I. TOPOGRAPHY AND GEOLOGY

CHAPTER I TOPOGRAPHY AND GEOLOGY

1.1 Site Location

The Study Area is located in southwestern Palawan Island on the coast of the Sulu Sea. The following is a diagram of the transportation network connecting the dam site to Manila via the nearest base at Brookes Point.

Manila	1 hour PAL jet	Puerto Princessa	6 hours by bus/ 3 hours by jeep 192km	Brookes Point	40 min by jeep (national road plus farm access road) approx 20km

Tamlang River Proposed Power Plant Site	1.5 hours walk	Tamlang River Dam Site

If the Rio Tuba Mine's Cessna airplane is used, however, only about 40 minutes is required from Puerto Princessa airport to the military airstrip at Samariniana south of Brookes Point. Roads south of Brookes Point are passable only during dry season (mid-February to end-of-June) due to poor drainage. There is also a motor boat which runs regularly between Brookes Point and the Rio Tuba Mine, approximately a 5 hour trip.

1.2 Topography

Palawan Island is long and narrow from north to south with the Mantalingajan range extending along the middle and slightly to the east. The main mountain is Mantalingajan (2,054m), the highest peak on Palawan Island. The Tamlang River springs from the said mountain flowing southeast into the Sulu Sea. Of the river's total 17km length, 11km pass through the mountainous area where the river is fed by approximately 10 smaller tributaries. The slope in the 4km of the lower mountainous region is about 1/17-1/20, while slope in the upper reaches is even steeper. Tropical rain forest is the main vegetation cover in the area; however, sparse woods and meadows increase along the river's upper reaches due to the steep incline.

Approximately 100 households are estimated within the catchment area, although the exact figure is difficult to verify due to migration.

According to field survey, there are about 9 landslides totalling $0.0504km^2$ or about 0.1% of the catchment area's $39km^2$.

1.3 Geology

The general topographical formations of the Study Area include the Mantaligajan range described above exceeding elevations of 1,500m, a lower range before the same along its eastern edge with elevations of 800m and alluvial lowland at elevatations of less than 100m. The varied topography of the area is reflected in the diverse geological structure of the same.

The higher mountainous area is composed of basic rock intrusions from the Cenozoic Period with crystalline schist on the eastern side and basaltic lava (plus tuffs in some areas) distributed from north to south which arose during submarine volcanic activity and accumulated precedent to and in uncomformity with the said schist. Basaltic rocks formed during the Mesozoic Era from the end of the Triassic to the mid-Cretaceous Period, becoming compound metamorphic rock as a result of weathering and alteration.

Granite intrusions occur in the metamorphic basalt near the site, an outcropping of which follows the Tamlang River for approximately 800m running northeast-southwest for a length of about 2km. Exposed portions of this rock system are frequent and generally much steeper than other rock formations. An outcropping of the same at the dam site creates a narrow river width forming steep cliffs on both banks with a slope of over 60° on the left and 45° on the right bank. The majority of granite out-croppings in the riverbed vicinity are more than CH grade in terms of dam foundation classification while fractured zones are comparatively rare and, except for the surface layer, rock is firmly fixed. D or CL-grade weathered grano diorite exists on part of the right bank. Field survey revealed however, that the depth was shallower than 10m and as such it was considered to be CH bedrock.

II. HYDROLOGY AND METEOROLOGY

CHAPTER II HYDROLOGY AND METEOROLOGY

2.1 Meteorological and Hydrological Data

In FIG. 2-1 the four meteorological conditions in each region of the Philippines is presented. This FIG also indidates that the project area is represented by meteorological condition IV; namely, rainfall more or less evenly distributed throughout the year. The sole PAGASA meteorological station for Palawan Island is located 150km northeast of Brookes Point at Puerto Princess Airport and therefore cannot be considered representative of the Project area. Fortunately however, meteorological observations were recently begun at Rio Tuba Mine. Meteorological data accumulated from the same was used for the Project area and is presented in TABLES 2-1 to 2-3 and FIG. 2-2.

As for precipitation data, daily rainfall was collected from Brookes Point (FIG 2-4) and this along with other meteorological and hydrological data and respective observation periods is presented in FIG 2-3.

Rainfall data for the Tamlang River Basin was recorded by the Rio Tuba Mine from mid-October to mid-December 1983. The reliability of the said data however, is limited given the short observation period. Observations recorded since July 1983 from 2 other rain gauges set up by the Rio Tuba Mine at the proposed power plant site on the Tamlang River and on the right bank downstream from the same will also be used.

2.2 River Basin

2.2.1 Introduction

River flow discharges were measured under the present Study as follows:

River	Drainage Area(km^2)	Rate of Discharge(m^3/sec)	Specific Discharge($m^3/sec/km^2$)
Tamlang	40	1.199	0.031
Marangas	38	0.512	0.013
Tanianbobog	21	0.478	0.023

The above measurements were recorded at the same time on February 18th 1984 to estimate dry season minimum discharge while the above drainage area is the same as that covered by the observation station.

As is clearly evident from the above data, Tamlang River discharge is the most abundant. Although 0.198m^3/sec from the Marangas River was diverted for irrigation use, the said intake was included within the above discharge of 0.512m^3/sec. Specific discharge of the Tamlanbobog River is also comparatively large; this is however, due to a large stable submerged discharge.

The Condwaga River which the Team was unable to visit during the subject survey period, springs from Mantalingaian mountain, the highest on Palawan Island, and flows westwards to the Sulu Sea. Although there are no meteorological records available for the western sea coast, a specific discharge similar to that of the Tamlang River may be expected from the greater percentage of rainfall in comparison with the east coast brought by cloud-bearing southeast winds.

2.2.2 Tamlang River

The Tamlang River originates near the summit of Mantalingaian mountain and flows into the Sulu Sea with a river channel length of approximately 18.5km. The said river is small and fast-flowing with a river slope ranging from 1/100 to 1/1000 in the downstream area, 1/10 to 1/100 at mid-stream, and greater than 1/10 upstream (FIG 2-4). Although visible outcroppings of rock occur frequently, there is a good vegetation cover in the basin with few eroded areas. At 10-year intervals, large quantities of sediment and debris are washed from the mountains during typhoons and deposited by flood waters along the entire river course from the mountains to the sea, creating a comparatively gently inclined alluvial plain. A V-shaped ravine has been carved by the upper and middle portions of the river, while in the lower reaches the river branches into several smaller flows due to sediment accumulation. The latter are characterized by unstable flow which, in the dry season, is entirely submerged in the riverbed.

Although the Tamlang River was previously surveyed for two irrigation projects by ADB (PIADP) and World Bank (PMSIP), it was not selected due to the high construction cost required for solution of the above sedimentation problem.

2.3 Tamlang River Flow Status

2.3.1 Measurement of Flow Discharge

(1) NIA Observations

NIA undertook monthly discharge measurements and intermittent water level readings from 1978 to 1982 for CIADP and PMSIP surveys. The stream-gauging station for the same was approximately 100m from the hydropower plant site proposed under the present Project, but was repeatedly washed out during floods. At present, river flow at the former station is very swift. From the data obtained for NIA projects at the time, the riverbed at the gauging station was estimated as shown in FIG 2-5.

Based on river cross-section observations made on May 26, 1980, an H-Q curve was made of the average riverbed. As the 1980 data is comparatively reliable, a parallel line was drawn of the above H-Q curve using monthly discharge rate observations from the same period. From this, representative H-Q curves of each month were made and the daily discharge rate for a one-month period in 1980 was calculated. Those portions lacking recorded data were completed with reference to precipitation levels at Brookes Point. The H-Q curve is illustrated in FIG 2-6 and daily discharge rate in TABLE 2-5. From the above calculations the average discharge rate for the year 1980 was concluded to be approximately $3m^3$/sec.

(2) Rio Tuba Mine Observations

The Rio Tuba Mine has been gauging water level since August 1983 at a stream-gauging station set up approximately 400m upstream from the above mentioned NIA station. As the said gauge is frequently washed out by even slight flooding, care must be taken to replace it at the same elevation and level as before. Monthly discharge rates have been recorded since February 1984.

(3) Study Team Observations

Discharge rate was measured 6 times during the Team field survey and the results of the same are shown in Table 2-6. Stream gauging was undertaken at the Rio Tuba Mine gauging station, the proposed dam site, and a site approximately 400m upstream from the same. Study of data obtained revealed that a large volume of water in dry season submerges underground at the Rio Tuba Mine gauging station, and the surface flow discharge is less than that upstream at the dam site. The average submerged flow rate calculated from the 6 observations is $0.21 m^3/sec$.

2.3.2 Precipitation

(1) Existing Precipitation Records

The area of the river basin within which the proposed dam site is located is $39 km^2$. The only records regarding precipitation within the said area are those made by the Rio Tuba Mine at the Upper Tamlang Rain Gauge Station. The observation period of these records however, is too short to allow reliable use for the present Project. Although located outside of the said drainage area, rainfall has been recorded since July 1983 at the Lower Tamlang Rain Gauge Station set-up by the Rio Tuba Mine directly downstream from the proposed power plant site. In addition, a third rain gauge station is located 10km to the northeast of the latter site within the compounds of a private home along the national road about 3km west of Brookes Point. The latter station was commissioned by PAGASA in 1956 and has been recording rainfall ever since.

In the present Study, records considered most accurate and reliable covering a 14-year period from 1970 to 1983 were used in data analysis. In this connection, it should be noted that average annual rainfall for the said 14-year period was 1,492mm in comparison with an annual average of 1,609mm for the 28-year period from 1956 to 1984.

A comparison of results from the Lower Tamlang Rain Gauge Station and Brookes Point is presented in the following table.

YEAR	MONTH	RAINFALL		NO. OF RAINFALL DAYS	
		Lower Tamlang River	Brookes Point	Lower Tamlang River	Brookes Point
1983	Aug	249.5	134.6	23	10
1983	Sept	243.7	264.5	21	11
1983	Oct	486.0	248.7	18	11
1983	Nov	514.5	331.6	25	13
1983	Dec	452.5	411.5	12	8
1984	Jan	143.0	172.7	14	6
Total		2,089.2	1,563.6	113	59

The above results clearly indicate that from August to January rainfall at the Lower Tamlang Rain Gauge Station is about 34% greater than that at Brookes Point although the latter has 52% or almost twice as many days of rainfall.

