APPENDIX I

TOPOGRAPHY AND GEOLOGY

APPENDIX I

TOPOGRAPHY AND GEOLOGY

1.1 Topography

Palawan Island where the Project area is located is long and narrow in shape, extending in a NE-SW direction. A chain of mountains, the Mantalingajan range runs through the island just east of the center. Mt. Mantalingajan with a peak elevation of 2,086m is the highest mountain on the island.

Rivers in and around the Project area originate in the Mantalingajan range, flowing southeastward to the Sule Sea on the east side of the divide and northwestward to the South China Sea on the west side. These rivers are very short because of the short distance from the Mantalingahan range to the sea. The Tamlang River, which was studied in the last survey, is only 17km in length, while the Candawaga and the Culasian rivers are only 29km and 27km long, respectively. The rivers have steep gradients in the mountainous area and hence no large tributaries exist resulting in a small catchment.

On the east side of the Mantalingajan range, flat areas along the coast directly adjoin the mountain, while on the west side hilly areas with elevations of 30 to 100m occur between the mountains and the flat area. The difference in topography between the east and west sides of the Mantalingajan range is due to geological conditions and geological structures.

The flat areas near the mouth of the Candawaga and Culasian rivers are considered as deltaic low flat land comprised of river sediments. In the hilly area, isolated hills and resultant complicated contour lines are frequently observed. The basins' mountainous area is a stream-dissected V-shaped valley. The Candawaga River passes through mountainous area for about 21km of its total 29km length with a riverbed gradient of less than 1/80 in areas below elevations of EL.100m. The riverbed gradient at 160m is about 1/40. The Culasian River, on the other hand, passes through mountainous area for about 14km of its total 21km and the riverbed gradient is gentler in comparison with the Candawaga River.

Sinkholes which are characteristic of limestone areas occur in the basin. The catchments are mainly covered by tropical virgin forests, and bedrock outcrops are found on some steep slopes.

1.2 General Geology

Stratigraphical tables for the Candawaga and Culasian river basins are presented below.

STRATIGRAPHY OF PROJECT AREA

Geological Age	Formation	Lithology
Quaternary	Alluvium	Clay, Sand, Gravel
Early Miocene or late Oligocene	Ransang Limestone	Limestone
Early Eocene	Pandian Formation	massive Sandstone with inter-bedded mudstone and shale
Paleocene	Panmas Formaiton	interbedded sandstone and shale with limestone
Pre-Tertiary	Irahauan -metavolcauics	pynoclastics and lava (almost pillow type)

Source: Geology and Mineral Resources of the Philippins, Vol. 1 Geology (1982), Table EII-5
Bureau of Mines and Geo-Sciences, Ministry of Natural Resources

(1) Geological Classification

1) Irahauan Metavolcanics

This formation comprises the bedrock of this area and is distributed in the Mantalingajan range and in the midstream of the Candawaga River. The Mantalingajan range is underlain by ultra-acidic rocks which intruded before the Tertiary period and form steep terrain. Altered volcanic rocks are distributed in belt shapes along both the east and west flanks of the intruded rock.

This formation was formed by submarine volcanic action and consists of multiple rock of altered basaltic lava. Volcanic action occurred from Triassic to mid-Cretaceous.

2) Panas Formation

This layer is widely overlaid in the Project area and consists of sandstone and shale. General lithofacies of this formation change due to the alternating ratio of sandstone and shale. Several sandy to silty deposit originated limestone layers are interbedded in this formation.

At riverbeds, the formation is fresh and hard, while on the mountain tops and upper slopes, it is highly weathered by high tropical temperatures and heavy rainfall forming a thick laterite layer. The deposit originated limestone is caved by subsurface flow.

This formation is considered to have been deposited during Paleocene, and unconformably and faultingly covers the lower layer.

3) Pandian formation

This formation is not distributed in the Project area and is overlaid from east-northeast to west-southwest along the coast 10km north of the mouth of the Candawaga River. It is composed of massive sandstone with shale, conforming with the lower layer, and was deposited during Eocene.

4) Ransang Limestone

In the northern mountainous portion of the Project area, Ransang Limestone is distributed as a massive rock (2km x 5km) at elevations of 200 to 400m. The area presents dissoluted topography which is a characteristic of limestone areas. The formation is assumed to have been formed during early Miocene to late Oligocene.

5) Forth Formation

The layers which comprise the forth formation are alluvial and form a flood plain along the coast consisting of unconsolidated layers of sand, clay and gravels.

In addition to this forth formation, talus deposits cover the foothills and mountains along the valleys.

(2) Geological Structure

Geological structures extend predominantly in a NE-SW direction. The Panas formation which is widely distributed in the Project area is an anticlinal rock structure.

Faults are found at each site along the midstream of the Candawaga and Culasian rivers. The strike is NW-SE and runs at right angles to the geological structure.

1.3 Geological Survey

Surface geology and drilling surveys have been conducted to determine general geological features of the Project area. Drilling surveys were conducted at the proposed Culasian power site and alternative Candawaga power site with 5 holes for a total depth of 100m. A general geological map of the Project area is presented in FIG.I-1.

Drilling was not carried out at the proposed intake dam site for the following reasons:

i) The scale of the proposed intake dam is small due to the proposed run-of-river type;

ii) Seepage which arises from geological conditions at the intake dam is not as important a factor as with the reservoir type dam;

iii) Fresh and hard shale outcroppings 80m in length are observed around the proposed intake dam site on the Candawaga River at elevation 255m, and it is judged that no major problem will arise from construction of an intake dam with a height of about 13.5m;

iv) Transport of the drilling rig to the proposed intake dam site was considered very difficult since there is no road for 7 to 8km;

v) During the survey, the Candawaga power site was considered an important alternative because of the effect to downstream irrigation, hence drilling at the Candawaga power site was conducted; and,

vi) The survey period was limited.

1.4 Geology at the Proposed Intake Dam

A geological map of the proposed intake dam on the Candawaga River is shown in FIG.I-2. The intake dam is proposed at a site where there are outcrops of hard Panas Formation shale on the left bank. Intake water level for the intake dam is 260m, dam height is about 13m and dam length is 50m.

Both abutments consist of fresh hard shale, while the riverbed consists of unconsolidated sand and gravel layers 4 to 5m in depth consisting of basalt and sandstone massive rock to sand. A survey however, must be carried out at the detail design stage to determine the depth of the unconsolidated layer. The hard shale on both abutments is a stable bedrock for the proposed intake dam in terms of both hardness and permeability.

1.5 Geology along the Proposed Canal Route

The proposed headrace from the intake on the Candawaga River to the powerhouse on the Culasian River is mostly open channel. The channel runs along the left bank of the Candawaga River for about 7,400m and a 300m tunnel is proposed through the mountain divide of the Candawaga and Culasian rivers.

The bedrock of the open channel is mostly hard sandstone and shale of the Panas Formation, while in the upstream area Irahauan Metavolcanic basalt and tuffaceous breccia are distributed. These layers are hard and fresh in the lower portion of the slope from the riverbed; in the higher portion, however, they are weathered to latelite. Major problems in excavation of the channels are as follows:

1) Hard Rock Portion

Hard fresh rocks generally form steep cliffs near the riverbed, so that a long cut will be required to construct an open channel. When the layer is a parallel structure, there is the risk of a potential slope slide.

Panas Formation has a NE-SW anticlinorium, and where topographic surface and geologic structure have the same direction, a slope slide may occur. Accordingly, geological structure should be examined during the detail design stage in areas where a long cut is required.

2) Highly Weathered to Talus Deposits

Excavation in highly weathered to laterite portions should be undertaken with due care to avoid landslide. Distribution of weathered rock should be ascertained during the detail design stage along the proposed canal route.

1.6 Geology along the Penstock and Powerhouse

(1) Proposed Culasian Power Station

Drilling was conducted at 3 locations in the proposed Culasian power station site. The penstock route is proposed on the right bank of the Culasian River where the bedrock consists of shale and sandstone of the Panas Formation. Along the penstock line, the slope of the riverbed (EL.63m) up to elevation 190m is stable with an average slope of 25°. Overburden is mostly gravel mixed clayey soil formed of talus deposits with a depth of about 2m.

Bedrock consists of shale and sandstone and geological structure around the site extends N20°E/23E with an incline of 20° on the mountain side along the penstock route. The top layer of bedrock is highly weathered to a depth of 3 to 7m. Unconfined compression strength of fresh sandstone bedrock is 800kg/cm^2 or more; the said strength for shale could not be obtained because the sample collapsed along cracks. Borehole water level is generally low and occurs in fresh rock.

At the power station, highly weathered CL class shale will be excavated. Excavation 6 to 9m in depth will be required to reach CM class slightly weathered rock.

In the site, flat portions are found at elevations 205 to 220m. This portion seems to be a post-terrace surface representing a potential landslide risk and, accordingly the penstock line was shifted to avoid the same (FIG.I-3).

Geological profiles obtained through drilling results are shown in FIG.I-4.

(2) Alternative Candawaga Power Station

Two drillings were conducted at the alternative Candawaga Power Station. The penstock line was selected on the right bank of the river. The bedrock of this portion is also sandstone and shale of the Panas Formation. A fresh sandstone outcrop is observed at the foot of the slope, while the slope is covered by talus deposits.

Average slope between EL.100 to 210m is 30° and talus which contains massive boulders with a depth of 10m or more is deposited at around elevation 120m creating a steep cliff. Excluding this portion, the depth of the talus overburden is about 3m.

Highly weathered bedrock is thinly distributed with a depth of 1m or less, and fresh sandstone rocks with an unconfined compression strength of 1,000kg/cm^2 or more occur in the shallow portion. This should present no problem as a penstock foundation. Borehole water level is almost the same elevation at the top of the fresh bedrock.

The mountain slope at the site drops directly into the river, and a comparatively large excavation at the mountain skirt will be required for construction of the powerhouse. Talus is deposited along the upper portion of the skirt with a depth of BH. 4. Potential sliding of the talus should be taken into account in detail design if the site is proposed for the powerhouse. Assumed geological profile is presented in FIG.I-5.

1.7 Rock Test Results

rock tests were performed on drill cores obtained from the field to ascertain the physical characteristics of the bedrock. The results are summarized below.

Bore Hole No.	Sampling Depth m - m	Density	Velocity of Supersonic Wave Vd km/sec	Vs km/sec
1.	9.70 - 10.00	2.533	3.88	2.25
2.	7.14 - 7.35	2.613	3.21	1.75
3.	10.08 - 10.30	2.641	2.29	1.39
4.	13.20 - 13.40	2.636	3.06	1.59
5.	13.36 - 13.61	2.488	4.10	2.03

Bore Hole No.	Dynamic Modulus of Elasticity x 10^5 kg/cm^2	Dynamic Poisson's Ratio	Uni-axial Compressive Strength kg/cm^2	Static Modulus of Elasticity kg/cm^2	Remarks
1.	3.25	0.25	1,388.7	2.79 x 10^5	Sandstone
2.	2.15	0.29	792.7	1.66 x 10^5	-do-
3.	1.25	0.21	72.6	-	Shale
4.	1.78	0.32	11.7	9.63 x 10^3	-do-
5.	2.79	0.34	993.2	2.32 x 10^5	Sandstone

1.8 Riverbed Material Survey

Sieve analysis was conducted to obtain data for concrete aggregate of the sand and gravel layer which extends between the mountainous area and flat land along the coast. Sand and gravel layers are also distributed along the valley in the mountains. These deposits are small and include boulders of 100mm diameter or more which would require uneconomical crushing for use as aggregate.

Sieve analysis was made for riverbed materials in the Candawaga and Culasian rivers at a total of 5 sites. The results, as shown in FIG.I-6, indicated 19 to 24% for samples under 5mm and 75 to 80% for samples 5mm and over. Accordingly, the nearly sand and gravel riverbed layer can be used for both fine aggregates (under 5mm sand) and coarse aggregate (5mm and over). These gravels have sufficient strength for concrete aggregate.

APPENDIX II

METEOROLOGY AND HYDROLOGY

APPENDIX II

METEOROLOGY AND HYDROLOGY

2.1 AVAILABLE DATA

General meteorological observations for Palawan Island have been made only at Puerto Princesa, the capital of Palawan Province. Although these observations were obtained over a long period of time and seemed reliable, the data cannot be applied to the Project Area because of the distance between the two areas.

In the west part of Palawan Island, daily observations have been carried out since 1956 when PAGASA established a rainfall station at Brooke's Point. The Rio Tuba Mining Corp. has been conducting meteorological, rainfall and water stage observations at the Rio Tuba Mine and relevant areas. In regards to the Candawaga River, the Rio Tuba Mining Corp. has conducted daily water stage and basin rainfall observations since June 1984.

FIG.II-1 shows meteorological and hydrological stations in and around the Project Area. Observation periods at these stations are depicted in FIG.II-2. In the Rio Tuba Mine, daily rainfall data for more than 10 years are available at Pier Area and Guintalunan.

2.2 Meteorology

The climate of the Philippines is principally dominated by prevailing winds. These are broadly divided into the Northeast Monsoon from December to January, the trade winds in April and the Southwest Monsoon from July to September. Climate classification by Mr. F. Jose Coronas is illustrated in FIG.II-3. Western Palawan where the Project Area locates belongs to climatic type I of the said classification, defined as having "two pronounced seasons: dry from November to April, wet during the rest of the year".

According to observations at the Rio Tuba Mine, annual average temperature is 27.4°C, and the difference between the maximum and minimum mean monthly temperature is slight at 3.3°C with a maximum of 29.7°C in April and a minimum of 26.4°C in July. Annual average relative humidity is 75.3% with a maximum and minimum mean monthly humidity of 81.7% in July and 67.1% in March, respectively. Dominating wind directions are north to northeast from November to May and southwest to southeast throughout the rest of the year.

Major monthly meteorological data are shown in the table below.

METEOROLOGY AT RIO TUBA MINE

	Jan.	Feb.	Mar.	Apr.	May	Jul.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Temperature (°C)	27.0	27.2	28.9	29.7	28.9	26.7	26.4	26.7	27.2	26.8	26.9	26.9	27.4
R. Humidity (%)	70.7	68.5	67.1	67.7	75.1	80.9	81.7	79.4	78.4	79.0	78.8	76.6	75.3
Evaporation (mm/day)	4.74	5.76	6.21	6.41	5.18	3.31	2.17	2.90	2.95	1.98	3.90	2.65	4.01

Note: 1978-82 average for temperature and r. humidity, 1983-84 average for evaporation.

