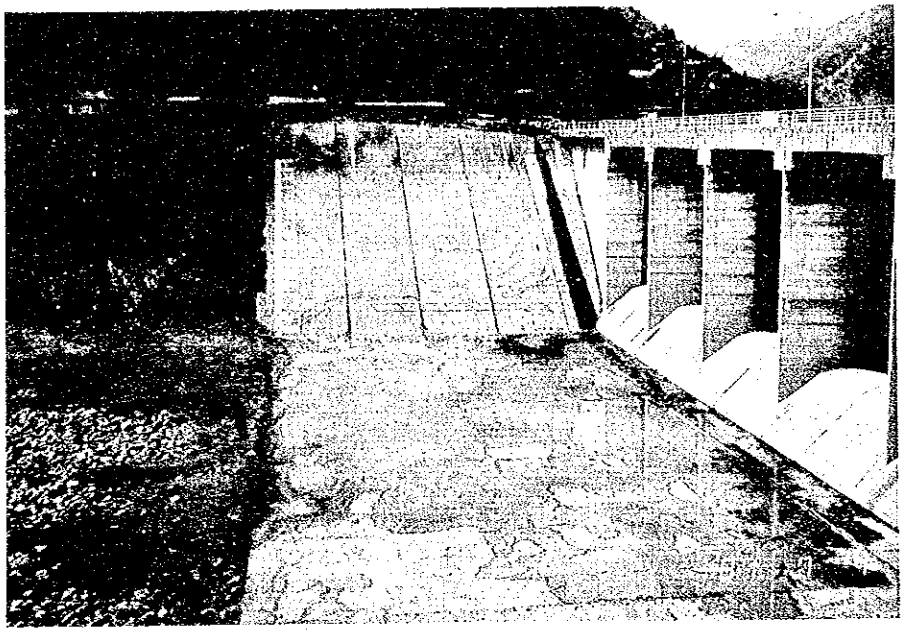
Sedimentation in the Labey River (W.L. 717.10m)

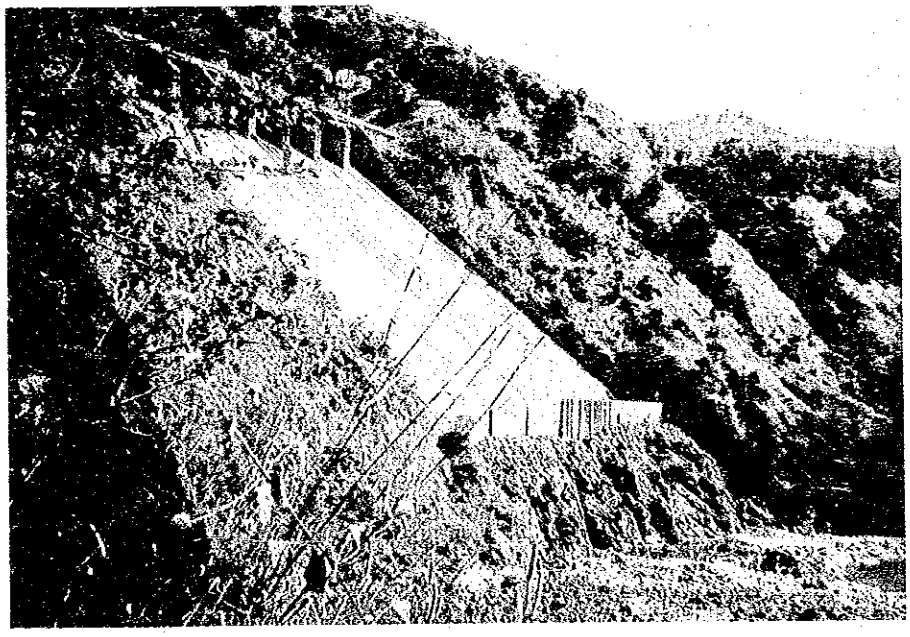


Sedimentation in the Bantay River (W.L. 717.10m)