(2) Average Rainfall

Although existing rainfall records within the catchment area itself are scarce, average rainfall for the same was determined by modification and addition of data collected over a long period of time at Brookes Point.

1) Calculation of Lower Tamlang Daily Rainfall

Rainfall data is based on data from Brookes Point, while the relationship between rainfall at Brookes Point (BP) and at Lower Tamlang is assumed as follows:

(Lower Tamlang annual rainfall) = (BP annual rainfall) x 1.34

(Lower Tamlang days of rainfall/year) = (BP days of rainfall per year) x 2

Based on the above, daily rainfall for each year from 1970-83 at Lower Tamlang was estimated from daily rainfall at Brookes Point during the same period. By adding 0.36 precipitation of the rainy day to the continous closest clear day of the same, the above two conditions were satisfied.

2) Estimation of Rainfall in the River Basin

In general, the higher the elevation, the greater the amount of rainfall. The ratio in the Project catchment area is estimated by PAGASA as a 10-20% increase in rainfall with every 100m in elevation. As a result of various calculations in the present Study however, a 10% rainfall increase was assumed for every 200m in elevation as shown below.

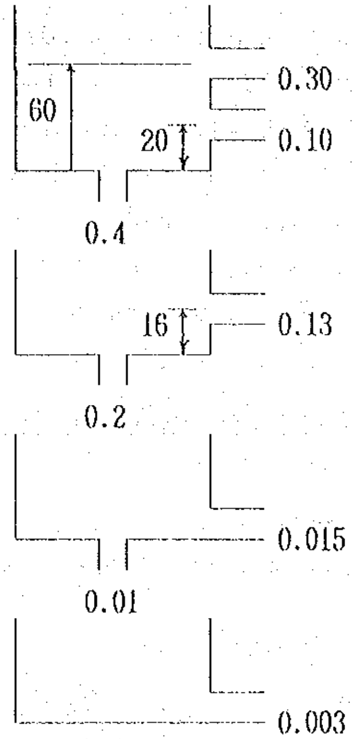
Elevation	River Basin Area (km^2)	Area Ratio (%)	Ratio to Lower Tamlang River
2,000	1.6	4.07	2.47
1,500	5.2	13.23	2.20
1,000	11.1	28.24	1.74
500	14.5	36.90	1.37
100 (Lower Tamlang)	6.9	17.56	1.10
Total	39.3km^2	100	1.58 1/

1/ Wieghted Average

Based on 1980 rainfall data for Brookes Point and in accordance with a calculation method described hereinafter, annual average rate of discharge was estimated at approximately 3.0m^3/sec. This figure was selected on the safe side in comparison with the aforementioned NIA estimate of 3.09m^3/sec and satisfies the assumption for average rainfall in the catchment area.

2.3.3 Estimation of Long-Term Daily Discharge

As actual long-term daily discharge data was unavailable, daily discharge was estimated by the tank model method based on average rainfall calculations for the river basin presented above. Said rainfall data and rate of discharge data from the NIA river gauging station was used to determine the tank model coefficient while the tank constant determined through simulation is as follows:



Daily discharge was estimated for the 14-year period from 1970-83 using the above tank model system and based on this estimation plus an infiltration rate of $0.07 m^3/sec$ (assumed safety factor: 3) recorded at the NIA gauging station, the average annual flow duration curve was formulated for the same period (FIG 2-7). In addition, the daily flow discharge was estimated for each year as shown in Table 2-7. Main results of the above calculations are as follows:

Average Discharge	: $3.22 m^3/s$
Maximum Daily Discharge	: $28.98 m^3/s$
Annual Cumulative Outflow	: 101.54mcm
Annual Rainfall in River Basin	: 3,174.1mm
Runoff Coefficient	: 0.82

2.4 Design Flood Flow and Sedimentation in the Reservoir

2.4.1 Estimation of Design Flood Flow

Although no flood data has been recorded in Palawan Island to date, daily rainfall at the dam site was estimated from daily rainfall data covering a 14-year period at Brookes Point near the Tamlang River. Based on this estimate, probable daily rainfall for a 100-year period was calculated according to the Iwai-method, a standard method for probability calculation widely used in Japan. From the 100-year probable rainfall estimate, 100-year probable flood flow was estimated by the rational formula and adopted as the design flood flow for the dam site.

(1) Estimation of 100-year Probable Rainfall

Based on daily rainfall data for the 14-year period from 1970-83, 100-year probable rainfall (R 100) was calculated by the Iwai method. The result was: R 100 = 338mm/day.

(2) Estimation of Design Flood Flow

Based on the above, average hourly rainfall intensity was determined and, using the rational formula, 100-year period design flood was estimated.

Rational Formula

$$Q = 0.2778 \cdot f \cdot R \cdot A \ (m^3/sec)$$

where,

A: catchment area = $39km^2$

R: average hourly rainfall intensity

F: flood discharge coefficient = 0.8

However, as flood arrival time (T) is 2.3 hours, R is as follows:

$$R = \frac{R100}{24} \cdot \frac{24^{0.6}}{T} = 58mm/hr$$

Therefore, design flood was determined as follows:

$$Q = 503 \div 510m^3/sec$$

2.4.2 Estimation of Sedimentation in the Reservoir

The most accurate estimations of sedimentation are based on sedimentation figures for nearby existing dams. Such data however, is unavailable for existing dams in Palawan Island and the Tsurumi formula commonly used in Japan, which corresponds comparatively well with actual data, was used to estimate sedimentation.

Formula

$$qs = K \cdot (C/A)^{0.8}$$

where,

qs: sediment ratio (m^3/km^2/year)

C: reservoir level = 1,100,000m^3

A: catchment area = 39km^2

K: constant = maximum value = 0.8
average value = 0.1
minimum value = 0.0006

The average value of constant K for the Study Area was determined to be about 70% (K = 0.1 x 70/100 = 0.07) on the basis of field survey.

Therefore,

$$qs = 0.07 \times \frac{1,100,000}{39} \quad 0.8 = 254m^3/km^2/year$$

Sedimentation for a 50-year life of the power plant with a sedimentation level of 179m, which presents no trouble for operation, is as given below.

$$259 \times 39 \times 50 = 500,000m^3$$

However, as dam stability calculations were based on a 100-year sedimentation period, sedimentation was determined at 1,000,000m^3, sedimentation level for which is EL 185m.

