IV. BASIC DESIGN

CHAPTER IV BASIC DESIGN

4.1 Climatic Conditions

The climate of the Project area is distinctly divided into a dry season (January - May) and a wet season (June - December) with an average annual rainfall of 1,600mm. Annual average temperature is 27.10°C while the maximum temperature is 37.4°C and the minimum is 20.9°C. Average humidity is 84%. Maximum wind velocity is about 24m/sec and although there was a typhoon in November 1968, direct typhoons occur only once every few decades.

Although the number of days of thunderstone during a one year period (IKL) is unclear due to lack of data, approximately 30 days per year is estimated due to the fact that about 7 days of thunderstorm occur in May just at the beginning of the rainy season and 35 days of thunderstorm were recorded on Cebu Island.

An earthquake has not occured in the area for over 20 years and accordingly 0.12 was selected as design seismic coeffecient for the dam. Design conditions for transmission lines are designated as follows:

- Maximum Temperature	40°C
- Average Temperature	30°C
- Minimum Temperature	10°C
- Average Humidity	84%
- Maximum Wind Velocity	40m/sec
- Seismic Factor (Horizontal)	0.2G

4.2 Civil Works

Preliminary designs of the civil works structures are presented as FIG 4-1 through 4-8. Detailed description of the principal structures is provided hereunder.

4.2.1 Dam

A concrete gravity-type dam was selected for the following reasons:

(1) The CH-grade grano diorite foundation indicates sufficient stability and safety with regards to bearing, sliding and percolation of water. Moreover, except on the upper face of the right bank, weathered rock is rare and foundation

treatment is for the most part unnecessary. The narrow gorge is also appropriate for concrete dam construction and particularly for arch dams.

(2) Adoption of an arch-type concrete dam was eliminated in consideration of construction procedures, cement quality, sedimentation, flood flow treatment, etc.

(3) Supply of sufficient volume and quantity of core materials in the case of a fill-type dam is difficult in the vicinity of the dam site. In addition, although a spillway will be installed on the right bank, the amount of excavation and concrete works required would be increased in the case of the fill-type dam due to topographical and geological factors and consequently, construction of the same would be uneconomical.

Although the narrow gorge at the proposed dam site may present a few difficulties for river diversion work, the location requiring the least construction work was selected. Said site is approximately 1,400m upstream from the point where the river meets the alluvial fan, and the riverbed slope at the same changes from 1/35 to 1/20.

As far as topography permits, the dam will be constructed to overflow at design flood discharge of 510m^3/sec along the crest of the dam without a sand flush gate. An automatic collapsible rubber dam 3.7m in height will be installed along the entire length of the dam crest to increase effective head. The said rubber dam will collapse automatically when overflow depth exceeds the set point at the top of the same and can be inflated back into position by motor.

The dam cross section will have an upstream slope of 0.2 and a downstream slope of 0.8. Design horizontal seismic coefficient was determined to be 0.12 and non-overflow level to be 192.0m (design flood elevation + 2.30m). Both downstream banks consist of hard grano diorite outcroppings and, although bank protection is not required, a 6.0m auxiliary dam for water cushion will be constructed to reduce overflow velocity and stabilize river flow. Although sediment deposits, including gravel deposits 3-4m in thickness, occur along the riverbed upstream from the dam, there are no significant landslides within the catchment area and sediment deposit level was determined to be 179.0m based on the annual sediment volume estimate of about 10,000m^3.

The effective depth of the regulating pond is 5.5m including the 3.7m of the raised rubber dam, and regulating capacity is approximately 400,000m^3.

4.2.2 Intake

As the headrace proposed under the Plan is a tunnel type to be constructed on the right bank, the intake structure will be located about 100m upstream from and independent of the dam site, thus reducing headrace length and avoiding complicated construction entailed by installation of an intake in the dam. The intake includes a float log protection, a trash rack (net interval 30mm) and a regulating gate. The latter will be an electrical remote control type. Intake site elevation will be such that power generation can take place even when the crest rubber dam is in the collapsed position.

4.2.3 Headrace

Two alternative plans, tunnel construction and open excavation, were considered for headrace installation from the intake to the head tank.

(1) Tunnel

The 1,102m of the total tunnel length (1,277m) would be designed with a section of 4.0m x 4.0m to use as a dam construction road. The 175.0m not used as a construction road would have a section of 2.0m x 2.0m for use as a water canal and the entire tunnel length would be used as a headrace. Approximately 70% of the tunnel would be unlined while 30% would have a mortar or concrete lining. Regulating gates would be installed at the upper and lower entrances of the tunnel. When water is shut-off the tunnel could be used for tunnel inspection and maintenance and as a connecting road to the dam site.

(2) Open Excavation Method

A bed for the headrace conduit 1,400m in length would be excavated and used as a construction road. Upon dam completion an FRPM pipe with an inner diameter of 1.50m would be embedded in the road surface and used as the headrace. Earth fill would be spread over the same to form protective layers and the surface would be used as a future access road.

Comparison of the two alternatives is presented in TABLE 4-1. As can be seen from the same, the open excavation method results in higher construction costs and decreased energy due to loss of head, and is thus considered economically disadvantageous compared to the tunnel method. Accordingly, the latter alternative was adopted as the headrace for the present Project.

Geologically the tunnel route consists mainly of hard rocks including grano diorite from the central construction portal to the upstream portion and metamorphic rock, particularly basaltic lava, in the downstream portion. Some weathered portions occur on the surface near the central construction portal and bore samples revealed a weathered layer about 4m thick near the tunnel's downstream portion.

Although there is minimal chance of leakage from the tunnel due to excellent foundation rock quality, a portion of the tunnel will be lined with shotcrete for reinforcement.

Tunnel excavation features are as follows:

Section	Headrace Tunnel	Temporary Road	Summary
4.0m x 4.0m	1,102.0m	220.0m	Downstream 70m Upstream 150m
2.0m x 2.0m	175.0m	-	Used only as headrace
Total	1,277.0m	220.0m	

4.2.4 Surge Tank

The surge tank site is located between the penstock and the headrace. As the weathered rock layer at this site is over 4m in depth, the surge tank foundation will be excavated to the level of good quality foundation rock to increase stability.

A steel shaft simple surge tank will be installed on the side of the excavated bank.

4.2.5 Penstock

The penstock route will follow the right bank where the lower mountains join the alluvial fan and the slope is a comparatively moderate 30°. Weathered layer along the route extends to a depth of 2-4m. Use of a steel conduit would consequently require increased earthworks to excavate the penstock bed to a stable foundation. FRPM pipe with an inner diameter of 1.35m has therefore been selected for penstock use and the same will be embedded for a total length of 216.0m. Portions where backfill may be subject to wash out will be sodded or reinforced with rubble masonry.

4.2.6 Powerhouse

River sediment layer thickness at the powerhouse site is about 4m. Part of the site will therefore be excavated from the steep hillside to ensure that the entire foundation of the powerhouse rests directly upon bedrock. A horizontal-shaft Francis turbine was selected and the elevation of the turbine and generator floor will be 85.80m. As the flood flow elevation is 92.0m, the side walls of the equipment room will be constructed of water tight reinforced concrete and the auxiliary control panel, etc. will be installed in a second storey at an elevation of 94.2m.

The floor area of the equipment room will be 136.0m^2 while that of the second storey will be 59.5m^2. As the elevation of the connecting road to the powerhouse will be 92.0m, heavy equipment will be lowered into the equipment room through an opening in the roof (elevation 94.2m). The opening will be fitted with a roof cover.

Equipment will be moved within the equipment room itself by a simple travelling crane with a maximum lifting load capacity of 12.0 tons. The outdoor substation will be set-up near the powerhouse on the right bank where the penstock is also located, and the foundation of the same will have an area of about 200m^2.

4.2.7 Tailrace

The shortest possible distance between the powerhouse and the Tamlang River was selected as the tailrace route and the sediment layer will be excavated along the same. The bottom width of the tailrace will be 2.20m and both side walls will have a slope of 1:0.5. The side walls will be reinforced with rubble masonry as high as flood water level to prevent collapse, while the surface of the tailrace bed will be left as is.

The right bank of the Tamlang River upstream from the point where the tailrace flows into it will also be reinforced with rubble masonry. Tailrace slope will be 1/1000 to increase the effective head including drop structures in part of the Tamlang riverbed.

4.3 Electro-Mechanical Equipment

Preliminary designs of the electro-mechanical equipment are presented as FIG. 4-4 and 4-9 through 4-12. Detailed description of the principal structures is provided hereunder.

4.3.1 Type and Turbine-Generator Unit

(1) Turbine

The proposed hydropower plant is a canal with regulating-pond type with an effective head of 101.3m at maximum output and a maximum turbine discharge of $4.5m^3/sec$.

A horizontal-shaft Francis turbine was selected from among those turbines suitable for mini-hydropower use presented in FIG. 4-13. Vertical-shaft turbine were also studied; however, the same entail greater civil works cost resultant from complexity of concrete foundation and building structures, althrough escavation works for the foundation would be less than the horizontal-shaft turbine. Moreover, vertical-shaft turbines require longer installation time, are less convenient for operation and maintenance. In consideration of the above, the horizontal-shaft turbine was selected as most advantageous.

Water quality studies indicate that water quality should have no significant influence on turbine operation. The turbine performance curve is presented in FIG. 4-14. Installation of one turbine unit is considered sufficient for daily operation by a regulating pond.

Turbine Features are set-in below.

- Type : Horizontal-shaft Francis Turbine
- Effective Head : 101.3m
- Maximum Turbine Discharge : $4.5m^3/sec$
- Rated Output : 4,000kW
- Rated Speed : 720rpm
- Specific Speed : 142m-kW
- Inlet Valve : Butter fly Valve
- Operation System : Electricity

(2) Generator

As the generator which is directly coupled to the turbine must be capable of independent operation and regulating voltage and frequency of transmission line, a horizontal-shaft, 3-phase, AC synchronized, air-cooled generator was selected.

Rated power factor was designated as 0.81 in consideration of the power factor of actual load at the Tuba Mine, rated power factor of the existing diesel generator, etc. The brushless excitation method was selected.

Generator Features are also set-in below.

- Type : Horizontal-shaft 3 Phase AC Synchronized Generator
- Rated Output : 4,700kVA
- Rated Voltage : 4.16kV
- Rated Power Factor : 0.81
- Rated Frequency : 60Hz
- Rated Speed : 720rpm
- Excitation Method : Brushless-type

4.3.2 Main Transformer

An outdoor, 3-phase, oil-immersed, self-cooled type transformer was selected with triangular primary connections, star secondary connections and neutral resistance grounding. The primary side conforms to the voltage of the generator while the secondary side conforms to the voltage of the transmission lines.

Transformer Features are set-in below.

- Type	: Outdoor 3-phase Oil-immersed Self-cooled Transformer
- Rated Capacity	: 4,700kVA
- Rated Voltage	: 4.16/34.5 ± 5% kV
- Rated Frequency	: 60Hz

4.3.3 Switch Gear

A vacuum circuit breakers with 4.16kV on the generator side and 34.5kV on the transmission line side was selected for minimal maintenance. An indoor-type metal-clad will be installed on the 4.16kV side and a conventional-type will be installed outside on the 34.5kV side. Both outside switchgears and insulators were designed in consideration of possible salt damage.

4.3.4 Control System

The hydropower plant will be supervised and controlled by the one-man control type system with operation located in the control room. A program controller capable of setting and controlling output and plant operation hours was selected to facilitate operation of the Rio Tuba Mine and PALECO diesel generators. In addition, the Rio Tuba Mine and PALECO will be in communication with the hydropower plant control panel by radio telecommunication. A cubicle built-in seal type alkali storage battery will be used as the power source for the control panel to minimize maintenance.

4.3.5 Transmission Lines

(1) Voltage

Transmission line voltage used in the Philippines is generally greater than 34.5kV. For the present Project however, 34.5kV was selected based upon study of transmission loss and transmission line construction cost including cost of the substations.

(2) Conductors

Aluminum conductor steel reinforced cable (ACSR) which is widely used for transmission and distribution lines in the Philippines was selected. As the transmission line route is only about 1.5km from the seacoast in some places, the above ACSR with several stranded steel reinforced cables was considered most reliable against salt damage. A 176.9MCM (89.7mm^2) conductor was selected for transmission capacity, minimal loss and minimal drop in (less than 5%) voltage.

(3) Insulators

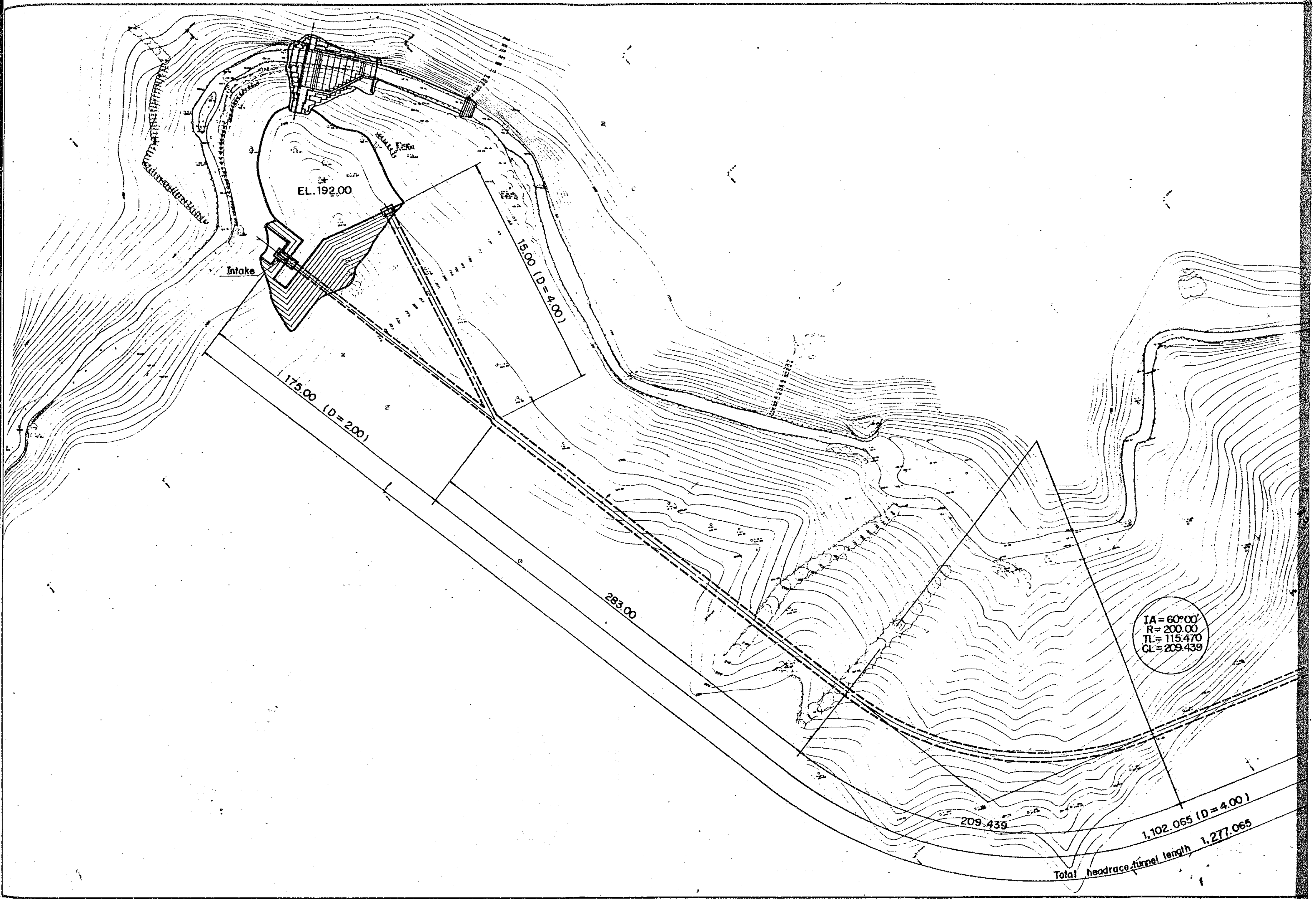
Four 250mm suspension insulator types will be used as close proximity of the transmission line route to the seacoast (1.5-10km) results in potential salt damage.

