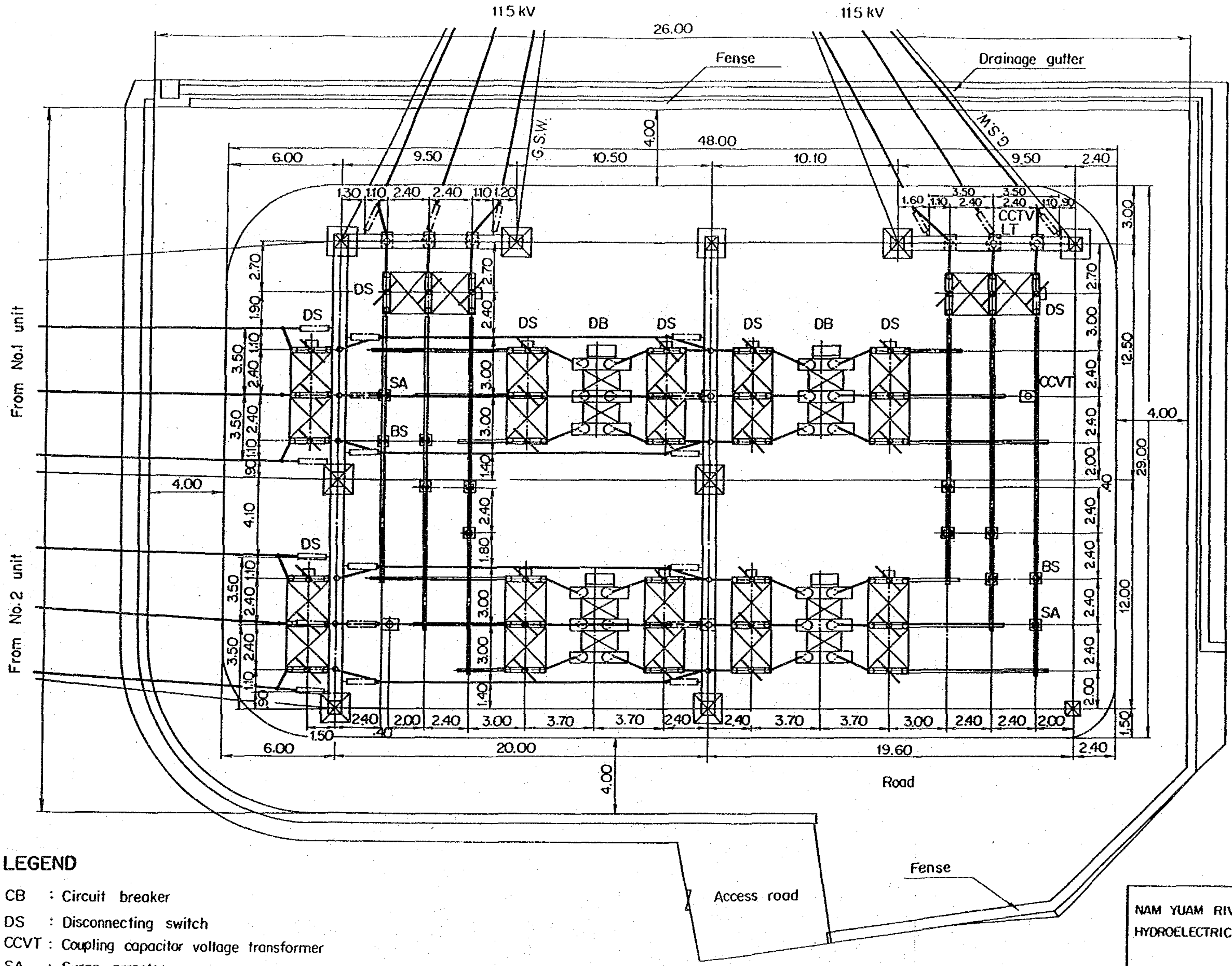


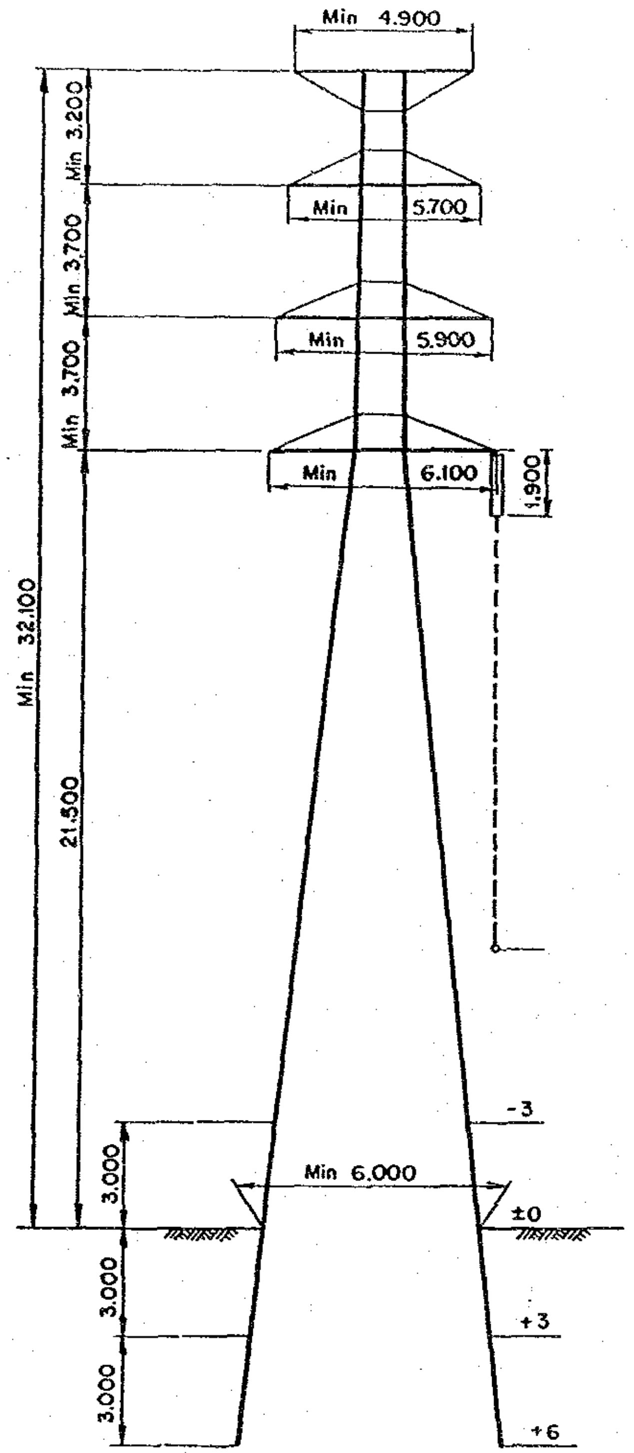
LEGEND

CB : Circuit breaker
DS : Disconnecting switch
CCVT : Coupling capacitor voltage transformer
SA : Surge arrester
BS : Bus support
LT : Line trap

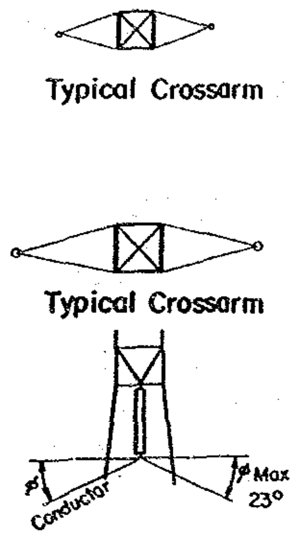
NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT

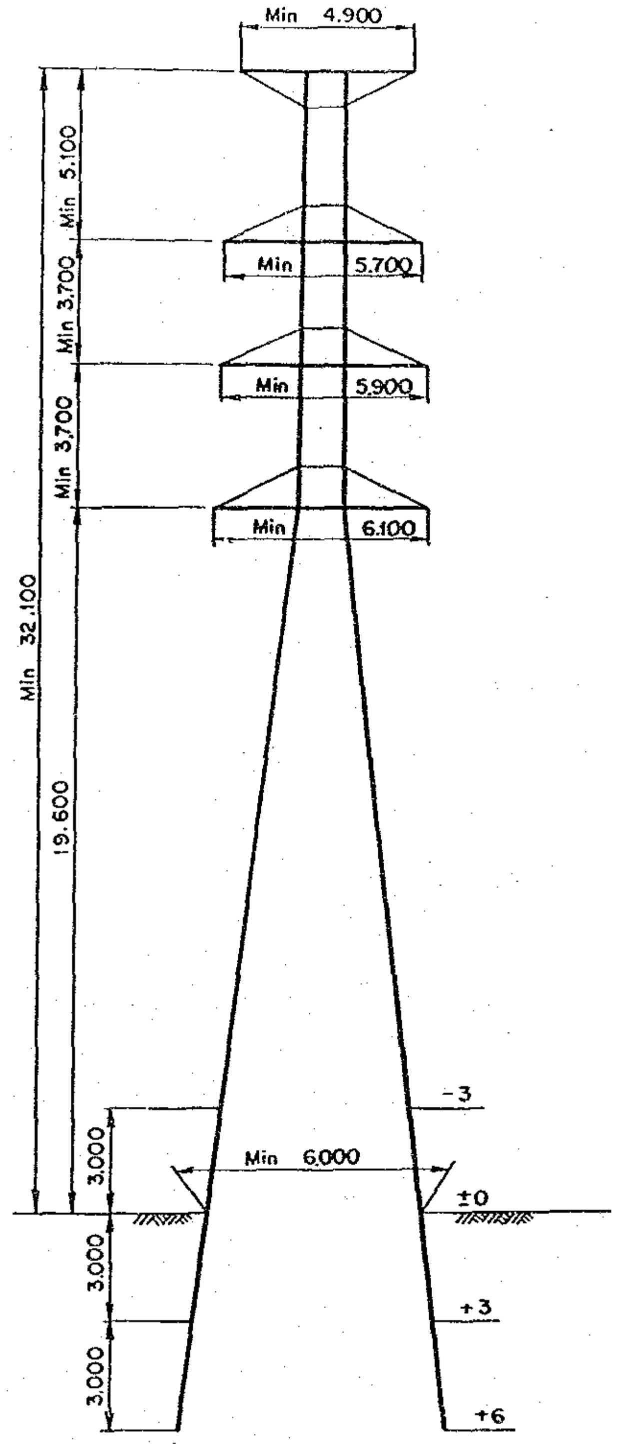
NAM NGAO PROJECT
SWITCHYARD

DWG. 10-9

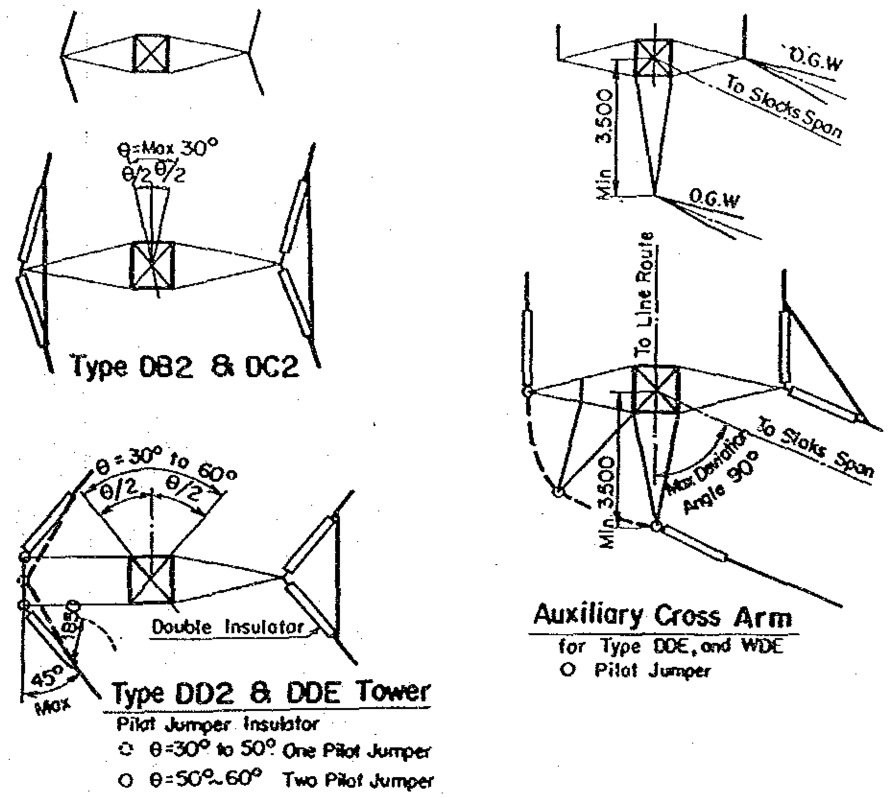


Type DA1 Tower

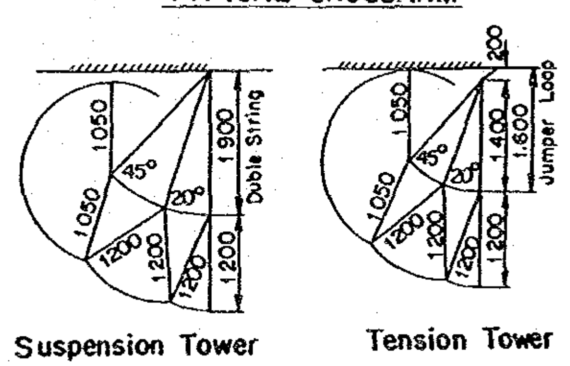




Type DB2 Tower



TYPICAL CROSSARM

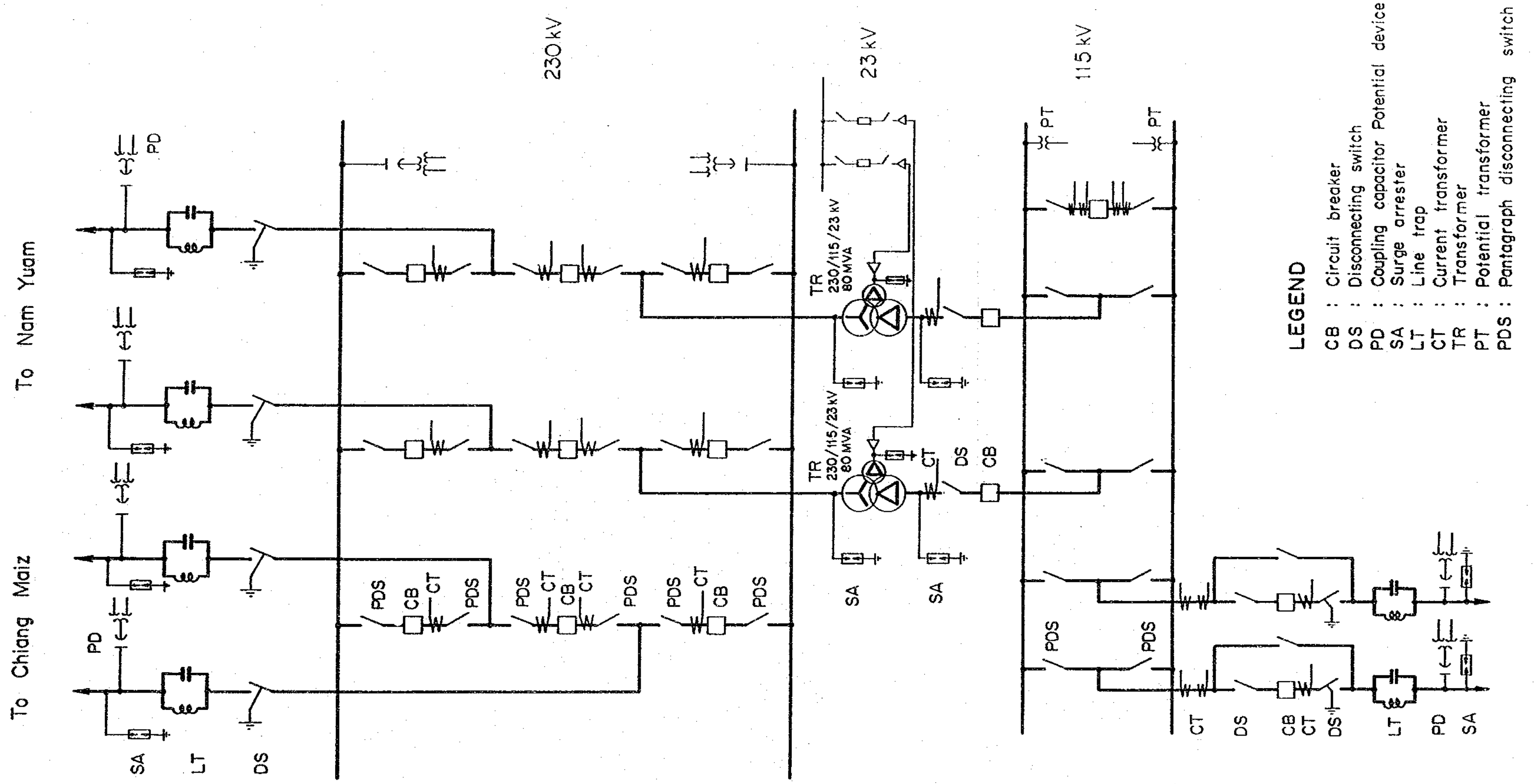


CLEARANCE DIAGRAM (S=1/100)

NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

115kv PRINCIPAL DIMENSION OF TOWER

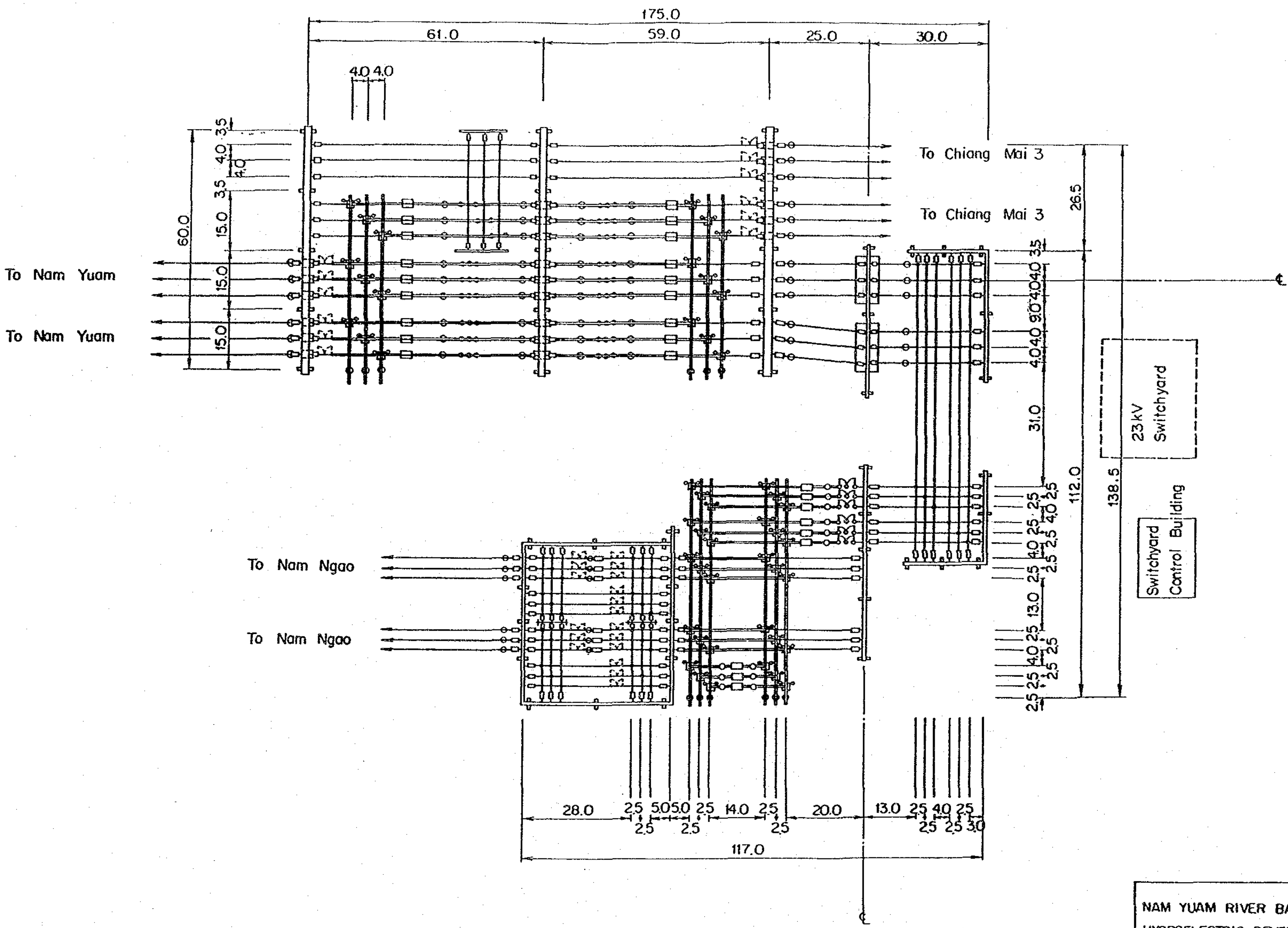
DWG. 10-10



NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE SARIANG SUB STATION
SINGLE LINE DIAGRAM

DWG. 10-11



NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT

MAE SARIANG SUB STATION
GENERAL ARRANGEMENT PLAN

DWG. 10-12

10.2 Mae Lama Luang Project

10.2.1 Dam and Appurtenant Structures

As shown in DWG. 10-13 and 10-14, a rockfill dam with a center core was selected for the dam type of the Mae Lama Luang Project, with the topographical and geological conditions at the dam site taken into consideration. It was determined to locate the spillway on the left bank, considering the layout of the powerhouse.

The design flood of the dam is set at 5,200 m^3/sec based on PMF, and the design flood for diversion facilities is set at 1,780 m^3/sec with a 100-year return period.

(1) Comparison of Dam Types

The most appropriate type of a 120-meter or so high dam at the Mae Lama Luang site was judged from topographical and geological conditions and material availability to be a rockfill dam. There are two types of rockfill dam: a rockfill dam with center clay core (Clay Core Type) and a rockfill dam with concrete facing (Concrete Facing Type).

A comparison study was made of a Clay Core Type and a Concrete Facing Type for the selection of the dam type for the Mae Lama Luang dam. The drawings of the two types of dams are shown in DWG. 10-13, 10-14, 10-15 and 10-16.