FIG. 2-1 **PHILIPPINE CLIMATE MAP**

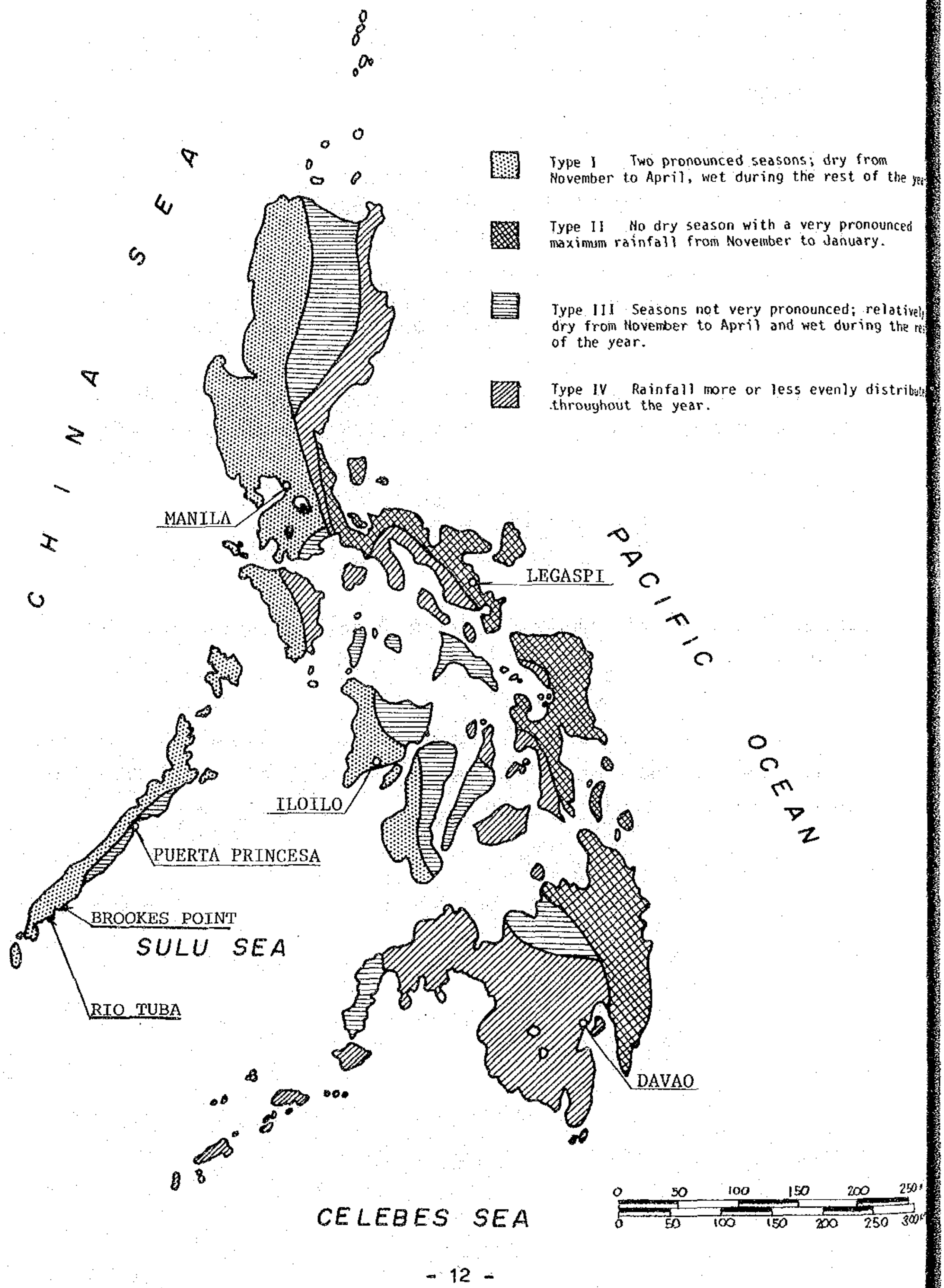


FIG. 2-2 METEOROLOGY, RIO TUBA MINE

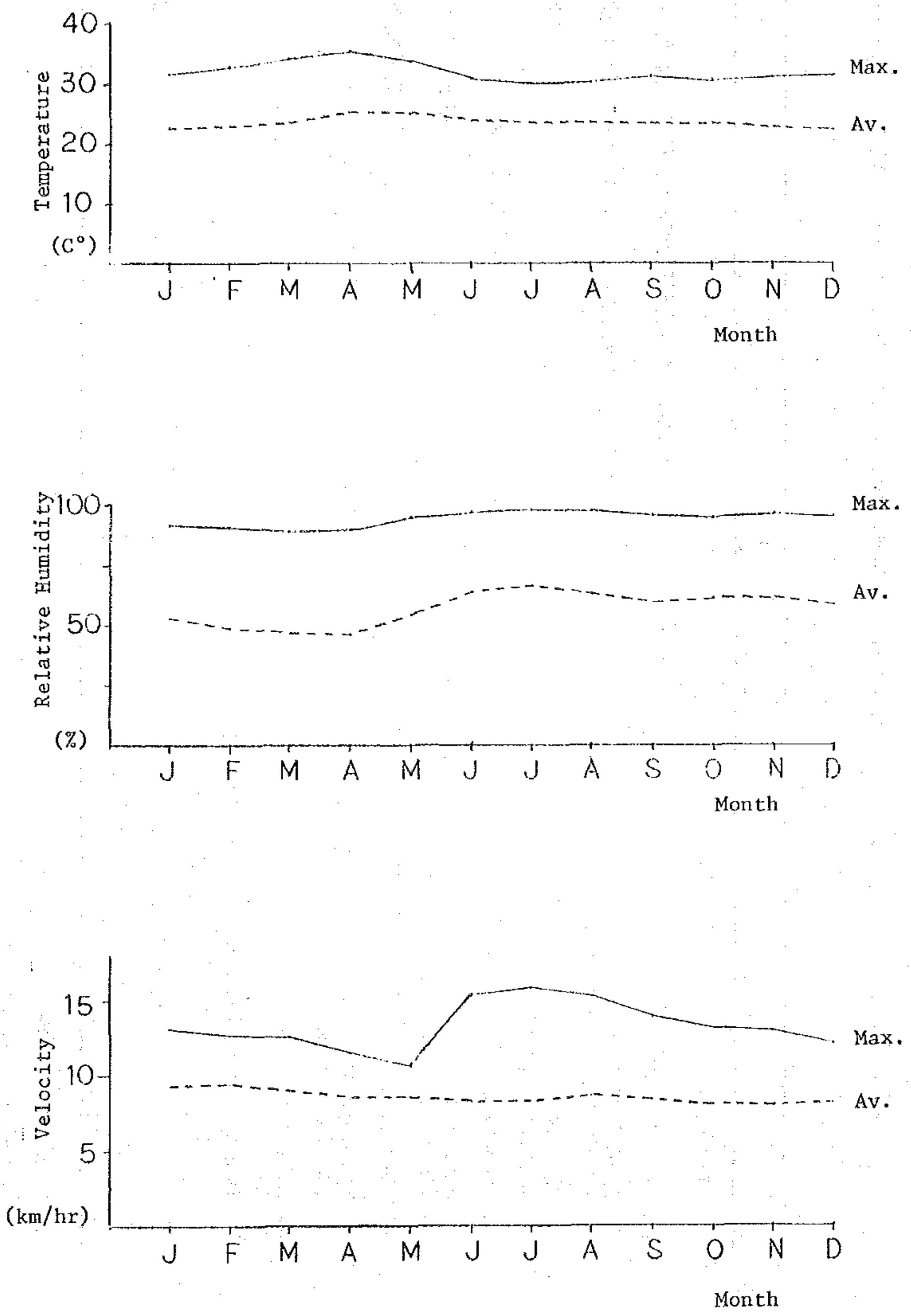


FIG. 2-3 **COLLECTED METEOROLOGICAL AND HYDROLOGICAL RECORDS**

