THE REPUBLIC OF THE PHILIPPINES

RE-STUDY
OF
THE SAN ROQUE MULTI-PURPOSE PROJECT

FINAL REPORT
(MAIN REPORT)

SEPTEMBER 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

It is with great pleasure that I present this report on the Re-study of the San Roque Multi-purpose Project to the Government of the Republic of the Philippines.

This report embodies the result of a field survey which was carried out in San Roque Area from November 1983 to November 1984 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the Republic of the Philippines to the Government of Japan.

The survey team, headed by Mr. Takao TERAE, had a series of discussion on the Project with the officials concerned of the Government of the Philippines and conducted a wide scope of field surveys and data analyses. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will be useful for the Project and contribute to 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 Japanese team.

Tokyo, September 1985

Keisuke Arita

Keisuke ARITA
President
Japan International Cooperation Agency

SUMMARY

SUMMARY

The San Roque Multi-purpose Project is being promoted for the purposes of

- o power generation
- o irrigation
- o water quality improvement
- o flood control

In 1979 the Italian Electroconsult (ELC) submitted a Feasibility Report on the project.

In July 1983 a preparatory survey team was dispached by the Japan International Cooperation Agency upon the request by the Philippine Government for technical cooperation, and the possibility of technical survey to be made by Japan was investigated. Accordingly, it was pointed out that the following three items of the ELC's Feasibility Report should be reviewed and additionally studied:

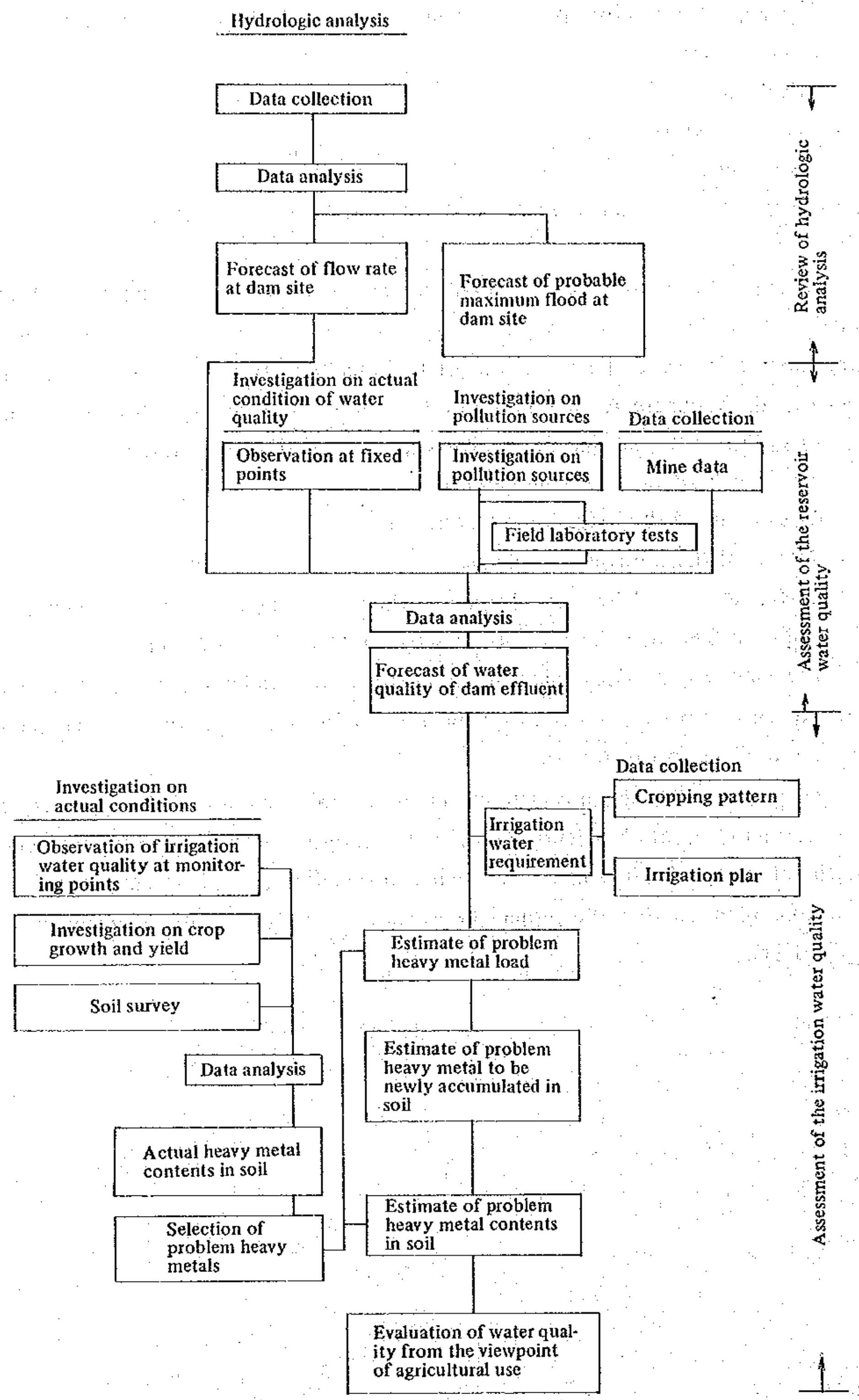
- o Assessment of the reservoir water quality
- o Assessment of the irrigation water quality
- o Review of the hydrologic analysis

In October of 1983, the Implementing Arrangement for the re-study was agreed upon between agencies of both parties and the study was started.

The field investigation was conducted for one year from the end of November 1983 to the end of November 1984, and the results of analyses of the collected data were summarized in this report.

JICA Re-study(the study hereinafter) was conducted in the following sequence.

Further it should be mentioned that the study is confined to the review and the additional study of a part of the ELC's Feasibility Report and is firmly based on the conditions planned that the project be known as the San Roque Multipurpose Project by ELC.



Flow Chart of the Study

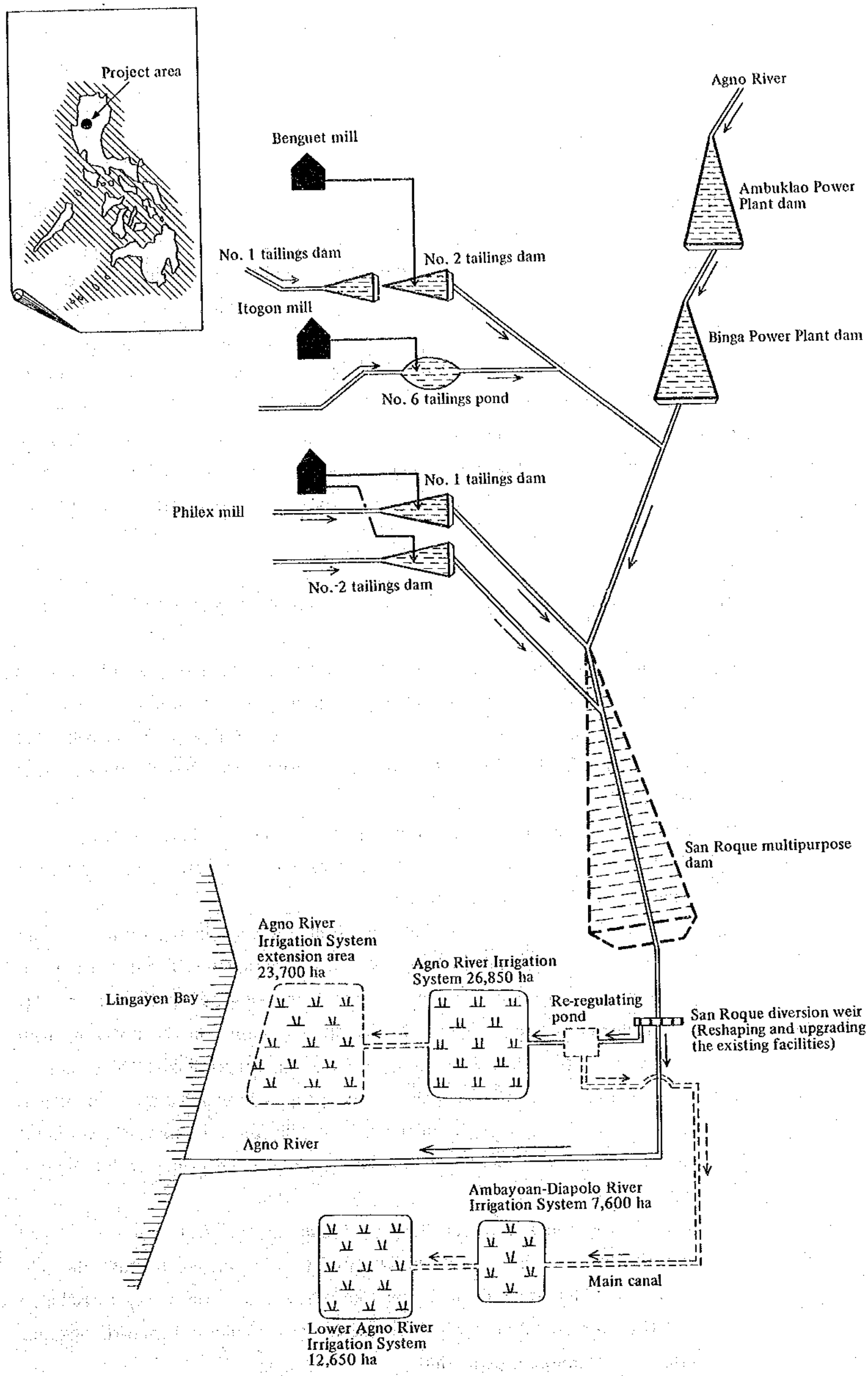


Fig. 1 Investigation area of the Agno River

5—

1. Review of the Hydrologic Study

Scope of the Study

The study is made for the purpose to confirm the appropriateness of the results of hydrologic analyses of the preceding ELC's Feasibility Study in 1979 and its additional study in 1983 in respect to two items such as the discharge and the probable maximum discharge of the Agno River at the proposed San Roque dam site. Data collected for the hydrologic analysis in the study comprise rainfall records at 17 raingauge stations and discharge records at 14 gauging stations in and around the San Roque catchment basin, operation records of power generation and spillway of the existing Ambuklao and Binga dams, and other related records. Effective coverage periods and reliability of all of the collected data are examined and then used for the hydrologic analysis.

Mean discharge at the proposed San Roque dam site is estimated in the following manner:

(a) The inflow-outflow analysis for the case of Ambuklao reservoir is made on the basis of reservoir operation and power generation data. Then, correlation between the analysis results and the rainfall in the surrounding area is examined. Taking the above correlation into account, mean values of inflow and outflow are estimated.

(b) In the same manner, the inflow-outflow analysis is made for the case of Binga reservoir and the results are also examined in respect to correlation with the rainfall of surrounding area.

(c) There exist insufficient rainfall and discharge data in the remnant basin between the Binga and proposed San Roque dam sites. The outflow from the remnant basin is, therefore, estimated putting use of specific run-off and run-off coefficient which are calculated based on the outflow from the upper basin of Binga dam and the mean area rainfall over the basin.

(d) The long-term mean discharge at the proposed San Roque dam site is obtained as the sum of the outflow from the Binga dam and the remnant flow from the catchment area between the Binga and proposed San Roque dam sites.

(e) The observation records at the San Roque gauging station are examined and the average value of discharge for 21 years, judged to have the reliability, is calculated. Comparison between the long-term mean discharge and the average value of observed discharge is made and then the average effective discharge is estimated.

The probable maximum flood discharge is estimated in the following manner:

(a) The probable maximum precipitation at Baguio is calculated and this point rainfall is converted into area rainfall in the San Roque catchment basin.

(b) The run-off coefficient in the Agno River basin during a storm is estimated and then the probable maximum precipitation in terms of effective rainfall over the San Roque catchment basin is evaluated.

(c) The peak discharge of probable maximum flood at the proposed San Roque dam site is analyzed in accordance with the probable maximum precipitation in terms of effective rainfall over the San Roque catchment basin.

Results of the Study

The long-term mean discharge at the proposed San Roque dam site is estimated to be 84.5 m^3/s. The average value of observed discharge records at the San Roque gauging station for 21 years, judged to have the reliability, is calculated to be 84.1 m^3/s.

The probable maximum precipitation in terms of effective rainfall over the San Roque catchment basin is evaluated to be 1,057 mm/day. Through the run-off analysis, the peak discharge of probable maximum flood at the proposed San Roque dam site is estimated to be 15,130 m^3/s.

Discussion

The long term mean discharge of 84.5 m^3/s estimated is similar to the measured discharge of 84.1 m^3/s at the San Roque gauging station as a mean of 21 years' data which are selected as dependable data. It is induced by this fact that the flow pattern of each hydrologic year as well as of the seasonal pattern are well incorporated in the estimation for the reason that the analysis and estimation are made based on the outflow from the upstream dams.

The peak discharge of probable maximum flood which is estimated to be 15,130 m^3/s through the study has still some allowance to the spillway maximum capacity of 15,600 m^3/s designed in ELC's Feasibility Study.

Conclusion

Difference between the mean discharge of 94.2 m^3/s shown in ELC's Feasibility Report and the long-term mean discharge of 84.5 m^3/s estimated under the study is approximately 10 per cent. Effective portion of the mean value of the measured data is approximately 5 per cent smaller than that of ELC's feasibility and additional studies. Such a difference in the mean discharge does not affect the scale of reservoir.

The spillway capacity designed in ELC's Feasibility Study has still some allowance even for the peak discharge of probable maximum flood estimated by the study.

2. Assessment of the Reservoir Water Quality

Objective and Scope of the study

The objective of the assessment of the reservoir water quality is to evaluate the water quality of the effluent from the proposed San Roque dam by forecasting the seasonal and long-term changes of the quality of the water stored in the reservoir on the assumption, conforming to ELC's Feasibility Study that all the mine tailings discharged within the catchment area of the dam are impounded in the reservoir[Note 1].

In order to achieve this objective, the following surveys were conducted:

- o Fixed-point observation – to determine the actual condition of the water quality
- o Pollution source investigation – to determine the actual condition of the pollution sources

and various tests and chemical analyses were carried out on the collected samples. Based on the data obtained by these surveys monthly estimated values for 30 years in the future were calculated.

Conditions for Estimation

The rate of flow and the load of pollutants for estimation were set as follows:

- o For the rate of inflow the value reviewed by the hydrologic analysis was used. (The calculation was made in 2 cases where the average flow rates had been repeated over a 30 year period and the measured values for 21 years were applied.)
- o The rate of outflow is calculated in accordance with the optimum dam utilization plan of ELC's Feasibility Study.
- o The operating scale[Note 2] and style of the mines will be maintained without modification during the estimation period and the load of pollutants discharged from the mines is supposed to remain constant.

The calculating method is based on the following assumption.

- o The concentrations of the dissolved matters in the stored water are homogeneous within the reservoir and those in the effluent from the dam are the same.
- o It is regarded that suspended solids which are not settled during the residence time while the influent reaches the intake for power generation are discharged in a suspended state.

Note 1): It is prohibited by the Philippine laws and regulations in force (Presidential Decree No. 463, otherwise known as the Mineral Resources Development Decree of 1974 and Consolidated Mine Administrative Order, implementing regulations of P. D. No. 463) to dispose of mine waste into natural drainage systems. It has not been decided as yet in the Philippines how to settle this legal matter.

Note 2): Including Philex' expansion plan of 5000 t/day.

9–

Estimated Results

The estimated values are shown in the following tables. The measured values of water at the proposed dam site and quality criteria of agricultural water are also listed for reference.

The estimation was made on Cu, Zn and As. It was judged that other noxious metals such as Pb, Cd and Hg did not require investigation because their contents in both solid samples and water samples were very low. Also, cyanogen was not investigated, although it was detected in the water at the proposed dam site, because the concentration was low and it was not an accumulative pollutant.

Concentration of Dissolved Matters and Suspended Solids

			Cu (mg/ℓ)	Zn (mg/ℓ)	As (mg/ℓ)	SS (mg/ℓ)
Estimated values	Fluctuation range[1]		0.002–0.009	0.008–0.055	0.0026–0.0061	290–3960[3]
	Average value[2]		0.004	0.019	0.0034	720
	Seasonal fluctuation	High	Jul.–Aug.	Apr.–May	Apr.–May	Apr.–May
		Low	Jan.–Feb.	Sept.–Oct.	Sept.–Oct.	Sept.–Oct.
	Long-term change		Not remarkable	Not remarkable	Not remarkable	Not remarkable
Measured values	Fluctuation range		0.010–0.036	0.003–0.014	0.0018–0.0049	410–2900
	Average value		0.015	0.004	0.0026	1600
Quality criteria of agricultural water		Philippines	0.2	2	0.1	–
		Japan	0.02	0.5	0.05	100

		T-Cu (ppm)	S-Cu (ppm)	T-Zn (ppm)	S-Zn (ppm)	T-As (ppm)	S-As (ppm)
Estimated values	Fluctuation range[1]	400–621	97–196	162–196	43–74	9–11	nil
	Average value[2]	520	140	180	58	10	nil

Note 1: Fluctuation range, when the measured values for the 21 years was taken as the rate of inflow is shown.
Note 2: Annual average for 15th year after the start of impounding when the rate of inflow is calculated using the average flow rate, is shown.
Note 3: Excluding abnormal values, which are caused by abnormal shortage of water or big flood.

Discussion

(1) Behavior of Cu, Zn and As

The Cu, Zn and As discharged from the pollution source are considered to be in the following states:

1) Dissolved in the state of ions
2) Suspended as hydroxides
3) Contained in suspended solids

It is considered that these elements change their states and load when they flow into and out of the San Roque Dam.

