REPUBLIC OF THE PHILIPPINES

NATIONAL IRRIGATION ADMINISTRATION

FEASIBILITY STUDY
ON
THE MATUNO RIVER DEVELOPMENT PROJECT

VOLUME 2
APPENDIX I AGRICULTURE COMPONENT

FEBRUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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APPENDIX I - I

METEOROLOGY AND HYDROLOGY

VOLUME 2

APPENDIX I

AGRICULTURE COMPONENT

APPENDIX I - I	METEOROLOGY AND HYDROLOGY
APPENDIX I - II	GEOLOGY AND CONSTRUCTION MATERIALS
APPENDIX I - III	SOIL AND LAND CLASSIFICATION
APPENDIX I - IV	AGRICULTURE AND AGRO-ECONOMY
APPENDIX I - V	SOCIO-ECONOMY
APPENDIX I - VI	WATER RESOURCES DEVELOPMENT
APPENDIX I - VII	IRRIGATION AND DRAINAGE
APPENDIX I - VIII	FLOOD CONTROL
APPENDIX I - IX	DAM AND RESERVOIR
APPENDIX I - X	INTEGRATED AGRICULTURE DEVELOPMENT APPROACH
APPENDIX I - XI	ORGANIZATATION AND MANAGEMENT
APPENDIX I - XII	IMPLEMENTATION SCHEDULE AND COST ESTIMATE

APPENDIX I-I

METEOROLOGY AND HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX I-I

METEOROLOGY AND HYDROLOGY

1. AVAILABLE DATA

1.1 Available Data

In the Project area, meteorological stations are installed at Bayombong, Solano and Sto. Domingo. However, the period of meteorological observation of these stations covers only 4 or 5 years, and is thus insufficient for proper data analysis. Among these stations, suitable data was collected from hydro-meteorological stations at Baretbet, Bagabag and Sto. Domingo, Bayombong, both eatablished in 1979 under the Magat River Multi-Purpose Project.

In the catchment basin of major rivers and their vicinity, except for a few stations which have comparatively well processed rainfall records, (25 years), meteorological stations do not provide adequate climatological data representive of the area. Location of the stations in the area and the observation period is provided in FIG. I-1, 2.

1.2 Installation of Meteor-hydrological Equipment

Due to shortage of meteor-hydrological data in the Project area, JICA established several meteor-hydrological stations. With the cooperation of NIA, equipment as listed in table form on the following page, was installed by the Team at several different locations. The siting of these stations presented in FIG. I-3 was determined on the basis of data required during the Project implementation stage. Since installation of these stations NIA has been carrying out observations thereat.

Location	Station	Equipment
Bayombong	Nueva Vizcaya P.I.O.	Rain Gauge (short term recording) Thermometer(maximum & minimum) Hydrometer (dry and wet valve) Anemometer Sunshine Recorder
Wacal	P.I.O. Hydromet Station	Thermometer(maximum & minimum) Hydrometer (dry and wet valve) Anemometer
Kayapa	New Station	Rain Gauge (long term recording)
Aritao	New Station	Rain Gauge (long term recording)
Batu	New Station	Water Level Gauge (short term recording)
Lamut	New Station	Water Level Gauge (short term recording)

2. METEOROLOGY

2.1 General Climate

Based on characteristics of rainfall pattern, the climate in the Philippines is classified by Caronas as follows:

Type I	Mindoro, Negros, Palawan, Western Luzon
Type II	Catanduanes, Sorsogon, Albay, Camarines, Camarines Sur, Quezon, Samar, Leyte
Type III	Cagayan, Isabela, Nueva Vizcaya, Mountain Province, Masbate, Romblon, Panay, Cebu, Negros, Palawan
Type IV	Batanes Province, Camarines Norte, Bondoc, Marinduque, Bohol, Albay

The Project area, belonging to Type III as shown in FIG. I-4, exhibits less marked seasonal change compared with other types. It may, however, be divided into two categories; a dry season between November and April, and a wet season between May and October. There is no distinct concentrated period of rainfall during the wet season. The dry season is particularly intense between January and March.

The Project area covers the basin of the Matuno River, adjacent to Baguio, the region of most abundant rainfall, and it thus abounds in water resources. The general topography of the area consists of a major valley saddled by Mt. Tabayoc (alt. 2,800m) to the north and by Mt. Palali (alt. 1,600m) to the south. Hence, the climate in the area is dominated by meteorological characteristics typical of valleys.

2.2 Temperature, Humidity and Wind

(1) Temperature

Since the area is located within the interior of the Luzon Region changes in temperature in the dry season are somewhat acute. However, the yearly average temperature is 26.1°C with 23.5°C in December as the minimum daily average, rising sharply to a maximum daily average of 29.9°C in April.

TABLE I-1 tabulates the monthly mean temperature recorded for Baretbet, Bagabag, Sto. Domingo and Bambang with some ommissions. FIG. I-5 shows the annual fluctuation of maximum, minimum and mean temperatures.

(2) Humidity

Humidity is generally high, although low humidity of around 70% occurs in March while humidity reaches a high of 91% in December. The relative humidity in Baretbet, Bagabag from March 1981 to January 1983 is tabulated in TABLE I-2.

(3) Wind

The subject area is located in a valley. Therefore, wind velocity is comparatively moderate, 5.0km/h to 8.0km/h from April to August. Well processed data on wind observation however, is not available.

2.3 Evaporation

Date of temperature, wind velocity, relative humidity and duration of sunshine in the Project area, all of which affect the amount of evaporation, is unfortunately inadequate for processing. Even data from the two hydro-met stations of Baretbet and Sto. Domingo is inadequate since recorded observation results of evaporation A-pan method date only from 1980. Therefore, data from nearby Talictic, (see the Data Book prepared as part of this feasibility study report) recorded from 1950 and located in climatic Type III, has been analysed to compensate for the insufficient data of the Project area. As constant daily observations from 1960-1967 were not recorded at Talictic station however, data was compiled from Tuguegarao station for that period. After 1973, Talictic Station shifted to Baligatan located near the existing Magat Dam site. Data from this location has been added to that from other stations to complete a 35 year record for analysis.

The results of analysis as given in TABLE I-3 and FIG. I-6 show the tendency of a mean 10-day evaporation period as comparatively high similar to the averages of Baretbet, Sto. Domingo, Wacal and Talictic. Data for the Project area is thus considered sufficient for analysis. TABLE I-4 shows the 10-day average evaporation in the service area.

2.4 Rainfall

The average annual rainfall in the mountain range where the Matuno River originates is estimated at 2,520mm, while that in the service area itself is as low as 1,480mm. Rainfall distribution in the service area is given in FIG. I-7. During May to October, about 75% of the annual rainfall occurs. Monthly rainfall fluctuates each year, the differential between the maximum year and minimum year of which is 200mm as shown in FIG. I-8. The rainfall distribution and the monthly maximum, minimum and mean rainfall in Salinas, Consuelo, Dupax, Bokod, Lamut and Itogon are presented in the Data Book.

2.4.1 Basic Data

Average rainfall for the service area and for the dam watershed area using the Thiessen polygon have been calculated separately. This approach is considered appropriate when adequate data is not available for the desired area. The observation points utilized were Salinas, Consuelo and Dupax within the basin, and Bokod and Lamut outside the basin. At Bokod, located across the mountain range from the Matuno basin, records from 1968 are not available. Thus, data covering 1956 through 1976 at Itogon, which correlates closely to that at Bokod, were utilized. 10-day rainfall data of Salinas, Consuelo, Dupax, Bokod, Lamut and Itogon are contained in the Data Book.

Monthly mean rainfall observed at each point is tabulated in TABLE I-5. Values of 10-day rainfall in the Data Book were calculated excluding missing observations, to derive an assumed average rainfall for any given period. (The same procedure is applied hereafter).

2.4.2 Average Rainfall in the Service Area

The center of the Project service area is near Solano where a rainfall observation station is located. However, data available at this station is not considered reliable because of frequent missing observations as well as the presence of irregular values. Although a rainfall observation station at Bagabag was installed in connection with the construction of Magat Dam, available records date only from 1978, and hence data does not correspond to available discharge records for the same period.

In the vicinity, there is a gaging station in Salinas, but its elevation of over 600m renders it unrepresentative of the area. Such being the case, despite the distance from the Project area, the average rainfall at 3 points, namely, Salinas, Lamut and Dupax, which are representative of the Nueva Viscaya valley, was utilized for determining the average rainfall for the Project service area.

However, when rainfall was not recorded at 2 of the three points, data at the other remaining point was regarded as 0mm. This was done in order to avoid possible irregularities in observation values at the 3 points and to ensure a margin of safety in computing effective rainfall. The daily calculations were carried out by computer, and TABLE I-6 shows the 10-day rainfall in the service area for 21 years (1956-76). Furthermore the breakdown results are contained in the Data Book as the daily rainfall for the service area for the same period. The average monthly rainfall for the service area for the same period is as follows.

Average Monthly Rainfall in the Service Area

unit: mm

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
21.3	16.8	39.9	82.4	158.7	127.9	203.5	254.3	192.5	175.5	132.2	77.2	1482.4

2.4.3 Average Rainfall in the Dam Watershed Area

The Thiessen polygon points covering the dam site basin are three observation stations, namely, Bokod, Salinas and Lamut.

As mentioned earlier, since the data at Bokod is available only from 1968, the data covering 1956 to 1967 at Itogon was supplemented for lacking data at Bokod. The same procedure was followed for Lamut, which also has records only from 1968, and for which no long standing observation station in the vicinity with correlative data exists. Thus, as shown below, the Thiessen polygon was divided into two parts, and for each period average rainfall was calculated by computer using the following area rates.

1956-67		1968-76	
Station	Rate of Area	Station	Rate of Area
Bokod	0.595	Bokod	0.464
Salinas	0.405	Salinas	0.333
		Lamut	0.203

The ten-day rainfall in the dam watershed area for 21 years (1956-76) is tabulated in TABLE I-7, and the average monthly rainfall for the same period is as presented below.

Average Monthly Rainfall in the Dam Watershed Area

unit: mm

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
25.9	19.1	48.3	97.3	258.1	304.5	426.9	506.1	337.5	236.8	127.2	65.0	2452.8

2.4.4 Annual Maximum Continuous Rainfall in Batu Basin

The selected observation points for the Theissen polygon and the rates for the areas in Batu basin are presented below.

1956-67		1968-76	
Station	Area Rate	Station	Area Rate
Bokod	0.228	Bokod	0.186
Salinas	0.460	Salinas	0.266
Consuelo	0.312	Consuelo	0.231
		Lamat	0.065
		Dupax	0.252

The maximum rainfall at Bokod during 1956-67 is interrelated with that at the Itogon point, with a coeffecient of 0.70. The annual maximum continous 1-day, 2-day and 3-day rainfall throughout each year from 1956-75 is presented on the following page.

ANNUAL MAXIMUM CONTINUOUS RAINFALL IN BATU BASIN

YEAR	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65
1 day	81.0	80.5	46.7	86.1	101.8	78.5	113.0	90.6	125.8	102.5
2 days	97.0	116.8	92.7	110.9	137.1	126.1	203.2	128.8	149.6	153.3
3 days	97.7	117.4	99.0	122.3	196.7	138.5	273.6	179.5	154.5	163.1

YEAR	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75
1 day	93.0	171.8	60.7	119.3	146.0	86.4	122.4	90.6	134.1	49.8
2 days	183.1	177.8	106.6	207.3	202.2	153.6	209.5	116.2	158.5	66.6
3 days	218.3	183.7	139.7	260.6	234.6	178.6	292.0	138.3	172.4	82.4

3. HYDROLOGY

3.1 River Condition

The Project area lies within the basin of the Cagayan River, the largest river in the Philippines, and on the upper most reaches of the Magat River, the main tributary of the Cagayan River. Therefore, rivers related to water resources and flood control in the Project area are all tributaries of the Magat River.

In this section, major rivers of upper Bagabag such as the Matuno and Lamut rivers are discussed. Small rivers like the Lanog River are mentioned under an independent section--Present Conditions of Irrigation and Drainage, APPENDIX I-VII.

3.1.1 Magat River

The Magat River traverses the province from south to north and makes up the Project boundary to the east.

At the lower reaches of the Magat River along the Project area the Magat Dam reservoir is located. The three rivers Matuno, Sta. Cruz and Sta. Fe meet at the upper reaches of Batu Bridge, Bambang, providing a total catchment area of 1,632km^2. The combined river length of the Sta. Cruz and Sta. Fe are shorter than the Matuno River, while longer by about 58km than the Sta. Fe River.

Maximum altitude in the catchment area of the Sta. Cruz and Sta. Fe rivers is about 1,600m. Natural vegetation in the catchment area is sparsely distributed causing erosion of hill slopes. This condition indicates an increasing tendency for soil erosion at the time of torrential rainfall, thereby increasing sedimentation in the river bed. This said tendency negatively affects the lower reaches of the Magat River resultant in flood aggravation. Currently, the government of the Philippines is undertaking, with financial aid from World Bank, a feasibility study on the Magat watershed. On the preliminary findings of this study, soil conservation and erosion control measures seem to be urgently necessary in this Project.

In the river basins of these 2 rivers, there are about 13,300ha of arable land with a water right of about 12.5m^3/s.

The main stream of the Magat River starts from Batu down to the junction of the Lamut River, about 35km. This section includes the intake weir of the Colocol Communal Irrigation System which is designed to irrigate about 3,300ha of land on the left bank in San Vicente near Bayombong. On the right bank of the river, Paitan and three other Communal Irrigation Systems have irrigation water intake structures serving about 520ha of land. Inhabitants along the river are dependent on this water supply for not only irrigation but also domestic consumption.

The river forms an isthmus where the stream is comparatively stable, while where the stream is not stable a distinguishable difference in water level between flood and drought periods can be observed. Therefore, except for the isthmus, it is difficult to divert water from the river for either irrigation or domestic supply.

3.1.2 Matuno River

Originating from Mt. Tabayoc, which has an elevation of 2,800m, the Matuno River stretches 81km, and contains a catchment area of 558km^2 at the Bante gaging station. This river, one of the tributaries of the Magat River, is the most abundant water resource of all the tributaries in the basin. Covered with lush rain forests, its catchment area can also be assumed to have superior water holding capacity.

This river mainly runs along the mountain side of the Project area, and only 2 Communal Irrigation Systems (Manamtam and Sto. Domingo) near the junction of Magat River, have an intake weir serving a total 580ha.

3.1.3 Lamut River

Originating from the mountain range near the Matuno River catchment area the Lamut River extends, down to the junction of the Magat River to form the northern Project boundary.

At the river junction the catchment area is about 400km^2, but the Lanog and Nangalisan rivers which are tributaries of the Lamut River join downstream and stretch across the Project area where they are used as irrigation water resources. These tributaries have a combined catchment area of about 156km^2.

Hydrological observation has been carried out by NIA with regards to water level by a staff gage installed on a bridge of National Highway No. 4, but the flow discharge amount has not been recorded. The Team observed the amount of flow discharge in July 1982 at this station at about 2.0m^3/s for 100km^2. Thus, drought season flow volume at the upper stream of the Project area with a catchment of about 225km^2has been estimated at 3.0-4.0m^3/s.

About 50% of the upper catchment basin of the Lamut River extends to the mountain area where vegetation is preserved and where rich water resources can be expected. Initially, dam construction in this mountain area was planned, but the foundation of the site was later determined as mainly composed of limestone which placed serious constraints on dam development.

Furthermore, in the mountainous area of the upper Lamut River the gently inclinated lands are used as terrace rice fields. In this area, 12 current CIS are currently serving 1,340ha with an additional 5 Communal Irrigation Projects proposed.

In consideration of the above circumstances, the water resources of the Lamut River would be difficult to develop on a large scale but could be considered under a supplemental scheme.

3.1.4 Other Tributaries of the Magat River

There are about 20 small rivers and creeks stretching throughout the Project area from the western hillside. Of these 12 major rivers currently serve the 33 Communal Irrigation Systems involving about 4,850ha. The total catchment area in the mountain area of these 12 rivers is about $120km^2$, made up primarily of the Bintawan River ($38km^2$), and Wacal Creek ($21km^2$), while the remaining are principally minor brooks.

There are no records for the flow discharge of these brooks and small rivers. During the initial study period, the Team carried out interviews, surveys and area reconnaissance. According to the results, most of the small rivers are dry in dry season, although in July 1982 flow discharge amount at the intake weir of Uddiawan CIS located on Bintawan River was estimated at about $1.4-1.6m^3/s/100km^2$.

In regard to these small rivers, as the water resources for irrigation are not reliable due consideration must be given to flow amount, and the economic aspect of construction and operation and management. However, since most of these small rivers flow together into the Lanog River, the downstream area can be irrigated by the same.

3.2 Daily Flow

3.2.1 Magat River

Discharge data of the Magat River which has a $1,784km^2$ catchment area was analyzed on the basis of a 17-year observation record from

1960-76 at the gaging station at Batu bridge. The annual average daily flow was 68.94m^3/s, while the mean annual drought flow was 19.76 m^3/s. Monthly average daily flow was 27.07m^3/s in the lowest month, equivalent to 1.52m^3/s per 100km^2 or almost half of the lowest monthly average daily flow of the Matuno River.

Magat River Monthly Average Discharge (Batu Gauging Station)

unit: m^3/s

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
49.15	34.47	28.13	27.07	46.08	68.48	95.09	108.75	110.56	106.35	89.32	61.19

1/ MEAN: 68.94

The above data is based on the review of daily flow data at Batu gauging station presented in 3.2.3. The 10-day mean discharge data at Batu is presented in TABLE I-8. Data for the period from 1956-59 are an estimated value and are derived from the correlation between Matuno River discharge at Bante as stated in 3.2.2.

3.2.2 Matuno River

Flow amount of the Matuno River which has a catchment area of 558km^2 was analyzed on the basis of a 17-year observation record from 1960-76 at the gauging station at Bante. The annual average daily flow is about 38.32m^3/s, and the mean annual drought flow is 13.06m^3/s in March and April. Monthly average daily flow in the lowest month of April is 16.91m^3/s equivalent to 3.03m^3/s per 100km^2. Monthly average daily flow in the highest month of October is 60.08m^3/s. This shows that the Matuno River is a rich water resource with an estimated annual flow amount of about $1.2 \times 10^9 m^3$.

Monthly Average Daily Flow of Matuno River (Bante Gauging Station)

unit: m^3/s

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
29.32	20.64	17.64	16.91	26.16	37.01	52.17	56.44	57.08	60.08	50.42	34.46

1/ MEAN: 38.32

The 10-day mean discharge data at Bante for a 17-year record from 1956-76 is tabulated in TABLE I-9. In the table, data from 1966-75 are revised based on the water level as stated in 3.2.3.

3.2.3 Review of the Daily Flow Data

(1) Bante Gauging Station

Observations were conducted from 1957-76 at the Bante gauging station. Observation records on water levels are available for the years 1966-75. Althouth there may have been some lapses in observation, the records were at first considered to be useful. However, the situation in fact turned out to the contrary when it was found that changes in the riverbed in a single year were drastic.

Also, records depicting relations between water levels and flow observed each year are considered lacking in accuracy as seen in FIG. I-9. Actually observed records indicating the changes in the riverbed over a one year period at the station are as indicated in TABLE I-10. Based on all available data a new rating curve for the records covering 1966-75 has been drawn in relation to the following conditions:

(a) The basic formulas for water level-flow

Water level: H (m)	Bante discharge (Q) m^3/s
0 - 0.99	$Q = 16 \times H^2 - 4 \times H$
1.00 - 1.99	$Q = 84 \times H^2 - 134 \times H - 62$
2.00 - 2.99	$Q = 80 \times H^2 - 120 \times H - 50$
3.00 -	$Q = 120 \times H^2 - 190 \times H - 100$

(b) Changes in riverbed are considered to be in the vertical direction and each H of the basic formula varies according to the values for large water increases in each year.

(c) The increase/decrease values of H are as presented on the following page.

Table of the Corrected Height of H

Year	No. of days	H (m)	Year	No. of days	H (m)
1966	I > 0	0.2	1970	I > 160	0.1
"	I > 141	-0.1	1971	I > 198	-0.2
"	I > 300	0.1	"	I > 300	0.0
"	I > 335	0.4	1972	I > 253	0.3
1967	I > 189	0.1	1973	I > 297	0.1
"	I > 269	-0.2	1974	I > 226	-0.2
"	I > 344	-0.1	1975	I > 79	-0.1
1968	I > 244	-0.25	"	I > 309	0.0
1969	I > 1	-0.3	1976	I > 145	0.0
"	I > 180	- -0	"	I > 247	0.1
"	I > 332	-0.25			

Note: I : Cumulative days from the begining of the year
H : Increased/decreased values of water level

(2) Batu Gauging Station

Observations were conducted from 1959-1975 at the Batu gauging station. Records maintained on water level are for the period from 1966-75. Upon close examination of the records, it was found that changes in the riverbed here were severe compared with those at Bante. Despite the fact that the major part of the Matuno River is a tributary of the Magat River, the latter river frequently has lower flow than that of the former as shown in FIG. I-10. This may be attributable to the fact that the observation frequencies of one to four times per year are not enough in relation to the yearly intensifying changes in the riverbed, thus making it difficult to grasp the real flow due to the lack of rating curves.

The maximum usable flow of the Magat River is roughly $25.0m^3$/s/day or less. Hence, it is essential to grasp an accurate minimum flow of this river. This can be accomplished by correlation with the Bante gauging station since the Batu gauging station is located downstream thereof.

The data obtained from 1-2 days' observation during the dry season in the period 1959 - 1975 at Bante and Batu stations can be construed as simultaneous observations. Thus, as shown in FIG. I-11, the following relative formula was determined by interrelating the Batu-Bante flow.

$$Q' \text{ Batu} = 1.68 \times Q' \text{ Bante} - 4.0$$

Based on the Bante flow, the Bato flow was determined from the following conditions:

Q BAN : Bante discharge

Q' BAT : Original Batu discharge

Q BAT : Bato discharge

$Q \text{ BAT} = Q' \text{ BAT}$

Where, $Q \text{ BAT} \geqq Q \text{ BAN}$

$Q \text{ BAT} \geqq 1.68 \times Q \text{ BAN} - 4.0$

$Q \text{ BAT} \leqq 2.5 \times Q \text{ BAN}$

3.3 Low Water Flow

Based on the data recorded at Batu and Bante gauging stations, the monthly lowest discharge of the Magat and Matuno rivers during the 17 year period from 1960-76 are tabulated in TABLE I-11.

The probable low water flow at both Batu and Bante gauging stations are shown in TABLE I-12.

3.4 Flood

3.4.1 Observed Peak Discharge

The observed peak discharge records in the Magat and Matuno rivers from 1960-1976 at Batu and Bante gauging stations including the additional observation of 1980 at Bante gauging station are tabulated in TABLE I-13. These records were observed at a fixed time but not recorded by the water level recorder. Accordingly, these records can not be considered as representive of actual maximum discharge, and it is presumed that further high water levels with a greater volume of flow might occur in the future.

3.4.2 Probable Rainfall

As stated earlier, the average basin rainfall is calculated based on the Thiessen polygon, and the said averages differ with the size of subject basin. Discussions on the probable rainfall in the Project area are presented hereunder.

(1) Probable rainfall at each observation point

Despite the fact that observation years are different among observation points, with some observations missing, the records can be used for calculating probable maximum annual rainfall as shown in TABLE I-14.

(2) Probable Rainfall at Damsite

The maximum annual average basin rainfall is based on the maximum value selected from among average daily values obtained at Thiessen polygon points. With this value as the maximum annual rainfall, probable values during the period 1960-1976 have been assumed for dam designs. (refer to TABLE I-15)

(3) Probable Rainfall at Batu

Unlike the damsite, Batu point has a larger basin with different rates of area on the Thiessen polygon, thus making differences in the occurence date of the maximum rainfall of the year.

The comparison of continuous rainfall between the annual average rainfall at the dam basin and the overall basin of the Magat River with the maximum average annual rainfall of the entire Batu basin, is presented in TABLE I-16. This comparison indicates that the maximum rainfall in the entire basin shows no trend of concentrated rainfall at the damsite, in particular, but rather a generally uniform pattern throughout the entire basin. Thus taking into account the simultaneity of the rainfall, these values have also been assumed as the rainfall at the damsite basin for flood control calculations.

3.4.3 Probable Flood

(1) Storage Function Method

The basic principal of storage function method for run-off analysis is the introduction of storage in a canal and in a basin in conversion of rainfall to run-off for the purpose of representing non-linear characteristics of the run-off phenomenon. The storage in a canal and basin is a parameter for the relation of storage volume and run-off amount.

First, the balance of rainfall and storage volume is calculated, whereby a hydrograph is obtained. Expressed in formula, storage volume in a basin (S) is expressed as an exponential function of run-off amount (Q) as given by:

$$Sl = K \cdot Ql^{P}$$

then applying the equation of motion and the equation of continuity, expressed as:

$$\frac{1}{3.6} \cdot f \cdot r \cdot A - Ql = dSl/dt$$

$$Ql(t) = Q\ (t + Tl)$$

where;

f:	inflow ratio
r:	average basin rainfall
A:	catchment area
Ql(t):	outflow considering lag-time
Sl:	apparent storage volume in a basin
Tl:	lag-time

Co-efficient K and P in the above equation are constants depending on the basin. The value of Sl has an inclination of becoming small when storage volume becomes large, and accordingly outflow in the next time period increases.

This storage function method developed in Japan appears adaptable to the Project basin because the run-off mechanism of the basin is quite similar to that of rivers in Japan. Especially, for assessing flood water based on relatively low water flow, this method is likely to give better results. Moreover the unit-graph method has a tendency to give false values for flood discharge when analyzed for relatively low water flow as in this case.

(2) Run-off Analysis

(a) Analysis for typhoon Nitang

Run-off analysis for typhoon Nitang (July 21-22, 1980) has been carried out on discharge data of Matuno River at Bante by a water level recorder and the rainfall data at Consuelo, Salinas, etc. recorded on an ombrograph.

As the results presented in FIG. I-12 show, actual and calculated run-off coincide closely. The storage function equation for the Matuno basin is $S = 60 \cdot Q^{0.5}$.

(b) Check analysis by typhoon Aring

The highest water level obtained by the water level recorder during typhoon Aring (Nov. 4-6, 1980) at Bante gauging station is 5.10m. This water level corresponds to a discharge of 2,200m^3/s on the water level discharge curve prepared on the basis of data at Bante.

On the other hand, calculated average basin rainfall by the Tiessen polygon based on data at Lagawe, Sto. Domingo and Bokod for the same period is tabulated in TABLE I-17. A check of typhoon Aring was accomplished based on this rainfall data and the above obtained storage function $S=60 \cdot Q^{0.5}$, as shown in FIG. I-13. As a result, calculated maximum flood discharge is 2,140m^3/s with base flow 50m^3/s, a value which coincides with the observed value of 2,200m^3/s.

On the basis of the above, the function of $S=60 \cdot Q^{0.5}$ for the Matuno River Basin has been adopted for subsequent flood analysis.

(c) Analysis for typhoon Aring at Magat Dam

Discharge of the Magat River during typhoon Aring was well recorded at the Magat Dam gauging station. After analysis using the rainfall data tabulated in TABLE I-17, a storage function of $S=450 \cdot Q^{0.5}$ was obtained, and as shown in FIG. I-14, calculated discharge and observed discharge coincide closely with each other.

In the same manner, the storage function of $S=140 \cdot Q^{0.5}$ for the Batu Basin, excluding the Matuno River Basin at Batu was obtained and flood analysis was calculated as shown in FIG. I-15.

(3) Probable Flood

The probable flood for flood control planning is analyzed below, whereas spillway design flood and diversion tunnel design flood are discussed in APPENDIX II under "HYDROPOWER COMPONENT".

(a) Distribution of probable rainfall

The river basin of the Project area is characterized by a relatively short depletion, and accordingly discharge from 1-day rainfall presents larger peak amounts than discharge caused by 2-day or 3-day rainfall.

Distribution of design rainfall is determined as the Talbot type. Based on a study of rainfall in Luzon island at Baguio, Tuguegarao and Aparri by PAGASA , the ratio of rainfall amount from 6 hours to 24 hours is 0.58, or $R6/R24=0.58$.

As stated earlier, rainfall in the area has no tendency to concentrate in the Matuno River Basin, consequently design rainfall is adopted uniformly for the entire Batu basin. The assumed 1-day probable maximum consecutive rainfall presented in TABLE I-15 is thus distributed for each return period as shown in TABLE I-18.

(b) Matuno River probable flood at Bante

The probable flood for this river has been determined utilizing the above calculated rainfall distribution and the storage function for the Matuno River, i.e. $S=450 \cdot Q^{0.5}$.

The result for a 100-year return period is presented in FIG. I-16, while for other possible return periods, a probable hydrograph is tabulated in TABLE I-19.

(c) Magat River probable flood at Batu

In calculating the probable flood for the Magat River, the entire basin at Batu is divided into two basins--Matuno River and the rest. The probable flood for the Matuno River is calculated above, and accordingly the flood from the rest of the basin is obtained as follows.

Analysis is made using the rainfall data mentioned in (a) above, storage function of the Magat River except for Matuno basin $S=140\ Q^{0.5}$, and the result for the 100-year return period as shown in FIG. I-17, whereas the results for the other return periods are tabulated in TABLE I-20.

The probable flood of the Magat River at Batu is determined by comparing of the above two probable floods, which are tabulated in TABLE I-21.