(4) Overhead Ground Wire

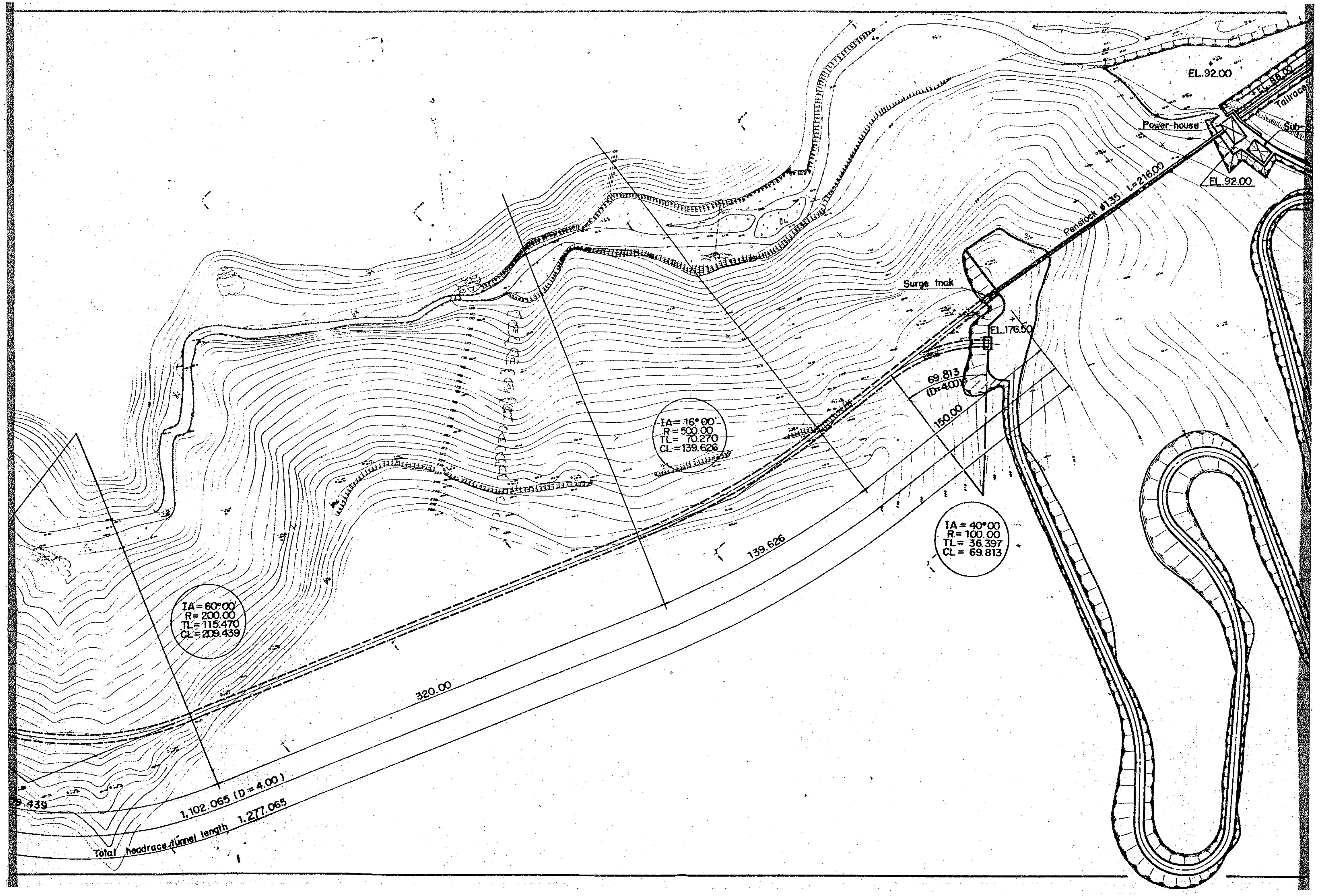
As the estimated IKL of the Project area is about 30 days, one overhead ground wire will be provided. AWG 2 (33.62mm^2) zinc coated stranded steel wire will be used with an oblique angle of within 45°.

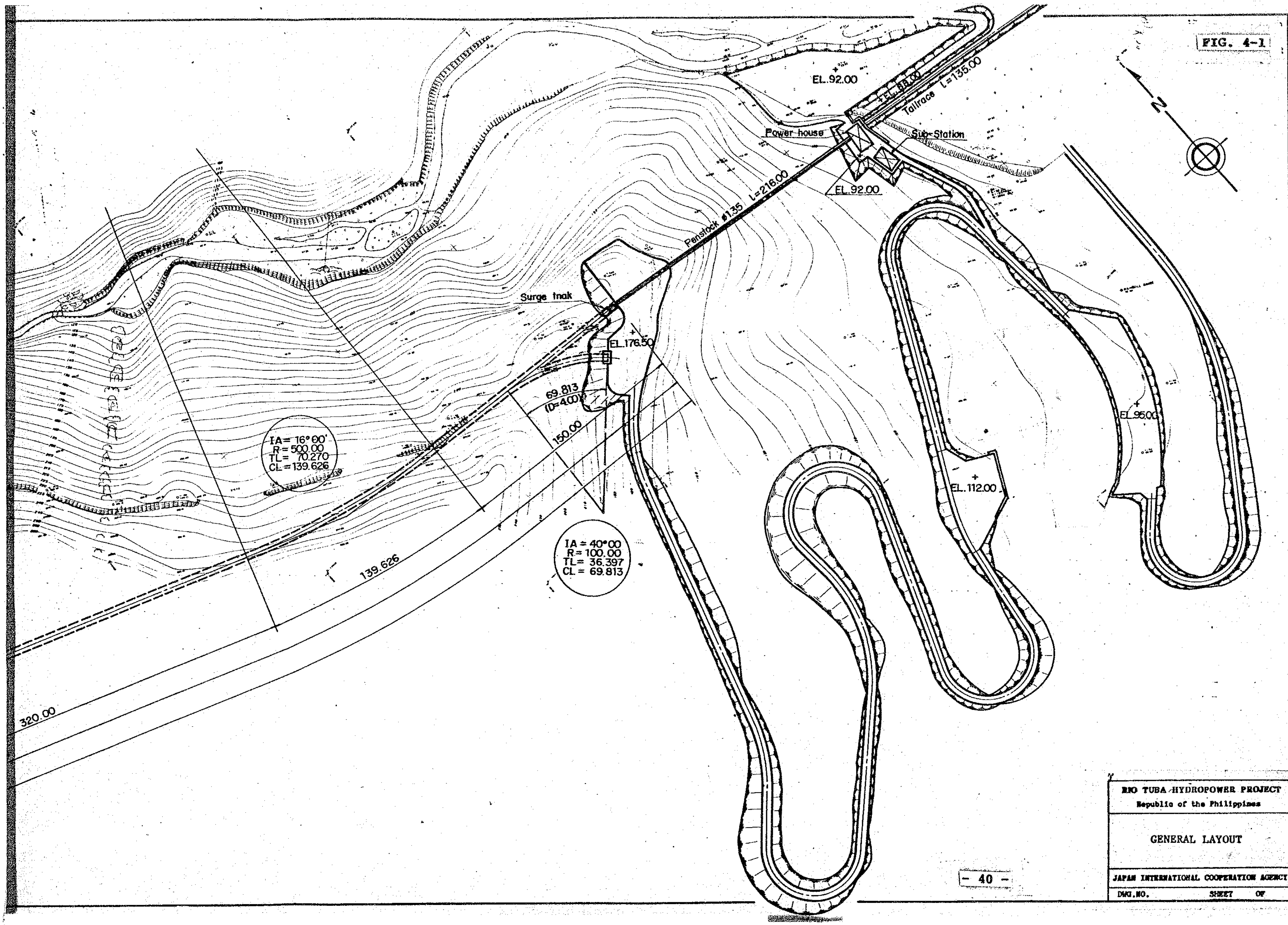
(5) Support Poles

Wooden poles will be erected at an average interval of 75m. Wooden poles are widely used in the Philippines as supports for transmission voltages of less than 69kV and also for 138kV. Hard Apiton trees impregnated with creosote will be used.



EL. 192.00
Intake
15.00 (D=4.00)
175.00 (D=2.00)
283.00
IA=60°00'
R=200.00
TL=115.470
CL=209.439
209.439
1,102.065 (D=4.00)
Total headrace tunnel length 1,277.065


EL.92.00
EL.88.00
Tailrace
Power house
Sub-S
EL.92.00
Penstock ø1.35 L=216.00
Surge tnak
EL.176.50
69.813
(D=4.00)
150.00
IA= 16°00'
R= 500.00
TL= 70.270
CL= 139.626
IA= 40°00
R= 100.00
TL= 36.397
CL= 69.813
139.626
IA= 60°00'
R= 200.00
TL= 115.470
CL= 209.439
320.00
209.439
1,102.065 (D=4.00)
Total headrace tunnel length 1,277.065



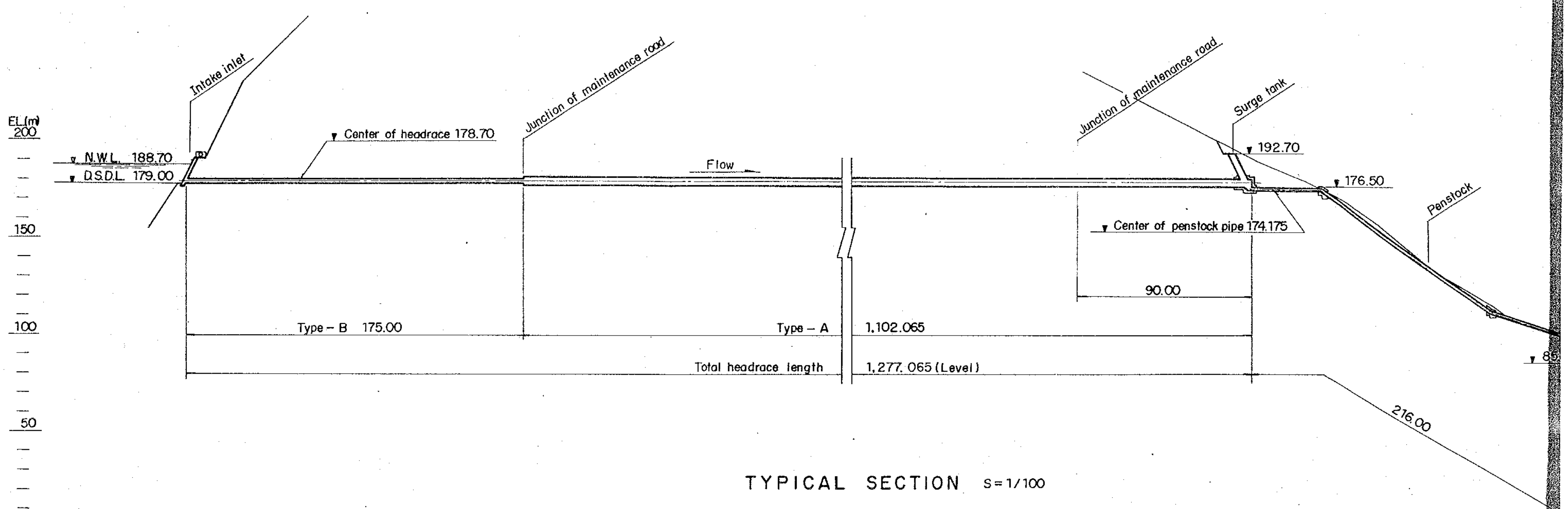
RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

GENERAL LAYOUT

JAPAN INTERNATIONAL COOPERATION AGENCY

DWG.NO. SHEET OF

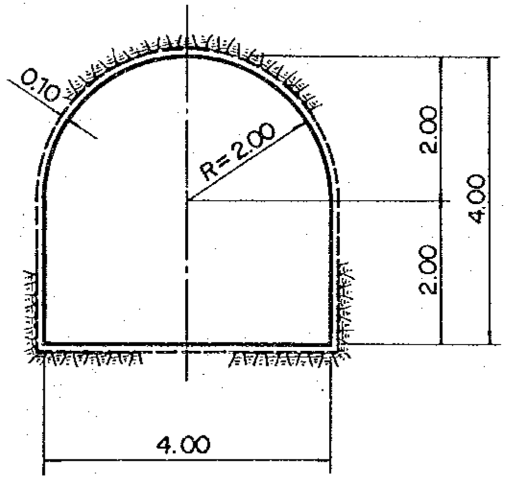
PROFILE OF WATERWAY S= 1/2,000



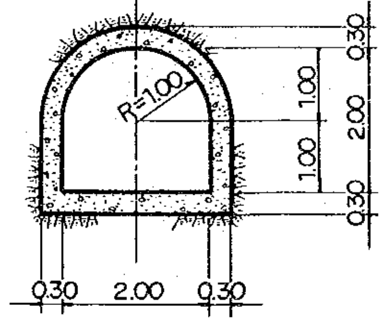
TYPICAL SECTION S=1/100

HEADRACE

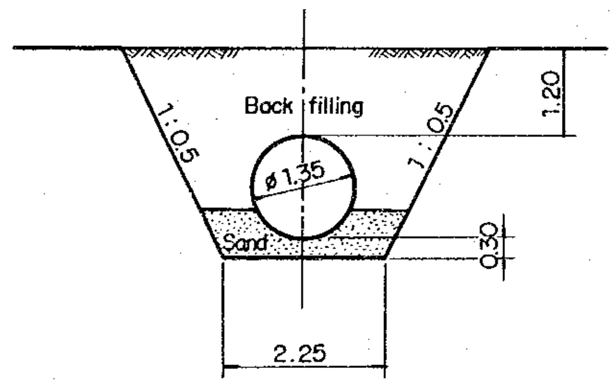
TYPE – A



TYPE – B



PENSTOCK



TAILRACE

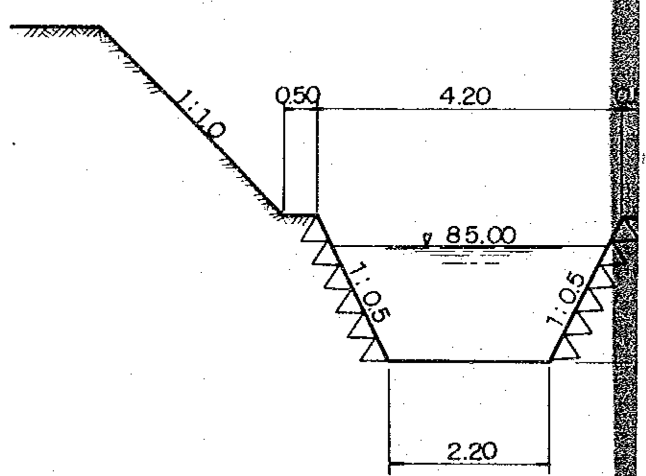
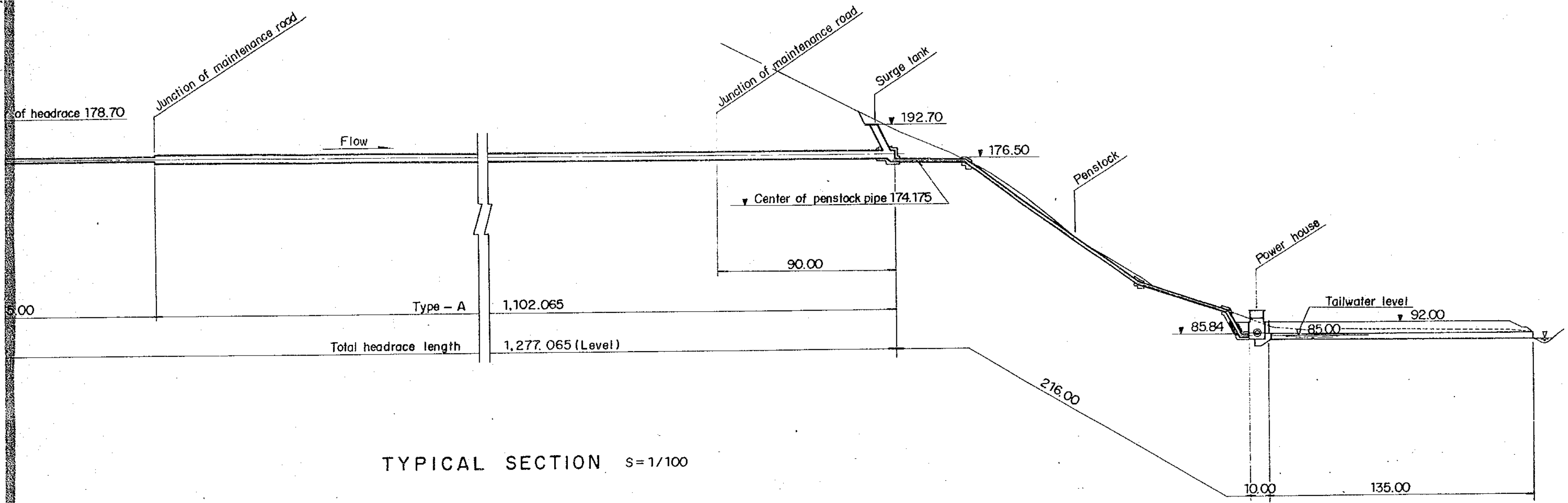