			Discharge from pollution source			Run-down as dam effluent		
			Cu (g/s)	Zn (g/s)	As (g/s)	Cu (g/s)	Zn (g/s)	As (g/s)
1 Dissolved metals		Mine source	2.0	1.4	0.1	0.4	1.6	0.3
		Natural	0.2	0.5	0.2			
2 Hydroxide		Note 1)	–	–	–	1.9	0.4	–
1 + 2			2.2	1.9	0.3	2.3	2.0	0.3
In suspended solids	Soluble	Mine source	25.9	17.2	–	6.8	3.2	–
		Natural	–	–	–	–	–	–
	Insoluble	Mine source	203.4	21.4	3.2	22.1	6.3	0.6
		Natural	8.2	13.3	0.6	0.6	1.0	–
	Subtotal		237.5	51.9	3.8	29.5	10.5	0.6
Total			239.7	53.8	4.1	31.8	12.5	0.9

Note 1: Those which are in the state of hydroxide when discharged from the mine are considered as soluble in the suspended solids. Only the hydroxides which were precipitated during the run-down are shown in this column. Finally they should be added to the soluble in the suspended solids.

As shown in the table, most of the dissolved Cu and a part of the dissolved Zn are changed into hydroxides when they are flowing into the dam[Note)] Since the hydroxides are discharged from the dam in a suspended state, the Cu and Zn loads which are in an ionic state or hydroxides in the effluent are not decreased.

The load contained in the suspended solids is reduced in proportion to the load contained in the sediments trapped in the reservoir and the trap efficiency is 88% for Cu, 80% for Zn and 84% for As.

Generally, when the stored water exhibits acidic properties, the metals contained in the sediments in the reservoir are eluted to some extent. Therefore, the amount of dissolved metals in the effluent increases. However, since the natural water in this area shows a weak alkalinity of about 8 in pH value, the amount of metals eluted from the sediments is very little. It means that most of the metals contained in the sediments are captured in the dam and are not discharged, although they may be soluble in an acidic state.

All the above is shown as a schematic diagram in Fig. 2. (The amount of metals contained in the suspended solids is omitted.)

Note: Most of the dissolved Cu discharged from the mine which uses the cyanidation method for refining is dissolved as cyano-copper complex ions which are unstable and are gradually decomposed.

(2) Changes of Concentrations of Dissolved Metals and Suspended Solids

Seasonal Fluctuation: As shown in Fig. 3, the seasonal fluctuation of the Cu concentration shows a pattern of high values in July and August during first half of the rainy season and low values in January and February during the first half of the dry season. The seasonal fluctuation of Cu concentration is affected by both the amount of dissolved Cu in the inflow and the dilution rate in the reservoir.

The seasonal fluctuation of concentration of Zn, As and suspended solids shows a pattern of high values in April and May during the low water period and low values in September and October during the high water period. This is affected by the dilution rate in the reservoir.

Long-term Change: Since the elution of Cu, Zn and As from the mill tailings accumulated in the reservoir is low, the concentration increases only slightly even in the latter periods when the accumulation of the mill tailings increases. That is, the long-term change is not very remarkable.

(3) Contents of Metals in Suspended Solids

Since the Cu content in the natural sands is small, the Cu content in the total suspended solids decreases in the rainy season when the suspended solids derived from the natural sands is added to the one from the mill tailings, i.e. the Cu content is divided into 2 groups:

Dry season: Total Cu 600 ppm ±, Soluble Cu 170 ppm ±

Rainy season: Total Cu 460 ppm ±, Soluble Cu 120 ppm ±

It is also the same with Zn and As.

Dry season: Total Zn 190 ppm ±, Soluble Zn 70 ppm ±, Total As 11 ppm ±

Rainy season: Total Zn 170 ppm ±, Soluble Zn 50 ppm ±, Total As 10 ppm ±

(4) Comparison between Estimated and Measured Concentrations

If the estimated concentration values of the dissolved matters are compared with the measured values of the dissolved matter in water at the proposed dam site,

Cu estimated values are lower than the measured values

Zn estimated values are higher than the measured values

As estimated values are almost the same with the measured values

The above forecast is explained by the following process.

Cu – While the dissolved Cu resides in the reservoir, it is changed into copper hydroxide, and therefore the dissolved Cu decreases.

Zn – While the suspended and flowed-down zinc hydroxide[Note)] resides in the reservoir, it dissolves again and becomes dissolved Zn.

As – It remains dissolved without changing its state.

Note: It is considered that most of it is now captured in the tailings dam.

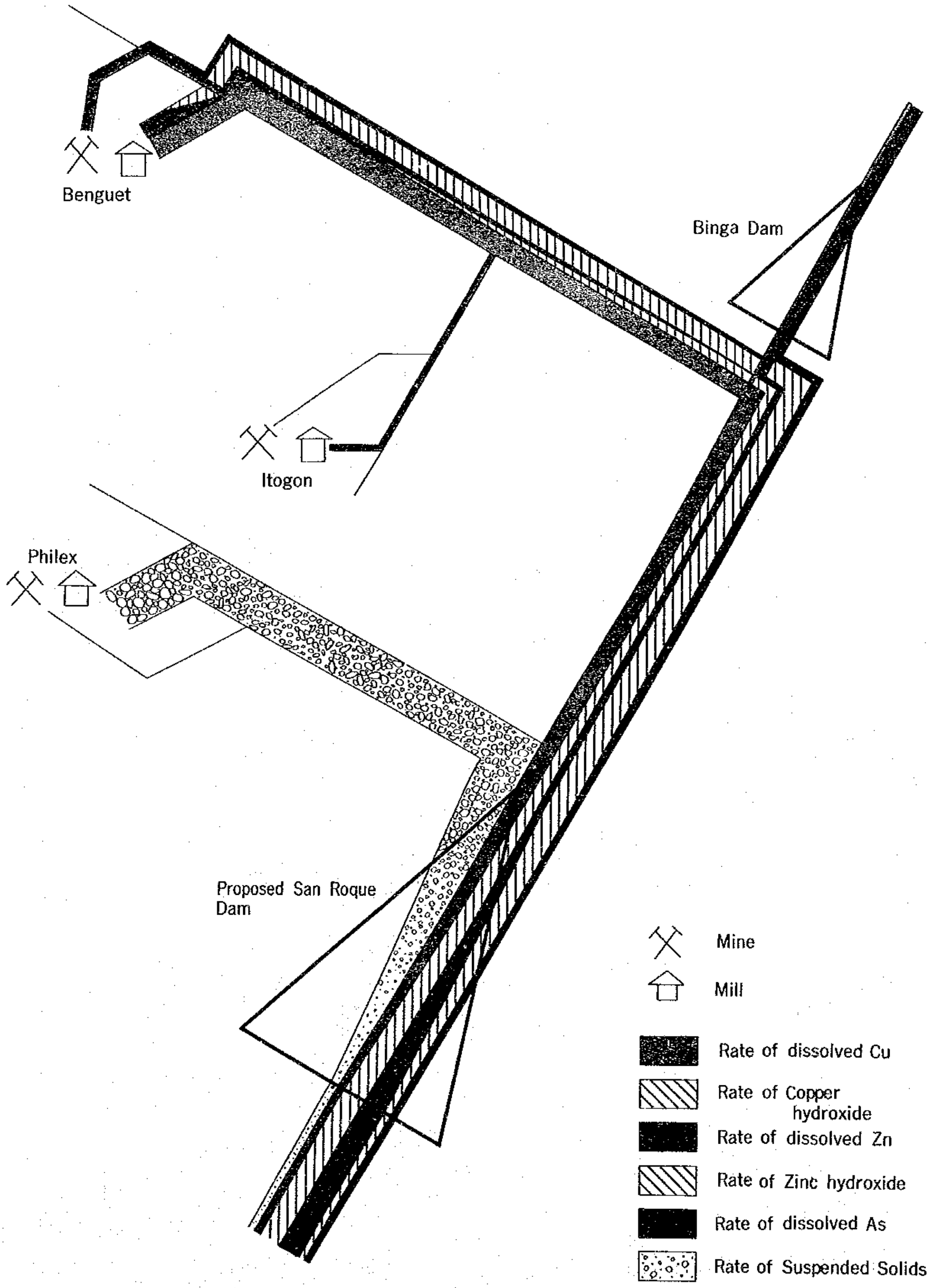


Fig. 2 Behavior of Cu, Zn, As, SS

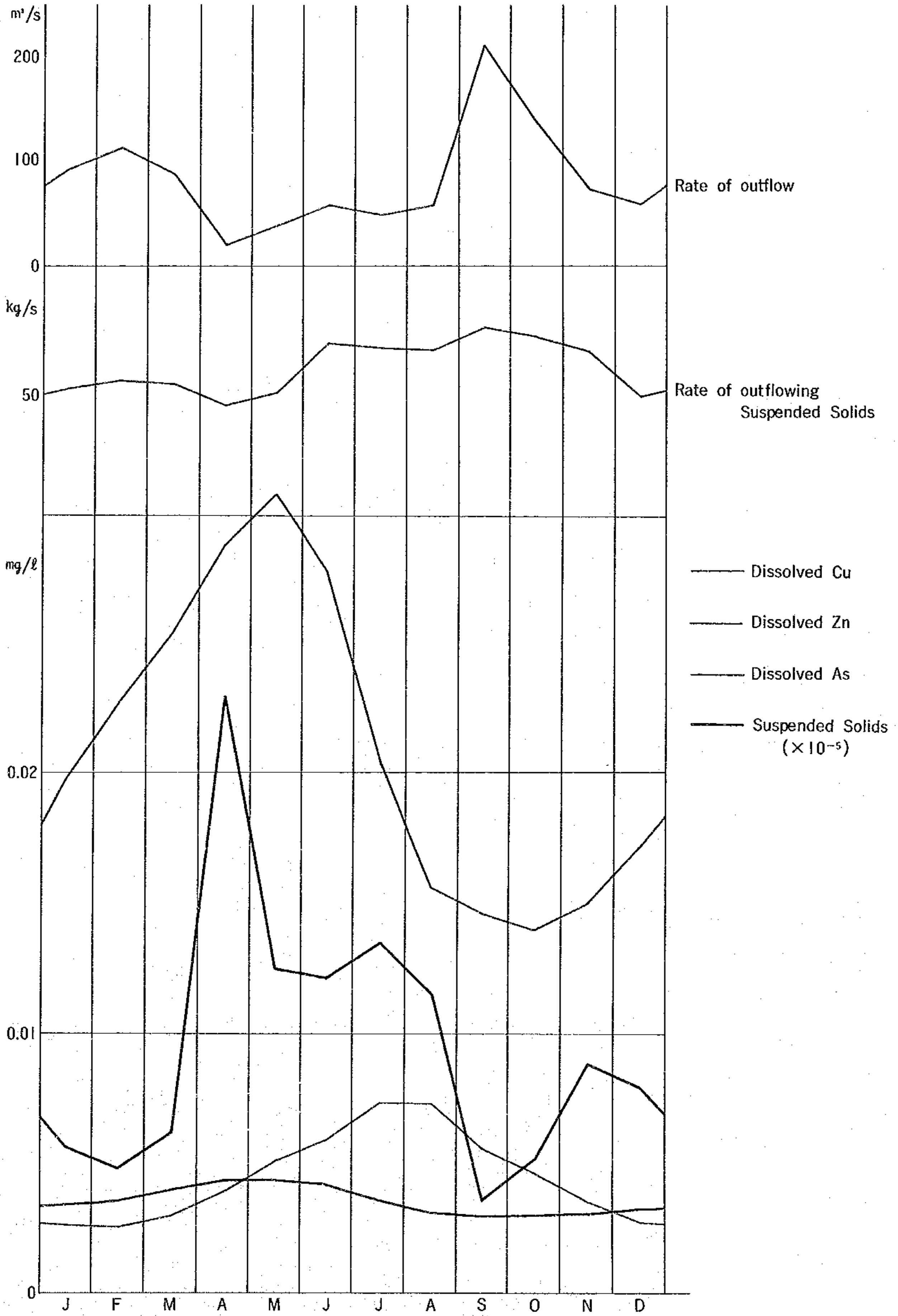


Fig3. Seasonal Fluctuation of Concentration of Cu, Zn. As and Suspended Solids

The comparison of concentrations between the suspended solids estimated to be discharged and the suspended solids actually measured has no substantial meaning because the estimated suspended solids consist mainly of the particles of less than 5 μ in size and the ones actually measured mostly of more than 5 μ. Attention should be paid to the difference in behavior caused by the difference in the particle size during the run-down (although the present suspended solids which are settled mainly in the irrigation canal and near the water inlet of the paddy, the estimated suspended solids will be delivered to the outlet of the paddy.

(5) Fluctuation Factors in Estimated Concentration

As already mentioned, the estimated concentrations of dissolved matters fluctuate according to the rate of inflow; in addition, they also fluctuate if there are any factors to vary the load.

As factors to increase the load of the outflowing dissolved matters, the following two conditions can be considered.

- o The rate of changing into hydroxide becomes low.
- o The rate of elution from the sediments in the reservoir becomes high.

Concerning the first, the estimation used the lowest value in the possible range for the rate of changing into hydroxide was done.

By such calculations, the following values were obtained:

Cu : average 0.019 mg/l, maximum value 0.031 mg/l

Zn : average 0.020 mg/l, maximum value 0.055 mg/l

In the case of Zn, the values change only slightly, but in the case of Cu, the values change greatly. The resulting Cu value of 0.031 mg/l is the highest value conceivable in the data presently made available.

Concerning the second factor, the amount of metals to be eluted from the sediments in the reservoir is so small that even if the elution rate now adopted is multiplied 10 times, the estimated values will hardly change. Therefore, it is considered that the estimated values will not be changed very much by this factor as long as the stored water maintains a weak alkalinity.

As for the factors to greatly increase the amount of the outflowing suspended solids, the following two factors can be considered.

- o The time for the suspended solids to reside in the reservoir becomes short.
- o In the grain size distribution of the suspended solids the fine particles increase.

The first factor may occur when the inflowing turbid water reaches the intake faster as a stratified flow, but at the moment we have no data to determine whether such a phenomenon occurs or not.

The second factor may occur when the milling process is changed at the mine. In case that the mine change the operating style, however, there would be many other factors to be considered, and therefore, it was decided that this point would not be taken into consideration.

Conclusion

As a result of the assessment of the reservoir water quality, it was found, that the concentrations of Cu, Zn and As dissolved in the effluent are all low, far lower than the water quality criteria for agricultural water (Class D) which is provided in "the Rules and Regulations of the National Pollution Control Commission (1978)".

It is also revealed that the suspended solids in the effluent have such characteristics as:

- o the concentration is high throughout the year
- o the particle size is small
- o they contain soluble Cu of more than 20 times dissolved Cu in water.

The above results suggest that some effect on the agriculture when the soluble Cu in the suspended solids and dissolved Cu are accumulated in the paddy soil should be investigated, such investigation was conducted by the irrigation water sector.

3. Assessment of the Irrigation Water Quality

Objective and Outline of the Study

The future quality of water to be released from the proposed San Roque dam is projected under the condition that all of mine tailings are directly discharged to tributaries of the Agno River without any treatment and impounded in the reservoir of the proposed San Roque dam as premised in the ELC's Feasibility Study. The main objective of the Study in the irrigation sector is to evaluate the projected water quality from the viewpoint of agricultural use.

Aiming at data collection and sampling, field observation works were continuously performed in areas commanded by the two existing irrigation systems for one year up to November 1984. The observation works were carried out to examine the influences of physical, chemical and mineral properties of mine tailings on (1) irrigation water, (2) paddy soils and (3) rice plant growth and its yield. The aforesaid areas comprise the Agno River Irrigation System (ARIS) diverting polluted river water for irrigation and the Ambayoan-Diapolo Rivers Irrigation System (ADRIS) with clean irrigation water sources.

On the basis of field observation records and results of laboratory tests, problem components are specified among heavy metals contained in mine tailings. Then, the annual inflow of problem heavy metals into the proposed San Roque irrigation development area is estimated as pollutant load, based on the irrigation diversion requirement given in the ELC's Feasibility Report and the quality of irrigation water projected in the Study. Next, accumulation of problem heavy metals into paddy soils is estimated taking into account the present level of problem heavy metal contents of soils and the estimated pollutant load in the proposed San Roque irrigation development area. From this, the projected quality of released water from the proposed San Roque dam is evaluated when the released water is used for future irrigation purposes.

Results of the Study

The sediments of Agno River is derived from mine tailings, which are reused as embankment materials of mine tailing dams, to large extent especially during the dry season. These sediments flow into ARIS area when irrigation water is diverted from the Agno River. As a result, ARIS has been suffering from reduction of irrigation service areas and losses in irrigation fee collection due to silting of canals as well as increase in operation and maintenance costs caused by desilitation of canals. Further, farmers benefited by ARIS has been forced to reduce net planted areas through introduction of settling basin at the inlet portion of their paddy fields to control sediments. The results of laboratory tests on water samples indicate that all of water soluble heavy metal contents have a level lower than limits allowed over which normal growth of rice plant is adversely affected. On the other hand, it is clarified through the results of soil analysis that sediments of the Agno River have a high level of copper contents. And also copper has accumulated with sediments in soils of the said settling basins for the last 25 years. The copper contents of soils in each settling basin correlate the duration of irrigation water supply by ARIS and vary from 1 to 350 ppm as a soluble copper which can be easily absorbed by rice plant. Usually, these sediments are controlled by a settling basin to large extent so that soluble copper contents of surface soils of main paddy fields reduce to around 30 ppm.

The results of crop survey show that paddy yield has good correlation with amount of fertilizers applied by farmers. It is also clarified that rice plants in ARIS excessively absorb heavy metals to some extent through the roots, and physical condition of surface soils become worse when sediments overflow from resettling basins to main paddy fields. In such case differences in growth of rice plants within the same paddy fields are distinctly observed and some accumulation of copper into rice plant roots is perceptible. The cadmium contents of brown rice sampled in ARIS are 0.02 ppm on an average and exceptional maximum value is 0.04 ppm.