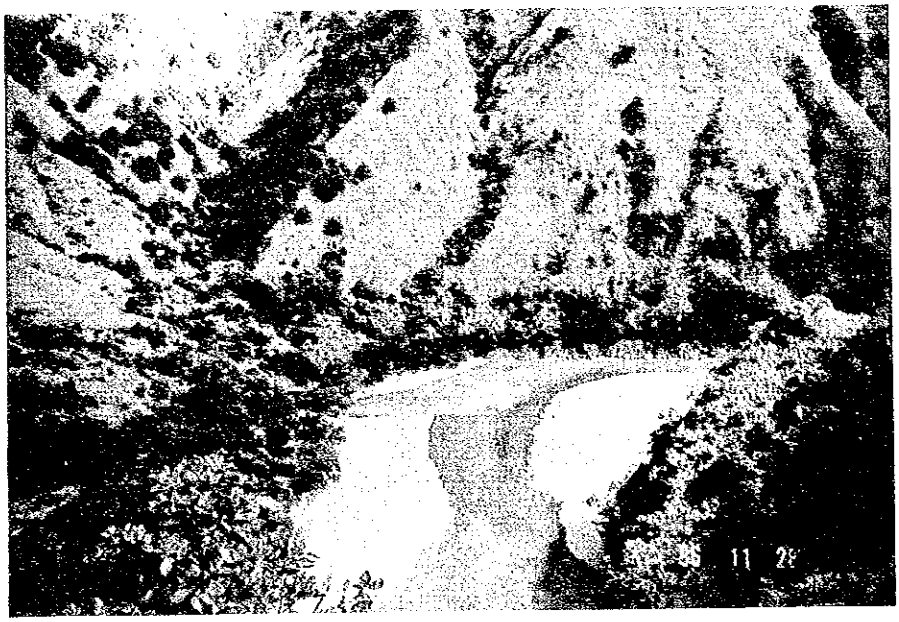


Spillway



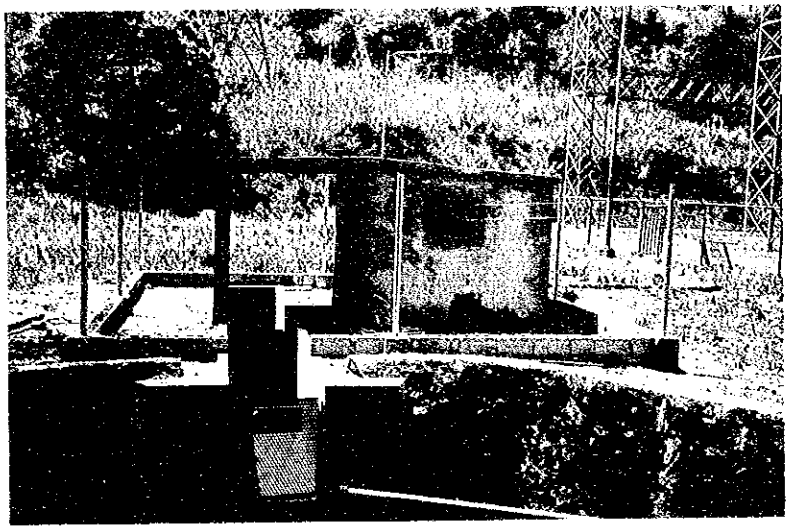


Sedimentation at the Tailrace

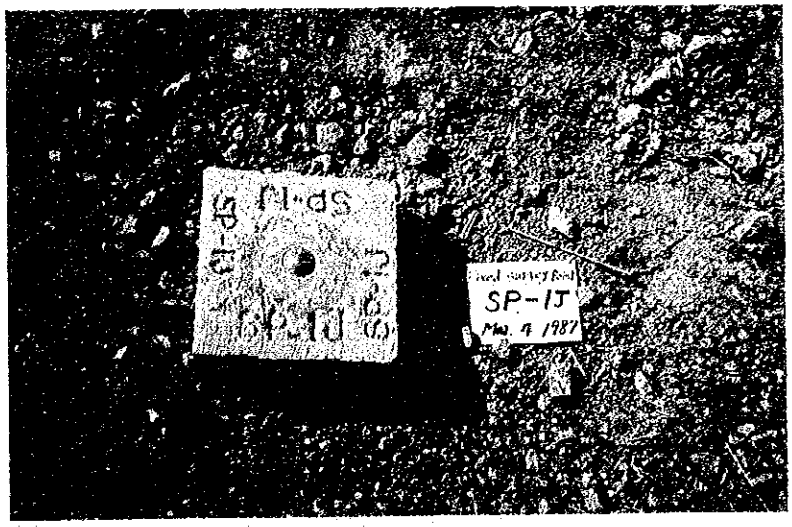


River Conditions at the Tailrace

Leakage Measurement Station



Dam Survey Point



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Introduction

Introduction

This is a final Report on the study of the required rehabilitation works for the Ambuklao Dam Project.

The objective of this study was to investigate the present conditions of the Ambuklao Dam and its powerstation facilities owned by National Power Corporation (NAPOCOR) to plan and supervise additional field investigations and provide guidance over dam monitoring in the field. Through these activities, optimization of the rehabilitation plan and the dam control standards were formulated on the basis of technical, financial and economic considerations.

The Rehabilitation Study

The Ambuklao Dam and its affiliated facilities are located 180 km north-northwest of Manila City and 36 km east of Baguio City. The Ambuklao Dam and its hydroelectric powerstation were designed by Harza Engineering Co., Ltd., USA, and were commissioned in 1956.

The main characteristics of the dam are as follows:

- Height of dam	:	129 m
- Crest of dam	:	452 m
- Type of dam	:	Rockfill dam with a central impervious core
- Catchment area	:	690 km^2
- Reservoir capacity	:	3.29 hundred million m^3
- Effective reservoir capacity	:	2.58 hundred million m^3

The Ambuklao powerstation operates as a main power source meeting the peak power demand of the Luzon Island by utilizing reservoir water with a maximum output of 75 MW.

The Ambuklao Dam Project has been in operation for more than 30 years. During this time, several rehabilitation programs had been proposed, such as safety control systems, more rigorous maintenance and surveillance, and landslide protection. However, none or very little of all these was done.

The Ambuklao Dam has suffered damages from the two major earthquakes which had occurred in the past the first at 0:15 AM and the second, at 9:07 AM on April 24, 1985. These earthquake effects and the high rate of sediment inflow into the reservoir, coupled with the sediment deposit around the power intake, caused serious problems to the operation of the powerstation. Thus, the rehabilitation plan for recovery and restoration of the proper operating conditions for the Ambuklao, after the occurrence of these earthquakes, has become an urgent and important issue.

NAPOCOR proceeded independently with the investigation and study of these problems, while requesting through the Government of the Philippines a technical assistance from the Japanese Government. To comply with this request, JICA (The Japan International Cooperation Agency) dispatched in August 1985 a pre-investigation team to the Philippines for discussions and inspection. As a result of the above, and in accordance with the scope of the work agreed between NAPOCOR and JICA, this developed into a study of the rehabilitation requirements for the Ambuklao Dam and its appurtenances.

The work on these studies started in November 1986.

The outline of the Ambuklao Dam Rehabilitation Project was as follows:

(1) Collection and analysis of data and information.

(2) Inspection and review of the existing monitoring system.

(3) Site inspection of the reservoir including power intake facili-

ties, dam, spillway, right and left abutments of the spillway, training wall at the upstream side of the right abutment of the spillway, powerstation (including access road and tunnel), tail-race tunnel and outlet.

(4) Formulation of the optimized monitoring system related to the safety control of the Ambuklao Dam.

(5) Additional field investigation works.

Guidance and supervision for the following additional field works required for the study:

- Topographic survey.
- Installation of dam monitoring facilities.
- Investigation works on drilling, trenching and pitting, and tests of embankment materials.
- Installation of leakage measurement device.

(6) Preparation of measurement manual

Measurement items consisting of:

- Leakage seepage measurement
- Dam displacement measurement
- Ground water level measurement

(7) Monitoring

Guidance and supervision over the following monitoring works were to be provided:

(a) Leakage and seepage measurement
(b) Dam displacement measurement
(c) Ground water level measurement

(d) Reservoir water level measurement
(e) Inflow and outflow into and from the reservoir
(f) Observation of rainfall and temperature
(g) Observation of earthquake
(h) Observation of landsliding

(8) Review of the stability analyses of structures.

(a) Dam
(b) Spillway training wall at the upstream side of the spillway right abutment.
(c) Bedrocks of the spillway left abutment.

(9) Review of the safety of structures.

(a) Review of the adequacy of the spillway capacity.
(b) Review of the causes of leakage and seepage in the power-station and its safety.

(10) Formulation of dam safety control system.

(11) Study and review of the safety against sediment deposits.

(12) Formulation of the rehabilitation plan.

(13) Preparation of the standards for the safety control system of the structures.