FIG. 4-2

PROFILE OF WATERWAY S=1/2,000



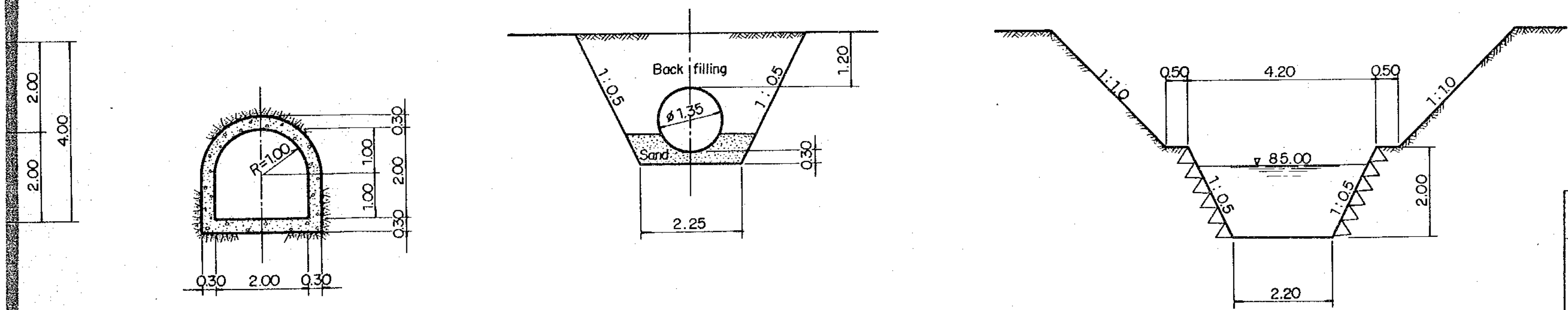
TYPICAL SECTION S=1/100

EADRACE

TYPE – B

PENSTOCK

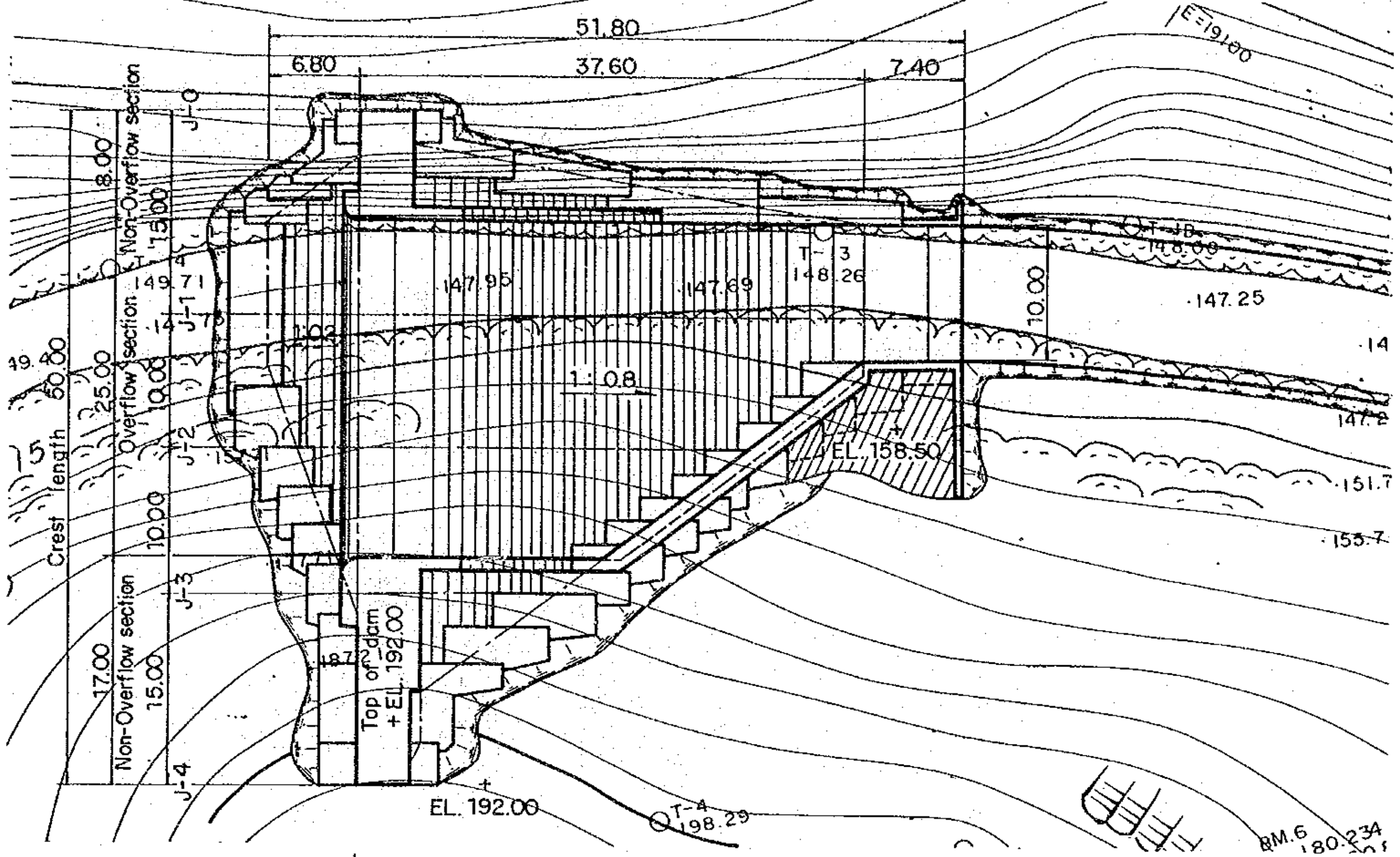
TAILRACE



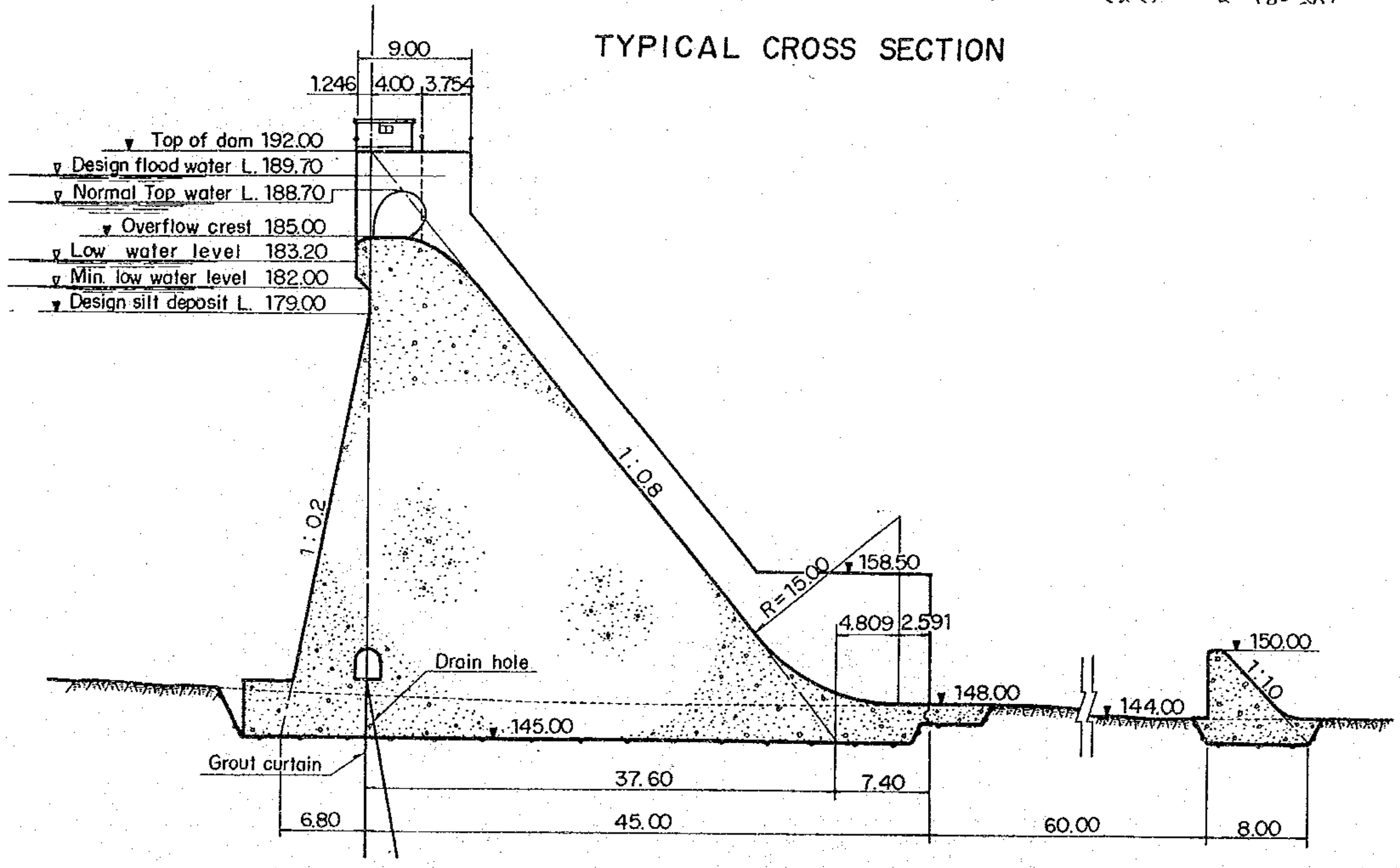
RIO TUBA HYDROPOWER PROJECT Republic of the Philippines
GENERAL PROFILE
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG.NO. SHEET OF