TABLE I-1

TABLE I-2

MONTHLY MEAN TEMPERATURE IN SERVICE AREA

Unit: mm/day

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
Baretbet, Bagabag													
1981		25.9	27.8	29.5	26.4	25.8	25.5	25.5	27.9	27.3	25.7	23.0	
1982	23.1	26.1	26.5	28.6	28.7	29.4	28.3	27.8	27.6	26.9	26.1	24.9	
1983	24.1												
Sto. Domingo, Bambang													
1981	24.1	-	31.0	31.5	25.1	24.8	24.8	25.1	24.6	22.8	-	23.0	
1982	-	-	-	-	-	-	25.7	24.1	23.5	23.3	23.7	23.2	
1983	23.5												
Mean	23.7	26.0	28.4	29.9	26.7	26.7	26.1	25.6	25.9	25.1	25.2	23.5	26.1

MONTHLY MEAN RELATIVE HUMIDITY IN SERVICE AREA

Baretbet, Bagabag

Unit: %

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981			64.6	68.9	84.3	83.2	87.8	83.0	87.8	93.0	91.5	90.3
1982	90.1	85.4	74.4	81.5	81.4	81.4	84.7	81.6	85.9	87.6	90.2	91.8
1983	90.9											
Mean	90.5	85.4	69.5	75.2	82.9	82.3	86.3	82.3	86.9	90.3	90.9	91.9

COMPARISON OF PAN EVAPORATION
BETWEEN SERVICE AREA AND TALICTIC

Station	Year	JAN				FEB				MAR				APR				MAY				JUN			
		F	H	L	T	F	H	L	T	F	H	L	T	F	H	L	T	F	H	L	T	F	H	L	T
Daretbet	1980									63 6	50 4	51 3	173.3	72.7	62 6	69.8	205.1	74.7	62.7	58.7	196.1	59.1	65.4	46.9	171.4
	1981	37.4	27.3	34 8	99.5	37.6	47.9	42.0	129.5	67.1	66 7	88 8	222.6	83 8	77.9	48.4	210 1	66 3	58 8	61.6	199.5	54.7	69.9	66.5	191.1
	1982	38 5	33.5	31 8	102.8	39.4	27.4	30.0	96 8	63.8	69.0	67.3	200 1	63 2	67.0	53.6	173.8	50.3	44.6	93.3	188.2	62.9	54.4	51.9	169.2
	mean	38.0	30.4	333	101.7	39 5	37.7	36 0	113.2	64.8	64.7	60 1	198 6	73 2	65.	57 3	146.3	63.8	55.4	71.2	203.4	58.9	6.2	55.1	177.2
Sto. Domingo	1980													66 0	70.4	77.0	213.4	77.4	54 3	40 7	180.4	62.7	68.0	57.2	104.9
	1981	32.0	43.3	48 4	123.7	55.4	64 7	46 7	166 8	67.2	75.4	91.8	214 4	83 7	75.8	44 6	215.1	77.6	48.3	68.2	194.1	52.6	45.6	53.6	151.8
	1982																								
	mean	32 0	43.3	48.4	123.7	55.4	64.7	46.7	166.8	67.2	75 4	91.8	234.4	74.9	73.1	66.3	214.3	77.5	51.3	58.5	187.3	57.7	55.3	55.4	168.4
Wacal	1980																	75.8	68.8	53.9	198.5	56.3	71.0	60.3	187 6
	1981	27.6	24 9	29.4	81.9	37 4	52.8	32.7	123 0	55.6	54.5	72.7	182 8	84.3	78.8	48.8	211.9	74.9	40.4	35.6	150.9	52.5	63.9	61.8	178.2
	1982	33.3	24.7	33.0	91.0																				
	mean	30 5	24.8	31.2	86.5	37.4	52.8	32.8	123.0	55.6	54.5	72.7	182.8	84.3	78.8	48 8	211.9	75.4	54.6	44.8	174.7	54.4	67.5	61.1	182.9
Mean in Service Area		33.5	32.8	37.6	103.9	44.1	51.7	38.5	134 3	62.5	64.9	77.9	205.3	77.5	72.6	57.5	207.6	72 2	53 8	58.2	184.2	57.0	62.0	57.2	196.2
Running Mean (Proposed Ep)		34.8	37.1	39.9	111.8	40.9	46.9	52.3	140 1	59 1	64.3	71.1	194.5	70.1	71.5	66.7	208.3	62.9	59.7	60.6	183.2	57.6	57.4	56.5	171.5
Talictic	1980																	89.0	62.3	76.0	227.3	73.0	82.6	67.6	223.2
	1981	38.7	33.8	28.4	100.9	40.0	52.1	45.6	137.7	67.2	69.3	100.0	236 5	101.0	91 6	62.5	254.1	79.8	50.4	61.2	191.4	75.2	47.0	57.9	100.1
	1982	36.3	34.9	35.5	106.7	43.1	45 9	45.0	124.0	60.8	74.6	68.7	204 1	65.3	48.8	80.4	194.7								
	mean	37.5	34.4	32 0	103.9	41.6	49.0	45.3	135.9	64.0	72.0	84.4	220.4	83.2	70.2	71.5	224.9	84.4	56.4	68.6	209.4	74.1	64.8	62 8	201.7
Running Mean (5 days)		34.6	36.3	38.9	109.8	38.9	46.4	54.4	139.7	62.9	69.8	74.8	207.5	76.3	78.7	73.1	220.1	70.2	71.0	70.0	211.2	65.3	65.5	53.8	194.6
Talictic	(1960-1976)	34.9	40.0	47.0	121.9	42.5	46.6	41.4	130.5	53.5	57.1	70.3	180.9	66.0	71.5	72.0	209.5	68.8	68.1	68 6	205.5	54.0	55.2	59 3	168.5
Running Mean (5 days)		38.4	40.5	42.2	121.3	43.5	46.2	48.2	137 9	53.8	57.7	63.7	175.2	67.4	70 0	69.3	206.7	69.8	66.3	62 9	199.0	61.0	58.9	55 9	175.8

Station	Year	JUL				AUG				SEP				OCT				NOV				DEC			
		F	H	L	T	F	H	L	T	F	H	L	T	F	H	L	T	F	H	L	T	F	H	L	T
Daretbet	1980	60.2	64.2	57 8	182.2	62.9	47.8	56.9	167.6	54.9	45.0	53.7	153.6	47.3	56.1	43.3	146.7	39.6	40.8	40.8	121.2	37.9	37.2	31.1	106.2
	1981	47.9	52.1	67 5	167.5	62.0	44.0	64.6	170.6	58.0	57.8	51.3	167.1	35.7	40.6	30.9	107.2	41.0	23.9	37.3	102.2	26.2	22.6	36.1	84.9
	1982																								
	mean	54.1	58 2	62.7	175.0	62.5	45.9	60.8	169.2	56.5	51.4	52.5	160.4	41.5	48.4	37.1	127.0	40.3	32.4	39.1	111.8	32.1	29.9	33.6	95.6
Sto. Domingo	1980	51.5	53.0	64 8	169.3	69.3	47.2	50.1	166.6	45.9	52.5	69.2	158 6	54 0	49.4	50.3	154.6	40.6	42.2	52.8	135.6	39.0	39.8	50.1	128.9
	1981	44.8	47.7	75 4	167.9	68.0	59.2	79.9	207.1	70.5	56.7	51 0	178 2	68.1	56.4	40.0	165.3	46.1	30.2	46.1	122.4	31.1	40.0	46.0	117.3
	1982																								
	mean	32.0	43.3	48.4	123.7	55.4	64.7	46 7	166.8	67.2	75.4	91.8	234.4	74.0	73.1	66.3	214.3	77.5	51.3	50.5	187.3	57.7	55.3	55.4	168.4
Wacal	1980	65.8	66.6	61.2	193.6	68.4	47.7	59.8	175.9	42 9	38 7	44.1	125.7	51.1	44.1	31.7	126.9	28.7	33.2	37 6	100.0	35.5	26.4	29.7	91.6
	1981	43.8	40.8	70.4	155.0	65.6	48.1	78.9	192 6	52.0	56.2	64.3	172.5	58.6	48.4	49.8	156.5	38.7	27.1	40.9	106.7	28.3	28.3	32.6	89 3
	1982																								
	mean	54.8	53.7	65.8	174.3	67.0	47.9	69.4	184.3	47.5	54.2	149.1		54.9	46.3	40.8	101.7	33.7	30.4	39.3	103.4	31.9	27.4	31.2	90.5
Mean in Service Area		52.4	54.1	66.2	172.7	66.1	49.0	65.1	100.2	54.1	51.2	54.1	159.4	52.6	49.2	41.2	143.0	39.1	33.0	42.6	114.7	33.0	32.4	37.7	103.1
Running Mean (Proposed Ep)		58.4	59.2	57.6	175.2	60.1	60.1	57.1	177.3	54 7	55.4	52.2	162.3	49.7	47.2	43.0	139.9	41.0	37 8	36.0	114.8	35.7	35.8	33.9	105.4
Talictic	1980	61.7	65.4	60.5	187.6	76.4	54.2	59.8	190.4	51.8	31.8	43 5	127.1	40.1	50.5	42.9	133.5	44.9	39.7	34.2	118.8	34.9	29.5	35.8	100.2
	1981	52 7	54.3	55.6	162.6	57.4	43.3	50.5	151.2	51.2	52.1	47.5	150.8	46.7	49.2	32.9	128.8	34.9	39.6	32.9	107.4	33.0	36.0	36.4	105.4
	1982																								
	mean	57.2	59.9	58.1	175.2	66.9	48.8	55.2	170.9	51.5	42.0	45.5	139.0	43.4	49.9	37.9	131.2	39.9	39.7	33.6	113.2	34.0	32.8	36.1	102.9
Running Mean (5 days)		60.6	60.6	58.2	179.4	57.8	56.1	52.9	166.8	48.6	47.5	46.5	142.6	43.7	43.3	42.2	129.2	40.2	37.0	36.0	113.2	35.2	34.8	35.0	105.0
Talictic	(1960-1976)	57.4	53.4	52.9	163.7	48.3	45.3	55.2	148.8	49.0	45.3	46.6	140.9	44.8	48.5	48.7	142.0	39.9	35.7	38.3	113.9	38.0	32.1	38.0	108.1
Running Mean (5 days)		55.6	54.3	51.5	161.4	56.0	50.1	48.6	149.7	48.3	48.2	46.8	143.3	46.8	45.7	43.5	136.0	42.7	40.1	36.8	119.1	36.4	36.3	36.6	109.3

PROPOSED EVAPORATION

Unit : mm

Month	10-day period	Observed mean EP at Baretbet	Observed mean EP at Sto. Domingo	Observed mean EP at Wacal	Mean EP in Service Area	Proposed EP (Running mean)
JAN	F	38.0	32.0	30.5	33.5	34.8
	M	30.4	43.3	24.8	32.8	37.1
	L	33.3	48.4	31.2	37.6	39.9
	T	101.7	123.7	86.5	103.9	111.8
FEB	F	39.5	55.4	37.4	44.1	40.9
	M	37.7	64.7	52.8	51.7	46.9
	L	36.0	46.7	32.8	38.5	52.3
	T	113.2	166.8	123.0	134.3	140.1
MAR	F	64.8	67.2	55.6	62.5	59.1
	M	64.7	75.4	54.5	64.9	64.3
	L	69.1	91.8	72.7	77.9	71.1
	T	198.6	234.4	182.8	205.3	194.5
APR	F	73.2	74.9	84.3	77.5	70.1
	M	65.8	73.1	78.8	72.6	71.5
	L	57.3	66.3	48.8	57.5	66.7
	T	196.3	214.3	211.9	207.6	208.3
MAY	F	63.8	77.5	75.4	72.2	62.9
	M	55.4	51.3	54.6	53.8	59.7
	L	71.2	58.5	44.8	58.2	60.6
	T	203.4	187.3	174.7	184.2	183.2
JUN	F	58.9	57.7	54.4	57.0	57.6
	M	63.2	55.3	67.5	62.0	57.4
	L	55.1	55.4	61.1	57.2	56.5
	T	177.2	168.4	182.9	176.2	171.5
JUL	F	54.1	48.2	54.8	52.4	58.4
	M	58.2	50.4	53.7	54.1	59.2
	L	62.7	70.1	65.8	66.2	57.6
	T	175.0	168.7	174.3	172.7	175.2
AUG	F	62.5	68.7	67.0	66.1	60.1
	M	45.9	53.2	47.9	49.0	60.1
	L	60.8	65.0	69.4	65.1	57.1
	T	169.2	186.9	184.3	180.2	177.3
SEP	F	56.5	58.2	47.5	54.1	54.7
	M	51.4	54.6	47.5	51.2	55.4
	L	52.5	55.6	54.2	54.1	52.2
	T	160.4	168.4	149.1	159.4	162.3
OCT	F	41.5	61.5	54.9	52.6	49.7
	M	48.4	52.9	46.3	49.2	47.2
	L	37.1	45.6	40.8	41.2	43.0
	T	127.0	160.0	141.7	143.0	139.9
NOV	F	40.3	43.4	33.7	39.1	41.0
	M	32.4	36.2	30.4	33.0	37.8
	L	39.1	49.2	39.3	42.6	36.0
	T	111.8	129.1	103.4	114.7	114.8
DEC	F	32.1	35.1	31.9	33.0	35.7
	M	29.9	39.9	27.4	32.4	35.8
	L	33.6	48.2	31.2	37.7	33.9
	T	95.6	123.2	90.5	103.1	105.4
ANNUAL		1,829.4				1,884.3

MONTHLY MEAN RAINFALL

Unit : mm

Month	Salinas	Consuelo	Dupax	Bokod	Lamut	Itogon
JAN	18.5	29.5	18.9	7.9	90.5	8.6
FEB	18.1	21.6	6.4	2.6	34.2	20.0
MAR	47.9	44.8	27.8	32.4	60.4	34.7
APR	96.3	66.7	80.1	60.8	105.6	98.2
MAY	182.6	187.6	149.3	317.7	196.4	292.3
JUN	138.3	219.2	142.5	319.7	197.1	428.3
JUL	299.7	355.3	184.8	626.5	220.2	665.1
AUG	396.0	361.8	180.0	566.1	244.7	691.4
SEP	227.3	341.3	194.3	423.8	208.9	484.3
OCT	231.9	284.5	166.6	281.0	257.4	304.9
NOV	174.1	185.8	86.6	136.6	205.9	122.8
DEC	109.0	71.2	32.1	16.4	92.2	27.0
TOTAL	1,939.7	2,169.3	1,269.4	2,791.5	1,913.5	3,177.6

TABLE I-6

10-DAY RAINFALL IN SERVICE AREA

Year		1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	MEAN
JAN		10.2	25.4	18.4	15.2	10.3	2.0	11.3	14.4	4.5	26.4	15.8	34.9	30.9	0.0	31.6	43.4	61.1	0.0	8.9	0.0	83.7	21.3
	1)	0.0	25.4	1.9	0.0	6.4	0.0	11.3	2.0	4.5	0.0	8.9	6.4	5.1	0.0	31.6	39.2	14.6	0.0	0.0	0.0	59.4	10.3
	2)	10.2	0.0	1.0	0.0	1.3	2.0	0.0	9.4	0.0	0.0	0.0	14.5	0.0	0.0	0.0	4.2	4.0	0.0	0.0	0.0	24.3	3.4
	3)	0.0	0.0	15.6	15.2	2.6	0.0	0.0	3.0	0.0	26.4	6.9	14.0	25.8	0.0	0.0	0.0	42.5	0.0	8.9	0.0	0.0	7.7
FEB		5.8	0.0	14.9	13.2	207.7	0.0	0.0	15.7	1.8	9.6	0.0	14.8	0.0	0.9	13.8	47.8	2.7	0.0	2.7	2.1	0.0	16.8
	1)	0.0	0.0	2.5	2.5	31.8	0.0	0.0	4.3	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
	2)	5.3	0.0	0.0	4.3	33.1	0.0	0.0	11.4	0.0	0.0	0.0	2.9	0.0	0.0	0.0	5.1	0.0	0.0	2.7	0.0	0.0	3.1
	3)	0.5	0.0	12.4	6.4	142.8	0.0	0.0	0.0	1.8	3.3	0.0	5.9	0.0	0.9	13.8	42.7	2.7	0.0	0.0	2.1	0.0	11.2
MAR		12.7	73.6	16.2	87.8	3.8	137.0	74.8	63.7	11.9	39.9	53.3	14.9	0.0	24.2	73.5	42.5	24.9	0.0	5.3	13.1	65.7	39.9
	1)	7.6	0.0	15.4	38.1	0.0	62.0	10.5	0.0	4.3	3.3	33.0	2.9	0.0	0.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3
	2)	0.0	20.3	0.0	29.7	0.0	73.0	4.6	0.0	4.5	0.0	0.0	6.3	0.0	24.2	4.8	39.8	19.7	0.0	0.0	0.0	40.0	12.8
	3)	5.1	53.3	0.8	20.0	3.8	0.0	59.7	63.7	3.1	36.6	20.3	5.7	0.0	0.0	29.7	2.8	5.2	0.0	5.3	13.1	25.7	16.9
APR		113.8	107.7	75.0	55.2	154.3	107.4	118.9	0.0	33.8	102.7	100.9	115.3	178.8	38.5	81.2	9.4	170.2	21.8	45.7	91.1	8.5	82.4
	1)	35.5	48.0	0.0	6.9	101.6	0.0	5.8	0.0	1.8	3.8	23.4	8.7	0.0	38.5	20.5	0.0	18.4	0.0	0.0	22.4	8.5	16.4
	2)	2.1	14.0	68.6	23.4	15.2	36.8	50.6	0.0	19.0	52.6	55.9	71.7	0.0	0.0	0.9	3.3	22.5	0.0	36.2	0.0	0.0	22.5
	3)	76.2	45.7	6.4	24.9	37.5	70.6	62.5	0.0	13.0	46.3	21.6	34.9	178.8	0.0	59.8	6.1	129.4	21.8	9.5	68.7	0.0	43.5
MAY		71.9	137.2	168.2	256.2	188.7	124.8	80.3	84.3	226.4	117.8	450.1	231.6	114.5	91.8	131.1	329.1	70.8	42.5	96.0	123.1	196.6	158.7
	1)	69.6	0.0	60.9	44.2	19.3	23.4	21.5	0.0	45.5	35.5	101.6	47.5	42.0	31.8	18.8	71.3	0.0	11.4	22.7	8.3	0.0	32.2
	2)	0.0	12.7	8.7	64.6	62.2	92.8	14.0	71.6	91.7	51.8	77.4	120.9	41.3	60.0	43.8	199.4	52.1	31.1	52.8	45.6	0.0	56.4
	3)	2.3	124.5	98.6	147.4	107.2	8.6	44.8	12.7	89.2	30.5	271.1	63.2	31.1	0.0	68.5	58.4	18.7	0.0	30.5	69.2	196.6	70.1
JUN		239.3	111.8	111.2	117.6	274.5	176.3	90.0	165.4	156.9	61.2	117.4	223.9	62.7	31.6	221.7	84.3	55.7	69.9	83.2	49.0	183.3	127.9
	1)	30.5	30.5	84.8	3.8	43.1	41.9	4.5	72.0	34.3	29.3	76.7	71.9	20.8	23.7	122.0	11.3	28.6	0.0	14.8	18.9	0.0	36.4
	2)	21.3	30.5	23.6	73.7	92.9	32.7	21.6	23.9	68.0	25.6	30.0	54.8	7.8	1.4	67.8	55.1	0.0	41.9	49.7	30.1	52.0	38.4
	3)	187.5	50.8	2.8	38.1	138.5	101.7	63.9	69.5	54.6	6.1	10.7	97.2	34.1	6.5	31.9	17.9	27.1	27.9	18.6	0.0	131.3	53.2
JUL		165.3	176.7	94.7	175.0	191.7	337.8	336.2	285.2	131.5	234.9	146.2	200.8	136.5	401.9	143.9	230.0	475.4	57.5	138.2	62.3	152.7	203.5
	1)	4.3	38.6	17.0	25.1	85.8	146.3	4.5	70.6	36.8	127.5	28.4	44.6	33.8	27.2	0.0	74.2	155.6	49.2	4.9	40.0	41.9	50.3
	2)	140.7	118.6	72.6	18.2	59.4	138.7	98.3	164.7	17.8	103.6	93.6	59.0	21.1	39.1	56.0	95.1	177.2	0.0	61.6	22.3	12.0	74.7
	3)	20.3	19.5	5.1	131.7	46.5	52.8	233.4	49.9	76.9	3.8	24.2	97.2	81.6	335.6	87.8	60.7	142.6	9.3	71.7	0.0	98.8	78.5
AUG		185.3	203.5	417.3	246.8	429.0	123.5	225.2	247.7	241.0	356.2	303.0	330.4	364.0	409.5	207.4	89.3	211.7	242.1	87.0	163.7	258.4	254.3
	1)	105.3	45.7	242.4	37.3	182.7	17.8	37.8	35.1	65.5	0.0	164.4	86.1	1998.3	115.6	47.5	0.0	77.2	48.2	11.9	44.6	117.2	75.3
	2)	7.6	55.4	5.3	141.9	168.1	95.6	138.2	163.0	88.6	122.4	34.0	127.4	95.6	122.5	44.8	27.7	119.4	60.1	61.8	18.5	94.4	85.4
	3)	72.4	102.4	169.6	67.6	78.2	10.1	48.2	49.6	86.9	233.8	104.6	116.9	170.1	171.4	115.0	61.6	15.1	133.8	13.4	100.6	46.8	93.7
SEP		187.9	365.7	302.7	172.1	337.8	69.0	222.6	205.6	259.8	190.9	82.9	334.4	155.9	75.2	313.8	260.2	170.2	84.1	25.5	88.4	136.9	192.5
	1)	101.6	223.3	107.8	56.4	219.6	4.5	12.4	115.7	50.6	25.4	31.5	98.0	67.9	44.2	108.8	97.4	20.1	35.0	0.0	63.9	33.9	72.3
	2)	16.5	134.3	78.7	18.0	99.4	28.2	62.4	46.0	86.9	108.8	49.1	63.2	44.4	0.0	179.1	31.9	114.6	35.2	7.7	17.3	103.0	63.1
	3)	69.8	8.1	116.2	97.7	18.8	36.3	147.8	43.9	122.3	56.7	2.3	173.2	43.6	30.9	25.8	130.9	35.6	13.8	17.8	7.2	0.0	57.1
OCT		135.9	169.1	328.7	111.9	233.1	213.9	21.6	25.4	300.0	110.3	82.8	252.4	70.2	120.1	374.0	406.1	11.2	209.8	183.2	118.9	126.0	175.5
	1)	54.6	91.7	101.8	67.5	67.3	87.4	8.9	12.2	262.9	75.1	14.5	156.8	37.9	80.4	84.9	341.6	11.2	115.2	19.8	8.0	99.1	85.7
	2)	28.0	77.4	37.0	27.9	163.3	112.0	12.7	3.6	39.4	15.3	17.0	84.8	22.5	32.9	230.7	28.9	0.0	94.6	75.5	95.2	0.0	57.1
	3)	53.3	0.0	189.9	16.5	2.5	14.5	0.0	9.6	77.7	19.9	51.3	10.8	9.9	6.8	58.4	35.6	0.0	0.0	87.8	15.7	26.9	32.7
NOV		238.8	101.6	91.7	190.1	13.2	130.6	47.6	27.4	254.5	101.7	196.5	399.6	29.3	50.8	153.3	163.4	151.3	95.8	152.4	139.7	46.4	132.2
	1)	40.6	0.0	70.9	11.6	3.1	19.1	36.9	7.6	93.2	42.2	65.1	147.0	0.0	0.0	50.4	17.5	108.2	2.6	70.0	124.7	24.5	44.5
	2)	99.1	101.6	20.8	170.4	7.6	0.0	5.6	0.0	139.2	48.0	3.8	147.4	1.9	5.7	57.2	67.7	8.0	50.8	37.4	15.0	21.9	48.1
	3)	99.1	0.0	0.0	8.1	2.5	111.5	5.1	19.8	22.1	11.5	127.6	105.2	27.4	45.1	45.7	78.1	35.1	42.4	45.0	0.0	0.0	39.6
DEC		169.4	17.5	9.4	77.8	14.7	129.1	21.6	98.1	139.5	33.3	47.9	315.0	14.0	39.9	177.8	102.9	6.7	0.0	75.0	111.1	21.6	77.2
	1)	73.4	1.3	0.0	54.5	7.6	0.0	21.6	6.9	3.6	0.0	26.6	105.5	0.0	0.0	93.3	8.4	0.0	0.0	23.5	10.0	21.6	21.8
	2)	47.1	16.2	9.4	19.0	4.6	0.0	0.0	91.2	135.9	7.9	5.8	103.7	14.0	0.0	84.5	0.0	6.2	0.0	51.6	63.8	0.0	31.5
	3)	48.9	0.0	0.0	4.3	2.5	129.1	0.0	0.0	0.0	25.4	15.5	105.8	0.0	39.9	0.0	94.5	0.5	0.0	0.0	37.3	0.0	24.0
TOTAL		1536.3	1489.8	1648.4	1518.9	2058.8	1551.4	1249.1	1232.9	1841.6	1384.9	1596.8	2468.0	1156.6	1284.2	1923.0	1808.4	1411.8	823.6	903.1	962.3	1279.7	1482.4

10-DAY RAINFALL IN DAM WATERSHED AREA

Year	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	MEAN
JAN	10.2	15.0	-	12.3	26.5	0.8	6.1	8.2	1.8	26.1	22.7	14.1	-	4.4	77.3	59.0	69.7	0.9	61.5	51.9	52.8	25.9
1)	0.0	15.0	1.8	0.0	2.6	0.0	6.1	1.7	1.8	0.0	19.9	2.6	0.0	0.0	68.4	52.2	46.3	0.5	9.5	4.8	39.8	13.0
2)	10.2	0.0	-	0.0	0.5	0.8	0.0	5.3	0.0	0.0	0.0	5.9	0.0	4.4	8.9	5.6	1.6	0.0	22.2	21.8	13.0	5.0
3)	0.0	0.0	-	12.3	23.4	0.0	0.0	1.2	0.0	26.4	2.8	5.7	-	0.0	0.0	1.2	21.8	0.5	29.8	25.3	0.0	7.9
FEB	21.9	4.2	-	13.2	153.6	0.0	3.4	6.4	0.9	7.3	10.9	15.8	1.2	5.2	33.0	79.7	2.3	8.6	3.0	10.0	5.6	19.1
1)	0.0	0.0	2.5	2.5	14.0	0.0	0.0	1.7	0.0	2.6	0.0	2.4	0.0	4.6	0.7	6.3	1.2	8.6	0.0	0.0	1.3	2.3
2)	21.9	0.0	0.0	4.3	37.0	0.0	0.0	4.6	0.0	0.0	0.0	1.2	0.1	0.0	0.0	0.0	0.0	0.0	1.1	9.1	2.2	3.9
3)	0.0	4.2	-	6.4	102.6	0.0	3.4	0.0	0.9	4.8	10.9	12.2	1.1	0.6	32.3	73.4	1.1	0.0	1.9	0.8	2.1	12.9
MAR	29.8	81.2	1.0	44.8	4.4	125.8	38.3	63.7	14.2	73.8	42.9	7.6	37.8	26.1	86.9	106.6	44.7	14.7	20.5	55.8	83.8	48.3
1)	4.1	21.0	0.2	19.4	0.0	86.6	11.5	0.0	3.4	2.6	32.4	2.2	32.3	0.0	37.7	14.6	0.0	0.0	0.1	10.3	34.8	14.9
2)	9.5	35.8	0.0	17.5	0.0	38.4	1.9	23.6	3.0	0.0	0.0	2.5	1.3	23.0	3.2	62.8	14.6	0.0	0.7	29.1	30.2	14.2
3)	16.1	24.4	0.8	18.8	4.4	0.8	25.0	40.1	7.7	71.2	10.5	2.9	4.2	3.1	46.0	29.2	30.1	14.7	19.7	16.3	18.7	19.3
APR	166.4	116.0	79.9	26.5	147.7	99.5	151.4	13.0	91.6	132.0	75.9	138.4	103.8	52.1	88.8	70.9	211.6	19.8	130.0	85.7	43.3	97.3
1)	26.8	50.1	0.0	2.8	62.5	0.0	44.4	0.0	1.8	1.5	16.7	91.9	0.0	40.4	30.4	26.7	62.9	0.0	18.0	29.5	35.5	25.8
2)	16.7	20.2	68.6	13.6	21.4	22.9	20.5	13.0	47.6	49.7	36.9	36.7	16.2	1.0	3.7	2.2	56.7	0.0	79.8	0.0	7.8	25.5
3)	122.9	45.7	11.3	10.1	63.8	76.5	86.5	0.0	42.2	80.7	22.3	9.7	87.6	10.7	54.7	42.0	92.0	19.8	32.2	56.2	0.0	46.0
MAY	178.4	100.1	264.4	243.4	256.3	197.9	135.1	80.0	282.3	284.2	644.7	168.1	190.8	210.2	189.8	502.4	227.8	231.3	147.7	236.1	646.7	250.1
1)	108.7	0.0	123.7	57.3	52.4	38.5	9.0	0.0	43.8	60.5	101.1	20.5	50.0	63.4	24.9	135.9	61.5	99.1	32.2	71.4	86.5	59.4
2)	10.0	13.7	15.4	101.5	64.8	93.0	17.9	41.7	113.8	26.2	337.8	82.8	57.2	122.9	78.3	278.6	80.9	85.4	34.0	51.3	31.4	83.7
3)	39.7	86.4	125.1	87.5	139.1	66.5	108.6	38.3	124.6	189.5	185.8	64.8	83.6	23.9	86.6	88.0	85.4	46.7	81.6	113.4	528.8	114.9
JUN	210.1	396.8	301.5	189.3	344.8	372.1	162.6	632.4	370.0	246.2	152.0	565.5	199.2	143.5	323.2	433.4	146.5	221.2	279.2	134.4	570.6	904.3
1)	44.8	73.6	230.4	55.9	95.6	49.2	64.6	326.3	130.6	83.3	66.5	388.4	56.3	78.0	169.4	173.8	87.4	42.9	189.3	21.9	23.2	116.7
2)	36.3	50.8	51.5	68.4	80.5	20.4	49.4	94.3	79.1	44.7	44.6	48.3	30.7	46.4	131.7	167.6	13.0	92.5	45.5	35.9	113.9	164.1
3)	129.0	272.3	19.6	63.9	168.7	302.5	48.6	211.8	160.3	118.2	40.9	128.8	112.3	19.2	22.1	92.0	46.0	85.9	44.5	76.6	433.5	123.7
JUL	205.6	281.2	455.4	275.3	174.0	653.3	893.1	346.7	171.9	613.8	236.2	273.4	405.1	848.4	311.3	422.4	1466.3	171.6	248.0	203.7	258.2	926.9
1)	30.4	68.3	104.4	42.1	66.8	224.5	86.2	76.2	47.3	83.8	120.9	93.1	69.2	105.7	57.3	84.4	360.6	57.6	37.6	63.2	63.1	192.5
2)	146.1	184.7	265.1	60.9	60.3	316.4	466.6	175.5	52.7	471.3	61.6	36.3	89.3	168.5	64.7	249.8	580.7	64.4	178.0	47.8	34.5	179.8
3)	29.2	28.1	85.9	172.3	46.9	112.4	340.4	95.0	72.0	59.6	53.6	143.9	246.7	574.2	189.3	138.3	525.0	49.5	32.3	92.7	160.6	154.7
AUG	442.2	426.2	427.8	290.9	1197.4	308.4	357.3	349.0	1007.8	291.4	357.9	678.4	772.5	890.4	397.7	368.0	529.6	404.9	505.0	364.6	259.9	506.1
1)	138.0	88.1	191.7	69.7	269.6	47.9	65.2	39.7	481.9	59.7	161.7	183.7	136.2	443.8	100.7	99.4	199.9	127.6	74.1	136.4	110.9	153.6
2)	143.1	205.3	43.7	124.5	714.8	117.4	102.5	224.8	406.6	95.6	109.6	219.3	240.3	196.0	127.0	152.6	224.3	108.0	269.1	96.8	65.4	189.8
3)	161.1	132.8	192.4	96.7	213.0	143.1	189.6	84.5	119.4	136.2	86.6	275.3	396.1	250.5	170.0	116.0	105.4	169.2	161.8	131.4	83.5	162.6
SEP	494.0	477.5	393.2	197.5	375.5	266.2	428.0	571.4	324.6	336.7	294.6	288.2	431.9	314.0	379.3	307.7	276.9	146.5	222.6	244.2	316.6	337.5
1)	48.1	75.1	66.6	25.1	53.6	84.5	41.6	13.9	304.5	72.2	11.6	112.6	40.7	82.9	235.4	408.2	27.5	218.2	115.7	36.4	95.5	142.4
2)	52.8	71.5	43.2	53.8	132.6	66.6	42.6	10.6	107.2	8.5	21.4	399.2	9.6	53.1	173.4	61.3	12.6	224.3	231.0	108.9	138.6	103.0
3)	93.4	6.7	86.5	-	19.3	4.9	8.9	11.5	69.7	19.6	40.6	5.4	4.0	18.1	76.8	18.1	2.7	37.4	270.6	34.3	82.5	92.0
OCT	194.3	153.2	196.3	-	205.4	156.1	93.1	35.9	481.4	100.3	73.6	517.2	54.3	154.0	485.7	487.5	42.8	479.8	617.3	179.6	144.8	236.8
1)	48.1	75.1	66.6	25.1	53.6	84.5	41.6	13.9	304.5	72.2	11.6	112.6	40.7	82.9	235.4	408.2	27.5	218.2	115.7	36.4	111.1	104.1
2)	52.8	71.5	43.2	53.8	132.6	66.6	42.6	10.6	107.2	8.5	21.4	399.2	9.6	53.1	173.4	61.3	12.6	224.3	231.0	108.9	18.2	90.6
3)	93.4	6.7	86.5	-	19.3	4.9	8.9	11.5	69.7	19.6	40.6	5.4	4.0	18.1	76.8	18.1	2.7	37.4	270.6	34.3	15.5	42.2
NOV	177.3	71.8	47.7	210.6	46.5	72.8	41.2	15.4	214.8	66.0	213.2	290.1	35.3	120.6	202.2	212.6	125.7	140.6	242.7	80.5	43.0	127.2
1)	26.9	40.9	31.5	6.4	4.3	7.7	24.2	3.1	65.9	25.7	50.5	180.8	3.7	21.1	46.8	28.7	100.5	12.4	112.9	69.9	15.5	41.9
2)	77.3	30.9	10.7	200.9	41.2	0.0	2.3	4.3	115.2	35.6	88.8	75.0	11.4	50.3	81.8	107.3	5.7	75.1	44.3	10.6	21.1	51.9
3)	73.1	0.0	5.4	3.3	1.0	65.1	14.8	8.0	33.7	4.7	73.9	34.3	20.2	49.3	73.7	76.6	19.5	53.1	85.5	0.0	6.4	33.4
DEC	78.4	17.3	9.4	33.7	7.4	129.1	8.9	91.8	105.9	13.5	-	170.7	17.9	53.7	149.1	148.4	22.9	37.3	107.8	91.0	25.2	65.0
1)	36.4	1.3	2.8	24.2	3.1	0.0	8.9	22.9	2.9	0.0	12.2	36.0	0.0	5.6	44.0	14.5	14.3	4.5	22.9	14.2	12.7	13.5
2)	22.2	16.2	6.6	7.7	1.9	0.0	0.0	68.8	102.9	3.2	10.0	43.9	17.9	13.5	77.7	9.4	8.4	28.0	79.5	44.6	10.0	27.3
3)	19.8	0.0	0.0	1.7	2.5	129.1	0.0	0.0	0.0	10.3	-	90.7	0.0	34.5	27.4	124.5	0.2	4.9	5.4	32.2	2.5	24.3
TOTAL	2208.4	2140.6	-	-	2939.4	2382.0	2318.6	2214.0	3067.1	2191.8	-	3127.6	-	2822.6	2724.1	3248.6	3166.7	1877.2	2585.3	1737.4	2450.4	2452.8