LIST OF PARTICIPANTS ON THE STUDY OF
AMBUKLAO DAM REHABILITATION PROJECT

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1.	Mr. Naoaki Yamada	- Team Leader
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5.	Mr. Ichiro Tomioka	- Mechanical Engineer
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Conclusions and Recommendations

Conclusions and Recommendations

If the present operating conditions continue, the Ambuklao Powerstation is anticipated to suspend its operation around 1995, mainly due to the problem of sedimentation. However, if suitable rehabilitation, maintenance and inspection measures are undertaken, the existing generating capacity could be kept at the present level for at least another 40 years, allthough the present reservoir volume, as expected, would be further reduced by sedimentation.

The main points of the rehabilitation plan include modification to the intake tower, repairs and improvements of the upstream face of the dam, repair or replacement of the turbine inlet valves, and improvements in the riverbed immediately downstream of the tailrace tunnel outlet. Several alternative plans were studied for the rehabilitation of the intake tower. As a result of comparative studies, it was finally decided to select the plan which allowed construction of a new tower and making various modification to the original design as required to cope with the sedimentation problems.

Economic evaluation of the rehabilitation plan was made by employing a system wide analysis based on the power development plan developed by NAPOCOR extending to the year of 2,000. The above economic evaluation indicated that the proposed rehabilitation plan was the most economical one from the various other plans considered.

In the part of the Report which follows, the main features of the Ambuklao Dam Project which have been analized are compiled and summarized and the required rehabilitation plan proposed.

1. Dam

The damages inflicted to the dam by the earthquake of April 1985 have been almost fully repaired except for the dam face. Although the epicenter of the earthquake was located very near the dam, no major problems occurred on the dam or its surroundings.

Minor superficial stability problems did occur on the upstream face of the dam. These, however, did not affect the overall stability of the dam.

(1) Dam Stability

a. Upstream face

Considerable damages to various parts of the upstream face of the dam have been observed which are assumed to have occurred due to the rising and lowering of the reservoir water level and the earthquake effects mentioned above. There are traces of erosion by wind and waves at about EL 733.00 and 752.00 meters. For certain conditions of earthquake, it is required, for these areas that emergency rehabilitation works be carried out as soon as possible to maintain the safety factor against sliding above the allowable levels.

b. Downstream face

A road ten meters wide for service and access purposes was constructed on the downstream face of the dam. It extends from the bottom to the top of the dam. The road was constructed by undercutting the design slope of the dam, thus, affecting, to a certain extent, the stability of the design slope. Stability analysis of certain such areas, conducted recently, indicated that the safety factor was reduced to below 1.0. During the earthquake of April 1985, localized, superficial, slope failures were observed at certain areas along the road.

The overall stability of the downstream slope, however, based on the existing design slope and shearing strength of the in-situ materials is considered to be adequate.

(2) The Ridge on the Left Abutment Downstream of the Dam

a. Prevention of scouring of the gully of the ridge

A fault is passing through the gully of the ridge. The bedrock due to the fault is weak. Therefore, every time when water is released through the spillway, scouring of the gully occurs which results in further loosening of the bedrock. To enhance the stability of the dam, further scouring of the bedrock at this location should be prevented by construction of a revetment.

b. Reinforcement of bedrocks of the ridge

Open cracks and partial sinking of the bedrock are observed along the crest of the ridge.

It is assumed that these conditions have been caused by the fault in the ceiling of the drainage adit located just beneath the ridge which caused loosening of the said bed-rocks.

As the bedrocks are very important for the abutment, safety measures must be taken to secure their stability.

2. Spillway

Unusual conditions were observed at and around the spillway area after the big flood of 1976 and the earthquake of 1985. The rehabilitation and monitoring works required in connection with the above had been carried out.

Some of the measures taken at that time were stabilization of the bedrock in the spillway left abutment and the spillway inlet training wall. The excessive rising of the reservoir water level

during the above flood caused anxieties about the adequacy of the capacity of the spillway.

With regard to the above, safety analyses, which proved that no specific measures were necessary, were undertaken.

(1) Stability of the Bedrock in the Left Abutment of the Spillway

Based on the data obtained by survey map, stability analyses of the area were made using bedrock strength properties of ϕ=45° and C=5 to 10 kg/cm^2. The analyses yielded a safety factor of over 1.0. However, periodic monitoring, including observation of underground water levels and displacement of the bedrock by inclinometer, should be carried out continuously. The above monitoring system should be maintained as long as necessary.

(2) Stability of the Training Wall at the Spillway Inlet

Partial cracks have been observed, however, the wall itself and the adjacent portion, had been well restored. The analysis performed for overturning, sliding and bearing pressure proved that the structure was stable.

(3) Discharge Capacity of the Spillway

The Ambuklao spillway has a discharge capacity of 1.2 times the discharge required for a 200-year return period flood.

This return period flood was computed by assuming the rainfall of the Agno River basin to be the same as that of the Baguio City, as not enough data on the rainfall for the Agno River basin were available. The above 200-year flood will correspond to the 2000-year flood for the Baguio City if the average rainfall data of the Baguio City basin were used.

If the Agno River basin rainfall data were used to compute various flood return periods, the above 200-year flood will correspond to a 19,000-year return period. The above examples illustrate clearly the big differences in the results of the flood studies obtained if different assumptions are made. They also underline the high sensitivity of the calculations.

It is, therefore, recommended that hydrologic observations along the Agno River basin should continue and necessary data collected. Based on the above discussion, it is judged, for the present, that the discharge capacity of the existing spillway is adequate, however, further studies in the future should be performed.

3. Reservoir

The annual sediment yield of the Agno River is about 3,600,000 m^3. This was calculated on the basis of the total sediment yield of the river from completion of the project to the present day. This sediment yield presents an extremely large figure as compared to other rivers in Southeast Asia.

Judging from the topographic and geologic conditions of the area around the reservoir, it is concluded that there is no immediate danger of large landslides developing around the reservoir which could provoke a large inflow of sediment deposits.

(1) Sediment Deposits

The sediment data collected to date for the Ambuklao are not enough to analyse the sediment volume flowing into the reservoir. However, from the collected data, it is concluded that the annual sediment yield for the Ambuklao reservoir has reached great proportions. This is true even if average

figures are considered. The sediment inflows have a tendency to be proportional to the river discharges.

It has been reported that, since the flood of 1984, the turbines of the powerhouse have had obstructions caused by silt and sand when in operation.

According to the latest map prepared in 1986, the sediment deposits around the power intake tower have almost reached the level of the intake sill.

The effects of the sediment deposit in the future on the power generation were analysed by a simulation method. The results of this study indicated that serious obstruction to the power generation could be expected the earliest by 1992 and the latest by 1995. The gradient of the advancing face of sand and silt was assumed to be 1 to 75.