FIG. 4-3

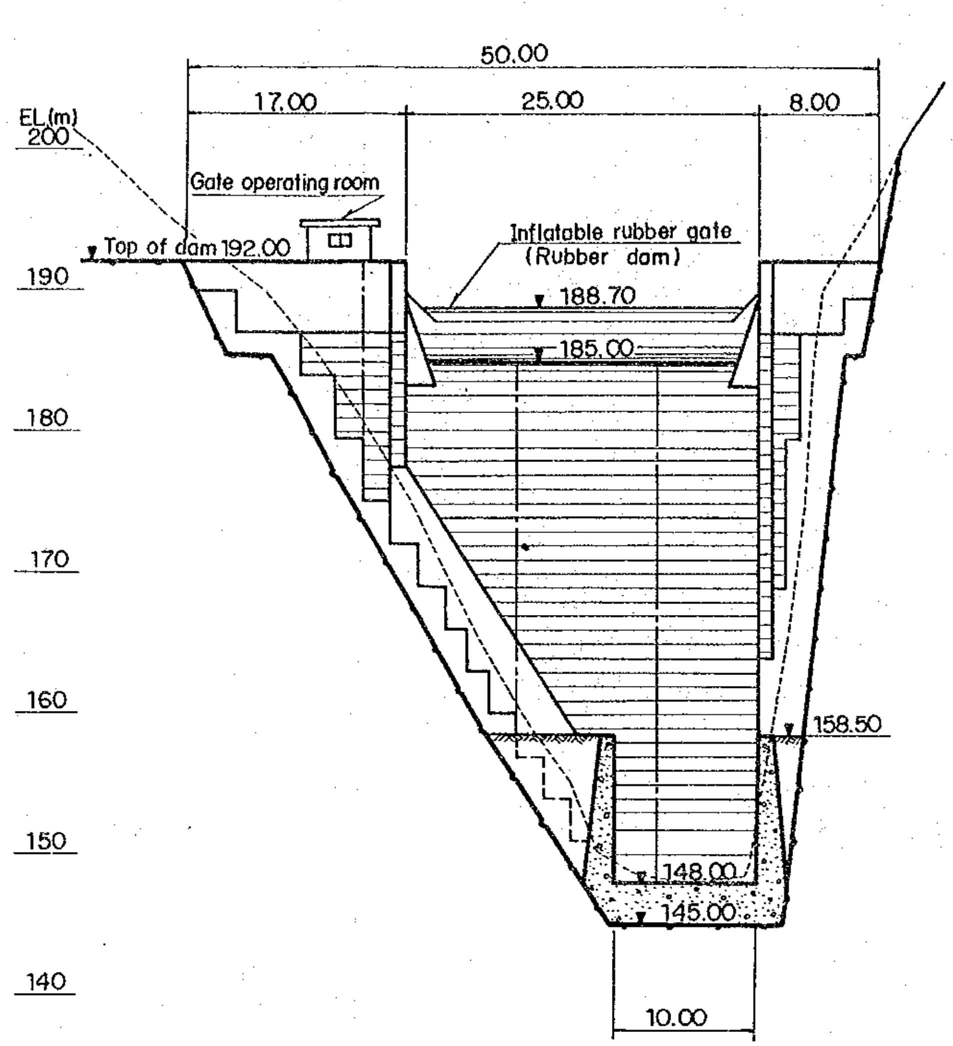
PLAN



TYPICAL CROSS SECTION



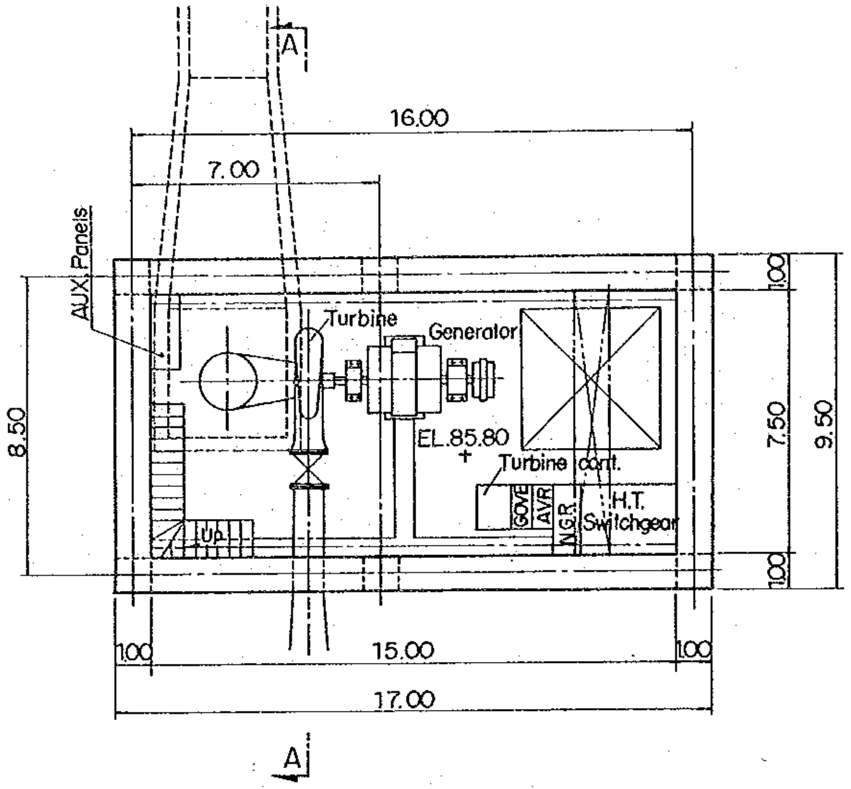
DOWNSTREAM FACE



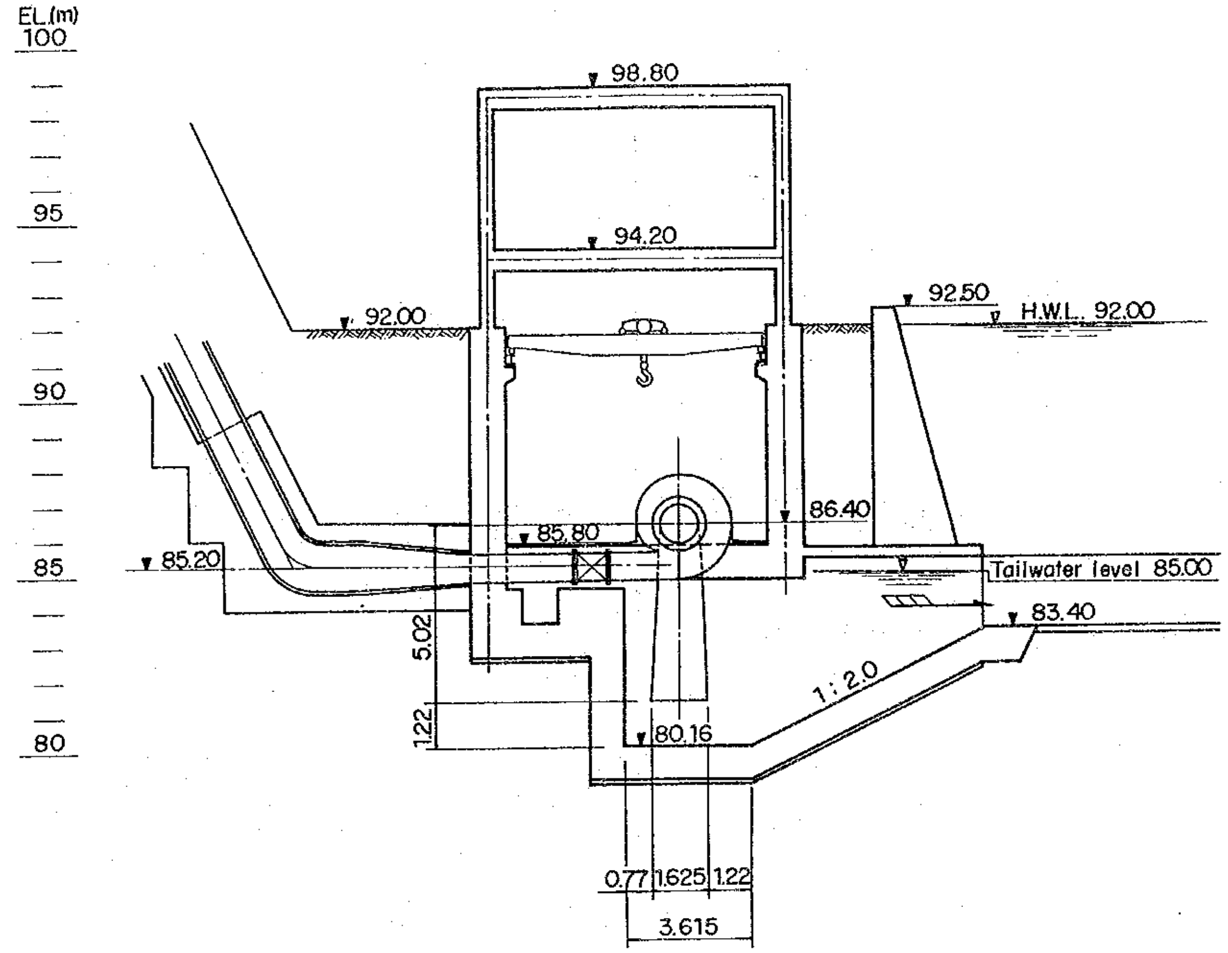
RIO TUBA HYDROPOWER PROJECT Republic of the Philippines
DAM PLAN, TYPICAL SECTION, DOWNSTREAM FACE
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG.NO. SHEET OF

FIG. 4-4

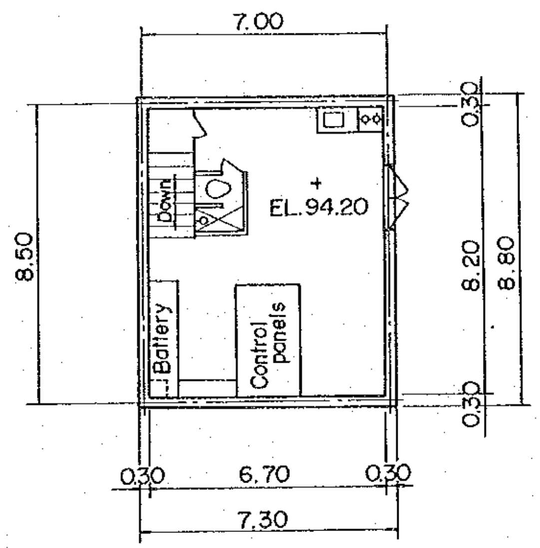
TURBINE & GENERATOR PLAN



SECTION A – A



CONTROL ROOM PLAN



RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

POWERHOUSE
PLAN, TYPICAL SECTION

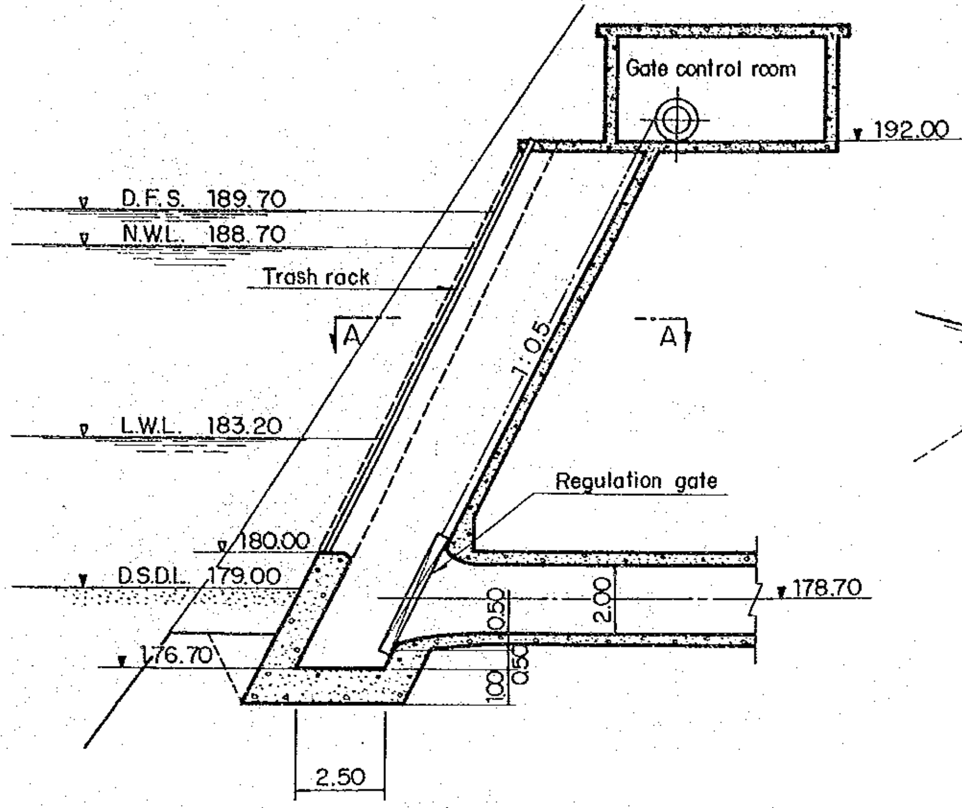
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG.NO. SHEET OF

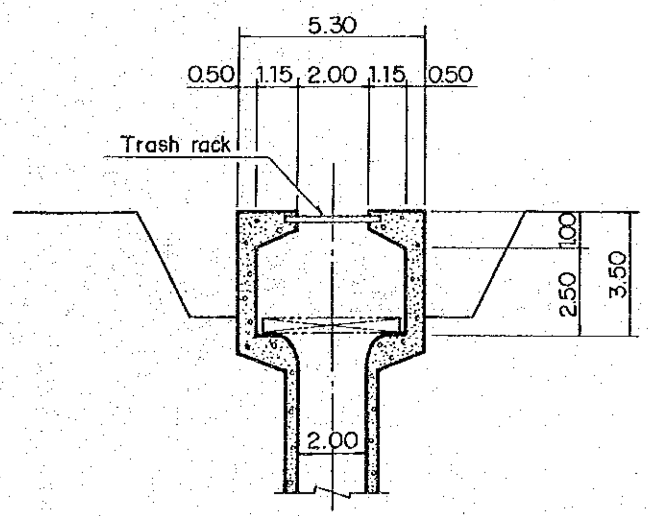
FIG. 4-5

INTAKE DETAIL

PROFILE

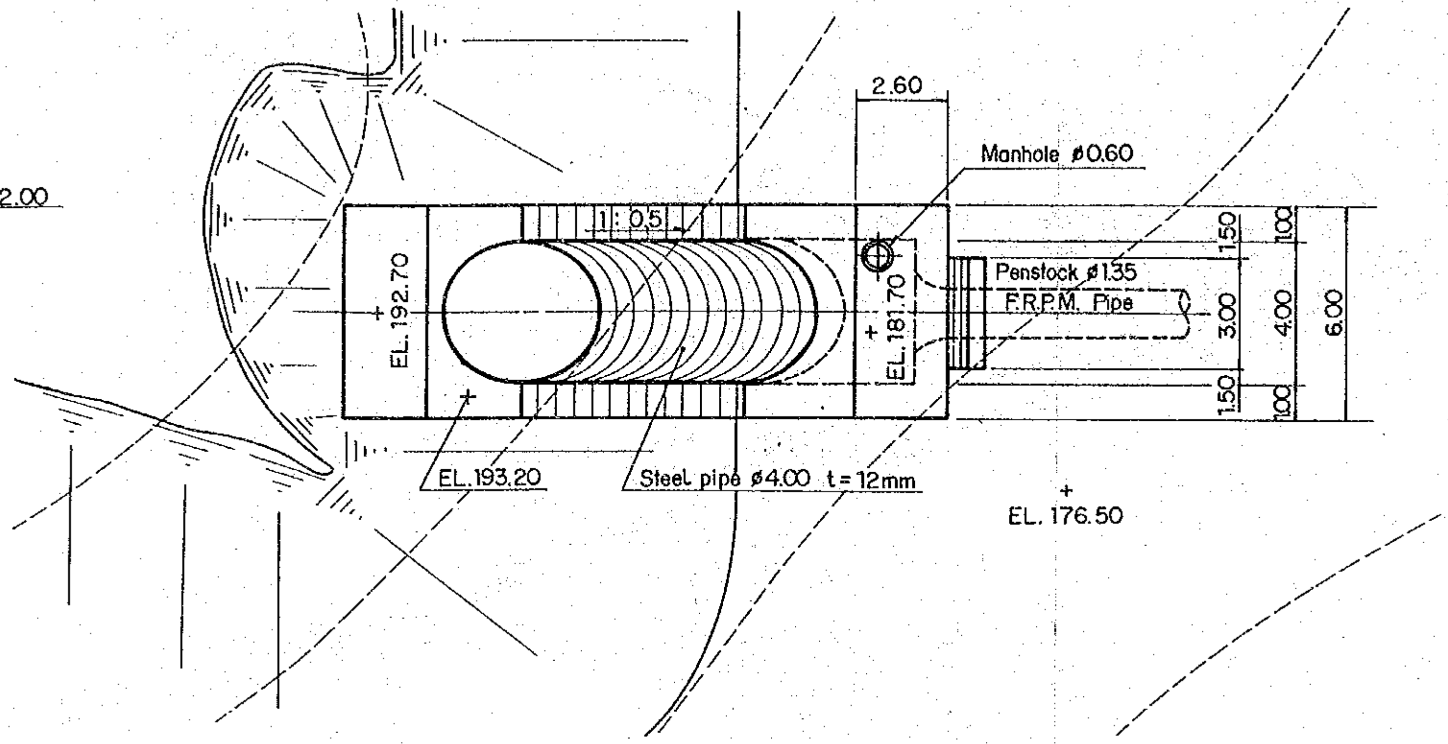


SECTION A — A

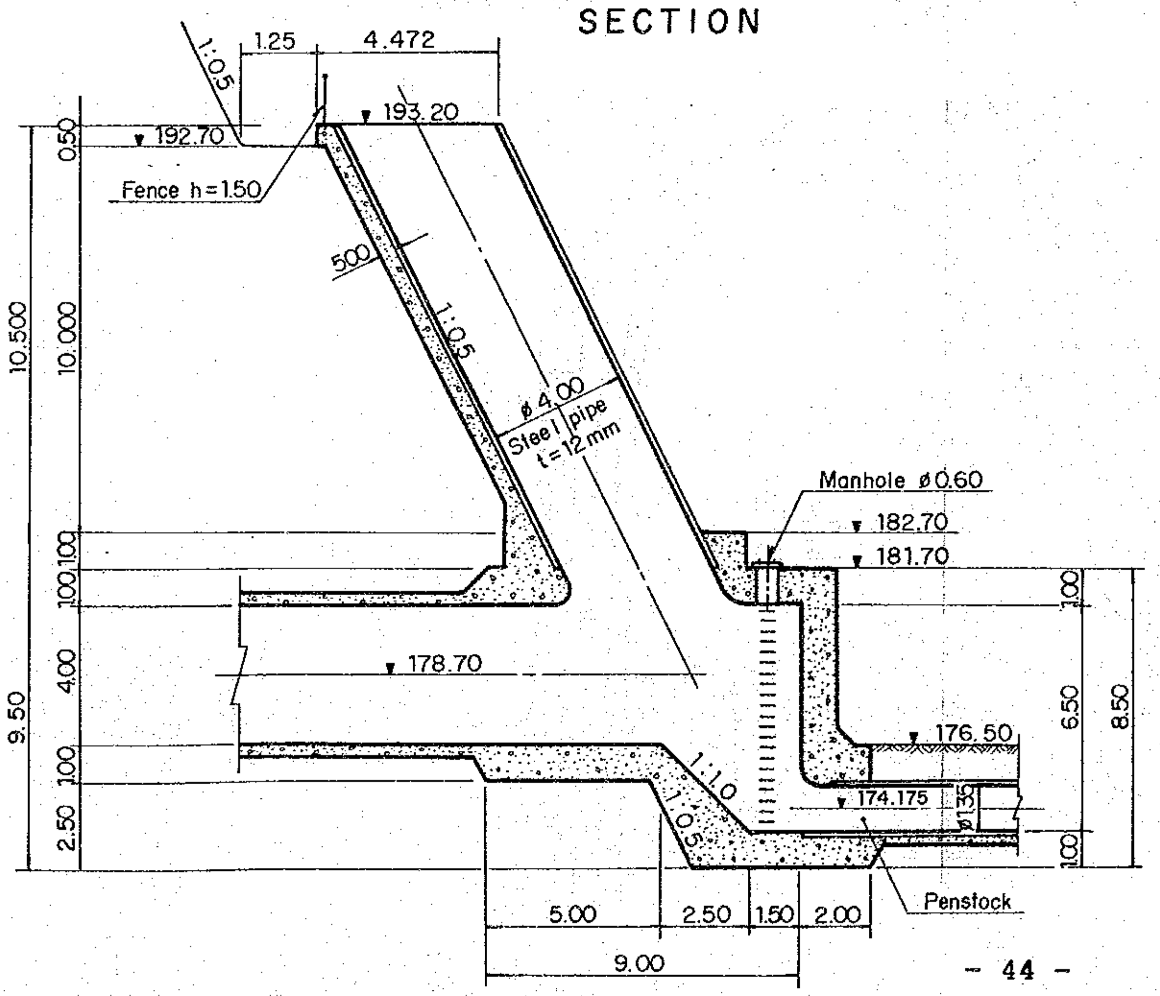


SURGE TANK DETAIL

PLAN



SECTION



RIO TUBA HYDROPOWER PROJECT Republic of the Philippines
INTAKE & SURGE TANK STRUCTURAL DETAIL
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG.NO. SHEET OF