TABLE I-7

TABLE I-8

MAGAT RIVER REVISED MONTHLY DISCHARGE AT BATU
(Catchment Area : 1,632km^2)

unit: m^3/sec

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	ANNUAL MRAN
1957*	55.49	35.03	30.78	30.74	28.17	30.20	38.91	48.32	76.88	57.47	62.12	41.60		
1958*	35.09	32.32	31.38	33.63	34.25	44.79	46.38	183.14	105.84	199.41	95.02	55.07		
1959*	44.37	34.14	39.11	23.99	34.64	25.94	27.06	36.82	59.86	58.43	103.52	114.27		
1960	72.34	96.88	60.10	49.65	45.69	64.44	83.26	219.96	141.43	139.07	55.69	33.40	1061.92	88.49
1961	22.65	17.36	27.06	20.23	29.09	42.31	73.77	74.32	87.20	131.79	50.72	28.19	604.69	50.39
1962	22.75	18.73	30.34	39.96	41.56	41.84	151.92	102.45	130.89	58.75	116.45	46.86	802.50	66.88
1963	35.25	50.59	38.44	28.18	33.55	112.95	97.31	156.14	169.09	89.31	59.12	94.08	964.01	80.33
1964	32.39	27.05	32.89	28.65	46.53	68.36	93.96	131.06	118.02	146.41	196.23	146.06	1067.62	88.97
1965	113.53	74.39	33.14	29.21	34.98	53.34	81.33	44.75	117.90	78.61	60.32	52.27	773.77	64.48
1966	42.44	33.58	28.63	18.56	161.20	65.77	71.62	76.60	50.58	28.45	176.50	116.66	870.60	72.55
1967	64.53	38.89	24.08	67.57	92.59	182.80	118.83	119.55	152.65	120.47	154.71	44.81	1180.48	98.37
1968	97.25	27.95	28.45	25.78	25.13	72.67	165.80	146.99	172.86	73.51	36.23	23.75	896.37	74.70
1969	18.36	9.43	8.73	10.17	14.57	16.82	64.14	82.75	102.18	102.75	39.84	39.45	509.19	42.43
1970	30.50	11.61	9.35	10.08	9.44	89.28	63.48	116.63	65.64	164.38	119.39	63.17	752.95	62.75
1971	37.94	40.25	48.56	33.55	66.12	66.55	80.61	93.17	77.20	205.50	120.27	94.08	963.80	80.32
1972	64.71	33.21	30.31	21.81	31.95	44.83	209.17	178.32	174.93	49.85	54.36	32.75	926.20	77.18
1973	20.02	19.61	17.31	10.97	19.62	29.51	38.39	45.55	81.05	257.49	127.79	79.33	746.64	62.22
1974	44.15	29.17	17.34	17.16	28.60	90.05	113.57	119.78	53.48	77.04	78.40	79.64	748.38	62.37
1975	64.38	32.17	22.75	24.51	14.39	15.03	18.55	64.69	133.15	32.35	36.21	46.22	504.40	42.03
1976	52.27	17.83	20.76	24.15	89.39	107.64	90.79	75.93	51.19	52.10	36.15	19.51	637.71	53.14
Total**	835.46	578.7	478.24	460.20	783.40	1164.19	1616.51	1848.65	1879.44	1807.83	1518.38	1040.23		1167.60
Mean**	49.14	34.04	28.13	27.07	46.08	68.48	94.09	108.74	110.56	106.34	89.32	61.19	824.18	68.68

Note: * The data are derived from Matuno river discharge
** The data are for 1960 to 1976

TABLE I-9

MATUNO RIVER REVISED MONTHLY DISCHARGE AT BANTE
(Catchment Area : 558km^2)

unit: m^3/sec

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	ANNUAL MRAN
1957	35.41	23.23	20.70	20.68	19.15	20.36	25.54	31.14	48.14	36.59	39.36	27.14	347.44	28.95
1958	23.27	21.62	21.06	22.40	22.77	29.04	29.99	111.39	65.38	121.08	58.16	562.10	46.84	
1959	28.79	22.70	25.66	16.66	23.00	17.82	18.49	24.30	38.01	37.16	64.00	70.40	387.04	32.25
1960	45.43	51.35	37.88	30.94	28.36	36.09	42.44	100.14	57.51	60.10	34.42	21.36	546.12	45.51
1961	14.37	12.16	16.86	14.43	18.58	24.22	29.58	30.46	36.56	62.73	21.78	16.33	298.06	24.84
1962	14.31	13.50	18.49	26.17	21.46	20.73	79.36	48.77	52.96	35.15	66.84	29.91	427.65	35.64
1963	22.36	32.49	25.26	19.15	22.34	62.17	49.59	77.72	87.42	47.75	30.75	57.05	534.05	44.50
1964	17.52	17.29	21.96	19.43	29.96	43.07	55.89	78.30	67.42	87.57	96.25	74.65	609.31	50.78
1965	68.42	39.56	21.36	19.15	22.32	33.85	47.62	27.54	70.80	45.86	32.99	22.03	451.50	37.63
1966	27.59	22.38	19.43	13.43	81.17	26.30	28.74	30.63	20.22	16.70	98.02	46.66	431.27	35.94
1967	25.80	15.55	9.62	27.02	36.62	86.25	70.51	56.89	70.39	68.62	82.10	19.02	568.40	47.37
1968	58.85	12.26	14.09	13.36	16.82	45.63	101.07	71.41	71.07	29.40	14.62	10.66	459.24	38.27
1969	8.46	7.98	7.58	8.26	8.29	9.89	40.56	51.65	63.20	59.87	26.10	25.66	317.50	26.46
1970	12.22	8.70	7.94	8.38	8.00	40.13	28.97	56.44	31.03	100.23	73.44	39.98	415.46	34.62
1971	24.84	26.18	30.65	19.70	31.70	31.59	44.88	57.29	47.20	124.71	73.97	58.39	571.10	47.59
1972	40.91	20.72	15.92	13.38	19.20	25.31	107.17	80.60	102.11	32.05	30.65	21.58	509.60	42.47
1973	13.51	12.48	10.69	8.90	14.06	19.72	25.21	29.50	50.63	149.74	78.44	49.61	462.49	38.54
1974	28.66	19.73	11.53	11.97	19.33	46.41	65.55	73.67	27.28	45.89	49.05	48.94	448.01	37.33
1975	40.71	21.53	15.92	16.97	10.95	11.32	13.41	40.89	81.64	21.65	23.94	29.89	328.82	27.40
1976	33.50	12.98	14.72	16.75	55.59	66.45	56.45	47.58	32.85	33.39	23.90	13.99	408.15	34.02
Total	584.93	414.39	367.32	347.13	509.68	696.35	961.02	1126.31	1126.87	1216.24	1019.56	718.41	9083.31	
Mean	29.25	20.72	18.37	17.36	25.48	34.82	48.05	56.32	56.09	60.81	50.98	35.92		37.85

Note: * Corrected by newly established seasonal rating curves.

GAUGING RECORDS AT BANTE ON MATUNO RIVER

No.	Date	H. (m)	Q. (m^3/sec)	A. (m^2)	Vm (m/sec)	W (m)	A/W
1.	1957 Jan 30	1.24	29.00	25.92	1.12	62.5	0.415
2.	1959 Apr 29	1.21	13.45	19.25	0.70	66.0	0.292
3.	1959 Aug 13	1.30	18.56	22.73	0.82	65.0	0.350
4.	1959 Oct 3	1.47	40.25	25.00	1.61	50.0	0.500
5.	1960 Nov 19	1.16	36.15	27.39	1.32	71.5	0.383
6.	1961 Feb 17	1.06	11.51	17.64	0.65	67.5	0.261
7.	1961 Oct 11	1.35	16.10	18.51	0.87	31.0	0.597
8.	1962 Mar 8	1.09	15.36	21.13	0.73	68.0	0.311
9.	1962 Nov 9	1.85	108.58	72.42	1.50	76.0	0.953
10.	1963 Feb 12	1.30	26.60	30.90	0.86	69.0	0.448
11.	1963 Jul 25	1.23	30.14	32.18	0.94	71.0	0.453
12.	1963 Sep 3	1.50	106.29	114.64	0.93	91.0	1.260
13.	1963 Dec 2	1.22	24.22	28.27	0.86	69.0	0.410
14.	1964 Feb 11	1.20	13.94	21.76	0.64	68.0	0.320
15.	1964 Jul 19	1.40	47.97	37.29	1.29	67.0	0.557
16.	1964 Dec 3	1.51	83.33	52.91	1.57	N.R.	
17.	1965 Mar 2	1.30	20.85	23.71	0.88	N.R.	
18.	1965 Sep 7	1.50	46.51	54.45	0.85	97.5	0.558
19.	1965 Nov 20	1.16	30.60	27.78	1.10	72.0	0.386
20.	1966 May 9	0.99	12.37	16.74	0.74	66.0	0.254
21.	1966 Aug 15	1.48	80.99	53.00	1.53	80.5	0.658
22.	1966 Oct 6	1.17	35.59	26.33	1.35	54.0	0.488
23.	1966 Dec 7	1.93	301.72	119.26	2.53	71.5	1.668
24.	1967 Jan 28	0.84	46.73	16.49	2.84	28.0	0.589
25.	1967 Jul 25	0.96	96.29	40.75	2.36	42.5	0.959
26.	1967 Dec 12	1.34	29.53	36.38	0.81	56.1	0.648
27.	1968 Feb 10	1.20	17.53	24.59	0.72	48.94	0.502
28.	1968 Oct. 5	1.72	105.88	51.05	2.07	68.50	0.745
29.	1968 Nov 16	1.28	14.98	15.88	0.94	43.52	0.365
30.	1969 Jan 22	1.16	4.64	13.33	0.35	45.28	0.294
31.	1969 Apr 18	1.13	8.07	11.20	0.72	47.92	0.234
32.	1969 Jun 16	1.19	12.08	14.64	0.82	53.24	0.275
33.	1969 Aug 2	1.62	73.11	33.83	2.17	48.82	0.693
34.	1969 Oct 14	1.48	52.80	30.12	1.74	63.92	0.471
35.	1970 Jun 5	1.24	28.04	21.50	1.30	40.81	0.527
36.	1970 Jul 23	1.19	27.98	24.92	1.12	51.65	0.482
37.	1970 Aug 26	1.47	50.21	32.71	1.54	52.92	0.618
38.	1970 Sep 27	1.32	54.39	66.49	0.92	72.65	0.915
39.	1971 Apr 30	1.13	18.62	15.31	1.22	27.48	0.557
40.	1971 May 19	1.25	48.96	29.19	1.73	44.42	0.657
41.	1971 Dec 1	2.12	150.44	80.98	1.90	62.92	1.287
42.	1972 Jan 22	1.20	26.40	22.64	1.16	35.35	0.640
43.	1972 Apr 20	0.95	14.81	13.91	1.06	26.26	0.530
44.	1972 Jun 4	1.16	34.53	24.92	1.38	56.80	0.439
45.	1972 Nov 15	0.92	19.50	19.81	0.98	28.00	0.708
46.	1973 Jan 7	0;76	20.09	29.62	0.68	29.80	0.994
47.	1973 Feb 26	0.66	10.42	17.98	0.58	29.20	0.616
48.	1973 Mar 25	0.54	7.66	11.27	0.68	27.40	0.411
49.	1973 May 12	0.57	6.35	9.11	0.70	29.50	0.309
50.	1973 Jun 12	0.94	19.48	N.R.	N.R.	N.R.	
51.	1975 Mar 14	1.20	14.28	15.58	0.91	38.5	0.405
52.	1976 Jun 16	1.81	32.19	34.00	0.94	136.0	0.25
53.	1976 Sep 8	0.81	5.12	18.18	0.28	38.5	0.472
54.	1976 Nov 15	0.63	7.78	18.31	0.42	33.0	0.555
55.	1980 Apr 1	0.97	19.58	19.35	1.01		
56.	1980 May 24	1.10	21.25	20.44	1.04		
57.	1980 Sep 12	1.33	37.17	30.16	1.23		
58.	1980 Oct 17	1.25	65.21	31.14	2.09		
59.	1980 Nov 21	2.15	44.61	30.44	1.47		
60.	1980 Dec 17	2.50	40.77	27.24	1.50		
61.	1981 Jan 21	N.R.	44.79	30.88	1.45		
62.	1981 Mar 24	1.85	12.01	13.07	0.92		
63.	1981 Apr 9	1.80	12.41	12.87	0.96		
64.	1981 May 19	1.81	12.85	13.76	0.93		
65.	1981 Jun 24	2.00	17.99	20.79	0.87		
66.	1981 Jul 24	2.19	47.29	30.70	1.56		
67.	1981 Aug 7	2.22	51.09	39.20	1.30		
68.	1981 Aug 26	2.27	53.12	31.32	1.70		
69.	1981 Sep 21	2.32	66.06	45.40	1.46		
70.	1981 Oct 20	2.24	33.84	26.04	1.30		
71.	1981 Oct 29	2.46	90.88	54.60	1.66		
72.	1981 Nov 11	2.48	108.87	62.28	1.75		
73.	1981 Nov 23	2.31	71.50	43.60	1.64		
74.	1981 Dec 9	2.33	60.14	40.88	1.47		
75.	1982 Jan 12	2.11	20.08	23.24	0.86		
76.	1982 Feb 10	2.13	18.02	16.81	1.07		
77.	1982 Feb 17	2.16	17.24	16.34	1.06		
(77'	1982 Feb 17	2.16	17.24	13.42	1.28)		
78.	1982 Feb 18	2.16	15.85	16.08	0.99		
(78'	1982 Feb 18	2.16	15.83	12.00	1.30)		
79.	1982 Feb 22	2.17	19.37	19.90	0.97		
(79'	1982 Feb 22	2.17	19.30	15.59	1.24)		
80.	1982 Feb 24	2.12	17.49	17.08	1.02		
(80'	1982 Feb 24	2.12	17.42	14.20	1.23)		
81.	1982 Feb 26	2.12	16.28	16.01	1.02		
(81'	1982 Feb 26	2.12	16.16	13.15	1.23)		
82.	1982 Mar 2	2.10	14.67	15.43	0.95		
(82'	1982 Mar 2	2.11	15.17	11.96	1.27)		
(83'	1982 Mar 3	2.10	15.21	12.10	1.26)		

Note: (') shows data of check measurement at upstream section by the Team. H; Gage Height, Q; Discharge, A; Flow Area Vm; Mean Velocity, W; Width of Water Surface

TABEL I-11

TABLE I-12

LOW-WATER FLOW

YEAR	BATU MONTH OCCURED	BATU DISCHARGE (m^3/s)	BANTE MONTH OCCURED	BANTE DISCHARGE (m^3/s)
1960	MAY	39.3	MAY	25.8
1961	FEB.	15.4	APR.	12.8
1962	FEB.	18.5	MAY	13.6
1963	APR.	26.7	APR.	18.3
1964	APR.	27.7	APR.	18.9
1965	APR.	27.6	APR.	17.7
1966	APR.	15.7	APR.	11.7
1967	MAR.	21.0	MAR.	8.4
1968	MAY	20.7	FEB.	11.1
1969	APR.	8.5	APR.	7.4
1970	MAR.	8.5	MAR.	7.4
1971	MAR.	29.5	APR.	16.5
1972	MAY	20.8	APR.	10.5
1973	APR.	10.9	APR.	8.9
1974	APR.	15.7	MAR.	10.5
1975	MAY	13.8	MAY	10.6
1976	MAR.	15.7	FEB.	12.0
Mean		19.76		13.06

PROBABLE LOW-WATER FLOW

Unit m^3/s

Return Period	1/100	1/75	1/50	1/30	1/20	1/10	1/5	1/3	1/2
Batu	6.67	6.99	7.50	8.25	8.95	10.46	12.64	15.09	18.17
Bante	5.44	5.65	5.99	6.47	6.91	7.85	9.16	10.59	12.31

OBSERVED PEAK DISCHARGE

Batu

YEAR	DISCHARGE (m^3/S)	G.H (m)	DATE	TIME
1959	1,154.20	3.78	NOV. 18	6.00 A.M.
1960	1,540.60	4.32	OCT. 14	6.00 A.M.
1961	410.00	2.60	JUL. 14	6.00 A.M.
1962	712.00	3.20	NOV. 6	6.00 A.M.
1963	439.90	2.60	AUG. 15	6.00 A.M.
1964	1,114.00	3.90	DEC. 15	5.00 P.M.
1965	567.40	2.90	JUL. 14	5.00 P.M.
1966	1,114.00	3.90	MAY 20	12.00 N.N.
1967	1,052.50	3.80	NOV. 5	6.00 A.M.
1968	613.50	3.00	SEP. 29	6.00 A.M.
1969	217.75	1.98	JAN. 1	6.00 A.M.
1970	1,175.50	4.00	SEP. 11	5.00 P.M.
1971	250.80	2.05	OCT. 10	6.00 P.M.
1972	358.90	2.39	JUL. 11	6.00 P.M.
1973	371.76	2.42	OCT. 17	7.00 A.M.
1974	492.25	2.73	JUN. 11	12.00 N.N.
1975	-	-	-	-
1976	2,874.17	6.70	MAY 21	7.00 A.M.

Bante

YEAR	DISCHARGE (m^3/S)	G.H (m)	DATE	TIME
1960	289.99	2.85	OCT. 14	5.00 P.M.
1961	149.60	2.25	OCT. 15	7.00 A.M.
1962	502.20	3.50	JUL. 22	7.00 A.M.
1963	625.00	3.60	AUG. 15	7.00 A.M.
1964	790.00	4.08	OCT. 5	2.30 P.M.
1965	459.00	3.10	SEP. 10	8.00 P.M.
1966	455.80	3.09	NOV. 23	7.00 A.M.
1967	861.00	4.00	NOV. 4	7.00 A.M.
1968	318.00	2.66	AUG. 30	7.00 A.M.
1969	180.00	2.20	JUL. 28	1.00 P.M.
1970	363.00	2,80	OCT. 15	1.00 A.M.
1971	520.45	3.55	OCT. 13	7.00 A.M.
1972	353.10	3.05	JUL. 17	1.00 P.M.
1973	432.10	3.30	OCT. 22	6.00 A.M.
1974	171.74	2.08	OCT. 18	4.00 P.M.
1975	366.00	2.81	-	6.00 P.M.
1976	273.40	2.52	MAY 24	-
1980	-	5.10	NOV. 5	8.00 A.M.

Note : Discharge is recorded as raw data without correction according to rating curves correction

TABLE I-14
TABLE I-15

PROBABLE MAXIMUM RAINFALL (24 Hours)

Unit : mm

Return Periods	Itogon	Consuelo	Salinas	Dupax	Lamut
1/1000	902.5	621.1	265.5	216.1	336.7
1/500	837.8	557.7	249.2	199.0	300.2
1/200	752.8	479.2	227.5	177.1	256.0
1/100	688.5	423.5	210.8	161.0	225.3
1/75	661.7	401.2	203.7	154.3	213.2
1/50	623.7	370.6	193.6	145.0	196.9
1/30	575.4	333.4	180.6	133.4	177.3
1/20	536.5	304.7	169.9	124.2	162.5
1/10	467.9	257.3	150.8	108.4	138.6
1/5	394.8	211.2	129.8	92.1	116.1
1/3	335.0	177.0	112.2	79.2	100.0
1/2	280.2	148.5	95.6	67.9	87.2

PROBABLE MAXIMUM CONSECUTIVE RAINFALL

for dam design

Unit : mm

Return Periods	1-day	2-day	3-day
1/200	258.1	356.5	429.8
1/100	239.9	334.0	402.0
1/75	232.0	324.5	390.1
1/50	222.8	310.7	373.0
1/30	206.3	292.6	350.7
1/20	194.5	277.6	332.1
1/10	173.4	250.3	298.4
1/5	150.2	219.3	260.3
1/3	130.8	192.5	227.4
1/2	112.5	166.5	195.5

for flood control

Unit : mm

Return Periods	1-day	2-day	3-day
1/100	182.53	285.26	348.20
1/75	177.81	275.69	332.08
1/50	170.94	262.12	316.19
1/30	161.94	244.87	295.81
1/20	154.42	230.93	279.16
1/10	140.53	206.34	249.39
1/5	124.64	180.04	216.89
1/3	110.68	158.50	189.71
1/2	96.90	138.70	164.17
1/1	19.53	53.22	44.99

COMPARISON OF PROBABLE MAXIMUM CONSECUTIVE RAINFALL AT DIFFERENT SITES

YEAR	A DAY	B 2 DAYS	C 3 DAYS	D 1-M/B	E 1-S/B	F 2-M/S	G 2-S/B	H 3-M/B	I 3-S/B
56	31.0	97.0	97.7	0.739	1.123	0.915	1.040	0.908	1.043
57	80.5	116.8	117.4	0.383	1.290	1.323	0.848	1.329	0.845
58	46.7	92.7	99.0	0.770	1.108	0.606	1.185	0.640	1.170
59	86.1	110.9	122.3	1.181	0.915	1.061	0.971	0.994	1.003
60	101.8	137.1	196.7	1.788	0.629	1.399	0.812	1.371	0.825
61	78.5	126.1	138.5	0.919	1.038	1.077	0.964	1.069	0.967
62	113.0	203.2	273.6	1.104	0.951	1.040	0.981	1.106	0.950
63	90.6	128.8	179.5	1.296	0.861	0.770	1.108	0.839	1.076
64	125.8	149.6	154.5	0.871	1.061	0.828	1.081	0.819	1.085
65	102.5	153.3	163.1	1.889	0.582	1.807	0.620	1.730	0.657
66	93.0	183.1	218.3	1.080	0.962	1.071	0.967	1.004	0.998
67	171.8	177.8	183.7	0.672	1.154	0.653	1.163	0.708	1.138
68	60.7	106.6	139.7	0.888	1.052	1.140	0.934	1.279	0.869
69	119.3	207.3	260.6	1.196	0.908	1.220	0.897	1.245	0.885
70	146.0	202.2	234.3	0.838	1.076	0.834	1.078	0.917	1.039
71	86.4	153.6	178.6	0.856	1.068	1.041	0.981	1.026	0.988
72	122.4	209.5	272.0	1.172	0.919	1.111	0.948	1.007	0.997
73	90.6	116.2	138.3	1.052	0.976	1.166	0.922	1.120	0.944
74	134.1	158.5	172.4	0.897	1.048	0.986	1.007	1.033	0.984
75	49.8	66.6	82.4	1.251	0.882	0.856	1.068	0.848	1.071

A: MAXIMUM 1-DAY AVERAGE RAINFALL IN WATERSHED AREA AT BATO
B: MAXIMUM 2-DAY AVERAGE RAINFALL IN WATERSHED AREA AT BATO
C: MAXIMUM 3-DAY AVERAGE RAINFALL IN WATERSHED AREA AT BATO
D: RATIO OF 1-DAY AVERAGE RAINFALL IN WATERSHED AREA AT DAM SITE TO (A)
E: RATIO OF 1-DAY AVERAGE RAINFALL IN REMAINING WATERSHED AREA TO (A)
F: RATIO OF 2-DAY AVERAGE RAINFALL IN WATERSHED AREA AT DAM SITE TO (B)
G: RATIO OF 2-DAY AVERAGE RAINFALL IN REMAINING WATERSHED AREA TO (B)
H: RATIO OF 3-DAY AVERAGE RAINFALL IN WATERSHED AREA AT DAM SITE TO (C)
I: RATIO OF 3-DAY AVERAGE RAINFALL IN REMAINING WATERSHED AREA TO (C)

TYPHOON ARING RAINFALL

Matuno Dam Basin

Hrs.	Station and Area Rate Bokod 0.464	Salinas 0.333	Lagawe 0.203	Weighted Mean
2	2.3	6.0	2.0	3.5
4	1.3	4.0	1.0	2.2
6	0.0	2.0	2.0	1.1
8	2.0	9.0	2.0	4.3
10	10.4	23.0	13.0	15.1
12	25.5	30.0	23.0	26.5
14	71.7	40.0	23.0	51.3
16	22.1	12.0	23.0	18.9
18	30.2	32.0	7.0	26.1
20	43.6	10.5	10.0	25.7
22	19.4	65.0	6.5	32.0
24	87.8	15.0	2.0	46.1
26	61.6	7.0	1.0	31.1
28	45.6	23.0	7.0	30.2
30	44.9	0.0	15.0	23.9
32	46.2	0.0	5.0	22.5
34	21.4	0.0	0.0	9.9
36	26.8	0.0	0.0	12.4
38	8.0	0.0	0.0	3.7
40	5.4	0.0	0.0	2.5
42	11.7	0.0	0.0	5.4
44	11.4	0.0	0.0	5.3
TOTAL	599.3	278.5	142.5	399.8

Batu Basin

Hrs.	Station and Area Rate Bokod 0.056	Salinas 0.234	Consuelo 0.340	Dupax 0.370	Weighted Mean
2	2.3	6.0	1.8	0.4	2.3
4	1.3	4.0	1.0	0.2	1.4
6	0.0	2.0	0.0	0.0	0.5
8	2.0	9.0	1.5	0.3	2.9
10	10.4	23.0	8.0	1.8	9.3
12	25.5	30.0	19.6	4.3	16.7
14	71.7	40.0	55.2	12.2	36.7
16	22.1	12.0	17.0	3.8	11,2
18	30.2	32.0	23.2	5.1	19.0
20	43.6	10.5	33.5	7.4	19.0
22	19.4	65.0	15.0	3.3	22.6
24	87.8	15.0	67.6	14.9	36.9
26	61.6	7.0	47.5	10.5	25.1
28	45.6	23.0	35.1	7.8	22.7
30	44.9	0.0	34.6	7.6	17.1
32	46.2	0.0	35.6	7.9	17.6
34	21.4	0.0	16.5	3.6	8.2
36	26.8	0.0	20.6	4.6	10.2
38	8.0	0.0	6.2	1.4	3.1
40	5.4	0.0	4.1	0.9	2.0
42	11.7	0.0	9.0	2.0	4.5
44	11.4	0.0	8.8	1.9	4.3
TOTAL	599.3	278.5	461.7	102.0	293.4

Magat Dam Basin

Hrs.	Station and Area Rate Bokod 0.092	Salinas 0.173	Consuelo 0.105	Dupax 0.085	Bagabag 0.169	Lagawe 0.261	Damsite 0.115	Weighted Mean
2	2.3	6.0	1.8	0.4	3.0	2.0	4.0	3.0
4	1.3	4.0	1.0	0.2	4.0	1.0	2.0	2.1
6	0.0	2.0	0.0	0.0	2.0	2.0	7.0	2.0
8	2.0	9.0	1.5	0.3	15.0	2.0	12.5	6.4
10	10.4	23.0	8.0	1.8	20.0	13.0	26.0	15.7
12	25.5	30.0	19.6	4.3	40.0	23.0	17.0	24.7
14	71.7	40.0	55.2	12.2	8.0	23.0	10.0	28.9
16	22.1	12.0	17.0	3.8	4.0	23.0	16.0	14.7
18	30.2	32.0	23.2	5.1	8.0	7.1	24.0	17.1
20	43.6	10.5	33.5	7.4	10.0	10.0	18.5	16.4
22	19.4	65.0	15.0	3.3	7.5	6.5	13.5	19.4
24	87.8	15.0	67.6	14.9	0.5	2.0	3.5	20.0
26	61.6	7.0	47.5	10.5	1.5	1.0	4.5	13.8
28	45.6	23.0	35.1	7.8	10.0	7.0	8.0	17.0
30	44.9	0.0	34.6	7.6	8.0	15.0	7.0	14.5
32	46.2	0.0	35.6	7.9	1.0	5.0	2.5	10.4
34	21.4	0.0	16.5	3.6	0.0	0.0	1.0	4.1
36	26.8	0.0	20.6	4.6	0.0	0.0	0.0	5.0
38	8.0	0.0	6.2	1.4	0.0	0.0	0.5	1.6
40	5.4	0.0	4.1	0.9	0.0	0.0	0.0	1.0
42	11.7	0.0	9.0	2.0	0.0	0.0	0.0	2.2
44	11.4	0.0	8.8	1.9	0.0	0.0	0.0	2.1
TOTAL	599.3	278.5	461.7	102.0	142.5	142.5	177.5	242.2