2.3 Rainfall

(1) Annual Rainfall

As shown in FIG.II-1, rainfall observations around the Project area are limited to the east coast of the island. The Provincial Profile of Palawan and interviews at the site, however, revealed that rainfall in the west coast of Palawan Island is comparatively higher than that in the east coast due to the influence of the Southwest Monsoon discussed previously. According to the Provincial Profile, an average rainfall of 2,900mm is observed at Culion, Cuyo, Coron and Linapacan on the west coast of the island , while only 1,700mm is recorded for Puerto Princesa and Brooke's Point in the east coast. Clear correlation between the east and west coast of southern Palawan, however, has not yet been established due to lack of data.

Annual rainfall at stations around the Project area are listed in the table on the next page. Rainfall at southern Bulanjao is greater, presumably because of the higher altitude of the observation station.

ANNUAL AVERAGE RAINFALL

Station	Altitude	Annual Ave. Rainfall	Annual Ave. Rainy Days	Period of Calculation
Brooke's Point PAGASA	EL. 10m	1,559	95	Jan. 1 1975-Dec. 31 1984
		1,984	98	Jan. 1 1983-Dec. 31 1984
Pier Area, Rio Tuba	EL. 0m	1,635	132	Jan. 1 1975-Dec. 31 1984
		2,075	150	Jan. 1 1983-Dec. 31 1984
Guintalunan, Rio Tuba	EL. 63m	1,737	147	Jan. 1 1975-Dec. 31 1984
		1,871	153	Jan. 1 1983-Dec. 31 1984
S.Bulanjao, Rio Tuba	EL.610m	3,794	161	Jan. 1 1983-Dec. 31 1984

(2) Monthly Rainfall

Monthly rainfall for 1983-84 at Brooke's Point, Pier Area, Southern Bulanjao and Guintelunan are presented in TABLE II-1. Monthly rainfall for 1975-84 at Pier Area are presented in TABLE II-2. These tables show that rainfall is greater from June to December in comparison with the rest of the year, although some fluctuations are observed.

2.4 Candawaga River Discharge

2.4.1 General

(1) River Conditions

The Candawaga River originates in the Mantalingajan range which extends through Palawan Island at an elevation of 2,000m, then flows northwest for 29km to the South China Sea. Of the total 29km, 21km is through mountainous area with a high gradient of more than 1/40. The gradient becomes gentler at around elevation 100m.

The basin is covered by virgin tropical forest with rock outcrops on some portions of the steeper slopes. Water holding capacity is assumed to be high judging from vegetation conditions. Rises and depressions in the flood discharge curve may be sharp because of the steep mountains and spot showers. Annual runoff coefficient is considered to be very high.

(2) Water Stage and Discharge Measurment

Water stage observations for the Candawaga River have been made by the Rio Tuba Mine from June 1984 at a site with an elevation of 100m and a catchment of $42.9km^2$. However, very few discharge measurements have been collected to date and thus discharge simulation on observed water stage seems difficult.

Results of discharge measurement by the Team for the Candawaga River are shown below. April 1985 discharge data does not correlate with rainfall; hence the discharge in April 1985 might represent drought discharge for the 1984-85 dry season. The drought discharge of the Candawaga River for 1984-85 has thus been estimated at $3.3m^3/s/100km^2$.

CANDAWAGA RIVER DISCHARGE MESUREMENT RESULTS

	Cross-line ($38.1km^2$)		Gauge Site ($42.9km^2$)	
	m^3/s	$m^3/s/100km^2$	m^3/s	$m^3/s/100km^2$
March, 30	1.269	3.33	-	-
April, 1	-	-	1.376	3.21
2	1.336	3.51	1.563	3.64
7	2.693	7.07	-	-
8	1.266	3.32	-	-
9	-	-	1.330	3.10
10	1.272	3.34	1.330	3.10

Note: Gross-line: EL.125m, Catchment Area $38.1km^2$
Gage site: EL.100m, Catchment Area $42.9km^2$

2.4.2 Daily Discharge Simulation

(1) General

Discharge data covering a period of at least 10 years are required for hydropower planning; however, such long term data were unavailable for the Candawaga River and, accordingly, simulation is required. In general, discharge can be simulated with about 2 years of observed data.

As discussed previously, observed water stage in the Candawaga River covers a very short period, and in addition, corresponding discharge measurements were made only 3 times in 7 months, resulting in insufficient data for simulation. Fortunately, discharge simulation was made in 1984 for the Tamlang River, which has similar catchment conditions by the Tank Model Method. Accordingly, discharge simulation was made assuming the hydrological structures of the Candawaga basin to be the same as those of the Tamlang River.

(2) Basin Rainfall

Rainfall generally increases with an increase in elevation. As the Candawaga River flows through mountainous terrain, estimation of basin rainfall considering altitude is very important for discharge simulation.

FIG.II-4 shows 10-day rainfall correlation for Pier Area and Southern Bulanjao at the Rio Tuba Mine. The rainfall increase ratio for an altitude of 100m is estimated at 10% and is upon the above correlation. The value seems appropriate compared to other data on the Philippines.

For discharge simulation, basin rainfall for the Candawaga River was developed assuming an increase ratio of 10% per 100m altitude based on the rainfall at Pier Area. The increase ratio was given a fixed value above 1,600m which is constantly covered by clouds. The ratio of Candawaga basin rainfall at Pier Area was obtained at 2.463 as shown in the following table.

Altitude EL. (m)	Ave. Altitude EL. (m)	Catchment Area (km^2)	C.A.ratio	Rainfall Increase Ratio	Weighted Ratio
2,000m	2,000	0.02	0.06	4.18	0.003
1,800-2,000	1,900	0.42	1.36	4.18	0.057
1,600-1,800	1,700	1.32	4.29	4.18	0.179
1,400-1,600	1,500	2.33	7.56	4.18	0.316
1,200-1,400	1,300	2.67	8.67	3.45	0.299
1,000-1,200	1,100	3.60	11.69	2.85	0.333
800-1,000	900	5.62	18.25	2.36	0.431
600- 800	700	7.35	23.87	1.95	0.465
400- 600	500	6.12	19.87	1.61	0.320
255- 400	328	1.35	4.38	1.37	0.060
		30.80	100.00		2.463

Monthly basin rainfall estimated by the above method is listed in TABLE II-3.

(3) Tank Model Simulation

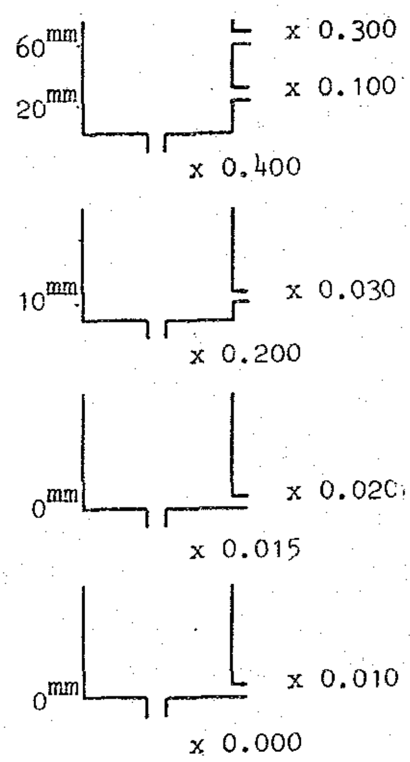
Tank structure for the Candawaga River has been assumed as follows:

TOP TANK
Ground Surface
Surface Discharge

SECOND TANK
Intermediate Runoff

THIRD TANK
Ground Water

FOURTH TANK
Ground Water



Evapotranspiration was assumed as in the table below based on data for Brooke's Point.

DAILY EVAPOTRANSPIRATION

Unit : mm/day

Jan.-Feb.	Mar.-Apr.	May.-Jun.	Jul.-Aug.	Sep.-Oct.	Nov.-Dec.
4.09	5.64	4.37	3.38	3.13	3.19

Simulation was performed for the proposed intake dam site with a catchment area of $30.8km^2$. Main features of river flow for the 1975-84 average were obtained as in the following table.

MAIN FEATURES OF CANDAWAGA RIVER FLOW

Year	Rainfall (mm)	Rainfall (MCM)	Total Discharge (MCM)	Runoff Coefficient	Ave. Discharge (m^3/s)	Min. Discharge (m^3/s)
1975	5276.9	162.5290	143.1360	0.880	4.538	1.036
1976	2876.7	88.6045	88.1388	0.944	2.787	0.456
1977	4118.1	126.8380	108.9350	0.858	3.454	0.310
1978	3152.6	97.1008	76.2085	0.784	2.416	0.307
1979	4444.4	136.8890	113.7880	0.831	3.608	0.466
1980	3594.7	110.7180	92.9854	0.839	2.940	0.498
1981	4254.8	131.0480	102.0160	0.778	3.234	0.430
1982	2332.4	71.8394	65.1860	0.907	2.067	0.401
1983	4481.3	138.0270	102.5710	0.743	3.252	0.064
1984	5735.0	176.6380	148.0750	0.838	4.682	1.142
Average	4026.7	124.0230	104.1040	0.845	3.298	0.511

The minimum discharge for the 1984-85 drought period obtained through simulation was $1.1m^3/s$ for April 7, 1985. This value is very similar to the discharge $1.0m^3/s$ obtained from the observed specific drought discharge of $3.3m^3/s/100km^2$, and thus simulation results appear reliable.

Monthly average discharge and flow duration curve of the Candawaga River obtained from the simulated daily discharge are presented in TABLE II-4 and FIG.II-5, respectively. Major values of the 10-year average flow duration for 1975-84 are presented in the following table.

1975-85 AVERAGE CANDAWAGA RIVER DISCHARGE

Unit: m^3/s

Max.	35-day	95-day	185-day	275-day	355-day	Min.	Ave.
33.25	6.05	3.87	2.50	1.23	0.57	0.51	3.29

2.4.3 Flood Analysis

Flood analysis was made for the discharge of the proposed intake dam. As data for flood and hourly rainfall is unavailable in and around the Project area, the Rational Formula using general data on the Philippines was employed to obtain probable peak discharge.

The Rational Formula is defined as follows:

$$Q = \frac{1}{3.6} \cdot f \cdot R \cdot A$$

Where, Q : peak discharge (m^3/s)
f : runoff coefficient (0.75)
R : rainfall intensity during the time of concentration (mm/hr)
A : catchment area ($30.8km^2$)

Time of concentration: t was obtained at 1 hour assuming a river length of 10km as follows;

$$t=0.21 \cdot L^{0.7}$$

Where, t: time of concentration (mm/hr)
L: river length (km)

Rainfall intensity during the time of concentration was determined at 95mm/hr as a value for a 100-year return period on the basis of PAGASA data.

The 100-year return period flood peak discharge has thus been obtained at $610m^3/s$ for the proposed intake dam site.

2.5 Effect on the Candawaga Downstream Area

(1) Present Condition

Although the southern area along the west coast of Palawan Island is economically depressed, lacking even road development, cultivated areas exist in the flat area along the coast. Cultivation is developed in Barangay Candawaga in the downstream area of the Candawaga River, and a portion is irrigated by a wooden intake installed on the Candawaga River.

Existing paddy field in the downstream area of the Candawaga River has been estimated at 200ha or less based on field interviews and a 1/50,000 topographical map. In addition, potential paddy field areas in the same area are identified as the 200ha of Communal Irrigation Project under the Palawan Integrated Area Development Project. Potential irrigable area in the lower Candawaga River has thus been estimated at 400ha.

(2) Effects of Hydropower Development

FIG.II-6 shows the topographical relation between the proposed hydropower development plan and the downstream area. In the present Project, trans-diversion of river water from the Candawaga River to the Culasian River is concluded as the most advantageous plan. This plan, however, will reduce discharge of the Candawaga River downstream.

Possible use of water in the downstream area for irrigation is considered. The catchment area downstream of the proposed intake dam site on the Candawaga River was determined to be sufficient to supply irrigation water for 400ha as follows:

- 10-day peak unit irrigation water requirement: 1.0 ℓ/s/ha
- irrigation area: 400ha
- 10-day peak irrigation water requirement: 0.4m^3/s
- design standard: 10-year return period drought
- peak period: 3rd 10-day, June
- catchment area at assumed irrigation intake: 16.9km^2
  (does not include catchment at intake for hydropower)
- basin rainfall increasing ratio to Pier Area: 1.291
- 10-year return period drought at assumed irrigation intake: 0.4m^3/s

Candawaga River discharge excluding the catchment of the hydropower intake was calculated at $0.43 m^3/s$, and the assumed requirement is $0.4 m^3/s$. As the results show, the trans-diversion scheme for hydropower development will not have any adverse effect on the downstream area except lowering of the water level due to decreased discharge.

2.6 Water Quality

Water quality of the Candawaga River is within the standard value as shown in the table below, and presents no problem for hydropower equipment.

Item	Unit	Observed Value	Standard Value
Turbidity	FTU	5.3	less than 10
PH (25°C)		8.2	6.5-8.5
Total Hardness as $CaCO_3$	ppm	99	less than 200
Residue	ppm	53	less than 500
Choloride (Cl^-)	ppm	16	less than 200
Sulfate (SO_4^-)	ppm	137.5	less than 150
Silica (SiO_2)	ppm	45	less than 50
Total Iron (Fe)	ppm	0.48	less than 0.5

APPENDIX III

PRELIMINARY DESIGN

APPENDIX III

PRELIMINARY DESIGN

3.1 Civil Works

(1) Intake Dam

An intake dam site is proposed on the Candawaga River about 16km upstream from the river mouth, with an elevation of approximately 256m. The left bank of the site presents fresh basalt outcrops with a height of 15m and a slope of 50° from elevation 260m. The slope of the upper portion of the outcropped area becomes a gentler 30° at 30m above the riverbed.

The right bank presents a rather gentle slope of 12° from the riverbed to a height of 20m, above which a slope of 35° continues to a height 20m. The depth of sand and gravels on the bedrock on the right bank of the river is assumed at about 3m.

Width of the riverbed is about 20m, while width of the stream is 6 to 7m. Rounded cobbles 50cm or more in diameter and rocks of about $2m^3$ are often found in the riverbed. Bedrock at the river center is assumed at a depth of about 5m judging from the topography and riverbed gradient at the site. Average riverbed gradient of the river is steep at approximately 1/35.

The right bank of the river at the proposed intake dam site forms a semi-circular line connecting two creeks which flow into the river 200m upstream and 130m downstream of the intake dam and passing 100m to the right side of the intake dam. The line seems to be due to a fault; however, infiltration water flow was not observed at the downstream creek. Considering that the elevation of the riverbed at the confluence of the said upstream creek is 261m and that the intake level is 260m, water pressure at the intake dam will be very low even if a fault actually exists. Thus the topography is not expected to have an adverse affect on the intake dam.