Discussions

Throughout the field observation works and laboratory tests, it is pointed out that the main problem in ARIS is the inflow of sediments containing copper to some extent so far as irrigation water is diverted from the Agno River having the present level of water quality. As these sediments are coarse in particle size, however, most of sediments can be controlled by intruding river water into a settling basin. Hence inflow of sediments to paddy fields can be declined resulting in reduction of copper to be accumulated in paddy soils under the present situation.

The projected quality of released water from the proposed San Roque dam suggests that the future irrigation water will not contain coarse sediments like the present ones and, on the contrary, will become rich in very fine suspended solid contents. It is considered that such a very fine suspended solid is hardly settled even through the water is at rest and also shows the same behavior of water. Further, the projection of water quality indicates the existence of copper in this very fine suspended solid to some extent.

In due consideration of the findings throughout the field observation and laboratory works as well as the projected quality of released water from the proposed San Roque dam, copper is selected for the further evaluation study. By referring to the proposed cropping patterns and irrigation plan mentioned in ELC's Feasibility Study, the future irrigation diversion requirement is calculated. Then, by using the projected water soluble copper and suspended solid contents as well as soluble copper contents of suspended solid, the annual inflow of copper at the intake site is obtained as pollutant load. Next, irrigation efficiency is taken into consideration. Hence, the accumulated amount of copper in the paddy field of 1 ha is estimated. The proposed San Roque irrigation development area totaling 70,800 ha comprises four systems. For each, a different cropping pattern is proposed resulting in variation of irrigation diversion requirement. The results of estimate of accumulated copper, therefore, vary from 1,150 to 1,350 g/ha as soluble copper. In case that the future quality of released water from the proposed San Roque dam is projected in the worst manner under the same given condition, the soluble copper to be accumulated will increase to a level between 1,650 and 1,950 g/ha.

The very fine suspended solid will spread the whole of paddy fields after flowing together with irrigation water from farm ditchs into paddy fields even though farmers will retain a settling plot. Compared with water soluble copper contents, the copper contained in the very fine suspended solid holds a large share. Except for the copper contained in outflow to drainage canals, the rest will remain into paddy soils. If all of the remaining copper is accumulated in surface soils neglecting absorption by rice plant and loss by deep percolation, this accumulated copper will be mixed with surface soils by tillage in every crop season. In case of tillage depth of 15 cm, hence, soluble copper concentration of surface soils will increase by around 0.8 ppm every year.

In the cropping patterns proposed in the ELC's Feasibility Study, the main patterns recommended are double cropping of rice and also crop diversification under which tobacco, cotton, corn and vegetables are incorporated as the dry season crop. According to the preceding observations in Japan, reduction of crop yield influenced by copper contained in soils will occur when the soluble copper concentration exceeds a level of 125 ppm. Following this, the approximate time duration required for reaching to the above limits allowed is estimated to be 120 years for ARIS and 160 years for other three irrigation systems. If estimation is done taking into account the projection of water quality in the worst manner, it will take about 75 years until the soluble copper concentration of soils attains to 125 ppm.

Actually, a part of soluble copper in surface soils reachs subsurface soils by percolation of water and also rice straws absorbing copper accumulated in surface soils are taken out from the paddy field. The copper contents of soils will, therefore, become lower than the estimated level of accumulation and the time duration aforementioned will also become longer.

Conclusion

Based on the ELC's Feasibility Study, it is projected that the released water from the proposed San Roque dam will have a large amount of very fine suspended solid containing copper to some extent if all of mine tailings are impounded in the reservoir of the proposed dam. This water having such characteristics in quality is provided to the proposed San Roque irrigation development area in the future. As a result, copper will accumulate in paddy soils through the spread of very fine suspended solid to the whole beneficial areas. After 120 to 160 years, thus, copper concentration of soils will reach the limits allowed over which copper determines the cause of crop yield reduction. This estimated period exceeds over the project evaluation period of 50 years which is set up in the ELC's Feasibility Report.

CONTENTS

CONTENTS

Page

PREFACE
SUMMARY
I. INTRODUCTION 1
1. STRUCTURE OF THE REPORT 1
2. BACKGROUND OF THE PROJECT 1
3. OBJECTIVES OF THE STUDY 2
4. SCOPE OF THE STUDY 2
5. SCHEDULE OF THE STUDY 3
6. THE JICA STUDY TEAM AND THE JICA ADVISORY COMMITTEE 3
7. THE PHILIPPINE COUNTERPARTS AND THE PHILIPPINE JOINT TECHNICAL COMMITTEE 5

II. FEATURES OF THE STUDIED AREA
1. LOCATION AND ACCESS 6
2. TOPOGRAPHY AND GEOLOGY 8
3. METEOROLOGY AND HYDROLOGY 10
4. EXISTING DAMS AND MINES 12
4.1 Existing Hydroelectric Dams 12
4.2 Mining Activities 12

III. REVIEW OF THE HYDROLOGIC ANALYSIS
1. SCOPE OF THE STUDY 15
1.1 Objectives of the Study 15
1.2 Methodology of the Study 15
2. AVAILABLE DATA FOR THE STUDY 16
2.1 Preceding Studies 16
2.2 Data used for the Study 16
3. DISCHARGE AT PROPOSED SAN ROQUE DAM SITE 18
3.1 Discharge at Existing Dam Sites 18
3.2 Outflow from the Basin between Ambuklao and Binga Dams ... 19
3.3 Discharge at Proposed San Roque Dam Site 19
3.4 Average Discharge at Proposed San Roque Dam Site 21
3.5 Available Discharge at Proposed San Roque Dam Site 21
4. PROBABLE MAXIMUM FLOOD AT PROPOSED SAN ROQUE DAM SITE 22
4.1 Probable Maximum Precipitation at Baguio 22
4.2 Probable Maximum Flood at Proposed San Roque Dam Site 23

5. OBSERVATIONS 24
5.1 Long-term Average Discharge 24
5.2 Evaluation of Spillway Capacity 24

IV. ASSESSMENT OF RESERVOIR WATER QUALITY
1. SCOPE OF THE STUDY 37
1.1 Purpose of the Study 37
1.2 Method of the Study 37
2. RESULTS OF THE FIELD SURVEY 41
2.1 Findings of the Fixed Points Observation 41
2.2 Findings of the Investigation of Pollution Sources 49
2.3 Results of Tests in the Field Laboratory 52
3. CALCULATION OF ESTIMATED WATER QUALITY VALUES 58
3.1 Calculating Method 58
3.2 List of Parameters (Input Data) 68
3.3 Results of the Calculation 72
4. EVALUATION OF ESTIMATED WATER QUALITY VALUES 87
4.1 Ingredients to be Investigated 87
4.2 Concentration of Dissolved Matters 87
4.3 Concentration of Suspended Solids and Metal Content in Suspended Solids 96
5. SUMMARY AND CONCLUSIONS 102

V. ASSESSMENT OF THE IRRIGATION WATER QUALITY
1. SCOPE OF THE STUDY 112
1.1 Objectives of the Study 112
1.2 Outline of the Study 112
1.3 Available References for the Study 113
2 RESULTS OF FIELD OBSERVATION WORKS 113
2.1 Present Situation of Existing Irrigation Systems 113
2.2 Irrigation Water Quality Survey 115
2.3 Soil Survey 116
2.4 Crop Survey 118
3 SELECTION OF PROBLEM HEAVY METALS 120
4. ASSESSMENT OF FUTURE QUALITY OF IRRIGATION WATER 120
4.1 Projected Water Quality 120
4.2 Methodology of Evaluation 121

4.3 Irrigation Plan 121
4.4 Accumulation of Copper in Soils..122
5. CONCLUSION 123

LIST OF FIGURES

Fig. 1 Investigation area of the Agno River
Fig. 2 Behavior of Cu, Zn, As and Suspended Solids
Fig. 3 Seasonal Fluctuation of Concentration of Cu, Zn, As and Suspended Solids
Fig. I-1 Time Schedule
Fig. II-1 Location Map of Project Area
Fig. II-2 Geologic Map of the Agno River Area
Fig. II-3 Isohyetal Map of Upper Agno River Basin
Fig. III-1 Reservoir Operation Record Available for the Study
Fig. III-2 Rating Curves on Water Level-Storage-Water Consumption
Fig. III-3 Location Map on Meteohydrological Stations
Fig. III-4 Rainfall Record Available for the Study
Fig. III-5 Discharge Record Available for the Study
Fig. III-6 Annual Correlation of San Roque Discharge with Rainfall/Discharge
Fig. III-7 Hydrograph for P.M.F.
Fig. IV-1 Location Map of Observation Points and Mines
Fig. IV-2 Location Map of the Regional Survey Points
Fig. IV-3 Seasonal Fluctuation of Cu Concentration
Fig. IV-4 Behavior of Dissolved Cu
Fig. IV-5 Seasonal Fluctuation of Zn Concentration
Fig. IV-6 Behavior of Dissolved Zn
Fig. IV-7 Seasonal Fluctuation of As Concentration
Fig. IV-8 Behavior of Dissolved As
Fig. IV-9 Seasonal Fluctuation of SS Concentration
Fig. IV-10 Behavior of Suspended Solids
Fig. IV-11 Fluctuation of Calculated Values in Run-3
Fig. V-1 Location Map of Monitoring Points for Irrigation Water Quality
Fig. V-2 Soluble Copper Contents of Surface Soils in ARIS
Fig. V-3 Horizontal Distribution of Copper Concentration of Rice Plant Leaf and Soluble Copper Contents of Paddy Soils

LIST OF TABLES

Table I-1	MEMBER LIST OF STUDY TEAM
Table I-2	MEMBER LIST OF ADVISORY COMMITTEE
Table I-3	MEMBER LIST OF COUNTERPART
Table I-4	MEMBER LIST OF JOINT TECHNICAL COMMITTEE
Table III-1	SUMMARY OF MEAN MONTHLY RAINFALL RECORD IN AND AROUND SAN ROQUE CATCHMENT BASIN
Table III-2	SUMMARY OF MEAN MONTHLY OBSERVED DISCHARGE RECORD IN AND AROUND SAN ROQUE CATCHMENT BASIN
Table III-3	ADJUSTED MONTHLY INFLOW INTO RESERVOIRS AND OUTFLOW FROM DAMS OF AMBUKLAO AND BINGA
Table III-4	ADJUSTED MONTHLY RUN-OFF FROM THE REMNANT BASIN BETWEEN AMBUKLAO AND BINGA DAMS AND AVERAGE MONTHLY DISCHARGE AT AMBAYOAN AND KALIPKIP STATIONS
Table III-5	SPECIFIC RUN-OFF AND RUN-OFF COEFFICIENTS OF CATCHMENT AREA
Table III-6	LONG TERM DISCHARGE CALCULATED
Table III-7	MONTHLY MEAN OBSERVED DISCHARGE FOR 21 YEARS AND LONG TERM MONTHLY MEAN DISCHARGE AT SAN ROQUE SITE
Table III-8	HOURLY RELATION BETWEEN RAINFALL DEPTH AND DURATION AT BAGUIO
Table III-9	HOURLY RAINFALL DEPTH AND DURATION WITHIN 24 HOURS EQUIVALENT TO EFFECTIVE PROBABLE MAXIMUM PRECIPITATION IN SAN ROQUE CATCHMENT BASIN
Table III-10	MONTHLY OUTFLOW FROM BINGA DAM
Table III-11	RELIABLE MONTHLY DISCHARGE OBSERVED AT SAN ROQUE GAUGING STATION
Table IV-1	REGIONAL SURVEY FOR pH AND EC IN THE BENGUET PROVINCE
Table IV-2	RESULTS OF CALCULATION ON DISSOLVED MATTERS OF RUN-1 & RUN-2 (1/2)
Table IV-3	RESULTS OF CALCULATION ON DISSOLVED MATTERS OF RUN-1 & RUN-2 (2/2)
Table IV-4	RESULTS OF CALCULATION ON DISSOLVED MATTERS OF RUN-3 & RUN-4 (1/2)
Table IV-5	RESULTS OF CALCULATION ON DISSOLVED MATTERS OF RUN-3 & RUN-4 (2/2)
Table IV-6	RESULTS OF CALCULATION ON DISSOLVED MATTERS OF CASE-1

Table IV-7	RESULTS OF CALCULATION ON DISSOLVED MATTERS OF CASE-2 & CASE-3
Table IV-8	RESULTS OF CALCULATION ON SUSPENDED SOLIDS OF RUN-1 (1/2)
Table IV-9	RESULTS OF CALCULATION ON SUSPENDED SOLIDS OF RUN-1 (2/2)
Table IV-10	RESULTS OF CALCULATION ON SUSPENDED SOLIDS OF RUN-3 (1/2)
Table IV-11	RESULTS OF CALCULATION ON SUSPENDED SOLIDS OF RUN-3 (2/2)
Table IV-12	RESULTS OF CALCULATION ON SUSPENDED SOLIDS OF CASE-2 & CASE-3
Table IV-13	LOAD OF POLLUTANTS DISCHARGED FROM MINES
Table V-1	SUMMARISED RESULTS OF LABORATORY TESTS ON DRY AND WET SEASON WATER SAMPLES
Table V-2	COMPARISON OF EXTRACTABLE COPPER CONTENTS IN SOILS
Table V-3	VARIATION OF SOLUBLE HEAVY METAL CONTENTS OF PADDY SOILS TAKEN AT INLET PORTION OF OR SETTLING BASIN IN PADDY FIELDS OF ARIS
Table V-4	RESULTS OF YIELD SURVEY FOR DRY SEASON CROP IN ARIS AND ADRIS
Table V-5	RESULTS OF YIELD SURVEY FOR WET SEASON CROP IN ARIS AND ADRIS
Table V-6	COPPER CONCENTRATION OF LEAF OF RICE PLANT IN ARIS AND ADRIS
Table V-7	PROPOSED CROPPING PATTERN BY SYSTEM UNDER SAN ROQUE MULTIPURPOSE PROJECT
Table V-8	AVERAGE MONTHLY IRRIGATION DIVERSION REQUIREMENT
Table V-9	AVERAGE MONTHLY ACCUMULATION OF SOLUBLE COPPER ON PADDY FIELD

I. INTRODUCTION

I. INTRODUCTION

1. STRUCTURE OF THE REPORT

Herein presented is the final report of the Re-study of the San Roque Multi-purpose Project being conducted in accordance with the Implementing Arrangement agreed upon on October 21, 1983 between the Japan International Cooperation Agency and the Philippine Authorities Concerned.

In view of the complexity and the large volume of the data obtained, there is the fear that important points will become obscure if all the data are assembled in a single volume.

Therefore, the submission of the report is in two parts; the Main Report in which the items directly related to the conclusions are expounded; and a Supporting Report in which appendices of the following titles are compiled.

Appendix "A"	Data of the Hydrologic Analysis
Appendix "B"	Data of the Fixed Points Observation
Appendix "C"	Data of the Investigation of Pollution Sources
Appendix "D"	Data of the Tests in the Field Laboratory
Appendix "E"	Outputs of the Calculation
Appendix "F"	Data of the Assessment of Irrigation Water Quality
Appendix "G"	Mining Activities in the Watershed of the Agno River
Appendix "H"	Outline of the Project Studied by the Electroconsult
Appendix "I"	Organization and Laws on the Pollution Control
Appendix "J"	Implementing Arrangement on the Project

2. BACKGROUND OF THE PROJECT

The middle courses of the Agno River had been the object of several dam construction studies over a long period of time.

The present project started in 1974, when the National Power Corporation (NPC) entrusted Electroconsult (ELC) with the study for the hydroelectric power potential of the area. The project came to be a multipurpose one in 1975, when the National Irrigation Administration (NIA) requested a modification of the scope of the study so as to include a plan for an irrigation development.

The final study result, the Feasibility Report on the San Roque Multipurpose Project which has the following objectives, was submitted in 1979.

29–

Power generation – to cope with the power demand in the near future.
Irrigation– to expand the irrigable land.
Water quality – to improve the water quality by trapping mine tailings in the reservoir.
Flood control – to regulate the flood peak discharge.

In response to the request for the technical cooperation in respect to the project by the Government of the Republic of the Philippines (GOP), the Preparatory servey team was sent by the Japan International Cooperation Agency (JICA) in July, 1983; and a GOP panel and a JICA team discussed the matter of a review of the Feasibility Study. Consequently, the Implementing Arrangement was agreed upon between the Agencies Concerned of both parties in October, 1983.

3. OBJECTIVES OF THE STUDY

The following objectives were confirmed in the Implementing Arrangement as the items to be re-studied.

Assessment of the reservoir water quality
Assessment of the irrigation water quality
Review of the hydrologic analysis

4. SCOPE OF THE STUDY

The JICA Re-study (the study hereinafter) was divided into three separate sectors in accordance with the objectives. The scope of each sector's study is as follows.

(1) Reservoir water quality

a. Conduct studies to forecast the short and long term quality of water stored in the reservoir on the assumption that all of the mine tailings discharged in the watershed of the proposed San Roque dam are trapped in its reservoir. [Note)]

(2) Irrigation water quality

a. Assess the effect of the physical, chemical and mineral properties of the mine tailings on the irrigation water, soils and plants in the project area.
b. Monitor the behavior of crop production in relation to the use of irrigation water from the Agno River.
c. Assess the future quality of the irrigation water if mine tailings are stored in the proposed San Roque reservoir.

Note): It is prohibited by the Philippine laws and regulations in force (Presidential Decree No. 463, otherwise known as the Mineral Resources Development Decree of 1974 and Consolidated Mine Administrative Order, implementing regulations of P.D. No. 463) to dispose of mine waste into natural drainage systems. It has not been decided as yet in the Philippines how to settle this legal matter.