DISTRIBUTED HOURLY RAINFALL
FOR FLOOD CONTROL

Unit : mm

hour	1/100	1/75	1/50	1/30	1/10	1/2
0	0	0	0	0	0	0
2	4.2	4.1	3.9	3.7	3.2	2.3
4	5.7	5.6	5.3	5.0	4.4	3.1
6	8.2	8.0	7.7	7.3	6.3	4.4
8	13.0	12.7	12.2	11.5	10.0	6.9
10	23.6	23.0	22.1	20.9	18.2	12.5
12	51.4	50.0	48.1	45.3	39.4	27.1
14	34.8	33.9	32.6	30.7	26.7	18.4
16	17.1	16.7	16.1	15.1	13.2	9.1
18	10.2	10.0	9.6	9.0	7.9	5.4
20	6.8	6.6	6.4	6.0	5.2	3.6
22	4.9	4.7	4.6	4.3	3.8	2.6
24	2.6	2.5	2.3	3.1	2.2	1.5

MATUNO RIVER PROBABLE FLOOD AT BANTE
FOR FLOOD CONTROL

Hrs.	Return Period					
	1/100	1/75	1/50	1/30	1/10	1/2
0	50.0	50.0	50.0	50.0	50.0	50.0
2	74.3	73.4	71.1	68.9	64.6	57.5
4	169.7	165.2	155.7	145.6	124.4	88.9
6	380.5	368.6	347.2	321.2	265.1	166.7
8	829.0	802.6	759.5	703.5	581.9	351.9
10	1,994.9	1,929.4	1,835.0	1,703.5	1,423.1	867.0
12	2,646.3	2,569.7	2,462.3	2,305.7	1,973.5	1,282.1
14	1,790.8	1,751.9	1,694.9	1,607.5	1,424.0	1,014.4
16	1,109.2	1,090.0	1,059.1	1,009.9	912.6	686.6
18	758.9	746.3	726.7	694.6	632.0	488.5
20	558.4	547.3	535.5	512.4	468.4	368.5
22	418.0	409.0	399.8	397.6	358.4	279.4
24	290.6	285.4	278.8	287.9	258.7	205.2
26	200.2	197.6	194.4	198.9	184.3	155.8
28	152.9	151.5	149.6	152.2	143.8	126.8
30	125.0	124.1	123.0	124.6	119.4	108.3
32	107.2	106.6	105.8	106.9	103.4	95.8
34	95.0	94.6	94.1	94.8	92.3	86.9
36	86.4	86.1	85.7	86.2	84.4	80.4
38	80.0	79.8	79.5	79.9	78.6	75.5
40	75.2	75.0	74.8	75.1	74.1	71.7
42	71.4	71.3	71.1	71.4	70.6	68.7
44	68.5	68.3	68.2	68.4	67.8	66.3

SANTA FE AND CRUZ RIVERS PROBABLE FLOOD
AT BATU FOR FLOOD CONTROL

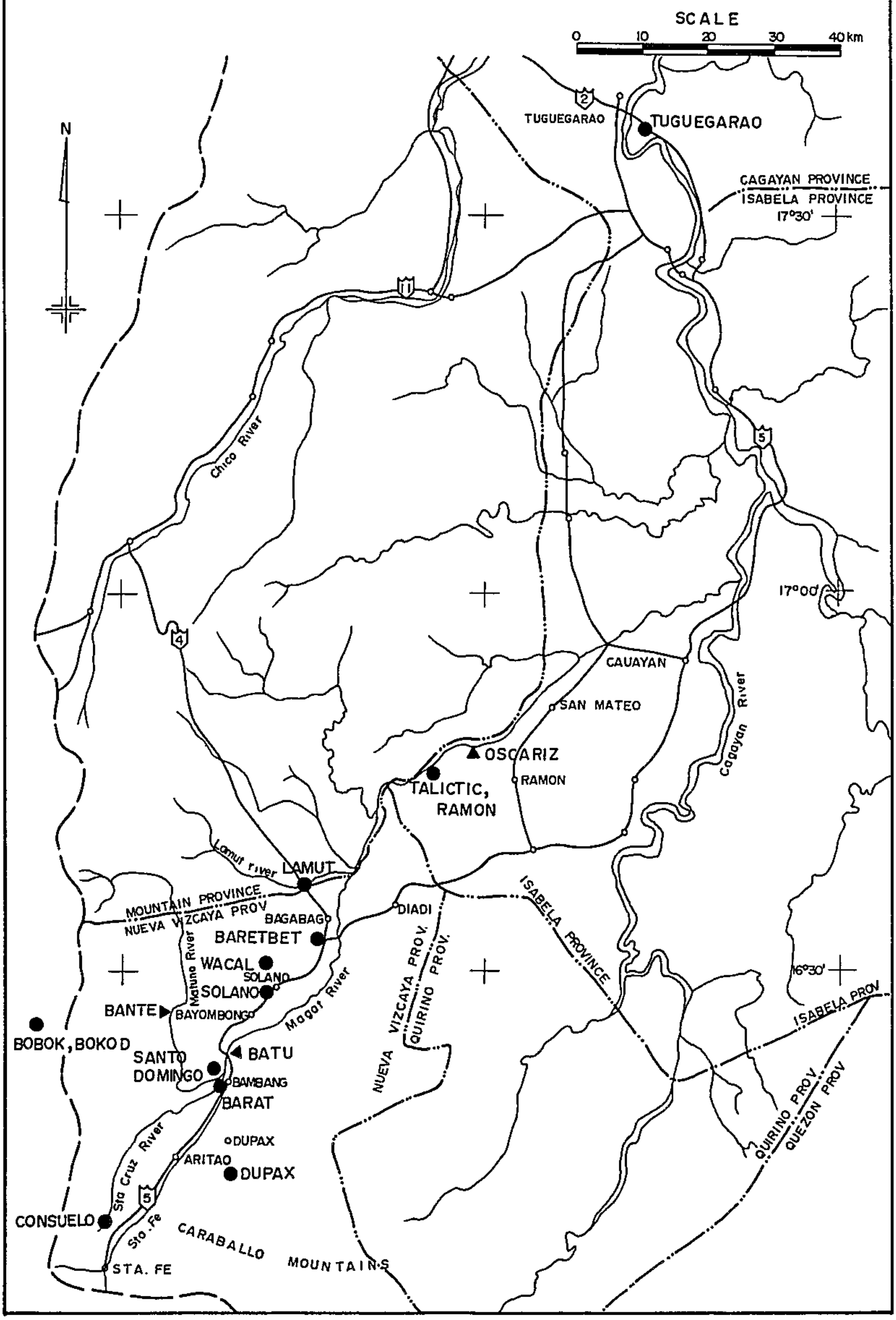
Hrs.	Return Period					
	1/100	1/75	1/50	1/30	1/10	1/2
0	118.1	117.4	115.7	114.0	110.8	105.5
2	198.2	194.3	186.0	177.3	159.3	130.1
4	413.1	400.5	377.5	350.5	293.5	199.1
6	967.5	933.4	876.6	805.2	654.6	390.2
8	2,612.1	2,514.2	2,368.9	2,173.1	1,762.5	1,003.4
10	4,209.0	2,065.6	3,860.7	3,570.2	2,959.7	1,761.3
12	3,635.0	3,536.7	3,393.5	3,180.7	2,730.2	1,770.0
14	2,586.7	2,532.3	2,448.2	2,318.3	2,048.6	1,430.7
16	1,870.9	1,836.8	1,784.3	1,700.6	1,528.8	1,123.9
18	1,409.5	1,383.2	1,350.4	1,292.3	1,174.9	895.6
20	1,081.2	1,060.6	1,036.7	1,016.4	922.2	712.5
22	801.8	788.5	771.3	775.2	704.3	556.5
24	593.8	586.0	575.8	578.1	535.5	442.7
26	466.7	461.7	455.1	456.6	429.0	366.8
28	383.2	379.8	375.3	376.4	357.4	313.7
30	325.3	322.9	319.8	320.5	307.0	275.0
32	283.6	281.9	279.5	280.1	270.0	246.0
34	252.5	251.2	249.4	249.8	242.2	223.7
36	228.7	227.7	226.3	226.6	220.7	206.1
38	210.0	209.3	208.2	208.5	203.7	192.0
40	195.2	194.6	193.7	193.9	190.1	180.6
42	183.2	182.7	182.0	182.1	179.0	171.1
44	173.3	172.9	172.3	172.4	169.8	163.3

MAGAT RIVER PROBABLE FLOOD
AT BATU FOR FLOOD CONTROL

Hrs.	Return Period					
	1/100	1/75	1/50	1/30	1/10	1/2
0	168.1	167.4	165.7	164.0	160.8	155.5
2	272.5	267.6	257.1	246.2	223.9	187.6
4	582.7	565.7	533.2	496.1	418.0	288.1
6	1,348.0	1,302.0	1,223.8	1,126.4	919.7	556.9
8	3,441.1	3,316.8	3,128.4	2,876.5	2,344.5	1,355.3
10	6,203.9	5,995.0	5,695.7	5,273.7	4,382.8	2,628.3
12	6,281.3	6,106.4	5,855.9	5,486.4	4,703.7	3,052.1
14	4,377.5	4,284.1	4,143.1	3,925.9	3,472.6	2,445.1
16	2,980.1	2,926.8	2,843.5	2,710.6	2,441.3	1,810.5
18	2,168.5	2,129.5	2,077.1	1,986.9	1,806.9	1,384.1
20	1,639.6	1,607.9	1,572.2	1,528.8	1,390.6	1,081.0
22	1,219.9	1,197.5	1,171.1	1,172.8	1,062.7	836.0
24	884.4	871.4	854.6	866.0	794.2	648.0
26	666.9	659.3	649.5	655.5	613.3	522.6
28	536.1	531.3	525.0	528.5	501.3	440.5
30	450.4	447.1	442.8	445.1	426.3	383.4
32	390.8	388.4	385.3	386.9	373.4	341.8
34	347.5	345.8	343.5	344.6	334.5	310.6
36	315.1	313.8	312.0	312.9	305.1	286.5
38	290.1	289.0	287.7	288.3	282.3	267.5
40	270.4	269.6	268.5	269.0	264.2	252.3
42	254.6	254.0	253.1	253.5	249.5	239.8
44	241.8	241.2	240.5	240.8	237.6	229.5

FIG. I - I

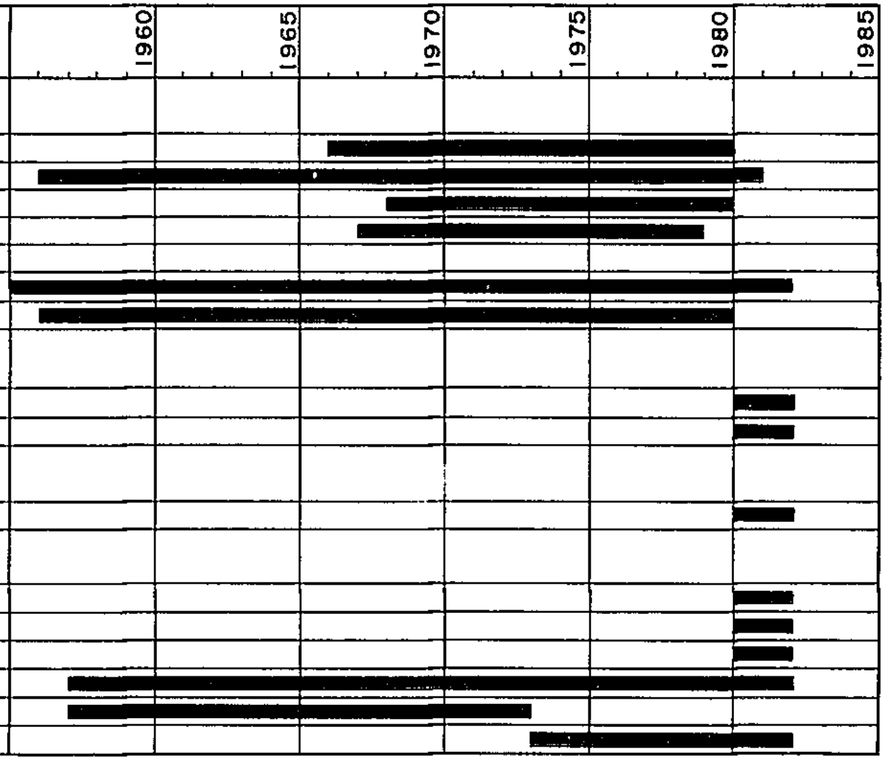
LOCATION MAP OF WEATHER AND HYDROGRAPHIC STATIONS



AVAILABLE DATA PERIOD

Weather Station

Station	Location: Latitude	Location: Longitude	Elevation (m)
Rainfall			
Bobok , Bokod	16° 27'	120° 50'	770
Balatok Itogon	16° 22'	120° 40'	
Nayon Lamut	16° 42'	120° 10'	
Solano	16° 31'	121° 11'	
Dupax	16° 17'	121° 05'	
Barat , Bambang	16° 23'	121° 06'	310
Cousuelo , Santa Fe	16° 10'	120° 57'	540
Temperature			
Santo Domingo (MRMP Hydromet St.)	16° 42'	121° 00'	
Baretbet, Bagabag (-do-)	16° 52'	121° 26'	
Humidity			
Baretbet, Bagabag (MRMP Hydromet St)	16° 52'	121° 26'	
Evaporation			
Santo Domingo (MRMP Hydromet St)	16° 42'	121° 00'	
Baretbet (-do-)	16° 52'	121° 26'	
Wacal			
Tuguegarao	17° 37'	121° 44'	18 6
Talictic , Ramon			
Baligatan	16° 08'	121° 46'	



Hydrographic Station

River , Station	Location: Latitude	Location: Longitude	Drainage Area (km2)	Remarks
Magat river , Batu	16°25'55"	121°07'04"	1,784	1956 incomplete
Magat river , Oscariz	16°51'00"	121°29'33"	4,150	1948,1965 incomplete
Matuno river , Bante	16°27'51"	121°03'30"	558	1955 incomplete

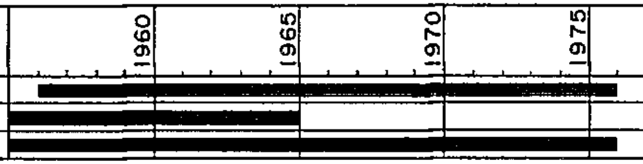
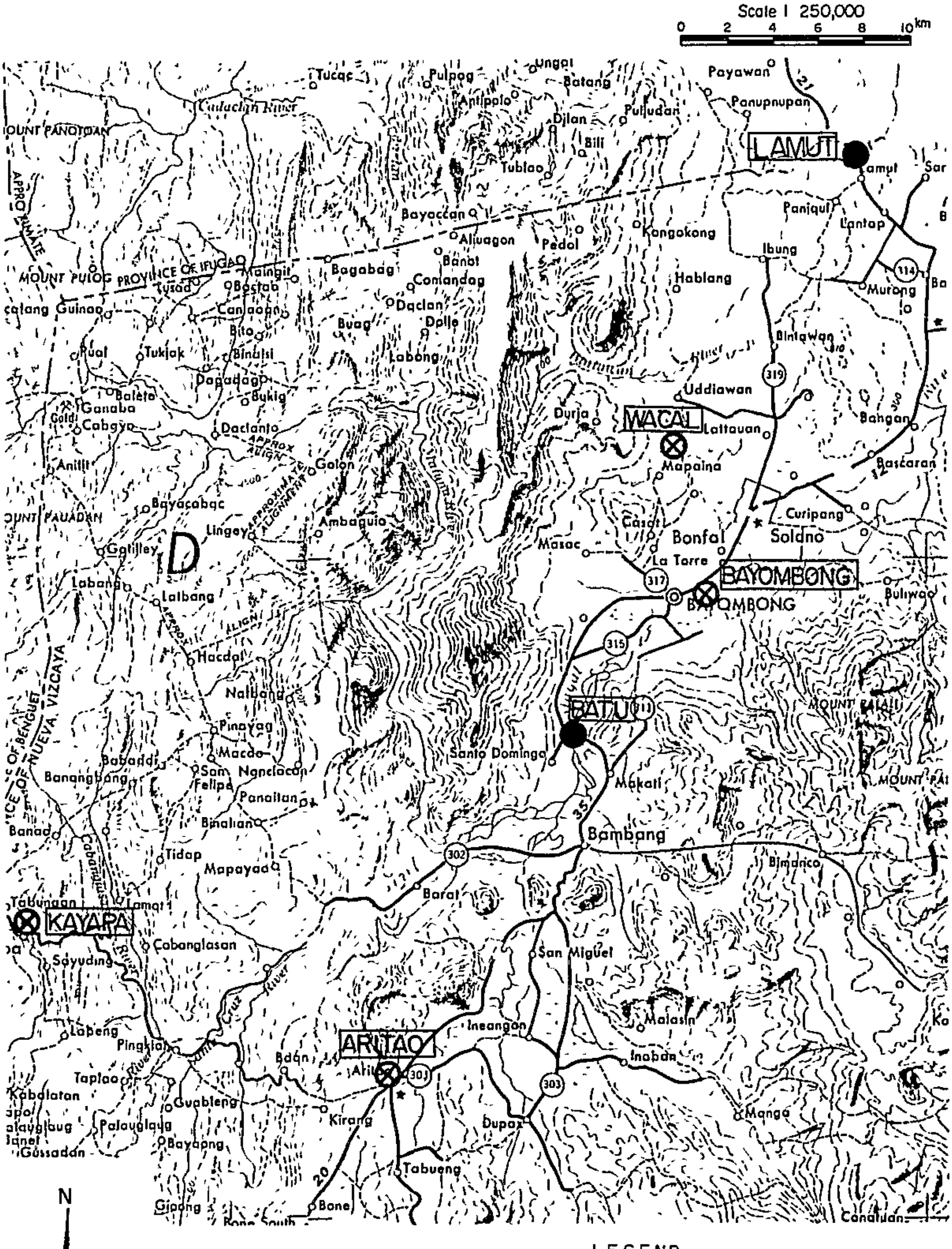
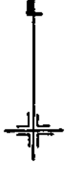


FIG. I-2

FIG. I-3

INSTALLED SITE OF METEO-HYDROLOGICAL EQUIPMENT





LEGEND

⊗ Meteorological Equipment
- Wacal
- Bayombong
- Kayapa
- Aritao

● Water Level Gage
- Batu, Magat river
- Lamut, Lamut river

FIG. I - 4

CLIMATE IN THE PHILIPPINES

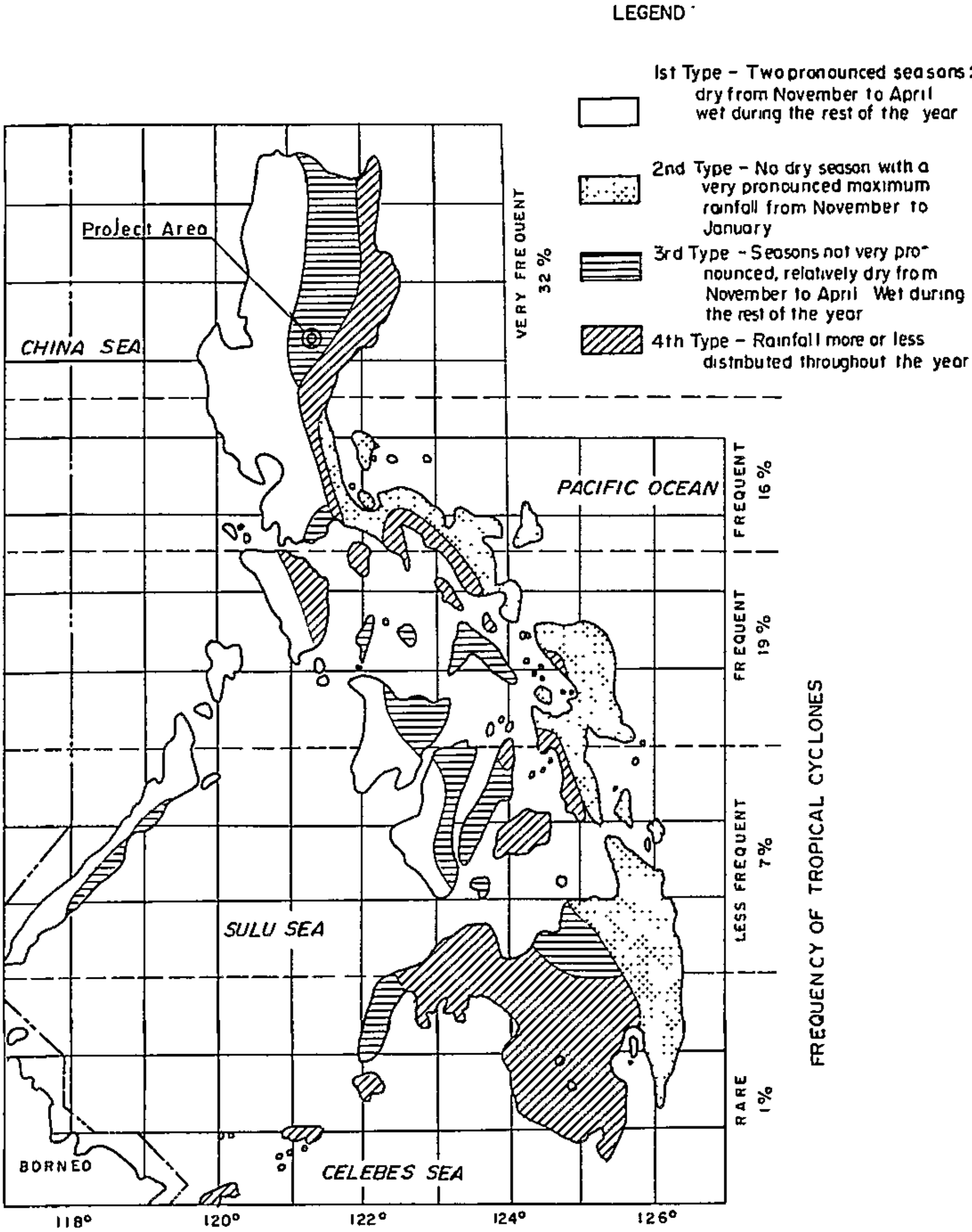
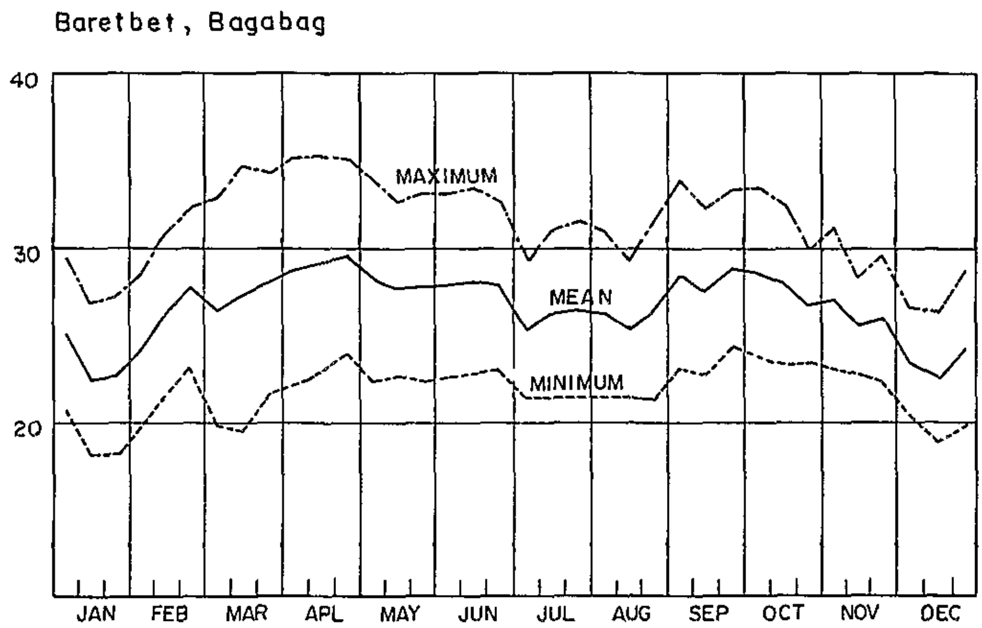


FIG. I - 5

FLUCTUATION OF TEMPERATURE



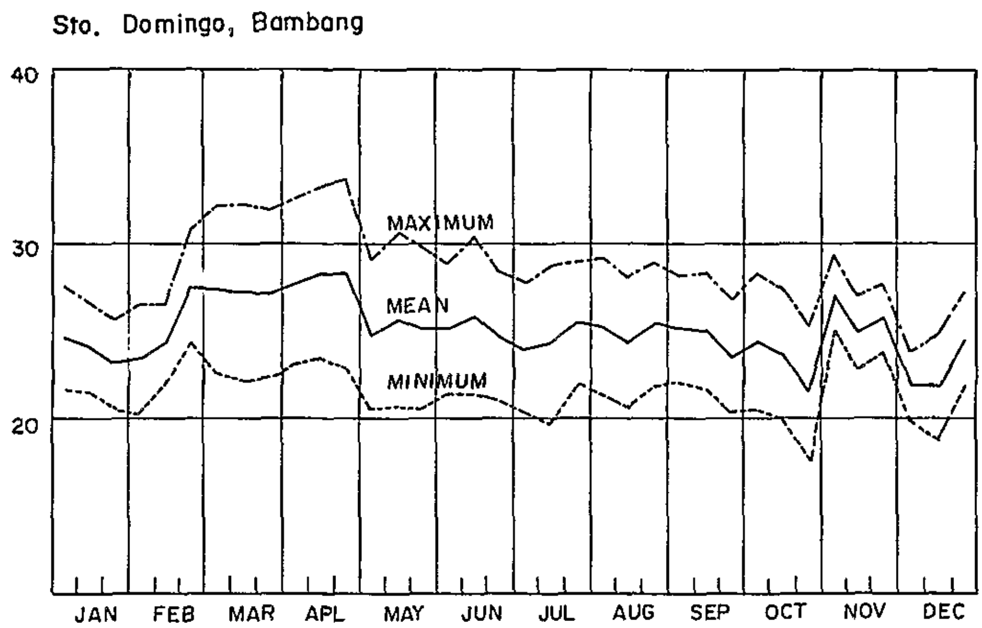


FIG. I-6

COMPARISON OF MEAN PAN-EVARORATION BETWEEN SERVICE AREA AND TALICTIC

Month		Pan-Evapolation (mm) Service Area 1980-1982	Talictic 1980-1982	Talictic 1960-1976
JAN	F	34.8	34.6	38.4
	M	37.1	36.3	40.5
	L	39.9	38.9	42.2
FEB	F	40.9	38.9	43.5
	M	46.9	46.4	46.2
	L	52.3	54.4	48.2
MAR	F	59.1	62.9	53.8
	M	64.3	69.8	57.7
	L	71.1	74.8	63.7
APR	F	70.1	76.3	67.4
	M	71.5	78.7	70.0
	L	66.7	73.1	69.3
MAY	F	62.9	70.2	69.8
	M	59.7	71.0	66.3
	L	60.6	70.0	62.9
JUN	F	57.6	65.3	61.0
	M	57.4	65.5	58.9
	L	56.5	63.8	55.9
JUL	F	58.4	60.6	55.6
	M	59.2	60.6	54.3
	L	57.6	58.2	51.5
AUG	F	60.1	57.8	51.0
	M	60.1	56.1	50.1
	L	57.1	52.9	48.6
SEP	F	54.7	48.6	48.3
	M	55.4	47.5	48.2
	L	52.2	46.5	46.8
OCT	F	49.7	43.7	46.8
	M	47.2	43.3	45.7
	L	43.0	42.2	43.5
NOV	F	41.0	40.2	42.2
	M	37.8	37.0	40.1
	L	36.0	36.0	36.8
DEC	F	35.7	35.2	36.4
	M	35.8	34.8	36.3
	L	33.9	35.0	36.6

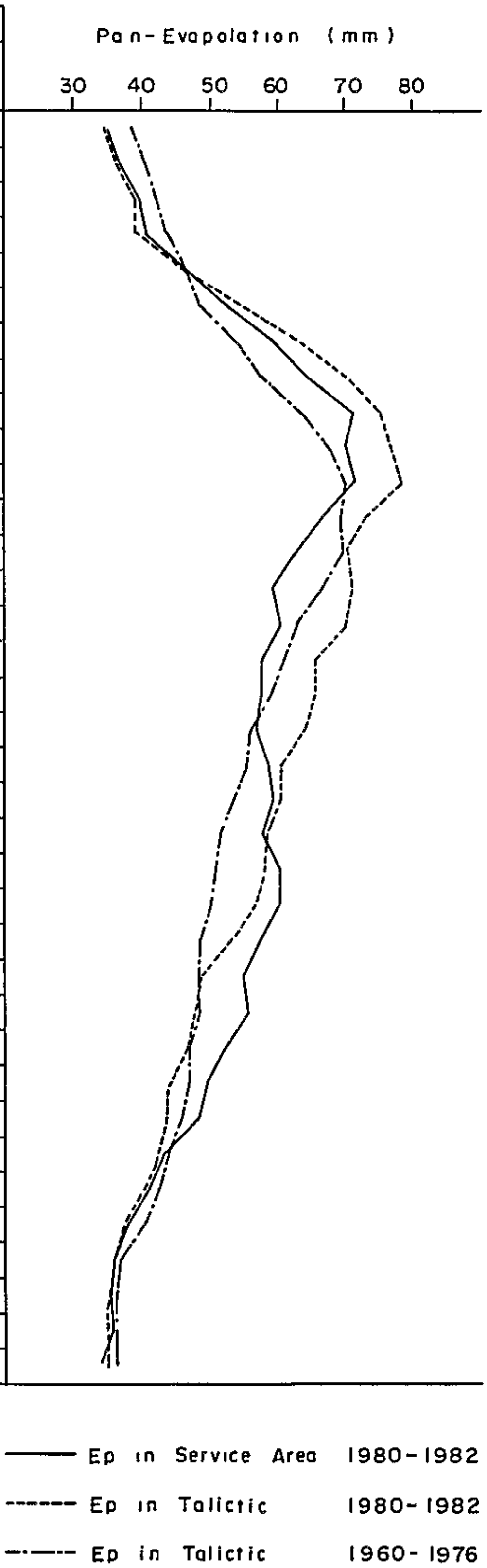
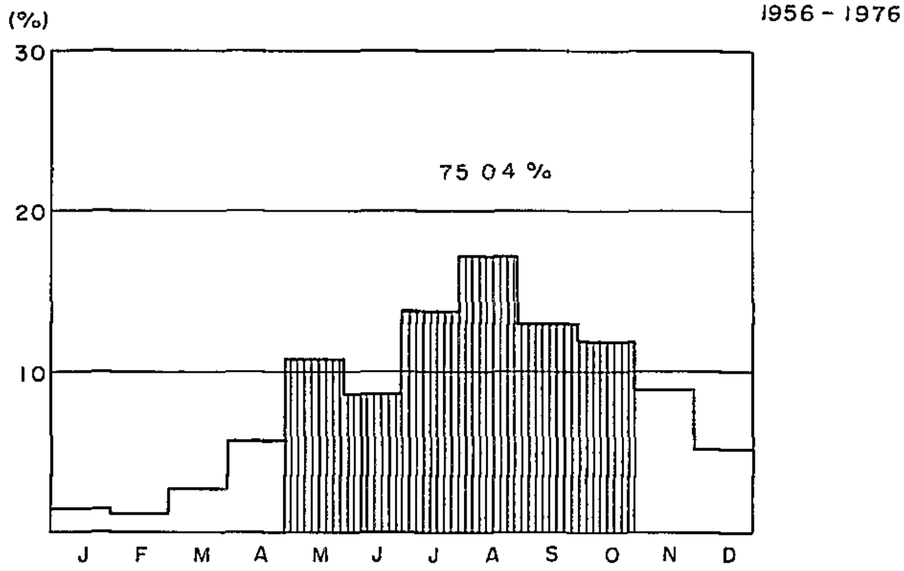
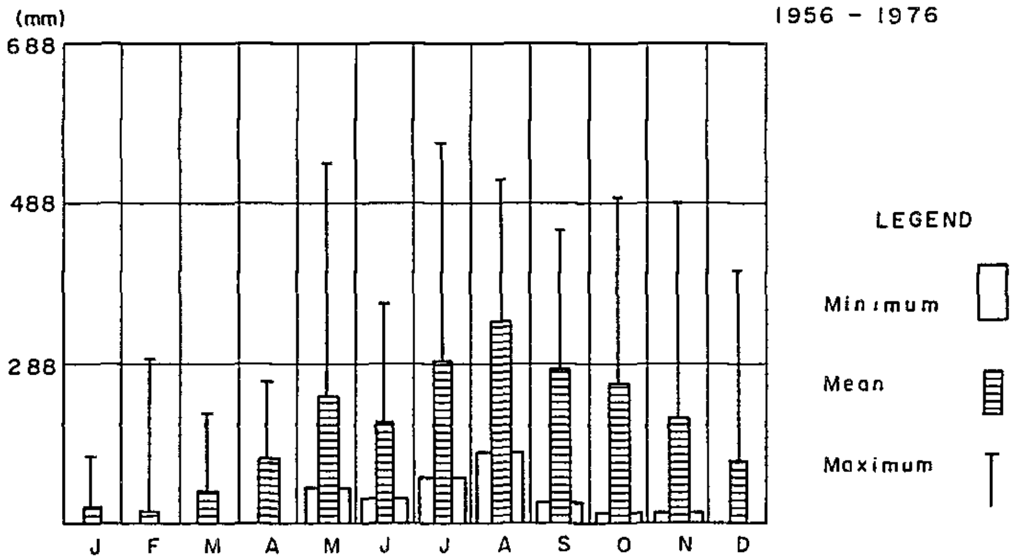