Excavation of sand and gravels to the bedrock is required for construction of the intake dam. A concrete gravity dam is proposed for the intake, with a height of 9.5m at the overflow section and of 13.5m at the non-overflow section. The overflow section is designed as a non-gated type with a crest elevation of EL. 260m. The length of the overflow section is 40.0m for the design flood of 610m^3/s. A cutoff is planned in the bedrock at the front side of the intake dam bottom to minimize seepage.

Sediment production and transportation in the Candawaga River is relatively stable, and this condition is projected to continue in future. A standard sluiceway is planned considering assumed absence of sediment load which often hinders water intake.

To minimize concrete volume, incorporation of the abundant rounded gravels in the core of the dam body is planned. The bedrock of the site is assumed to be of basalt, and no grouting will be required if fresh bedrock is found after excavation.

The elevation of the bottom of the downstream apron is 3.5m lower than the downstream riverbed, and a water cushion energy dissipator will be formed. Accordingly no gravel riprap is planned; only a cutoff to prevent erosion is designed at the downstream end of the apron. A 90m portion of the downstream riverbed from the end of apron with a width of 15m is to be excavated for smooth discharge of design flood water.

The design overflow depth during the design flood discharge of 610m^3/s for the crest length of 40m is 3.5m and design flood water level above the dam crest EL. 260m is EL. 263.5m. The elevation of the non-overflow section is thus decided at EL. 264.0m allowing 0.5m of freeboard.

Stability analysis for the intake dam was undertaken, and the results show safety against overturning, sliding and overstressing.

(2) <u>Intake Gate</u>

An intake gate will be installed at the front side of the intake dam in the left bank with a design capacity of 3.85m^3/s. Water will be led to the settling basin 170m downstream from the intake. Maximum flow velocity is designed at 0.5m/s to minimize sediment load inflow, and intake width is decided at 4.4m. A screen is planned at the entrance of the intake. The upper portion of the entrance is covered with an orifice type concrete wall to prevent surplus water inflow during flood.

A control gate with a height of 1.7m and a width of 1.5m will be installed at the back side of the screen for operation and maintenance. A protuberance will be placed on the bottom of the intake and sand flush gates on the front side to prevent sedimentation at the gate front and to smoothly flush sediment from the sand sluiceway of the dam. The freeboard of the canal wall just downstream of the intake is minimized to allow discharge from the canal to the river when water flows unexpectedly into the canal.

(3) Settling Basin

Wash load which enters the canal will have an adverse effect on the canal, reducing flow areas and also causing abrasion of metals in the penstock and turbines. Generally, it is advantageous to install a settling basin near the intake facilities; for this site however, it is not economical because of the steep terrain.

Accordingly, the settling basin site is proposed 170m downstream from the intake where the mountain slope is relatively gentle. Construction works will be facilitated farther from the intake allowing sufficient work space.

Storage volume was not planned for the intake dam, and consequently the sedimentation settling effect of the intake is very small. The average flow velocity for the settling basin was designated at 0.3m/s and its dimensions were determined as follows:

Effective width: 7.8m
Effective length: 22.5m
Effective water depth: 1.65m

A transition canal is proposed between the settling basin and the downstream canal to prevent sediment flow downstream.

At the end of the settling basin, a sand sluice gate of 1.0 x 1.5m is planned. A side spillway with a length of 19m will be installed to spill excess water. At the end of the settling basin, a control gate of 1.5 x 2.0m is proposed for operation and maintenance of the canal.

(4) Diversion Canal

The proposed total length of the diversion canal is 7,700m which includes 7,400m of open channel and accompanying culvert and non-pressure tunnel to trans-divert water from the Candawaga basin to the Culasian basin. The longitudinal gradient of the canal and tunnel is designed at 1/1,000.

Geologically, the proposed canal route passes through talus deposits with a bedrock of basalt, limestone, shale, sandstone and intermediate layers of these rocks. The tunnel portion consists mainly of sandstone and shale bedrock. Clayey and highly weathered rock are found in some portions of the route, and the slope is generally stable, with no landslides or slope collapse. Almost all portions are covered by heavy vegetation.

Canal route alignment was plotted on the 1/2,000 topographical map prepared by the Team during the survey. During the detail design stage, a more detailed topo-survey of the route is required as the bed elevation is very important for design of the open canal.

The canal bed route is proposed for use as an operation and maintenance road, as well as for a construction road and it would be economical to minimize canal width. For the open channel portion, the width of the canal bed is designed at 6.0m with 2.2m for the canal and the remaining 4.0m for road. The canal section is determined to have a square width of 1.5m, a height of 1.95m and a side wall thickness of 22cm. The canal bed is designed at the same elevation as the road surface.

Reinforced concrete culverts are proposed where the channel crosses creeks. The culverts will have a width of 1.5m, a height of 1.9m and a wall thickness of 25cm.

The minimum tunnel dimensions required for construction is proposed due to the small design discharge of $3.85m^3/s$. Tunnel dimensions include a height of 2.5m, a width of 2.0m, and a concrete lining thickness of 20cm with semi-circular upper portion.

Concrete lining is considered even for the hard rock portion in order to minimize the sectional area considering the roughness coefficient.

(5) Head Tank and Side Spillway

The function of the head tank is to regulate discharge difference between the penstock and the canal which is caused by generator load variation. Also sediment will be settled in the head tank. The proposed head tank is situated between the entrance of penstock and the tunnel exit.

A creek at the exit of the tunnel can be advantageously utilized for minimizing the cost of the side spillway and head tank. Head tank length is designated at 231m along the contour line. Surging from turbine shut-off will reach the end of the head tank, and the capacity of the head tank was determined to minimize the effect of surging on the diversion tunnel and canal. The tank will have a width of 5m, an effective water depth of 2.0m and a length of 231m. The capacity of the tank is sufficient to provide a maximum discharge of $3.85m^3/s$ for 2-3 minutes in the case of sudden load increase. Screen and control gates will be installed in front of the entrance to the penstock, and a sand flush gate will be placed at the sand sluice way.

The side spillway is propsoed to spill surplus water into the creek. The proposed power station will operate with load adjustment and thus continuous spill is expected in rainy season. Portions along the creek where erosion may occur will be protected by a concrete wall and bed concrete. These protection works should be determined during the detail design stage.

(6) Penstock

The proposed penstock alignment avoids a possible slide near elevation 215m. The bedrock of the penstock route is shale and sandstone and the route runs 240m westward on a hill ridge with a slope of 7° subsequently turning S65°W for 552m with slopes of 16° to 60°. The penstock divides into two just before the powerhouse and leads to the turbine passing the control gate. Depth of the bedrock along the penstock route slope is assumed at 3-4m in the upper portion, 1-2m in the lower portion and 1m or less at slopes steeper than 30°.

FRPM pipe is proposed for the penstock from the entrance for 420m with diameters of ϕ1.65m to ϕ1.35m to minimize head loss. Steel pipe is planned for the downstream portion considering joint works. FRPM pipe is to be embedded to prevent weathering and to maintain stability and the surface slope will be stabilized by seeding or soil cement works.

(7) Powerhouse

The powerhouse site is proposed at an elevation of about 63m on the Culasian River right bank. The riverbed is composed of sand and gravels with diameters of 30cm or less, and the thickness is estimated at 2-3m on the river bank and 4-5m at the river center.

The right bank slope of the riverbed is steep at 55-60°, and bedrock outcroppings occur. To minimize excavation volume for powerhouse construction, the powerhouse is located near the river center, despite the flow capacity of the Culasian River during flood and the depth of the bedrock. Tailrace canal alignment is planned parallel to the river to avoid water inflow during flood.

Installation of two horizontal shaft Francis turbines is proposed, and a single floor structure is sufficient. The generator room will have a width of 10m, a length of 22m and a height of 8m. The operation and administration room is proposed on the upstream side of the second floor. Housing of the turbine and generator axis is proposed at an elevation of 63.8m, only 0.8m above the tailrace water level of 63.0m Accordingly, to protect generators and turbines during flooding of the Culasian River, the wall which surrounds the powerhouse is designed at a thickness of 1.0m.

The space between the river and the mountain slope is very narrow and the substation area is planned with an embankment on the upstream side and a concrete wall on the river side.

(8) Future Works

1) Values of topographical coordinates which are used in this study are independent as no benchmarks are available in the vicinity of the site. Also elevation was determined independently on the basis of a 1/50,000 topographical map. In the detailed design stage, absolute values should be determined referring to possible benchmarks.

2) Detailed topographical survey of the canal route should be carried out to determine the exact length, location, etc. of the diversion canal.

3) A detailed topographical and geological survey is required for the terrace near the penstock to prevent sliding. Penstock alignment and powerhouse location should be determined on the basis of these detailed surveys.

4) Erosion protection and bed concrete locations for the head and side spillway should be determined based on the detailed topographical and geological survey of the release creek.

3.2 Electrical Works

(1) Turbine

Hydropower generation under the Project is run-of-river type utilizing an effective head of 185.1m and a maximum discharge of $3.85m^3/s$. In order to utilize low river flow and to maximize generated energy, installation of two turbines is proposed. A graph for selection of turbine type for mini-hydropower is presented in FIG. III-1. On the basis of this graph, both Francis and Pelton types are suitable for the given head and maximum discharge. The horizontal shaft Francis turbine (wide range type) was adopted for the following reasons.

a) Cost for the Pelton turbine is 20% higher than that of the Francis.

b) The 355-day discharge of the Candawaga River flow duration is 0.57m^3/s, which corresponds to 30% of the maximum discharge for 1 unit of 1.925m^3/s. The wide range type Francis can handle 25% of the maximum discharge.

c) There is no difference in generated evergy for the Pelton and Francis types.

The turbine efficiency curve is presented in FIG. III-2. Main features of the turbine are as follows:

Type	: Horizontal shaft Francis (wide range type)
No. of Units	: 2
Effective Head	: 185.1m
Max. Discharge	: 3.85m^3/s
Max. Output	: 3,110kW
Rated Speed	: 1,200 rpm
Specific Speed	: 98.1m/kW

(2) Generator

The cycle and voltage of the electric system to which the proposed generator will be connected should be adjusted to the proposed power station. Accordingly a horizontal shaft three-phase synchronous generator is adopted. The generator will also be a forced-air-cooled type. The load power factor of the present Rio Tuba system is about 0.85, and, as the power factor will be improved with the proposed segregation plant, the rated power factor is planned at 0.90. The brushless type excitation method is proposed as it is maintenance free. The generator efficiency curve is presented in FIG. III-3

Main features of the generator are as follows:

Type	: Horizontal shaft three-phase synchronous
No. of Units	: 2
Max. output	: 3,320kVA
Rated voltage	: 4.16kV
Rated Power Factor	: 0.91
Rated Frequency	: 60Hz

Rated Speed	: 1,200 rpm
Excitation Method	: Brushless type (alternating current excitor and semiconductor rectifier)

(3) Main Transformer

An outdoor type three-phase oil-immersed self-cooled type transformer was adopted as the main transformer. A trianglar connection is adopted for side 1 and a star connection for side 2 with a neutral point for grounding. Voltage of side 1 is to be adjusted to the generator while that of side 2 is to be adjusted to the transmission.

Main Features are as follows:

Type	: Outdoor type three-phase oil-immersed self-cooled
No. of Units	: 2
Rated Capacity	: 6,600 kVA
Rated Voltage	: 4.16/69 ± 5% kV
Rated Frequency	: 60Hz

(4) PALECO Connection Transformer

The transformer which connects the PALECO system will be an outdoor three-phase oil-immerged self-cooled type. Both side 1 and 2 will be star connections.

Main features of the generator are as follows:

Type	: Outdoor three-phase oil-immersed self-cooled type
No. of Units	: 1
Rated Capacity	: 2,200 kVA
Rated Voltage	: 69 ± 5%kV/34.5kV
Rated Frequency	: 60Hz

(5) Switchgears

Vacuum circuit breakers are adopted for the 4.16kV side, 34.5kV side and 69kV side as it is maintenance free. Indoor metal cladding is proposed for the 4.16kV side and the outdoor conventional type is proposed for the 34.5 and 69kV side. Potential salt damage will be taken into account in design of switching devices and insulators.

(6) Control System

For both generating and transformer stations, a one-man control system with a switchboard is proposed. At the generating station, load and frequency control will be made by a speed governor.

(7) Transmission Line

1) Basic Conditions

The year is divided into distinct dry and rainy seasons, and annual rainfall is about 2,000mm. Annual average temperature is 27.4°C, while the maximum is 37.4°C and the minimum is 20.9°C. Annual average relative humidity is 75.3%. Maximum wind speed is about 24m/s, and typhoons are rare at a rate of less than 1 in 10 years.

Data on the number of the thunder storms per year are not available, but interviews indicate that thunder storms usually occur for about 7 days when the rainy season starts. For this Project, 30 days of thunder storms are assumed annually. Earthquakes are also rare. The following data were adopted in design of the transmission line.

Max. Temperature	: 40°C
Ave. Temperature	: 30°C
Min. Temperature	: 10°C
Max. Wind Speed	: 40m/s
Earthquake Coefficient	: 0.2G

2) Selection of Voltage

A transmission voltage of 34.5kV or more is generally used in the Philippines. For the Project, 69kV is adopted on the basis of maintenance cost and transmission loss comparison for 34.5kV and 69kV.

3) Electrical Wiring

ACSR which is generally used in the Philippines was adopted. As the proposed transmission line passes near the coast, twisted copper wire which is more resistant to salt damage is proposed.

Electric wire size was determined to maintain transmission capacity and voltage drop within 5% and to maintain transmission loss for both power and energy to 5% or less. The size is thus determined as 110.8MCM (56.14mm^2).

4) Insulators

A 250mm chinning insulator is adopted considering that most of the transmission route is 10km or less from the coast. Five pieces are adopted in consideration salt damage.

5) Overhead Grounding Wire

Considering that annual thunder storms in the area are about 30 days, a one-line overhead grounding wire of AWG 2 (33.62mm^2) is proposed.

6) Support

Wooden supports with an average support interval of 75m are adopted. In the Philippines, wooden poles are generally used for transmission of 69kV or less, and sometimes for 138kV line.

(8) Communication System

The power line carrier system is proposed for communication between the power plant and Rio Tuba Mine. Radio communication is also conceivable, although this is easily affected by natural conditions. Communication to PALECO will be made by radio.

APPENDIX IV

CONSTRUCTION SCHEDULE AND COST ESTIMATES

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4.1 CONSTRUCTION SCHEDULE

The main civil works for the proposed hydropower scheme include construction of the intake dam and trans-diversion canal. Almost all construction sites are on steep terrain, and even in the low flat area there is no access road for vehicles from barangay Candawaga and Culasian along the South China Sea to the proposed power station and intake dam.