(3) Hydrologic analysis

a. Review the hydrologic analysis to confirm the availability and dependability of water resources for the project.

Further it should be mentioned that the study is confined to the review and the additional study of a part of the ELC's Feasibility Report and is firmly based on the conditions planned that the project be known as the San Roque Multipurpose Project by ELC.

5. SCHEDULE OF THE STUDY

The study was carried out according to the schedule shown in Fig. I-1.

The sectoral study of the hydrologic analysis was completed in May, 1984 and the results and evaluation were expounded in the first interim report which was submitted at the end of May, 1984.

Field surveys for the reservoir water and the irrigation water qualities were completed at the end of November, 1984, and the results of the analyses and assessments of water qualities are described in this report.

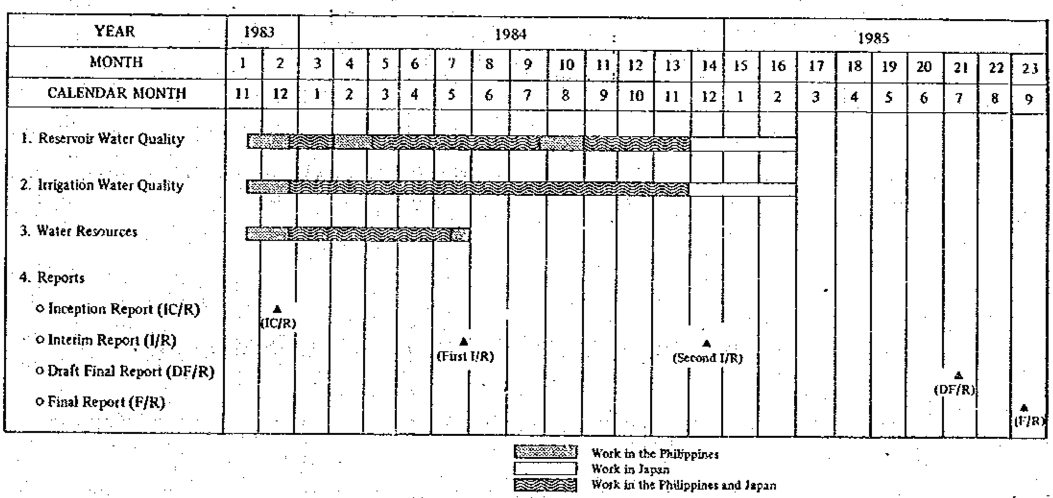


Fig. I-1 Time Schedule

6. THE JICA STUDY TEAM AND THE JICA ADVISORY COMMITTEE

The study has been implemented by a JICA Study Team with 17 experts in total as listed in Table I-1.

JICA has established an Advisory Committee composed of 6 authorities shown in Table I-2, that deliberated on the plan of study, results of the study, etc.

Table I-1 MEMBER LIST OF STUDY TEAM

Sector and Name	*Specialty*
Reservoir water quality	
Takao TERAE	Team leader
Kuniaki KATO	Chief Engineer (Sampling)
Isao MARUFUJI	Engineer (Sampling)
Osamu MIYAISHI	Senior engineer (Field test)
Masami IWAYA	Engineer (Field test)
Hideya KIKUCHI	Senior engineer (Water quality survey)
Takashi MATSUOKA	Analytical engineer
Ken-ichiro WATANABE	– ditto –
Akira ISHIDOYA	– ditto –
Katsuhiko BABA	Drilling expert
Takeshi OSADA	Engineer (computation, home work only)
Irrigation water quality	
Tetsuo YAGUCHI	Irrigation engineer
Yutaka MATSUMOTO	Agronomist cum Soil expert
Naoto MORIOKA	Soil expert
Takashi KIMIJIMA	Agronomist
Water resources	
Takao ICHIMIYA	Deputy team leader cum Hydrologist
Toshiki ITO	Hydrologist (home work only)

Table I-2 MEMBER LIST OF ADVISORY COMMITTEE

Name	Charge
Tsunemasa IMAIZUMI	Chairman
Akira SATO	Mine tailings
Kazuo KURODA	Water quality
Shooshi YOKOTSUKA	Hydrology
Jiro NAKAJIMA	Irrigation
Hiroshi MASUJIMA	Cultivation and soil

7. THE PHILIPPINE COUNTERPARTS AND THE PHILIPPINE JOINT TECHNICAL COMMITTEE

The counterparts and members of the Joint Technical Committee for this project were nominated as shown in Tables I-3 and I-4.

Table I-3 MEMBER LIST OF COUNTERPART

Name	Speciality	Place
E. Abesamis	Chief Counterpart	National Power Corporation
G. Bantugan	Water Quality Engineer	National Power Corporation
L. Umali	Site Manager	National Power Corporation
G. Wi	Hydrologist	National Power Corporation
E. Punzal	Irrigation Engineer	National Irrigation Adm.
L. Baraquio	Irrigation Engineer	National Irrigation Adm.
A. Lazaro	Agricultural Engineer	National Irrigation Adm.
C. Tuzon	Soil Technologist	National Irrigation Adm.
M. Cabalda	Mining Engineer	Bureau of Mines & Geo-science
P. David	Geologist	Bureau of Mines & Geo-science

Table I-4 MEMBER LIST OF JOINT TECHNICAL COMMITTEE

Name	Speciality	Place
Jose U. Jovellanos	Chairman	National Power Corporation
Eduardo P. Abesamis	Member	National Power Corporation
Gonzalo A. Bantugan	Member	National Power Corporation
Santiago L. Zapanta	Member	National Power Corporation
Jose B. del Rosario	Member	National Irrigation Adm.
Pedro P. Tercino	Member	Ministry of Public Works & Highways
Jesus M. Sunga	Member	National Economic & Dev. Authority
Felipe N. Robeniol	Member	National Pollution Control Commission
Leonides T. Samaniego	Member	Ministry of Natural Resources
Michael V. Cabalda	Member	Bureau of Mines & Geo-sciences
Luis M. Sosa	Member	National Water Resources Council

II. FEATURES OF THE STUDIED AREA

II. FEATURES OF THE STUDIED AREA

1. LOCATION AND ACCESS

The Agno River traverses southward within the Cordillera Central Mountain Range of Luzon and debouches to the Pangasinan Plain where it turns west to enter the South China Sea at the Lingayen Gulf. The length of the main river is about 270 km. The San Roque Dam is proposed to be located at the end of the canyon close to the plain with its catchment area of about 1,250 km^2.

The proposed damsite lies on a straightline connecting Manila to Baguio City, some 150 km in a direct line from Manila and 30 km from Baguio.

As the national highway No. 11 connecting Manila with Baguio and its branches cross the Pangasinan plain in all direction, the irrigable land is favorably located in point of transportation. The upper courses of the Agno River are hard to approach in general because of the sparse population and steep mountainous terrain.

An approach road to the proposed damsite has been constructed by NPC.

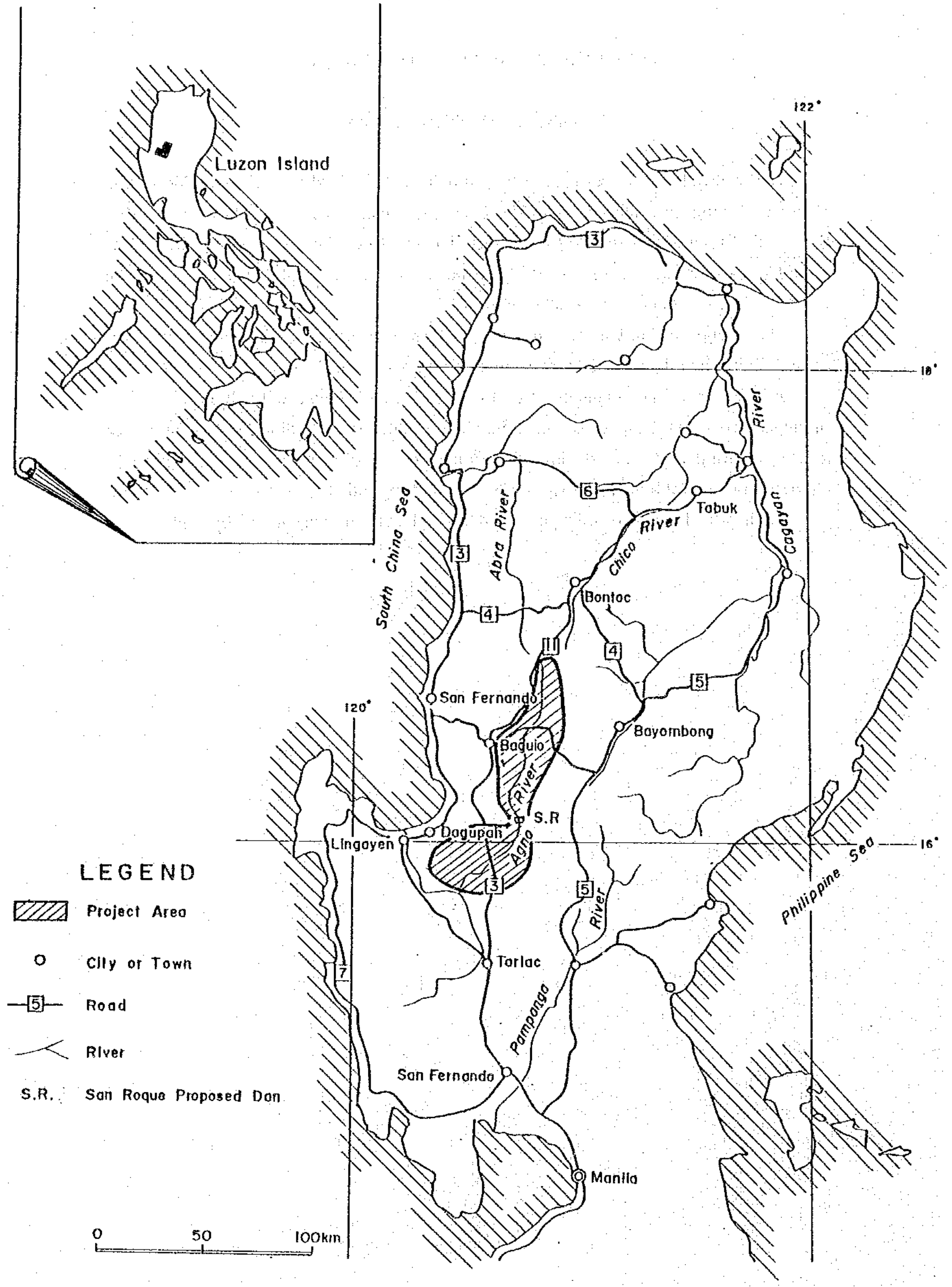


Fig. II-1 Location Map of Project Area

2. TOPOGRAPHY AND GEOLOGY

The upper courses of the proposed San Roque damsite are topographically in a youthful stage being characterized by steep mountains and narrow canyon. Erosion has considerably increased as a rsult of recent deforestation.

There are two existing hydroelectric power dams, such as Ambuklao and Binga upstream from the proposed damsite, River bed elevations at the Ambuklao, the Binga and the proposed damsite are 630m, 480m and 100m respectively indicating that the upper reaches of the proposed damsite is of steep gradients.

The lower courses of the proposed damsite, the Pangasinan Plain, is a wide and flat low land. The Agno River flows slowly with some meandering. Its sediment transport capacity is sharply reduced and the sediments carried by the river are deposited in fans and bars.

The Cordillera Central Mountain Range was subjected to orogenic movement which occurred near the end of Neogene time and is underlain by the following rock units in ascending order.

Undifferentiated Volcanics:

The altered volcanic rocks of Cretaceous to Paleogene time which are generally called "meta-andesite".

Lower-Middle Miocene Sediments:

The rock formation consists of a thick sequence of sedimentary rocks, conglomerate, calcareous sandstone, arkose, wacke and siltstone. The limestone member occurs as lenticular intercalated beds.

Neogene Intrusives:

The rocks are batholithic intrusives consisting of granodiorite, quartz diorite, diorite, etc. and intrude the Undifferentiated Volcanics and Lower-Middle Miocene Sediments.

Upper Miocene Sediments:

The rock formation is a thick sequence of poorly sorted conglomerate associated with thin interbeds of tuffaceous wacke, claystone and siltstone.

Quaternary Volcanics:

The rocks occur as isolated cone shaped plugs of andesitic to dacitic composition.

The Pangasinan Plain is covered with thick alluvial deposits which are made up principally of unconsolidated fluvial sediments.

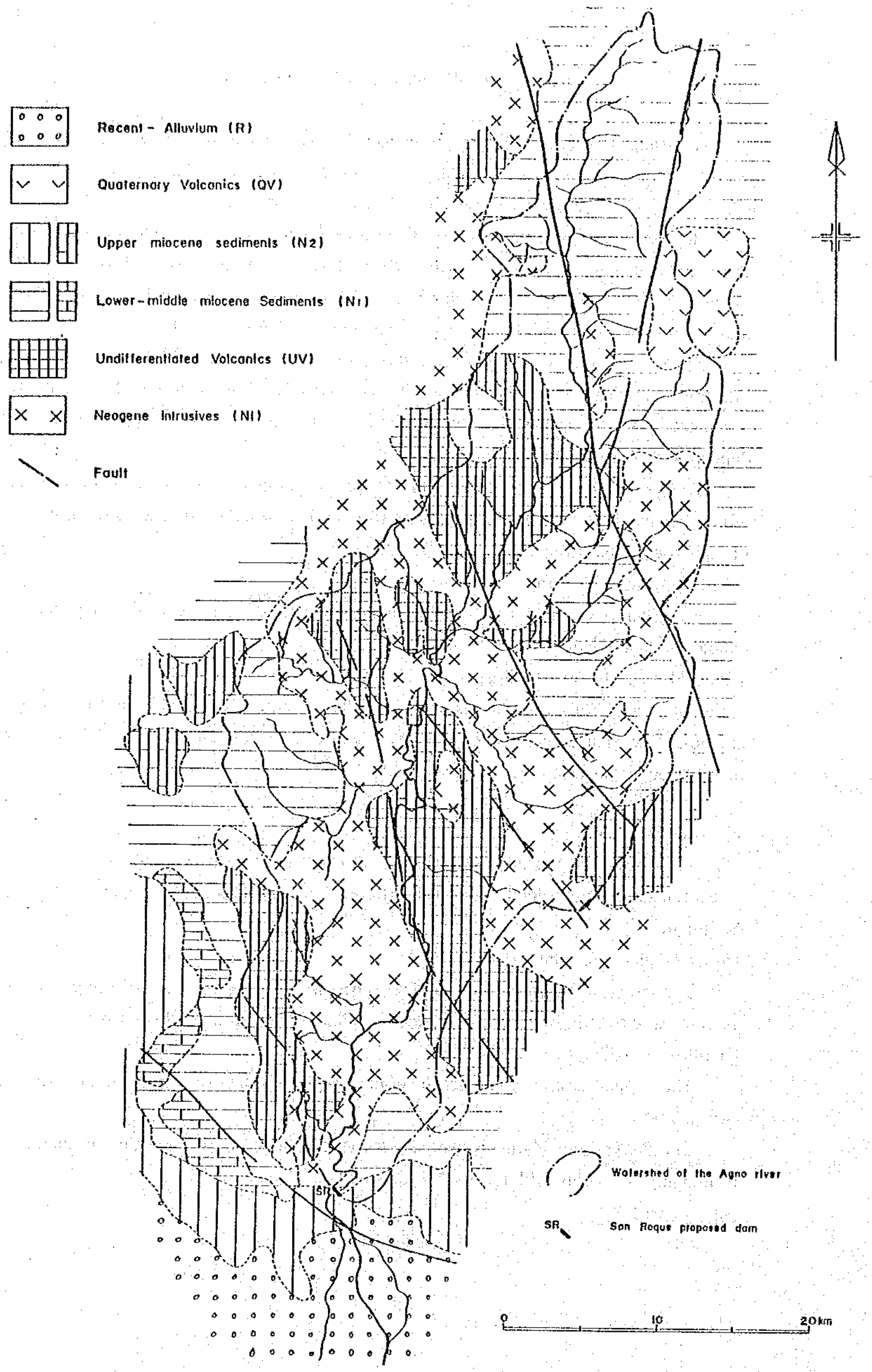


Fig. II-2 Geologic Map of the Agno River Area

3. METEOROLOGY AND HYDROLOGY

The Upper Agno basin receives a high precipitation as much as 3,000 mm a year influenced by the south-west monsoon, steeply sloped topography and the fact that the Luzon Island is in the path of typhoons.

The rainy season extends over a six month period from May to October, and the dry season over six months for the rest of the year. The hydrologic year coincides approximately with the calendar year. As observed on the isohyetal map (Fig. II-3), precipitation is heavier along the eastern and western watershed than in the northern mountain area or in the strip along the river.

Baguio city, located slightly outside the western watershed, is well-known for its heavy rainfall. The yearly rainfall of 9,038 mm recorded in 1911 is the largest record among accurate records in the Luzon Island. As a recent monthly record, a high monthly rainfall of 4,775 mm in July 1972 (yearly rainfall was 7,256 mm) was seen. In spite of the fact that the Baguio city is not in the watershed, the rainfall of Baguio is thought to represent the hydrologic characteristics of the upper Agno basin.

The upper Agno basin is not only in the heavy rainfall area, but it also shows a very high outflow having a mean specific outflow of 6.5 m^3/s from every 100 km^2 of the basin and an outflow coefficient of 0.7.