FIG. I-7
FIG. I-8

MONTHLY RAINFALL DISTRIBUTION IN THE SERVICE AREA



MONTHLY MAX, MIN, MEAN RAINFALL IN THE SERVICE AREA



WATER DEPTH - DISCHARGE RELATION AT BANTE AND BATU

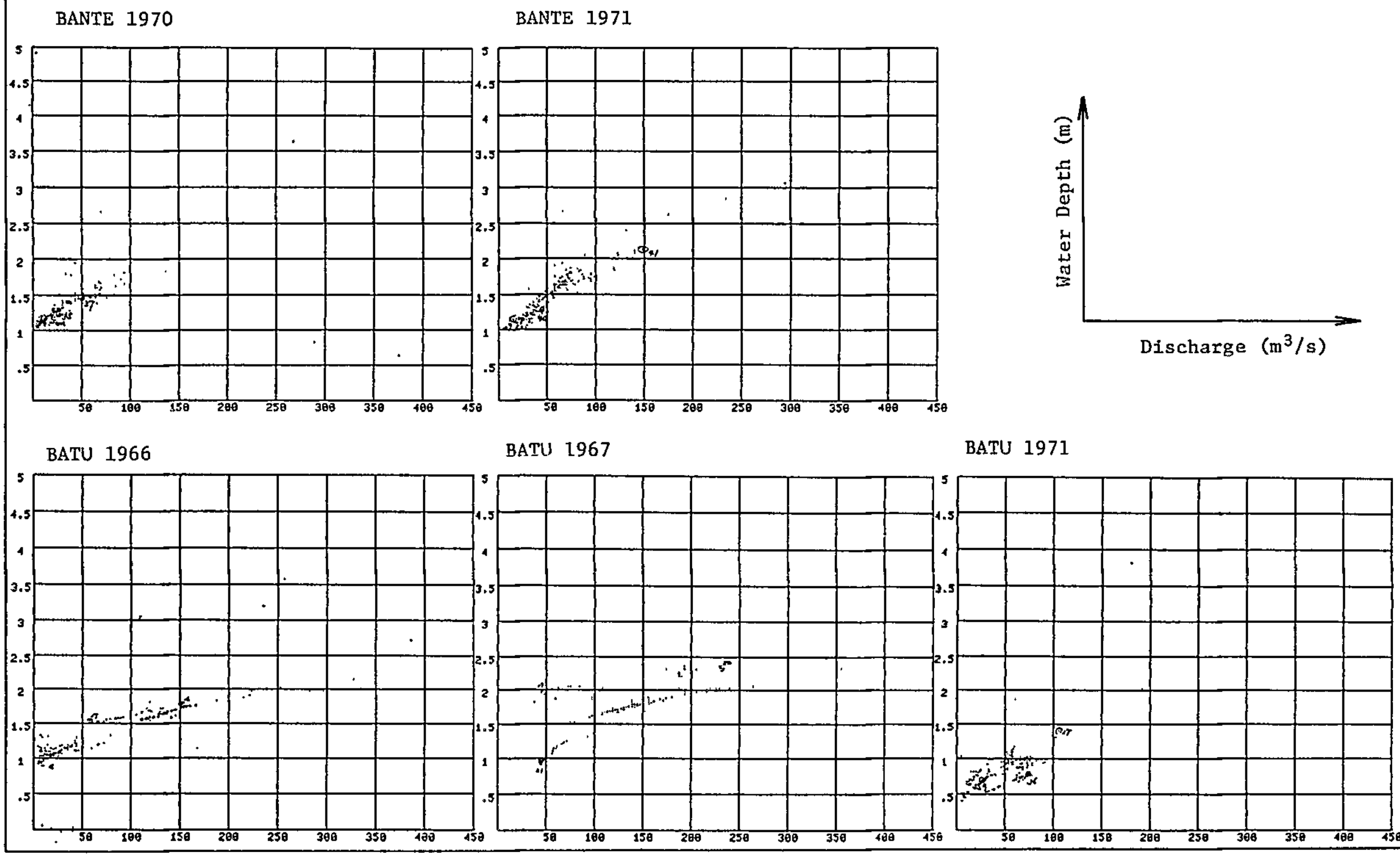
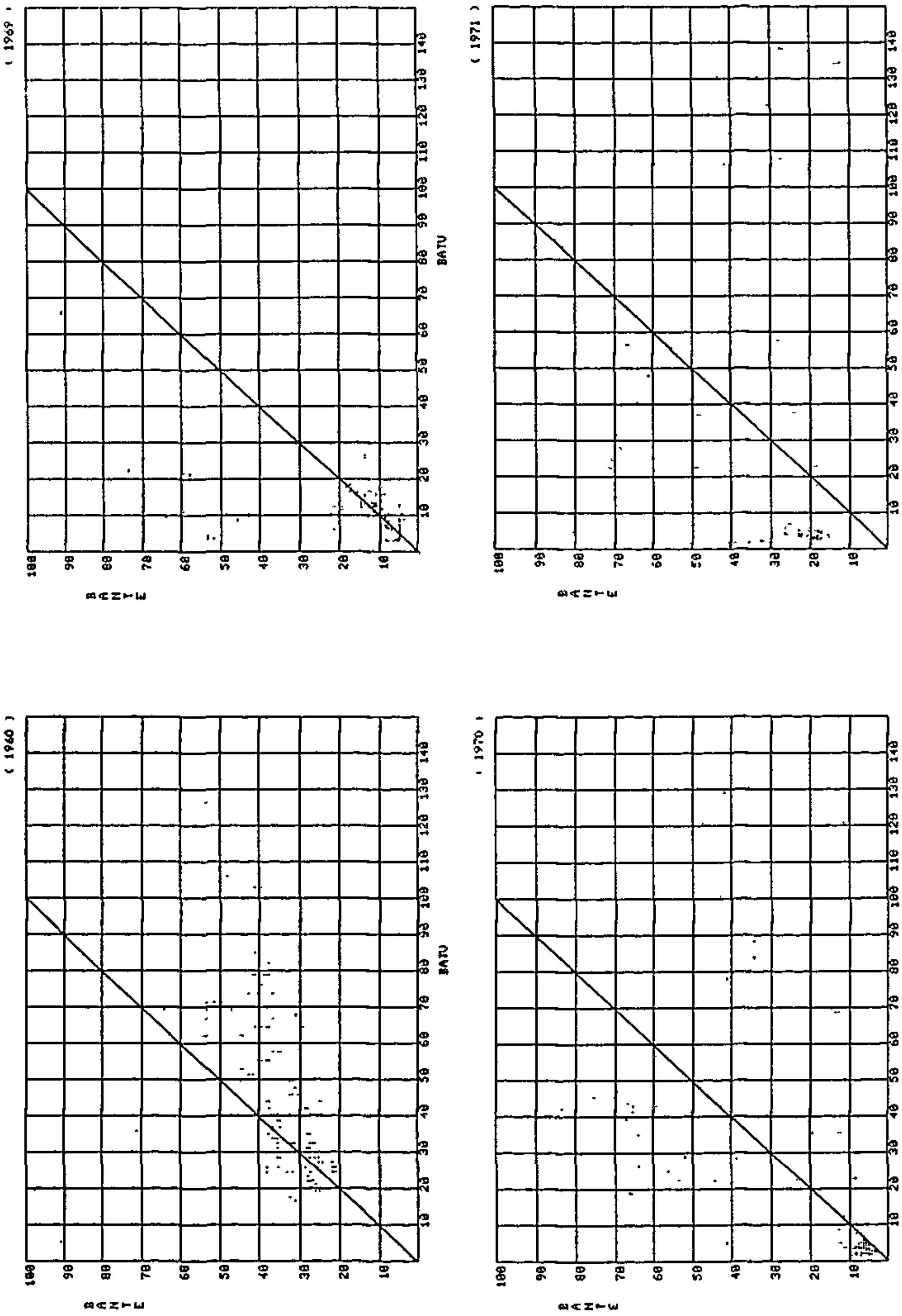


FIG. I - 9

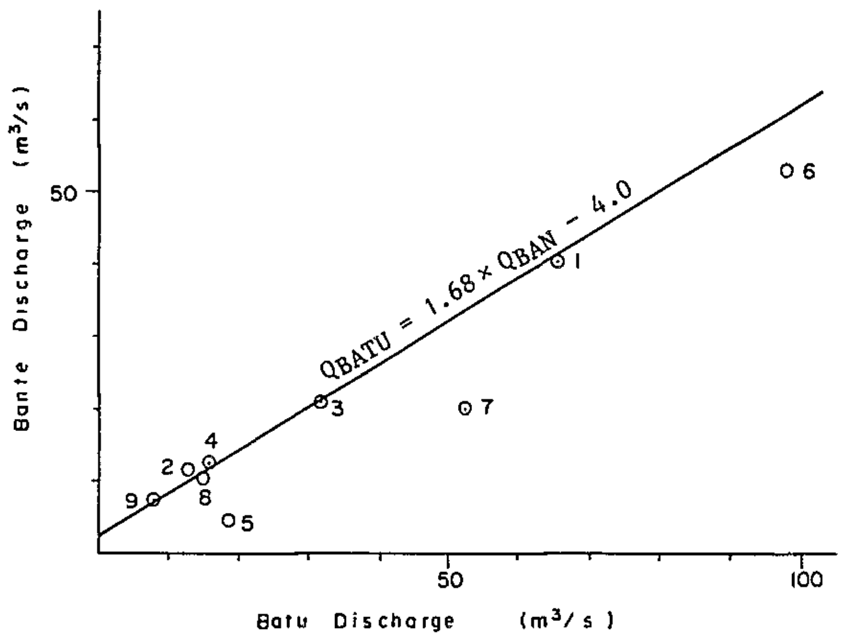
FIG. I - 10



BATU - BANTE DISCHARGE

FIG. I-11

CORRELATION BETWEEN BATU-BANTE DISCHARGE



NO	Discharge at Batu			Discharge at Bante		
	DATE	Q (m³/s)	H (m)	DATE	Q (m³/s)	H (m)
1	Oct 4, '59	65.62	---	Oct 3, '59	40 25	---
2	Feb 16, '61	12 74	1 44	Feb 17, '61	11 51	1 06
3	Mar 3, '65	31.54	0.58	Mar 2, '65	20.85	1.30
4	Mar. 8, '66	15 72	1.01	Mar 9, '66	12 37	0.99
5	Jan 21, '69	18 32	0 78	Jan. 22, '69	4 63	1.16
6	Aug 25, '70	97 80	---	Aug 24, '70	52.92	---
7	Jan 5, '73	52.34	0 21	Jan 7, '73	20 09	0 76
8	Feb 26, '73	14.78	0 15	Feb 26, '73	10 42	0 66
9	Mar 24, '73	7.56	0 13	Mar. 25, '73	7 66	0.54

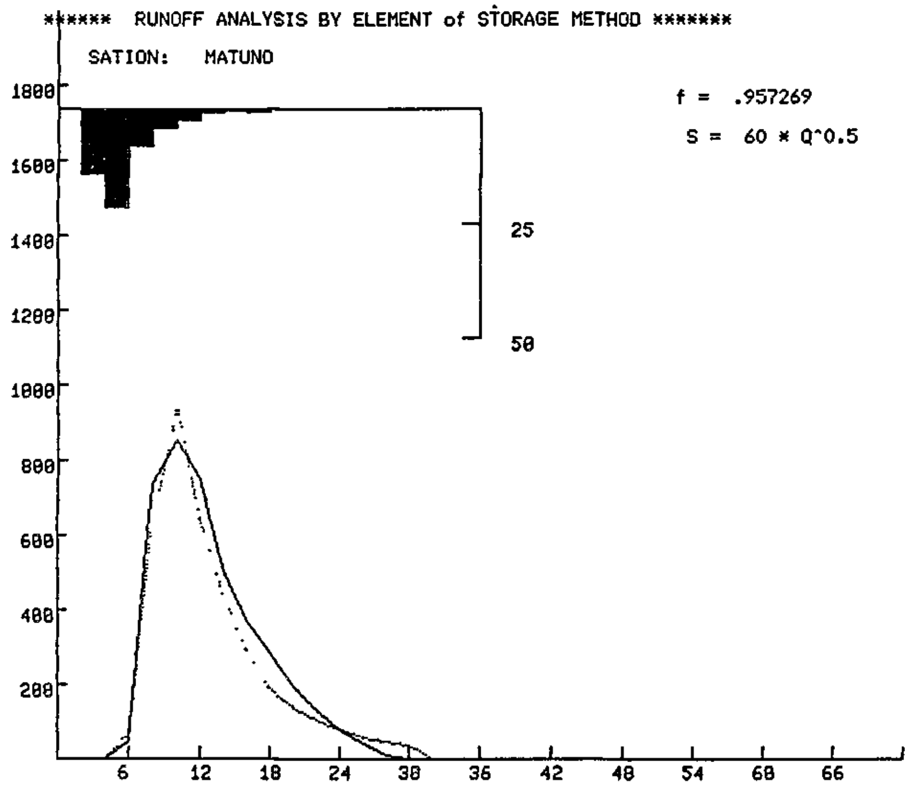
FIG. I - 12

RUN-OFF ANALYSIS AT BANTE FOR TYPHOON NITANG

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

f = .957269 :
S = 60 * Q ^.5

I	R	ER	RREAL Q	EST. Q	TOTAL Q
(0)	15.0	0.0	0.0	0.0	0.0
(1)	9.1	0.1	1.0	70.7	70.7
(2)	14.2	13.6	49.0	625.5	625.5
(3)	21.4	20.5	737.0	939.8	939.8
(4)	8.3	7.9	852.0	642.1	642.1
(5)	4.2	4.0	755.0	430.4	430.4
(6)	2.7	2.6	501.0	287.8	287.8
(7)	0.8	0.8	371.0	190.4	190.4
(8)	0.5	0.5	284.0	139.3	139.3
(9)	0.7	0.7	196.0	106.5	106.5
(10)	0.2	0.2	133.0	79.2	79.2
(11)	0.0	0.0	77.0	59.9	59.9
(12)	0.0	0.0	40.0	46.9	46.9
(13)	0.0	0.0	13.0	37.8	37.8
(14)	0.0	0.0	1.0	0.0	0.0
TOTAL	77.1	50.8			

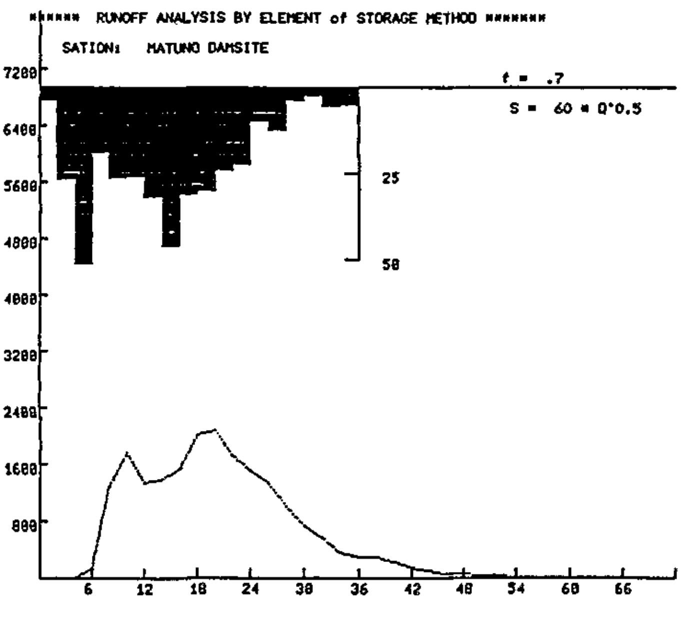


RUN-OFF ANALYSIS AT BANTE FOR TYPHOON ARING

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

f = .7 ; S = 60 * Q ^.5

I	R	ER	RREAL Q	EST. Q	TOTAL Q
(0)	11.9	0.0	0.0	0.0	0.0
(1)	15.1	2.8	0.0	157.0	157.0
(2)	26.5	18.6	0.0	1283.4	1283.4
(3)	51.3	35.9	0.0	1777.8	1777.8
(4)	18.9	13.2	0.0	1339.6	1339.6
(5)	26.1	18.3	0.0	1393.4	1393.4
(6)	25.7	18.0	0.0	1531.4	1531.4
(7)	32.0	22.4	0.0	2021.5	2021.5
(8)	46.1	32.3	0.0	2090.5	2090.5
(9)	31.1	21.8	0.0	1735.1	1735.1
(10)	30.2	21.1	0.0	1524.1	1524.1
(11)	23.9	16.7	0.0	1322.7	1322.7
(12)	22.5	15.8	0.0	1003.7	1003.7
(13)	9.9	6.9	0.0	742.4	742.4
(14)	12.4	8.7	0.0	561.1	561.1
(15)	3.7	2.6	0.0	355.7	355.7
(16)	2.5	1.8	0.0	290.9	290.9
(17)	5.4	3.8	0.0	291.1	291.1
(18)	5.3	3.7	0.0	229.0	229.0
(19)	0.0	0.0	0.0	144.5	144.5
(20)	0.0	0.0	0.0	99.7	99.7
(21)	0.0	0.0	0.0	73.0	73.0
(22)	0.0	0.0	0.0	55.8	55.8
(23)	0.0	0.0	0.0	44.1	44.1
(24)	0.0	0.0	0.0	35.7	35.7
(25)	0.0	0.0	0.0	29.5	29.5
(26)	0.0	0.0	0.0	24.8	24.8
(27)	0.0	0.0	0.0	21.1	21.1
(28)	0.0	0.0	0.0	18.2	18.2
(29)	0.0	0.0	0.0	15.9	15.9
(30)	0.0	0.0	0.0	14.0	14.0
(31)	0.0	0.0	0.0	12.4	12.4
(32)	0.0	0.0	0.0	11.0	11.0
(33)	0.0	0.0	0.0	9.9	9.9
(34)	0.0	0.0	0.0	8.9	8.9
(35)	0.0	0.0	0.0	8.1	8.1
(36)	0.0	0.0	0.0	7.4	7.4
(37)	0.0	0.0	0.0	6.8	6.8
(38)	0.0	0.0	0.0	6.2	6.2
(39)	0.0	0.0	0.0	5.7	5.7
(40)	0.0	0.0	0.0	5.3	5.3
(41)	0.0	0.0	0.0	4.9	4.9
(42)	0.0	0.0	0.0	4.6	4.6
(43)	0.0	0.0	0.0	4.3	4.3
(44)	0.0	0.0	0.0	4.0	4.0
(45)	0.0	0.0	0.0	3.7	3.7
(46)	0.0	0.0	0.0	3.5	3.5
(47)	0.0	0.0	0.0	3.3	3.3
(48)	0.0	0.0	0.0	0.0	0.0
TOTAL	400.5	264.2			



RUN-OFF ANALYSIS AT MAGAT DAM FOR TYPHOON ARING

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

f = .65 :
S = 450 * Q ^.5

I	R	ER	RREAL Q	EST. Q	TOTAL Q
(0)	13.9	0.0	0.0	0.0	0.0
(1)	16.5	4.2	60.0	184.3	184.3
(2)	26.6	17.3	860.0	1382.7	1382.7
(3)	34.3	22.3	1410.0	2869.3	2869.3
(4)	16.4	10.7	2680.0	3736.7	3736.7
(5)	19.4	12.6	3860.0	4637.7	4637.7
(6)	19.7	12.8	4860.0	5446.0	5446.0
(7)	20.9	13.6	6280.0	6461.3	6461.3
(8)	26.7	17.4	6820.0	7081.3	7081.3
(9)	18.5	12.0	6900.0	7146.2	7146.2
(10)	20.4	13.3	6500.0	7155.2	7155.2
(11)	17.9	11.6	6050.0	6780.2	6780.2
(12)	13.9	9.0	5400.0	5853.2	5853.2
(13)	5.8	3.8	5160.0	4891.3	4891.3
(14)	7.1	4.6	4200.0	4076.2	4076.2
(15)	2.2	1.4	3300.0	3269.7	3269.7
(16)	1.4	0.9	2750.0	2743.1	2743.1
(17)	3.1	2.0	2200.0	2418.5	2418.5
(18)	3.0	2.0	1750.0	2065.3	2065.3
(19)	0.0	0.0	1400.0	1702.3	1702.3
(20)	0.0	0.0	1150.0	1427.4	1427.4
(21)	0.0	0.0	980.0	1214.3	1214.3
(22)	0.0	0.0	500.0	1045.6	1045.6
(23)	0.0	0.0	250.0	0.0	0.0
TOTAL	287.7	171.5			

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

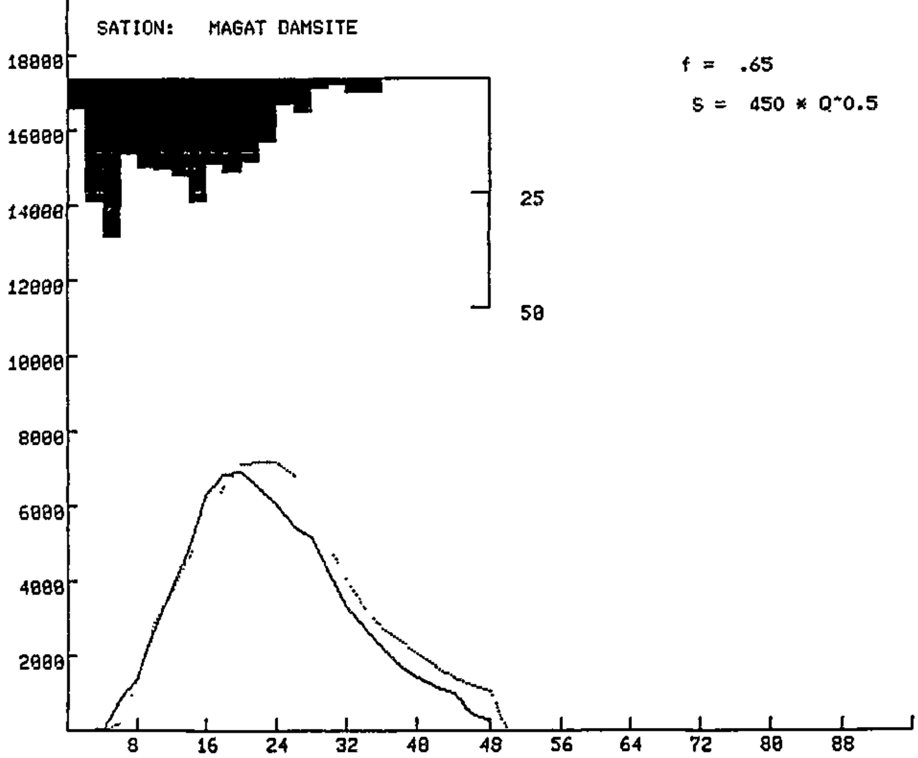


FIG. I - 15

RUN-OFF ANALYSIS AT BATO FOR TYPHOON ARING

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

f = .7 :
S = 140 * Q ^.5

I	R	ER	RREAL Q	EST. Q	TOTAL Q
(0)	7.1	0.0	0.0	0.0	0.0
(1)	9.3	0.0	0.0	10.3	10.3
(2)	16.7	11.7	0.0	167.9	324.9
(3)	36.7	25.7	0.0	408.5	1692.0
(4)	11.2	7.8	0.0	518.6	2296.4
(5)	19.0	13.3	0.0	671.4	2011.1
(6)	19.0	13.3	0.0	821.8	2215.2
(7)	22.6	15.8	0.0	1111.1	2642.6
(8)	36.9	25.8	0.0	1341.7	3363.2
(9)	25.1	17.6	0.0	1325.0	3415.4
(10)	22.7	15.9	0.0	1226.8	2961.8
(11)	17.1	12.0	0.0	1019.1	2543.3
(12)	8.2	5.7	0.0	834.2	2156.9
(13)	10.2	7.1	0.0	679.3	1683.0
(14)	3.1	2.2	0.0	518.8	1261.2
(15)	2.0	1.4	0.0	426.9	988.1
(16)	4.5	3.1	0.0	379.9	735.7
(17)	4.3	3.0	0.0	318.1	609.0
(18)	0.0	0.0	0.0	249.9	540.9
(19)	0.0	0.0	0.0	201.5	430.5
(20)	0.0	0.0	0.0	166.0	310.4
(21)	0.0	0.0	0.0	139.1	238.8
(22)	0.0	0.0	0.0	118.3	191.3
(23)	0.0	0.0	0.0	101.8	157.6
(24)	0.0	0.0	0.0	88.5	132.6
(25)	0.0	0.0	0.0	77.7	113.4
(26)	0.0	0.0	0.0	68.8	98.2
(27)	0.0	0.0	0.0	61.3	86.1
(28)	0.0	0.0	0.0	0.0	21.1
TOTAL	275.7	181.5			

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

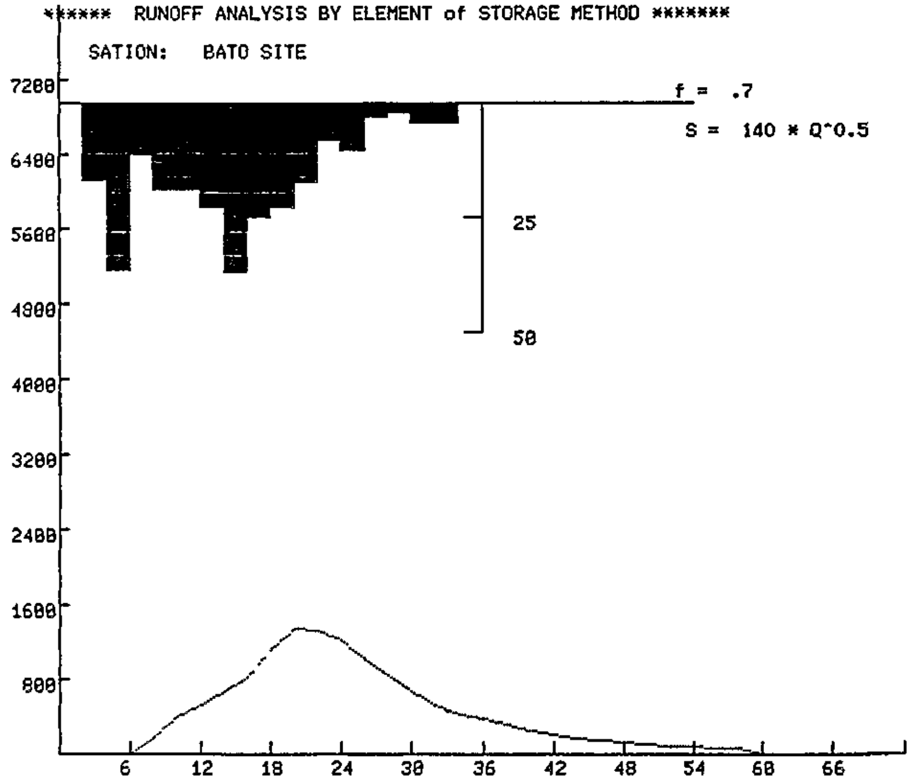


FIG. I - 16

100-YEAR RETURN PERIOD FLOOD AT BANTE FOR FLOOD CONTROL

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

f = .8 :
S = 60 * Q .5

I	R	ER	RREAL Q	EST. Q	TOTAL Q
(0)	0.0	0.0	0.0	0.0	0.0
(1)	4.2	3.4	0.0	24.3	24.3
(2)	5.7	4.6	0.0	119.7	119.7
(3)	8.2	6.6	0.0	330.5	330.5
(4)	13.0	10.4	0.0	779.0	779.0
(5)	23.6	18.9	0.0	1944.9	1944.9
(6)	51.4	41.1	0.0	2596.3	2596.3
(7)	34.8	27.8	0.0	1740.8	1740.8
(8)	17.1	13.7	0.0	1059.2	1059.2
(9)	10.2	8.2	0.0	708.9	708.9
(10)	6.8	5.4	0.0	508.4	508.4
(11)	4.9	3.9	0.0	368.0	368.0
(12)	2.7	2.2	0.0	240.6	240.6
(13)	0.0	0.0	0.0	150.2	150.2
(14)	0.0	0.0	0.0	102.9	102.9
(15)	0.0	0.0	0.0	75.0	75.0
(16)	0.0	0.0	0.0	57.2	57.2
(17)	0.0	0.0	0.0	45.0	45.0
(18)	0.0	0.0	0.0	36.4	36.4
(19)	0.0	0.0	0.0	30.0	30.0
(20)	0.0	0.0	0.0	25.2	25.2
(21)	0.0	0.0	0.0	21.4	21.4
(22)	0.0	0.0	0.0	18.5	18.5
(23)	0.0	0.0	0.0	16.1	16.1
(24)	0.0	0.0	0.0	0.0	0.0
TOTAL	182.6	146.1			