Major works which directly affect the overall construction schedule are the access road joining the coast to the proposed powerhouse site, the connecting road from the powerhouse to the intake, and the intake dam. Considering this fact, construction of the pilot access and connecting roads will be given high priority. The final section of the pilot road will be expanded by heavy excavation equipment and the total construction period is 28 months.

The detailed construction schedule is presented hereunder.

(1) Intake Dam

Construction of the intake dam will commence after completion of the connecting road which will also be used as the channel bed. Maximum depth of sand and gravel river deposits is assumed at 5m. To lower the river water level for construction of the dam body, the riverbed will be excavated to a width of 5m and a depth of 2m. At the same time, excavation of both abutments will be completed after which concrete will be placed. The bypass channel will be excavated at an elevation of 256.5m on the right bank, simultaneons to excavation of the downstream channel. Excavation of the river center and concrete placement for the intake dam body will be followed by construction of the cofferdam embankment and diversion of water into the bypass channel 4m wide and 3m deep.

The concrete plug for the bypass channel will be made after completion of concrete works for the intake dam body by leading water to left bank sand sluiceway. The upstream and downsteram sides of the cofferdam will be embanked by the blanket method using riverbed materials and clayey talus deposits.

Dam concrete will be carried by 3 truck mixers after batching and mixing cement, fine aggregates and coarse aggregates at the aggregate plant 2.5km downstream of the powerhouse on the Culasian River. A concrete pump will be used to place concrete for the intake dam at a rate of $50m^3$/day for 5 months totaling $5,000m^3$.

(2) Diversion Canal & Tunnel

The diversion canal bed will also be used as the connecting road, and thus construction of the canal bed has a significant effect on the overall schedule. As discussed previously, a pilot road will be built first and 12 months will be required to complete the construction of the canal bed.

Four months will be required for completion of the 300m tunnel portion. A maximum of 3 leg drills will be used for drilling, and a RS-55 class ($0.17m^3$) rocker shovel for mucking. The tunnel will be lined after completion of excavation from the upstream portion using steel forms and a concrete pump.

Concrete for the open channel portion will be placed by belt conveyor.

(3) Powerhouse and Other Facilities

Powerhouse and facilities except for the intake dam and diversion canal and tunnel will be completed during construction of the intake dam. Earthwork equipment used for the open channel will subsequently be used for the intake dam, intake gate and settling basin, and those used for the access and connecting roads will be used for head tank, penstock and powerhouse construction.

(4) Concrete Aggregate

Required cement volume for total work except for temporary works and the substation basement is about $28,000m^3$, and required aggregate volume is $33,000m^3$. Intake dam site upstream deposits, powerhouse upstream deposits and tunnel excavation material can be used as concrete aggregate. However, these sites can supply only a limited volume which is insufficient.

Accordingly, concrete aggregate will be taken from riverbed deposits 2.5km downstream of the powerhouse. Sand and gravels at the site are widely deposited without extra-large boulders. No crushing will be required and coarse and fine aggregates for all concrete works can be obtained by sieving and washing.

At the aggregate plant site, a stockpile, cement silo and concrete batcher will also be installed and concrete will be mixed by truck mixer during transport to the site.

(5) Construction Machinery and Materials

Major construction machinery and materials are listed in the following tables.

1) **ACCESS ROAD AND CONNECTION ROAD**

Machine	Specification		Unit No.	Note
Crawler drill	Air consumption	$10m^3$/min.	2	Excavation
Leg drill	-do-	$3m^3$/min.	6	- do -
Pick hammer	-do-	$1m^3$/min.	6	- do -
Bulldozer	20t class		2	- do -
Dozer shovel	$0.7m^3$		2	- do -
Backhoe	$0.7m^3$		2	- do -
Dump truck	11t		2	Hauling
Compressor	$10.5m^3$/min.		2	Excavation

2) DIVERSION CANAL AND TUNNEL

Machine	Specification	Unit No.	Note
Crawler drill	Air consumption $10m^3/min.$	3	Excavation
Leg drill	-do- $3m^3/min.$	9	- do -
Pick hammer	-do- $1m^3/min.$	12	- do -
Bulldozer	20t class	3	- do -
Dozer shovel	$0.7m^3$	2	- do -
Backhoe	$0.7m^3$	3	- do -
Dump truck	11t	2	Hauling
Compressor	$10.5m^3/min.$	3	For tunnel
Rocker shovel	$0.17m^3$	1	- do -
Battery car	4t	1	- do -
Truck mixer	$4.5m^3$	3	For concrete
Concrete pump	$55m^3/H$	1	- do -
Vibrator	0.5PS	3	- do -
Belt conveyer	Portable B=5m L=5m	3	- do -
Submergible pump	ø4"	2	- do -
- do -	ø3"	4	- do -
Turbine pump	ø3" He=190m	1 (set)	- do -
Generator	125kVA	1	- do -
- do -	35-40kVA	1	- do -

3) **INTAKE DAM**

Machine	Specification	Unit No.	Note
Crawler drill	Air consumption $10m^3$/min.	3	Excavation
Leg drill	- do - $3m^3$/min.	3	- do -
Pick hammer	- do - $1m^3$/min.	5	- do -
Bulldozer	20t class	1	- do -
Dozer shovel	$0.7m^3$	1	- do -
Backhoe	$0.7m^3$	1	- do -
Dump truck	11t	2	Hauling
Compressor	$10.5m^3$/min.	3	
Truck mixer	$4.5m^3$	3	For concrete
Concrete pump	$55m^3$/H	1	- do -
Vibrator	0.5PS	3	- do -
Vibrator	high frequency	3	- do -
Belt conveyer	portable B=5m L=5m	3	
Submergible pump	ø8	3	
- do -	ø6	3	
- do -	ø4	3	
- do -	ø3	5	
Generator	125kVA	1	
- do -	85kVA	1	
- do -	65kVA	1	
Drilling rig	L = 40-150m	1 (set)	Drilling & grouting
Grouting mixer	200ℓ	1	- do -
Grouting pump	50-120ℓ/min.	1 (set)	- do -

4) AGGREGATE PLANT

Machine	Specification	Unit No.	Note
Bulldozer	11t class	1	Material collection
Dozer shovel	$0.7m^3$	1	- do -
Backhoe	$0.7m^3$	1	- do -
Dump truck	11t	2	- do -
Sieving plant	60t/H	1 (set)	- do -
Pump	ø6 "	1	Washing
- do -	ø4 "	2	- do -
Aggregate bin	50-20mm, $100m^3$	1 (set)	- do -
- do -	20- 5mm, $50cm^3$	1 (set)	
- do -	Sand $80m^3$	1 (set)	
Cement silo	200t	1	
Batcher	15t(Cement, Sand, Aggregate)	1	For concrete
Generator	75kVA	1	For pump, belt con-veyer and lights
Compressor	$3.5m^3/min.$	1	For batcher

5) **MAJOR MATERIALS**

Machine	Specification	Unit No.	Note
Cement	Portland cement	7,800	
Reinforcing bar	deformed bar	1,320	
Gate	B = 1.0 - 3.5m	8 unit	Includes 2 sand flush gates
FRPM pipe	D = 1.65-1.35m	430m	For penstock
Steel pipe	D = 1.35-0.62m	122m	-do -
Turbine & generator	3,000kW	2 unit	Horizontal shaft Francis
Substation	7,500kVA	2 unit	
Transmission	69kV x 38km	1 set	Includes 2 substations for receiving

(6) Electricity during Construction

All electricity during construction will be supplied by diesel generator since there is no existing line in the vicinity. A portable compressor will be used for air supply.

Electric facilities required during construction are as follows:

Facilities and Site	Capacity	Remarks
Client temporary facilities	125kVA x 1 unit	office, accomodation
Contractor temporary facilities	125kVA x 2 unit	office, accomodation, workshop
Intake dam	125kVA x 1 unit 85kVA x 1 unit 65kVA x 1 unit	drainage pump
Tunnel	125kVA x 1 unit	drilling water pump, lighting
	35kVA x 1 unit	
Penstock	75kVA x 1 unit	welding, carrier
Powerhouse	75kVA x 1 unit	drainage pump, lighting
Aggregate Plant	75kVA x 1 unit	washing pump, batching

(7) Transportation Plan

There is no road or pier around the project area. A temporary pier, access and connecting roads must be constructed to transport machinery and materials to the site. As the sea near the Project area is generally shallow and studded with coral reef, large ships cannot approach the shore. A temporary pier 50m in length will be constructed for about 40 to 50t class boats to land workers, cement, reinforcement bars and forms. Other heavy machinery, turbines, generator, etc. will be brought several kilometers offshore and then carried to the shore by a landing craft. The heaviest piece of equipment is the transformer, which weighs 19t with dimensions of 4.5m width, 5.0m length and 5.5m height. The area at the river mouth of the Culasian River to about 1km along the seashore is relatively deep and appropriate for landing of heavy materials.

A gravel paved access road will be constructed from the shore to the proposed powerhouse with an effective width of 4.5m for 7km in the flat area and for 2.5km in mountainous area totalling 9.5km. A gravel paved connecting road and operation and maintenance road will be constructed for the diversion canal with a width of 4.5-4.0m for a length of 9.2km. The total 20km of road construction will be completed within 12 months in 5 construction areas.

Materials for the transmission line will be landed at the existing pier of the Rio Tuba Mine and transported along the existing 5-10m road by vehicle to the proposed Sandoval substation. From the substation to the powerhouse, materials will be carried by dozer shovel through the hilly area.

TABLES

1983-84 MONTHLY RAINFALL AND RAINY DAYS COMPARISON

	1983								1984									
	B.P.		Pier		S. Bulaujao		Guintalunan		B.P.		Pier		S. Bulaujao		Guintaluran		Candawaga	
	Rf.	No.	Rf.	No.	Rf.	No.	Rf.	No.	Rf.	No.	Rf.	No.	Rf.	No.	Rf.	No.	Rf.	NO.
Jan	91	4	25	3	95	5	43	6	173	6	179	14	285	15	150	12	N.D.	N.D.
Feb	10	1	9	2	35	2	21	2	33	3	26	3	33	6	15	2	N.D.	N.D.
Mar	0	0	7	1	1	1	0	0	38	5	22	4	99	8	52	7	N.D.	N.D.
Arp	8	1	0	0	6	1	0	0	102	7	82	6	214	9	59	6	N.D.	N.D.
May	0	0	0	0	0	0	0	0	91	7	198	15	220	14	115	15	N.D.	N.D.
Jun	311	10	218	11	406	15	205	12	431	18	275	19	481	18	217	20	265	18
Jul	294	13	281	18	780	24	267	21	111	8	139	13	250	18	135	14	417	17
Aug	135	10	309	19	386	24	267	23	180	16	181	15	247	11	195	17	277	13
Sep	244	11	245	28	391	25	161	19	165	11	216	20	549	19	221	17	N.D.	N.D.
Oct	249	11	304	19	544	22	219	20	249	16	685	29	228	23	712	28	980	27
Nov	332	13	226	23	608	25	209	21	N.D.	N .D.	100	7	143	6	53	10	134	13
Dec	412	8	201	13	182	18	135	16	211	9	226	17	410	12	295	18	289	18
Year	2,084	82	1,824	137	3,431	162	1,526	140	(1,784)	(106)	2,325	162	4,156	159	2,215	166		

Note: 1. Rf : Rainfall (mm)
2. No. : No. of Rainy Days
3. Yearly rainfall and rainydays' Number of B.P. are not include November's values.
4. N.D. : No Data

TABLE II-2

1975-84 MONTHLY RAINFALL AT PIER AREA UNIT (MM)

Unit: mm

	Jan.	Feb.	Mar.	Arp.	May	Jun.	JUl.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1975	62	34	25.5	41	59.5	243.5	183	257.5	297.5	369.5	163	406.5	2142.5
76	0	0	0	0	1	173.5	174.5	123	285.5	107.5	193	111.5	1169.5
77	66	30.5	14	0	30.3	219	299	237.5	555.5	99.5	100.7	18.5	1670.5
78	26.5	3.5	0	3	85	30	37.5	180	301	378.5	173.5	61.5	1280
79	4	0	0.5	59	67.5	189.5	487.5	107.5	133.5	592.5	102	61	1804.5
80	10	35.5	11.5	31.5	94	332	325	186.5	107	151	89.5	91	1464.5
81	211	15.5	0	17.5	29.5	244	182.5	224.5	229	104.5	243	221.5	1722.5
82	0	10.5	3	28	123	233	123.5	151.5	26.5	170	62	16	947
83	25	8.5	7	0	0	218	281	309	244.5	304	225.5	201	1823.5
84	178.5	25.5	21.5	81.5	197.5	274.5	139	181	215.5	684.5	100	225.5	2324.5