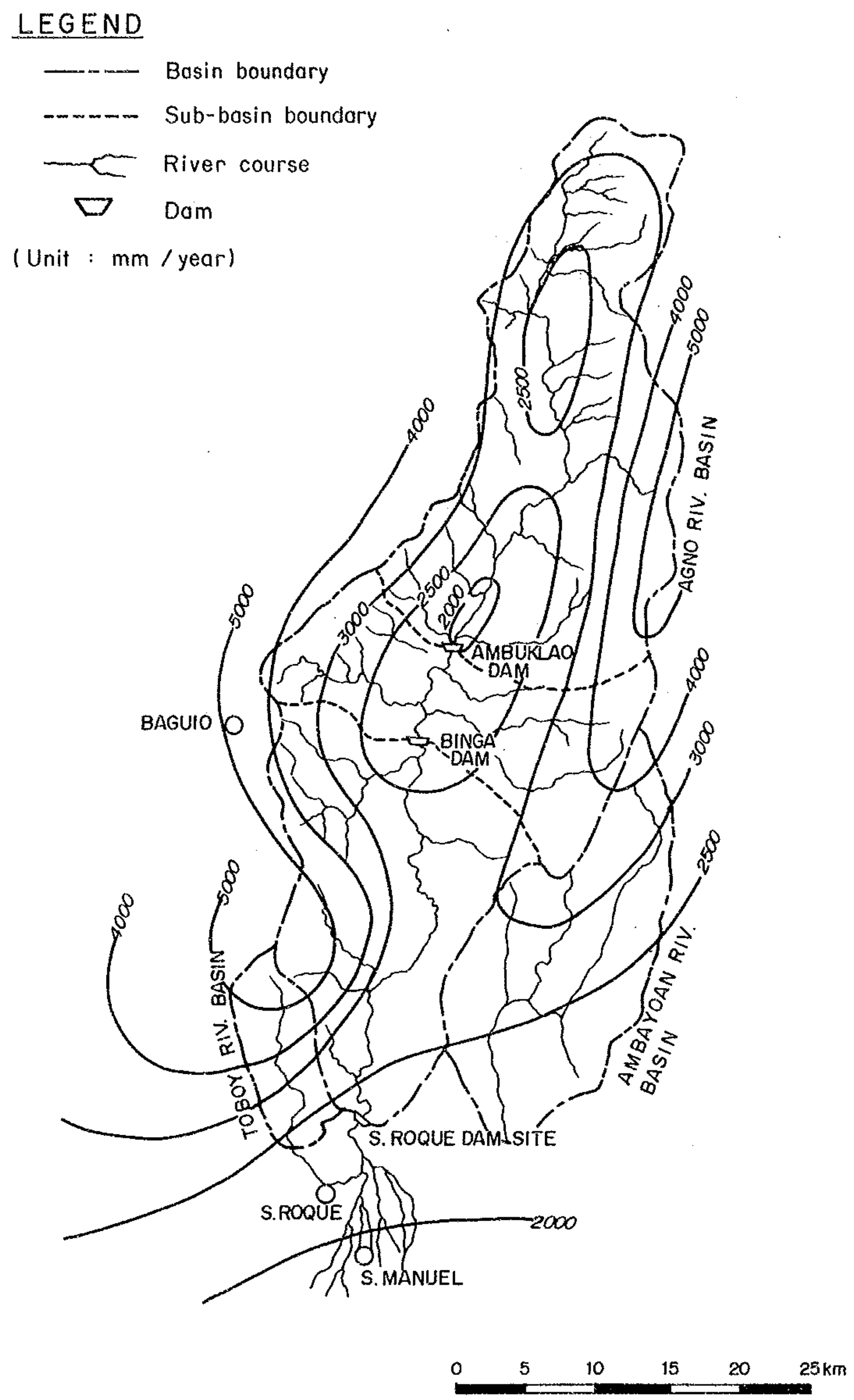


Fig. II-3 Isohyetal Map for Upper Agno River Basin

4. EXISTING DAMS AND MINES

4.1 Existing Hydroelectric Dams

There are two existing dams on the Agno River upstream from the proposed San Roque damsite. The Ambuklao dam and Binga dam had been put in operation in December 1956 and January 1960 respectively. Main features are as follows.

Item	Ambuklao	Binga
Catchment area (km^2)	617	860
Mean inflow (m^3/s)[*2]	41.3	57.3
Type of dam	Rockfill	Earth-Rockfill
Height of dam (m)	129	107
Crest elevation (El.m)	758	586
Fill volume of dam (million m^3)	6.02	1.89
Spillway gate (mxmxnos.)	12.5x12.5x6	12.5x12.0x6
Normal high water level (El.m)	752	575
Low water level (El.m)	694	555
Effective capacity (million m^3)	258	48.2
Effective capacity/yearly inflow[*2]	0.20	0.03
Installed capacity of power station (MW)	75	100

Source: Booklet by the Public Relation Office, NPC
* Source: Value obtained by the present study

As seen in the above table, the effective capacities of existing reservoirs are not as large as those compared with the yearly inflow volume. Especially, the Binga reservoir has an effective capacity which is smaller than one-half month's average inflow. Hence the time difference between the inflow and outflow is not great. In case of the Ambuklao reservoir, the time difference is not more than one month even during the rainy season. In case of the Binga reservoir, a monthly-wise time difference is not noticeable. These facts were confirmed by the present study.

4.2 Mining Activities

The southern section of the Cordillera Central Mountain Range is the most important mining district in the Philippines and dotted with many copper and gold mines.

The mines located in the watershed of the Agno River are listed below.

Mining company	Mine	Principal Commodity	Location
Philex Mining Corp.	Sto. Tomas II	Cu	Tuba Itogon, Benguet
Benguet Corp.	Acupan	Au	Itogon, Benguet
	Antamok	Au	– ditto –
	Baco	Au	– ditto –
	Kelly	Au	– ditto –
Itogon-Suyoc Mines Inc.	Itogon	Au	Itogon, Benguet
Baguio Gold Mining Co.	St. Niño	Cu	Tublay, Benguet (closed in 1982)

The present state of these mines are described in the Appendix "G" Mining Activities in the Watershed of the Agno River. An outline of the mines is presented here.

(1) Sto. Tomas II mine of the Philex Mining Corp.

The mine is located about 20 km south of Baguio City and is accessible from Baguio City by a well-maintained mine road.

The mining activities started in 1958. By progressively increasing its capacity, the mine is operated at a rate of 27,000 t/day at present.

The Sto. Tomas II deposit is of porphyry copper type and its copper ores which occur as disseminations and veinlets of chalcopyrite in silicified rock, are mined by the block caving method.

A concentrator of the Philex Mining Corp. called "Banget Concentrator" is producing copper concentrates by the floatation method with a capacity of 27,000 t/day. The mill tailings are impounded in the tailings dams No. 1 in the Albian Creek and No. 2 in the Manaa Creek.

The plan of constructing the 745 ML concentrator was withdrawn and the existing 1020 ML concentrator will operate at 32,000 t/day, higher by 5,000 t/day by September, 1985 as an alternative plan.

(2) Gold mines of the Benguet Corp.

The Acupan Ore Deposit started production in 1906 and the Antamok in 1933. The Baco which has lately succeeded from the Atok Big Wedge Mining Co., launched production in 1980 and furthermore the Kelly was opened in 1981. These ore deposits are located east of Baguio City along the Ambalanga River and are easy to reach from Baguio City by paved roads.

Gold-bearing quartz-clay veins are mined in these four ore deposits and gold ores are conveyed through haulage tunnels and treated at the centralized Balatoc Mill.

The Balatoc Mill is producing gold bullion by the cyanidation method with a capacity of 3,250 t/day.

The mill tailings are fed into the sand-fill plant to recover coarser sand which is about 30% of the tailings and finer tailings are disposed of in the phase II tailings dam through a channel of the Phase I tailings dam which has been inoperative since 1978.

(3) Itogon Mine of the Itogon-Suyoc Mines, Inc.

The Itogon Mine is located facing the eastern border of the Acupan ore deposit and is accessible from Baguio city by road via Itogon Village.

The mining activities started in 1926. It had been operated at a rate of 250 – 300 t/day until recent times, then expanded to 350 t/day from the 3rd quarter of 1984.

Gold-bearing quartz veins are pit mined and gold bullion is being produced by the cyanidation method.

The Mill tailings are impounded in the tailings pond in the downstream.

(4) Sto. Niño Mine of the Baguio Gold Mining Co.

The mine is located at Tublay Benguet, northeast of Baguio City, and can be reached by following the Mountain Trail up to KM 21 and then by the mine access road to the mine.

The mine started operation in 1972 by the engineering staff of the Philex Mining Corp. at a rate of 3,300 t/day, but closed in 1982.

The porphyry copper type ore deposits were mined by an open pit method and copper ores were floated to produce copper concentrates.

III. REVIEW OF THE HYDROLOGIC ANALYSIS

III. REVIEW OF THE HYDROLOGIC ANALYSIS

1 SCOPE OF THE STUDY

1.1 Objectives of the Study

The study is made for the purpose to confirm the appropriateness of the results of hydrologic studies made in the preceding feasibility and additional studies done by ELC in respect to two items such as the discharge and the probable maximum discharge of the Agno River at the proposed San Roque dam site.

1.2 Methodology of the Study

For the hydrologic analysis, rainfall and discharge data in and around the catchment basin of the proposed San Roque dam, operation records of power generation and spillway of the Ambuklao and Binga dams, and other related records are collected. These data are good for estimating the outflow from the upper basin of the Binga dam which occupies two thirds or 68 per cent of the San Roque catchment basin.

In the hydrologic analysis, the inflow into two existing reservoirs are calculated firstly, and results are examined putting into use of the collected rainfall data. Based on the analysis results which are examined to be appropriate, the characteristics of inflow into the existing reservoirs and outflow from the dams are studied. Then, the mean discharge at the proposed San Roque dam site is estimated from the calculated outflow from the Binga dam referring to the rainfall pattern in the San Roque catchment basin as well as to the discharge data and outflow characters of two rivers such as Ambayoan and Toboy which flow neighbouring to the east and west of the upper Agno River.

Whilst in parallel with the said works, the actually measured discharge data of the upper Agno River at the San Roque gauging station are examined to clarify the dependability. Reliable portions of the data are thus selected and the mean discharge is calculated. These results are used for the examination of the reliability of the analysis results mentioned before.

Process to estimate probable maximum flood discharge (PMF) adopted in the Study is as follows; namely (a) probable maximum precipitation (PMP) is calculated for important rain-gauge stations in and around the San Roque catchment basin, (b) point rainfall is converted into area rainfall, (c) outflow analysis is made, and (d) finally PMF is calculated. As for PMP, also the probable precipitation is calculated for examining the calculated PMP. For these calculation, an assumption is made that the two reservoirs presently operated are not existing because these two reservoirs do not have flood control capacity sufficient to decrease the flood peak discharge.

2 AVAILABLE DATA FOR THE STUDY

2.1 Preceding Studies

(1) Mean Discharge at Proposed San Roque Dam Site

The San Roque gauging station is located immediately downstream from the proposed San Roque dam site. Records of water level and discharge of this station covering a considerable long period of time are available, but the dependability of these records has been said to be low for various reasons. On the other hand, the rainfall records of Baguio cover long time period and their accuracy is dependable. The rainfall of Baguio has fair co-relationship with the hydrologic characteristics of the San Roque catchment basin.

In the hydrologic analysis of ELC's feasibility study, measured discharge records of the San Roque gauging station are used for the years in which good correlation is observed with the Baguio rainfall. For the years in which the good correlation is not observed, as well as for the years in which discharge data at the existing two dam sites are not available, the discharge at the proposed San Roque dam site is estimated based on the rainfall data of Baguio.

The mean discharge at the proposed San Roque dam site was 94.2 m^3/s according to the preceding feasibility study done by ELC. Later in July 1983, ELC made a review on the hydrologic study, and presented a revised mean discharge of 93.7 m^3/s.

(2) Design Flood Discharge

In ELC's feasibility report, the design flood discharge of 12,800 m^3/s is adopted for the design of the spillway. This value is a sum of 11,100 m^3/s as the basic design value and 1,700 m^3/s as a surplus capacity. The basic value is introduced based on PMF analysis. The surplus capacity is explained as a possible artificial flood discharge caused by the gate operation of the Binga dam under abnormal condition.

2.2 Data used for the Study

(1) Data of Reservoir Operation

The coverages of reservoir operation and power generation data of the Ambuklao and Binga dams are from 1957 for the former and from 1960 for the latter, both of which are the years of completion of respective dams, up to 1982. Both data are almost continuous and consecutive except for two years, 1973 and 1974, during which data of outflow volume are not available.

Data on water level of reservoir and electric power output or water discharge used for power generation are expressed in the daily basis and used without being processed. Spillway data with some blank periods are collected in the hourly basis, and used being converted into the daily basis. For such blank periods, the monthly data are used as substitution. Effective coverage periods of all of the said data are as graphed in Figure III-1.

In addition, the reservoir water level viz storage curve and table as well as the reservoir water level viz necessary discharge for generation of 1 kWh curve and table for the existing two dams are collected. Among these, the data prepared immediately after completion of dams are used for the inflow-outflow analysis for the both cases of Ambuklao and Binga reservoirs. These curves are as shown in Figure III-2.

(2) Rainfall Data

Rainfall data of 17 rain-gauge stations are collected. Of them, 12 stations are located in the San Roque catchment basin, four stations are located around and near the San Roque catchment basin, and one is located on the plain of lower reaches of the Agno River, as shown in Figure III-3. Data coverage periods are as shown in Figure III-4.

Though each of 16 stations in and around the San Roque catchment basin covers about 80 km^2 on the average, the locations are biased rather in the upper basin of Ambuklao dam site. Especially in the left bank side of the lower basin of Ambuklao dam site, there is none except for the Binga rain-gauge station. This fact is a hindering factor in estimating the outflow from the basin between the Binga and proposed San Roque dam sites.

Rainfall data of Baguio covers a period from 1902 up to date. However, the data of the pre-war time are excluded from the Study as the blank periods continue intermittently. After 1949 through 1983, the data cover fully though blank periods of short time are seen.

Monthly rainfall data collected are as compiled in APPENDIX A and mean values for the coverage period are summarized in Table III-1.

(3) Discharge Data

Data of water level and discharge are collected on 14 gauging stations. Of them, 12 stations are located on the upper reaches of Agno River upstream from the proposed San Roque dam site and two are located on the neighbouring rivers, as shown in Figure III-3. Data coverage periods are as shown in Figure III-5. Taking into account size of catchment area and data coverage period, four stations such as Adaoay, Ambuklao, Binga and San Roque are used for the Study.

More than 50 years' data are available on the San Roque gauging station with number of blank periods. For the period after the commission of the Binga dam, however, the discharge at the San Roque gauging station is influenced very much by the discharge from the Binga hydro-electric power station which is made on hourly basis. Further, measurement of water level at the San Roque gauging station is made with the ordinary gauge staff by twice readings a day. Hence the discharge data at the San Roque gauging station do not fully reflect the actual status of discharge.

Monthly observed discharge collected in as compiled in APPENDIX A and mean values for the data coverage period are summarized in Table III-2.

3 DISCHARGE AT PROPOSED SAN ROQUE DAM SITE

3.1 Discharge at Existing Dam Sites

(1) Discharge at Ambuklao dam site

Putting use of data of reservoir operation and power generation after construction of the Ambuklao dam, the daily inflow into the reservoir and the daily outflow from the dam are calculated on the basis of calculation formulas as described in APPENDIX A. As to the inflow, the values for 1957, 1973 and 1974 can not be calculated directly because of absence of the daily reservoir water level data. The daily inflow estimated is examined in the following two steps in form of monthly mean values.

Firstly, the obtained inflow into the Ambuklao reservoir is compared with the rainfall records of Baguio and Ambuklao, and periods during which inflow is obviously smaller than the rainfall are found. Such unbalances are caused mostly by the absence of daily data of spillage or by the daily data which are wrongly expressed in the smaller side. Hence the values in such periods are corrected or supplemented referring to the reservoir water level data, then the analysis of inflow and outflow is made again. Mean value of the inflow and outflow is 40.8 m^3/s including those estimated by the said method.

Next, the correlation between the analysis results and the rainfall in the surrounding area is examined. As correlation of 1960 and 1968 is poor, these two years' data are excluded in the further study. Thus, number of years used for the calculation is 28 for the outflow and 25 for the inflow. The adjusted monthly inflow into the reservoir is 41.3 m^3/s and the outflow from the dam is 41.2 m^3/s as summarized in Table III-3.

(2) Discharge at Binga dam site

In the same manner as mentioned in the above, the inflow-outflow analysis is made and the results are examined. Like the case of Ambuklao, deficiency of daily spillage data is supplemented and analysis is made again. Mean monthly values of inflow and outflow calculated from the values which include the measured values are 57.3 m^3/s for the period of 26 years and 57.2 m^3/s for the period of 29 years, respectively, as shown in Table III-3.

Examination is also made on correlation with the rainfall of surrounding area in the same manner. As there is no year for which correlation is poor, results of inflow and outflow calculation are same as the obtained monthly values.

3.2 Outflow from the Basin between Ambuklao and Binga Dams

The catchment area of the basin between Ambuklao and Binga dams is 243 km^2 and its outflow is calculated by means of subtracting the Ambuklao outflow from the Binga inflow. Differences of measured values at the Ambuklao and Binga dam sites are deemed to be the outflow from the remnant basin for the period before construction of each dam, and the differences of outflow from the Ambuklao dam and inflow into the Binga reservoir are deemed to be the remnant flow for the period after the dam construction. In case that the Binga inflow is smaller than Ambuklao outflow, the remnant outflow is deemed nil.

To examine the appropriateness of the result of calculation, the correlation with the rainfall is examined. As a result, such five years as 1960, 1961, 1967, 1968 and 1972 are excluded in due consideration of poor correlation, exception from the inflow-outflow analysis for the Ambuklao reservoir and existence of negative remnant values. The remnant outflow calculated for the remaining 22 years is 15.0 m^3/s as tabulated in Table III-4.