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

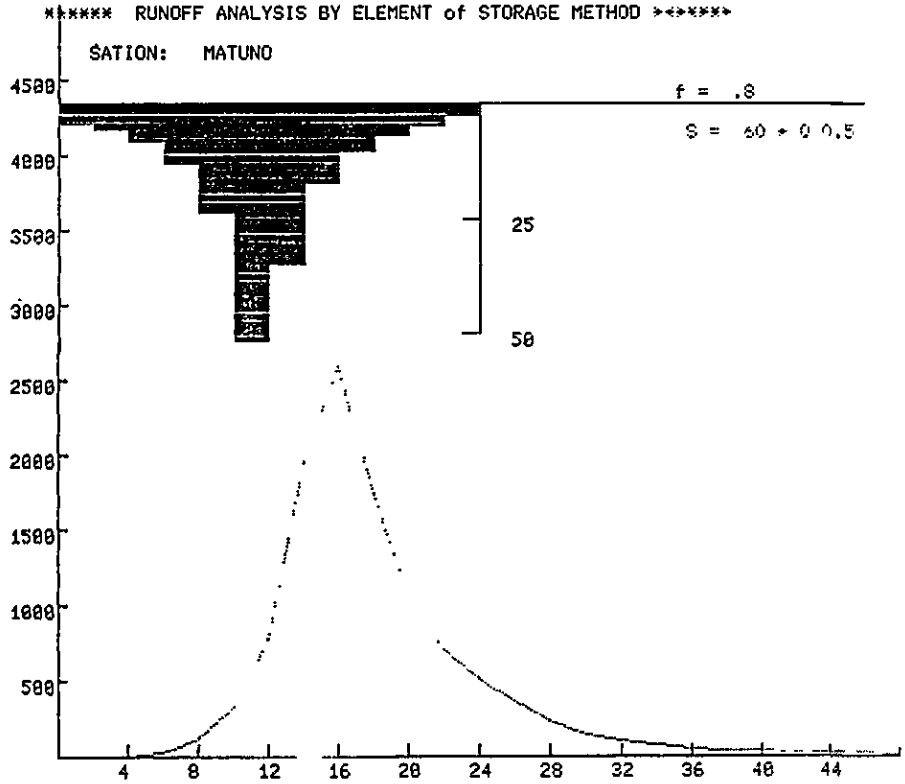


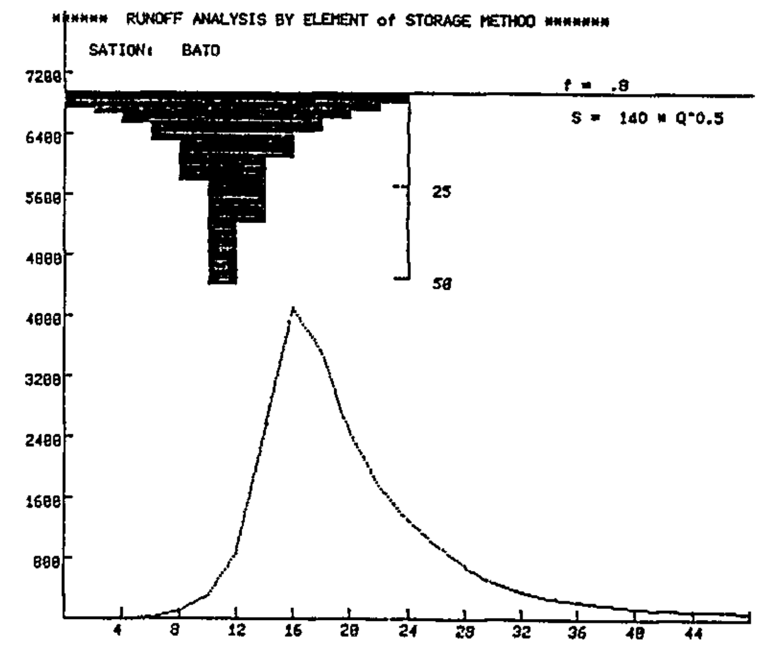
FIG. I - 17

100-YEAR RETURN PERIOD FLOOD AT BATU FOR FLOOD CONTROL

****** RUNOFF ANALYSIS BY ELEMENT of STORAGE METHOD *******

f = .8 ; S = 140 * Q ^.5

I	R	ER	RREAL Q	EST. Q	TOTAL Q
(0)	0.0	0.0	0.0	0.0	0.0
(1)	4.2	3.4	0.0	18.1	18.1
(2)	5.7	4.6	0.0	98.2	98.2
(3)	8.2	6.6	0.0	313.1	313.1
(4)	13.0	10.4	0.0	867.5	867.5
(5)	23.6	18.9	0.0	2512.1	2512.1
(6-)	51.4	41.1	0.0	4109.0	4109.0
(7)	34.8	27.8	0.0	3535.0	3535.0
(8)	17.1	13.7	0.0	2486.7	2486.7
(9)	10.2	8.2	0.0	1770.9	1770.9
(10)	6.8	5.4	0.0	1309.5	1309.5
(11)	4.9	3.9	0.0	981.2	981.2
(12)	2.7	2.2	0.0	701.8	701.8
(13)	0.0	0.0	0.0	493.8	493.8
(14)	0.0	0.0	0.0	366.7	366.7
(15)	0.0	0.0	0.0	283.2	283.2
(16)	0.0	0.0	0.0	225.3	225.3
(17)	0.0	0.0	0.0	183.6	183.6
(18)	0.0	0.0	0.0	152.5	152.5
(19)	0.0	0.0	0.0	128.7	128.7
(20)	0.0	0.0	0.0	110.1	110.1
(21)	0.0	0.0	0.0	95.2	95.2
(22)	0.0	0.0	0.0	83.2	83.2
(23)	0.0	0.0	0.0	73.3	73.3
(24)	0.0	0.0	0.0	65.1	65.1
(25)	0.0	0.0	0.0	58.2	58.2
(26)	0.0	0.0	0.0	52.3	52.3
(27)	0.0	0.0	0.0	47.3	47.3
(28)	0.0	0.0	0.0	43.0	43.0
(29)	0.0	0.0	0.0	39.2	99.2
(30)	0.0	0.0	0.0	35.9	35.9
(31)	0.0	0.0	0.0	33.0	33.0
(32)	0.0	0.0	0.0	30.5	30.5
(33)	0.0	0.0	0.0	28.2	28.2
(34)	0.0	0.0	0.0	26.2	26.2
(35)	0.0	0.0	0.0	24.4	24.4
(36)	0.0	0.0	0.0	0.0	0.0
TOTAL	182.6	146.1			



APPENDIX I - II

GEOLOGY AND CONSTRUCTION MATERIALS

APPENDIX I-II

GEOLOGY AND CONSTRUCTION MATERIALS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

APPENDIX I-II

GEOLOGY AND CONSTRUCTION MATERIALS

1. TOPOGRAPHY AND GENERAL GEOLOGY

1.1 Topography

The Project area is comprised of the hilly area of the Matuno River basin and the low flatland of the Magat River sub-basin extending along both banks of the Magat River.

The Matuno River has its source in the vicinity of the Pulog mountains located 30km northwest of the Project area. It flows southward through rugged hills, exiting the mountains near Manamtam at the southern edge of the Project area, and joins with the Santa Cruz and Santa Fe rivers at Santo Domingo to form the Magat River.

The Magat River courses northward creating a broad floodplain across the alluvial lowland around Bayombong, joins with the Lamut River at the northeastern periphery of the Project area, exits the hilly region and transits Magat Dam to flow into the Cagayan River.

The mountains of the Matuno River basin constitute rugged terrain ranging in elevation from 600-1,600m. The Matuno River is fed by numerous tributaries of which the Nansiacan River located upstream from A-site possesses the largest catchment area.

The Magat River sub-basin is comprised largely of flatland 220-300m in elevation, sporadically dotted with isolated hills 600m or less in elevation. The foothills at the western edge of the sub-basin feature gradual slopes covered by talus and terrace deposits. The area of the sub-basin is 150km^2.

1.2 General Geology

In terms of geologic structure, the Project area is composed of sedimentary and intrusive rock of post Cenozoic Tertiary formation. As shown in the geological map, FIG. II-1, and the general geological profile (E.W), FIG. II-2, the mountainous portion of the Matuno River basin is covered by widely distributed conglomerate and sandstone of the Miocenic Natbang formation. This formation is covered unconformably by limestone of the Macde formation in the lower basin area as well as in the vicinity of the mountain summits along both banks. In mountainous and flat areas of the Magat River sub-basin, pyroclastic rock of the Eocenic Caraballo Group and Oligene to Eocenic intrusive diorite is distributed. Within the basin and in the surrounding foothills, the formations discussed above are covered by Pleistocene to Holocenic terrace, talus and river deposits.

On the basis of existing data and field surveys conducted by the Team, the geologic formations of the Project area are presented in TABLEs II-1 and II-2.

The characteristics of each individual formation are discussed below.

(1) Natbang Formation

This formation is chiefly composed of conglomerate with frequent interbedding of sandstone, siltstone and calcareous sandstone.

Conglomerate consists of round and sub-angular cobbles 10-20cm in diameter or less (rarely 30cm in diameter) contained within a sandy matrix. At times conglomerate grade into a strata of coarse sandstone 1m or less in thickness. Principal types of cobble are andesite, basalt, and diorite, with lesser amounts of limestone, sandstone and siltstone present.

Fresh portions of conglomerate are light gray to light bluish gray, hard and exhibit strong resistance to erosion. Weathered portions range in color from yellow brown to orange brown. In highly weathered portions' cobbles are easily crushed and the matrix exhibits a large clay content.

Sandstone intercalated in conglomerate consists generally of fine to coarse grained sandstone in layers of one to several meters thickness. Fresh portions are massive, exhibit little cracking, and are light gray to gray. Although bedding overall is not clearly evident, occasional bedding at 2 or 3cm-10cm intervals is present. In comparison to conglomerate, most sandstone is slightly less consolidated and more brittle. Weathered portions are yellow brown to orange brown and extremely brittle. Highly weathered sections are sandy in consistency.

Siltstone intercalated within conglomerate generally comprises thin strata of 2m or less. Compared with sandstone, its distribution frequency and continuity is small. Fresh portions are dark gray, with bedding planes evident at 2-10cm intervals. Although fresh portions are relatively hard, cracking at right angles to bedding planes is extensive, making such portions more brittle than conglomerate or sandstone. Extensively weathered sections are gray-brown and soft.

Calcareous sandstone indicates sedimentary deposits containing various types of clastics and calcareous sediment. These materials are further classified into calcirudite to calcurenite and sandy limestone depending on mixture ratios and granule size. Strata are intercalated within conglomerate and range in thickness from 0.5-10m, which is generally intergradational with calcareous sandstone. Fresh portions are dark gray intermixed with gray white to white, and are hard, massive, without bedding planes, and exhibiting almost no cracking. Resistance to weathering is generally greater than that of conglomerate. However, along boundaries with conglomerate, some hydrodissolution is occasionally evident.

(2) <u>Macde Limestone</u>

Macde limestone contains crystalline, sandy and fossiliferous components. It is gray white to milky white and does not exhibit clear bedding. Relatively continuous cracks are formed at 1 to several meter intervals. At certain points, northwardly dipping cracks striking EW are present which appear to be bedding planes.

Limestone is fresh, hard and resistant to weathering. Precipices composed of limestone outcroppings are present on mountain sides. Open cracking is evident due to dissolution of the limestone. Near mountain summits and at the top of small ravines, numerous sinkhole-like depressions are found. Open small caves are in evidence on precipice portions.

(3) Intrusive Rock

Intrusive rock consists of uniform diorite and is distributed from the opposite bank of Manamtam to the vicinity of St. Domingo. Judging from the distribution pattern for diorite, it is clear that it at least intrudes into the Caraballo Group.

(4) Caraballo Group

The Caraballo Group constitutes the lowermost stratum of the Project area and is distributed in the Magat River sub-basin and its environs. It is classified into formations I, II and III, with Formation II found along the mountainous eastern boundary of the basin (Magat River right bank) and Formation III located inside the basin and on its western edge.

Formation II is composed primarily of fine to coarse grained tuff, while Formation III consists of (from east to west) tuffaceous breccia, fine grained tuff, and tuffaceous rock to condesitic basalt intercalated with sandstone to mudstone.

Although the precise geologic structure of Caraballo Group remains unclear, however, judging from its distribution pattern, it is considered a monoclinic structure striking roughly north to south and dipping to the west. According to "Geological Map of the Philippines" (1:1,000,000), a westward dipping fault line is situated at the eastern to south eastern edge of the basin at what is believed to be the boundary between formations II & III. This fault is considered as a factor in the formation of the Magat River sub-basin.

(5) Terrace Deposits

Holocenic and Pleistocenic terrace deposits are distributed in the Project area. Pleistocenic terrace deposits are found along the riverbed of the Matuno River and at the upper and middle reaches of the Lamut River where they form generally level areas with some undulation. Strata contain unconsolidated to semi-consolidated sand and gravel. Pebbles and cobbles are from pre-existing base rock, and are round to sub-angular in contour with diameter size ranging from 2, 3cm to 20cm.

Holocenic terrace deposits are widely distributed on the level area within the Magat River sub-basin. Strata thickness is 10-20m. Strata consist of unconsolidated gravel, sand, clay, etc.

(6) Talus Deposits

Talus deposits are distributed at the base of mountains. Strata consist of unconsolidated cobbles of limestone and conglomerate, other rock fragments, sand and clay. Locations of this formation are generally along narrow areas, with the exception of the fan-shaped distributions occurring on the left bank at Bante and the western portion of La Torre.

(7) River Deposits

River deposits consist of unconsolidated sand and gravel strata formed by round to sub-angular cobbles with diameters of 2/3cm to 300cm from pre-existing base rock. River deposits are distributed along the riverbed and floodplain of the Matuno and the Magat rivers.

2. GEOLOGICAL INVESTIGATION AT DAM SITES

2.1 Existing Survey Data

Previous to the JICA team survey, NIA carried out a geological survey covering principally dam site C from 1979-82.

Dam Site	Drilling Site	Number of Drilled Hole	Depth of Drilled Hole (m)
C Site (Downstream)	left abutment	AD-2	30.0
	river bed	AD-3	30.0
	right bank	BC-1	50.0
Total		3 holes	110.0

2.2 Initial Survey

From January to March 1982 the following surveys and studies were conducted by the JICA team:

- Collection and review of geological data on the Project area and its environs
- Study of findings from previous geological surveys
- General geological survey of the Project area for selection of dam sites and overview of geologic structure of envisaged inundation (reservoir) area
- Selection of candidate borrow sites for construction materials
- Preliminary delineation of envisaged irrigation benefit area
- Examination of existing drilled cores

2.3 Secondary Survey

The secondary survey was carried out from July 1982 to March 1983 by the JICA team in cooperation with NIA experts. Survey activities are outlined in FIG. II-3, and TABLES II-3 - II-6 and consisted of drilling investigation, seismic prospecting, test pits and laboratory testing.

In conjunction with the above survey, geologists of the Team conducted surface geological surveys of candidate dam sites and inundation areas, candidate borrow sites, and the envisaged irrigation benefit area. Survey of site C placed major emphasis on investigation of cavitation and permeability in limestone formations in and around the site while survey at site B_2 focused chiefly on the depth of weathered strata and permeability.

3. GEOLOGY AT DAM AND RESERVOIR SITES

3.1 Dam Site C

3.1.1 Topography and Geology

Site C is situated 5.5km southwest of Santo Domingo at the lowest reaches of the Matuno River. River width at the site is a relatively narrow 30m, with both banks constituting steep slopes of limestone at 45°-60°. Numerous sinkholes are present in the vicinity of summits (EL. 600-800m) on both banks. Small cavitations are found on slopes along both banks.

Bedrock at the site is limestone. Visual inspection indicates that limestone is massive and hard, although open cracks and cavitation are present in surface portions due to dissolution. Details of limestone structure remain unclear due to the absence of clear bedding planes. However, on the basis of limited data available, it is assumed that the said formation strikes east to west and dips north at 30°-40°. The northern boundary of the limestone formation is formed by a fault line striking east to west and dipping steeply to the north.

Boring conducted at site C is as indicated in FIG. II-3. Boring results are presented in FIG. II-4 (borehole log), FIG. II-5 (geological cross-section) and DATA BOOK (drilling core log). Rock classifications applied in this report are described in TABLE II-7.

As the boring results at BC-1, ADH-3 show, riverbed is composed overall of good rock, without the presence of pronounced cracking. However, to a depth of approximately 30m, cracks are oxidized. Permeability at BC-1 is 18-20 Lugeon to 10m below riverbed sand and gravel. Below that, Lugeon values of 4-11 are obtained. Sections of high permeability are limited.

At ADH-3 (left bank, mountain base, 20m higher than the riverbed), what is believed to be a cave is evident between 7.5-12m. Pronounced cracking from dissolution is present at 27.90-29.80m. Borehole water level is slightly less than the riverbed at -23m.

oxidized and numerous traces of worm-eaten dissolution are present. In particular, for depths of 73.1-76.0m and 90.0-95.0m, cores are gravel to cylindrical fragment, core recovery rate is low, cracking is extensive, and dissolution of cracking is considered prevalent. For the entire borehole depth, permeability has high values from 30-50 Lugeon. At 25-30m, a spring with water head of at least 8.8m is present.

Limestone displays good hardness, with single axial compression strength estimated at 400-800kg/cm^2. However, the presence of numerous dissolution cavities indicates unfavorable permeability for dam foundation.

3.1.2 Site C as a Dam Site

Dam construction in an area of limestone formation generally poses the following problems.

Firstly limestone often features pronounced cracking and cave formations caused by dissolution (referred to as open cracking below). Inundation can accordingly result in large scale seepage. Seepage can result in reduction of reservoir efficiency, abnormal flooding to adjacent basin, and structural instability.

Secondly where a cave(s) is present at or near the dam foundation, foundation sinking may result. Where continuous open cracking is found on gradual slopes, shear resistance of foundation rock is sharply reduced, thereby affected foundation bearing strength in the case of a concrete type dam.

Lastly in the case of pre-Tertiary limestone, it is generally considered that adverse effects from dissolution are not posed for dam stability and reservoir area foundation. However, as acidic water accelerates the dissolation process, attention should be given to the water quality within the basin area.

Reference: dissolution rates (M.M. Sweeting, 1966)

surface	0.040 mm/year
sub-surface strata	0.043 mm/year

C site is considered inappropriate as a dam site by virtue of the following points:

(1) Surface survey and aerophotography indicate the presence of numerous sinkholes spread widely along both banks. At present, the base of the sinkholes are filled with earth and sand. Although elevations are higher than the proposed dam crest, there is a strong possibility that water passes are genetically formed at considerable depth. In areas of limestone distribution, rivulets of surface water are not in evidence. The lack of such rivulets suggests that surface water permeates the ground, thereby creating an extensive groundwater system. Although it is not precisely clear where this groundwater flows to (in general, the movement of surface and groundwater in limestone formations is extremely complex, and water balance analysis is accordingly difficult), the fact that springs are not present on slopes implies that seepage most likely occurs to great depth.

(2) The presence of caves (lateral caves; 3 locations; EL. 500-650m) on mountain slopes on both banks of the site implies that at the time of cave formation the groundwater table level was at least around the same elevation. At present however, the groundwater table has dropped from this former level and the possibility is accordingly high that erosion has progressed to a considerable depth.

(3) Open cracking is present in all outcroppings. The depth of such cracking, however, remains unclear. On the basis of boring results as cracking and oxidation are observed at great depths in BC-2 and ADH-2, cracking is also considered present at great depths at elevations above the riverbed elevation.

(4) Lugeon valves from BC-2 indicate high permeability at 30-50 Lugeon over the entire interval. As borehole bottom is around EL. 450m, permeability at greater depths and at the center of the ridge remains unclear. However, from (1) and (2) above, it may be concluded that permeability is high throughout the entire limestone formation.

(5) BC-2 is located in the vicinity of the source of a small riverlet at EL. 525m. Although it may be considered that this point provided a water supply for riverlet formation previously, at present a water collecting basin is not topographically in evidence. As a consequence, water gathered at this point is believed to be groundwater from higher elevations. Spring water inside the borehole likewise appears topographically to be supplied from sinkholes in the vicinity of the mountain summit. This in turn suggests that an extensive groundwater system exists throughout the area.

At less than 25m, groundwater level is shallow with -12.50m in BC-2. However, confirmation is required as to whether this represents the stable groundwater level, and whether or not fluctuations in spring water conditions occur. Karstic spring water is generally perennial at low elevations and intermittent at high locations, with such tendency even more pronounced in areas such as the Project area where distinct wet and dry seasons exist. Consequently, the spring water and groundwater level confirmed at BC-2 are not considered perennial. Obervations of these conditions are accordingly necessary over a continuous 1 year period.

(6) Since limestone bearing the above mentioned characteristics is widely distributed throughout the dam and reservoir area site, seepage at site C poses the greatest problem.

(7) The extent of area requiring seepage prevention works, and seepage prevention methods must be clarified. The groundwater level along the length of the dam axis must be determined. At least the area where groundwater level is higher than reservoir level elevation, and including distribution of impermeable rock requires seepage prevention works.

Groundwater level must be observed continuously for one year[1/] (1-2 times/month) in order to ascertain the range of fluctuation along the dam axis. Seepage prevention works are necessary to a vertical depth where rock of permeability of Lugeon 1 or less is distributed. The extent of works for the reservoir foundation are to be determined on the basis of permeability, seepage length, head, geologic structure, etc.

On the basis of permeability of rock along and in the vicinity of the seepage prevention line, the appropriate seepage prevention method is to be studied and determined, the general procedure in most countries is to apply curtain grouting[2/], although grounting, cut-off, reservoir area lining, etc. are other possible methods.

At present, the extent of area requiring seepage prevention is large, and appropriate seepage prevention works are considered extremely difficult. In order to clarify precise range and method to be used would require large additional amounts of time and money[3/]. On the basis of survey results to date, a high possibility exists that appropriate seepage prevention measures would be impossible.

(8) The presence of open cracking and caves at the dam site is as described earlier a potential cause of foundation subsidence, drop in shear strength, uplift, etc. Precise extent of such danger at the site remains unclear however. Such details must be clarified through further survey and investigation although this would be easier to implement than that for the aforementioned seepage problem.

1/ Hydrological survey of Karst region normally requires observation records over numerous years.

2/ In the case of large caves, either curtain grouting or filling with concrete is possible.

3/ Geological and hydrological survey in Karst region requires 10-20 years for thorough execution.

(9) With the exception of such special circumstances as problems with water quality like sulfidic changes, the presence of hot springs, etc., within the basin area dissolution of limestone is not normally considered a problem. However, in the case of the Project area, Ca deposits are heavily distributed on the floor of rivulets, suggesting that the speed of limestone dissolution is high, and accordingly requiring further careful study.

On the basis of the points discussed above, water seepage is the major problem at site C. Numerous dams have been built in various countries in areas of limestone distribution, and in virtually every case, seepage has been a problem requiring careful monitoring during construction, initial inundation, and subsequent operation and maintenance. However, no precedent in other countries exists for dam construction on post pre-Neogene limestone.

As discussed earlier, extensive amounts of time and money would be required to clarify problems related to seepage, bearing capacity and rock dissolution. At this current stage, it is considered that the possiblity of successful seepage prevention works is extremely low. Sites B_2, B_1 and A exhibit for fewer problems compared to site C. Since other more economical and realistic sites are available, site C is deemed inappropriate as a dam site for the Project.

3.2 Dam Site B_2

3.2.1 General

Site B_2 is located on a curving portion of the Matuno River 3km upstream from site C. Riverbed is EL. 390m and river width is about 50m. Both banks form steep slopes of roughly 50°. On the left bank, a narrow ridge of EL. 510m-530m protrudes to the west. Although this ridge limits dam size, it is topographically favorable for spillway construction.

Geology at site B_2 is given in FIG. II-6. Site B_2 is composed primarily of conglomerate belonging to Natbang formation consisting of early to mid-Miocenic deposits, conglomerate minorly intercalate sandstone of 20m in thickness and thin layers of calcereous sandstone of 3-7m in thickness. Numerous outcroppings of this formation are present, although on the gradual slope of the left bank it is covered by a 2-3m layer of talus deposits and on the riverbed by a river deposit stratum with a maximum thickness of 15m.

Fresh portions of conglomerate display high permeability in locations where cracking is concentrated; however, this may be rectified through standard grouting procedures. Overall, fresh portions are blocked, hard and generally satisfactory for a high dam foundation. In weathered portions of surface strata fine grained sections of matrix alters to brown sandy clay. Cobbles are decomposed, and the overall nature of these weathered portions is loose and lacking in sufficient strength and impermeability for dam foundation. These portions will accordingly require excavation prior to construction. Excavated material may be utilized as core material for rockfill dam construction.

The envisaged inundation area above site B_2 is of the same geologic structure as the site and topography is also similar. However, since the weathered portion of this area is generally shallow, rockfall which is seen in abundance downstream is infrequent and only of small-scale. The reservoir area is accordingly relatively stable. Nevertheless inundation following dam construction can be expected to accelerate the weathering process, resulting in increased scale and frequency of rockfall occurence. A program of forestation, landslide prevention works, etc. would accordingly be necessary.

3.2.2 Drilling Investigation

In order to confirm depth of weathered strata and to determine permeability, boring was conducted for sampling of cores and utilization of boreholes for in-situ permeability testing. Borehole locations and lines at site B_2 are indicated in FIG. II-7.

Boring results are given in FIG. II-8 (borehole log), FIG. II-9 (geographical cross-section) and DATA BOOK (drilling core log). These results show that weathering depth of base rock is 20-40m on the left bank and 7-20m on the right bank. Weathering extends deeper on more gradual slopes. Intercalations of sandstone tend to be slightly deeper than conglomerate.

Groundwater was observed at 40m below ground surface on the left bank, and at 30m below the surface on the right bank. Results from permeability testing are given in FIG. II-10 and 11. On the basis of these findings, permeability of weathered portions has been determined at 10^{-3}-10^{-4}cm/s (for soft rock with only slight cracking 1 Lu ≈ 10^{-5}m/s).

Underlying slightly weathered to fresh portions exhibit Lugeon values of 5-30. For riverbed formation, even fresh sections show Lugeon values of 20-30. Relatively numerous cracking in that formation accounts for the relatively high Lugeon values in comparison with fresh rock elsewhere. Although permeability overall for the site is slightly high, cement grouting would provide sufficient stability for dam construction.

3.2.3 Seismic Prospecting

Seismic prospecting was conducted at site B_2 on the left bank along 3 lines for a total of 1,540m, and on 1 line on the right bank for 605m.

Bank	Line Name	Length
Left bank	A line	825m
- do -	B line	440m
- do -	C line	275m
Right bank	D line	605m
Total		2,145m

Measurements were carried out by NIA experts. On the basis of recorded data, a 1/1000 scale velocity layer cross sectional diagram was prepared.

Velocity layers were broadly divided into 4 strata. Comparison of rock characteristics for each stratum is presented on the following page. Velocity layer cross-sectional diagram for each line are given along with boring results in FIG. II-12.

Velocity stratum	Velocity (km/s)	Rock characteristics	Stratum thickness (m)
1st Stratum	0.3 - 0.5	Topsoil, talus, weathered rock soil	1 - 7
2nd Stratum	0.7 - 1.0 0.6 - 0.7 1.0 - 1.2	Heavily weathered rock (included portions of talus)	5 - 20 (max. 40)
3rd Stratum	1.6 - 2.0	Moderately weathered rock	10 - 30
4th Stratum	3.0 - 3.2 3.5 - 3.2	Slightly weathered rock to fresh rock	
Low velocity zone	2.5 (estimated) velocity unknown	Shear zone, fractured zone, deep strata weathered zone	

On the basis of comparison of velocity layer classification for seismic waves, and boring results, the geologic characteristics of the left bank at site B_2 may be described as follows.

The first velocity layer (0.3-0.5km/s) consists of cover material including topsoil, talus, weathered rock soil, etc. With the exception of cliff at distances from 720-780m of A line, this stratum is 1-7m in thickness and is roughly distributed throughout the entire site area.

The second velocity stratum (0.7-1.0km/s) is mainly composed of heavily weathered rock in the form of loose earth and sand, including portions of unconsolidated sedimentary deposits. On the basis of core examination, this heavily weathered portion is determined as D-class, and 5-20m in thickness. In the vicinity of 400m on B line, where topography constitutes a ridge-like section, the second velocity stratum is 40m in thickness. From results of boring at B-6 hole, this is due to distribution of heavily weathered conglomerate belonging to D-class. For suitability of structural foundation, the 40m of weathered zone at this point would most likely require excavation. On the slope portion at 700-750m on A line, a high velocity reading for this stratum of 1.8-1.2km/s was obtained, probably due to the fact that weathered soil has fallen away.

The third velocity stratum consists of materials belonging to CL to CM classes including one portion of D class. Although sections composed of rock fragments and blocks exhibit hardness, cracking is pronounced throughout the stratum along which weathering has progressed. This stratum is accordingly identified as moderate to mildly weathered rock.

The fourth velocity stratum (3.0-3.2, 3.5-3.7km/s) constitutes the foundation velocity stratum for the site area and comprises a slightly weathered to fresh layer of conglomerate. Due to variation in degree of cracking and weathering throughout the stratum, some difference in velocity is evidenced from location to location. The depth of this stratum from ground surface is generally 30-60m with the exception of the riverbed and relatively low marsh area along lines B and D where the said depth is 10m.

Within the fourth velocity stratum, low velocity zones are present wherein velocity values are relatively less than those of adjacent areas. Seven such zones where identified along the 4 measurement lines. Of these, the low velocity zones at 170-240m on A line and at 260-280m on B line are considered as bearing relationship to the fault at 200m on the A line. In the case of other low velocity zones, they appear to be the results of fault cracked zone, deep strata weathering, deterioration resulting from folding, etc. However, the precise nature of relationship and continuity with surrounding formations remains unclear.

3.2.4 Site B_2 as a Dam Site

At site B_2, dam crest elevation is topographically limited in the vicinity of 500m. Strengthwise, a rock fill dam is considered feasible to a crest elevation 500m. However, the amount of foundation excavation necessary for removal of the weathered portion is large, and seepage prevention works are widely required for the left bank ridge portion. Although economical comparative study is to be done, judging from the weathered rock condition, a dam crest elevation of 480m would be more advisable. In the case of a gravity concrete type dam, conglomerate strength and weathering condition of rock would limit dam height to 60-70m.

Conventional practice dictates that dam axis be as perpendiular to river axis as possible. In this regard, site B_2 is well situated as both banks constitute steep slopes. At the same time, the left bank ridge portion requires seepage prevention works. However, the fact that spillway construction is facilitated by topography and that the bypass becomes short, site B_2 will constitute a superior dam site with lesser height.

The left bank constitutes a ridge-like section, featuring a thick belt of weathered rock. As seepage by piping, etc. is a problem, grouting works are required. The extent of area necessitating grouting reaches at least to points where the groundwater level exceeds the reservoir water level. Required grouting depth extends below the groundwater level to fresh rock where Lugeon values are less than 5. Although the present groundwater level at B-1 on the left bank ridge section is high, the minimum level during the dry season must be ascertained. At present, grouting may be considered necessary at least throughout the entire ridge portion to a depth of about EL. 460m.

Based on the boring investigation results on the right bank riverbed portion the said riverbed portion may be considered for the present as basically identical to the left bank side thereby requiring grouting to 80% of the dam height.

At present for seepage prevention in weathered portions, grouting is considered as possible. However, the following points require clarification through grouting tests: 1. effectiveness of grouting in weathered portions; 2. methodology for evaluating effectiveness; 3. effectiveness of packer (for ex., whether or not slip grouting is necessary); 4. intrusion material; 5. grouting hole interval; 6. intrusion pressure; etc.