Therefore, it is recommended that, in order to prevent the above from occurring, the powerstation facilities should be urgently protected against the sediment deposits and its production of electric energy should be kept at the present level.

(2) Landslides along the Reservoir

There are several topographic locations around the reservoir which may be subjected to minor landslides. Presently, no place around the reservoir where a large-scale landslide could occur, has been observed. However, continuous surveillance of the area around the reservoir should be carried out by means of aerographycal survey and other relevant means for detection of any possible potential landslides.

4. Powerstation

The Ambuklao Powerstation is of the underground type and is located immediately underneath the dam. Because of the location, it could be assumed that a large amount of reservoir water would seep through the bedrock into the powerhouse. In order to understand and monitor this problem, gauging station had been installed around the powerhouse and the seepage was measured, however, no serious seepage had been observed.

(1) Turbine Leakage

At the time of the field investigations, November 1986, a large volume of leakage from the sealing equipment of Turbine Nos.1 and 2 was observed. Since the leakage water was mixed with the silt and sand, the curbon packing of the sealing equipments was assumed to have been heavily damaged. Depending on the time when the first leaking had occurred, it is assumed that a large amount of water might have been lost through this leakage.

It is concluded that if no measures were taken to prevent the inflow of sands, maintenance and repair of the turbines will keep increasing in the future, resulting in loss of time and money.

This is expected to be fully improved by the improvement works for the turbines, but, separately, the intake system of the cooling water should also be improved. Purification of the cooling water will also be required.

(2) Inlet Valve Leakage

Although it is uncertain, as the inspection of the valves after dewatering could not be made yet, it is expected that

soon the leakage from the inlet valves of the turbines will reach the amount of about 3,000 ltr./min. This prediction was made by NAPOCOR. It is presumed that the valves, which have been in use for over 30 years, might have been scoured at their tips and, therefore, unable to close properly and completely.

Based on the inspection after dewatering, a judgement of whether the valves should be repaired or substituted by new ones should be made.

For the rehabilitation plan, it is proposed that the existing valves be replaced if it is found that they are seriously damaged. It should be pointed out that for proper maintenance of the turbines the inlet valves should function properly.

5. Tailrace

The main problem in the tailrace area of the river is the effect which the sediments in this area may have on the power generation.

The tailrace water level at the present is approximately at EL.597.0 meters which is approximately four meters higher than the initial water level assumed in the original design. This causes no obstruction to the functioning of the turbines, although the effective head acting on the turbines is reduced by about four meters.

The sedimentation of the tailrace area is caused by the reservoir of the Binga Dam which receives an annual sediment yield of about 450,000 m^3 from its own basin. Therefore, any radical measure with regard to the Ambuklao tailrace would have a close relationship with the sediment measures to be taken for the Binga reservoir.

(1) Effects of the Sediment on the Power Generation

The tailrace water level at the Ambuklao Powerstation has increased by about four meters due to sedimentation. A study of the effects of the above on the generation indicated that the surge tank of the tailrace tunnel would reach full capacity during powerplant operation, however, without any adverse effects on the operation of the units. Even in case of an emergency closure of the units, the hydraulic analysis indicated that there would be no problem with the operation of the units. However, it is recommended that further detailed hydraulic studies be made at the engineering stage to verify the proper performance of the tailrace tunnel.

(2) Sedimentation in the Tailrace Area

Due to the increase in the water level at the tailrace outlet, it is estimated that about 3 percent of the effective head is being lost. Required countermeasures were studied. However, they were not found to be economically feasible, as big benefits could not be expected due to the excessive level of the rehabilitation cost. It is, thus, recommended that, for the time being, an investment for recovery of the head lost due to the sedimentation at the tailrace outlet should not be made if there were no serious obstruction to the generation.

It is recommended, however, that certain improvements in the tailrace outlet area still be made as part of the sedimentation countermeasures program to be undertaken for the Binga reservoir, until the final rehabilitation measures for the tailrace are specified.

6. Rehabilitation Plan

The rehabilitation plan for the Ambuklao Project is based on the compilation of measures selected on the basis of comparative studies of various measures proposed and found to be most economical. In addition, in these studies, safety and design, construction and functional requirements, were also considered. The economic evaluation of the proposed measures was carried out on the basis of a system wide analysis.

(1) The Plan

The rehabilitation works with regard to the sedimentation problem and the upstream face of the dam are the major repair works of all the works considered, and, therefore, the most expensive.

Five rehabilitation schemes were considered for the problem of sedimentation. They were Schemes A, B, C, D and E which comprised of the following:

Scheme A - Removal of sediments by use of a big dredging boat.
-"- B - Heightening of the existing intake tower.
-"- C - Provision of a large capacity sediment removal facility.
-"- D - Provision of a new intake tower (sloping type).
-"- E - Provision of a new intake tower (vertical type).

As described in detail further below, the above five schemes were thoroughly studied with a purpose of selecting the scheme which was most economical and suitable, in particular from point of view of construction and operation. On the basis of the results of the above studies, Scheme E was found to be such a scheme.

For the upstream face of the dam, a rehabilitation plan which resulted in minimum work and cost was adopted.

For the inlet valves of the turbines, it is proposed that the existing valves by substituted with new valves.

For the sedimentation in the tailrace area, as a provisional treatment, a plan to provide a channel along the riverbed for about 1,500 meters was adopted.

In addition, as an emergency, it is proposed that a rehabilitation plan which will include dredging of the sediments accumulated around the intake tower should also be provided.

The work items of the proposed rehabilitation plan and their respective costs are as follows:

Work Item	Cost
Modification of the intake tower	US$19,350,000
Improvement of the upstream face of the dam	US$ 7,333,000
Replacement of the inlet valves of the turbines	US$ 2,133,000
Clearing and riverbed improvement at the tailrace area	US$ 1,333,000
Dredging of sediments around the intake tower	US$ 5,456,000
Total	US$35,605,000

If the field investigations, land compensation, engineering and NAPOCOR administrative costs and contingencies are added to the above US$35,605,000, the total cost of rehabilitation works will become US$42,436,000.

It is estimated that the period for the modification of the intake tower will be about five years. The rehabilitation of the upstream face of the dam can easily be completed within the above period. Replacements of the inlet valves of the turbines and the riverbed improvements at the tailrace area could be carried out during the last year of rehabilitation.

However, as dredging of sediments from the area around the intake tower would be affected by the sediment inflow into the reservoir, it is very important that these particular measures be implemented as soon as possible.