TABLE II-3

CANDAWAGA RIVER MONTHLY MEAN SIMULATED DISCHARGE

Unit : mm

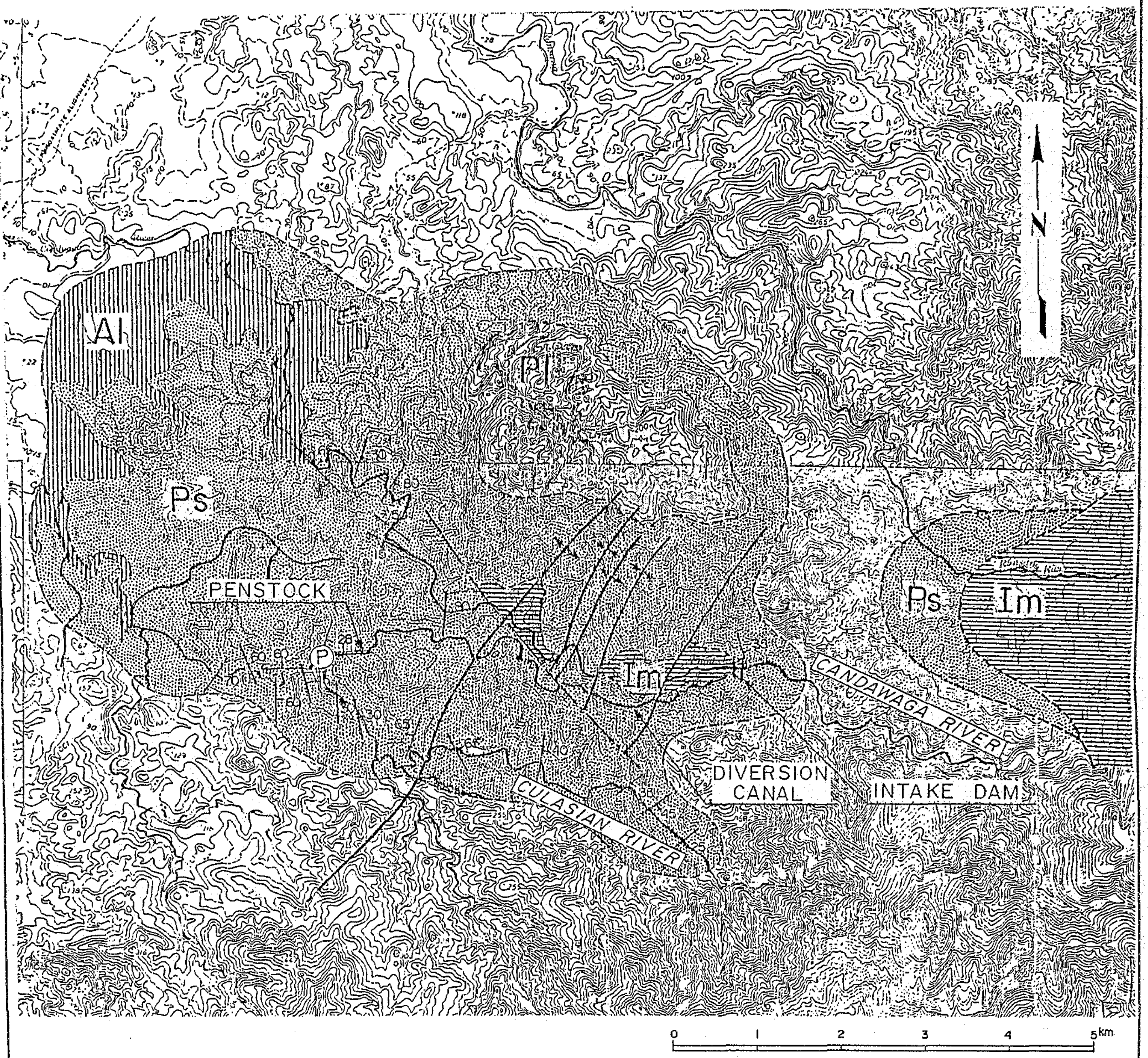
	Jan.	Feb.	Mar.	Arp.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
1975	5.26	3.23	2.22	1.58	1.24	3.63	3.49	6.02	6.27	8.16	5.44	7.68	4.53
76	4.41	2.25	1.31	0.85	0.58	2.00	3.37	2.60	5.60	3.13	3.70	3.60	2.78
77	2.30	1.53	0.99	0.56	0.50	2.36	5.13	4.83	11.77	5.31	3.65	2.41	3.45
78	1.50	0.93	0.62	0.41	0.80	0.63	0.53	2.01	5.00	7.67	5.57	3.18	2.41
79	1.75	1.00	0.65	0.90	0.81	1.89	8.13	4.90	3.13	11.37	5.00	3.35	3.60
80	1.98	1.51	0.91	0.77	1.52	3.76	7.18	4.92	3.67	3.60	2.67	2.62	2.94
81	4.32	2.04	1.11	0.66	0.52	2.49	3.32	5.26	4.62	3.33	4.48	6.48	3.23
82	2.39	1.37	0.84	0.68	1.63	3.29	3.16	3.07	1.99	3.00	1.97	1.29	2.06
83	0.86	0.51	0.32	0.20	0.11	2.08	5.00	6.17	4.53	7.09	5.59	6.21	3.25
84	4.36	3.08	1.76	1.94	3.00	4.76	3.71	4.44	4.53	11.91	5.92	6.58	4.68
(85)	(4.95)	(2.71)	(1.67)	(4.21)									
75-84	2.91	1.75	1.07	0.86	1.07	2.69	4.30	4.42	5.11	6.46	4.40	4.34	3.29

Note : C.A = 30.8km^2

FIGURES

FIG. I-1

GENERAL GEOLOGICAL MAP OF PROJECT AREA



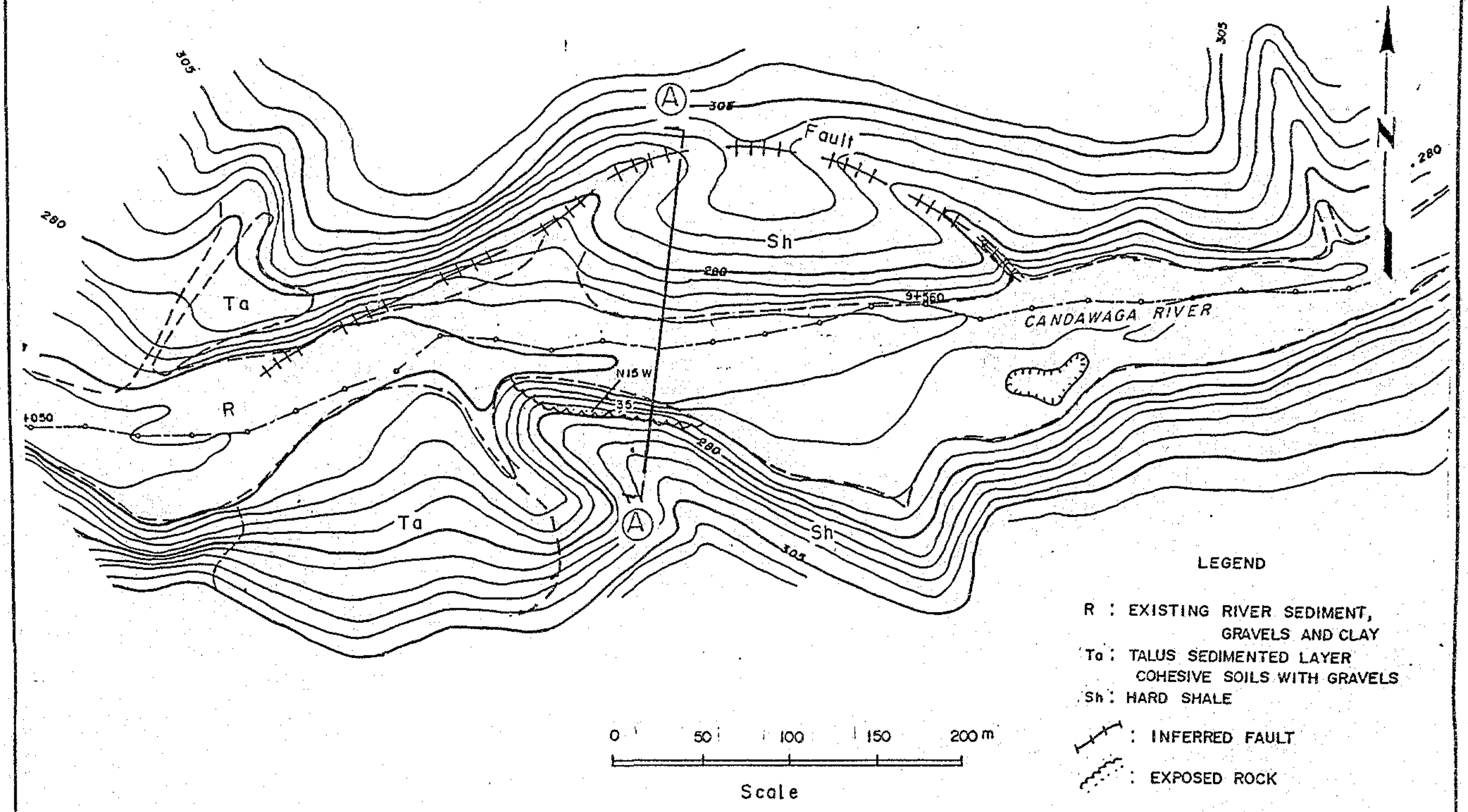
LEGEND

GEOLOGICAL AGE		FORMATION	LITHOLOGY
QUATERNARY		ALLUVIUM (Al)	CLAY, SAND, GRAVEL
EARLY MIOCENE OR LATE OLIGOCEINE		RANSANG LIMESTONE (Rl)	LIMESTONE
EARLY EOCENE		PANDIAN FORMATION (Pd)	MASSIVE SANDSTONE WITH INTERBEDDED MUDSTONE AND SHALE
PALEOCENE		FOVWATION (Ps)	INTERBEDDED SANDSTONE AND SHALE WITH LIMESTONE
PRE-TERTIARY		IRAHAUAN - METAVOLCANICS (Im)	BASALTIC COMPLEX PYROCLASTICS AND LAVA (AMOST PILLOW TYPE)

- : STRIKE AND INCLINATION OF STRATUM.
- : STRIKE AND INCLINATION OF FAULT
- : INFERRED GEOLOGICAL BORDER LINE
- : ANTICLINE STRUCTURE
- : SYNCLINE STRUCTURE