Where spillway foundation consists of CL class rock or better, no problem is anticipated in support strength. However, at B-6 downstream, weathered strata is relatively thick.

4. CONSTRUCTION MATERIAL FOR B_2 DAM

4.1 General

If the type of dam at site B_2 is assumed to be rockfill, the following kinds and amounts of embankment materials become necessary:

- impervious material (core material) 611,000m^3
- semi-pervious material (filter) 566,000m^3
- pervious material (rock, rip-rap) 3,159,000m^3

Materials found within the Project area are discussed below in terms of possible construction application.

(1) River Deposits

River deposits consist of gravel and sand, and are distributed on the Matuno riverbed in the vicinity of site B_2 and along the Magat riverbed. These deposits have potential use as semi-pervious material and concrete aggregate. Deposits on the Matuno River are small in quantity, with excavation thereof limited by spatial conditions.

(2) Talus Deposits

Talus deposits are distributed on gradual slopes adjacent to the western edge of the Magat sub-basin and on the right bank at Bante. They consist of gravel and sand, with large clay content. Although these deposits appear suitable for impervious material, the large clay content makes adequate strength a potential problem.

(3) Terrace Deposits (Holocenic)

These deposits are distributed throughout the Magat sub-basin. They consist of unconsolidated gravel, sand and clay. Some portions contain large amounts of clay. Strata thickness is irregular and continity is lacking. As a result, the deposits are considered unstable and not suitable as embankment material.

(4) Terrace Deposits (Pleistocenic)

These deposits are distributed at the mouth of the Matuno River and on gradual slopes at the western side of the Magat sub-basin. They consist of unconsolidated to semi-consolidated gravel and sand with some clay content, and have potential application as impervious material. However, a long access road is necessary to reach deposit locations.

(5) Limestone

Limestone is distributed near ridgetops on both banks of the Matuno River near sites A and B_2, as well as throughout the general vicinity of site C. Limestone is intercalated with sandstone and marl and exhibits progressed cracking. Nevertheless, overall weathering is slight, hardness is good, and the limestone accordingly has potential as pervious material.

(6) Conglomerate

Conglomerate is distributed as bedrock in the Matuno River basin in the vicinity of sites A and B_2. The weathered portion of surface strata is in the form of earth and sand, and has potential application as impervious material. Fresh portions show relatively little cracking and are of good hardness, indicating possible use as pervious material. However, intercalations of weak sandstone and siltstone are present, making selective excavation of appropriately strong and stable portions a problem.

(7) Diorite

Diorite is distributed on both banks from the mouth of the Matuno River to the entrance of the Magat sub-basin. Fresh portions are massive, hard, with little cracking, and accordingly considered appropriate for use as pervious material. Surface strata show heavy weathering and transformation into weathered granite. Considerable excavation is accordingly necessary to reach fresh portions. Another disadvantage is that areas of distribution are located far from the dam site.

(8) Pyroclastic Rock

Pyroclastic rock is distributed in the vicinity of Bayombong adjacent to the Magat sub-basin. The rock is relatively unweathered, blocked, with numerous hard portions in surface strata. It accordingly is considered to have potential application as rock material. However, composition is of clastic rock, such as andesite and andesitic tuff, and thus not uniform. This makes selective excavation of suitable material difficult. An additional disadvantage is the remoteness of areas of distribution.

4.2 Possible Borrow Areas

Of the embankment materials discussed in the previous section, samples were recovered through surface survey, through boring at locations indicated in FIG. II-3 and from 1-3m deep test pits at points most advantageous as candidate borrow areas and were subjected to laboratory testing.

Boring was aimed at ascertaining the weathering depth of conglomerate, strata thickness of talus deposits as impervious materials, and cracking and weathering depth characteristics of limestone as pervious material. Results of boring are given in FIG. II-13 and DATA BOOK (drilling core log). Laboratory testing was carried out to determine physical properties, including strength, permeability, durability, etc. for each type of material.

Investigation works for embankment material are summarized in the table presented on the following page.

Material	Location of Borrow Area, Distance	Geology	Test Item		
			Boring	Test Pit	Lab. Test
Impervious Material	Near Bante (2.9km)	Talus & highly weathered conglomerate	350m (10)	17.2m (6)	14
Concrete Aggregate	Near Batu Bridge (10.5km)	River deposits Sand & gravel	-	27.7m (13)	25
Rock Material	Near Bante on Right Bank (2.7km)	Limestone	60m (1)		9

On the basis of results from boring and test pit excavation, materials may be utilized as follows:

(1) For the first 10m of conglomerate surface stratum, weathering is progressive, and this portion is potentially appliable as impervious material. However, at some sections the gravel content rate reaches 70-80%. Consequently, the amount of usable material decreases depending on the point of distribution.

(2) Talus deposits distributed on relatively steep slopes consist of conglomerate composed of terrace secondary deposits (as observed in Borrows C-III). These deposits may be applied as impervious material, as is the case with the weathered portion of conglomerate discussed above. Talus deposits found on gradual slopes in Borrow C-II exhibit at some points a large clay content. The additional fact that these deposits include large cobbles of limestone of 20, 30cm - 1m dia. makes them inappropriate as construction material.

(3) The first 5m of the surface stratum of limestone in Quarry III is somewhat weathered. At some points, intercalations of weak sandstone and mudstone are present, with progressive cracking in

evidence. However, overall the limestone is massive, hard and accordingly promising as pervious material.

Details of laboratory test results are given in Section 4.3. Results of the above survey and study of distribution, configuration, and site, are shown in FIG. II-14. Classification of geologic formations according to type of application as embankment material is presented in TABLE II-8. On the basis of these findings, optimum candidate borrow sites are as follows:

(1) Impervious Material (core)

The borrow site for this material is Borrow C-III as indicated in FIG. II-14. The site is situated 2.9km downstream from site B_2 on the right bank near Bante. It encompasses deposits of weathered conglomerate and terrace secondary deposits of conglomerate. The site is advantageously located for access road construction.

Laboratory test results discussed subsequently indicate sufficient strength and impermeability for application of the material in this area as impervious material.

The amount of material available at the site is distributed over the site area for 6ha at a usable thickness of 10m. Ample material is accordingly present to satisfy the construction requirement of 600,000m^3.

For reference, an excavation configuration has been proposed as in FIG. II-15, and the amount of embankment material to be excavated computed as shown below at approximately 620,000m^3.

(a) Determination of excavation configuration

In order to recover 600,000m^3 of impervious material, the excavation configuration of the candidate borrow area has been determined as follows:

i) excavation design surface is to be EL. 450m, given the gradient of the access road;

ii) excavation slope gradient is to be 1:1.0; and,

iii) excavation height is to be 10-20m, with step width to be as shown in FIG. II-16.

(b) Available amount of material

The estimated amount of material available with the excavation configuration discussed in (a) above is indicated in TABLE II-9. If the factor for actually recoverable material is set at 0.8, given separation of non-usable material, loss in-transit, etc., the available amount of embankment material is 625,000m^3.

(2) Semi-Pervious Material (Filter, Concrete Aggregate)

The borrow site for this material is Borrow F - II indicated in FIG. II-14. The site is located 10.5km to the east of site B_2 and encompasses the river deposits distributed on the riverbed upstream from Batu Bridge at the entrance to the Magat sub-basin. Although the site is at considerable distance from site B_2 requiring construction of a long access road, deposits are widely distributed, excavation depth required is shallow, and plant may be easily installed.

River deposits consist of unconsolidated sand and gravel. Results of laboratory testing indicate appropriate gradation distribution and durability for use as construction material. However, where said material is applied as filter material, large cobbles must be selectively removed. The 2 layer filter method is recommended for effective use of the said cobbles. In the area above Batu bridge alone, these deposits are distributed over 90ha, amply sufficient material to satisfy construction requirements.

The necessary embankment material is estimated at 600,000m^3. Excavation of an area 1,000m x 600m to a depth of 2m would yield approximately 1.2 million m^3 of material. Even given a usability rate of 50%, this would yield 600,000m^3 of applicable material.

(3) Pervious Material (Rock, Rip-rap)

The site for recovery of pervious material is Quarry III indicated in FIG. II-14. The site is located 2.7km downstream of site B_2 on the right bank and encompasses a limestone formation. Site location is advantageous for access road construction.

Limestone contains intercalations of weak sandstone and mudstone, with progressive cracking present. Traces of dissolution are also evident. Nevertheless, overall the formation is massive, only slightly weathered and hard. Laboratory test results discussed subsequently indicate appropriate characteristics for construction material use.

Given the excavation contour shown in FIG. II-17, the amount of available raw material is estimated at 38 million m^3. Taking into account various recovery factors (p, f, e, c), the actual amount of usable rock and rip-rap is calculated at 32 million m^3, which is equivalent to the estimated amount of material required for construction.

(a) Determination of excavation contour

i) Excavation design surface is determined at EL. 400m which is 25m above the Matuno River level EL. 375m.

ii) Excavation slope gradient is determined at 1:0.5.

iii) Excavation height is determined at 10m, with step width of 5m as shown in FIG. II-18.

iv) Excavation height is determined at 100m, with excavation area to be as depicted in FIG. II-17.

(b) Available amount of material

The estimated amount of material available through excavation as described above is shown in TABLE II-10. With recovery factors (p, f, e, c) determined at 0.8, 0.9, 0.9 and 1.3 respectively, the actual amount of usable material is calculated at 3.2 million m^3.

4.3 Material Characteristics

Laboratory test results have been collected for each candidate borrow site, and are given in TABLEs II-11 to 14. A capsulation of the said results is presented hereafter.

(1) Impervious Material

Test results for borrow sites C-I, III and IV are indicated in TABLE II-11, while those for borrow site C-V are given in TABLE II-12.

Values for borrow sites C-I and IV are from tests on the weathered portion of conglomerate, those for C-III from terrace secondary deposits of conglomerate, and those for C-V from talus deposits.

(a) Borrow sites C-I, III and IV

As shown in FIG. II-19, gradation distribution is slightly finer overall than for materials used on Magat Dam. Clay content is low at 15% and material is within USBR standards. $\gamma dmax$ is high at $1.8g/cm^3$, and permeability coefficients after compaction are small at $10^{-8}m/s$. As impervious material, materials show appropriate qualities.

Wn is 10-23% at an average 17.2%, which is slightly large compared to the Wopt (13.5%). However, considering that the samples were collected during the rainy season, it will not be necessary to dry materials prior to construction.

Sample materials were taken from the surface of the borrow pit, and accordingly these materials contain more fine-grained particles than the materials for actual construction. Furthermore, sizes over No. 4 seive were abandoned for testing because of the limited size of mold. Considering the above condition and the fact that the materials for construction will be taken from deeper portions and will contain more coarse material, a bigger $\gamma dmax$ than the above is expected.

(b) Borrow site C-V

Material at this site is clayey, with high natural water content (Wn) at 30-60% and small $\gamma dmax$ at $1.5g/m^3$. Accordingly, this material is not deemed appropriate for embankment material.

(2) Semi-Pervious Material

Samples for testing were taken from river deposits at borrow site F-II. Test results are indicated in TABLE II-13.

Samples showed a high specific gravity of 2.6-2.8. Graduation was 10 to 40% sand, 40 to 60% pebble, and 10-30% cobble, with a tendency for coarser material in the upstream direction. Maximum cobble size was about 25cm. Gravels were primarily andesite, diorite, and tuff, with some limestone. Satisfactory results as indicated below were obtained from the Los Angels test. On the basis of its properties discussed above, the material was deemed appropriate for use as semi-pervious material.

Los Angels Test	Desirable Value	Results by NIA
100 revolution loss (%)	less than 10	3 - 5
500 " " (%)	less than 40	14 - 19

As maximum cobble size is 25cm, material can be applied as concrete aggregate without difficulty. However, for use as filter material, cobbles must first be removed. In this regard, material at the downstream portion of the site near Batu Bridge would appear to require relatively less cobble removal.

(3) Pervious Material

Testing was conducted on drilling cores of fresh conglomerate for Quarry I and limestone for Quarry III.

(a) Quarry I

Single axial compression strength even after 24 hour saturation was large at 3.45kg/m^3 or more, indicating appropriateness for application as pervious material.

No.	Unconfined Compressive Strength Surface dry (kg/cm^2)	Saturated (kg/cm^2)	Water absorption ratio (%)	Density (g/cm^3)
1	625	539	1.14	2.43
2	780	350	1.56	2.63
3	597	-	2.34	2.66
4	-	345	1.81	2.41

(b) Quarry III

Nine samples were selected from the BM-2 drilling core, and subjected to physical and dynamic testing.

Test results have been collated in TABLE II-14. A capsulation is presented below of test content and results.

i) Physical tests

The weight of samples in natural, imposed wet and imposed dry states (W1, W2 and W3 respectively), and submerged weight in imposed wet condition (W4) were observed. On the basis of the weights above, apparent specific gravity water absorpion ratios (Wab), effective void ratio (øef), moisture content (W) and moisture percentage (W') were determined.

- Apparent specific gravity

  The apparent specific gravity in the natural state ranges from 2.55-2.68. Those in imposed dry and imposed wet states are 2.50-2.67 and 2.58-2.69 respectively. The apparent specific gravity in each state is in the relation of (imposed dry) $<$ (natural) $<$ (imposed wet) and each of the values obtained was sufficient for rock materials for dam construction.

- Water absorption ratio

  The water absorption ratios present low values at 0.66-3.07%. The values have a correlation to rock classification as shown in FIG. II-20.

- Effective void ratio

  The effective void ratios vary from 1.31-7.67%, of which values of 2-3% are superior.

- Moisture content and moisture percentage

  The moisture content is 0.29-1.97% and the moisture percentage is 0.29-1.93%. The results show that samples with high water absorption ratio and effective void ratio have higher moisture content and moisture percentages.

ii) Ultrasonic velocity test

The results of ultrasonic velocity tests show that the longitudinal wave velocity (Vp) is 4.27-5.85km/s, and shear wave velocity (Vs) is 1.43-2.37km/s. Based upon the above results and the unit weight dynamic moduras of elasticity (Ed) and the dynamic poisson's ratio (vd) were calculated using the following formula.

$$Ed = \frac{2PVs^2(1 + \nu d)}{g} \times 10^5 \ (kg/cm^2)$$

where; g is gravity acceleration (9.8m/s²)

$$\nu d = \frac{(Vp/Vs)^2)-2}{2((Vp/Vs)^2-1)}$$

The calculated value of Ed is 1.55 - 4.30 x 10^5 (kg/cm^2) and that of νd are 0.39-0.44.

As shown in FIG. II-21, the values of Vp and Vs and rock classification correlate weakly. And as shown in FIG. II-22, samples with less effective void ratio present largest Vp and Vs.

iii) Unconfined compressive strength

The unconfined conpressive strength (σc) of limestone is 153.4-1, 191.7kg/cm², and as shown in FIG. II-23, except for some samples with lower values, rocks classified as CM and CH have sufficient strength.

FIG. II-24 shows that the rocks with a less effective void ratio have higher unconfined compressive strength.

Static modulus of elasticity (Es) and static poisson's ratio (νs) are also obtained based on the relation between stress and strain as shown in FIG. II-25. The values of Es and νs are 2.18 -6.3 x 10^5 (kg/cm^2) and 0.17-0.38 respectively.

iv) Tensile strength

The obtained value of tensile strength of CL rock is 29.3kg/cm^3, and that of CM to CH rock is 62.0kg/cm^2.

5. SITE GEOLOGY AT DIVERSION DAM SITES

5.1 Magat Diversion Dam

The Magat diversion dam is planned for construction at the entrance to the Magat sub-basin, 1km southwest of Bayombong.

Strata distributed at the site consist from top strata downward of Holocenic river deposits, Holocenic or Pleistocenic terrace deposits (considered as pleistocenic on the basis of boring and seismic prospecting) and bedrock composed of pyroclastic rock belonging to Tertiary Eocenic and Paleocenic Caraballo Group. Works of boring and seismic prospecting are given in TABLE II-15.

Boring was carried out at locations indicated in FIG. II-26. Results are shown in the borehole log in FIG. II-27, and DATA BOOK (drilling core log). River deposits are composed of unconsolidated pebbles to cobbles and sand, with almost no clayey content. Terrace deposits consist chiefly of unconsolidated pebbles to cobbles and sand, with a large matrix clay content. Compaction of terrace deposits is better than that seen in river deposits. The nature of pyroclastic rock was not confirmable through boring; however, observation of surface outcrops in the vicinity show that it is composed primarily of andesite and andesitic tuff. Bedrock contour line is as indicated in FIG. II-28.

Results from seismic prospecting show a seismic wave velocity for river deposits of 0.3-0.5km/s. Average stratum thickness is 5-7m. Terrace deposits indicated a seismic wave velocity of 2.0km/s, with an average stratum thickness of 20-30m. Pyroclastic rock evidenced a seismic wave velocity of 3.0-4.0km/s. A cross-sectional diagram for the proposed diversion dam section is shwon in FIG. II-29.

permeability around 10^{-2}cm/s is possible. In such case, at the detailed design stage it is necessary to conduct permeability testing towards ascertaining a more precise permeability coefficient.

5.2 Manamtam Diversion Dam

Manamtam diversion dam is planned for construction near the mouth of the Matuno River, 1.5km downstream from site C.

Based on the general geological map Holocenic river deposits and bedrock consisting of Tertiary Miocenic Conglomerate are presumably distributed in the site.

Boring results conducted at BI-4 as indicated in FIG. II-27 show that river deposits consist of unconsolidated pebbles to cobbles and sand, with only small clayey content. Composition is loose, and although layer thickness could not be precisely confirmed, it is considered to be around 15m or more. Conglomerate appears to have the same characteristics as that at site B_2, although because of the riverbed weathered portion thickness is believed to be considerably shallow.

As structural foundation, river deposits must be selected for economic reasons due to the distribution depth of bedrock. However, the loose portion of 2-3m depth at the surface of river deposits must be removed prior to construction. As at Bayombong diversion dam site, permeability testing must be conducted prior to detailed design due to the assumed high permeablity of the river deposits at the site.

6. SITE GEOLOGY ALONG IRRIGATION CANAL

6.1 Investigation

Proposed main canals are Santo Domingo main canal, mountain side main canal, Colocol main canal, and Lanog right and left main canal. Routes are indicated in FIG. II-30 and capsulated on the following page.

(1) <u>St. Domingo Main Canal</u>

The canal runs from the proposed Manamtam diversion dam on the Matuno River northeastward along the mountain base at St. Domingo, traversing the southern slope of the Magat River sub-basin in a northerly course to La Torre.

(2) <u>Mountain Side Main Canal</u>

The canal runs from the proposed Magat diversion dam on the Magat River, exiting isolated hills from the northwest, passing along the mountain base at the western side of the Magat sub-basin, and following a northerly course to the upper reaches of the Lamut River.

(3) <u>Colocol Main Canal</u>

The canal runs from the proposed Magat diversion dam past Solano, passes northward along the alluvial plain on the west bank of the Magat River, and exits isolated hills to terminate at Bagabag.

(4) <u>Lanog Main Canal</u>

The right and left main canals run from the proposed Lanog diversion dam in the vicinity of the confluence of the Bintauan and Lanog rivers, and exit isolated hills to pass northward along the alluvial plain to the vicinity of the confluence of the Lamut and the Magat rivers.

Geologic survey conducted along the above canal routes consisted of surface survey and all core boring with standard penetration test. Boring operations are indicated in TABLE II-15. Boring locations are as shown in FIG. II-26. Borehole log is given in FIG. II-27.

6.2 Site Geology

Topography of each canal route may be broadly categorized as slightly undulating diluvial plain at the base of mountains, and alluvial plain. The canal length for each category is tabulated below.

Main Canal	Canal Length (km)	
	Foot of Mountain (Diluvial plain)	Alluvial plain
St. Domingo M.C.	21.20	-
Mountain Side M.C.	16.45	9.60
Colocol M.C.	4.00	17.10
Lanag M.C.	4.80	17.20

The geologic formations distributed within each topographical classification are as follows.

(1) Foot of Mountain

The mountain foot portion consists of gradual slopes on the western side of the Magat sub-basin and in the vicinity of isolated hills within the sub-basin. Geologic structure consists of weathered bedrock covered with Pleistocenic terrace and talus deposits.

Bedrock is composed primarily of conglomerate belonging to the Natbang formation, and pyroclastic rock of the Caraballo group. Surface stratum is generally heavily weathered and crushable by hammer. However, the bedrock in the isolated hills evidence only mild weathering and hard characteristics.

Terrace deposits consist of unconsolidated to semi-consolidated sand and gravel, containing round to sub-angular pebbles and cobbles of 2, 3-20cm. Surface stratum is weathered, and includes substantial declayed gravel.

Talus deposits, including deposits originated from fan-shaped configurations, conist of unconsolidated sandy and clayey strata containing limestone cobble and angular to sub-angular cobbles of bedrock fragments. In one portion of surface strata, organic clayey sand is distributed. Boring results and topographical conditions of the area suggest that groundwater may be expected at 2m or deeper.

The geologic conditions discussed above indicate that no major problem need be anticipated in canal construction along mountain foot portions. However, some slight difficulty in canal excavation regarding disposal of limestone boulders and the hard portion of bedrock may be expected.

(2) Alluvial plain

Alluvial plain is distributed widely throughout the Magat River sub-basin at an elevation of 220-300m. It is composed of Holocenic terrace and river deposits.

As described earlier, terrace deposits consist of unconsolidated pebbles, cobbles, sand and clay. Although sand and gravel are the chief components, deposits around Bayombong exhibit a large clayey content. Maximum clayey stratum thickness around Bayombong was confirmed at BI-11 at 10m.

River deposits, also discussed earlier, are composed of unconsolidated pebbles, cobbles, and sand. Clayey content is virtually absent. Stratum surface is extremely loose. A 1-2m deep excavated pit exhibits side failure.

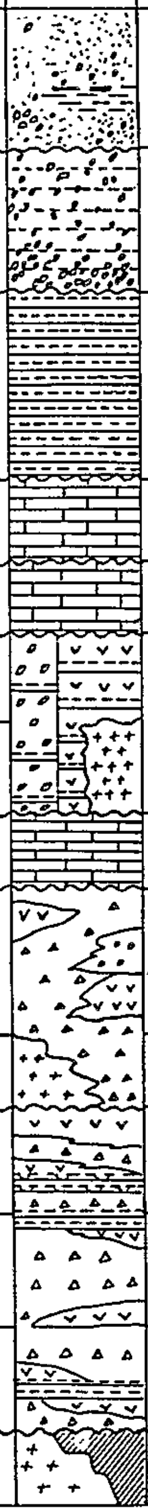
Overall, groundwater table depth is extremely shallow, located in terrace deposits within 5m depth. In river deposits, the groundwater table is within 2-3m depth.

Wet lowland and paddy area, where groundwater content is high, pose potential problems for canal construction. An appropriate drainage plan based on structure configuration is accordingly necessary.

STRATIGRAPHICAL TABLE

Geological Age	Formation	Rock Facies
Holocene		River Deposit, Flood Plain Deposit Terrace Deposit, Talus Deposit
Pleistocene		Terrace Deposit
	Macde Limestone	Limestone
Miocene	Natbang Formation	Conglomerate, Sandstone
Eocene	Garaballo Group (Formation II, III)	Pyroclastic Rock Volcanic Flow
Oligocene - Eocene	Intrusive Rock	Diorite

STRATIGRAPHY OF CARABALLO MOUNTAINS

PERIOD	EPOCH	FORMATIONS	SCHEMATIC COLUMN	ROCK FACIES
Quaternary	Holocene	River deposits, Deposits of flood plain, Talus deposits		Sand and gravels, silt and clay loose deposits
	Pleistocene	Terrace deposits		Sand and gravels, silt and clay dense deposits
Tertiary	Pliocene	Matuno Formation		Alternation of sandstones and mudstones
	Miocene	Aglipay Formation		Limestone
		Macde limestone		Limestone
		Natbang Formation: Palali Formation; Palali Batholith		Natbang F. : Conglomerate with alternating sandstones and mudstones. Palali F. : Basalt and andesite lavas, mudstones sandstones, pyroclastics Palali Batholith: Syenite, monzonite
	Oligocene	Santa Fe Formation		Limestones
		Mamparang Formation		Andesite and Basalt lavas and pyroclastics Conglomerate
		Coastal Batholith Dupax Batholith		Diorite
	Eocene	Caraballo Group: Formation III		Andestic lava and tuff breccia with alternating sandstone, shales, tuffs
	Eocene / Paleocene	Caraballo Group: Formation II		Tuffaceous sandstones and shales Basaltic lava and pyroclastics dolerites with alternating siliceous sandstones and shales
	Paleocene	Caraballo Group: Formation I		Andestic pyroclastics and lava, with alternating sandstones and shales
Cretaceous		Basement Complex		Tonalites, Schists.

Based on Bureau of Mines and Geo-Science;
Geology and Mineral Resources of the Philippines, 1981.

LIST OF WORK QUANTITY FOR SITE B_2

Boring

Bore Hole No.	Site	Ground Elevation (m)	Drilling Length (m)	Permeability Test (nos)	Contractor	Note
B - 1	Dam axis	514.49	50.05	12*(4)**	NIA	left bank
B - 2		525.31	70.00	21 (13)	NIA	- do -
B - 3		534.59	50.00	-	NIA	- do -
B - 4		491.17	60.00	5	NIA	- do -
B - 5		528.20	50.25	8 (5)	NIA	- do -
B - 6		479.09	50.00	-	NIA	- do -
B - 7		389.47	60.00	9 (2)	JICA	river bed
B - 8		507.826	70.30	4	NIA	right bank
B - 9		544.997	55.60	10 (1)	NIA	- do -
TOTAL			516.20	69 (25)		

Note: * Packer method
** Open end method

Seismic Exploration

Line	Site	Interval (m)	Length of Line (m)	Contractor
A (main)	Dam axis	5	825	NIA
B (main)	- do -	5	440	NIA
C (sub)	Perpendicular	5	275	NIA
D (sub)	to dam axis	5	605	NIA
TOTAL			2,145	

LIST OF WORK QUANTITY FOR SITE C

Boring

Bore Hole No.	Site	Ground Elevation (EL.m)	Drilling Length (m)	Permeability Test (Nos.)	Contractor	Note
BC - 1	Lower side of dam axis on river-bed	365.0	50.0	14	NIA	
BC - 2	Upper side dam axis at left side of mountain	524.0	100.0	19	JICA	inclined of 45°
TOTAL			150.0	33		

LIST OF WORK QUANTITY FOR BORROW AREA

Boring

Bore Hole No.	Site	Elevation	Drilling Length (m)	Contractor	Note
BM - 2	Bante Right Bank	486.48	60.0	JICA	
BM - 3	- do -		30.0	JICA	
BM - 5	- do -		20.0	JICA	
BM - 7	- do -		10.0	JICA	
BM - 8	- do -		10.0	JICA	
BM - 9	- do -		60.0	JICA	
BM -10	- do -		40.0	JICA	
BM -11	- do -		60.0	JICA	
BM -12	- do -		40.0	JICA	
BM -13	Left Bank		40.0	JICA	
BM -14	- do -		40.0	JICA	
TOTAL			410.0		

Test Pitting and Sampling Works

Pit No.	Elevation	Length of Excavation (m)	Sampling Depth (m)	Site
TM - 1		3.0	1.0 2.0 3.0	Bante Left Highland
TM - 2		3.0	1.0 2.0 3.0	- do -
TM - 3		3.0	1.0 2.0 3.0	- do -
TM - 4		2.2	no samples taken	Right Bank
TM - 5		3.0	1.5 3.0	- do -
TM - 6		3.0	1.0 2.0 3.0	Dam Site B2
TOTAL		17.2		

TABLE II-6

ITEMS AND NUMBERS FOR LABORATORY SOIL TEST

Sample from Matuno B_2 Dam Borrow Area

Sample Identification		Gradation ASTM D-22-63	Liquid Limit ASTM D-423-61T	Plastic Limit ASTM D-424-59	Moisture Content ASTM D-2216-63T	Procter Compaction ASTM D-1557-A	Specific Gravity ASTM D-854-58	Permeability
TM-1	0.0 - 1.0m	0	0	0	0		0	
	1.0 - 2.0	0	0	0	0	0	0	0
	2.0 - 3.0	0	0	0	0		0	
TM-2	0.0 - 1.0	0	0	0	0		0	
	1.0 - 2.0	0	0	0	0	0	0	0
	2.0 - 3.0	0	0	0	0		0	
TM-3	0.0 - 1.0	0	0	0	0		0	
	1.0 - 2.0	0	0	0	0	0	0	0
	2.0 - 3.0	0	0	0	0		0	
TM-5	0.0 - 1.0	X	X	X	0		0	
	1.0 - 2.0	0	0	0	0	0	0	0
	2.0 - 3.0	0	0	0	0		0	
TM-6	0.0 - 1.0	0	0	0	0		0	
	1.0 - 2.0	0	0	0	0	0	0	0
	2.0 - 3.0	0	0	0	0		0	
	TOTAL	14	14	14	15	5	14	5

Note: 0: Tested
X: Not Tested

QUALITY CLASSIFICATIONS OF ROCK IN DAM FOUNDATIONS

Classification	Characteristics
A	Rock-forming minerals1/ are fresh and not weathered or altered. Joints and cracks are very closely adhered with no weathering along their planes. A clear sound is emitted when hammered.
B	Rock-forming minerals are weathered slightly or partially altered, the rock being hard. Joints and cracks are closely adhered. A clear sound is emitted when hammered.
C_H	Rock-forming minerals are weathered but the rock is fairly hard. The bond between rock blocks is slightly reduced and each block is apt to be exfoliated along joints and cracks by strong hammering. Joints and cracks sometimes contain clay and other material which may be colored by limonite. A slightly dull sound is emitted when hammered.
C_M	Rock-forming minerals are weathered and the rock is slightly soft. Exfoliation of the rock occurs along joints and cracks by normal hammering. Joints and cracks sometimes contain clay and other material. A somewhat dull sound is emitted when hammered.
C_L	Rock-forming minerals are weathered and the rock is soft. Exfoliation of the rock occurs along joints and cracks by light hammering. Joints and cracks contain clay. A dull sound is emitted when hammered.
D	Rock-forming minerals are weathered, and rock is very soft. There is virtually no bond between rock blocks, and collapse occurs at the slightest hammering. Joints and cracks contain clay. A very dull sound is emitted when hammered.