FIG. 4-6

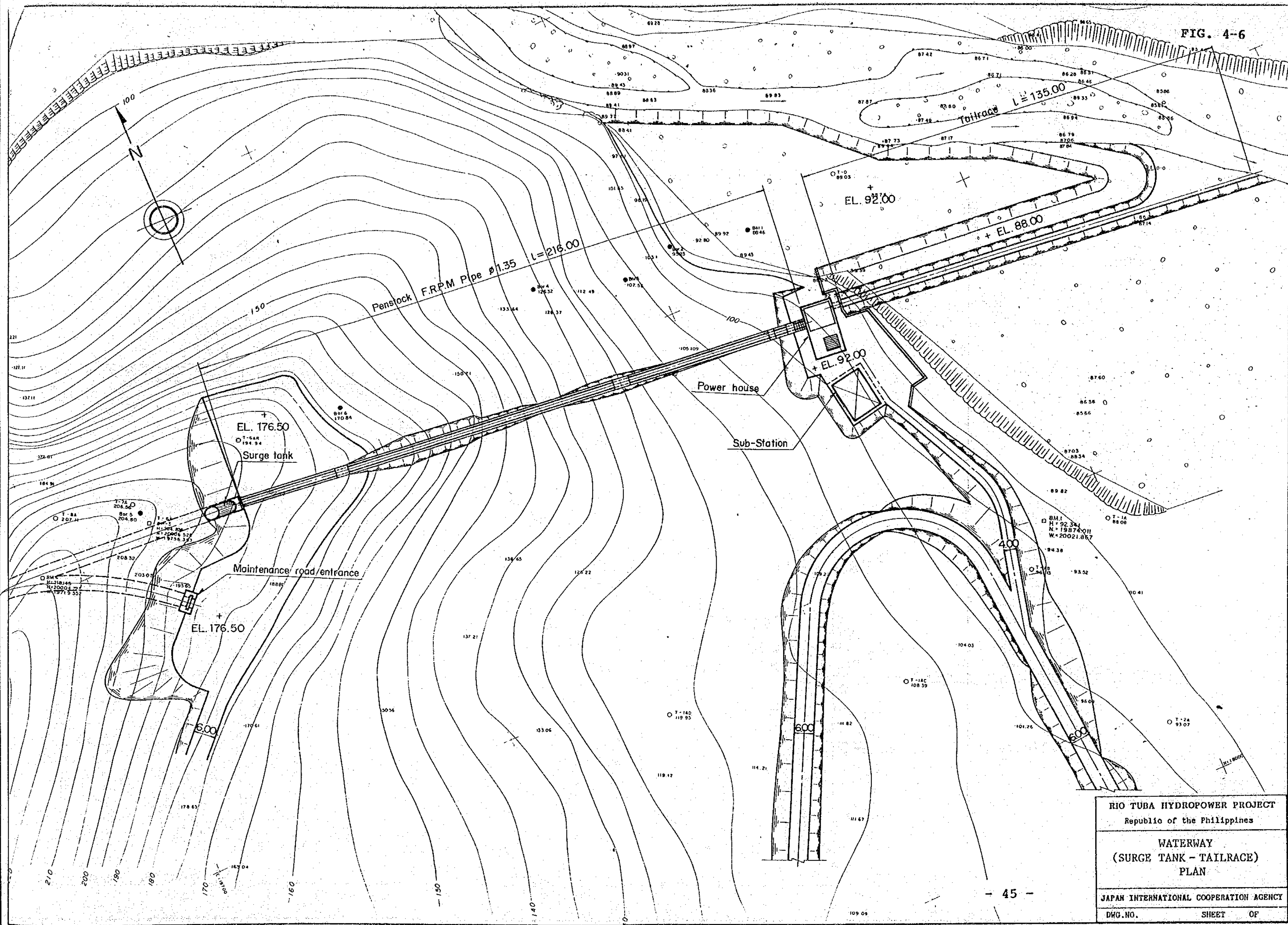
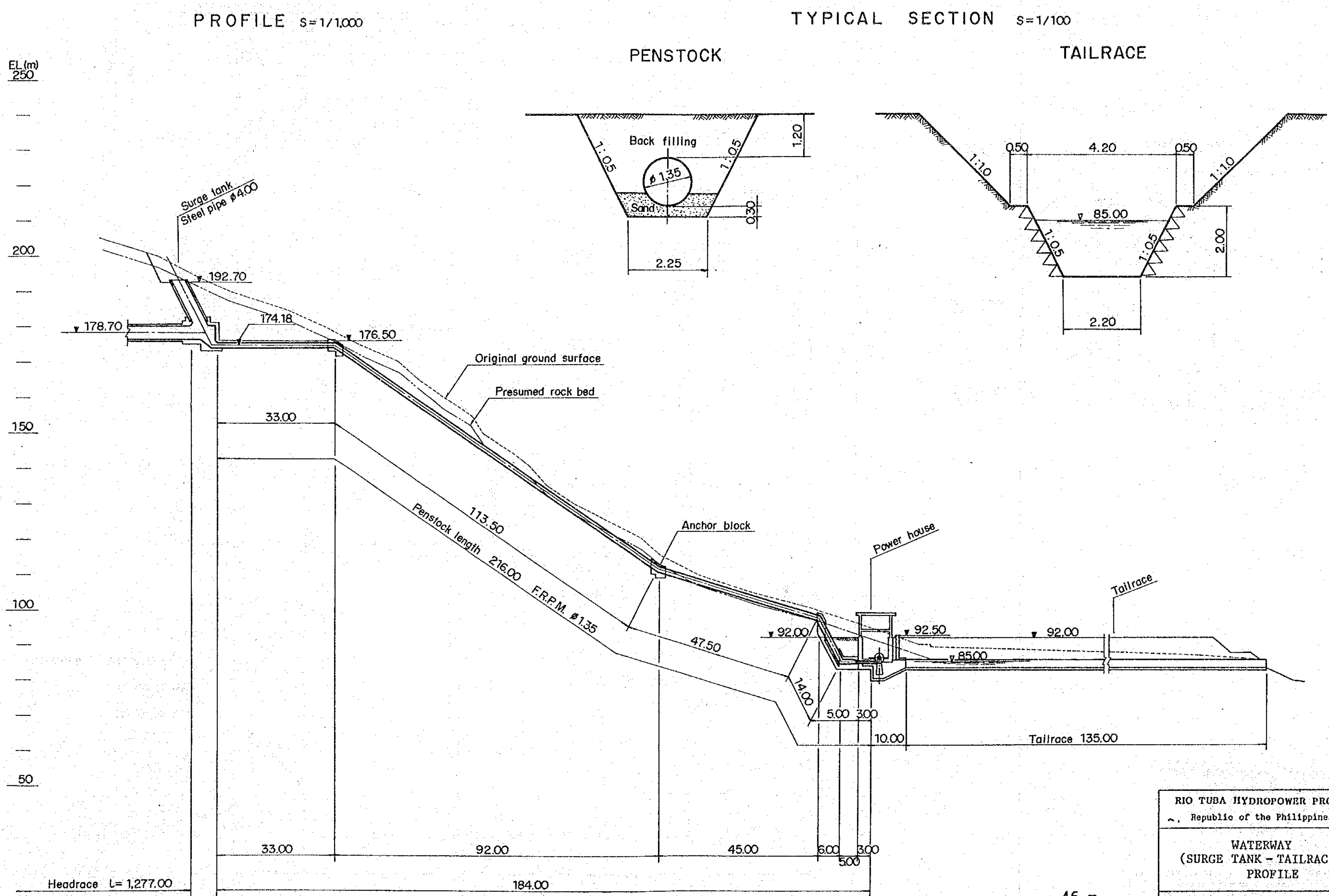

Penstock F.R.P.M Pipe ø1.35 L=216.00
Tailrace L=135.00
EL. 92.00
+ EL. 88.00
EL. 176.50
Surge tank
Power house
Sub-Station
Maintenance road/entrance
EL. 176.50
N
BM.1
RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines
WATERWAY
(SURGE TANK - TAILRACE)
PLAN
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG.NO.
SHEET
OF

FIG. 4-7



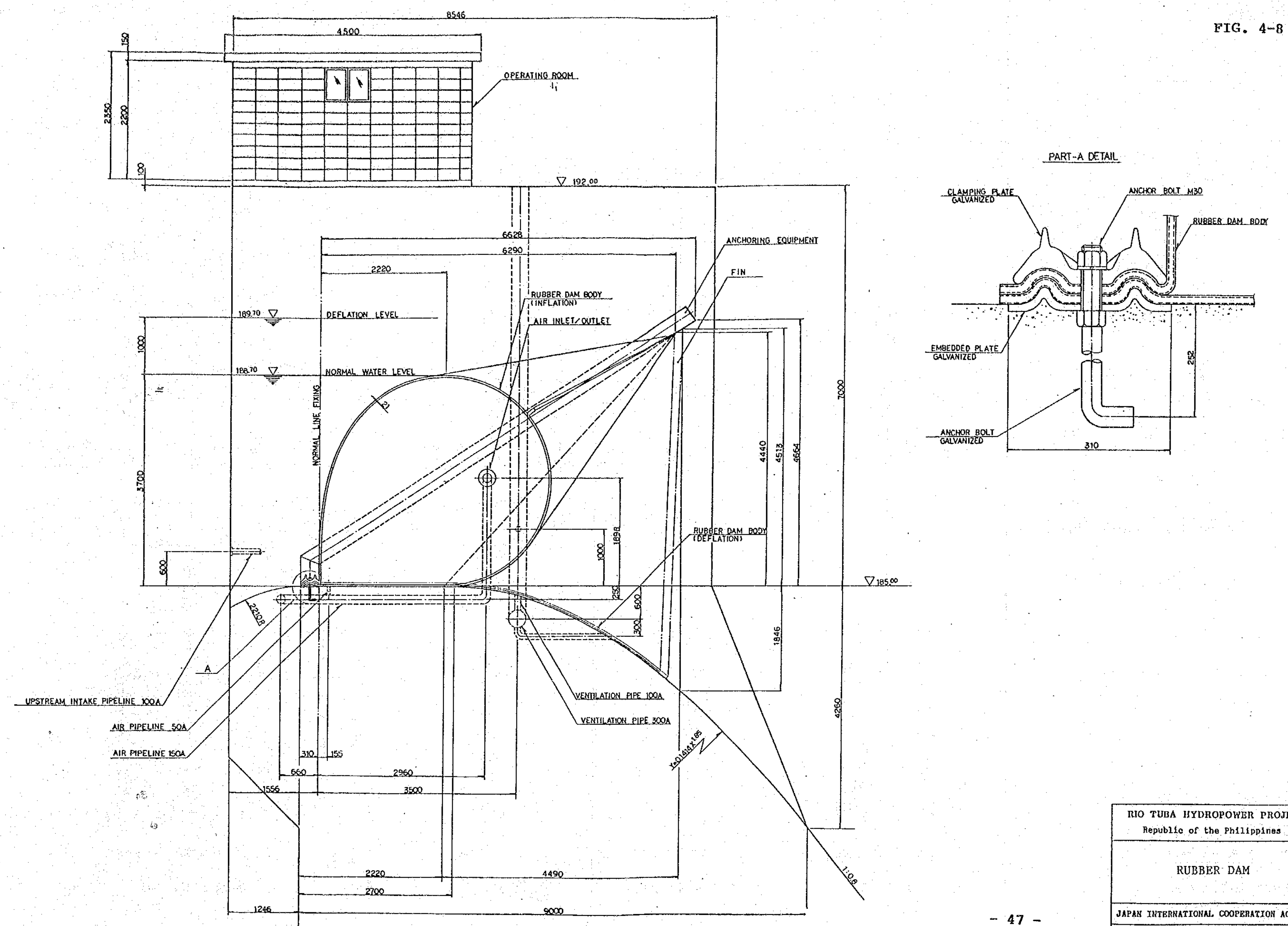
RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

WATERWAY
(SURGE TANK - TAILRACE)
PROFILE

JAPAN INTERNATIONAL COOPERATION AGENCY

DWG.NO. SHEET OF

FIG. 4-8



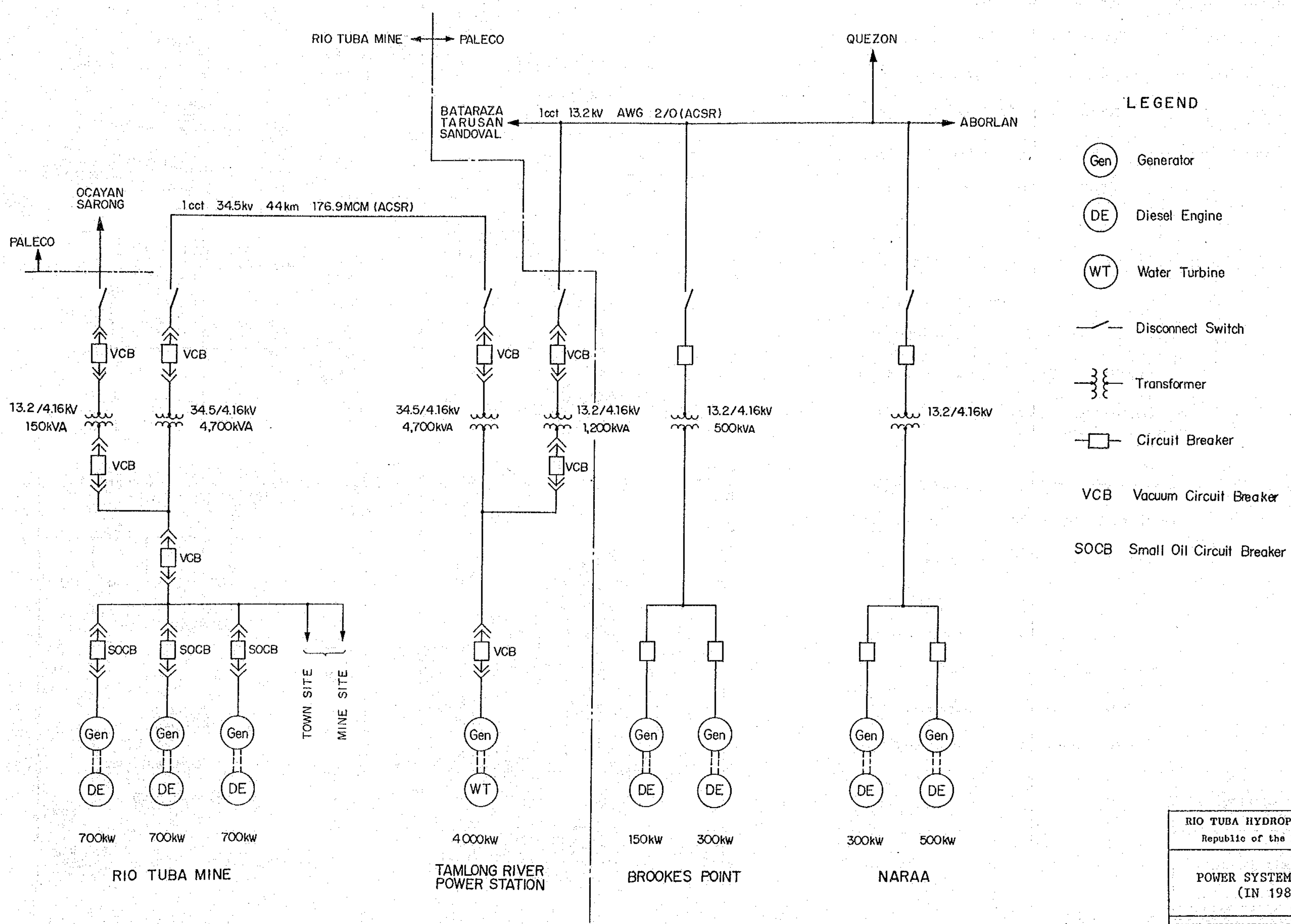
RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