The dam volume, excavation volume and estimated related construction cost of each type of dam are shown in the table below:

Comparison of Dam Types

Item	Unit	Clay Core Type	Concrete Facing Type
Dam Volume*	10^3 m^3	3,820	3,300
Excavation Volume	10^3 m^3	650	302
Construction Cost	MB	576	582

* Including upstream coffer dam

Comparing the construction cost of the two types, a significant difference cannot be seen. Therefore, either type is possible for the Mae Lama Luang dam. Since the good quality impervious core, filter and rock materials are available quantitatively in the vicinity of the dam site, a rockfill type with a center core is adopted in this report.

(2) Diversion Facilities

The design flood for the diversion facilities at the Mae Lama Luang site is set at 1,780 m^3/sec with a 100-year return period. A diversion method using tunnels is adopted, taking into account the topography of the site and the layout of the structures. Two diversion tunnels are excavated on the left bank.

A fill type dam is selected for the upstream cofferdam. The cofferdam is economically planned as part of the main dam body at the upstream end.

The crest elevation of the upstream cofferdam is determined taking into account the embankment volume during the dry season of six months and the capacity of the diversion tunnel.

On this basis, it was determined to install two diversion tunnel of 9 m in inner diamter, 818 m (No. 1) and 675 m (No. 2) long and an upstream coffer dam with a crest elevation of EL. 97 m. The diversion tunnels has concrete lining at the entrance and exit, and shotcrete lining for the other part.

(3) Dam

The dam projected to be built at the Mae Lama Luang site is a Clay Core Type, and its dimensions are as follows:

Dam height	:	119 m
Crest length	:	355 m
Total embankment volume	:	3,820 x 10^3 m^3
(including upstream coffer dam)		

Regarding the geological conditions of the dam site, the foundation is composed mainly of non calcareous rock consisting of quarts porphry and quartzite, and calcareous sandstone and partly of sandstone. The dam axis is determined taking account of the results of the geological and topographical survey.

The dam has a upstream slope of 1:2.0 and a downstream slope of 1:1.8 determined on the basis of a design seismic coefficient of 0.10 and examples of actual design values of the materials in Thailand.

For the foundation treatment, a grout curtain method is adopted with the geological conditions taken into consideration.

As described in section 6.4.2, limestone covered by calcareous shist is distributed on the right bank, and the groundwater level is low. The permeability of the limestone is assumed to be high and its distribution crosses the dam in the upstream and downstream directions, foundation treatment is necessary to prevent leakage from the reservoir.

(4) Spillway

As shown in DWG. 10-17, the spillway is located on the left bank taking the geology and topography of the site into account.

The spillway capacity is designed so as to be capable of discharging a peak of 5,200 m^3/sec of PMF at a normal high water elevation of 165 m. The detailed spillway feature are a crest elevation of 151 m and the total crest length of 60 m including piers. Further, the spillway is designed to be equipped with four radial gates of 12.0 m in width.

The ski jump type is adopted for the dissipater of this spillway, and the direction of the center of the spillway and the location of the end sill is selected so as not to affect the other structures.

(5) Bottom Outlet

The bottom outlet is so designed that one of the two diversion tunnels can be utilized to discharge water downstream and draw down the reservoir water level in an emergency. The upstream part from the valve chamber in the tunnel is a structure having concrete lining, and the downstream part is lined with shotcrete.

The elevation of the bottom outlet is set at 116 m, and water is discharged to the valve chamber installed in the tunnel through a vertical shaft (inner diameter: 4 m).

A high-pressure slide gate of 1.5 m in diameter and a jet flow gate of 1.5 m in diameter is installed in the valve chamber.

10.2.2 Waterway and Powerhouse

As shown in DWG. 10-15 and 10-18, taking the topographical condition into account, the waterway and the powerhouse are located on the right bank.

(1) Waterway

The waterway is designed for the maximum power discharge of 330 m^3/sec.

The intake is located immediately upstream of the dam. The elevation of the sill of 121.5 m is in such a position that there is no harmful for taking water even at the LWL of 146.0 m, considering sedimentation.

A headrace consists of one tunnel which is 142 m long and 8.6 m in inner diameter. The route was determined taking into account the depth of the tunnel from the ground surface.

A penstock, 337 m long and 8.6 m - 4.5 m in diameter, consists of the embedded type. The penstock is trifurcated and connected to three turbines in the powerhouse. The penstock's route was selected by taking the topographical and geological conditions into consideration. Trifurcation design was adopted for the penstock, taking into account the structure and economics. The details are explained in Appendix.

(2) Powerhouse and Switchyard

The type of powerhouse is the outdoor type and its location is selected so as to provide the smooth flow of power discharge from the draft. The turbine center and draft dimensions are determined to ensure sufficient protection for the turbine and draft against cavitation. Also, the dimensions of the powerhouse are determined taking account the dimensions of the turbines, generators and auxiliary equipment and the size of the rooms.

The switchyard is designed to be installed at a site having an elevation of 86 m which is to be located on the yard between the dam foot and the powerhouse. This elevation is determined taking into account the highest water level of 84 m on the downstream side for the PMF.

10.2.3 Electromechanical Equipment

(1) Selection of the Number of Main Units

The relevant factors to determine the number of the main units are the same as those described in section 10.1.3 (1).

The planned dimensions of the Mae Lama Luang project include an effective head of 85 m, maximum power discharge of 330 m^3/sec, and an installed capacity of 240 MW. The number of the main units is to be determined from two, three or four units.

The two unit plan (120 MW x 2) has to use a larger main unit with a difficulty in workability, and a reduced degree of freedom of operation compared with the three unit plan (80 MW x 3).

The four unit plan (60 MW x 4) has no problem with operation or workability, but is less economical than the three unit plan.

The three unit plan (80 MW x 3) has no problem with power system, workability and operation, and is the most suitable regarding development scale, so the three unit plan is to be employed.

(2) Selection of the Main Unit

The number of the main units of the Mae Lama Luang project is three (3), and its planned dimension includes effective head of 85 m, and the maximum turbine discharge of a single unit: 110 m^3/sec.

Under the above conditions, the vertical Francis turbine is the most suitable, so that is to be employed.

Followings are the features of the main unit equipment.

Turbine

Type	Vertical Francis turbine
Number of units	3 units
Normal effective head	85 m
Maximum turbine discharge	110 m^3/s
Normal output	83 MW
Revolving speed	200 rpm

Generator

Type	Three phase AC synchronous generator
Number of units	3 units
Output	90 MVA
Power factor	0.9 (Lag.)
Voltage	13.8 kV
Frequency	50 Hz
Revolving speed	200 rpm

Main transformer

Type	Outdoor three phase transformer
Number of units	3 units
Capacity	90 MVA
Voltage	13.8 kV : 230 kV

(3) Arrangement of Equipment in the Powerhouse

The Mae Lama Luang powerhouse is to be constructed as an outdoor type, and the three main units are installed at a distance of 21 m between them.

A carrying-in crane is to be installed in the assembly room for carrying in equipment underground, and an overhead crane is installed in the main unit room for assembling equipment.

Turbines, generators and various accessories are to be located underground.

In the buildings on the ground offices, a storage room and workshops are to be located as well as equipment required for monitoring and control such as a control room and a relay room.

(4) Main Circuit and Outdoor Switchyard

Since the Mae Lama Luang power station is an important power source in the north region, a unit system with high reliability is to be employed for the main unit.

The synchronous system uses a low voltage synchronous system for maintainability and for support of the plant power source.

Generators and main transformers are to be connected by an isolated phase bus, and a 230 kV CV Cable is used to connect the main transformer to the switchyard.

SF_6 gas insulated switchgear is employed for the 230 kV outdoor switchyard since there is little space around the Nam Yuam power plant if the conventional type of the 230 kV outdoor switchyard equipment is used.

The bus bar uses a duplex bus bar system considering EGAT's design guidelines and the significance of the power plant.

The SF_6 gas insulated switchgear type switchyard is shown in DWG. 10-20, and the equipment locations in a conventional type switchyard in DWG. 10-21.

A skeleton is shown in DWG. 10-19.

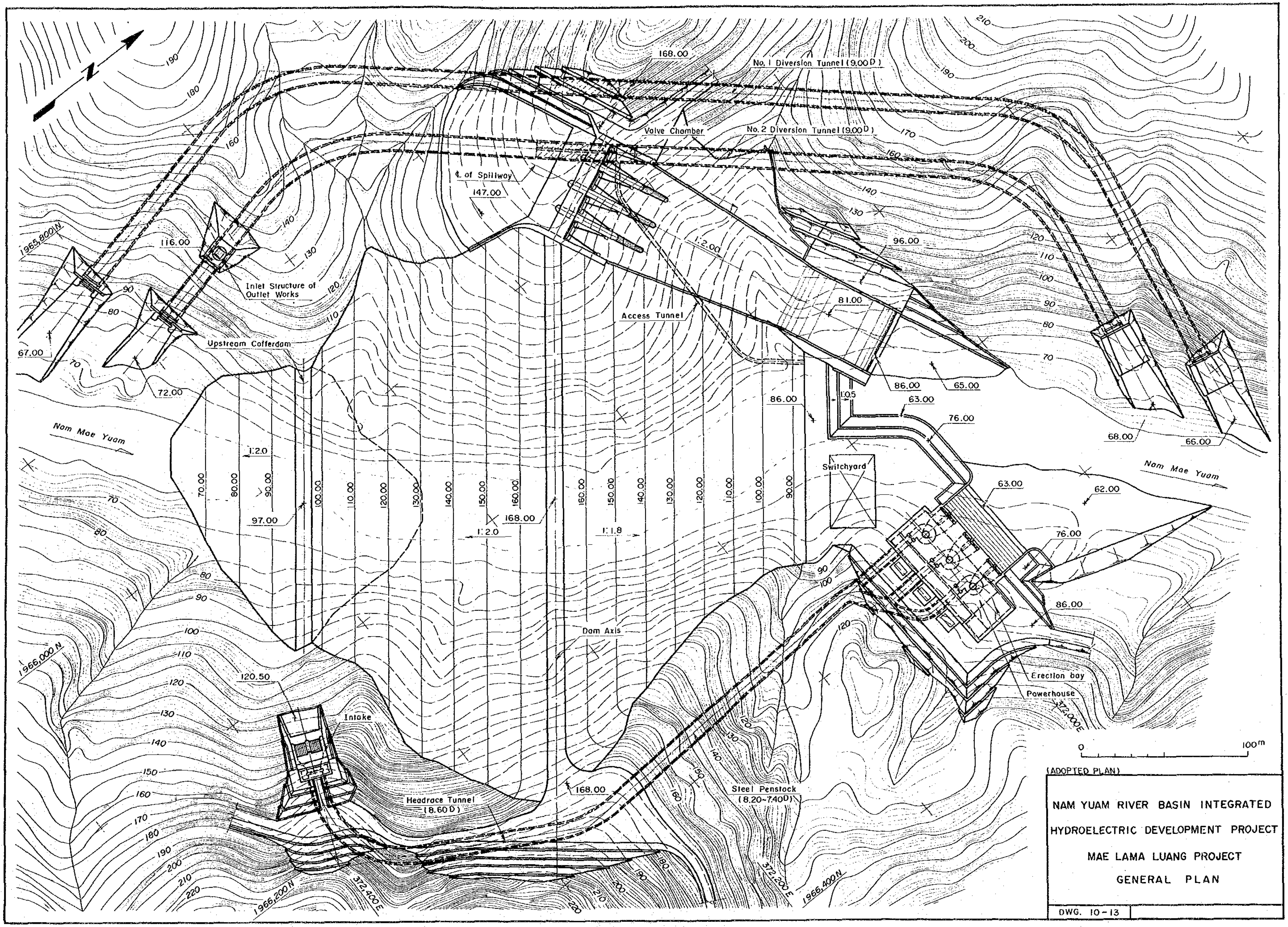
10.2.4 Transmission Lines

Transmission lines of 230 kV, 2-circuit ACSR 1,272 MCM is constructed over a distance of about 200 km from the Mae Lama Luang power station to the Chiang Mai 3 substation via the point where the Mae Sariang substation is scheduled.