FIG. I-2

GEOLOGICAL MAP AT THE INTAKE POINT OF CANDAWAGA RIVER



Ⓐ – Ⓐ SECTION

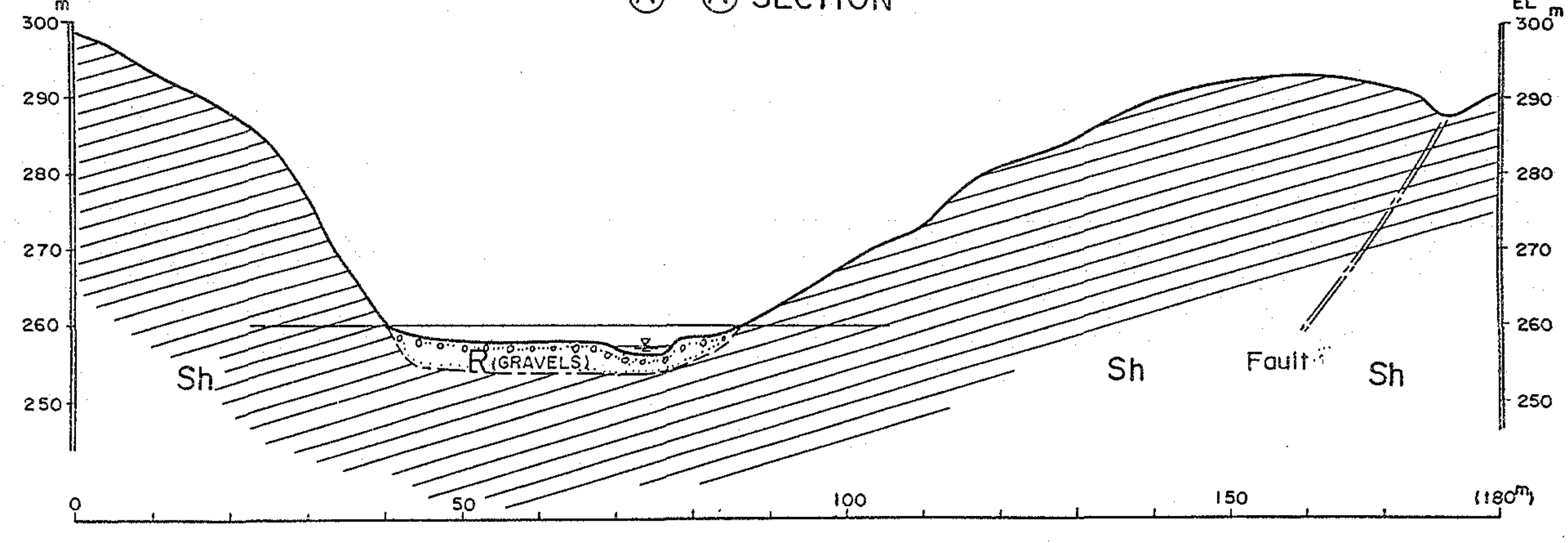


FIG. I-3

CULASIAN POWER SITE TOPOGRAPHICAL SINGULARITY

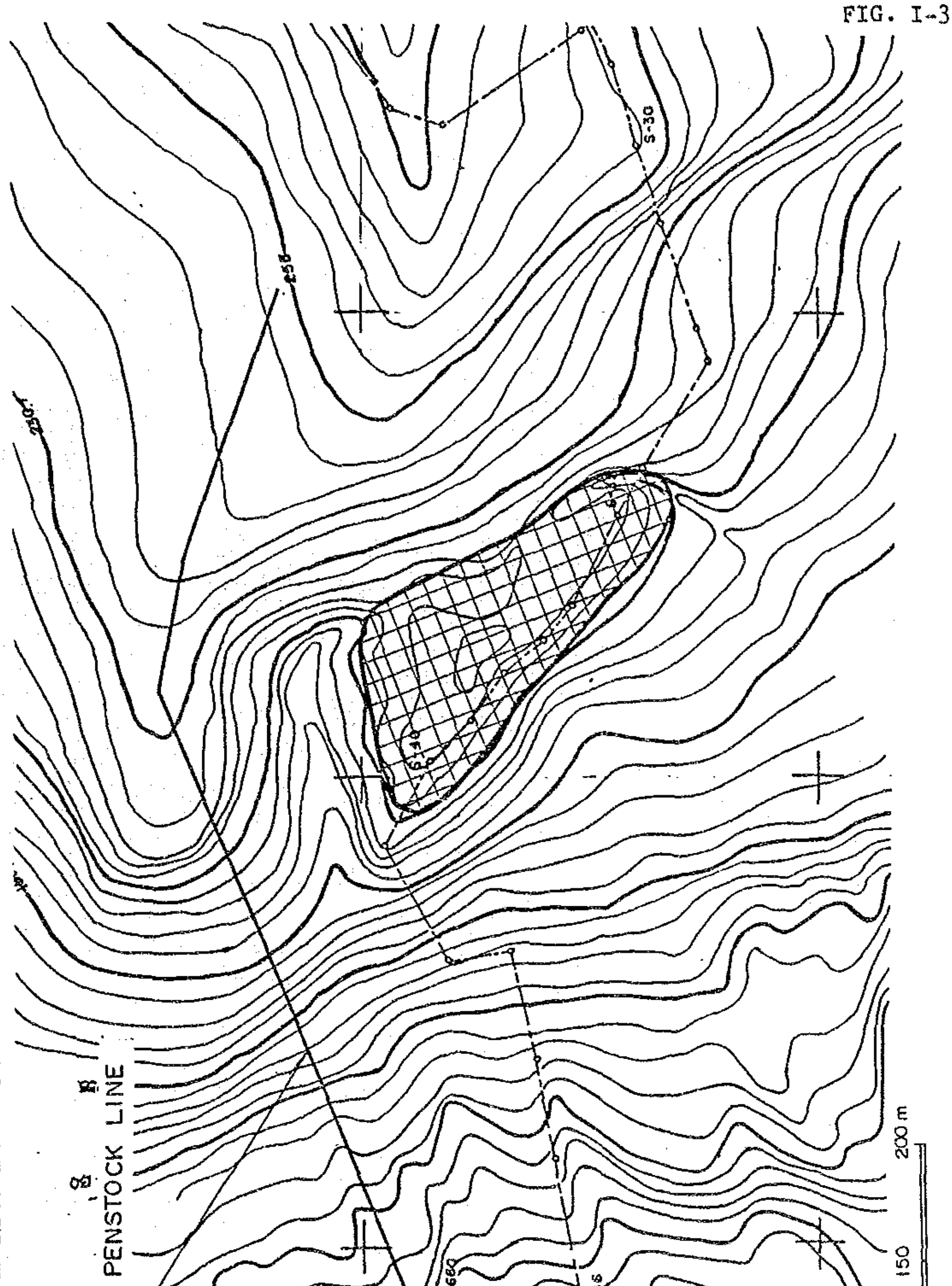


FIG. I-4

GEOLOGICAL PROFILE OF CULASIAN POWER SITE PENSTOCK LINE

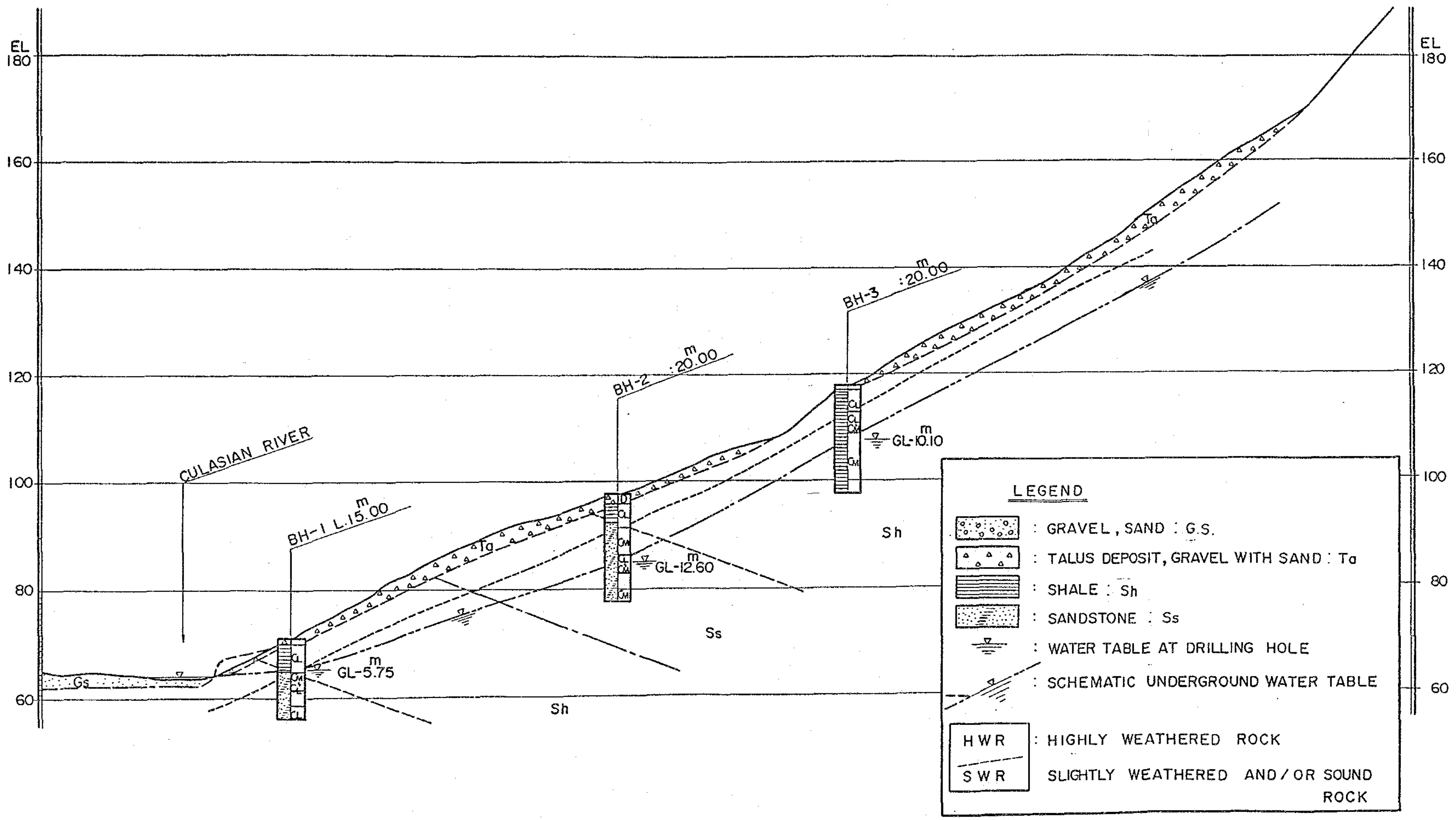
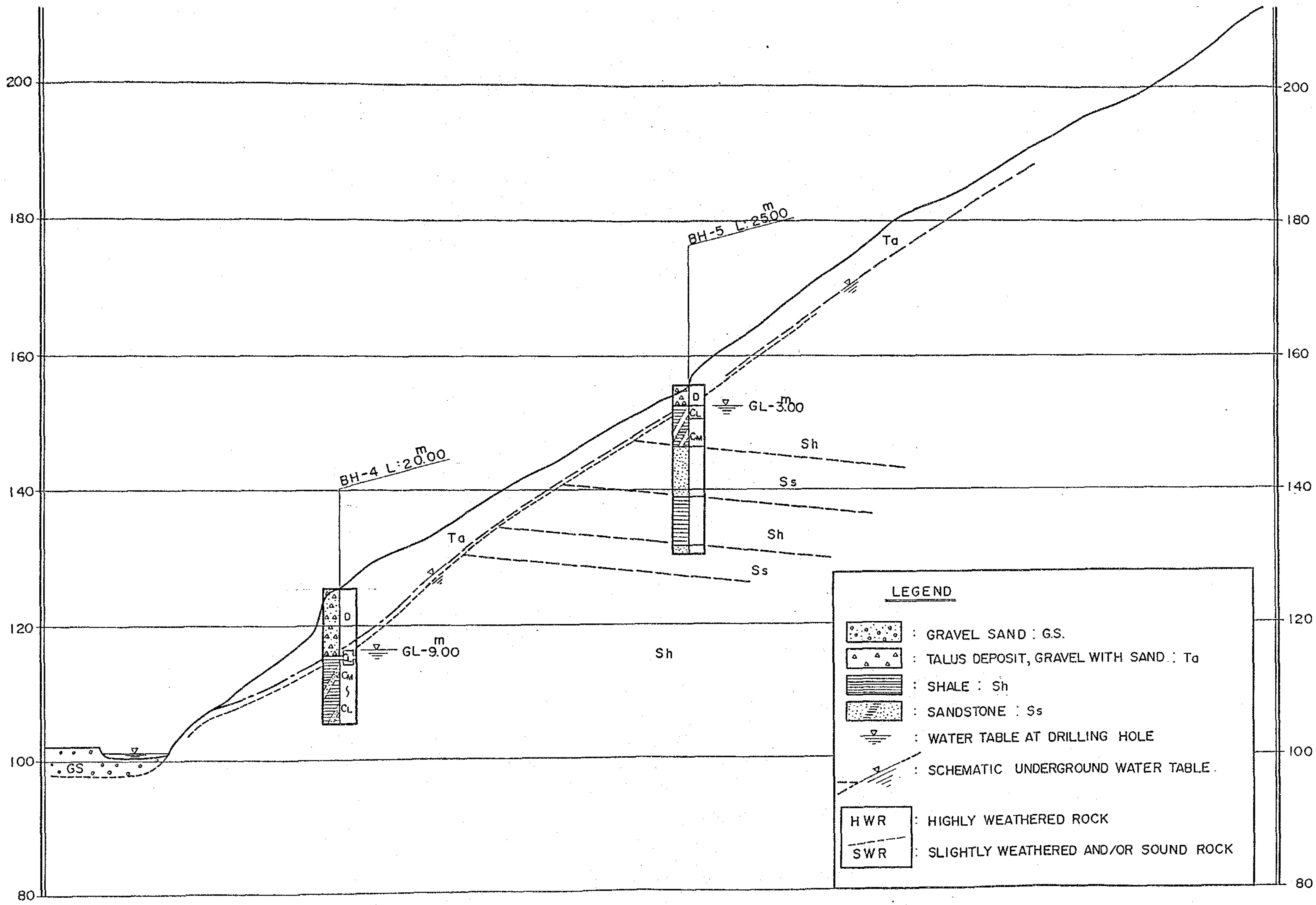


FIG. I-5

GEOLOGICAL PROFILE OF CANDAWAGA POWER SITE PENSTOCK LINE



GRAIN SIZE ACCUMULATION CURVE OF AGGREGATE MATERIAL

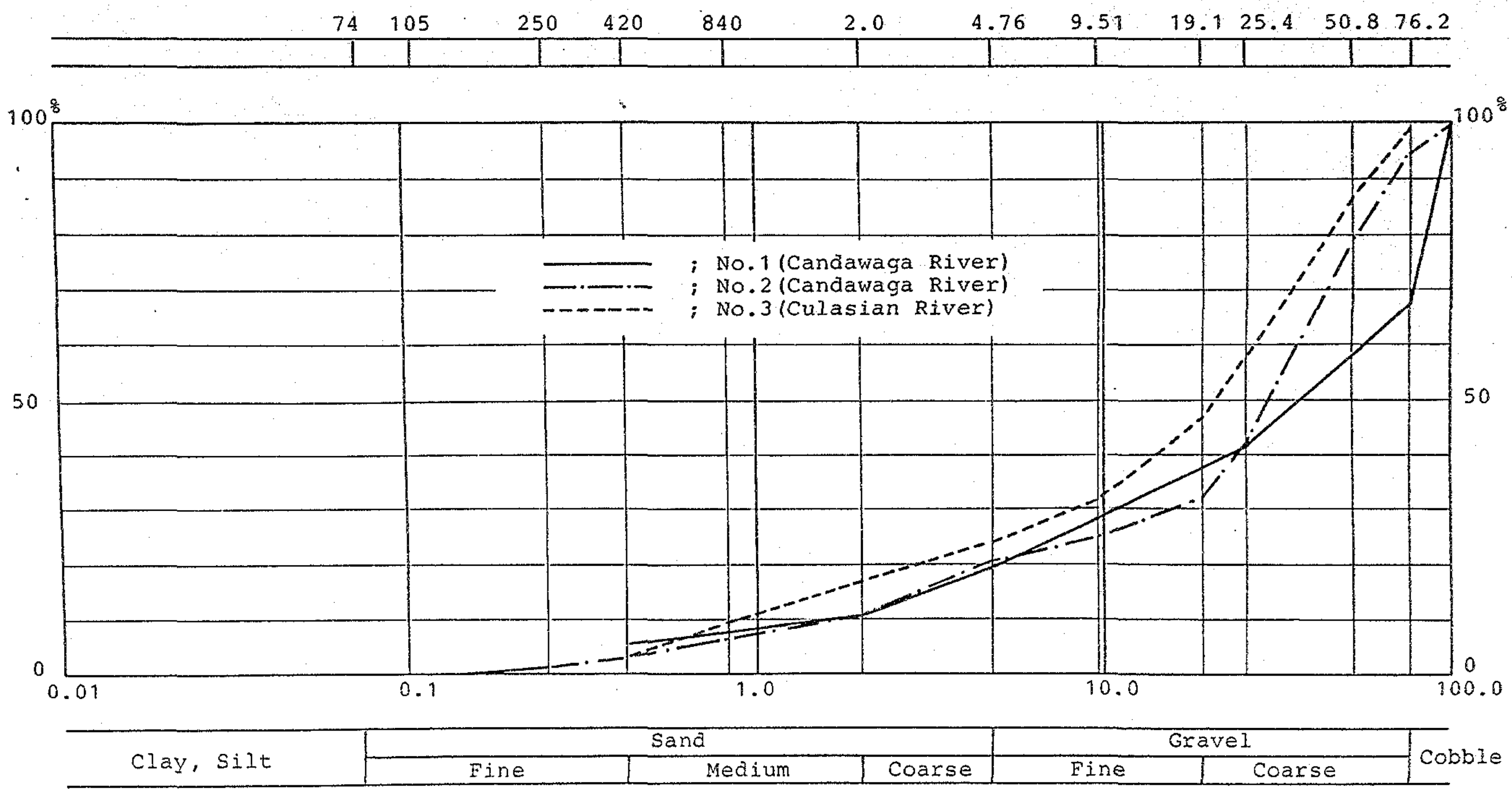
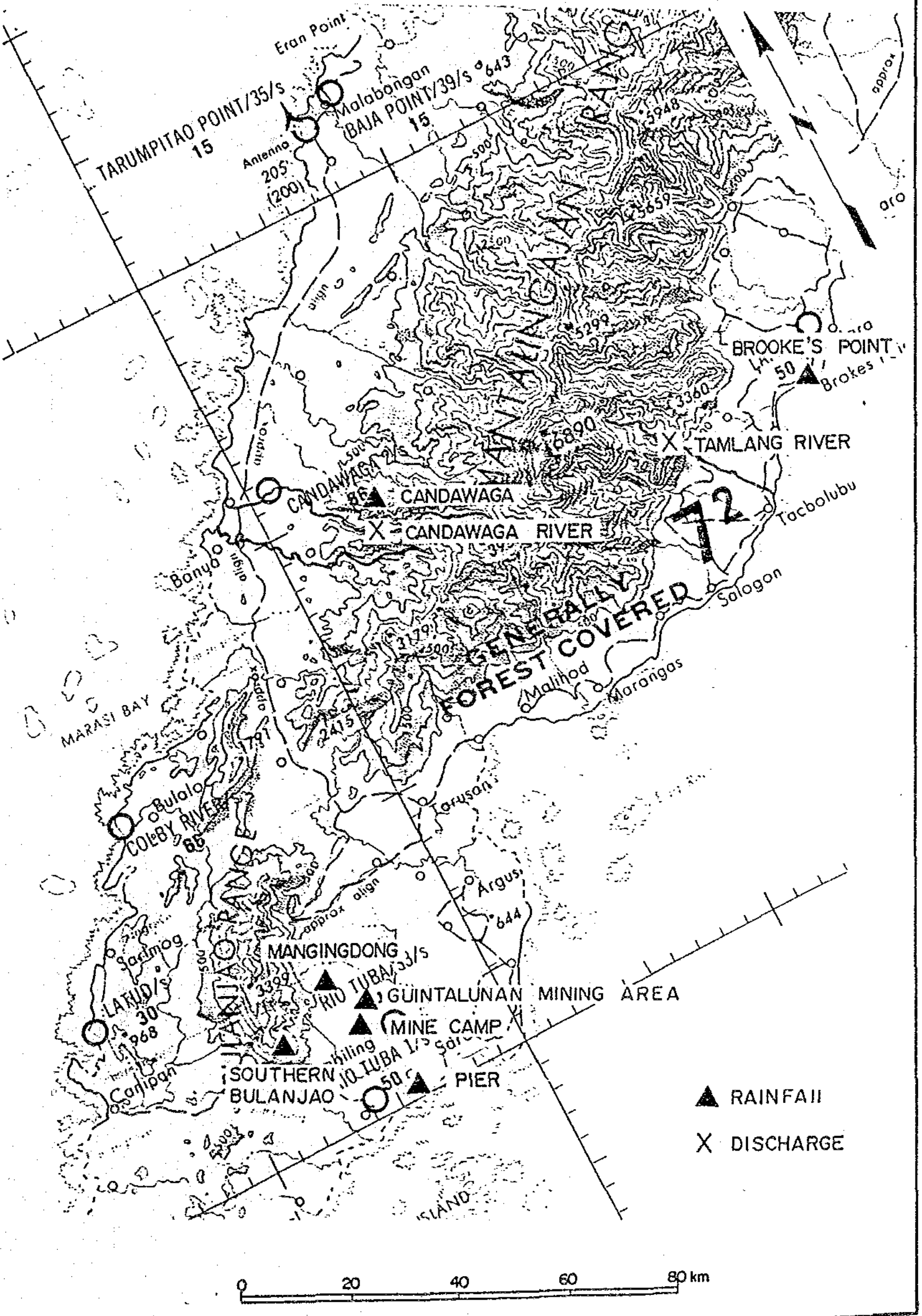
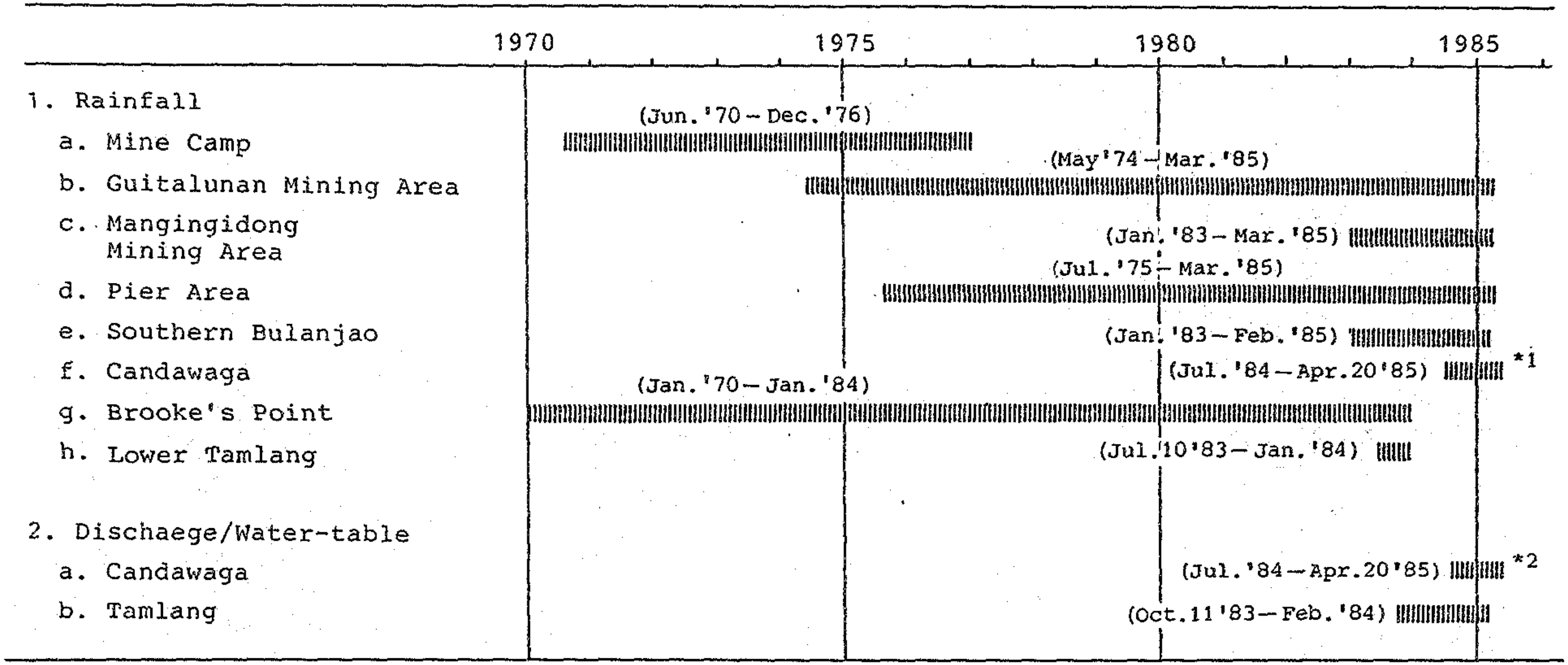