RUBBER DAM

JAPAN INTERNATIONAL COOPERATION AGENCY

DWG.NO. SHEET OF

FIG. 4-9

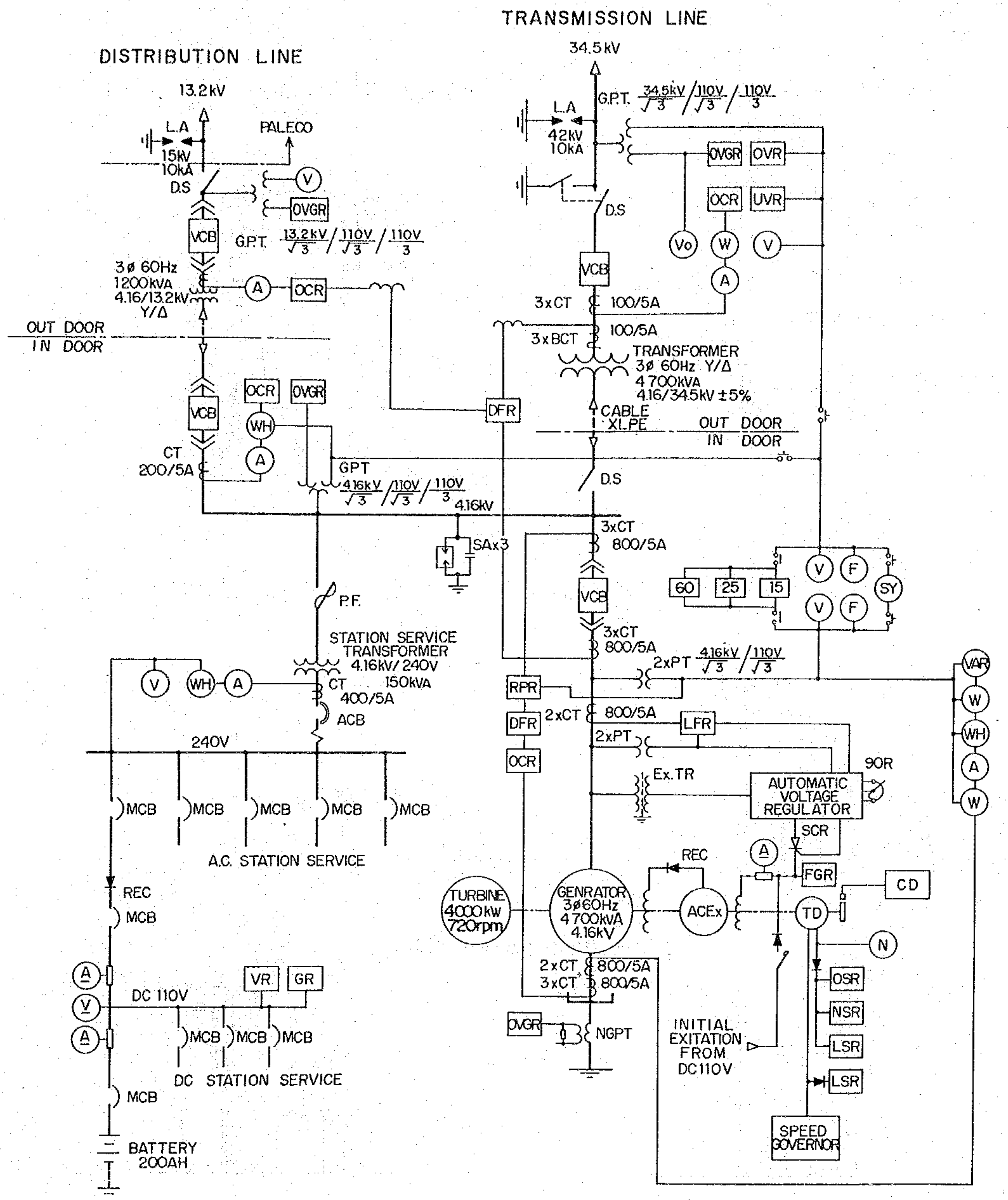


RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

POWER SYSTEM DIAGRAM
(IN 1988)

JAPAN INTERNATIONAL COOPERATION AGENCY
DWG.NO. SHEET OF

FIG. 4-10



LEGEND

- OCR Over Current Relay
- OVR Overvoltage Relay
- UVR Undervoltage Relay
- DGR Directional Ground Relay
- DFR Differential Relay
- LFR Loss-of-field Relay
- RPR Reverse Power Relay
- FGR Field Ground Relay
- OVGR Over Voltag Ground Relay
- VR Voltag Relay
- GR Ground Relay
- OSR Over Speed Relay
- NSR Nominal Speed Relay
- LSR Low Speed Relay
- (V) Voltmeter
- (Vo) Grounding Voltmeter
- (A) Ammeter
- (A) D.C. Ammeter
- (V) D.C. Voltmeter
- (F) Frequency meter
- (SY) Synchroscope
- 60 Voltage Matcher
- 15 Speed Matcher
- 25 Synchronizer
- CD Crawling Detector
- (W) Wattmeter
- (WH) Watt-hourmeter
- (VAR) Var-meter
- (N) Speed Meter
- Rectifier
- Shyristor
- Current Transformer
- Potential Transformer
- VCB : Vacuum Circuit Breaker
- CB : Circuit Breaker
- MCB : Molded Circuit Breaker
- DS : Disconnecting Switch
- PF : Power Fuse
- LA : Lightning Arrester
- PT : Potential Transformer
- CT : Current Transformer
- BCT : Bushing Type C.T.
- SA : Surge Absorber
- Ex.TR : Exiting Transformer
- TD : Tachometer Dynamo
- NGPT : Neutral Grounding Potential Transformer
- AC.Ex. : AC Exciter

RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

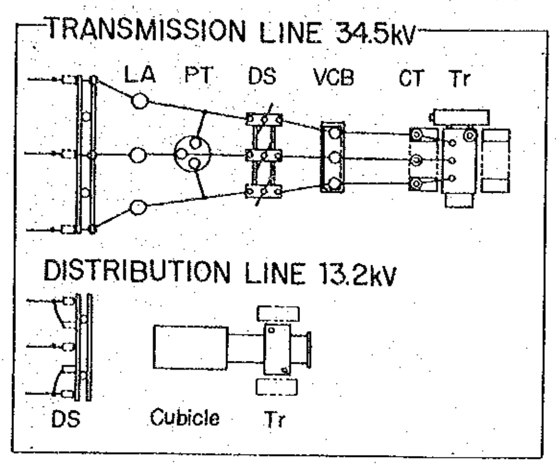
SINGLE LINE DIAGRAM

JAPAN INTERNATIONAL COOPERATION AGENCY

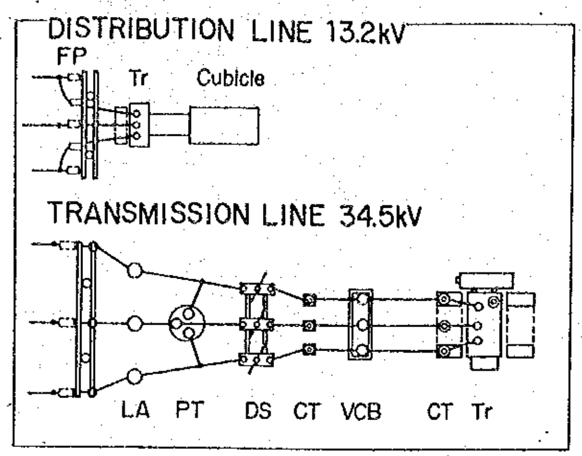
DWG.NO. SHEET OF

FIG. 4-11

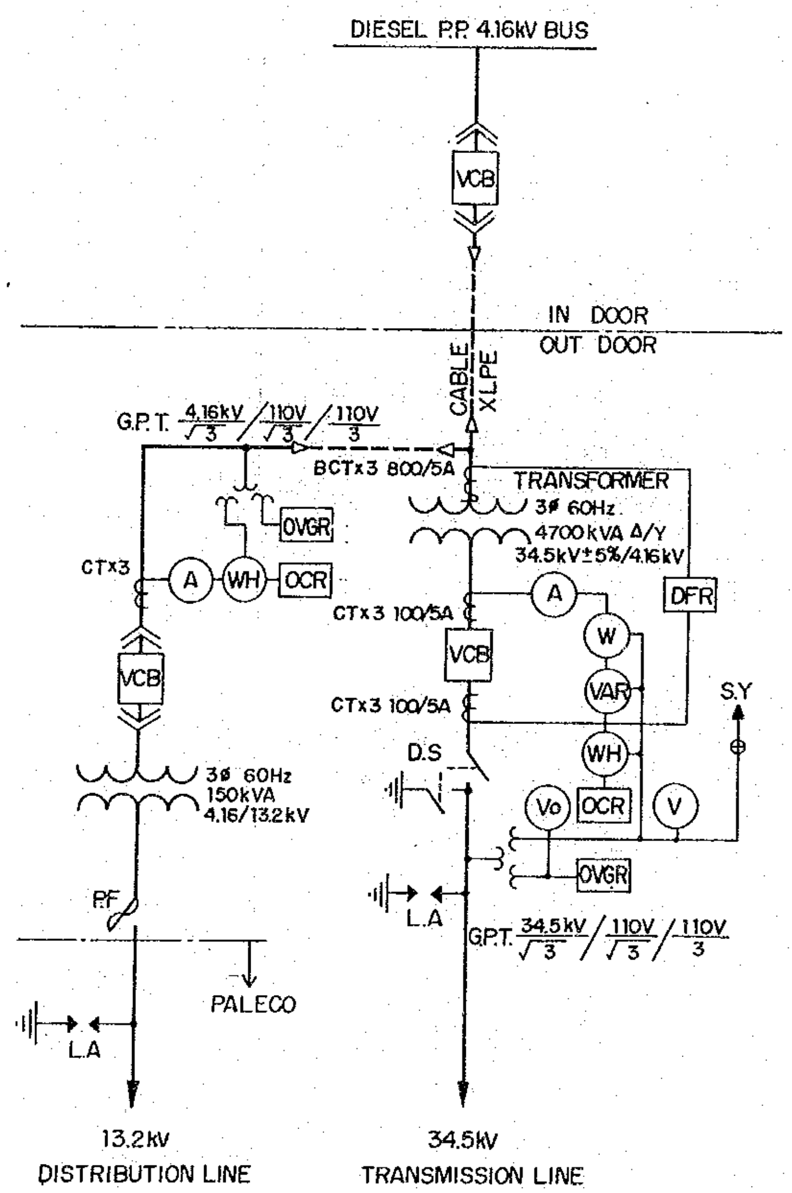
POWER STATION SIDE



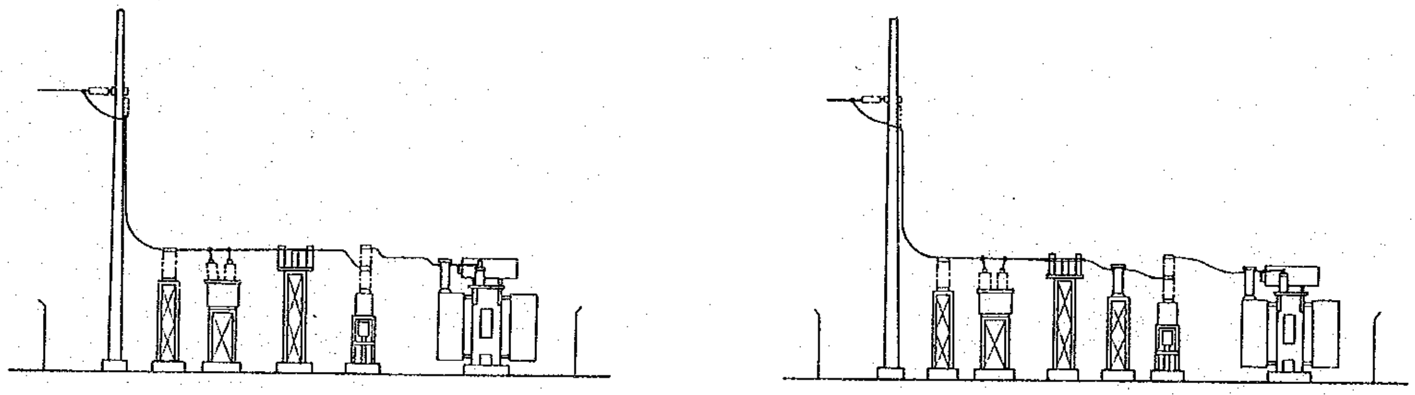
RIO-TUBA MINING SIDE



SINGLE LINE DIAGRAM (RIO-TUBA MINING SIDE)