3.3 Discharge at Proposed San Roque Dam Site

(1) Procedure

For the estimation of the remnant flow from the catchment area between the Binga and proposed San Roque dam sites, no measured discharge record except for those at the San Roque gauging station and insufficiency of rainfall data are taken into account. Under this condition, the long term mean discharge at the proposed San Roque dam site is estimated in the manner mentioned below:

(a) Specific run-off and run-off coefficient are calculated based on the outflow from the upper basin of Binga dam and the mean area rainfall over the same basin.

(b) Discharge at the proposed San Roque dam site is estimated putting use of obtained specific run-off and run-off coefficient.

At the same time characteristics of two neighbouring river basins such as Ambayoan and Toboy are put into consideration for increasing the dependability of the estimated values.

(2) Run-off of neighbouring basin

There is the Ambayoan gauging station on the Ambayoan River to the east of the proposed San Roque dam site as well as the Kalipkip gauging station on the Toboy River to the west of the proposed San Roque dam site. These gauging stations are located on similar latitudes. Catchment areas are 281 km^2 and 74 km^2, respectively, for the Ambayoan and Kalipkip gauging stations.

Mean discharge of the Ambayoan gauging station is calculated excluding data of 1958, 1966, 1976 and 1977 which have poor correlation with the Baguio rainfall. Mean discharge of the Kalipkip gauging station is calculated excluding data of 1964 and 1972 which have poor correlation with the Baguio rainfall. Average monthly discharges at both stations are as shown in Table III-4.

(3) Estimated mean discharge at Proposed San Roque dam site

From the aforementioned arguments on the inflow into reservoirs and the outflow from dams at Ambuklao and Binga, mean discharge of the Ambayoan and Toboy Rivers at the Ambayoan and Kalipkip gauging stations, and mean yearly rainfall over each catchment area which is introduced from the isohyetal map as shown in Figure II-3, the specific run-off and run-off coefficients of each catchment area are calculated as shown in Table III-5. Both of the specific run-off and run-off coefficients are generally high probably because of the facts that the topography consists of steep slopes and that more than 90 per cent of yearly rainfall is concentrated in six months' rainy season.

The outflow from the remnant basin of 390 km^2 between the Binga and proposed San Roque dam sites is calculated on the basis of mean yearly rainfall of 3,200 mm obtained from the isohyetal map as shown in Figure II-3. Taking into consideration (1) specific run-off from the remnant basin between the Ambuklao and Binga dam sites, (2) specific run-off from the Ambayoan River basin, and (3) mean yearly rainfall over the basins related, the specific run-off of the subject basin is calculated to be 0.070. Long term mean discharge is thus calculated to be 84.5 m^3/s as shown in Table III-6.

3.4 Average Discharge at Proposed San Roque Dam Site

(1) *Observed discharge at San Roque gauging station*

As to the observation records at the San Roque gauging station for the period after 1949, the examinations are made through the correlation analysis with rainfall at Baguio and outflow from the Binga dam. The results of examinations are as shown in Figure III-6. The discharge records at San Roque gauging station for years that well relation is not given from one of either correlation are excluded from the average estimation.

The monthly average discharge for 21 years, judged to have the reliability, are as summarized in Table III-7 and the average value of discharge at the San Roque gauging station for 21 years is calculated to be 84.1 m^3/s.

(2) Average discharge at proposed San Roque dam site

The average run-off from the drainage area of existing Binga dam is analyzed to be 57.2 m^3/s. The run-off from the remnant basin between the Binga and proposed San Roque dam sites is estimated to be 27.3 m^3/s on the average. Hence discharge at the proposed San Roque dam site is estimated to be 84.5 m^3/s on the average. The average discharge of 84.5 m^3/s is, thus, concluded as a long term average at the proposed San Roque dam site.

3.5 Available Discharge at Proposed San Roque Dam Site

The estimated average value of 84.5 m^3/s has no difference with mean of observed records of 84.1 m^3/s. It is proved that annual average of the observed record at the San Roque gauging station are rather reliable if the unreliable record period to be discarded could be found.

In ELC's feasibility and additional studies, annual average discharge at the proposed San Roque dam site were estimated principally from the correlation with Baguio rainfall. As to the result of ELC's studies, long-term average discharge at the proposed San Roque dam site was estimated to be 94.2 m^3/s and 93.7 m^3/s, respectively. Average discharge obtained by the Study has 10.3 per cent difference with the former and 9.8 per cent with the latter.

As regards discharge estimated by ELC's studies, 83.4 m^3/s and 80.9 m^3/s are obtained as the average for the period of 34 years from 1949 to 1982 and for 21 years, selected among 34 years above as a reliable data period, respectively. Both of the above are lower than the average discharge estimated through the Study or the average of observed records for selected 21 years.

Since a part of inflow volume into the reservoir will be released directly through the spillway during flood, the effective discharge should be estimated excluding high inflow parts beyond a level. It is assumed that inflow over monthly average of 200 m^3/s becomes uneffective although reservoir operation study shall be made precisely as released volume depends on the reservoir water level variation. For the period of 21 years, the average effective discharge is obtained assuming that uneffective monthly discharge over 200 m^3/s is counted as 200 m^3/s. As to the long term average of effective discharge for 21 years, 72.2 m^3/s for the observed record at San Roque gauging station and 76.4 m^3/s for the estimation by ELC's studies are obtained. The latter is 5.8 per cent larger than the former.

4 PROBABLE MAXIMUM FLOOD AT PROPOSED SAN ROQUE DAM SITE

4.1 Probable Maximum Precipitation at Baguio

Among the collected daily rainfall records at Baguio, the records for 33 years are employed for the estimation of PMP. In addition, the following data are available for the Study: (a) maximum monthly records on various duration-rainfall for the period from 1950 to 1977, (b) maximum daily rainfall records for 33 years, (c) daily rainfall records during the biggest five storms observed at Baguio and five stations in the Agno River basin, and (d) various duration-rainfall records during 24 hours at Baguio. These data are compiled in APPENDIX A.

No other records except that of daily rainfall and depth-duration are available for the Study. Therefore the statistical method, developed by Hershfield based on the observed records, is applicable for the PMP Study in case that only annual maximum daily records are available.

Through Hershfield's method, PMP at Baguio is estimated to be 2,203 mm/day applying maximum daily record to the equation given in APPENDIX A.

Several frequency distributions, such as Iwai, Gumbel and Pearson III, are examined applying annual maximum daily rainfall records at Baguio. Probable maximum precipitation of 2,203 mm/day at Baguio estimated through the statistical method is almost same or as 11 to 13 per cent high as 10,000 years value of each distribution.

The estimated PMP of 2,203 mm/day indicated a value 63 per cent higher than estimated in ELC's feasibility study in which 24 hours rainfall of 1,350 mm is considered as maximum rainfall at Baguio. It also corresponds to 2.25 times high as the maximum record of daily rainfall of 979.4 mm/day at Baguio.

The relation between rainfall depth and duration equivalent to the estimated PMP is analyzed. As a result, hourly relation between rainfall depth and duration equivalent to the PMP at Baguio are as summarized in Table III-8.

4.2 Probable Maximum Flood at Proposed San Roque Dam Site

(1) Average rainfall over Agno River basin

Daily rainfall records at representative five stations in the San Roque catchment basin are analyzed to transpose the point rainfall to the basin rainfall over the drainage area. To estimate average rainfall over the drainage area, simple mean value without any weighted factor is used since the location of five stations are concentrated in upper part of the catchment basin.

The transposition rate of Baguio point rainfall to the upper Agno average rainfall is evaluated to be 0.6 considering that the objective of the Study is to estimate probable maximum flood. Accordingly, the probable maximum rainfall all over the San Roque catchment basin is evaluated to be 1,322 mm/day that is 60 per cent of 2,203 mm/day of Baguio point rainfall.

(2) Effective rainfall over Agno River basin

The run-off coefficient in the Agno River basin during a storm is estimated to be 0.8 taking the maximum value out of selected five storms excluding a storm in 1967 into consideration.

The probable maximum precipitation in terms of effective rainfall over the San Roque catchment basin is evaluated to be 1,057 mm/day corresponding to 2,203 mm/day of Baguio point rainfall, transposition rate of 60 per cent and run-off coefficient of 80 per cent. Hourly rainfall depth and duration within 24 hours equivalent to the effective PMP are as summarized in Table III-9.

(3) Probable maximum flood at proposed San Roque dam Site

The probable maximum flood at the proposed San Roque dam site is analyzed in accordance with PMP in terms of effective rainfall over the San Roque catchment basin. Run-off volume for PMF is estimated by the analysis of Nakayasu's unit hydrograph method since the information for the past flood is scarcely available for the Study. The method is detailedly expressed in APPENDIX A.

Peak discharge of PMF at the proposed San Roque dam site is estimated to be

15,130 m^3/s through the run-off analysis described above. A hydrograph for PMF at the proposed San Roque dam site is as shown in Figure III-7.

5 OBSERVATIONS

5.1 Long Term Average Discharge

Throughout the hydrologic analysis under the Study, the following conclusions are obtained:

(a) The mean discharge of 84.5 m^3/s estimated is similar to the measured discharge of 84.1 m^3/s at the San Roque gauging station as a mean of 21 years' data which are selected as dependable data. It is induced by this fact that the flow pattern of each hydrologic year as well as of the seasonal flow pattern of each hydrologic year are well incorporated in the estimation for the reason that the analysis and estimation are made based on the outflow from the upstream dams.

(b) Difference between the mean discharge of 94.2 m^3/s shown in ELC's feasibility report and the mean discharge of 84.5 m^3/s estimated under the Study is approximately 10 per cent.

(c) Effective portion of the mean value of the measured data is approximately 5 per cent smaller than that of ELC's feasibility and additional studies.

(d) Taking into account the topographic conditions of the proposed dam site and reservoir area at San Roque, such facts as mentioned above would have no influence upon the dam plan proposed in ELC's feasibility study.

(e) Monthly outflow data from the Binga dam and reliable monthly discharge record observed at the San Roque gauging site are tabulated in Tables III-10 and III-11, respectively, as materials for the assessment of the reservoir water quality.

5.2 Evaluation of Spillway Capacity

Spillway design flood of 12,800 m^2/s is given through ELC's feasibility study for the proposed San Roque dam. Peak discharge of PMF at the proposed San Roque dam site obtained through the Study is 15,130 m^3/s and 18 per cent large as the above design value.

The peak discharge of PMF, however, has still some allowance to the spillway maximum capacity of 15,600 m^3/s designed in ELC's feasibility study.

Flood control capacity of 150,000,000 m^3 is planned through ELC's feasibility study. This capacity corresponds to 11.5 per cent of PMF's inflow volume for 96 hours that is estimated to be around 1,310,000,000 m^3.