(2) Economic Evaluation

In the Power Development Program (Original Plan) of NAPOCOR of June 1987, the losses or reduction in the capacity of the Ambuklao Powerstation due to sedimentation were not reported. However, according to the analysis of the results of the above study, it is found that, it is found that, if the powerstation is not soon rehabilitated, a considerable loss of capacity could occur after 1996.

In the economic studies covered in this Report, the followng two methods were basically considered:

(a) The original plan comprising all work items of the rehabilitation plan previously mentioned.

(b) An alternative plan, which does not call for repairs of the Ambuklao Powerstation, but in addition to the existing project, provided for construction of a Geothermal Powerstation with a capacity of 55 MW.

Furthermore, for reference purposes only, a study was also made to determine the cost benefits assuming that

the power demand is met by supply from the existing Ambuklao Powerstation without undergoing any repair works. The fact that reliance on such powerstation should be decreased was taken into consideration. The above was considered to be, in addition to the above two cases, the third case studied.

The economic evaluation was made for all cases on the basis of a system wide analysis covering the whole Luzon Grid of NAPOCOR.

The above studies clearly indicated that the proposed Ambuklao Dam Rehabilitation Plan, described above under Item (1), was the most advantageous. This plan provided the most economical solution which was also reliable, safe and easy to implement, and did not require an alternative development.

The I.R.R. of about 42% can be obtained from the comparison of the rehabilitation plan as a main program and the alternative development. Even in the case that no alternative development is considered, the result shows that the rehabilitation plan is more advantageous since the I.R.R. of 17.69% can be obtained.

7. Dam Safety Control System

A Civil and Architectural Section (tentatively named, and at the same level of responsibility as the present Mechanical and Electrical Sections) is to be established within the Central Maintenance and Technical Services Department (CMTSD) of Northern Luzon Regional Center (NLRC). The proposed staffing should be composed of two civil engineers and three assistants. This section will be responsible for maintenance, inspection, repair works, surveillance and monitoring of the Ambuklao Dam and its

auxiliary structures. In addition, this section is proposed to also be responsible for maintenance and inspection of the civil structures of all the power projects of NLRC, such as Binga and Angat Powerstations.

It is further proposed that a Hydro-Civil Maintenance Division (tentatively named and at the same level of responsibility as the Project Design Division) within the Hydro Power Project Department, Engineering (Main), of the NAPOCOR Head Office in Manila, be established. Its staff should consist of several civil engineers with functions and assignments for the overall management of inspection, maintenance and repair works of civil structures. Coordination with the Civil and Architectural Section of the CMTSD of the Regional Center, and planning and analyses of monitoring data compiled by the Technical Services Department from the civil engineering view point, will also be the responsibility of this division.

It is emphasized that one civil engineer should be permanently assigned to the Ambuklao Powerstation for the purposes of daily dam operation and maintenance of civil structures.

8. Further Steps to be taken for the Ambuklao Dam Rehabilitation Project

A characteristic of the rehabilitation project is to overcome progressive sedimentation in the reservoir which requires urgent implementation of the countermeasures without allowance of any idle time from now on. Saying more concretely, it is indispensable to complete at least power intake improvement work in 1996. In addition, during above improvement work, the existing intake should be kept away from the inflow of sand and silt.

The intake improvement work requires 5 years to complete, which is a longer period of implementation than normally estimated for this

type of project because it involves underwater works inside the reservoir. Accordingly, 1996 time for completion means that the work should be commenced in the 3rd quarter of 1992.

Considering pre-contract activities such as bidding and contract conclusion which often take a period of one to one and half years, further field investigations and detailed design work have to start in 1989 and bid documents be ready for issuance around the middle of 1991 in order to maintain the above-mentioned construction milestone.

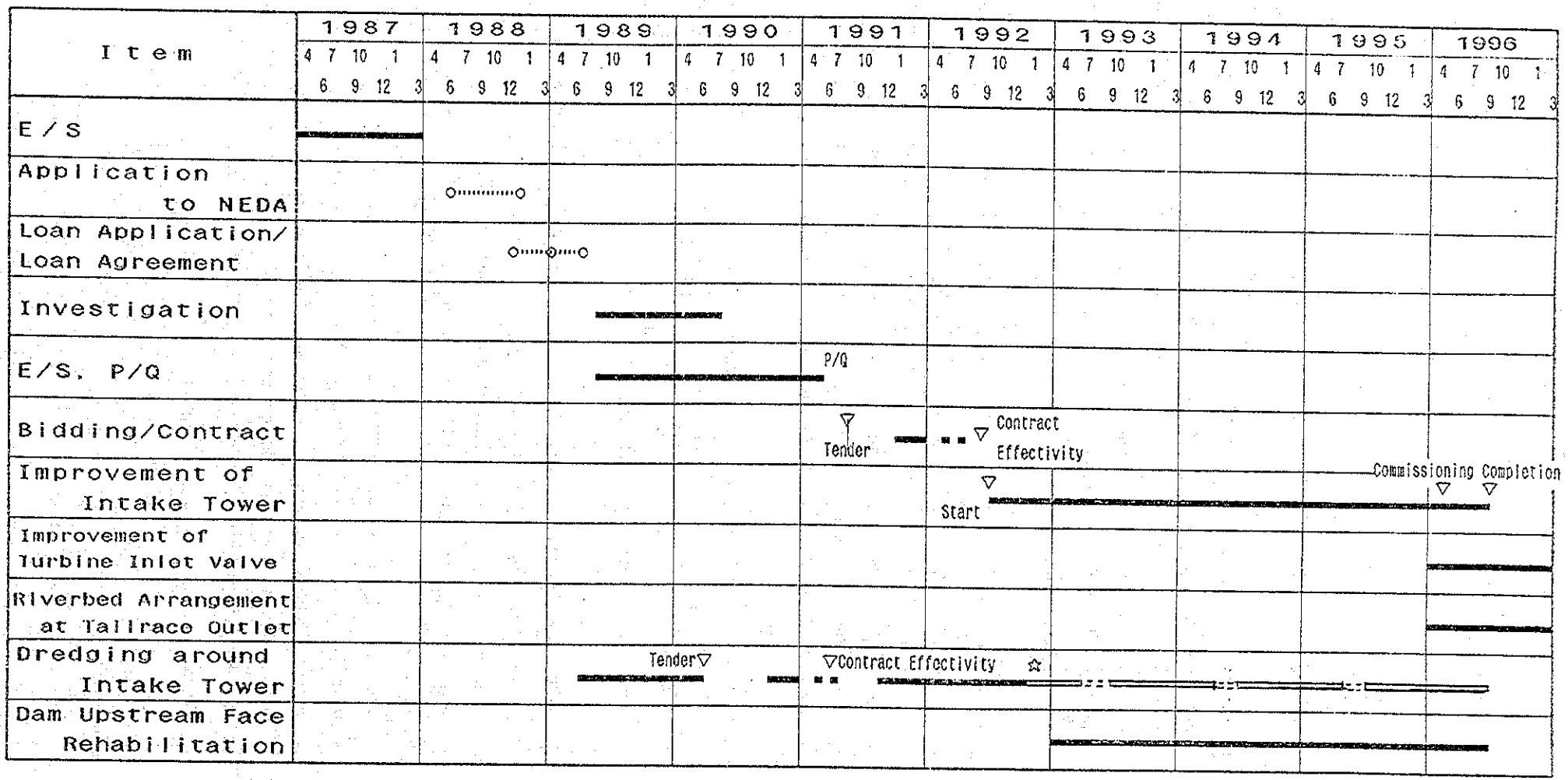
A part of further field investigations (survey and drilling works) has to be carried out under the reservoir water, and their progresses will much depend on the reservoir water level. It is, therefore, recommended to program the work schedule with considerable time allowance. Details of further field investigations are given in 12.4.2.