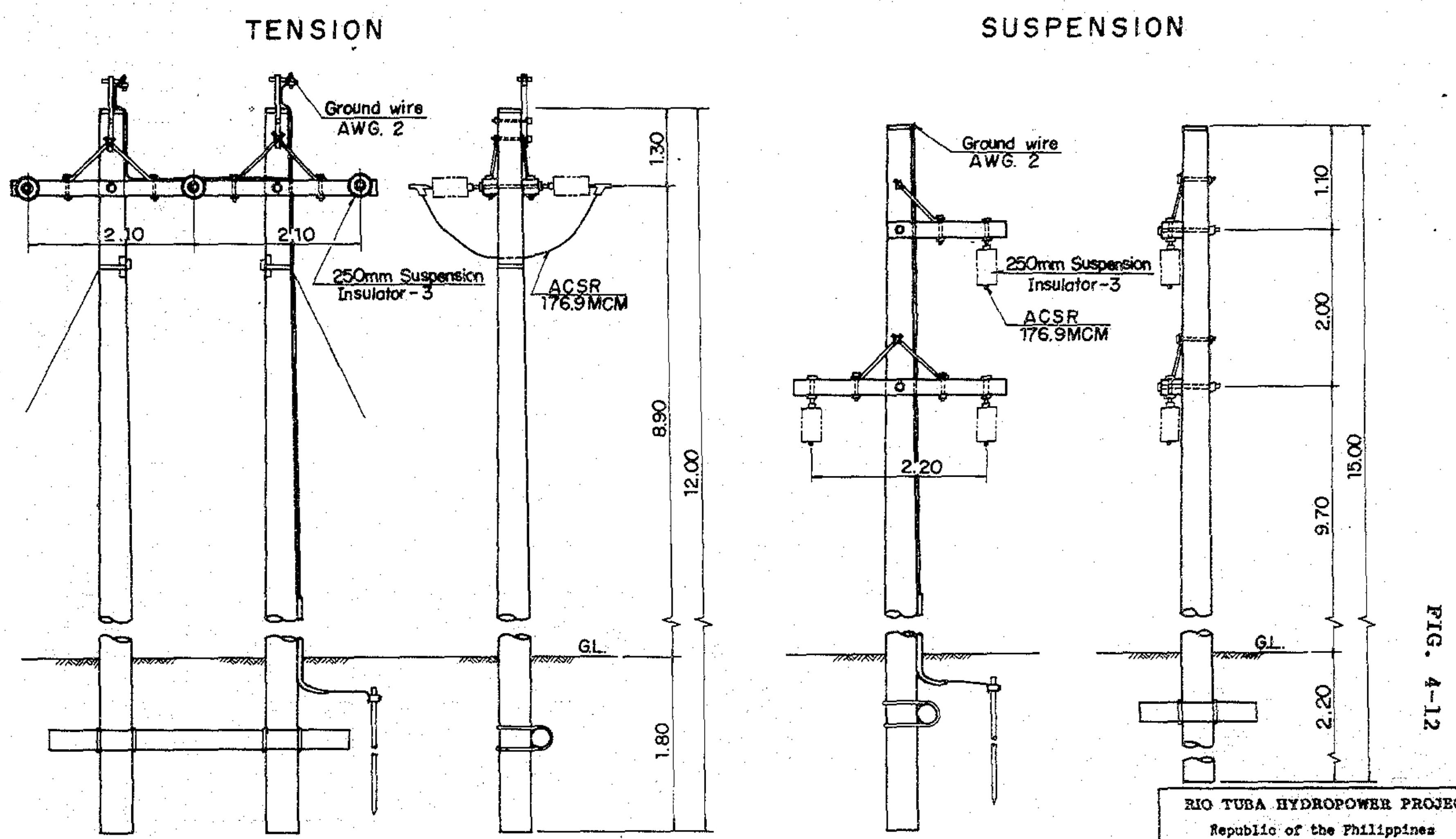
TRANSMISSION LINE 34.5kV



DISTRIBUTION LINE 13.2kV

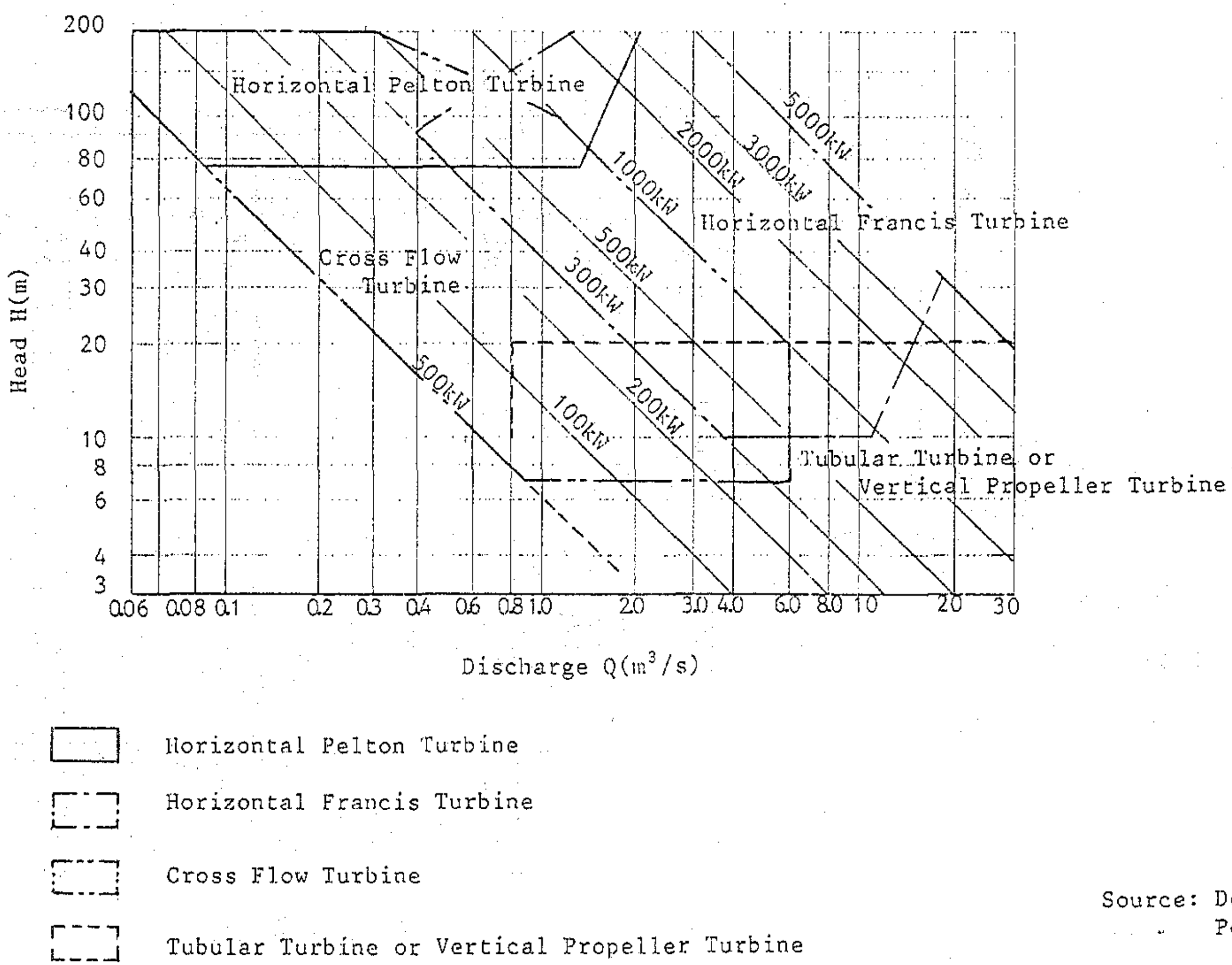
RIO TUBA HYDROPOWER PROJECT Republic of the Philippines
SUBSTATION
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG.NO. SHEET OF

FIG. 4-12



RIO TUBA HYDROPOWER PROJECT Republic of the Philippines	
DETAIL OF POLE DIMENSION & DIAGRAM 34.5KV TRANSMISSION LINE TENSION, SUSPENSION	
JAPAN INTERNATIONAL COOPERATION AGENCY	
DWG.NO.	SHEET OF

FIG. 4-13 **TURBINE TYPE SELECTION CHART**



Source: Design Criteria for Mini-Hydrc Power in Bicol Region, Feb. '8

FIG. 4-14 PERFORMANCE CURVES

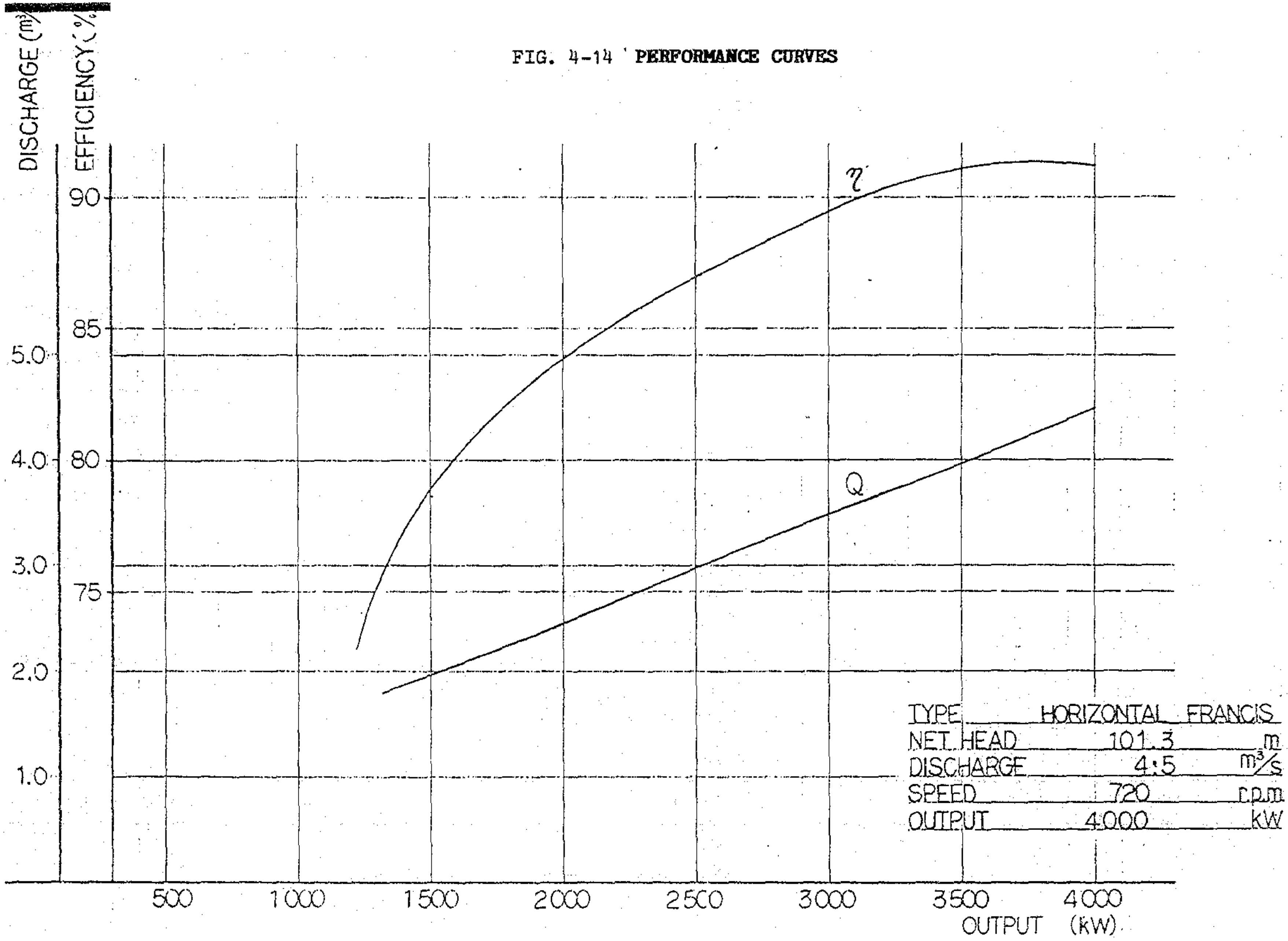


TABLE 4-1 **HEADRACE COMPARISON**

Item	Tunnel	Cut-and-Cover Method
Construction	Width: 4m Height: 4m - used as temporary road during dam construction - gate installed at upper and lower terminus - used as inspection/maintenance road during water shutdown	Width of conduit bed: 6.0mm FRPM pipe: dia 1.50m - embedded pipe, covered with earth fill, the surface to be used as a roadway
Headrace Length (m)	1,500 (including entrance)	1,400
" Excavation (m^3)	22,500	119,000
" Friction Loss (m)	0.20 when, 0.0084xQ=0-4.5m^3/sec	5.9 when 0.2908xQ=0=4.5m^3/sec
Effective Head (m)	101.3	95.6
Generation Capacity MWH	20,510	$20,510 \times \frac{95.6}{101.3} = 19,360$
Direct Construction Cost (¥)	313,000 ¥/m=472.8 million	378,000¥/m=529.2 million
Direct Construction Cost for Headrace/Generation Capacity (¥/kWh)	23.2	27.3
Inspection Road	- tunnel may be used as access road to dam site during water shutdown; however, no access road exists when power plant is in operation	- surface over bedded conduit may be used as access road

V. CONSTRUCTION PROCEDURES AND COST ESTIMATE

CHAPTER V CONSTRUCTION PROCEDURES AND COST ESTIMATE

5.1 Construction Procedures

The construction works of this Project consist mainly of civil works including the dam and represents large scale development on the island. In consideration of the steep terrain of the proposed construction site and the resultant scale and complexity of civil works, 28 months was allotted for the construction period (TABLE 5-1). The major portion of the said period isdevoted to construction of the temporary access road to the dam site which will follow the headrace tunnel route, and dam concrete placing. Both of these activities are key points in the entire construction schedule and accordingly, particular attention will be given to the same. Construction facilities, materials, etc. required for tunnel excavation will be lifted in by helicopter as far as the central tunnel portal and, when necessary, certain tasks will be performed in 2 shifts to ensure smooth work progress. The overall tentative facilities for the construction works is presented as FIG. 5-1. Detailed description of the principal activities is given hereunder.

5.1.1 Dam Construction

Construction of temporary cofferdams and temporary diversion conduits, excavation of the riverbed and concrete placing work will all be undertaken during the dry season. As the maximum flow discharge in dry season is estimated at about $4.0m^3$/sec, a corrugated conduit (inner dia:1,350mm) will be installed on the right bank for temporary drainage. During concrete placing river flow will be diverted through a temporary by-pass in the dam (1.5m x 2.0m) which will be closed upon completion of concrete work.

The cofferdam consists of a primary cofferdam made from riverbed deposits and a secondary concrete cofferdam located inside the former. An impervious clayey material from the right bank will be used as a blanket for the primary cofferdam.

Main temporary facilities required for concrete placing will be installed so as to be operational within 3 months after tunneling has been accomplished. During the above 3-month interval, foundation excavation works and river diversion works will be undertaken, upon completion of which concrete placing will occur. A total of approximately 17,000m^3 of concrete will be placed by a 4.5 ton tower crane (R=20m) with a 1.0m^3 bucket at an average daily rate of 200m^3 for an average 11 days per month, covering a total period of about 9 months.

5.1.2 Headrace Construction

As the headrace tunnel will be used during dam construction as a transportation road, progress of headrace construction must procede according to a strict schedule. To facilitate construction, an additional portal will be installed mid-way along the tunnel and equipment and materials required will be transported by helicopter to a heliport set-up in the vicinity of the same.

All tunnel excavation from the portal near the head tank and the central portal will be performed in the upstream direction at a rate of 150m per month. For the 14.28m^2 excavation area, a hydraulic jumbo will be used for rock drilling and blasting, while a RS-85 rock shovel and an 8 ton diesel locomotive will be used for transportation of the excavated materials.

The 175.0m of the tunnel length which will not be used as a construction road (excavation area:5.58m^2) will be excavated after the completion of the construction road.

5.1.3 Waterways and Powerhouse

Construction of waterways other than the headrace and of the powerhouse will be completed during the dam construction period. Equipment for the same consists mainly of earthwork machinery to be appropriated from headrace and dam construction. Concrete work equipment, etc. for the dam and headrace will also be used in common for powerhouse and waterway construction.

5.1.4 Construction Equipment

The main equipment for dam construction is as follows:

Equipment	Specifications	No. of Units
Crawler Drill	$10m^3$/min air consumption	5
Leg Drill	$3m^3$/min air consumption	16
Coal Pick Hammer	$1m^3$/min air consumption	16
Bull Dozer	11t	5
Backhoe	$0.4m^3$ bucket capacity	5
Breaker	800kg	2
Dump Truck	11t	9
Compressor	$7m^3$/min.	8
Compressor	$10.5m^3$/min.	9
Truck Mixer	$4.5m^3$	5
Concrete Pump	$30-35m^3$/Hr	1
Vibrator	Maximum Frequency	8
Vibrator	Rod-Type	5
Cycle Converter		1
Belt Conveyor	Portable ℓ=5.0m	4
Belt Conveyor	B=600 ℓ=150m	1
Aggregate Plant	60t/h	1
Batch Plant	$1.0m^3$ x 2 units	1
Cart	$1.0m^3$ x 2 units	1
Locomotive	8t	1
Bucket	$1.0m^3$	3
Tower Crane	R=30m, 4.5t	3
Power Generator	125KVA	9
Grouting Machine		1
Conduits	ϕ125-ϕ200	1

The main equipment for tunnel construction is as follows:

1) Surface

Equipment	Use	No. of Units
Portable Compressor 100Hp	Rock shovel	2
5-Step Turbine Pump 75kw	Drilling	2

Equipment	Use	No. of Units
Fan ø800 22kw	Ventilation	2
D4-class Bull Dozer	Disposal of excavated material	2
Car Dumper 4.5m^3	Earth extraction	2
Water Tank 5m^3	Turbine pump	2
Truck 2t	Light on-site transport	2
Generator 180kVA	Jumbo motor	2
Mobile Crane 13t	Rail shipping	2

2) Tunnel

Hydraulic 3-boom Jumbo	Rock drilling	2
Rock Shovel 0.4m^3	Slag loading	2
Granby 4.5m^3	Slag transport	1.6
Diesel Locomotive 8t	Slag transport	2
Cherry Picker	Shift of steel car	2
Leg Drill 3m^3/min	Rock trimming	2
Coal Pick Hammer 1m^3/min	Rock trimming	4

Main materials required are as follows:

Material	Specifications	Quantity
Cement	Ordinary	4,500t
Steel	Deformed bar	400t
Rubber Dam	H 3.7m, L 25m	1 no
Gate	2.5m-3.5m	3 no
FRPM Pipe	D 1.35m	300m
Turbine-Generator	4,000kW	1 unit
Control Panel		1 lot
Substation and Transmission Line Facility		1 lot

5.1.5 Concrete Aggregate

Total concrete volume is approximately 21,000m^3 including 17,000m^3 for the dam, and the volume of aggregate required for the same is about 30,000m^3. Possible aggregate borrow sites include the tunnel excavation site, the riverbed upstream from the dam site, the area downstream from the powerhouse, and the mountains in the area. Of these, use of riverbed deposits upstream from the dam is least economical due to the combined deposits of boulders and gravel. The site downstream from the powerhouse on the other hand, has a very small percentage of boulders and will therefore be used as the main aggregate borrow site. The quantity of aggregate at the same is insufficient however, and accordingly any shortage will be compensated by material obtained from tunnel excavation, particularly from the upstream side of the tunnel's central entrance where soil content is less and material is easily obtained.

Good quality fine aggregate can be found in large quantities about 1km from the powerhouse and collection efforts will therefore be concentrated at the same. As aggregate obtained from the riverbed, mountains and tunnel site will vary in size, a crushing plant has been planned at the site downstream from the powerhouse to sort necessary aggregate size.

5.1.6 Power Supply

As supply of electricity for construction works is not possible from the existing power system (Refer to Chapter III & IV) all power will be supplied by diesel generators while air will be supplied by portable compressors. Capacity and number of generator units required are as follows:

- Dam Site	125kVA x 5 units
- Powerhouse Site	125kVA x 4 units
- Total	125kVA x 9 units

5.1.7 Transportation Plan

The largest and heaviest piece of equipment to be shipped from Japan under the present Project is the main transformer, with a height of 4.3m, a width of 3.5m, a depth of 3.8m and a weight of 13.5 tons. Puerto Princessa, which has port facilities, and Brookes Point were both considered as possible unloading sites. Puerto Princessa, however, is 200km from the Project site on the Tamlang River and inland transportation would thus be difficult, while port facilities at Brookes Point, although presently undergoing improvement to allow side docking of 1,000 ton vessels, are inadequate.

About 9km south of the powerhouse site is Salogon, a village located where heavy equipment is hauled overland. A road 4m in width extends from the seacoast to the national highway, about 2km away. Although the width is fairly narrow, the said road is completely straight and level, sufficient for passage of a large truck. The powerhouse site is 7km from the junction of the seacost road and the national highway, resulting in a total combined length of 9km. Overland shipping from Salogon is therefore recommended and also the Rio Tuba Mine's pier which is used for ore shipment may be used for unloading. As the sea around eastern Palawan Island can become quite rough during the dry season hindering shipping and unloading, heavy equipment will be shipped during the rainy season.