Note: 1/ Except quartz

BORROW AND QUARRY SITE EVALUATION

Material	Site	Geology	Explanation	Evaluation
Impervious Material (Core)	Borrow C-I	Weathered Conglomerate	Quality is good. Stock pile is needed because the material is excavated soil at site B_2. Quantity is not sufficient.	○
	" C-II	Talus Deposits	Inadequate because of clayey character and existence of large limestone gravel.	×
	" C-III	Weathered Conglomerate & Talus Deposits	Quality is good. Deposited area distribution is advantageous for planning of access road.	◎
	" C-IV	Weathered Conglomerate	Quality is good. Deposited area distribution is unfavorable for planning of access road. Deposited area is narrow.	○
	" C-V	Talus Deposits	Inadequate because of clayey character. Deposited area is far from site B_2.	×
Semi-Pervious Material (Filter & Concrete Aggregate)	Borrow F-I	River Deposits (Matuno)	Quality is good. Quantity is not sufficient. Deposited area is narrow.	○
	" F-II	River Deposits (Magat)	Quality is good. Deposited area is wide. Transport length is to some extent long.	◎
Pervious Material (Rock & Rip-rap)	Quarry I	Fresh Conglomerate	Quality is good, although much unqualified material has to be selected and removed. Deposited area distribution is not advantageous for planning of access road.	△
	" II	Lime-stone	Quality is good. Deposited area is narrow and unfavorable for planning of access road.	△
	" III	Lime-stone	Quality is good. Deposited area distribution is advantageous for planning of access road.	◎

Note: ◎ good ○ fair △ poor × unusable

ESTIMATED VOLUME OF IMPERVIOUS MATERIAL AT BORROW C-III

Section No.	Measured Area (A) m^2	Interval Between Sn&Sn+1 (D)m	Volume $(\frac{An+An+1}{2} \times D)m^3$	Remarks
S - (1)	2,200			
		40	76,000	
S - (2)	1,600			
		60	114,000	
S - (3)	2,200			
		60	150,000	
S - (4)	2,800			
		60	162,000	
S - (5)	2,600			
		60	132,000	
S - (6)	1,800			
		60	96,000	
S - (7)	1,400			
		40	52,000	
S - (8)	1,200			
TOTAL			782,000	
Possible Volume			625,000	Safety Factor 80%

TABLE II-10

ESTIMATED VOLUME OF PERVIOUS MATERIAL AT QUARRY III

Section No.	Interval (m)	Area (m^2)	Volume (m^3)
0-		0	
	3		200
0		130	
	55		144,400
1		5,120	
	60		483,900
2		11,010	
	60		783,300
3		15,100	
	60		929,100
4		15,870	
	60		913,800
5		14,590	
	60		503,100
6		2,180	
	33		36,000
6+		0	
TOTAL			3,793,800 (v)

Available quantity for embankment (V)

$(V) = p \cdot f \cdot e \cdot v \cdot c$
$= 0.8 \times 0.9 \times 0.9 \times 3{,}793{,}800 \times 1.3$
$\doteqdot 3{,}200{,}000\ (m^3)$

where p = 0.8 gathering ratio
f = 0.9 safety factor of difference
e = 0.9 safety factor of difference
c = 1.3

TABLE II-11

SUMMARY OF LABORATORY SOIL TEST OF IMPERVIOUS MATERIAL AT BORROW C-I, III, IV

Sample Identification	Gradation Analysis Clay %	Silt %	Sand %	Gravel %	Symbol	Liquid Limit %	Plastic Limit %	Moisture Content (Natural)	Compaction Test Opt. Moist. Content	Max. Dry Dens. (PCF)	Specific Gravity	Coefficient of Permeability (K) cm/s
BORROW C-I												
TM - 6												
0.0 - 1.0m	13	29	38	20	GC	36.15	23.90	16.83		112.98	2.679	
1.0 - 2.0	12	33	31	24	GC	35.30	23.31	18.80	11.10	($1.8077 tf/m^3$)	2.636	6.41×10^{-8}
2.0 - 3.0	13	31	31	25	GC	37.05	23.59	21.31			2.678	
BORROW C-III												
TM - 5												
0.0 - 1.0	-	-	-	-	-	-	-	17.53		112.75	-	
1.0 - 2.0	13	41	21	25	CL	40.15	23.58	17.72	14.20	($1.8040 tf/m^3$)	2.665	8.91×10^{-9}
2.0 - 3.0	29	37	27	7	CL	38.40	22.78	13.54			2.694	
BORROW C-IV												
TM - 1												
0.0 - 1.0	14	39	20	27	MH	51.10	31.76	21.41		111.35	2.650	
1.0 - 2.0	19	50	15	16	ML	40.45	27.03	17.73	15.00	($1.7816 tf/m^3$)	2.622	1.97×10^{-8}
2.0 - 3.0	15	40	31	14	CL	39.35	24.82	14.70			2.679	
TM - 2												
0.0 - 1.0	16	30	47	7	SM	41.95	26.77	17.89		111.90	2.655	
1.0 - 2.0	21	59	16	4	CL	29.00	19.04	16.56	15.20	($1.7904 tf/m^3$)	2.650	8.20×10^{-8}
2.0 - 3.0	19	58	20	3	CL	37.40	22.56	22.78			2.650	
TM - 3												
0.0 - 1.0	11	25	22	42	GC	35.85	22.14	20.16		118.30	-	
1.0 - 2.0	19	39	35	7	CL	34.80	18.28	11.28	12.00	($1.8928 tf/m^3$)	2.665	1.95×10^{-9}
2.0 - 3.0	18	30	12	40	GC	30.07	18.10	10.13			2.651	

TABLE II-12

SUMMARY OF LABORATORY SOIL TEST OF IMPERVIOUS MATERIAL
AT BORROW C-V

Sample Identification		Gradation Analysis Clay %	Sand %	Gravel %	Symbol	Liquid Limit %	Plastic Limit %	Moisture Content (Natural)	Compaction Test Opt. Moist. Content (%)	Max. Dry Dens.(t/m^3)	Specific Gravity	Coefficient of Permeability (K) cm/s
BORROW C-V												
1	1.0 - 2.7m	47	53	0	SM	45	15	32.6 - 44.6	25.7	1.528	2.68	
2	1.0 - 5.0	63	37	0	ML	46	14	33.8 - 40.6	23.3	1.515	2.56	
4	1.0 - 3.0	69	31	0	CL	39	14	37.5	25.3	1.479	2.51	
5	1.5 - 3.0	63	14	23	MH	59	29	36.9 - 62.9	23.9	1.568	2.73	
6	1.0 - 3.0	86	14	0	MH	105	59	56.6 - 71.4	33.2	1.313	2.60	
7A	1.0 - 2.0	65	35	0	CH	113	85	65.5	28.5	1.426	2.60	
7B	2.0 - 3.0	41	17	42	GM	53	20	28.9	17.2	1.670	2.61	
8	0.5 - 2.5	93	7	0	MH	95	50	14.7 - 60.7	30.6	1.346	2.63	
9	1.0 - 3.0	66	24	10	ML	41	6	50.1	28.0	1.410	2.65	
10A	1.0 - 2.5	94	6	0	CH	109	68	74.7	19.3	1.533	2.50	
10B	2.5 - 4.0	34	20	46	GM	55	30	35.0	14.6	1.807	2.79	
11	1.0 - 2.5	38	46	16	SM	37	8	38.3	22.2	1.556	2.56	

TABLE II-13

SUMMARY OF LABORATORY TEST OF CONCRETE AGGREGATES

Sample Identification		Specific Gravity		Absorption %		Unit Weight (lbs/ft3)		Los Angels Abrasion Test (%) Wear Grading					
		Fine	Coarse	-No.4	+No.4	3" max	sand	A		B		F	
								100rev	500rev	100	500	200	1,000
BORROW F-II													
TP- 1A	(0.7 - 1.7m)	2.62	2.81	2.8	0.40								
B	(1.7 - 2.5m)	2.60	2.70	3.0	0.85								
TP- 2A	(0.0 - 1.0m)	2.66	2.76	2.8	0.51								
B	(1.0 - 2.0m)	2.64	2.79	2.8	0.45								
RS	(0.0 - 2.2m)	2.65	2.74	2.8	0.55	138.2 (2.214	138.5 2.219*)	4.88	19.0	2.80	14.00	3.63	16.61
TP- 3A	(0.0 - 1.0m)	2.62	2.78	2.7	0.45								
B	(1.0 - 2.0m)	2.62	2.77	2.8	0.69								
RS	(0.0 - 2.0m)	2.64	2.75	2.8	0.65	137.6 (2.204	138.2 2.214*)	3.39	16.41	2.68	13.88	7.48	16.18
TP- 4A	(1.0 - 2.0m)	2.64	2.76	2.4	0.63								
TP- 5A	(0.0 - 1.0m)	2.63	2.75	2.4	0.61								
B	(0.7 - 2.0m)	2.60	2.72	3.0	0.78								
TP- 6A	(0.7 - 2.0m)	2.65	2.74	2.1	0.63								
TP- 7A	(0.0 - 1.0m)	2.62	2.74	3.0	0.61								
B	(1.0 - 2.0m)	2.62	2.82	2.8	0.39								
TP- 8A	(0.0 - 1.0m)	2.64	2.71	2.8	0.39								
B	(1.0 - 2.0m)	2.61	2.78	2.9	0.43								
TP- 9A	(0.0 - 1.0m)	2.60	2.77	2.8	0.45								
B	(1.0 - 2.0m)	2.62	2.74	2.7	0.81								
TP-10RS	(0.0 - 3.0m)	2.63	2.71	2.7	0.90	134.6 (2.156	138.9 2.225*)	2.95	16.4	3.04	15.08	3.87	15.13
A	(0.0 - 1.0m)	2.63	2.76	2.7	0.62								
B	(1.0 - 2.0m)	2.62	2.71	2.0	0.90								
C	(2.0 - 3.0m)	2.65	2.76	2.3	0.60								
TP-11A	(1.0 - 2.0m)	2.65	2.75	2.8	0.62								
TP-12A	(1.0 - 2.0m)	2.63	2.77	2.6	0.69								
TP-13A	(0.7 - 2.0m)	2.60	2.78	2.8	0.39	142.0 (2.278	154.4 2.473*)	3.18	17.5	3.56	17.56	4.04	17.34

Note: * t/m3

SUMMARY OF ROCK TEST

Sample No.			BM 2-1	BM 2-2	BM 2-3	BM 2-4
Sample Depth		m	12.10	18.30	26.70	37.40
Rock Type			limestone	limestone	limestone	limestone
Rock Classification			CL	CM	CM - CH	CM (CL)
Apparent Specific Weight	Natural State		2.57	2.58	2.66	2.65
	Dry State		2.54	2.54	2.64	2.62
	Wet State		2.60	2.60	2.67	2.65
Coefficient of Water Absorption		Wab %	2.36	2.18	0.97	1.27
Effective Void Ratio		ϕef %	5.99	5.54	2.56	3.33
Water Content 1/		W %	1.23	1.36	0.73	1.19
Water Content 2/		W' %	1.21	1.34	0.72	1.17
Density		ρ g/cm^3	2.606	2.592	2.677	2.668
Ultrasonic Velocity	Longitudinal Wave	Vp km/s	5.00	4.52	5.70	5.96
	Shear Wave	Vs km/s	2.02	1.95	2.31	2.37
	Dynamic Modulus of Elasticity	(Ed)x10^{5}kg/cm^2)	3.05	2.79	4.09	4.30
	Dynamic Poisson's Ratio	(ν_d)	0.40	0.39	0.40	0.41
Unconfined Compressive Strength		(σ_c) kg/cm^2	666.8	153.4	740.1	804.5
Static Modulus of Elasticity		(Es) x 10^5 kg/cm	2.18	3.47	5.06	6.30
Static Poisson's Ratio		(ν_s)	0.38	0.38	0.29	0.30
Tensile Strength		(σ_t) kg/cm^2				
Shearing Strength		(τ_o) kg/cm^2				

Remarks: $\tau_o = \frac{1}{2}\sqrt{\sigma c \times \sigma t}$

water content 1/. . . . . water content in percent to dry weight
water content 2/. . . . . water content in percent to total weight

SUMMARY OF ROCK TEST

Sample No.			BM 2-5	BM 2-6	BM 2-7
Sample Depth		m	40.20	52.20	60.00
Rock Type			limestone	limestone	limestone
Rock Classification			CM (CL)	CH	CH
Apparent Specific Weight	Natural State		2.62	2.63	2.67
	Dry State		2.58	2.62	2.67
	Wet State		2.63	2.64	2.68
Coefficient of Water Absorption		Wab %	1.72	0.89	0.49
Effective Void Ratio		ϕef %	4.45	2.32	1.31
Water Content 1/		W %	1.31	0.49	0.29
Water Content 2/		W'%	1.30	0.49	0.29
Density		ρ g/cm^3	2.639	2.656	2.651
Ultrasonic Velocity	Longitudinal Wave	Vp km/s	4.69	5.59	5.85
	Shear Wave	Vs km/s	1.97	2.27	2.27
	Dynamic Modulus of Elasticity	(Ed)x10^5kg/cm^2)	2.92	3.90	3.92
	Dynamic Poisson's Ratio	(νd)	0.39	0.40	0.41
Unconfined Compressive Strength		(σc) kg/cm^2	357.3	1191.7	687.8
Static Modulus of Elasticity		(Es) x 10^5 kg/cm	3.72	5.53	5.01
Static Poisson's Ratio		(νs)	0.17	0.27	0.25
Tensile Strength		(σt) kg/cm^2			
Shearing Strength		(τo) kg/cm^2			

Remarks: $\tau_o = \frac{1}{2}\sqrt{\sigma c \times \sigma t}$

SUMMARY OF ROCK TEST

Sample No.			B-7-8	B-7-8'	BM-2-9	BM-2-10
Sample Depth		m	15.50	15.50	12.30	28.45
Rock Type			limestone	limestone	limestone	limestone
Rock Classification			CH	CH	CL	CM - CH
Apparent Specific Weight	Natural State		2.53		2.55	2.68
	Dry State		2.47		2.50	2.67
	Wet State		2.56		2.58	2.69
Coefficient of Water Absorption		Wab %	3.51		3.07	0.66
Effective Void Ratio		ϕef %	8.66		7.67	1.76
Water Content 1/		W %	2.64		1.97	0.46
Water Content 2/		W'%	2.57		1.93	0.45
Density		ρ g/cm^3	2.517	2.549	2.573	2.683
Ultrasonic Velocity	Longitudinal Wave	Vp km/s	1.81	2.46	4.27	5.63
	Shear Wave	Vs km/s	0.91	0.90	1.43	1.80
	Dynamic Modulus of Elasticity	(Ed)x10^{5}kg/cm^2)	0.563	0.594	1.55	2.57
	Dynamic Poisson's Ratio	(νd)	0.33	0.42	0.44	0.44
Unconfined Compressive Strength		(σc) kg/cm^2	98.5			
Static Modulus of Elasticity		(Es) x 10^5 kg/cm	0.177			
Static Poisson's Ratio		(νs)	0.34			
Tensile Strength		(σt) kg/cm^2		7.4	29.3	62.0
Shearing Strength		(τo) kg/cm^2		13.5		

Remarks: $\tau_o = \frac{1}{2}\sqrt{\sigma c \times \sigma t}$

TABLE II-15

LIST OF WORK QUANTITY FOR IRRIGATION SERVICE AREA

Boring

Bore Hole No.	Site	Ground Elevation (EL.m)	Drilling Length (m)	Standard Penetration Test (Nos.)	Contractor
BI - 1	Colocol Intake	275.98	15.0	2	JICA
BI - 2	- do -	274.76	25.0	6	
BI - 3	Sto. Domingo	328.72	15.0	4	
BI - 4	- do -	356.00	15.0	3	
BI - 5	Bintauan	231.18	15.0	4	
BI - 6	Buenavista	282.64	10.0	4	
BI - 7	- do -	299.36	10.0	5	
BI - 8	La Torre	274.86	10.0	5	
BI - 9	Bintauan	266.57	15.0	2	
BI -10	La Torre	273.24	10.0	5	
BI -11	- do -	273.31	10.0	5	
BI -12	- do -	272.91	10.0	5	
BI -13	Mabaina Cr.	282.28	10.0	5	
TOTAL			170.0	55	

Seismic Exploration

Seismic Line No.	Site	Blasting Interval (m)	Length of Seismic Line (m)	Contractor
A	Colocol Intake	5	1,285	NIA
B	Colocol Intake	5	1,060	NIA
	Colocol Intake	5	640	NIA
C				
TOTAL			2,985	

GEOLOGICAL MAP

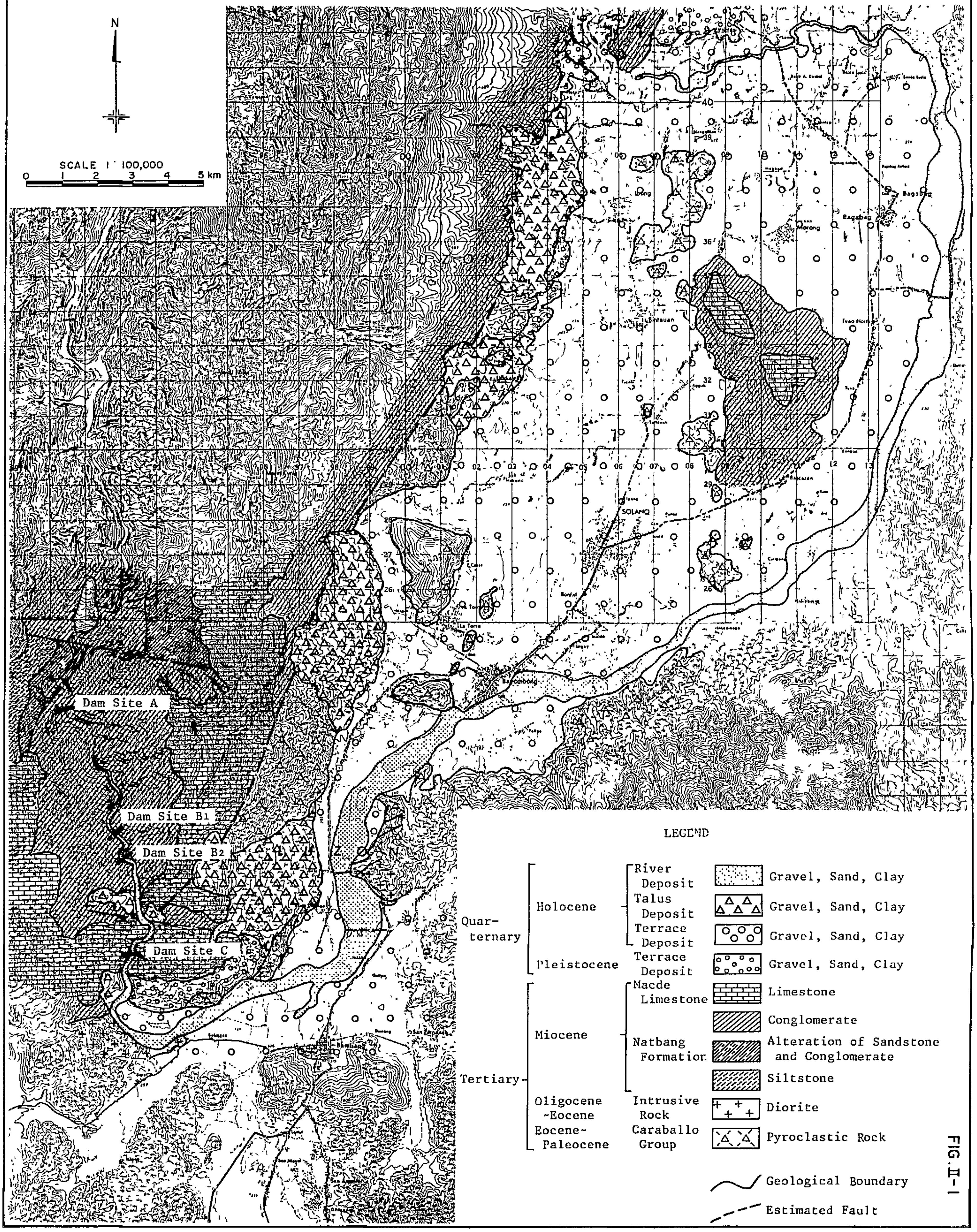


FIG. II-1

FIG. II - 2

GENERAL GEOLOGICAL PROFILE (E - W)

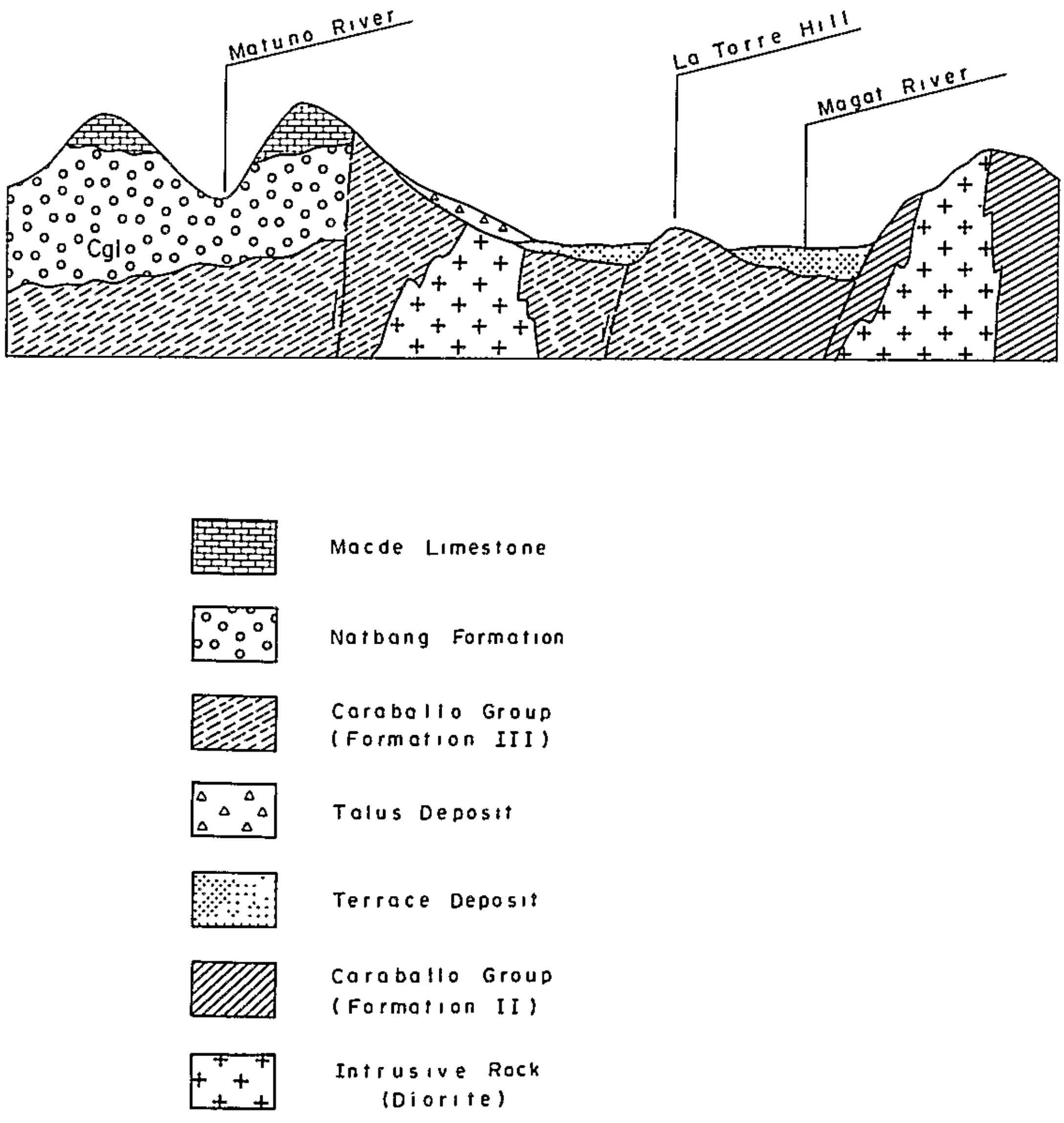


FIG. II-3

LOCATION MAP OF INVESTIGATION

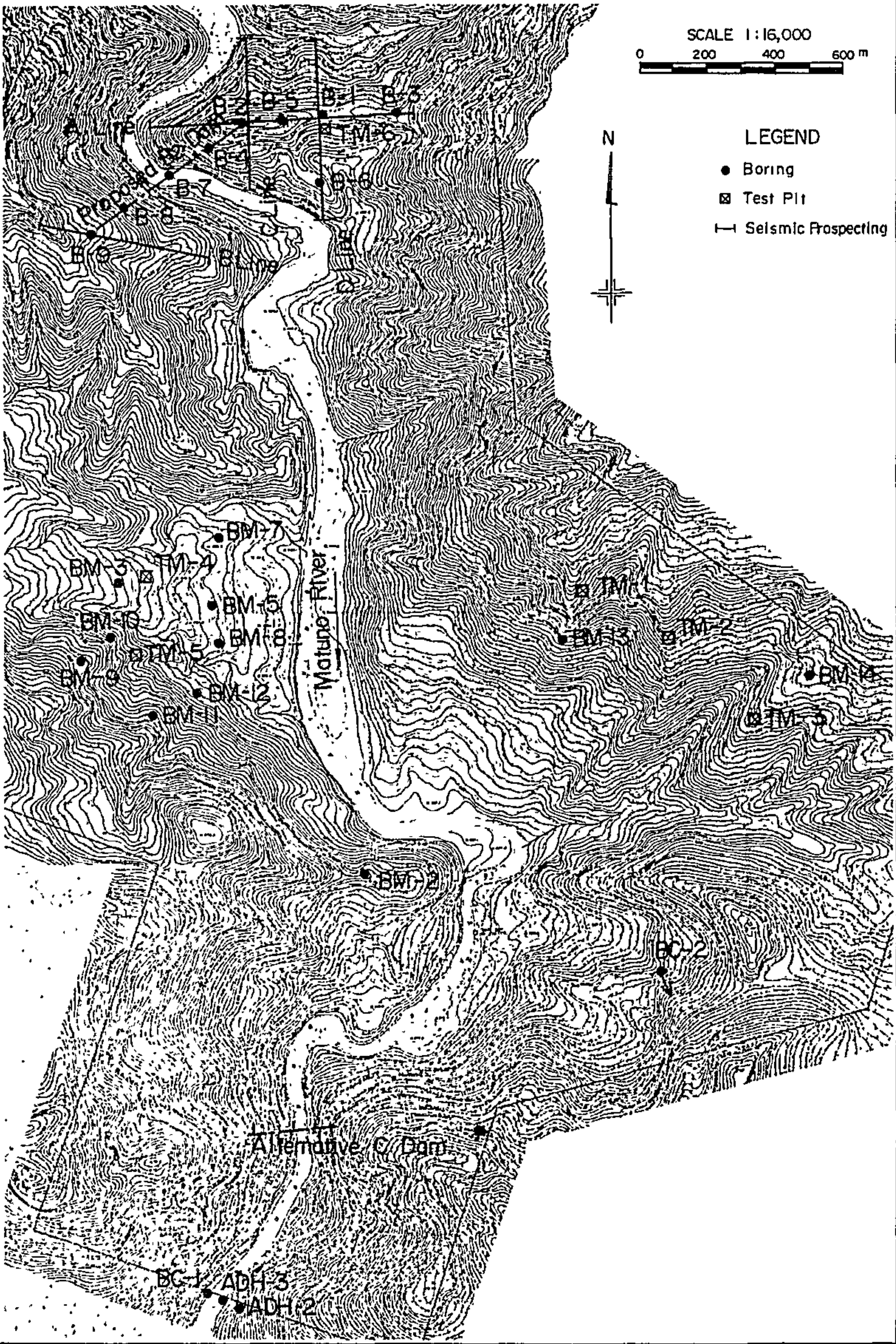
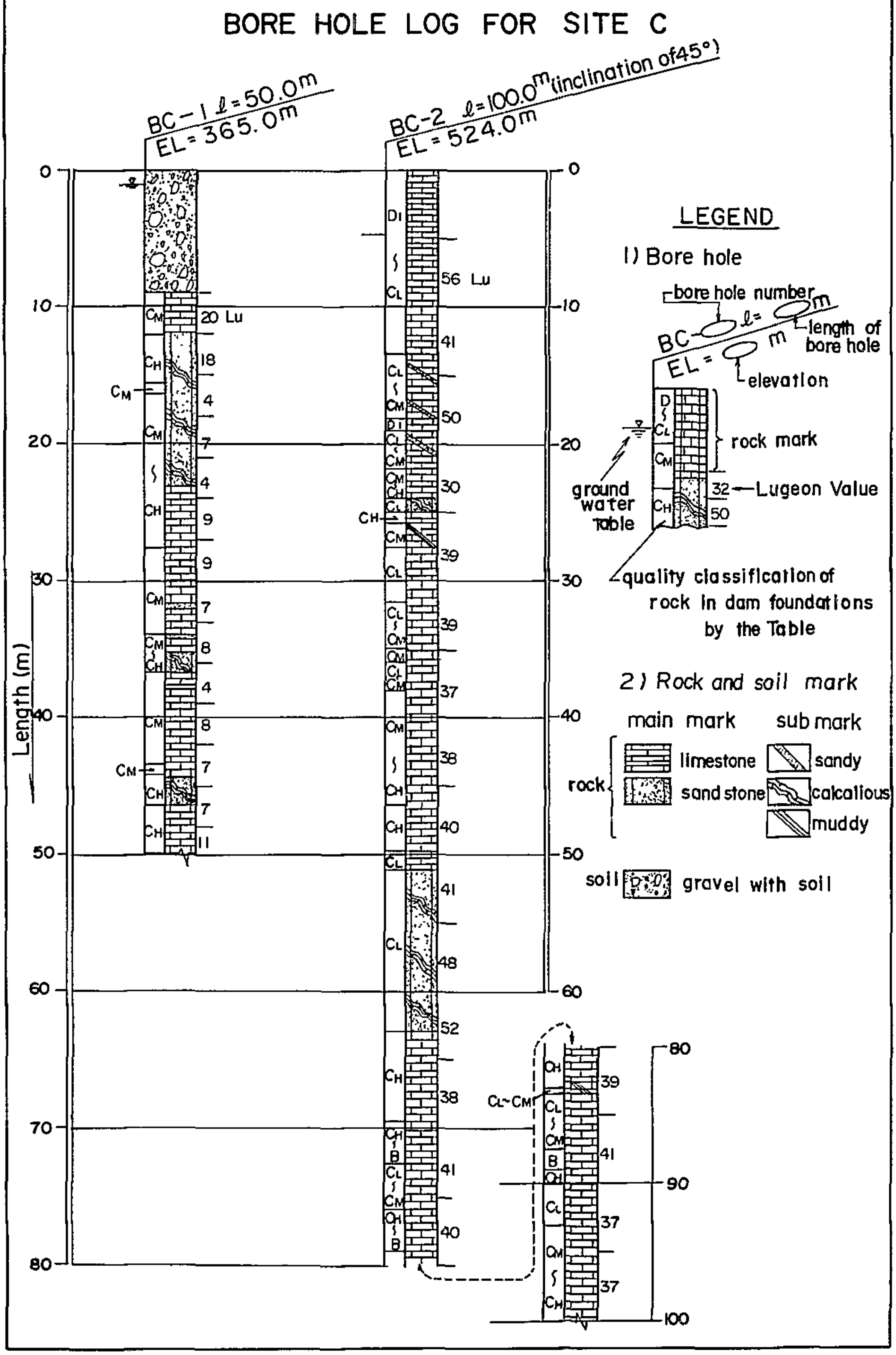


FIG. II-4


BORE HOLE LOG FOR SITE C
BC-1 ℓ=50.0m
EL=365.0m
BC-2 ℓ=100.0m (inclination of45°)
EL=524.0m
Length (m)
LEGEND
1) Bore hole
bore hole number
length of bore hole
elevation
rock mark
Lugeon Value
ground water Table
quality classification of rock in dam foundations by the Table
2) Rock and soil mark
main mark
sub mark
rock
limestone
sand stone
sandy
calcalious
muddy
soil
gravel with soil