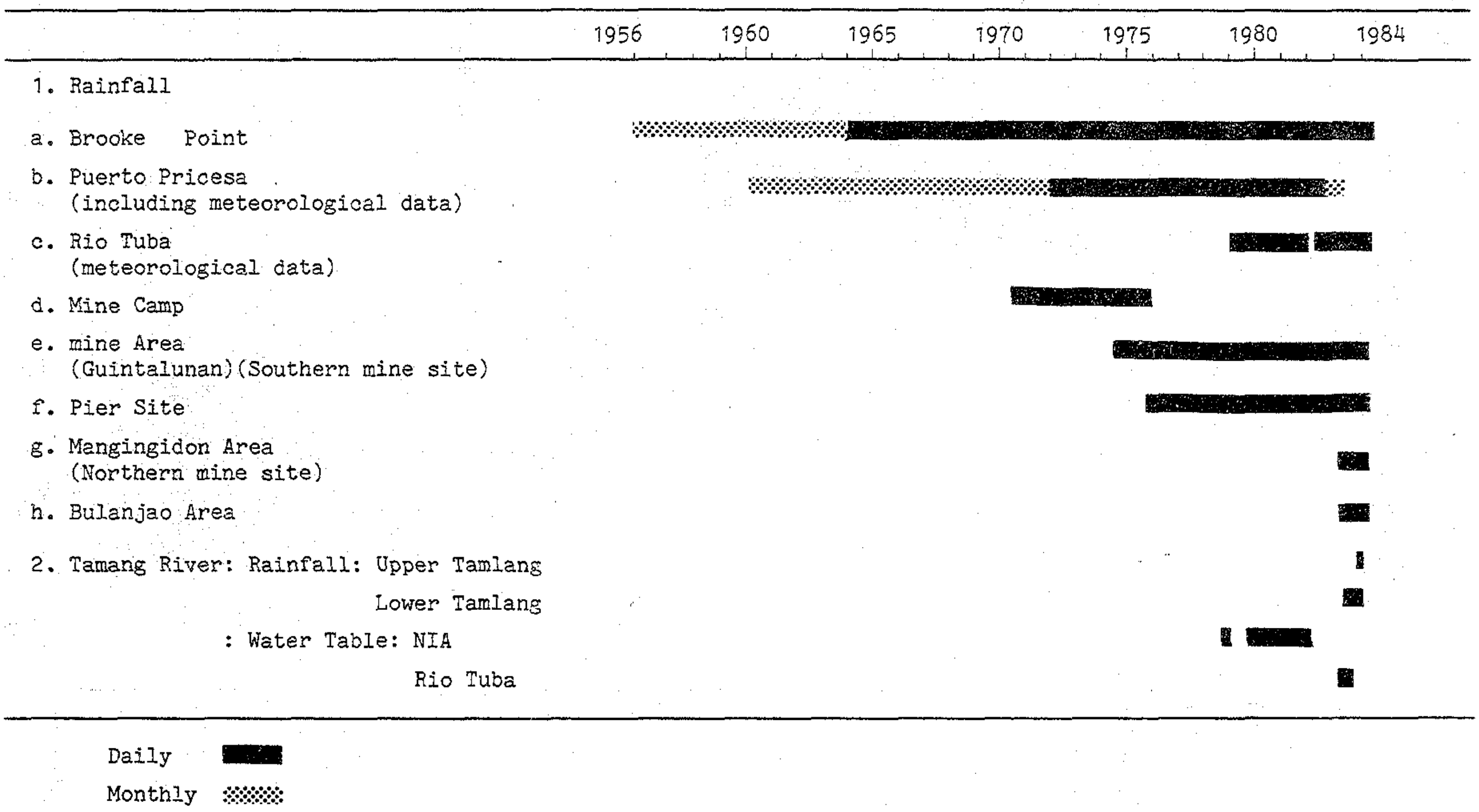


FIG. 2-4 **PROFILE OF TAMLANG RIVER**

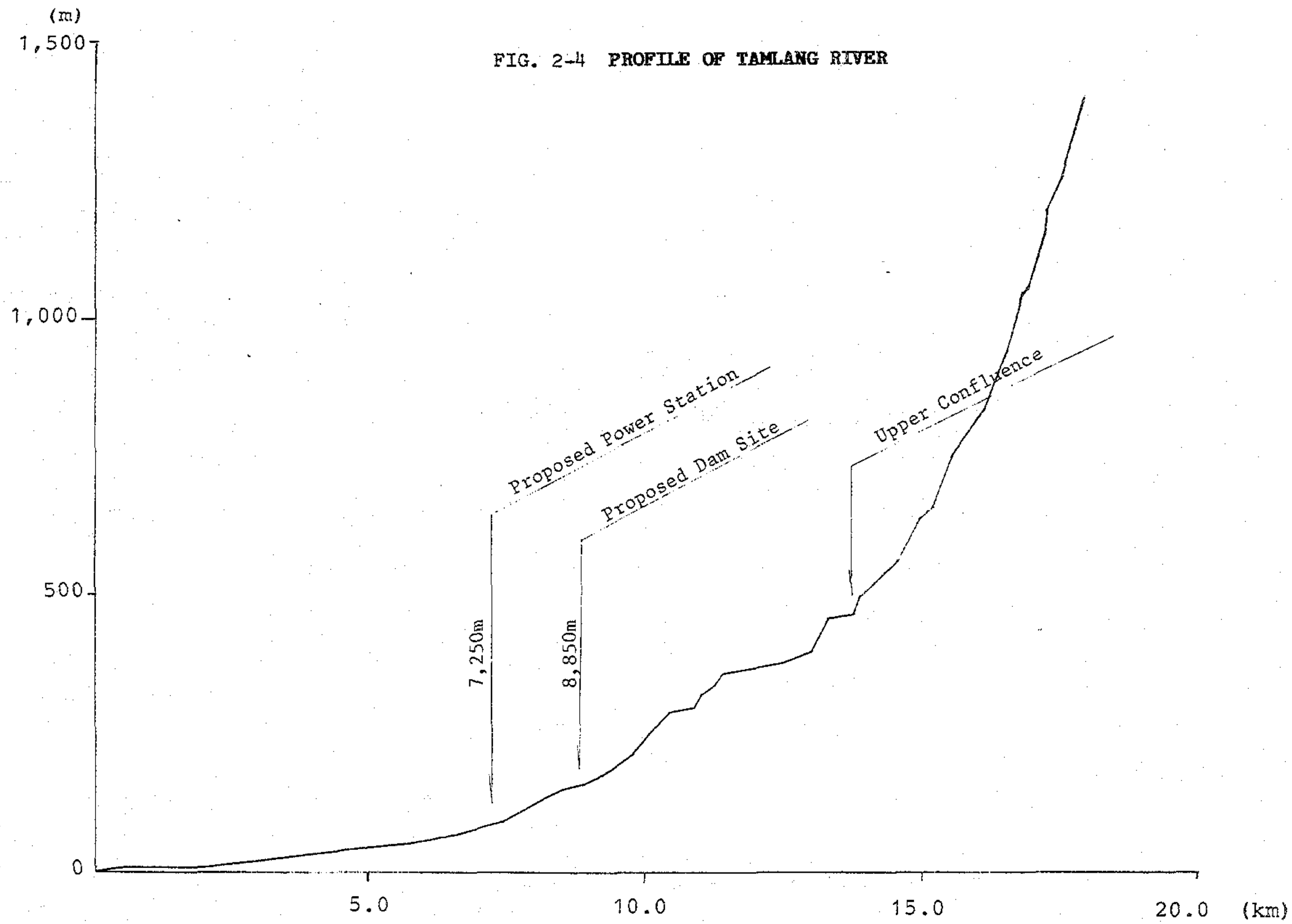
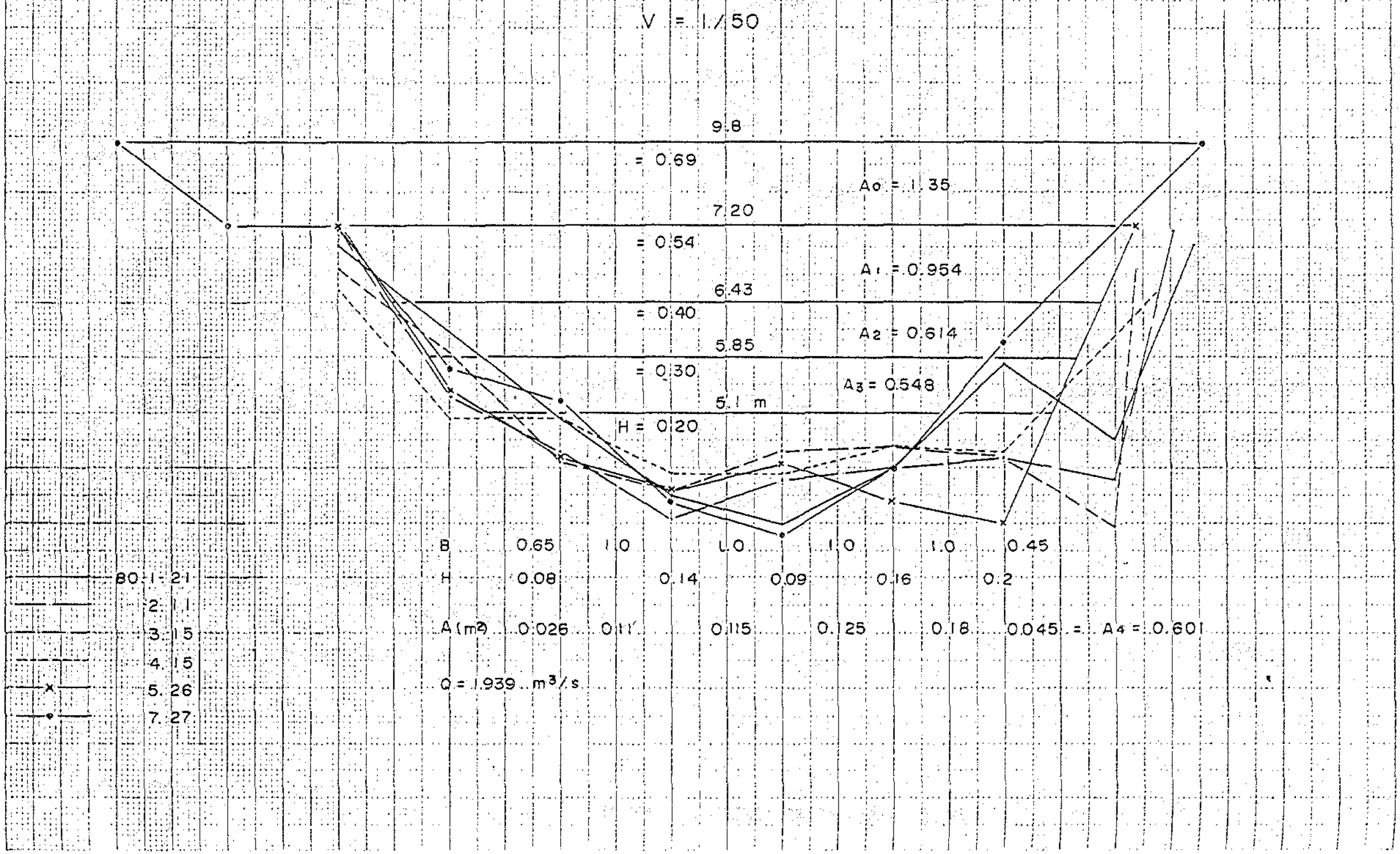