On the other hand, even at present time, the inflow of sand and silt to the intake is gradually increasing. As a matter of fact, OM cost for Ambuklao Power Station amounts 3 folds as compared to those for other hydro plants of similar type.

Immediate countermeasure by means of dredging facilities is regarded necessary to dredge sediment deposit around the existing intake tower for maintaining continuous operation of the Ambuklao Plant until the completion of proposed intake improvement work.

The installation of dredging facilities is included within the scope of the proposed Ambuklao Dam Rehabilitation Project. It is, however, recommended to proceed with the implementation of only this item as earlier as possible than the proposed Rehabilitation Project if procurement of dredging equipment can be made separately.

Work Schedule of Ambuklao Dam Rehabilitation Program



Main Report

1. Collection and Analysis of Data

1. Collection and Analysis of Data

During the site investigations conducted for a period of 30 days from November 17 to December 16, 1986, and the studies by the pre-investigation team, various data related to the study for the Rehabilitation Project were collected. The required additional field investigations for further studies and reviews were based on these data as described in the subsequent sections.

List of the compiled data is presented below.

(a) Data on topography, hydrology, earthquake and sediment

Topographic map of the Ambuklao Dam Basin 1/50,000, 3 sheets

Flood inflow record for the Ambuklao Dam, Hourly, from 1975 to 1985

Rainfall record for the Ambuklao Dam Basin, Daily, for 1975, '76, '84 and '85

Reservoir water level record for the Ambuklao Dam, Hourly, for 1975, '76, '84 and '85

Location map for the rainfall gauging stations of the Ambuklao Dam River Basin, 1 set

Record of the sediment volume for the reservoir of the Ambuklao Dam, 2 sets

Distribution map of the sediment in the reservoir of the Ambuklao Dam, 1 set

(b) Dam, spillway, intake tower, surge tank and powerhouse

Design criteria and detailed map of the Ambuklao Dam, 1 set

Location map for the dam monitoring facilities, 1 set

(c) Others

Monitoring record of the vibrations of the arms of the spillway tainter gates. Data from the previous rehabilitation works, 1 set of photographs

(d) Additional data not included in the Inception Report

Location map for the rainfall gauging stations of the Binga Dam Basin

Daily rainfall records of the Binga Dam Basin, 1956 to 1986

Daily inflow records of the Ambuklao Dam, 1956 to 1986

Location map for the water level gauging stations of the Binga Dam

Water level records at the dam

Monthly average water level record for the Ambuklao Dam, 1975,'76,'84 and '85

Inflow, water level and rainfall records for the maximum flood of the year for the Ambuklao Dam, 1975 to 1985

Topographic map (1/50,000) of the area of the Binga Dam Basin, 3 sheets

Record of the sediment volume of the Binga reservoir

Distribution map of the sediment in the Binga reservoir

(e) References

Power Development Plan, May 30, 1986, 1 set

Treatment of the sediment deposited in the tailrace of the Ambuklao Dam, 1 set

Monthly inflow into the reservoir of the Ambuklao Dam (1968 to 1986), 1 set

Hydrologic data (1985), 1 set

Brief drawing of the Ambuklao Hydroelectric Powerstation, Boked, Bengnet Region, 1 set

2. Existing Monitoring System

2. Existing Monitoring System

As affected by the results of the site investigations conducted to survey the conditions and the performance of the existing monitoring system for the Ambuklao Dam, the following types of instruments and monitoring intervals, presently adopted, are clarified below.

It was determined that, of all the instruments installed, some were not required, and others did not function. Comments on the performance of the instruments are given further below.

	Instrument	Type	Monitoring Interval as of Dec.,1986
(1)	Electric piezometer	1 SP 6 SP 7 TPV 10 TPV 11 SP 4 SPA	three times a week
(2)	Open pipe piezometer	3 AD 5 AD 7 AD	three times a week
(3)	Open pipe piezometer at the dam crest	PZ-1 PZ-2	twice a day
(4)	Drain hole	DDH-1 to DDH-28	three times a week
(5)	Inclinometer	DDH-A to DDH-D	The indicator has been out of order for one and a half year.
(6)	Crack meter		Daily
(7)	Observation well		Not monitored
(8)	Seismograph		Out of order
(9)	Alignment at the dam crest		Not defined

Based on the above, comments and suggestions for monitoring were made in 1986 as follows:

(a) Measuring intervals - Enough at present and further study is required (by JICA expert).

(b) Electric piezometer - All instruments are out of order. Continuous monitoring is not required. Electric piezometers should be replaced by driving new boreholes.

(c) Open pipe piezometer - Very good condition. It should be monitored continuously.

(d) Open pipe piezometer - PZ-1 and PZ-2 indicate a high water level and correct water level respectively. Data is not useful. However, monitoring should be carried out continuously, for the present.

(e) Inclinometer - Indicator is out of order. Monitoring should be continued carefully after replacement with a new instrument.

(f) Crack meter - Monitoring is not required. Crack and pit should be repaired as required and as soon as possible to avoid inflow and infiltration of rainfall.

(g) Observation well - Out of order. JICA expert recommends installation of a new water leakage measuring station.

(h) Seismograph - Out of order. JICA expert recommends installation of a new seismograph.