In addition to the road from the powerhouse to the surge tank, a construction road will be constructed at the dam site for on-site transportation. The majority of dam construction materials will be transported along the headrace tunnel while tunnel materials will be carried in by helicopter.

5.2 Cost Estimate

5.2.1 Preconditions

Construction cost was estimated according to the following preconditions:

a) Cost estimate was based on construction procedure natural conditions at the proposed site, construction scale, technical standards, etc.

b) The estimated scope covered all construction work, including dam, waterways, powerhouse, civil works and electrical facilities, transmission lines from the Rio Tuba Mine and related transformer facilities.

c) Estimates of the amount of construction work were based on basic plan drawings.

d) The majority of construction equipment, engineering equipment and main materials will be imported from foreign countries.

e) Generator, transmission, and transformer machines will be designed, manufactured and supplied by foreign countries.

f) Unit construction costs were estimated from Philippine domestic prices and Japan domestic prices of March 1984 with an exchange rate of ₱1/¥16.6.

g) Estimated cost of consulting services includes cost of detailed implementation design and construction supervision.

h) Physical contingency was calculated as approximately 15% of direct construction cost.

i) Price escalation during construction was estimated according to construction schedule and expenditure schedule.

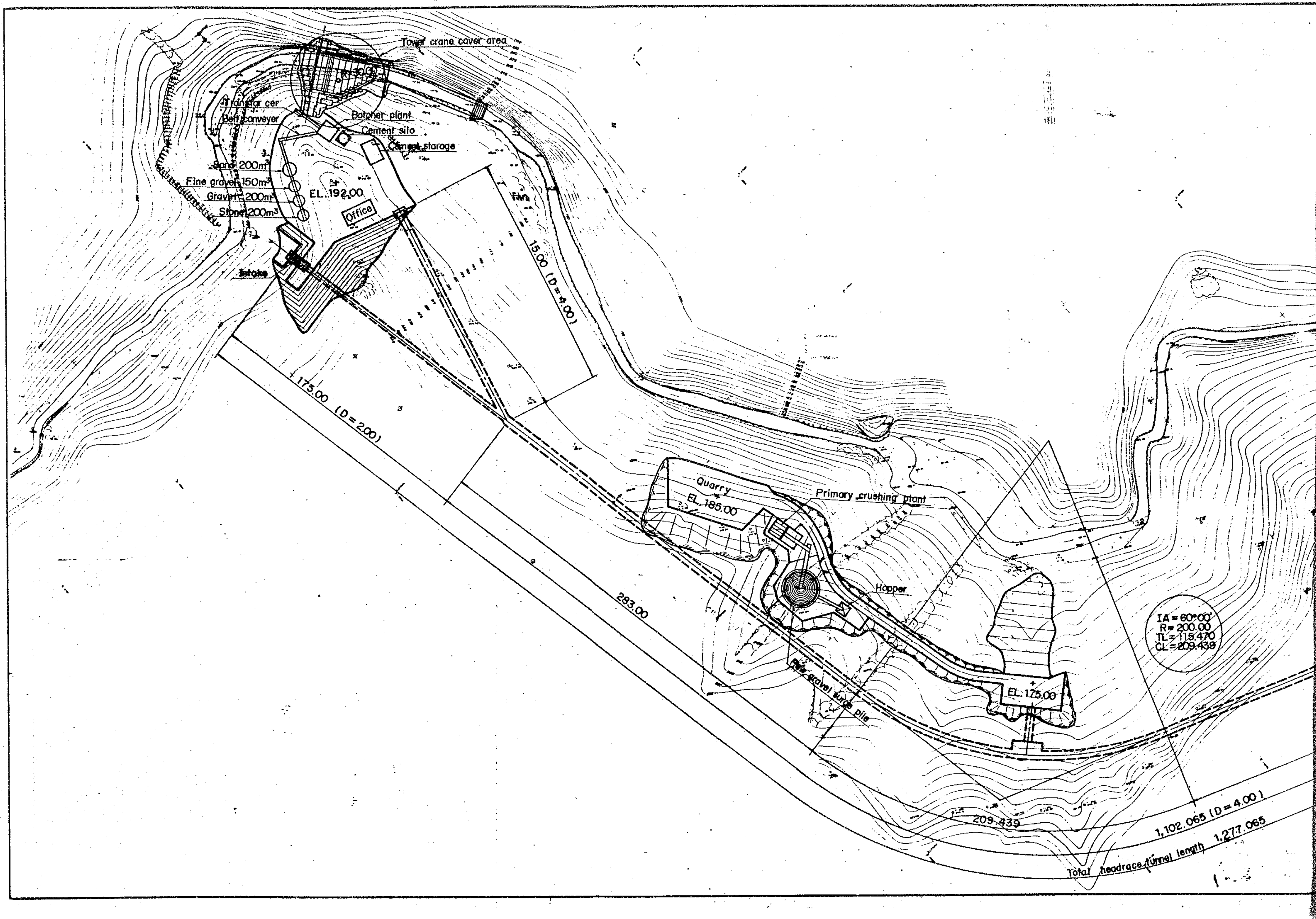
5.2.2 Cost Estimate and Expenditure Schedule

Estimated costs are as given below while expenditure schedule is presented in the subsequent table.

		Million Yen
1.	Civil Works Cost	
	Dam	1,333.7
	Intake	70.3
	Headrace Tunnel	737.4
	Surge Tank	93.6
	Penstock	63.9
	Tailrace	65.5
	Powerhouse (building, equipment foundation)	293.7
2.	Electrical Facilities	
	Powerhouse Equipment (turbine, generator, etc.)	448.0
	Transmission Lines	168.0
3.	Consulting Services	300.0
4.	Physical Contingency (including land compensation)	278.7
5.	Price Escalation	181.3
	Total	4,031.3

million yen

Expenditure Schedule					
Year / Item & Cost	1	2	3	4	Total
Civil Works	1,030.4	1,174.0	159.9	294.0	2,658.3
Electrical Facilities	44.8	358.4	-	44.8	448.0
Transmission Lines	16.5	132.0	-	16.5	165.0
Physical Contingency	67.6	184.0	25.1	-	278.7
Consulting Services	120.0	120.0	60.0	-	300.0
Price Escalation	105.7	73.8	1.8	-	181.3
Total	1,387.0	2,042.2	246.8	355.3	4,031.3


Tower crane cover area
Transfer car
Belt conveyer
Batcher plant
Cement silo
Cement storage
Sand 200m³
Fine gravel 150m³
Gravel 200m³
Stone 200m³
EL. 192.00
Office
Intake
Fan
15.00 (D=4.00)
175.00 (D=2.00)
283.00
Quarry
EL. 185.00
Primary crushing plant
Hopper
gravel surge pile
EL. 175.00
IA=60°00'
R=200.00
TL=115.470
CL=209.439
209.439
1,102.065 (D=4.00)
Total headrace tunnel length 1,277.065

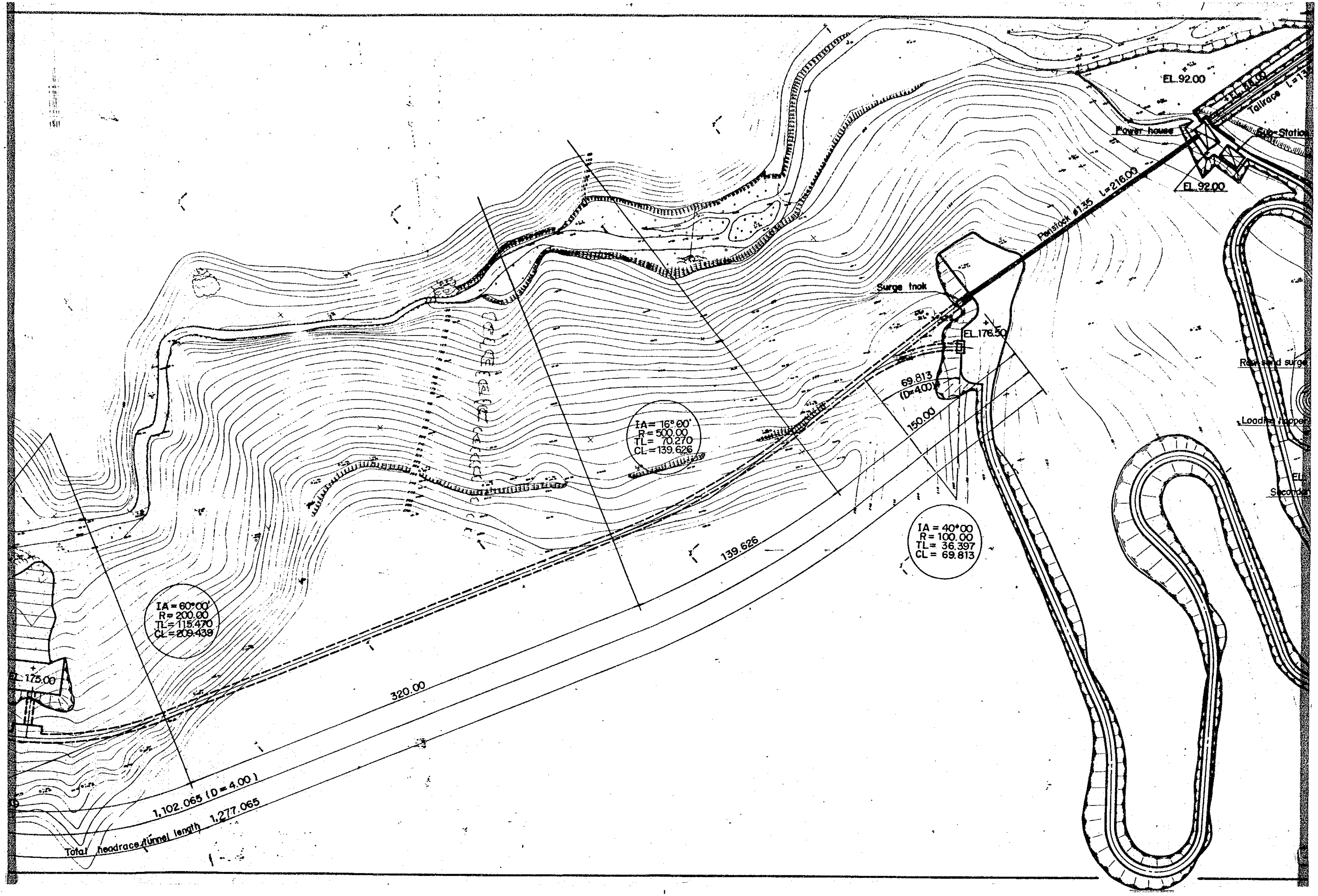
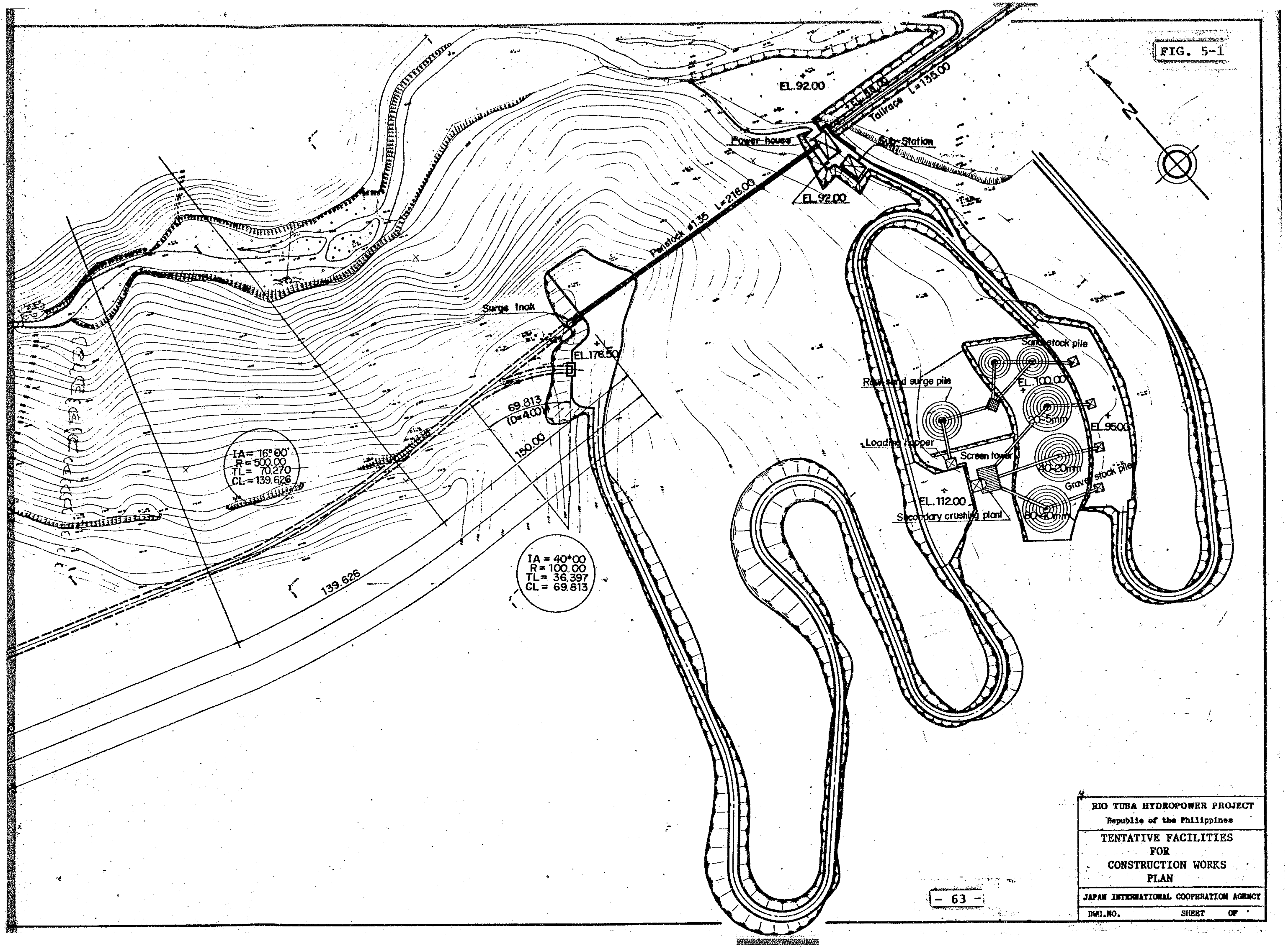

EL.92.00
Tailrace
Power house
EL.92.00
Penstock ø1.35 L=216.00
Surge tnak
EL.176.50
69.813
(D=4.00)
150.00
IA = 16°00'
R = 500.00
TL = 70.270
CL = 139.626
IA = 40°00
R = 100.00
TL = 36.397
CL = 69.813
139.626
IA = 60°00'
R = 200.00
TL = 115.470
CL = 209.439
EL.175.00
320.00
1,102.065 (D = 4.00)
Total headrace tunnel length 1,277.065

FIG. 5-1



RIO TUBA HYDROPOWER PROJECT
Republic of the Philippines

TENTATIVE FACILITIES
FOR
CONSTRUCTION WORKS
PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY

DWG.NO. SHEET OF

Table 5-1 Implementation Schedule

Item	Unit	Amount	1st Year												2nd Year												3rd Year											
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Preparatory Works																																						
Temporary Facilities								Aggregate Plant for Tunneling							Concrete Placing Facilities												Removal											
Civil Works																																						
Tunnel Works	m	1,510																																				
Diversion Works	set	1																																				
Dam	m³	Excavation 6,700 Concrete volume 17,000																									Rubber Dam		Plug Works									
Intake	set	1																																				
Surge Tank	set	1																																				
Penstock	m	180																																				
Tailrace	m	300																																				
Powerhouse	set	1																											Site Development									
Electro-Mechanical Works																																						
Turbine & Generator	set	1	Manufacturing Design								Manufacturing										Transportation					Erection												
Transmission Line & Substation	set	1																																				
Filling Reservoir, Test	set	1																																				
Commissioning																																						
			Dry Season						Rainy Season						Dry Season						Rainy Season						Dry Season						Rainy Season					

JICA