FIG. 2-5 RIVERBED ELEVATION AT NIA GAUGING STATION



$Y = aX^b$

FIG. 2-6 RATING CURVE, 1980 TAMLANG RIVER

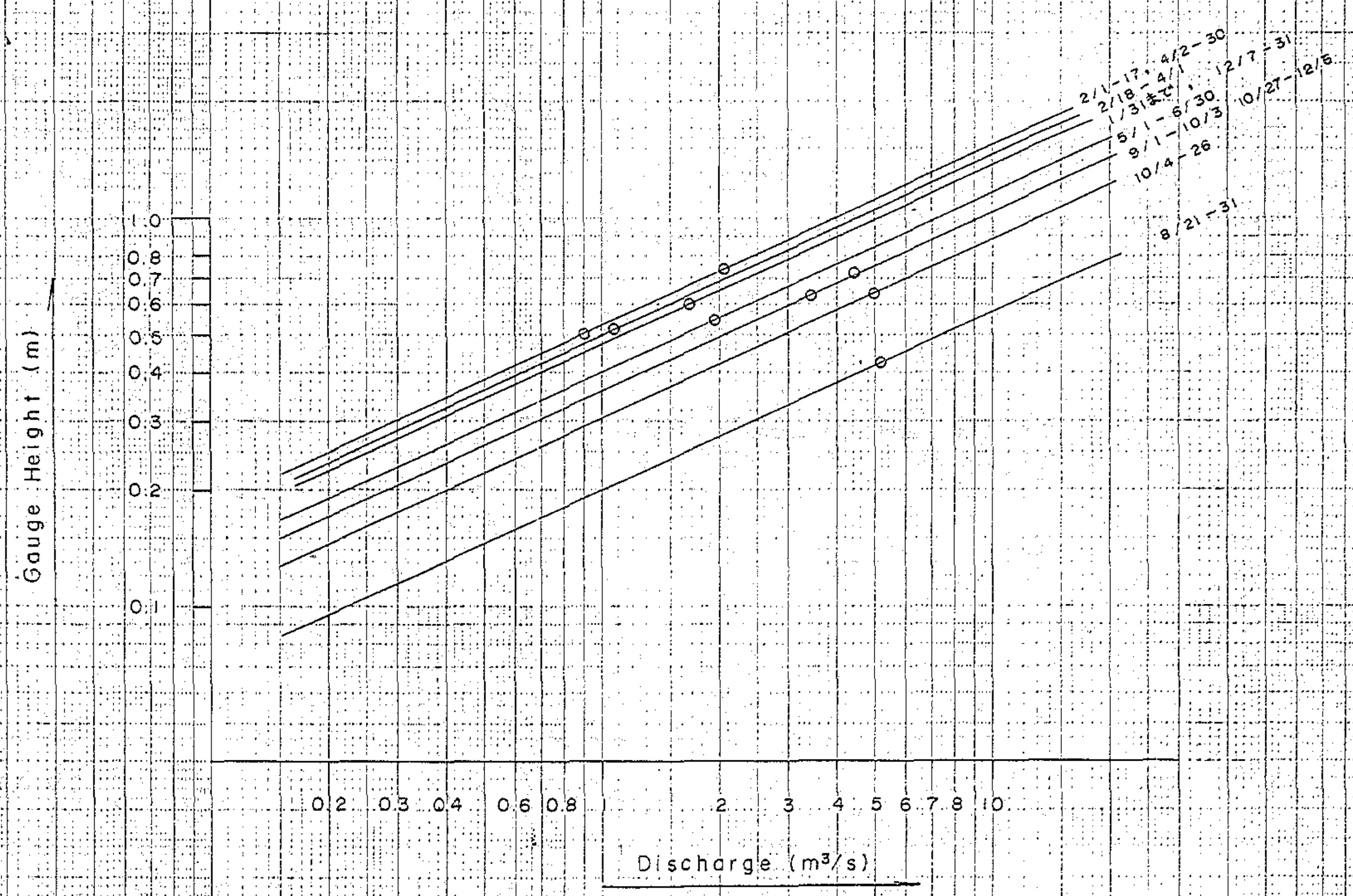


FIG. 2-7 **TAMLANG RIVER FLOW-DURATION CURVE**

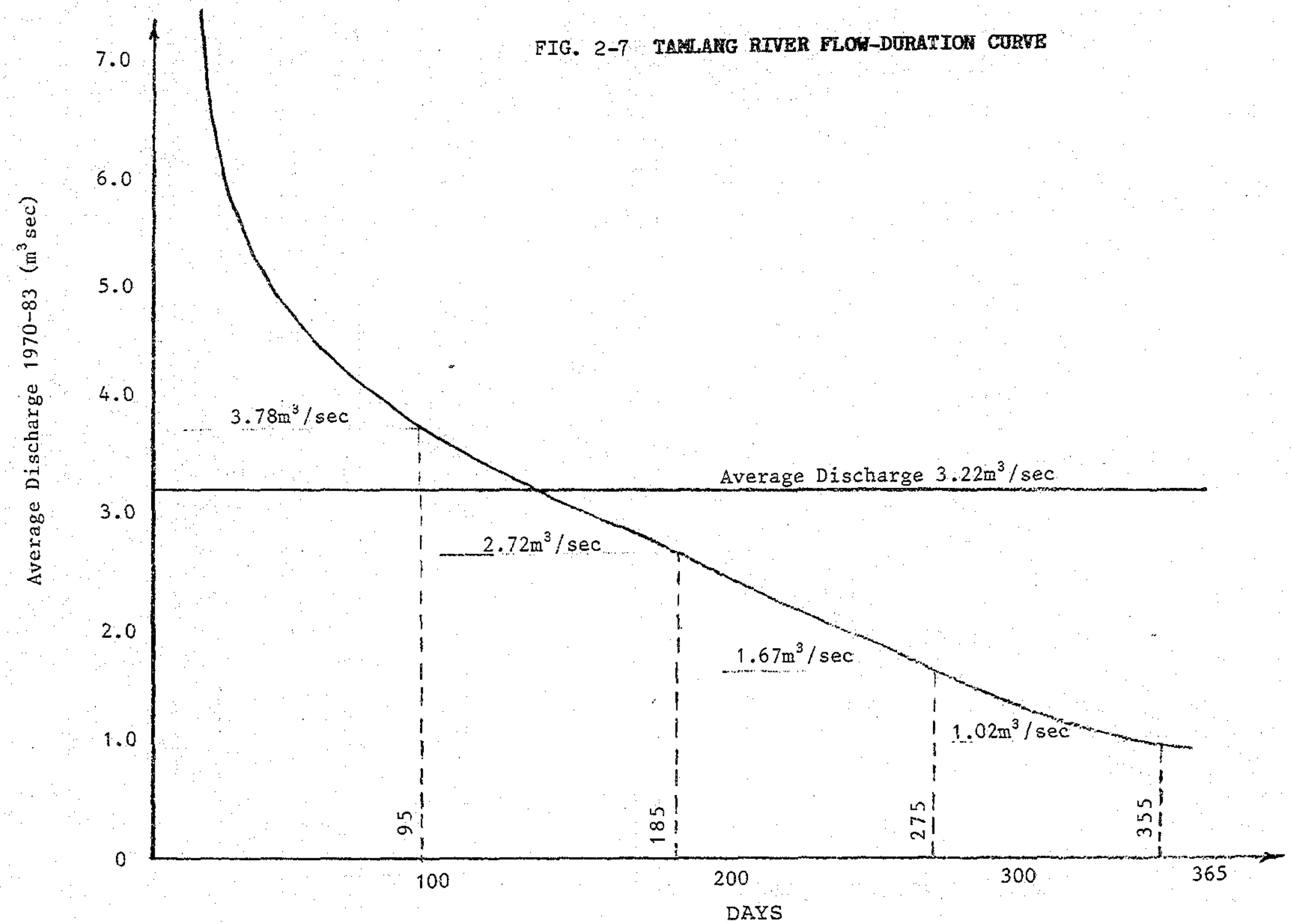


TABLE 2-1 **MAXIMUM AND MINIMUM TEMPERATURE, RIO TUBA MINE**

(°C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1979	34.7	35.4	36.1	37.4	33.7	30.9	29.6	31.5	32.3	29.9	31.9	30.7
	23.4	24.0	25.0	26.6	25.1	23.7	23.0	23.9	23.4	23.4	22.8	22.3
1980	31.2	32.0	32.7	35.3	34.2	30.4	30.7	30.6	31.2	31.2	31.2	30.9
	22.7	22.4	22.7	25.1	25.0	24.1	24.0	23.8	24.0	24.1	23.7	23.8
1981	30.0	32.6	33.3	34.5	33.5	29.9	29.4	29.8	30.8	30.8	30.0	31.1
	23.5	23.1	22.9	24.2	25.0	23.5	22.5	22.6	23.0	23.4	21.9	20.8
1982	30.6	31.3	33.1	33.5	32.0	29.2	29.6	28.9	30.3	30.0	31.8	32.5
	20.9	22.1	21.6	23.4	23.0	21.8	22.4	22.1	22.0	21.6	21.7	21.9
1983	31.7	32.8	35.3	35..8	35.8	34.0	32.0	31.5	31.9	31.9	31.2	32.1
	22.6	22.9	25.8	26.3	27.0	25.7	25.0	25.5	25.2	24.5	24.1	24.3
Average	31.7	32.8	34.1	35.3	33.8	30.9	30.3	30.5	31.3	30.8	31.2	31.5
	22.6	22.9	23.6	25.1	25.0	23.8	23.4	23.6	23.5	23.4	22.8	22.6

Note: Upper column is maximum temperature while lower column is minimum.

TABLE 2-2 **MAXIMUM AND MINIMUM RELATIVE-HUMIDITY, RIO TUBA MINE**

(%)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1979	79.0	75.7	73.2	74.4	94.8	96.4	96.5	94.3	95.0	96.8	99.4	98.6
	36.1	34.2	33.8	33.5	53.6	63.8	67.9	58.2	55.6	66.6	61.6	58.7
1980	98.0	97.4	96.7	97.6	98.2	99.6	99.8	99.9	98.1	96.7	97.7	96.5
	58.1	52.3	51.4	49.8	54.8	68.9	69.9	66.9	63.7	61.5	64.0	64.9
1981	94.5	94.0	93.0	94.9	98.1	99.2	99.8	96.8	96.3	94.7	98.9	97.6
	60.9	51.4	50.2	50.0	55.4	66.1	67.4	64.0	59.9	60.8	66.4	61.8
1982	94.0	95.2	94.5	96.1	97.7	99.2	99.3	98.6	98.6	96.4	95.7	95.3
	54.7	55.5	50.4	51.9	58.7	69.9	65.9	63.3	60.5	59.8	54.3	48.7
1983	91.3	90.6	86.3	85.2	87.1	89.4	91.7	98.2	89.6	89.0	89.1	87.4
	52.5	48.5	46.5	43.5	49.6	51.9	58.7	60.3	57.5	55.2	57.1	56.7
Average	91.4	90.6	88.7	89.6	95.1	96.8	97.4	97.6	95.5	94.7	96.2	95.1
	52.5	48.5	46.5	45.7	54.4	64.1	66.0	62.5	59.4	60.8	60.6	58.2

Note: Upper column is maximum relative-humidity while lower column is minimum.

TABLE 2-3 **MAXIMUM AND AVERAGE WIND VELOCITY, RIO TUBA** 1979-83

unit: km/hr

AVE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAX	13.0	12.6	12.6	11.5	10.6	15.3	15.8	15.2	13.8	13.0	12.8	12.0
AV	9.2	9.4	9.0	8.5	8.6	8.2	8.3	8.6	8.3	8.0	7.9	8.1
Direc-tion	SE NE	SE NE	NE SE	SE NE	SE	*	*	SE	SE NE	SE NE	SE NE	SE