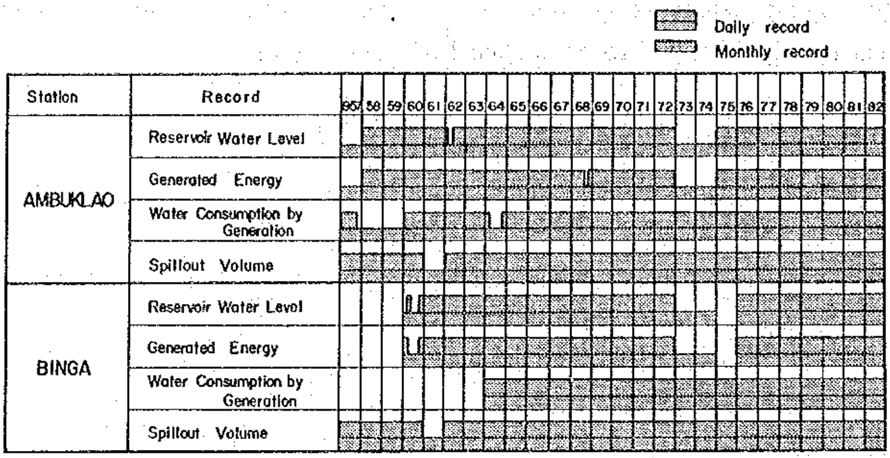


Fig. III-1 Reservoir Operation Record Available for the Study

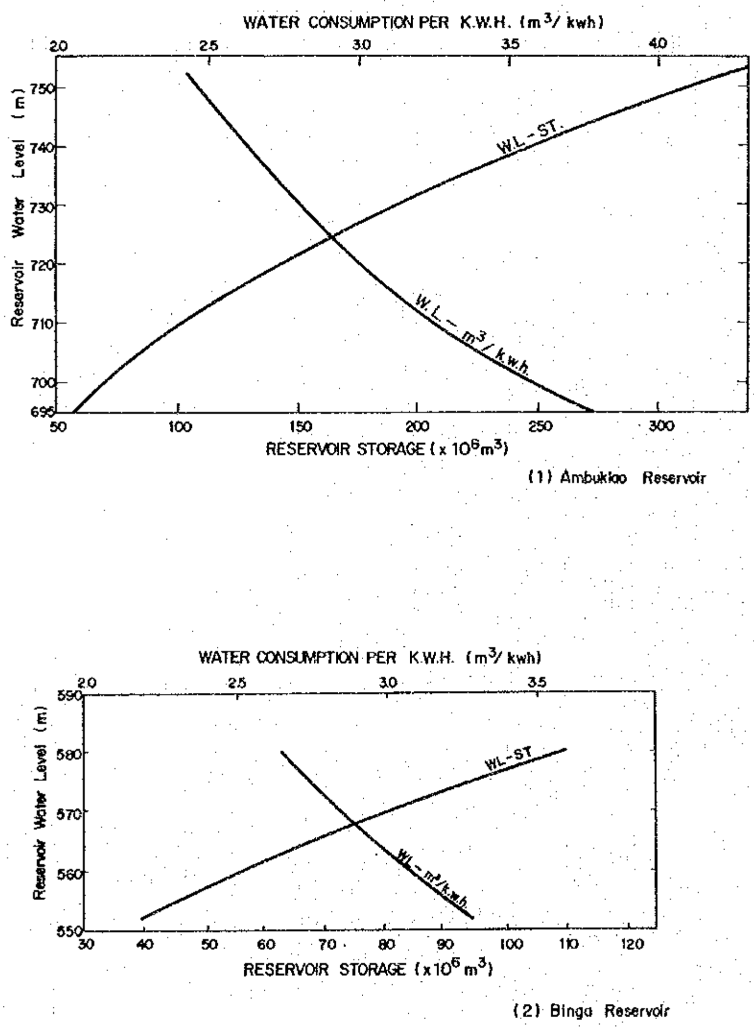


Fig. III-2 Rating Curves on Waterlevel – Storage – Water Consumption

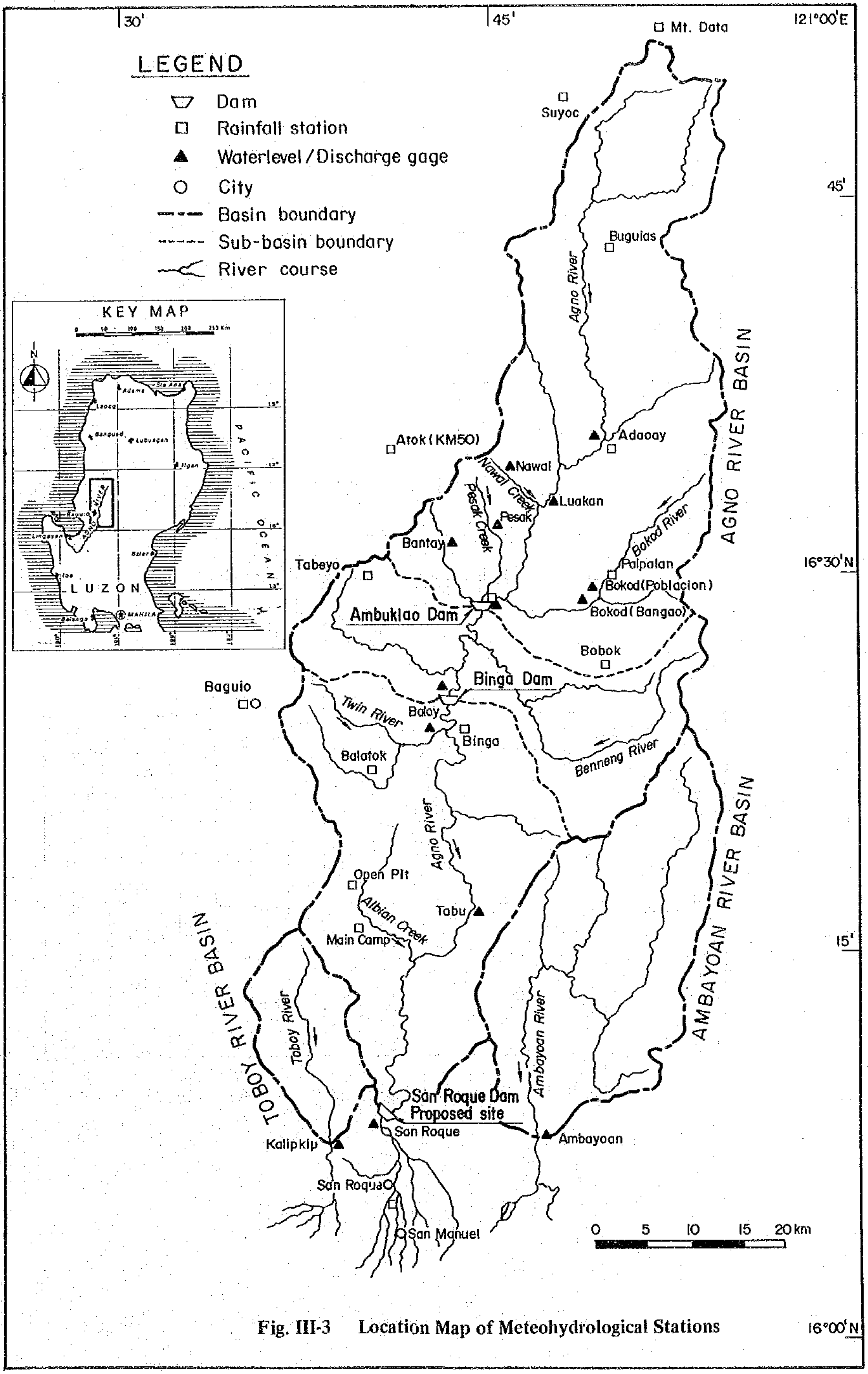


Fig. III-3 Location Map of Meteohydrological Stations

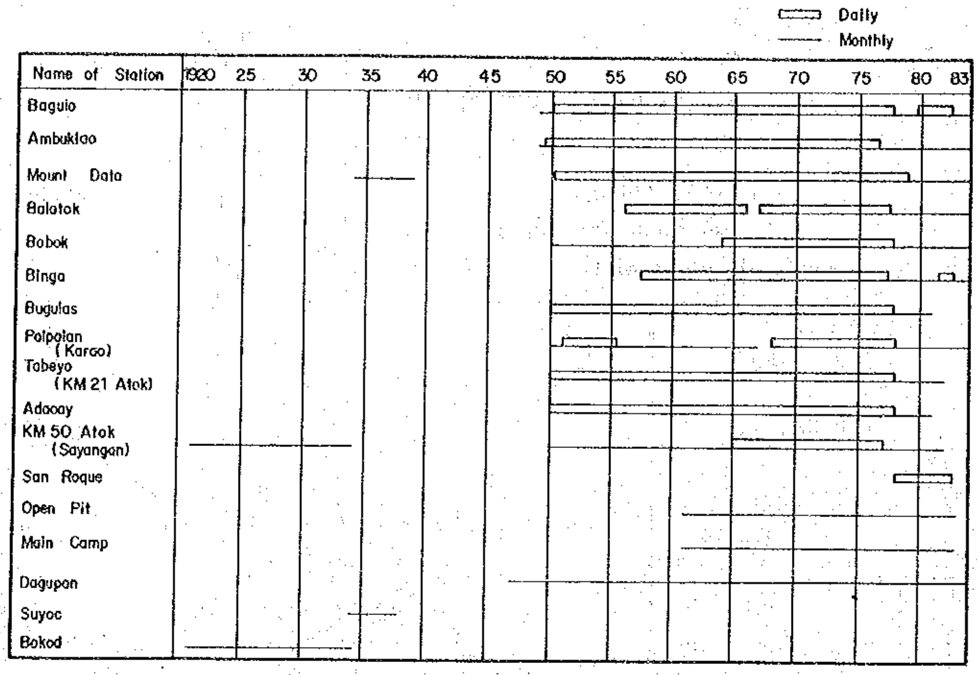


Fig. III-4 Rainfall Record Available for the Study

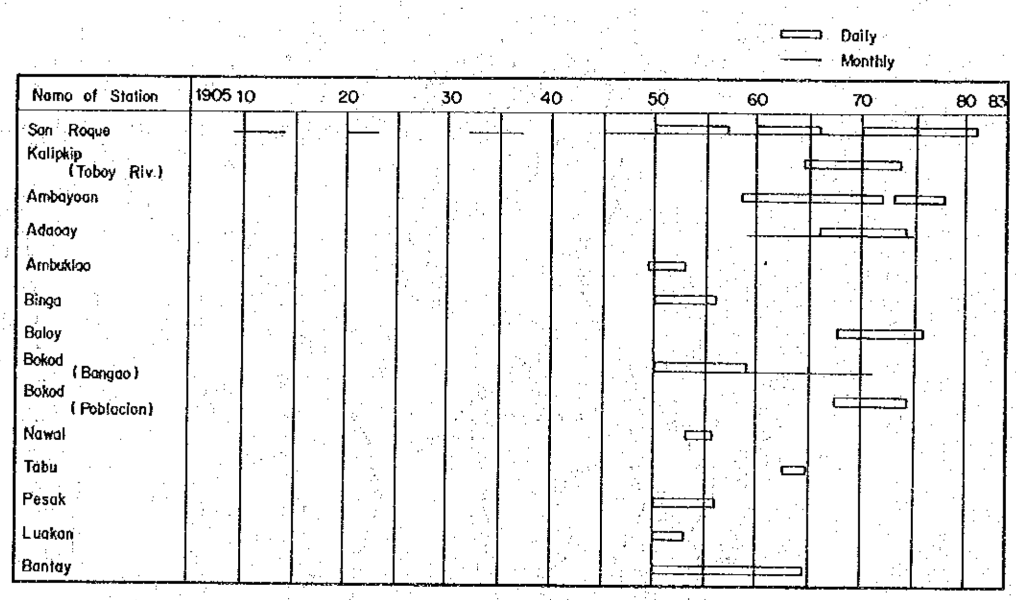


Fig. III-5 Discharge Record Available for the Study

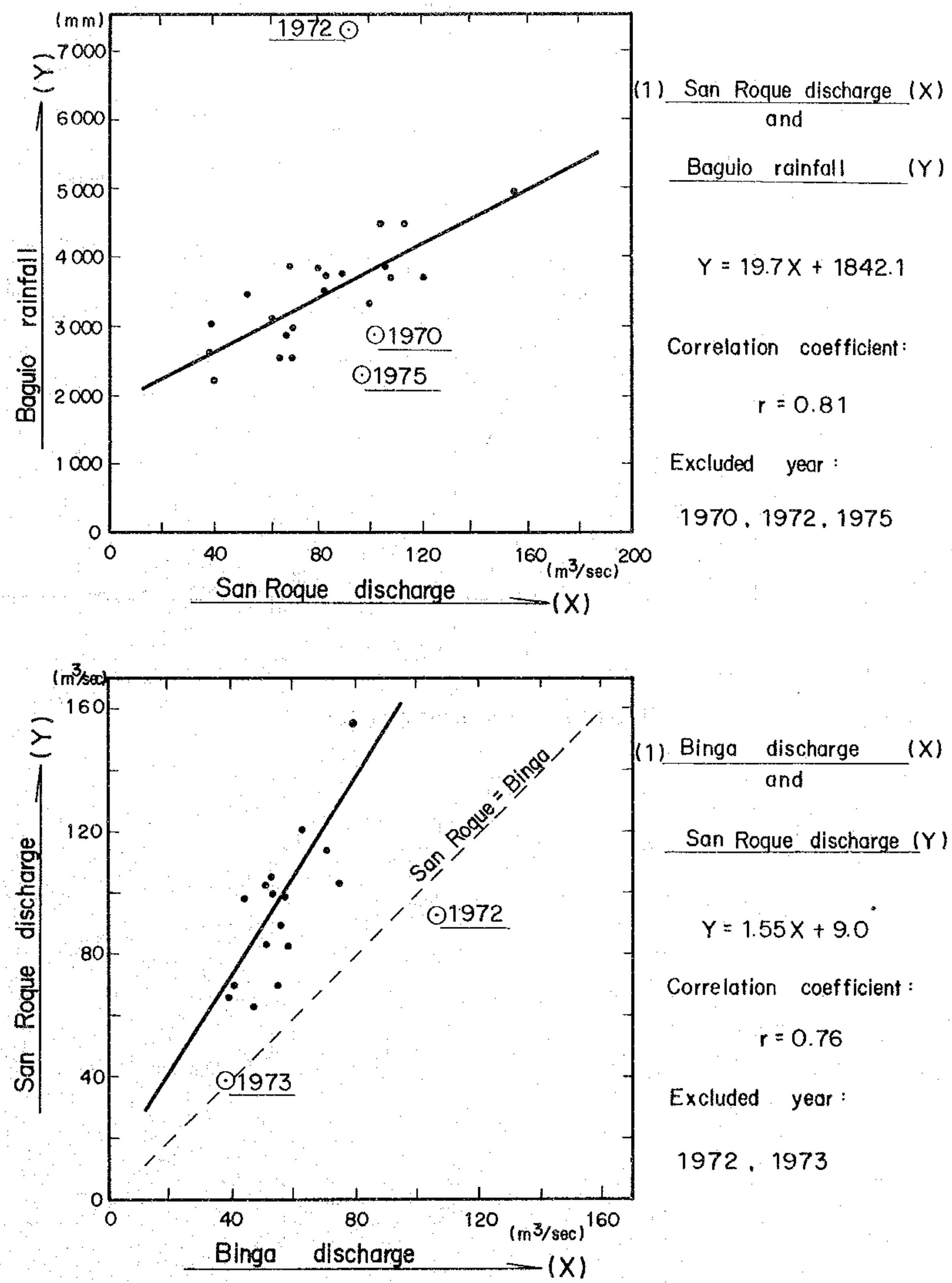


Fig. III-6 Annual Correlation of San Roque Discharge with Rainfall/Discharge

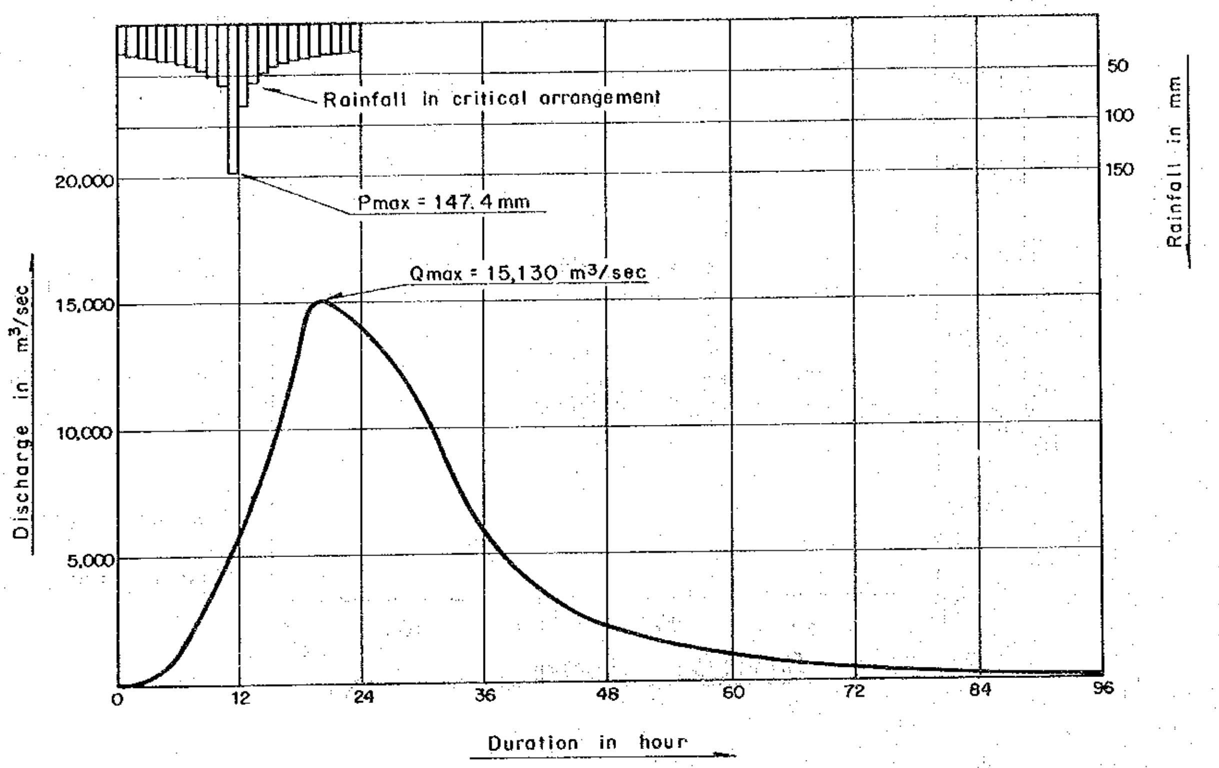


Fig. III-7 Hydrograph for P.M.F.

Table III-1 SUMMARY OF MEAN MONTHLY RAINFALL RECORD IN AND AROUND SAN ROQUE CATCHMENT BASIN

Unit: mm

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Baguio	21	8	33	95	311	447	764	855	597	334	156	32	3,654
Ambuklao	5	7	41	100	207	276	436	478	330	189	88	19	2,177
Bobok	7	8	36	77	242	361	508	544	415	228	134	22	2,582
Mount Data	24	27	79	197	378	395	622	582	470	362	236	103	3,476
Suyoc	20	46	103	214	486	263	629	696	301	343	232	108	3,440
Buguias	14	6	41	83	204	311	387	516	319	188	125	40	2,234
Adaoay	14	15	49	97	280	282	493	602	484	258	149	39	2,762
Atock	64	51	132	201	485	611	899	1,068	688	365	176	73	4,813
Palpalan	26	38	48	123	380	530	668	937	746	461	261	81	4,298
Bokod	9	13	33	113	215	415	599	530	411	225	110	21	2,694
Tabeyo	14	24	59	149	361	446	658	774	595	288	116	30	3,512
Binga	6	5	31	62	268	330	559	488	358	199	91	14	2,411
Balatok	6	10	32	97	258	432	648	710	474	304	108	23	3,102
Open Pit	28	13	55	148	569	764	1,286	1,310	824	598	176	53	5,823
Main Camp	28	12	51	130	505	733	1,174	1,238	860	538	183	42	5,496
San Roque	0	3	11	31	101	165	339	513	315	111	68	0	1,659
Dagupan	6	6	18	77	210	332	496	601	338	163	71	20	2,339

Table III-2 SUMMARY OF MEAN MONTHLY OBSERVED DISCHARGE RECORD IN AND AROUND SAN ROQUE CATCHMENT BASIN

Unit: m^3/s

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
San Roque	32.3	23.9	21.7	23.6	40.1	60.7	142.4	216.1	210.4	145.4	89.3	52.8	88.2
Ambuklao	14.1	9.9	9.1	9.2	18.0	24.8	63.2	129.7	78.7	76.2	29.8	24.4	40.6
Binga	17.8	12.0	10.5	12.6	21.3	39.2	70.4	153.0	92.4	87.2	66.3	26.4	50.8
Ambayoan	5.4	4.1	3.4	3.2	5.9	24.8	32.8	50.3	45.6	35.8	16.4	8.2	19.7
Kalipkip	0.6	0.4	0.3	0.7	1.1	5.3	14.1	13.4	12.7	10.3	3.0	1.4	5.3
Adaoay	8.8	6.2	5.1	4.7	9.0	18.3	47.1	47.8	46.7	33.0	23.5	12.1	21.9
Luakan	8.9	6.5	5.7	5.6	14.9	17.0	37.4	74.3	46.3	44.5	17.9	12.6	24.3
Tabu	39.0	34.5	32.7	28.1	35.8	71.6	90.6	340.9	436.0	95.8	48.9	43.7	108.1
Bangao	2.2	1.6	1.4	1.5	2.2	4.1	7.9	12.4	12.7	8.6	6.5	3.8	5.4
Poblacion	1.9	1.8	1.6	1.9	1.6	2.9	10.2	9.6	7.5	8.3	5.0	2.7	4.6
Nawal	0.2	0.1	0.1	0.1	0.1	1.8	1.3	2.6	4.0	1.0	3.9	0.4	1.3
Pesak	0.3	0.3	0.2	0.2	0.4	2.0	2.8	4.4	3.9	2.2	2.3	0.5	1.6
Bantay	0.6	0.4	0.4	0.6	1.0	2.6	4.1	42.2	4.7	2.1	2.1	0.7	5.1
Baloy	2.1	1.6	1.5	1.6	1.9	2.9	5.9	5.4	4.2	3.6	2.7	2.5	3.0

Table III-3 ADJUSTED MONTHLY INFLOW INTO RESERVOIRS AND OUTFLOW FROM DAMS OF AMBUKLAO AND BINGA

Unit: m³/s

Month	Ambuklao		Binga	
	Inflow	Outflw	Inflow	Outflow
January	11.7	17.2	21.1	22.6
February	7.3	17.0	20.2	21.3
March	5.9	18.3	20.6	20.6
April	5.7	19.0	21.6	22.1
May	19.0	21.4	27.9	29.8
June	36.5	33.5	50.2	50.8
July	92.6	64.2	98.3	89.3
August	102.1	82.1	136.4	129.0
September	87.8	74.8	114.8	109.5
October	65.6	73.5	86.9	96.1
November	40.5	47.0	59.4	64.0
December	20.6	26.8	30.5	31.3
Mean	41.3	41.2	57.3	57.2

Table III-4 ADJUSTED MONTHLY RUN-OFF FROM THE REMNANT BASIN BETWEEN AMBUKLAO AND BINGA DAMS AND AVERAGE MONTHLY DISCHARGE AT AMBAYOAN AND KALIPKIP STATIONS

Unit: m³/s

Month	Run-off from Ambuklao-Binga Remnant Basin	Ambayoan Station	Kalipkip Station
January	4.5	4.8	0.6
February	3.6	3.9	0.4
March	2.9	3.5	0.3
April	2.8	3.4	0.8
May	8.6	3.9	1.2
June	12.3	16.3	6.1
July	30.2	33.5	10.1
August	43.9	50.9	14.5
September	33.1	41.9	14.3
October	19.6	36.0	12.0
November	12.0	14.0	3.0
December	6.5	6.9	1.2
Mean	15.0	18.3	5.4

Table III-5 SPECIFIC RUN-OFF AND RUN-OFF COEFFICIENTS OF CATCHMENT AREA

Catchment Area	Upstream from Ambuklao	Between Ambuklao and Binga	Ambayoan	Kalipkip
Drainage area (km^2)	617	243	281	74
Mean discharge (m^3/sec)	41.3	15.0	18.3	5.4
Mean run-off depth (mm/year)	2,111	1,947	2,054	2,301
Mean rainfall (mm/year)	3,000	3,000	2,800	3,750
Specific run-off ($m^3/s/km^2$)	0.067	0.062	0.065	0.073
Runoff corfficient	0.704	0.649	0.733	0.614