FIG. II-1

METEOROLOGICAL AND HYDROLOGICAL STATION



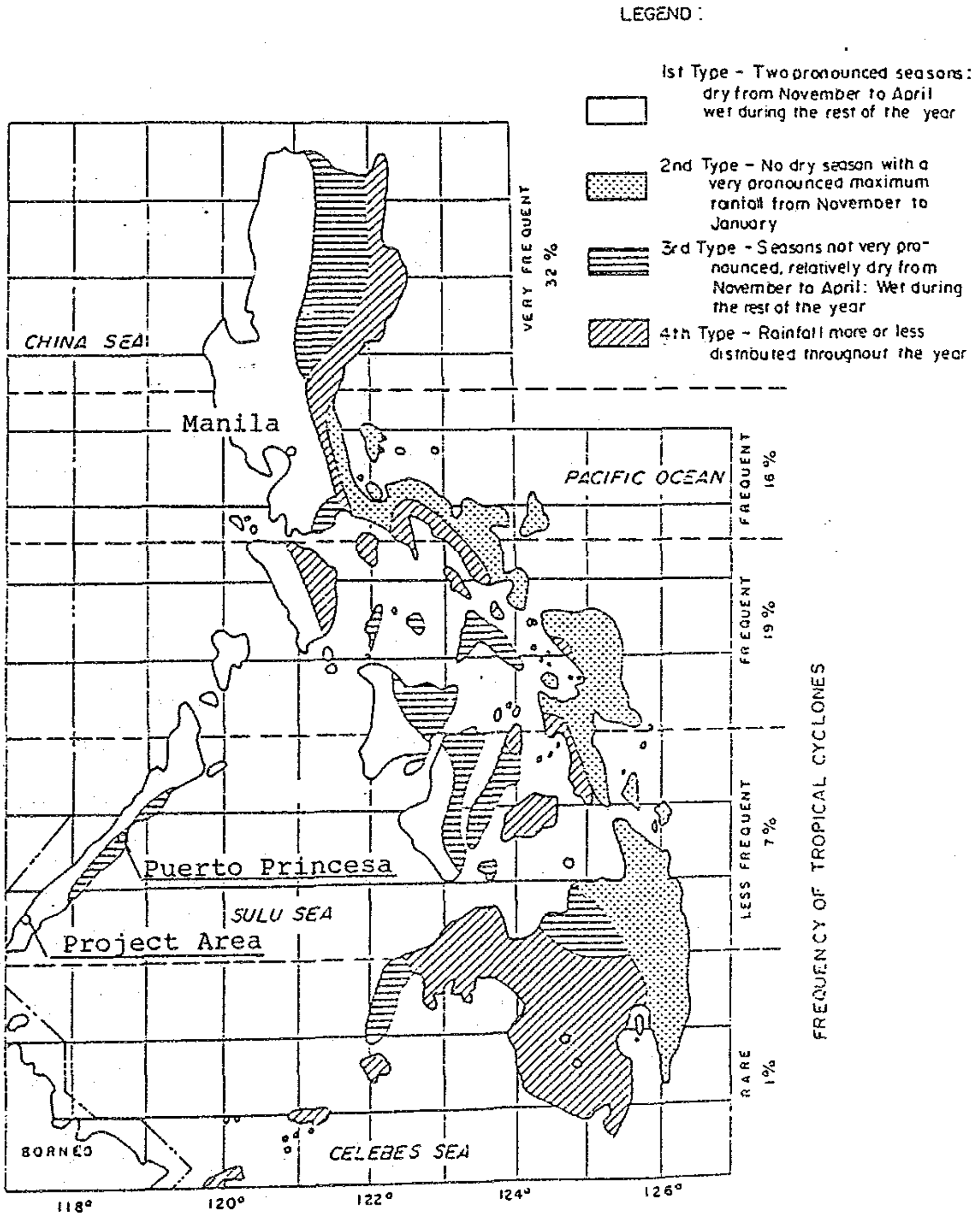
AVAILABLE METEOROLOGICAL AND HYDROLOGICAL RECORDS



*1. Sep.'84 lacking
*2. Sep.'84 lacking

FIG. II-3

THE PHILIPPINES CLIMATE CLASSIFICATION BY CORONAS



PIER AREA-S.BULANJAO
10-DAY RAINFALL CORRELATION

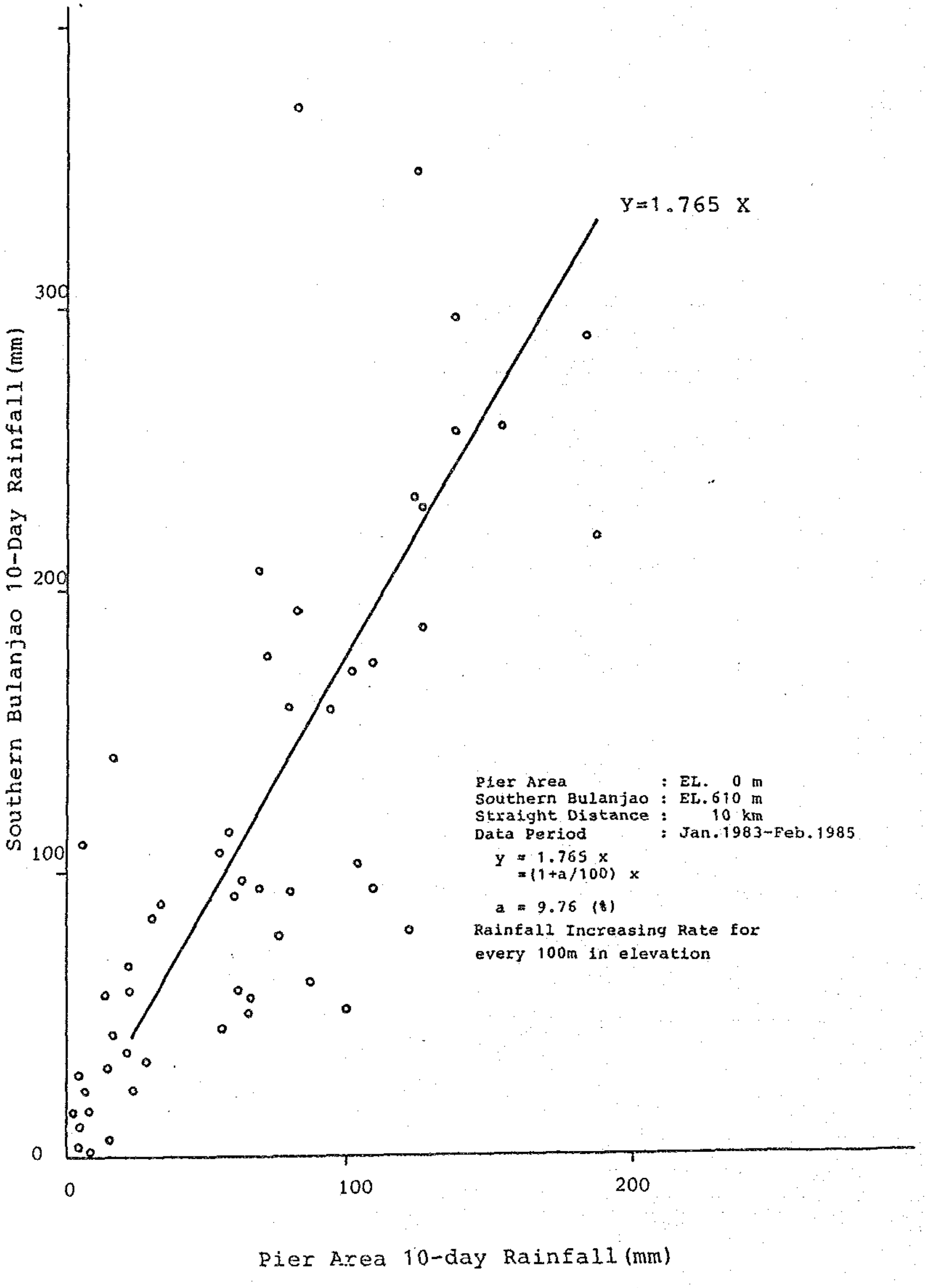


FIG. II-5

CANDAWAGA RIVER 1975-'85 AVERAGE FLOW DURATION CURVE

STATION : INTAKE DAM SITE (RIVER BED EL.255.0m)