TABLE 2-4 **MONTHLY RAINFALL BROOKES POINT PALAWAN**

unit: mm

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1956	293.1	134.1	26.2	100.9	151.1	170.2	144.3	154.4	110.0	189.5	165.4	637.5	2,276.7
1957	10.2	50.5	39.7	84.8	63.8	214.1	324.4	273.6	273.6	119.6	90.7	8.1	1,553.1
1958	37.1	66.0	10.2	3.3	140.7	150/4	203.5	191.8	134.4	219.5	287.0	79.0	1,523.4
1959	76.2	1.8	81.0	14.5	162.6	166.9	196.3	270.3	101.6	237.7	252.7	142.7	1,704.3
1960	96.3	63.5	175.0	39.1	85.3	145.5	103.1	202.7	298.8	198.9	303.0	82.8	1,704.0
1961	100.3	0	3.5	36.1	126.9	169.4	122.2	165.1	143.3	162.3	185.4	153.2	1,367.7
1962	67.1	5.8	80.5	75.9	178.1	135.6	383.5	173.5	321.6	50.8	253.7	692.7	2,418.8
1963	127.5	5.8	17.3	7.6	48.8	266.7	157.5	243.8	58.2	160.5	248.9	214.4	1,557.0
1964	8.6	21.1	1.0	78.0	232.7	137.7	98.6	211.3	194.6	112.0	333.2	186.4	1,615.2
1965	109.0	4.6	44.2	30.7	204.2	193.6	261.4	94.0	200.4	167.6	217.4	233.9	1,761.0
1966	45.5	23.6	35.8	55.6	694.9	237.0	261.1	226.3	178.3	201.4	230.7	187.8	2,378.0
1967	309.5	5.0	139.5	52.8	72.0	53.2	184.0	164.9	123.0	231.1	242.2	18.2	1,595.4
1968	99.0	9.3	0	15.2	0	147.3	101.6	222.1	329.9	138.0	287.0	178.2	1,527.6
1969	0	0	0	10.1	96.2	100.5	115.4	104.0	86.1	67.2	291.2	311.7	1,177.4
1970	54.5	30.2	32.4	2.3	90.1	152.2	88.5	172.6	149.8	231.0	365.7	147.1	1,516.4
1971	91.4	40.6	5.1	5.0	40.5	120.1	87.3	39.9	109.1	269.0	74.2	106.3	988.5
1972	29.3	7.0	77.2	27.3	106.6	169.9	141.1	163.9	154.2	137.2	462.3	5.1	1,481.1
1973	0	0	254,4	68,5	127.0	102.5	182.1	158.9	214.5	186.1	180.3	369.3	1,614.6
1974	135.8	100.0	35.0	15.2	137.6	110.5	134.6	33.9	101.6	144.7	157.4	328.1	1,434.4
1975	55.9	0	46.5	47.6	48.5	105.2	781.5	153.4	88.9	237.7	51.5	1,055.6	2,072.3
1976	59.7	36.3	10.1	72.6	119.8	113.4	135.8	125.9	111.8	184.3	253.0	383.5	1,606.2
1977	70.9	7.6	0	0	82.4	62.5	340.0	124.3	235.2	68.9	163.8	56.4	1,212.0
1978	25.4	0	0	73.5	138.2	45.0	71.6	114.9	79.8	111.1	305.8	41.2	1,006.5
1979	0	2.5	0	11.7	82.6	154.0	185.7	54.1	62.8	378.4	62.2	141.2	1,135.2
1980	64.7	0	13.2	27.9	110.5	212.2	186.5	167.7	103.0	210.7	287.7	192.9	1,577.0
1981	152.0	0	0	0	89.5	186.7	178.9	85.0	155.1	133.5	525.9	193.7	1,700.3
1982	2.5	35.6	2.3	47.0	121.3	219.1	160.1	210.5	59.9	168.5	174.1	38.1	1,239.0
1983	90.9	10.2	0	7.6	0	311.0	293.9	134.6	243.7	248.7	331.6	411.5	2,083.7
Average													
('70-83)	59.5	19.3	34.0	29.0	92.5	147.4	169.1	124.2	133.5	193.5	242.5	247.8	1,492.3
('56-83)	79.0	23.8	40.3	36.1	126.8	155.4	179.4	158.4	154.7	177.3	242.3	235.6	1,609.1

TABLE 2-5 DAILY RIVER DISCHARGE CONVERTED FROM NIA GAUGING RECORDS (1980)

(unit: m^3/sec)

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
1	2.39	2.23	1.19	2.24	2.13	1.42	4.61	8.23	2.62	2.62	6.69	5.64	1	
2	2.10	2.39	1.36	1.15	1.74	1.63	5.19	7.15	3.69	2.05	6.11	5.11	2	
3	1.56	1.75	1.39	0.92	1.81	1.59	4.46	8.81	3.82	2.42	5.56	4.40	3	
4	1.98	1.51	1.39	1.20	1.42	1.59	4.61	7.82	4.40	4.10	4.75	4.82	4	
5	2.49	1.95	1.39	1.24	1.20	1.70	3.71	6.27	4.89	4.81	5.48	5.33	5	
6	2.04	2.39	1.42	0.98	1.81	1.66	3.03	5.01	5.18	5.41	6.36	5.64	6	
7	1.59	2.10	1.39	1.04	1.39	1.52	4.16	5.35	5.33	4.10	5.72	2.90	7	
8	1.15	1.56	1.39	0.75	1.36	2.05	3.29	6.52	4.27	3.52	6.69	2.57	8	
9	0.94	1.98	1.59	0.59	1.77	1.97	3.10	8.23	3.75	3.31	6.11	2.50	9	
10	1.20	2.49	1.85	0.75	2.13	2.09	2.84	7.82	3.22	2.44	6.36	2.54	10	
11	1.39	2.04	1.29	0.94	2.34	2.75	2.00	5.68	2.62	2.67	5.56	2.86	11	
12	1.48	1.59	1.29	1.27	1.74	3.04	2.10	5.57	2.14	3.73	4.61	2.81	12	
13	1.64	1.15	1.34	1.13	1.39	3.29	1.90	5.13	2.88	4.25	4.82	2.50	13	
14	1.32	0.94	1.12	0.92	1.14	3.67	2.00	5.35	2.99	5.06	5.11	2.73	14	
15	1.05	1.20	1.05	0.88	1.52	3.95	2.13	7.82	2.57	5.59	4.61	2.86	15	
16	1.24	1.39	1.17	1.02	1.52	3.56	1.95	7.63	2.57	4.65	5.26	2.50	16	
17	1.45	1.48	1.24	0.75	2.13	3.45	2.00	6.27	3.16	3.73	4.96	2.73	17	
18	1.29	1.64	1.37	0.67	2.30	3.04	2.16	5.13	3.33	2.86	5.56	2.94	18	
19	1.07	1.32	1.59	1.04	1.93	2.84	2.00	5.57	3.69	3.38	5.04	2.90	19	
20	1.34	1.05	1.37	1.13	1.39	3.24	2.10	4.60	3.33	3.66	4.47	2.50	20	
21	1.67	1.24	1.95	1.27	1.74	3.40	2.72	5.07	3.10	3.52	5.18	3.42	21	
22	1.70	1.45	1.88	1.13	2.43	3.29	3.29	5.07	2.73	4.10	5.11	2.90	22	
23	3.11	1.29	1.24	1.09	2.79	2.94	3.03	6.46	2.28	4.90	4.47	3.75	23	
24	2.57	1.07	1.64	0.75	2.38	2,89	3.29	7.55	2.14	5.59	5.18	3.70	24	
25	2.50	1.34	1.12	0.69	1.97	2.61	3.16	9.09	2.28	8.18	4.61	3.11	25	
26	2.35	1.05	1.29	0.69	2.61	2.17	3.03	10.38	2.47	9.12	5.11	2.86	26	
27	3.02	1.32	1.64	1.00	3.35	1.77	3.64	12.41	2.28	6.95	5.18	2.50	27	
28	3.65	1.59	1.32	1.02	2.05	1.52	3.16	11.17	2.73	6.36	4.40	2.65	28	
29	2.46	1.34	1.17	1.24	1.52	1.42	3.36	9.26	2.37	5.72	4.82	2.98	29	
30	3.11		1.56	1.15	2.70	1.32	4.61	7.71	1.44	6.69	5.04	2.86	30	
31	3.33		1.45		2.70		4.78	8.56		6.78		2.73	31	
Average[1/]	1.94	1.58	1.40	1.02	1.95	2.45	3.11	7.18	3.14	4.59	5.30	3.30		3.09

Note: No Records: Esimated value from similar precipritation.
No Records: Interpolated from similar discharge in 1981.
1/ Year average: 3.09m^3/sec

TABLE 2-6 **RESULTS OF DISCHARGE MEASUREMENT, TAMLANG RIVER, 1984**

Date	Gauge Height 1/ (m)		Discharge (m^3/sec) Gauging Stn. 2/	Damsite 3/	Damsite 4/	Notes
Feb. 1	0.35	0	2.235			
13	0.30	0	1.495	1.754	1.840	measured by CKC equipment
15	0.295					
16	0.289	0	1.297	1.392	1.359	- 20 -
17	0.281					
18	0.274		1.199			
20	0.27					
21	0.267	0	0.957	1.429	1.123	- by Rio Tuba Mine
22	0.265					
23	0.263					
24	0.261	0	1.091	1.197	1.073	- do -
27	0.252	0	0.959	1.021	0.970	- do -
29	0.247					
Mar. 1	0.244	0	1.043	1.307	1.002	- by CKC -
3	0.238					
Average		0	1.140	1.350	1.228	