Table III-6 LONG TERM MEAN DISCHARGE CALCULATED

Basin	Catchment area (km^2)	Discharge (m^3/sec)	Note
Outflow from Binga dam	860	57.2	
Remnant basin between Binga and San Roque	390	27.3	Specific run-off =0.070
San Roque dam proposed site	1,250	84.5	

Table III-7 MONTHLY MEAN OBSERVED DISCHARGE FOR 21 YEARS AND LONG TERM MONTHLY MEAN DISCHARGE AT SAN ROQUE SITE

	Mean of Observed Discharge (m^3/s)	Ratio to Annual Total (%)	Long Term Average Discharge (m^3/s)
January	30.2	2.99	30.3
February	23.0	2.28	23.1
March	19.8	1.96	19.8
April	20.0	1.98	20.1
May	40.2	3.98	40.4
June	62.4	6.18	62.7
July	119.8	11.87	120.4
August	225.8	22.37	226.9
September	215.2	21.32	216.2
October	138.7	13.74	139.3
November	75.5	7.48	75.8
December	39.1	3.87	39.2
Mean	84.1	—	84.5

Table III-8 **HOURLY RELATION BETWEEN RAINFALL DEPTH AND DURATION AT BAGUIO**

Duration (hr)	Depth (mm)	Duration (hr)	Depth (mm)
1	307.1	13	1,506.4
2	472.0	14	1,577.2
3	606.9	15	1,646.1
4	725.4	16	1,713.1
5	833.0	17	1,778.9
6	932.7	18	1,843.1
7	1,026.2	19	1,905.9
8	1,114.8	20	1,967.5
9	1,199.3	21	2,028.0
10	1,280.2	22	2,087.3
11	1,358.1	23	2,145.6
12	1,433.4	24	2,203.0

Table III-9 **HOURLY RAINFALL DEPTH AND DURATION WITHIN 24 HOURS EQUIVALENT TO EFFECTIVE PROBABLE MAXIMUM PRECIPITATION IN SAN ROQUE CATCHMENT BASIN**

Duration (hr)	Depth (mm)	Duration (hr)	Depth (mm)
1	147.4	13	723.1
2	226.6	14	757.1
3	291.3	15	790.1
4	348.2	16	822.4
5	399.8	17	853.9
6	447.7	18	884.7
7	492.6	19	914.8
8	535.1	20	944.4
9	575.7	21	973.4
10	614.5	22	1,001.9
11	651.9	23	1,029.9
12	688.0	24	1,057.4

Table III-10 MONTHLY OUTFLOW FROM BINGA DAM

Unit: m^3/s

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1950	21.7	15.1	12.0	11.3	30.2	34.7	116.4	309.5	83.4	200.8	35.3	23.4	74.5
1951	15.1	10.0	8.7	8.9	30.3	39.7	106.3	243.1	129.0	43.9	36.0	23.4	57.9
1952	14.8	13.1	11.6	16.8	24.0	34.2	29.1	97.3	87.1	67.0	34.0	28.6	38.1
1953	15.9	11.4	9.6	11.8	14.1	97.5	122.8	160.0	(86.3)	(38.2)	127.1	42.8	—
1954	22.3	14.2	15.0	14.6	13.7	15.1	26.8	75.7	69.9	64.1	124.6	23.9	40.0
1955	17.1	8.3	6.4	12.4	15.4	14.1	21.3	32.4	(36.5)	60.3	41.0	16.0	—
1960	—	20.4	20.2	—	—	—	—	—	54.2	50.4	39.8	23.2	—
1961	20.9	23.6	18.3	18.5	20.2	102.4	110.9	128.6	81.1	56.0	45.9	22.3	54.1
1962	19.7	20.6	23.1	19.1	18.3	28.3	118.2	170.2	69.6	62.5	33.0	28.9	50.9
1963	28.8	28.4	26.9	22.9	28.2	62.4	84.3	81.7	178.8	67.0	29.5	23.4	55.2
1964	26.3	18.3	17.8	23.7	26.0	40.4	50.7	208.4	150.6	136.3	80.5	66.5	70.5
1965	29.6	27.8	29.9	32.6	33.6	60.1	76.9	88.8	73.7	65.2	26.4	18.3	46.9
1966	20.7	29.2	26.5	25.2	58.2	74.3	68.1	75.2	103.7	41.7	49.0	49.2	51.7
1967	25.2	26.2	30.4	31.3	34.6	71.3	82.9	127.4	131.8	208.6	98.4	35.0	75.3
1968	30.1	26.8	27.3	26.4	35.3	21.3	47.3	237.2	335.0	119.5	25.0	18.0	79.1
1969	20.7	17.2	20.4	22.1	33.9	48.9	59.3	149.7	106.2	78.7	34.6	30.8	51.9
1970	21.3	17.3	20.9	34.9	32.8	54.0	54.2	66.7	82.0	101.0	57.0	55.0	49.8
1971	31.0	35.9	30.9	33.4	27.3	37.4	78.9	122.9	79.2	175.9	64.5	32.1	62.4
1972	37.4	37.0	32.7	31.1	35.5	54.6	508.9	287.7	105.6	72.3	46.4	30.7	106.7
1973	39.4	19.2	11.7	1.6	19.6	29.9	40.6	45.5	63.5	74.1	63.8	39.3	37.3
1974	21.8	23.5	17.7	19.6	23.7	62.1	63.9	141.0	102.5	326.6	199.4	68.7	89.2
1975	33.4	28.0	27.3	30.6	31.2	29.7	47.6	65.4	84.1	73.1	44.6	23.0	43.2
1976	17.8	18.8	15.2	24.6	100.8	203.5	269.8	102.1	94.7	72.3	58.3	36.9	84.6
1977	16.9	13.9	5.5	1.5	5.3	15.8	39.1	54.6	139.9	63.1	45.3	18.7	35.0
1978	8.9	20.5	29.8	38.4	23.2	37.1	38.6	166.3	175.2	147.4	79.9	23.6	65.7
1979	24.9	26.1	33.7	26.8	19.4	45.2	55.9	74.8	48.7	51.9	20.2	16.1	37.0
1980	12.5	16.8	25.4	26.7	44.1	24.6	52.6	68.9	105.2	68.0	206.9	29.4	56.7
1981	14.8	23.2	19.4	15.4	30.0	57.4	88.9	134.5	138.4	70.1	71.6	37.2	58.4
1982	22.7	28.5	23.9	35.6	26.2	27.0	39.8	96.4	83.2	71.6	37.0	24.0	43.0
Mean	22.6	21.3	20.6	22.1	29.8	50.8	89.3	129.0	109.5	96.1	64.0	31.3	57.2

Table III-11 RELIABLE MONTHLY DISCHARGE OBSERVED AT SAN ROQUE GAUGING STATION

Unit: m³/s

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1949	31.9	21.1	16.2	13.8	11.9	25.0	97.6	126.5	181.3	165.5	64.0	51.1	67.2
1950	45.7	23.4	18.5	18.5	43.7	49.6	180.8	357.9	121.9	289.6	56.7	31.3	103.1
1951	22.9	16.1	10.6	12.5	54.6	68.0	105.3	327.3	212.0	70.9	53.9	35.1	82.4
1952	21.1	18.0	13.0	18.7	37.1	56.3	49.5	180.6	154.2	139.1	58.2	31.8	64.8
1953	24.5	16.6	13.7	13.4	15.2	148.0	219.2	358.2	184.7	121.8	116.2	56.2	107.3
1954	31.3	19.6	17.0	18.8	19.9	24.1	37.1	148.8	182.9	121.0	143.0	65.4	69.1
1955	26.1	18.6	13.1	11.3	15.8	21.5	46.7	84.3	107.4	81.4	42.0	17.2	40.5
1956	21.9	14.3	12.4	18.1	26.9	24.0	40.9	82.6	170.0	84.2	74.7	54.7	52.1
1957	37.8	27.5	27.0	32.9	29.7	49.3	73.5	106.9	207.2	119.6	74.4	60.9	70.6
1958	42.9	28.0	25.5	23.2	25.2	42.8	69.9	61.1	66.4	44.6	23.5	21.5	39.5
1960	30.4	20.9	15.5	19.9	29.3	74.8	84.8	444.8	112.9	80.9	27.4	14.8	79.7
1961	25.0	25.2	23.2	22.2	29.3	47.2	164.7	135.4	157.1	106.3	46.2	40.1	68.5
1962	27.2	20.4	29.1	31.5	43.5	36.4	180.2	175.0	243.8	104.8	45.1	44.9	81.8
1963	48.9	39.5	35.2	28.1	22.3	153.6	112.3	131.9	347.6	92.0	36.7	18.6	88.9
1964	17.2	18.8	10.0	24.1	17.1	21.4	55.7	502.1	255.3	282.2	99.5	57.0	113.4
1965	14.0	9.2	13.6	10.4	6.3	33.4	193.6	167.2	129.7	116.4	29.9	16.0	61.6
1966	7.9	8.0	8.1	8.6	229.4	175.9	156.8	178.6	244.6	60.0	54.3	58.5	99.2
1968	27.1	14.5	10.3	14.9	28.5	15.7	108.0	561.1	726.0	275.0	60.1	24.9	154.7
1969	21.7	20.4	24.0	10.0	43.0	64.3	213.7	244.8	350.2	188.3	58.2	18.2	104.7
1971	72.2	70.4	54.9	41.3	47.8	84.3	200.5	270.9	240.6	259.6	71.2	23.1	119.7
1980	36.5	32.0	24.9	28.7	77.5	95.4	124.1	95.0	123.6	109.7	350.3	79.3	98.1

IV. ASSESSMENT OF RESERVOIR WATER QUALITY

IV ASSESSMENT OF RESERVOIR WATER QUALITY

1. SCOPE OF THE STUDY

1.1 Purpose of the Study

The study purposes to assess the quality of the outflow from the proposed San Roque dam by means of estimating the quality of water stored in the reservoir in terms of seasonal fluctuation and a change over a long period of time. This is being done on the assumption that all of the mine tailings discharged in the watershed of the proposed dam are impounded in its reservoir as premised in the ELC's Feasibility Study.

1.2 Method of the Study

In order to obtain data to forecast the water quality,

1. An observation on water quality at fixed points and
2. An investigation of pollution sources

were conducted.

1) Fixed points observation

To grasp the state of the pollution as a natural process and as a phenomenon contingent upon mining activities, the following 5 points shown in Fig. IV-1 were selected.

Fixed Point A:

The object of the observation here is to determine the natural state of the water discharged from the Binga Dam. As the Binga Dam is located in a place free from the influence of mining activities, this point was set as one to represent the natural water in the San Roque Dam watershed.

Fixed Point B:

This point is set on the Ambalanga River. Mines and mill plants belonging to the Benguet Corp. and the Itogon-Suyoc Mines Inc. are located in the watershed of the Ambalanga River. The object here is to check the influence of these facilities.

Fixed Point C:

This point is set on the Albian Creek. The mine and the mill plant as well as the

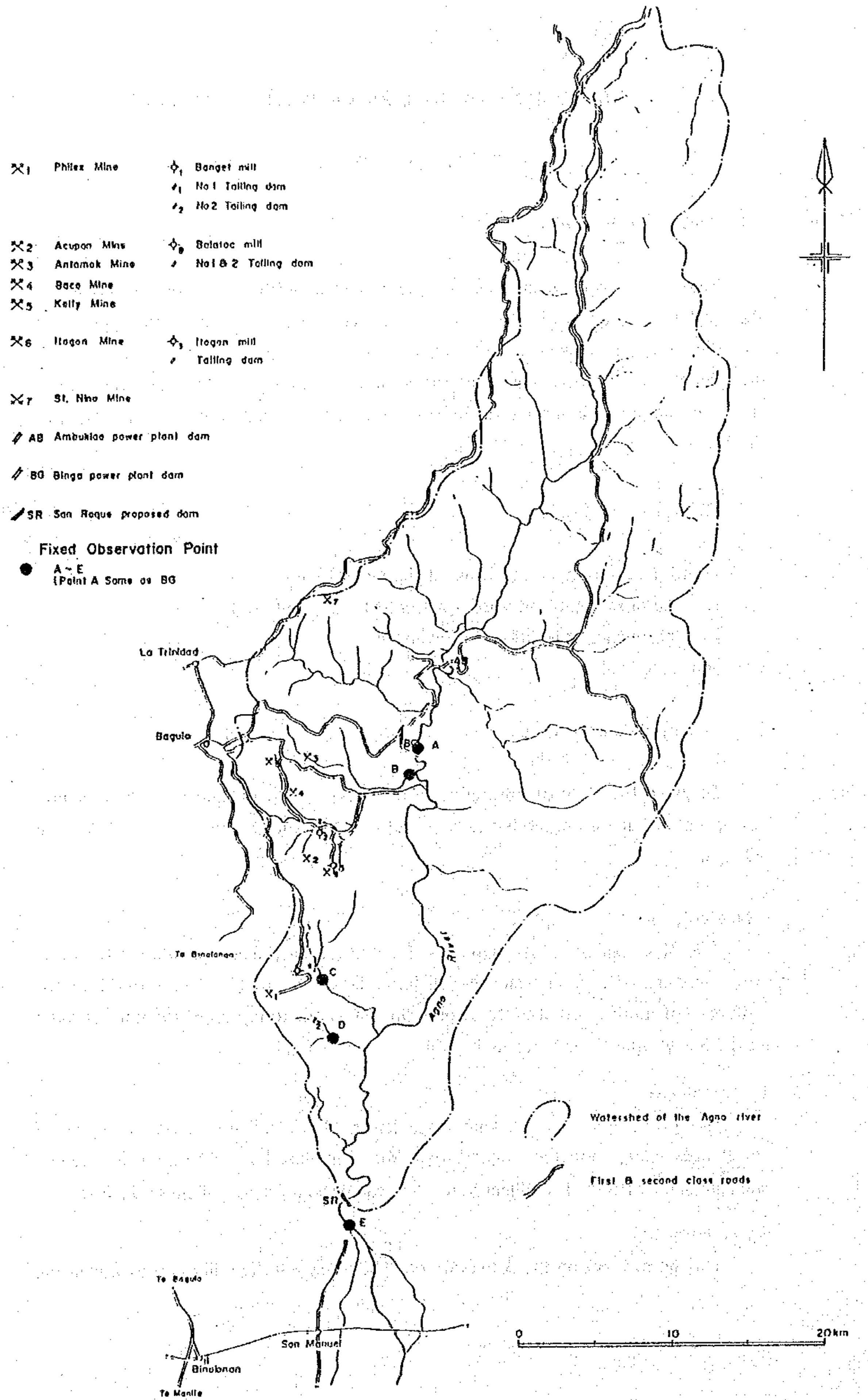


Fig. IV-1 Location Map of Observation Points and Mines

Tailings Dam No. 1, which belong to Philex Mining Corp., are located above this point.

Fixed Point D:

This point is set on the Manaa Creek. A 745 ML Adit and the Tailings Dam No. 2 of Philex are located above this point.

The Fixed Point D in combination with the Fixed Point C permits an observation of all the waste materials discharged from Philex.

Fixed Point E:

This point is fixed on the Agno River below the proposed dam site and affords a most important point of observation enabling an overall understanding of the state of pollution which is caused naturally or by mining activities.

Observation work which consists of the measurements of the flow rate, pH, electric conductivity (EC), dissolved oxygen (DO), turbidity and transparency and the collection of samples for chemical analysis were carried out for one year, beginning at the end of November, 1983 and ending at the end of November, 1984 in order to cover all of the seasonal changes. At the fixed Point A to D the observation and sampling were done once every 10 days, and at the Fixed Point E the observation was done 4 times a day, the water sampling once a day, and the SS sampling once every 10 days.

2) Investigation of Pollution Sources

Within the framework of the investigation of the pollution sources, field observation, sampling and various tests at the field laboratory were carried out.

Natural pollution

Data obtained at the Fixed Point A (Binga Dam) can be used to represent the condition of natural water.

To confirm the nature of natural sand, observation and samplings for chemical analysis and for grain size analysis on sediments in reservoirs of the Ambuklao dam and the Binga dam were conducted.

Pollution caused by mining activities

Mine drainages and mill tailings discharged by Philex Mining Corp., Benguet

Corp. and Itogon-Suyoc Mines Inc. were considered as the main pollution sources caused by mining activities.

Mine water is drained from the following adits;

Philex	1,020 ML Adit
	745 ML Adit
Benguet	Acupan Adit
	Antamok Adit
Itogon-Suyoc	1,300 ML Adit

Mine water from Philex 1,020 ML Adit is not discharged directly into the river, because it is utilized for mill water. At the adits, the flow rate and the water quality were observed and filtrates were collected for chemical analysis.

Mill tailings are discharged from the following mill plants:

Philex	Banget Mill
Benguet	Balatoc Mill
Itogon-Suyoc	Itogon Mill

At the outlets, measurement tests of water quality as well as collection of filtrate and solid samples for chemical analysis and for the field laboratory tests were conducted. Furthermore, observation on the mill tailings impounded in the tailings dam were carried out.

Tests in the field laboratory

The following tests were undertaken at the temporary field laboratory:

Extraction test by the shaking method

Extraction test by the aeration method

These tests aimed at determining the extent of an elution of heavy metals which take place when the tailings flow down streams.

Extraction test by the wet and dry repetition method

Model test

These tests aimed at determining the extent to which the pollutants were eluted from mill tailings settled in the San Roque Reservoir.

Grain size analysis (including Precipitation test)

This analysis aimed at understanding the grain size distribution of natural sand and mill tailings.

Extraction test for sieved samples under an acidic condition

This test aimed at understanding the elution from mill tailings after they have drifted down from the proposed reservoir.