The Chiang Mai 3 substation (230/115 kV) is to be completed before completing the Mae Lama Luang power station.

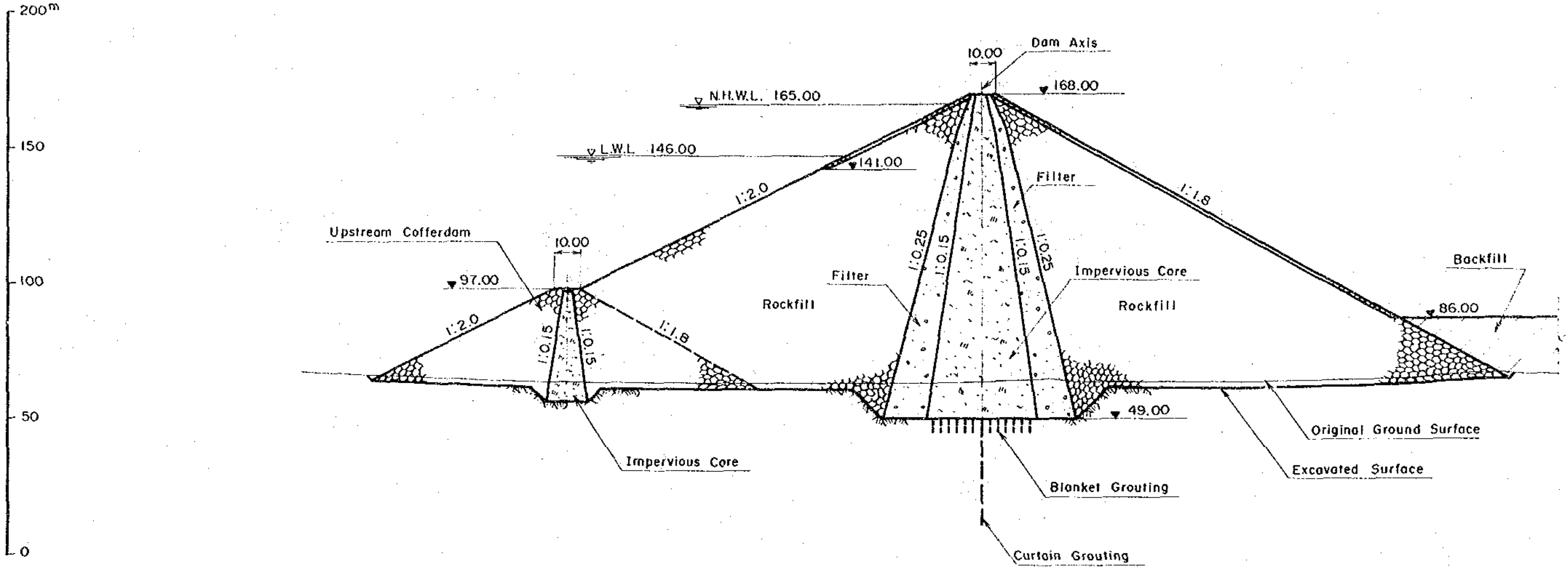
Also considering EGAT's standards, the major dimensions of the steel towers for the 230 kV transmission lines were designed.

The major dimensions of the 230 kV steel towers are shown in DWG. 10-22.

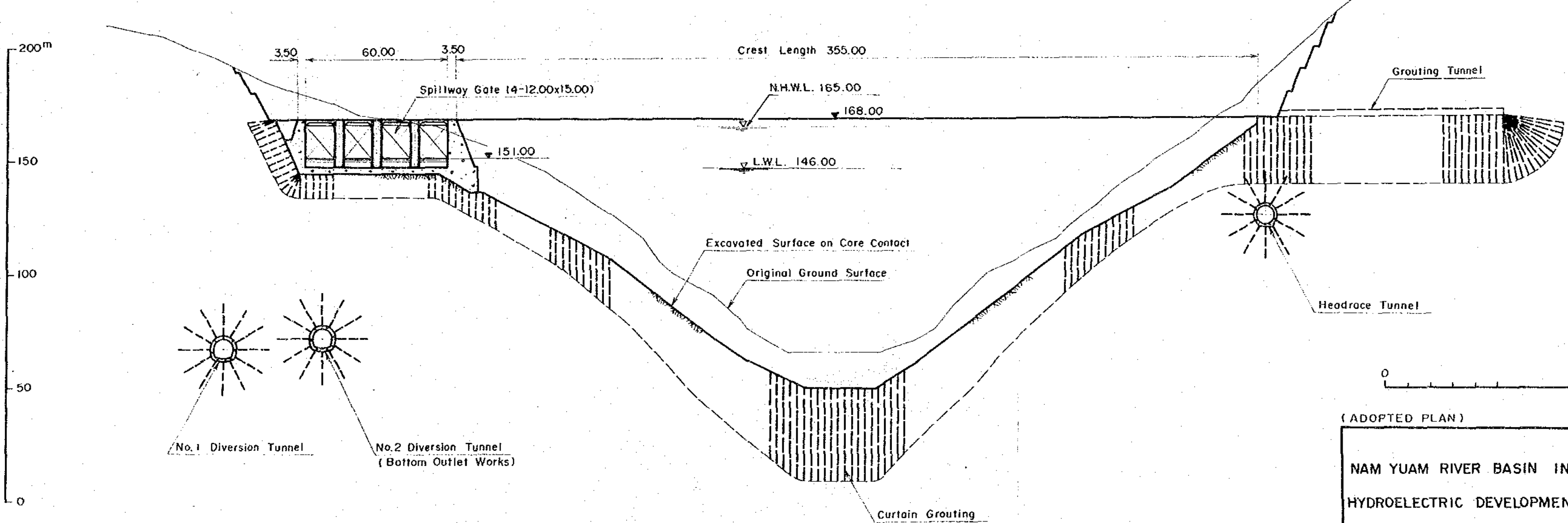


N
No. 1 Diversion Tunnel (9.00D)
No. 2 Diversion Tunnel (9.00D)
Valve Chamber
℄ of Spillway
147.00
168.00
116.00
Inlet Structure of Outlet Works
Upstream Cofferdam
Access Tunnel
1:2.00
96.00
81.00
86.00
65.00
63.00
76.00
1.05
Switchyard
Nam Mae Yuam
Nam Mae Yuam
67.00
72.00
68.00
66.00
62.00
97.00
1:2.0
1:2.0
1:1.8
Dam Axis
120.50
Intake
Headrace Tunnel (8.60D)
Steel Penstock (8.20~7.40D)
Erection bay
Powerhouse
1965,800 N
1966,000 N
1966,200 N
1966,400 N
372,000 E
372,200 E
372,400 E
0
100m
(ADOPTED PLAN)
NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT
MAE LAMA LUANG PROJECT
GENERAL PLAN
DWG. 10-13