1/ Rio Tuba Gauging Station, 350m upstream of the proposed power station

2/ Rio Tuba Gauging Station

3/ 100m downstream of the proposed damsite

4/ 400m upstream of the proposed damsite

TABLE 2-7 SIMULATED FLOW DURATION

unit: m^3/sec

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	MEAN
5	9.75	8.98	12.10	10.39	9.38	23.26	13.44	10.22	9.74	10.18	9.96	18.90	7.69	24.17	12.71
15	6.47	4.74	6.77	6.90	7.07	13.94	10.26	6.11	5.23	5.97	6.09	10.25	5.28	11.84	7.64
25	5.94	4.10	5.69	5.97	6.12	8.92	7.84	5.24	3.80	4.38	5.57	7.32	4.84	9.59	6.09
35	5.22	3.88	4.95	5.44	5.33	6.77	6.59	4.90	3.28	3.84	5.10	6.28	4.50	8.14	5.30
45	4.86	3.61	4.46	5.08	5.00	6.02	5.85	4.67	2.95	3.67	4.83	5.56	4.29	7.13	4.86
55	4.69	3.40	4.18	4.68	4.61	5.57	5.28	4.35	2.79	3.54	4.54	5.14	4.12	6.38	4.52
65	4.44	3.17	3.96	4.48	4.38	5.19	4.87	4.20	2.59	3.19	4.33	4.78	4.01	6.03	4.26
75	4.25	3.04	3.80	4.33	4.05	4.76	4.56	4.06	2.52	3.03	4.19	4.40	3.85	5.75	4.04
85	4.09	2.95	3.64	4.15	3.89	4.45	4.33	3.96	2.42	2.85	4.10	4.10	3.73	5.43	3.86
95	4.00	2.85	3.49	4.01	3.61	4.24	4.02	3.83	2.32	2.78	3.96	3.86	3.66	5.28	3.71
105	3.81	2.78	3.34	3.83	3.42	4.03	3.84	3.69	2.22	2.68	3.82	3.73	3.56	4.85	3.54
115	3.67	2.71	3.23	3.72	3.32	3.79	3.67	3.48	2.13	2.64	3.69	3.59	3.44	4.58	3.41
125	3.49	2.67	3.11	3.54	3.21	3.67	3.57	3.35	2.07	2.57	3.62	3.46	3.37	4.23	3.28
135	3.34	2.62	2.99	3.37	3.12	3.49	3.46	3.28	2.00	2.48	3.53	3.34	3.28	4.11	3.17
145	3.19	2.45	2.87	3.14	3.04	3.37	3.33	3.18	1.97	2.39	3.40	3.22	3.17	4.01	3.05
155	3.06	2.33	2.79	3.00	2.94	3.28	3.21	3.08	1.90	2.23	3.26	3.13	3.11	3.83	2.94
165	2.95	2.23	2.66	2.87	2.85	3.22	3.16	2.97	1.85	2.10	3.18	3.05	2.99	3.73	2.84
175	2.82	2.13	2.57	2.77	2.69	3.15	3.08	2.86	1.81	2.01	3.75	2.97	2.86	3.64	2.75
185	2.74	2.02	2.47	2.65	2.64	3.06	3.02	2.75	1.74	1.89	2.97	2.91	2.78	3.40	2.65
195	2.64	1.95	2.42	2.55	2.56	2.97	2.95	2.62	1.70	1.79	2.73	2.83	2.72	3.11	2.54
205	2.49	1.90	2.26	2.37	2.49	2.88	2.87	2.51	1.62	1.73	1.10	2.75	2.66	2.84	2.42
215	2.37	1.86	2.02	2.25	2.43	2.76	2.82	2.44	1.56	1.70	2.23	2.66	2.57	2.39	2.29
225	2.19	1.79	1.86	2.17	2.37	2.61	2.76	2.31	1.49	1.50	2.13	2.57	2.53	2.19	2.18
235	7.11	1.72	1.69	2.07	2.29	2.51	2.68	2.13	1.44	1.35	2.00	2.47	2.46	1.92	2.06
245	2.01	1.63	1.56	1.95	2.23	2.45	2.56	1.90	1.40	1.22	1.85	2.32	2.32	1.72	1.94
255	1.95	1.54	1.49	1.86	2.15	2.32	2.46	1.70	1.35	1.13	1.56	2.21	2.15	1.50	1.81
265	1.87	1.46	1.46	1.75	2.06	2.1	2.37	1.58	1.30	1.03	1.44	1.97	2.01	1.35	1.70
275	1.81	1.37	1.42	1.66	1.97	2.08	2.27	1.45	1.27	0.98	1.33	1.74	1.88	1.21	1.60
285	1.72	1.31	1.34	1.52	1.90	2.01	2.17	1.30	1.25	0.93	1.20	1.56	1.77	1.00	1.50
295	1.60	1.22	1.28	1.41	1.82	1.70	2.05	1.25	1.16	0.81	1.10	1.45	1.60	0.91	1.40
305	1.48	1.15	1.22	1.30	1.69	1.77	1.96	1.17	1.08	0.72	1.05	1.32	1.43	0.88	1.30
315	1.33	1.05	1.14	1.21	1.55	1.65	1.87	1.08	1.00	0.69	0.94	1.25	1.30	0.85	1.21
325	1.22	0.99	1.07	1.14	1.43	1.58	1.81	1.05	0.96	0.67	0.83	1.19	1.23	0.82	1.14
335	1.07	0.96	1.01	1.05	1.33	1.44	1.73	1.02	0.88	0.64	0.79	1.11	1.16	0.79	1.07
345	0.99	0.93	0.95	0.96	1.18	1.32	1.62	1.00	0.85	0.62	0.76	0.98	1.04	0.76	1.00
355	0.93	0.92	0.88	0.90	1.05	1.30	1.51	0.97	0.84	0.60	0.71	0.95	0.96	0.73	0.95
365	0.90	0.87	0.81	0.87	1.01	1.14	1.35	0.88	0.81	0.57	0.70	0.91	0.92	0.71	0.89

Note: Above values do not include infiltration flow (0.07 m^3/sec).

III. GENERAL PLAN

CHAPTER III GENERAL PLAN

3.1 Tamlang River Hydropower Plant

River slope along the Tamlang River is 1/17-1/20 along the 4km corridor between the higher mountains and the alluvial fan while that in the reaches immediately above and below this portion is more moderate. A comparative study was conducted to determine the optimum development plan for effective use of head in the 4km portion where flow is swifter (Refer to Main Text, Chapter 5). Study results indicate clearly that the high dam canal type with high intake elevation and daily regulating capacity is the most economical plan. As the proposed dam site is located on a good foundation of CH grade granite bedrock in a narrow river gorge the same is particularly suitable for dam construction.

Due to the steep terrain through which the intake channel must pass, a tunnel will be excavated and used as a temporary construction road, and later converted to the headrace. In consideration of effective use of head, influence of flood flow level, advantages of operation and maintenance, economical point, etc., the right bank just upstream from the alluvial fan was selected as the powerhouse site.

An outline of the project features are:

- Power Plant Site	: Brookes Point
- Catchment Area	: 39.0km^2
- Intake Water Elevation	: 188.7m
- Tail Water Elevation	: 85.0m
- Gross Head	: 103.7m
- Generation Method	: Canal with regulating-pond type (weekend regulating possible)
- Maximum Output	: 3,800kW
- Maximum Turbine Discharge	: 4.5m^3/sec
- Effective Head	: 101.3m
- Annual Potential Energy	: 20.51GWH

3.2 Transmission Lines

The transmission line route from the Tamlang River hydropower plant to the Rio Tuba Mine was determined in consideration of the following items and as shown on FIG. 3-1:

a) minimum length;
b) utilization of roadsides as much as possible in consideration of construction schedule, prompt delivery of construction materials, preservation of goods, and easy operation and maintenance; and,
c) minimum number of road and river crossings.

The total extended length of the transmission line is approximately 44km. The first 24km tranveres the flat area from the power plant to near Balalacao, of which about half passes through rice paddy and coconut fields and the remainder through grassland and mixed forest. The subsequent 12km is mainly mixed forest with some coconut fields and the final 8km passes through mixed forest and the level area around the Rio Tuba Mine.

3.3 Rio Tuba Mine Substation

A conventional-type outdoor transformer will be set up near the existing diesel power plant to link the Rio Tuba Mine's existing electrical system with the future hydropower plant and transmission line. A 3-phase, 4,700kVA transformer will be installed in the substation. Voltage will be stepped down at the substation from 34.5kV to 4.16kV for use at the diesel power plant. A vacuum circuit breakers will be installed for both the 34.5kV and 4.16kV sides to reduce maintenance.

The 4.16kV side will be an indoor metal-clad type and will be installed in the control room within the existing diesel powerhouse along with a control panels for the outdoor facilities. Existing equipment will be used to supply electricity required for the above.

3.4 PALECO Power Distribution Network

Under the present Project, 514kV of electric power will be generated by the hydropower plant for PALECO and this amount will steadily increase, reaching 1,000kW of power distributed to local residents after the first 10 years. Accordingly link-up with the PALECO distribution network will be required in several locations. The 3 alternatives below were studied with regards to the same.

Alternative A: link-up via a substation to be set-up near Bataraza

Alternative B: direct link-up from the hydropower plant

Alternative C: link-up from the substationsat the Rio Tuba Mine and the hydropower plant

Alternative C was selected for the following reasons.

First, although B has the lowest construction cost, the cost for distribution lines to the southern villages is higher resulting in greater overall cost for PALECO in comparison with C and thus possible delay of extension of services to rural communities. Construction costs for A were the highest of the three.

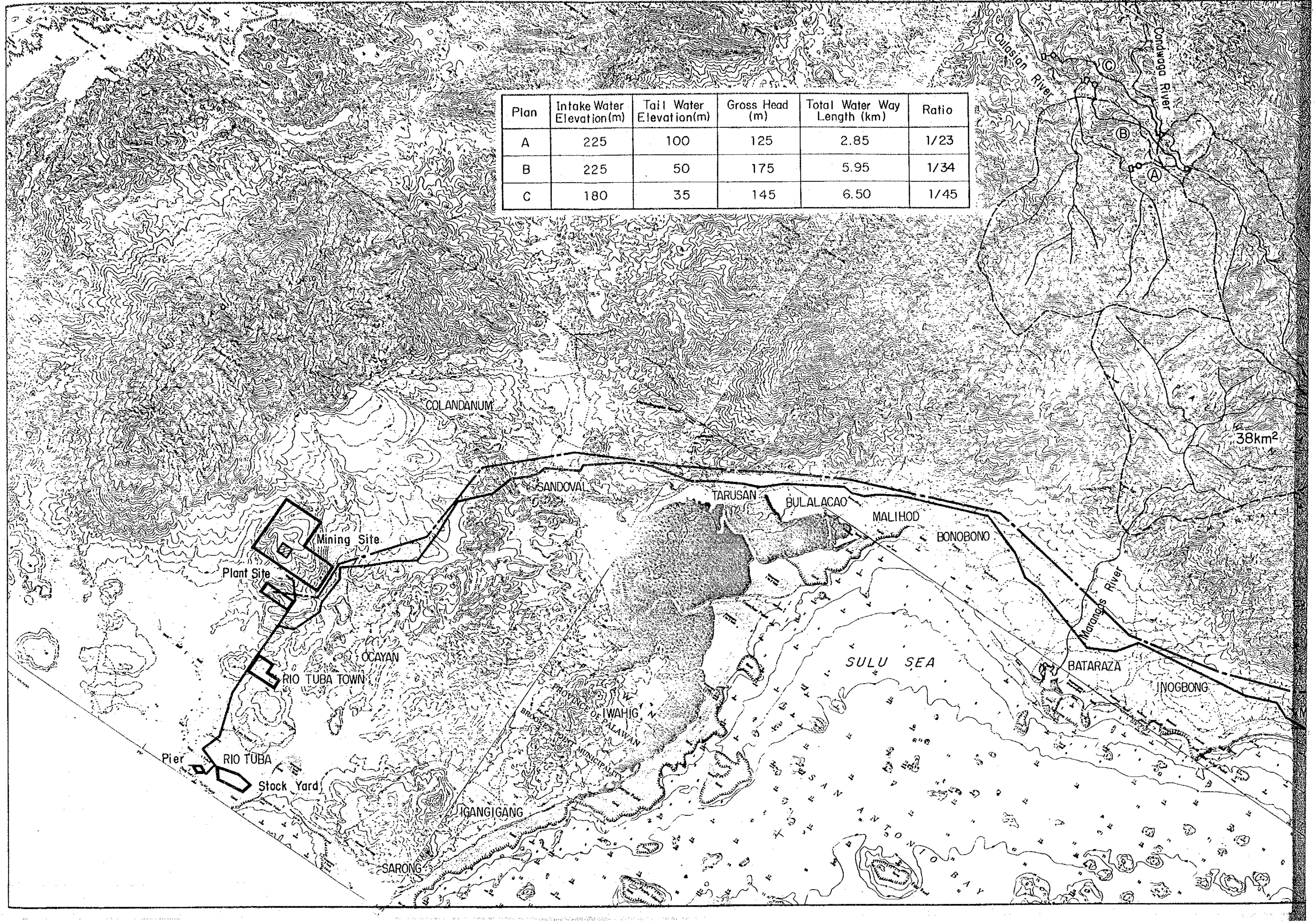
Secondly, operation and maintenance is the easiest for alternative C as both substations are on Rio Tuba Mine property.