CATCHMENT AREA : 30.8km^2

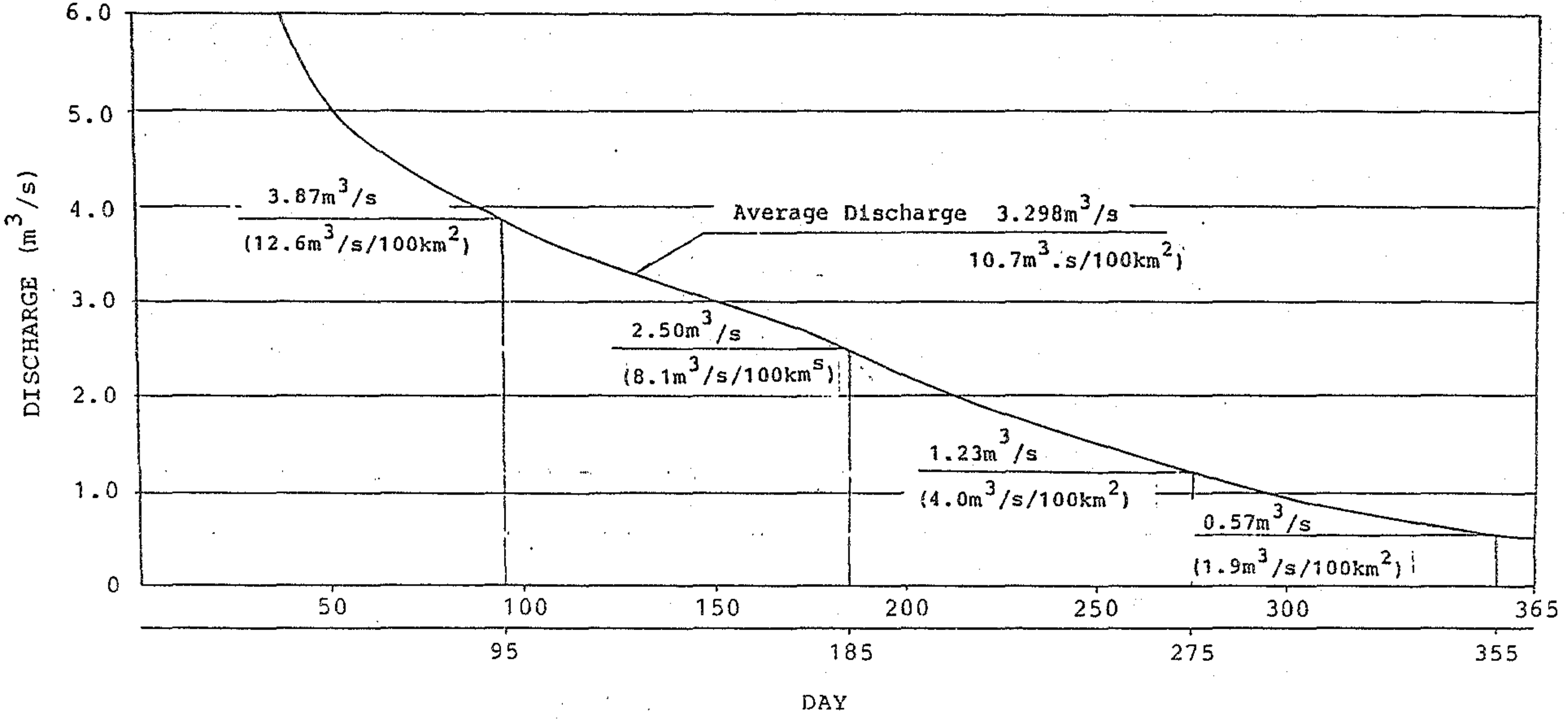


FIG. II-6

POTENTIAL IRRIGATION AREA IN THE DOWNSTREAM OF THE CANDAWAGA RIVER

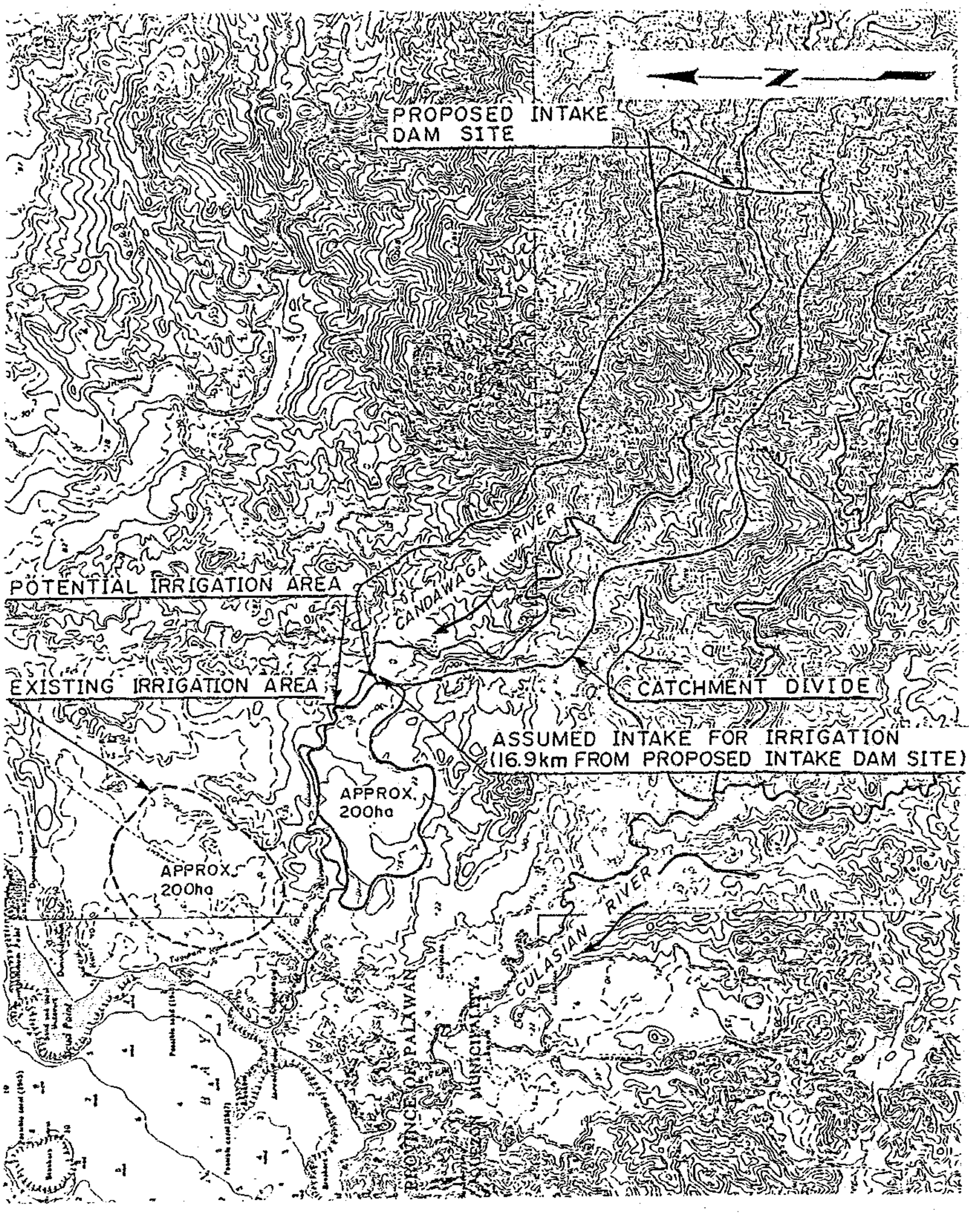


FIG. III-1

TURBINE TYPE SELECTION CHART

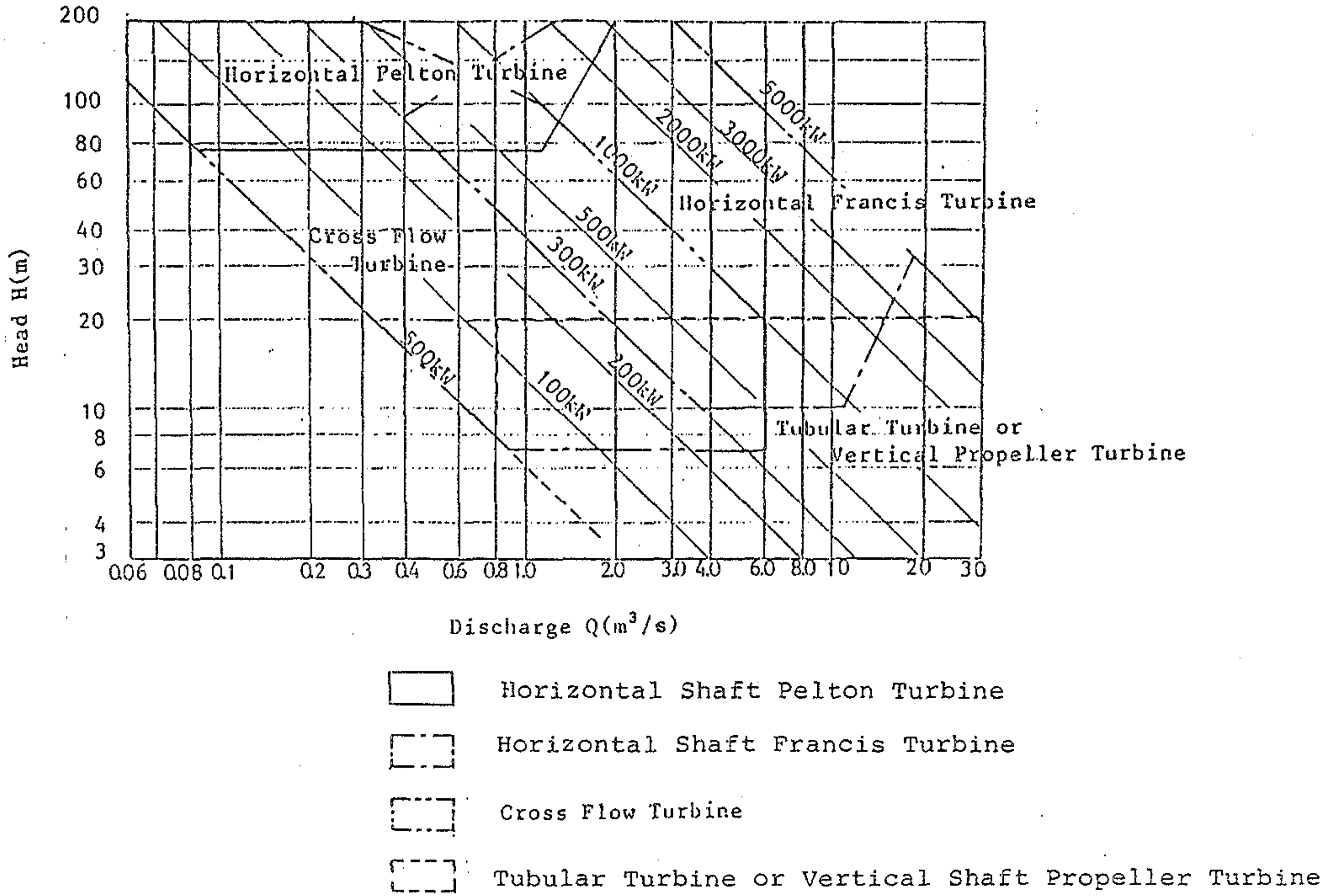
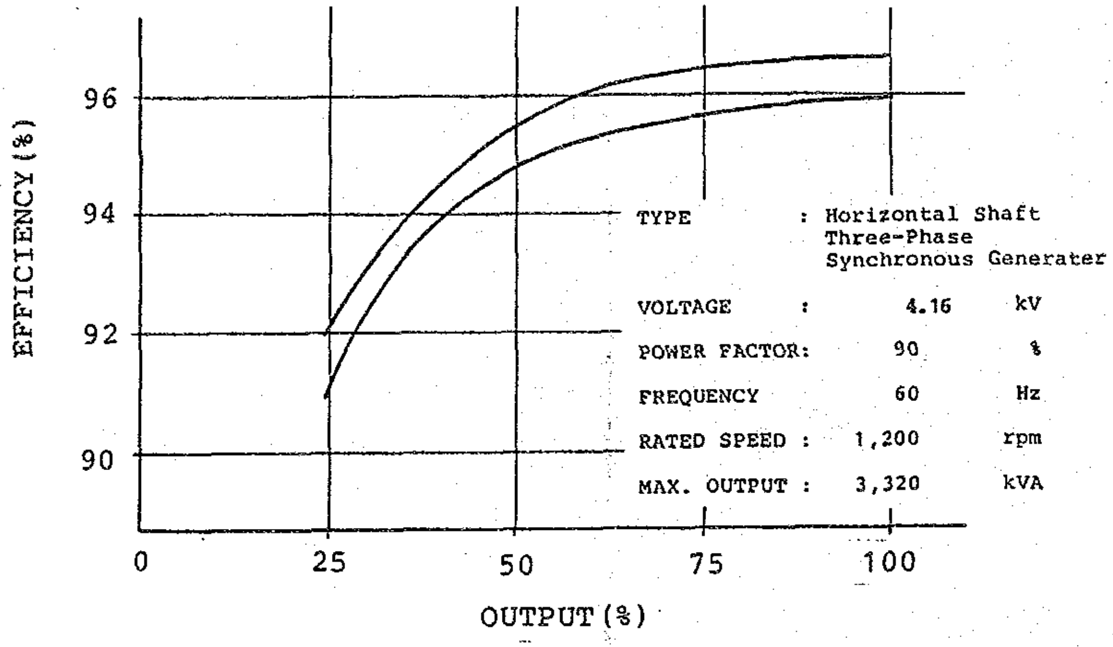


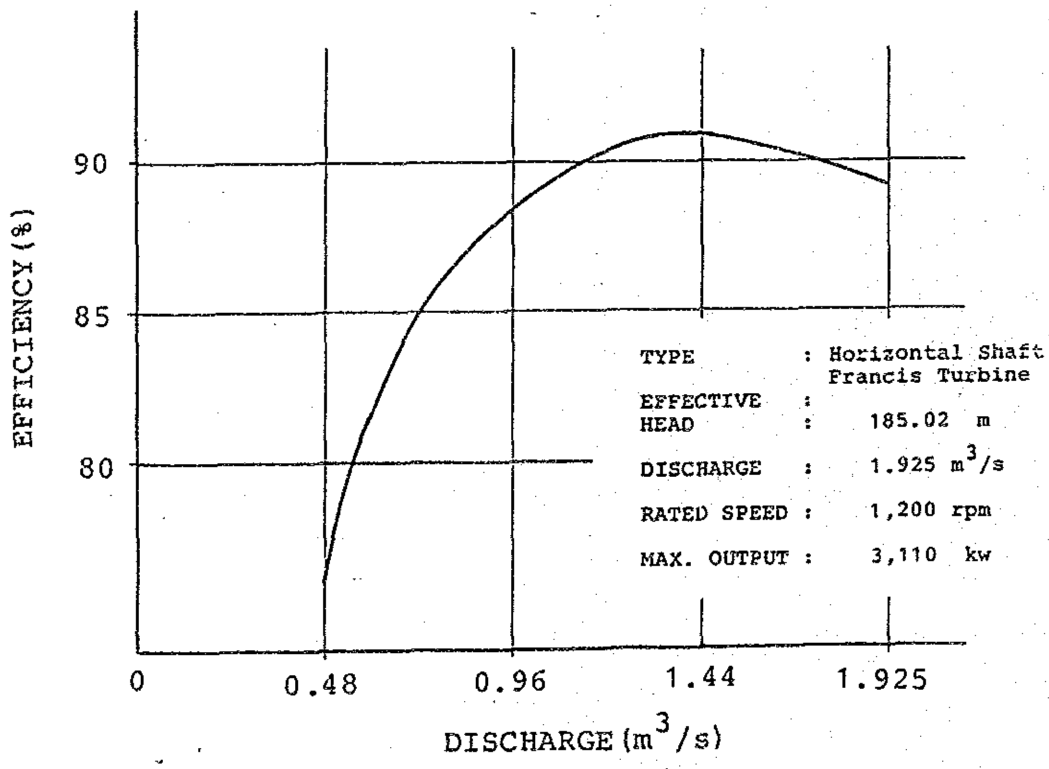
FIG. III-2

FIG. III-3

GENERATOR EFFICIENCY CURVE



TURBINE EFFICIENCY CURVE



JICA