(i) Dam crest alignment - Monitoring should be continued periodically twice a year in accordance with the schedule. In case of a heavy rainfall or earthquake, the alignment should be checked immediately.

3. Site Investigations

3. Site Investigations

Initially, four experts of the JICA Study Team for the Ambuklao Dam Rehabilitation Project were dispatched to the project site on November 17, 1986, to perform site investigation for about one month. Additional three experts were dispatched on December 1, 1986, to join and assist the first group in the site investigations which were to be completed on December 16, 1986.

The JICA Study Team comprised the following personnel:

(a) Mr. Naoaki YAMADA (Team Leader)
Period: 17 Nov.'86 - 16 Dec.'86

(b) Dr. Tsuguo HARADA (Civil Engineer - Design)
Period: 17 Nov.'86 - 16 Dec.'86

(c) Mr. Yuichiro TSURUMAKI (Civil Engineer - Design)
Period: 17 Nov.'86 - 16 Dec.'86

(d) Mr. Megumu KAWAHARA (Geologist)
Period: 17 Nov.'86 - 16 Dec.'86

(e) Mr. Ichiro TOMIOKA (Mechanical Engineer)
Period: 1 Dec.'86 - 16 Dec.'86

(f) Mr. Tamotsu FUJIWARA (Civil Engineer - Monitoring)
Period: 1 Dec.'86 - 16 Dec.'86

(g) Dr. Haruo TANAKA (Technical Advisor)
Period: 1 Dec.'86 - 8 Dec.'86

The main activities of the Study Team were as follows:

(1) Discussion of the contents of the Inception Report with the staff of NAPOCOR and presentation of the Report.

(2) Field inspection of the deformations and the damage to the dam, sedimentation in the reservoir and tailrace outlet, and existing conditions of the landslide areas.

(3) Collection of information related to the study and monitoring system.

(4) Review of previous studies and monitoring methods already planned or executed. Programming of additional field works including sedimentation investigation and monitoring based on the results of the above review.

(5) Investigation of sedimentation in the reservoir and the river channel. Observation of landslide areas. Observation of the vegetation in the basin area and study grain size distribution in the riverbed.

(6) Preparation of specifications for the additional field works.

The results of the above work were presented to NAPOCOR as "Technical Specifications" and "Brief Report".

Mr. Tamotsu FUJIWARA (Civil Engineer - Monitoring) visited the Philippines again for guidance over the additional field works and installation of new monitoring instruments which were to be undertaken by NAPOCOR, from January 15, 1987 to the end of March 1987. Thus, when the JICA Study Team visited the Philippines on July 1, 1987, for the explanation and presentation of the Interim Report, confirmation of the sedimentation data for the upstream area of the dam and the low water levels of the reservoir, which could not be verified during the last visit, was possible to perform. Mr. Tamotsu FUJIWARA visited the project site two additional times, during the period from July 1 to July 14, 1987, and November 1 to November 14, 1987, for guidance of monitoring works and review of their results.

Based on the data and information collected in the Philippines during the site investigations and received subsequently from NAPOCOR, various analyses, mentioned in previous Chapters, were carried out in Japan. In addition to the above, Mr. Shuhei OGAWA, an economics and energy expert, joined the Study Team for performance of economic evaluation of the works.

4. Monitoring System

4. Monitoring System

Based on the discussions with NAPOCOR, the basic concept of the monitoring works was formulated as illustrated on the attached organization chart.

The future requirements for monitoring of the dam and the generating facilities including maintenance, surveillance and control system, are described in Chapter 10.

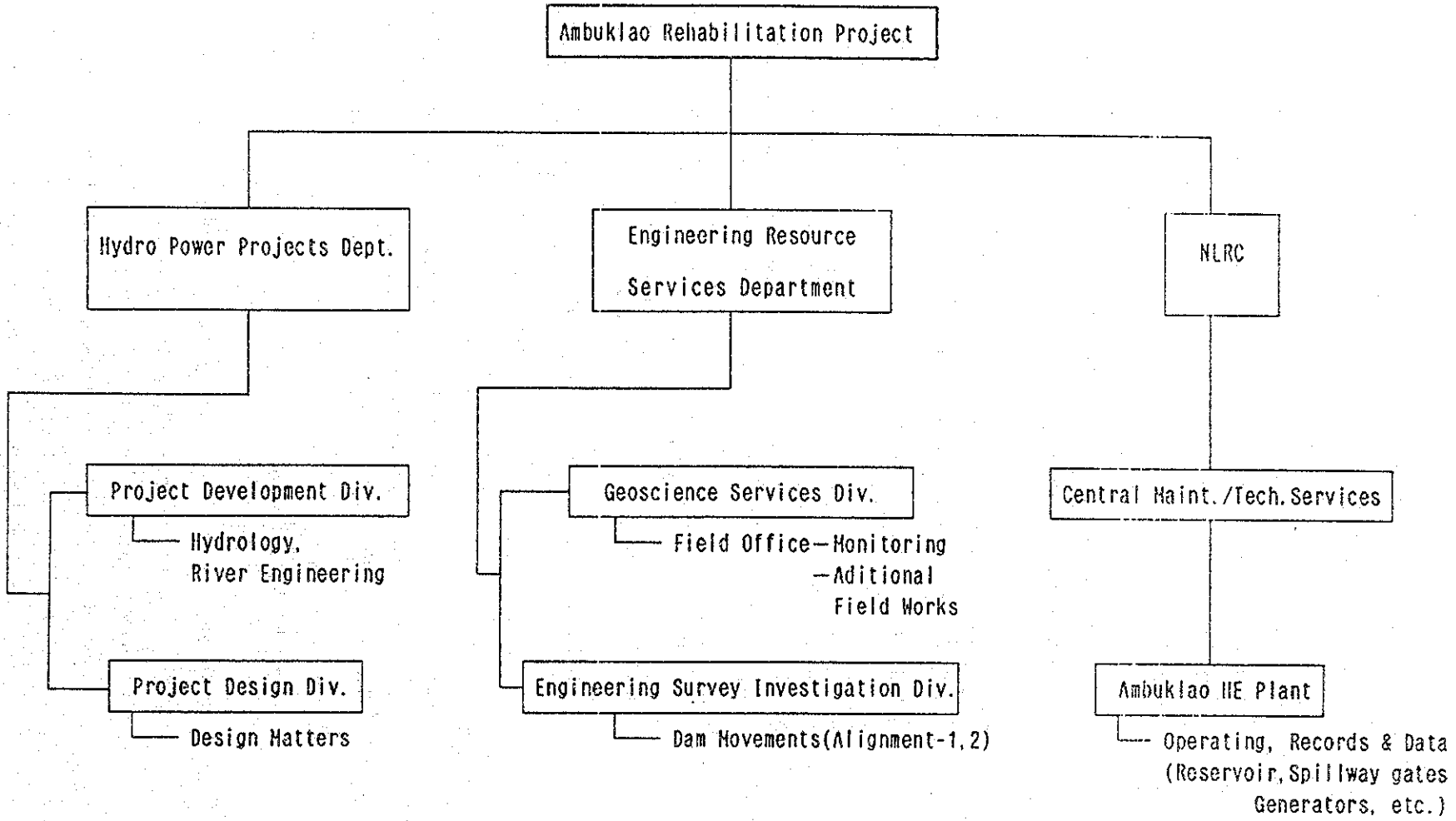
As shown in Fig.-4.1, the whole monitoring system will have to be the concern of the various divisions in the Engineering Resources and Services Department. The specific assignments are as follows:

Group	Main Functions
Engineering Surveys and Investigation Division	Dam Deformation measurements applying geodetic methods.
Geoscience Services Div.	Maintain/operate geologic stations and evaluate data from inclinometer installations and water levels at piezometer stations.
Hydrology Services Group	Maintain/operate hydrologic stations, evaluate data from reservoir inflow, rainfall seepage.

The Ambuklao Hydroelectric Powerstation will have a close cooperation with the NAPOCOR Head Office in collecting the data on the actual conditions of the operation of the reservoir, spillway gates, generators, etc., and with regard to all the monitoring works at the site.

The above monitoring system is also considered to be appropriate for use as a permanent system. Therefore, it should be adopted for such use in the future. However, all monitoring data collected and adjusted by the Technical Services Department should be transferred to the Hydro Power Project Department as required for further evaluation by the civil engineers of the department.

Fig – 4.1 Organization Chart for Ambuklao Rehabilitation Project



5. Additional Field Works and Geological Conditions

5. Additional Field Works and Geological Conditions

5.1. Surveys for Stability Analysis of the Dam

Surveys, as outlined below, were carried out by NAPOCOR as required not only for the stability analysis of the dam but also for the formulation of the rehabilitation program. These survey data were made available as required to the JICA Study Team.

5.1.1. Ground Survey

(1)	Ground survey of the upstream face of the dam	S = 1/500
(2)	Ground survey of the left abutment of the spillway	S = 1/500
(3)	Ground survey of the area immediately downstream of the dam	S = 1/500
(4)	Ground survey at the proposed site of the debris barrier (Pesac River)	S = 1/500
(5)	Ground survey of the area from the tailrace to the downstream river channel	S = 1/1000

5.1.2. Vertical Cross-sectional Survey

(1)	Vertical cross-sectional survey of the upstream face of the dam	S = 1/200
(2)	Cross-sectional survey of the Bokod River flowing into the reservoir	S = 1/200

(3) Cross-sectional survey of the proposed site of the debris barrier (Pesac River) S = 1/200

(4) Vertical cross-sectional survey of the area from the tailrace to the downstream river channel S = 1/200

5.2. Installation of Dam Monitoring Facilities

As deformation measurement facility for the dam, Alignment 1 and Alignment 2 were set up on the dam crest. For the above, the fixed control points SP-14J and SP-1J, and the target points SP-25J and SP-3J, were newly set up at both banks, respectively. Further, the existing movable targets DA-3 to 20 and DA-85 on the dam crest were all inspected and put in proper order (See Figs.-5.1 and 5.2).

5.3. Drilling, Trenching and Pitting Works, and Testing of Dam Embankment Materials

Eleven holes, DWH-1 to 11, were drilled for groundwater level observation at the left abutment of the spillway (See Fig.-5.3).

In addition, for the observation of sedimentation in the reservoir, two boreholes were drilled, one about 50 m upstream of the intake tower, and the other at the confluence with the Bantey River. One additional drilling was also carried out by NAPOCOR at the point about 100 m upstream of the intake tower.

Drilling of 13 boreholes were completed as of the end of December 1987, leaving borehole No. DWH-11 still to be completed. The trenching and pitting works and the material tests for the dam embankment were not considered to be necessary for this study and, therefore, were not carried out.

5.4. Installation of Seepage Measurement Station

The seepage measurement station with an automatic recording device was newly installed at the edge of the downstream face of the dam (See Fig.-5.4 and 5.6).

The underground powerhouse of the Ambuklao Dam Project and its various tunnels are located just beneath the dam. Therefore, these underground openings form a certain type of a large underground drainage system which allows most of the water seeping through the dam and the bedrock to drain out into these openings. The water level measurement period using the leakage measurement device installed at the edge of the downstream face of the dam is considered to be very short and is limited to the rainy season only.

There has been only one experience in rainy season since the installation of the seepage measuring station. Then, the data should be collected on the measurement over at least three consecutive years, since an unusually high seepage through the dam should take place at the time of heavy rainfalls during the rainy season, it is sure that the station will prove effective as measuring function. The last rainy season is believed to be of the one in the drought year.

Therefore, it is recommended to continue monitoring works for the next three years (in case of draught year it is extended further.), and as a result, unless any specific condition would happen, it is recommended to relocate the leakage measurement station to either of other sites as proposed below.

1) adequate site around the Control House located farther downstream.

2) other filldam site where particularly requires seepage measurements.

As a measure supplementing the above, the triangular and square weirs for leakage measurement (SW-1, SW-2A, SW-3, SW-7A, SW-12) were installed at 13 locations inside the tunnels all around the underground powerhouse (See Fig.-5.5).

5.5. Schedule of Additional Field Works

The implementation program and the actual progress of the various field works mentioned in the previous chapters are summarized in the attached Table-5.2.

5.6. Geological Conditions of Ambuklao Area

5.6.1. Geological Background

The Agno River flows from north to south controlled by one of branch fault zone of the Philippine Fault. The fault zone is so wide as to swallow the damsite and reservoir area.

The principal rocks of Agno River in the vicinity of dam site is a series of metamorphic rocks and diorite.

The metamorphic rocks are originated from andesitic and/or basaltic lava, extruded into sea water in the Cretaceous or Paleogene age, and from sedimentary rocks such as tuff, tuff-breccia and clayslate. These rocks were later strongly altered mechanically mainly by the mountain-building movement which produced numerous fractures and joints in them.

Diorite intruded into the metamorphic rocks in Neogen (Miocene) age, giving some heat alteration to the latter's rocks.