Thirdly, power can still be supplied from PALECO for the power plant's use when power is temporarily shut-down.

Finally, some electricity for electrification of rural communities as well as for construction purposes could be supplied by PALECO via extension of distribution lines to the hydropower plant vicinity before construction commences.

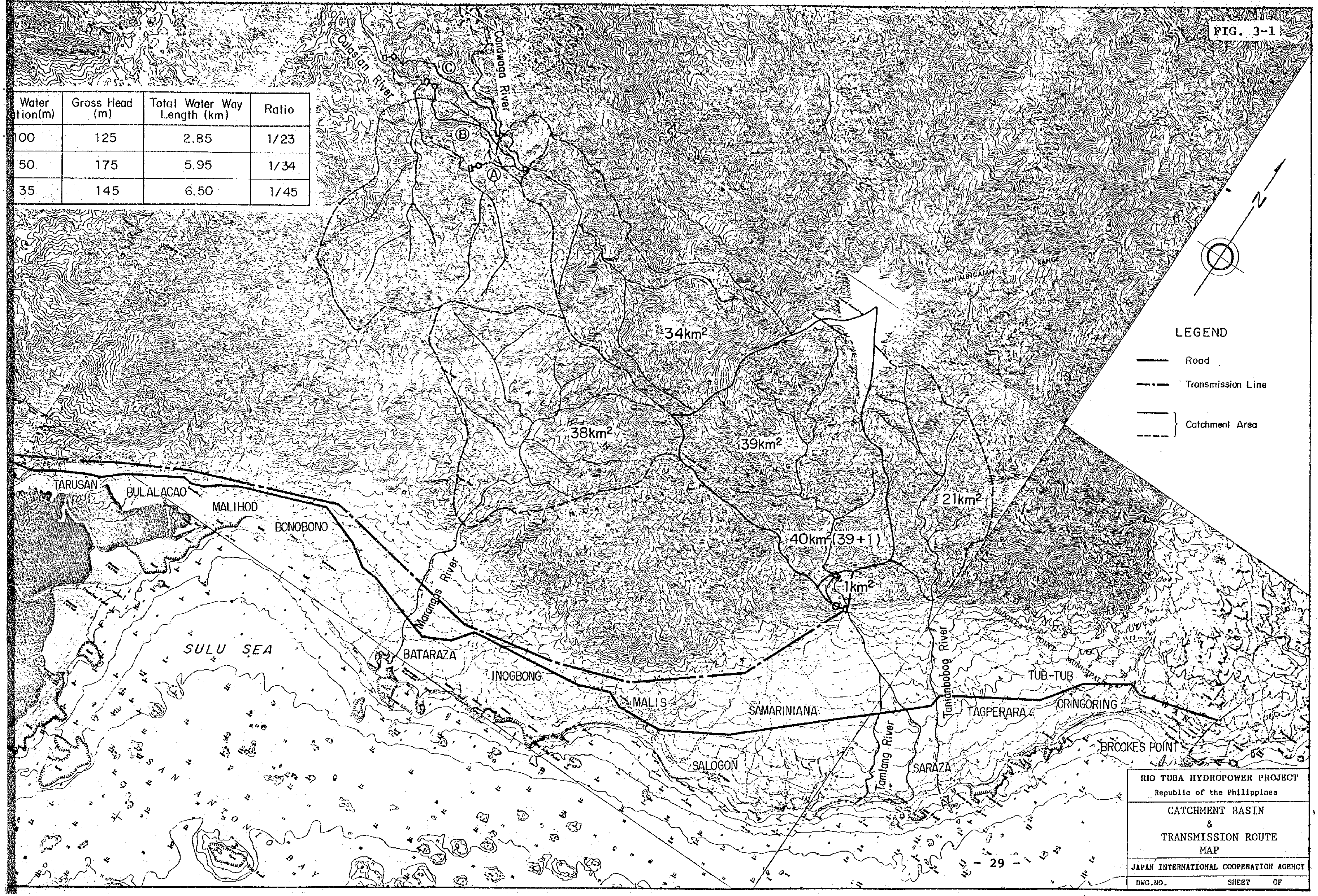
Accordingly, one 1,200kVA and one 150kVA, 3-phase transformer will be installed at the hydropower plant and the Rio Tuba Mine substation, respectively. Connection work for the secondary side of the transformer will be undertaken by PALECO. Common use of the 34.5kV transmission line poles and 13.2 distribution lines should be minimized.

The electrical network for the hydropower plant upon commencement of operation is given in FIG. 3-2.



Plan	Intake Water Elevation(m)	Tail Water Elevation(m)	Gross Head (m)	Total Water Way Length (km)	Ratio
A	225	100	125	2.85	1/23
B	225	50	175	5.95	1/34
C	180	35	145	6.50	1/45

FIG. 3-1



Water ation(m)	Gross Head (m)	Total Water Way Length (km)	Ratio
100	125	2.85	1/23
50	175	5.95	1/34
35	145	6.50	1/45

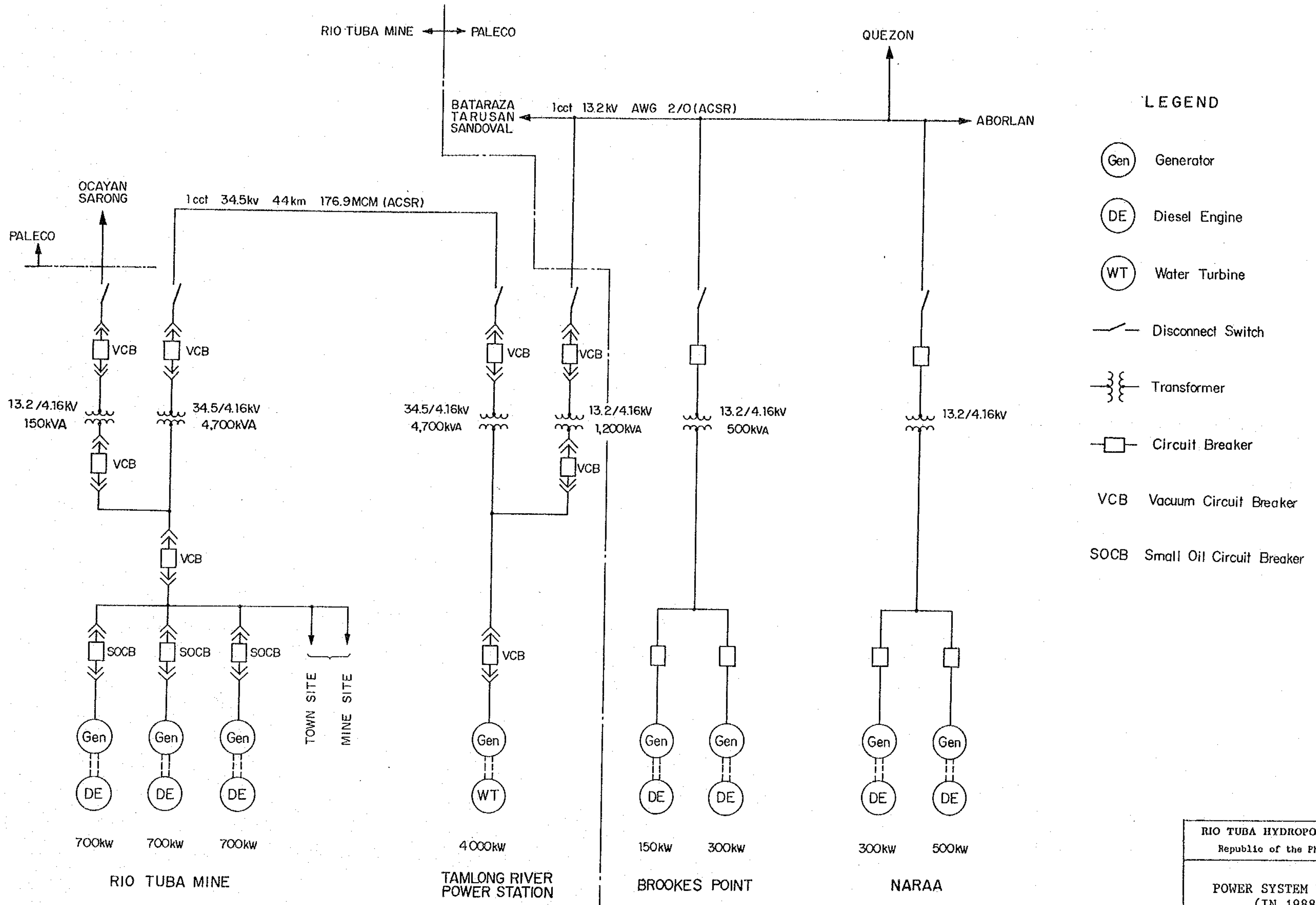
RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

CATCHMENT BASIN
&
TRANSMISSION ROUTE
MAP

JAPAN INTERNATIONAL COOPERATION AGENCY

DWG.NO. SHEET OF

FIG. 3-2



RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

POWER SYSTEM DIAGRAM
(IN 1988)

JAPAN INTERNATIONAL COOPERATION AGENCY

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