TYPICAL SECTION OF DAM



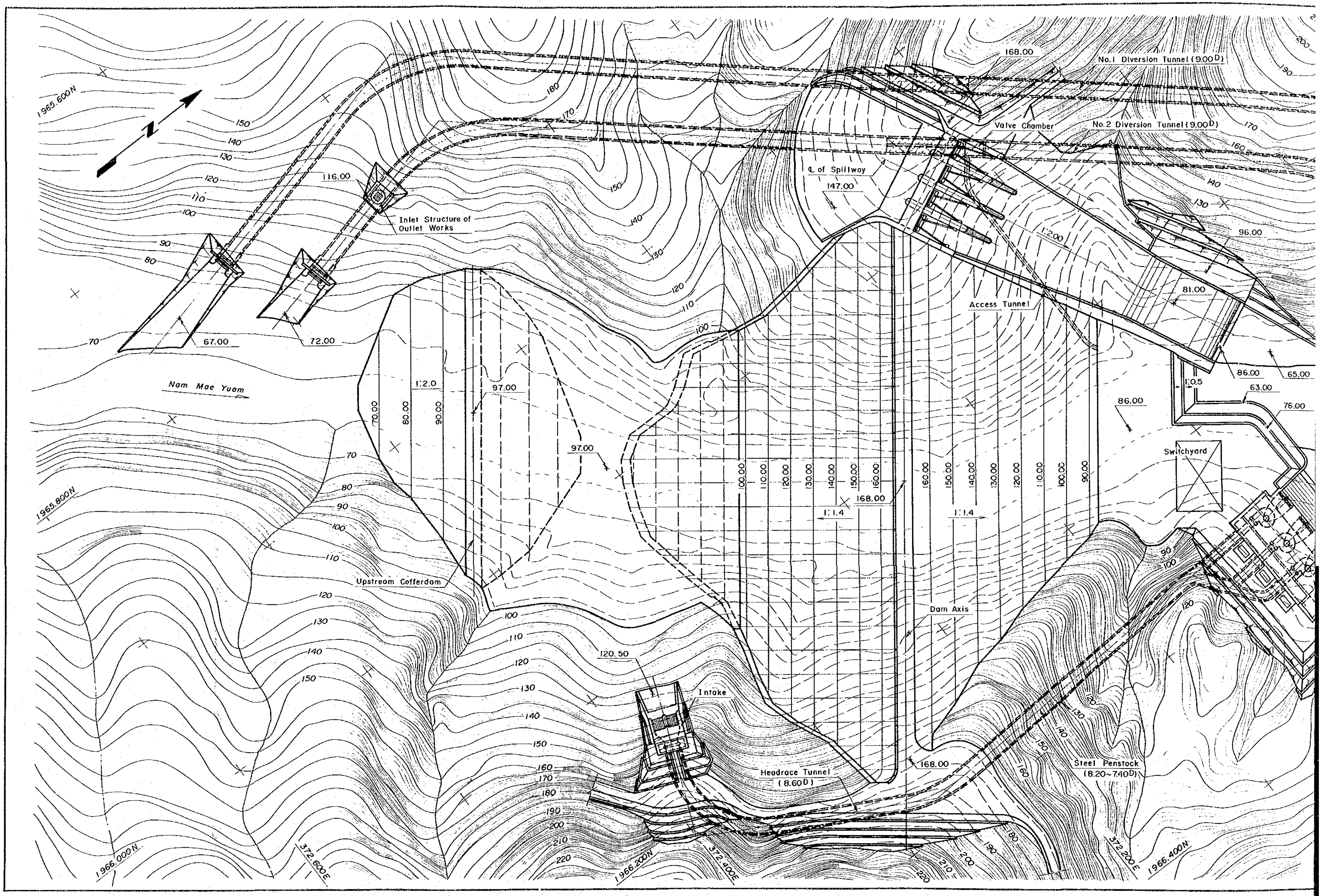
PROFILE OF DAM



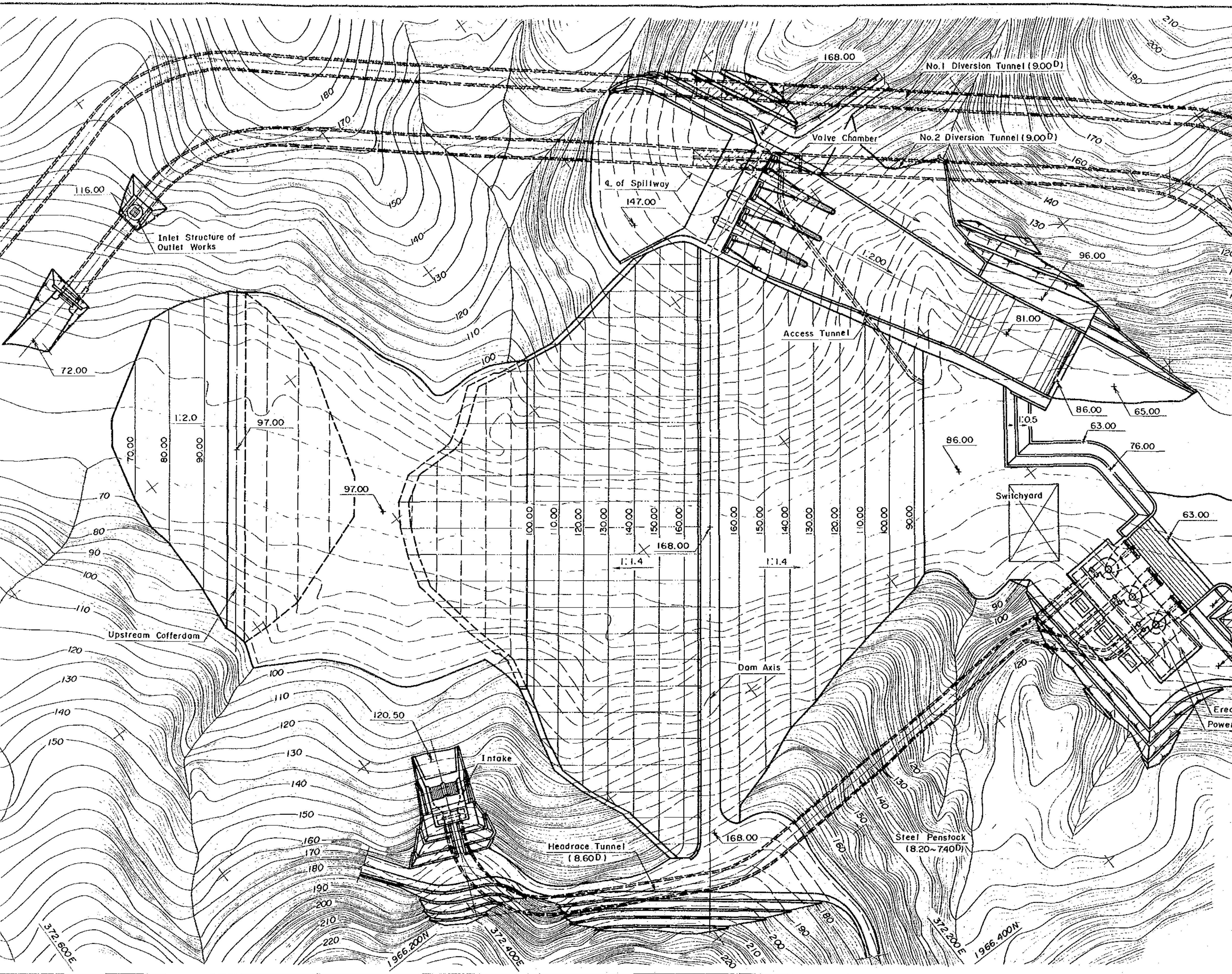
(ADOPTED PLAN)

NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT
MAE LAMA LUANG PROJECT
SECTION OF DAM

DWG. 10-14



No.1 Diversion Tunnel (9.00D)
No.2 Diversion Tunnel (9.00D)
Valve Chamber
168.00
℄ of Spillway
147.00
116.00
Inlet Structure of
Outlet Works
67.00
72.00
Nam Mae Yuam
96.00
81.00
Access Tunnel
86.00
65.00
63.00
76.00
1:0.5
1:2.0
1:2.00
97.00
86.00
Switchyard
168.00
1:1.4
Upstream Cofferdam
Dam Axis
120.50
Intake
Headrace Tunnel
(8.60D)
168.00
Steel Penstock
(8.20~7.40D)
1965.600N
1965.800N
1966.000N
1966.200N
1966.400N
372.600E
372.400E
372.200E



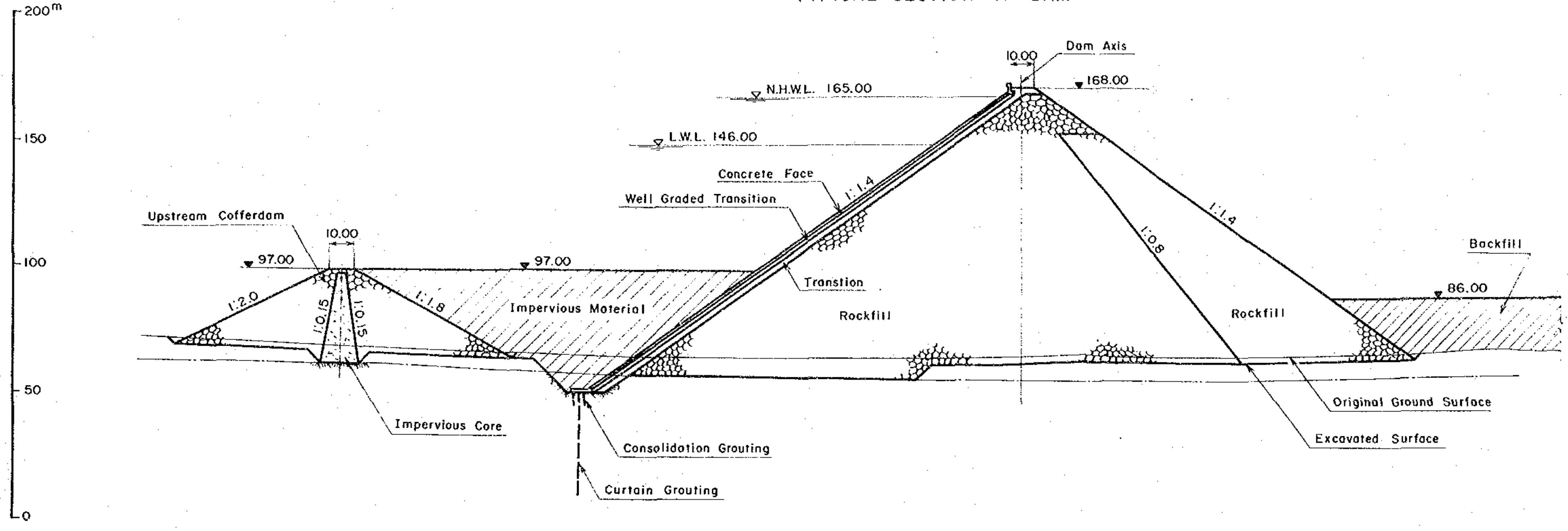
NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT

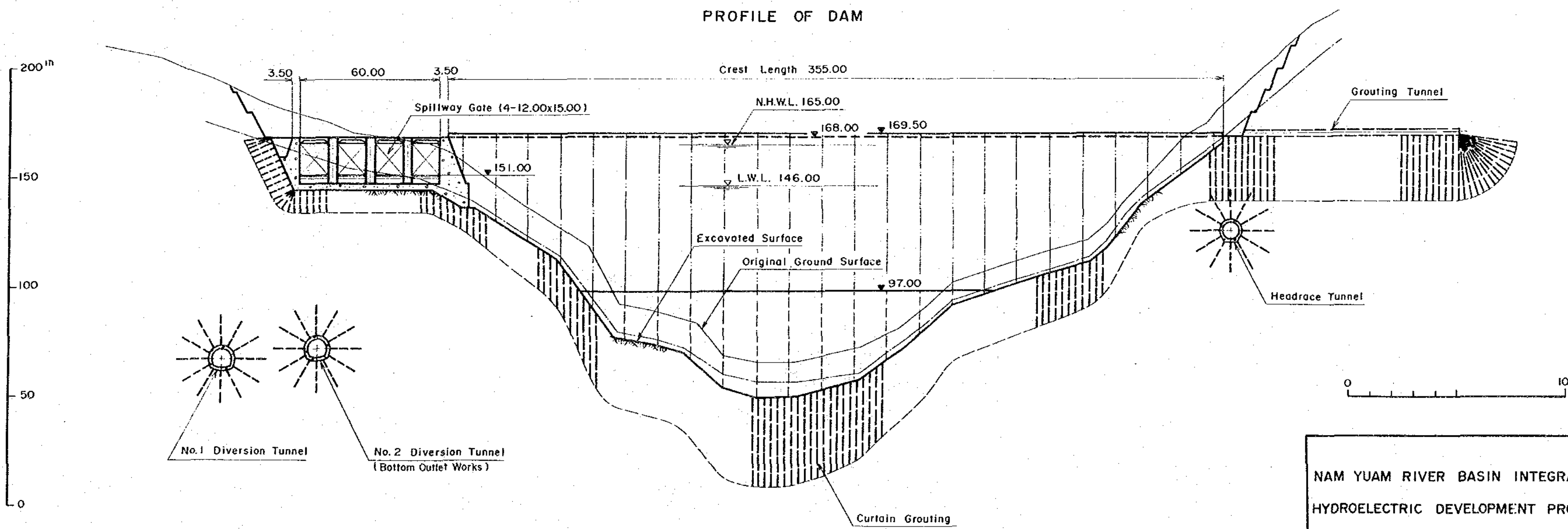
GENERAL PLAN

DWG. 10-15

TYPICAL SECTION OF DAM



PROFILE OF DAM



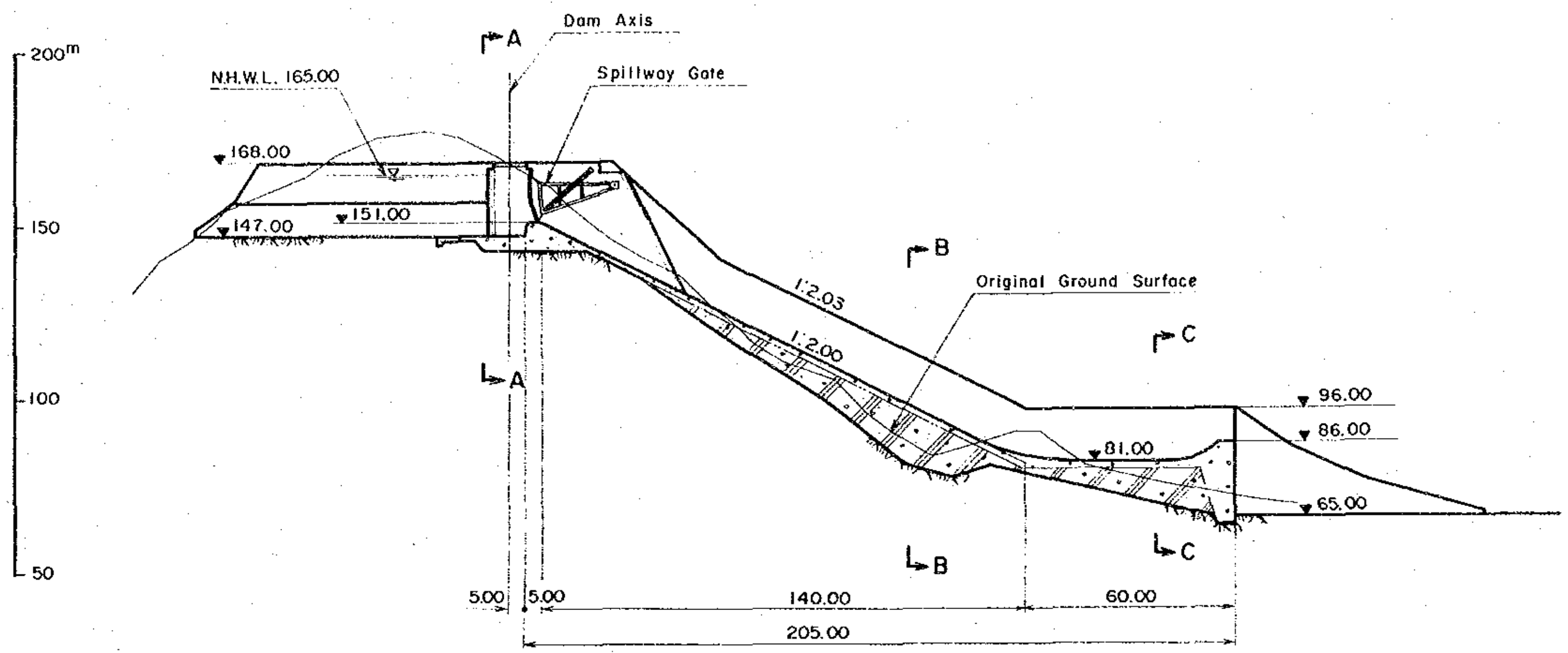
NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT

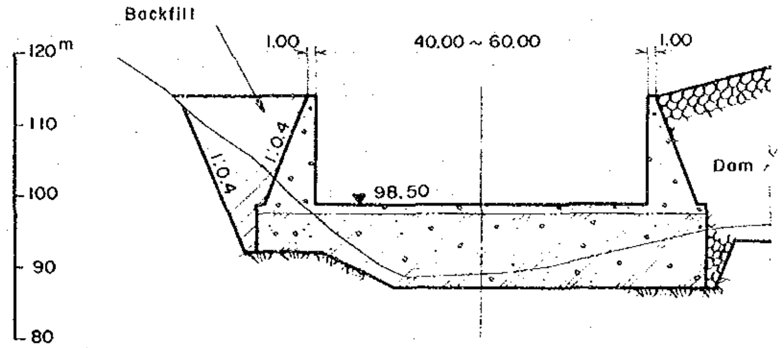
SECTION OF DAM

DWG. 10-16

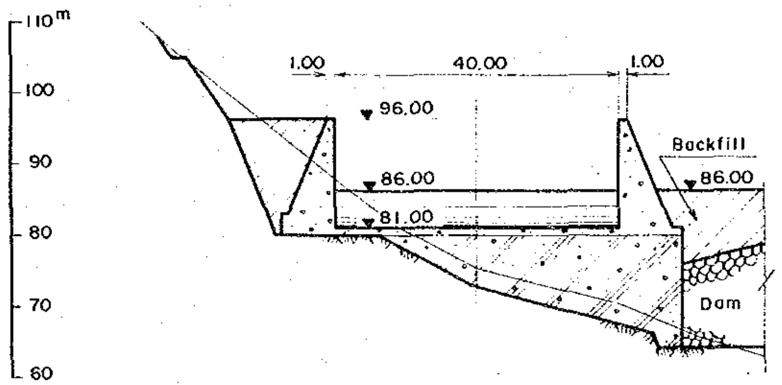
PROFILE



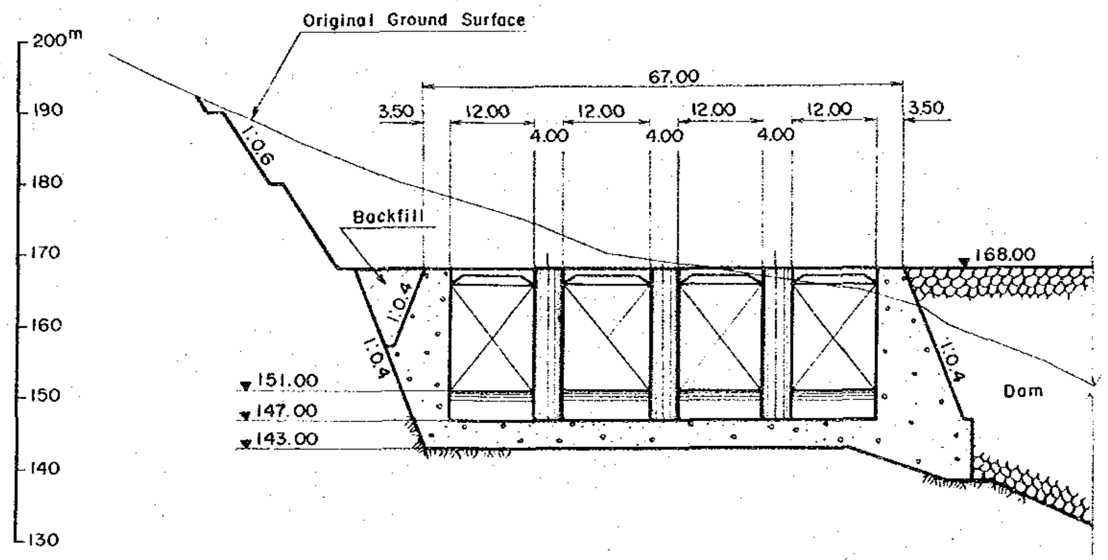
SECTION B – B

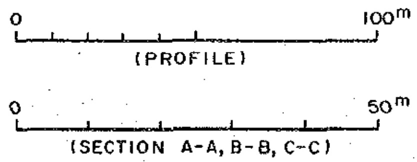


SECTION C – C



SECTION A – A





(ADOPTED PLAN)

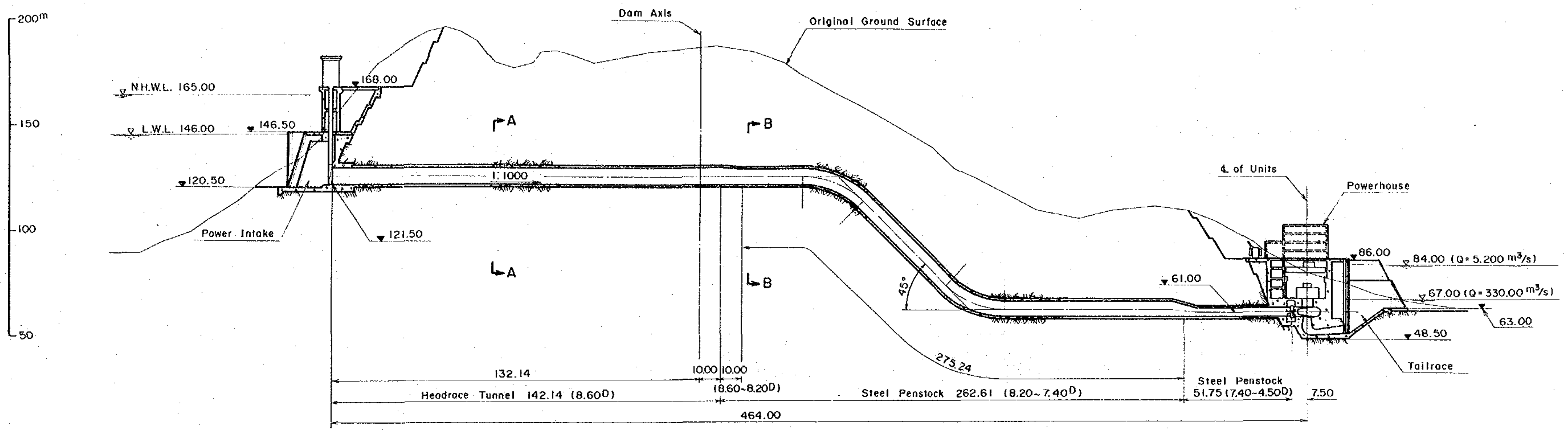
NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT

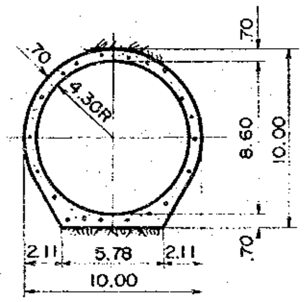
SPILLWAY

DWG. 10-17

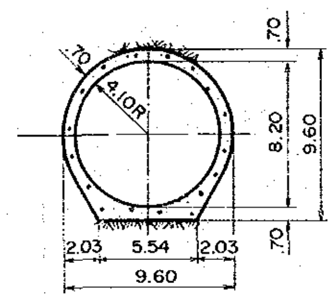
PROFILE OF WATERWAY



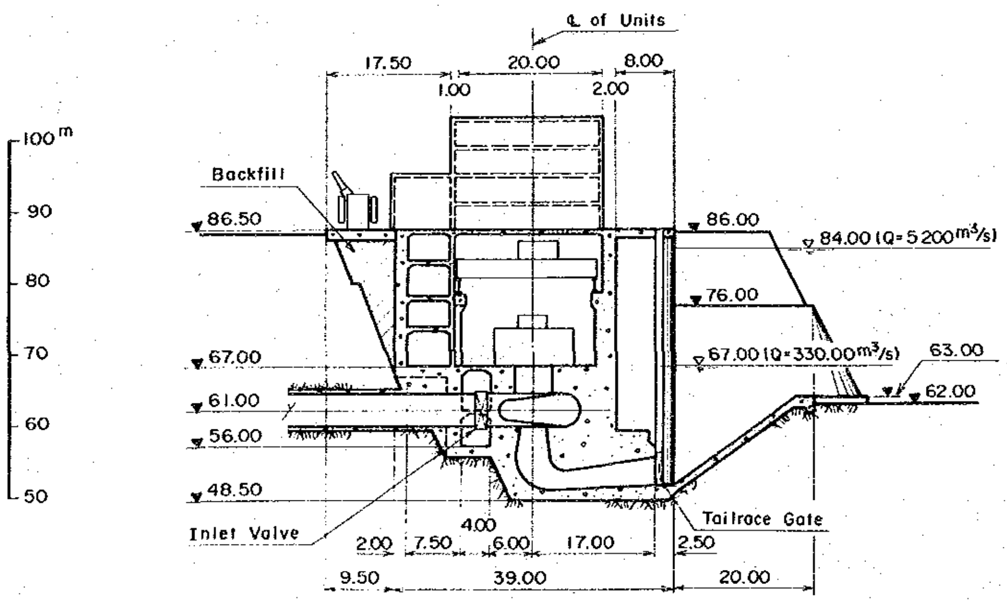
SECTION A – A



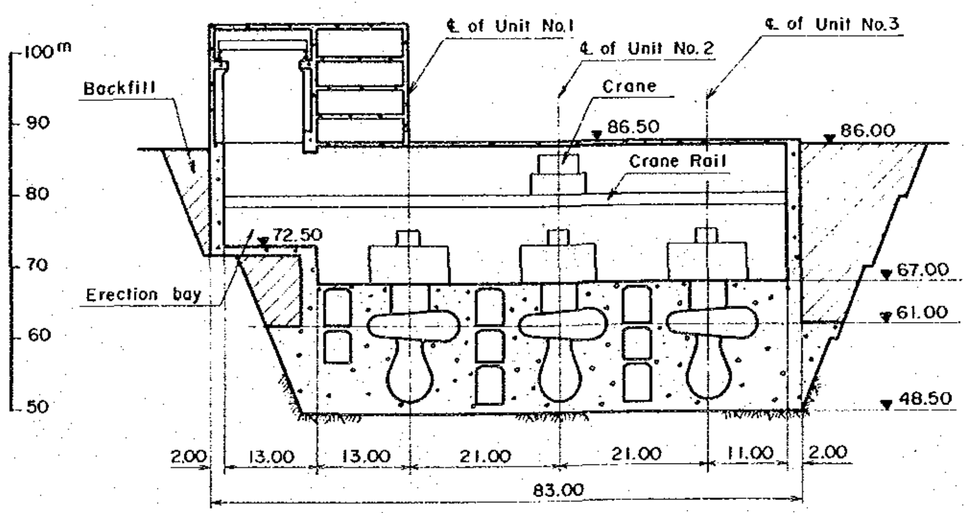
SECTION B – B

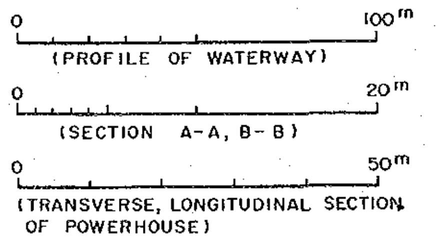


TRANSVERSE SECTION OF POWERHOUSE



LONGITUDINAL SECTION OF POWERHOUSE





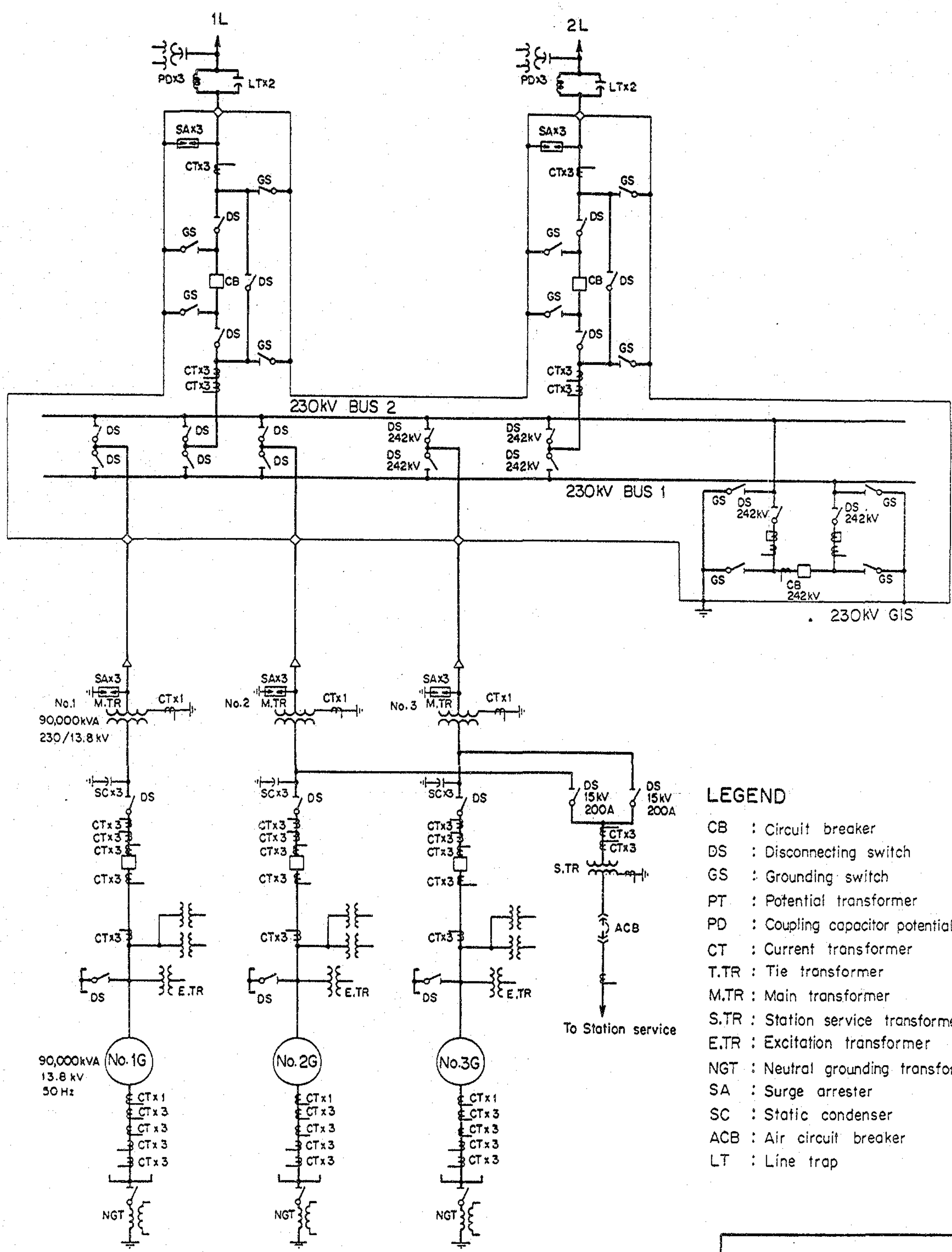
(ADOPTED PLAN)

NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT

WATERWAY

DWG. 10 - 18



LEGEND

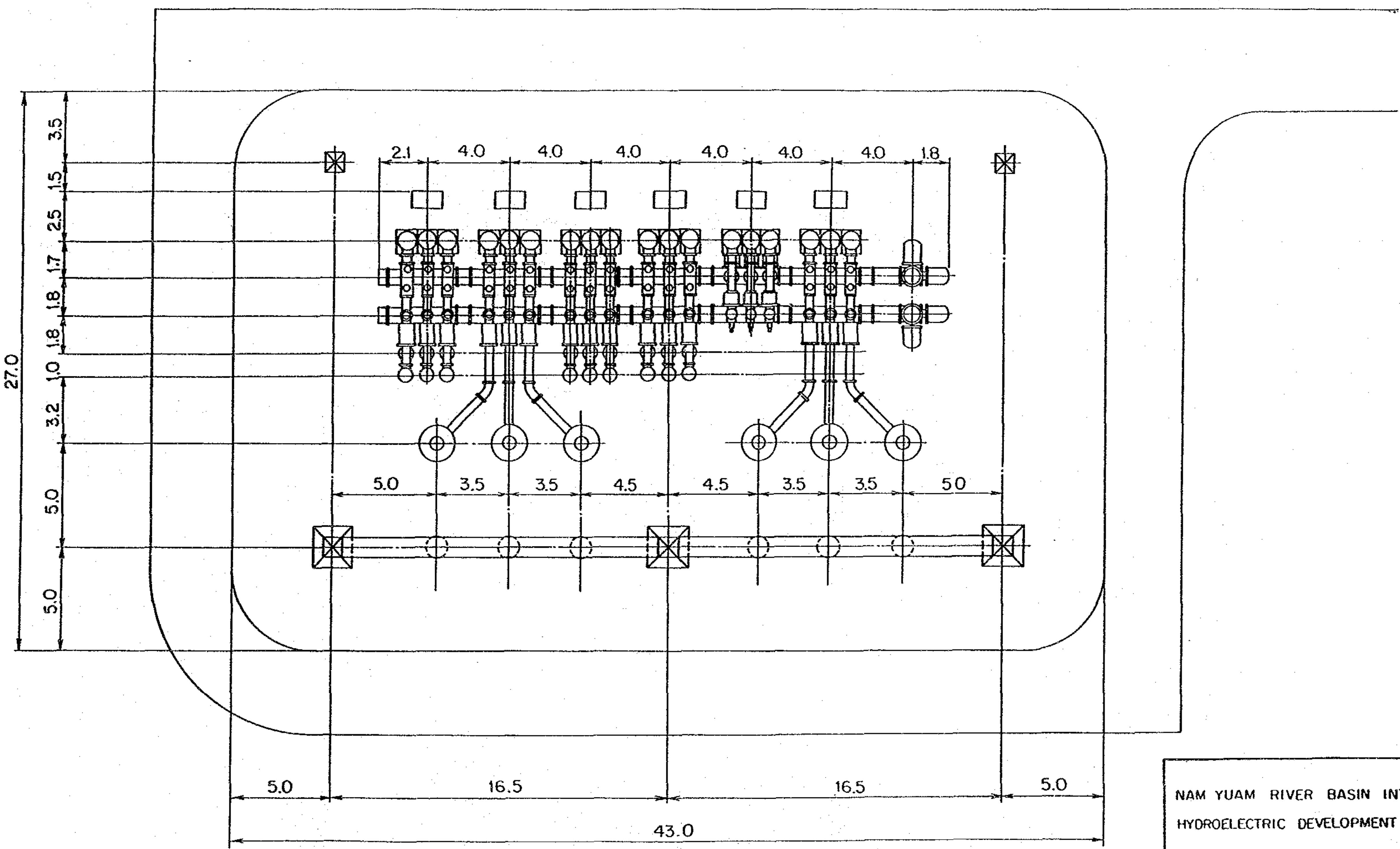
CB : Circuit breaker
DS : Disconnecting switch
GS : Grounding switch
PT : Potential transformer
PD : Coupling capacitor potential device
CT : Current transformer
T.TR : Tie transformer
M.TR : Main transformer
S.TR : Station service transformer
E.TR : Excitation transformer
NGT : Neutral grounding transformer
SA : Surge arrester
SC : Static condenser
ACB : Air circuit breaker
LT : Line trap

NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT

SINGLE LINE DIAGRAM

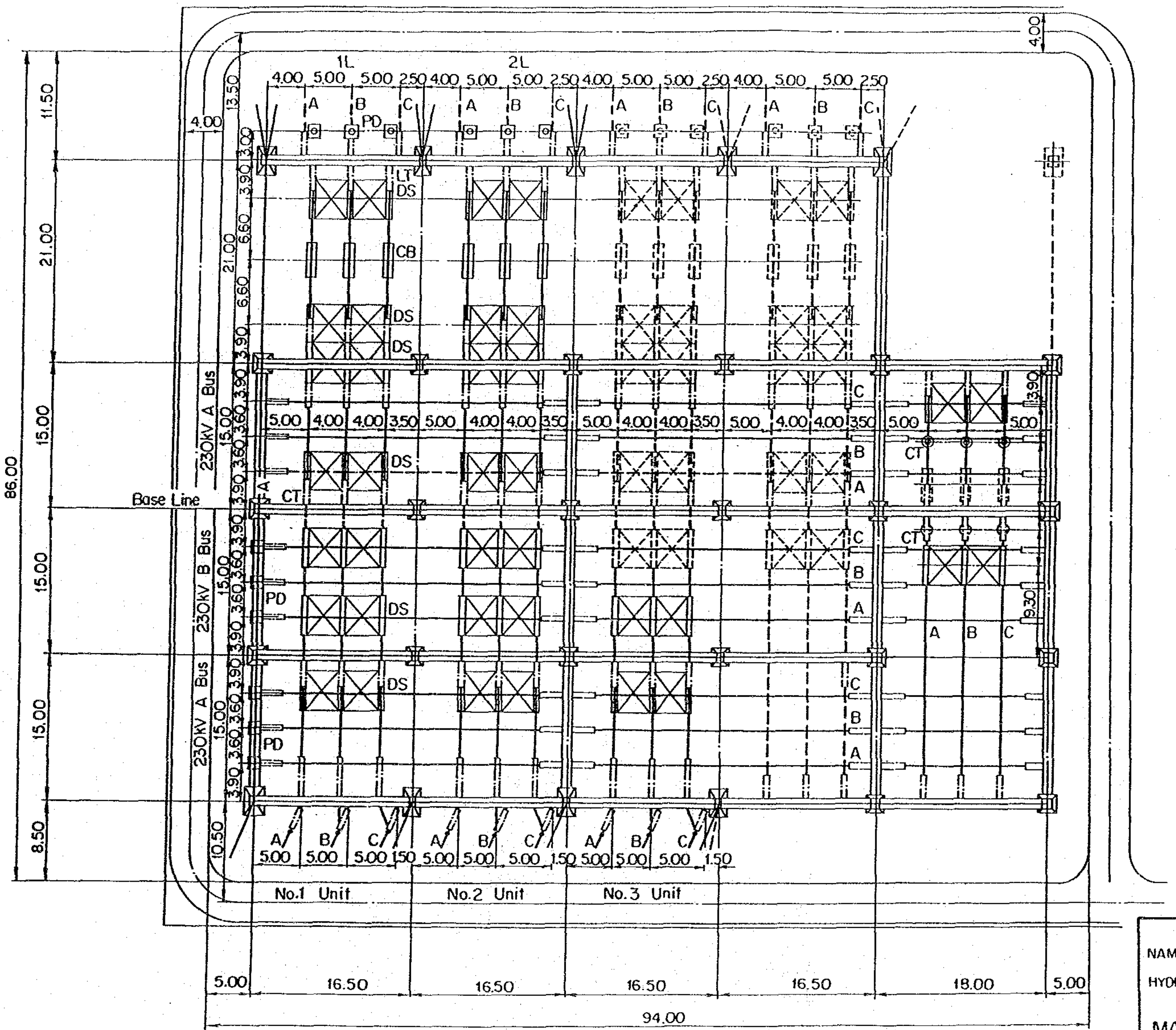
DWG. 10-19



NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT
SWITCHYARD
(G I S)

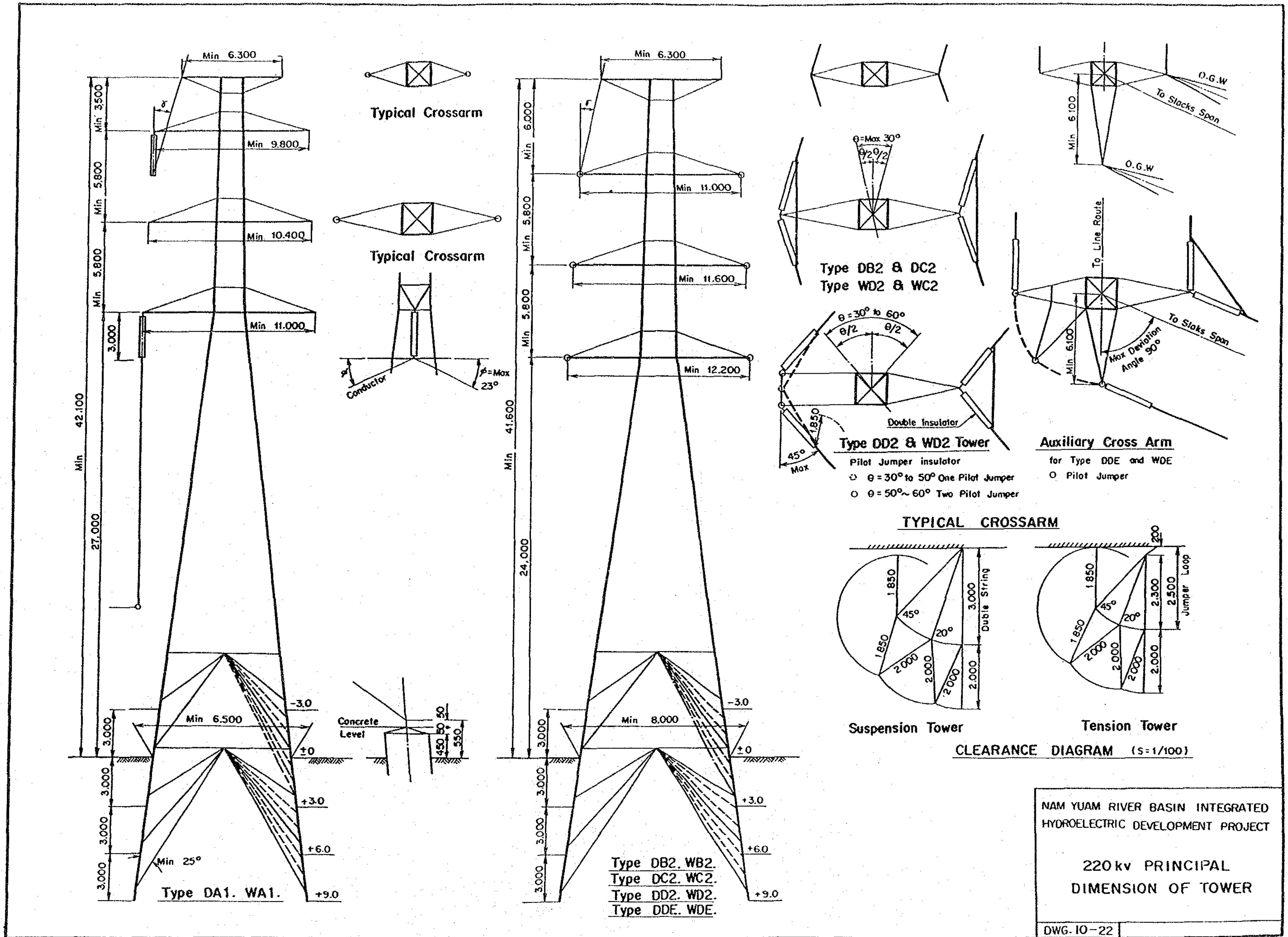
DWG. 10-20



NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

MAE LAMA LUANG PROJECT
SWITCHYARD
(CONVENTIONAL)

DWG. 10-21


Min 6.300
Min 3.500
Min 9.800
Min 5.800
Min 10.400
Min 5.800
Min 11.000
3.000
Min 42.100
27.000
Min 6.500
3.000
-3.0
±0
+3.0
+6.0
+9.0
3.000
3.000
3.000
Min 25°
Type DA1. WA1.
Typical Crossarm
Typical Crossarm
Conductor
φ=Max 23°
Concrete Level
50
50
450
550
Min 6.300
Min 6.000
Min 11.000
Min 5.800
Min 11.600
Min 5.800
Min 12.200
Min 41.600
24.000
Min 8.000
-3.0
±0
+3.0
+6.0
+9.0
Type DB2. WB2.
Type DC2. WC2.
Type DD2. WD2.
Type DDE. WDE.
θ=Max 30°
θ/2 θ/2
Type DB2 & DC2
Type WD2 & WC2
θ=30° to 60°
θ/2 θ/2
1.850
45° Max
Double Insulator
Type DD2 & WD2 Tower
Pilot Jumper insulator
θ = 30° to 50° One Pilot Jumper
θ = 50°~ 60° Two Pilot Jumper
O.G.W
To Slacks Span
Min 6.100
O.G.W
To Line Route
To Slaks Span
Min 6.100
Max Deviation Angle 90°
Auxiliary Cross Arm
for Type DDE and WDE
Pilot Jumper
TYPICAL CROSSARM
1.850
45°
3.000
Duble String
20°
1.850
2.000
2.000
2.000
2.000
Suspension Tower
200
1.850
2.300
2.500
Jumper Loop
45°
20°
1.850
2.000
2.000
2.000
2.000
Tension Tower
CLEARANCE DIAGRAM (S=1/100)
NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT
220kv PRINCIPAL DIMENSION OF TOWER
DWG. 10-22

CHAPTER 11

CONSTRUCTION PLANNING AND COST ESTIMATE

CHAPTER 11 CONSTRUCTION PLANNING AND COST ESTIMATE

CONTENTS

List of Tables

List of Figures

CHAPTER 11 CONSTRUCTION PLANNING AND COST ESTIMATE

11.1 Construction Planning and Construction Schedule

11.1.1 Basic Conditions

The main factors affecting the construction planning and the construction schedule of the projects are as follows:

(1) Meteorology

The meteorological conditions for the projects are as described in Chapter 5. The construction schedule was prepared according to these meteorological conditions. Further, rainy season which affects the construction schedule is 6 months from May to October.

(2) Transportation

With regard to the access road to the project sites, it is possible to utilize national roads of Route 108, 1085 and 1194. The access road to the Nam Ngao site from the Route 1085 is branches from Ban Sop Ngao to the site, shown in Fig. "General Plan of the Project" at the beginning of this report.

The access road to the Mae Lama Luang dam site, which is to be constructed by EGAT, branches from the Route 1194.

(3) Construction Materials

- Cement

  The cement is to be supplied by the cement mill at Nakhon Sawan, 700 km from the Mae Lama Luang Project site.

- Reinforcement Bars, Steel Materials and Other Construction Materials

  The principal items of construction materials such as reinforcement bars, steel materials, explosive materials and so on are supplied mostly from Bangkok, 900 km away from the Nam Yuam Integrated Project site.

- Aggregates for Concrete

  Aggregates are collected and/or manufactured from river deposit in the vicinity of the confluence of the Yuam and the Moei rivers for the Mae Lama Luang Project, and from the confluence of the Ngao and the Yuam rivers for the Nam Ngao project.

- Embankment Materials

  Core material, filter material and rock material for the dam embankment would be supplied from borrow areas, river deposits and quarries in the vicinity of the project sites.

- Site Electricity

  Diesel generating plants are used during construction.

11.1.2 Construction Planning and Construction Schedule

On the basis of the local condition above and the construction quantities, construction schedule was planned.

Assuming that the Nam Ngao Project and the Mae Lama Luang Project are to be commissioned in the year 1997, the construction schedules of the two projects are shown in Fig. 11-1 and Fig. 11-2, respectively.

(1) Nam Ngao Project

- Preparation Works

  The preparation works are comprised of: the construction of the access roads to the dam site, and construction of the camp and site facilities including electricity supply.

  The works are to be started at the beginning of 1993.

- Diversion Tunnel

Since the river diversion is a prerequisite for the start of the dam work, it is necessary that construction work of the diversion tunnel is started at the first year. The tunnel should be excavated, lined and grouted within a period of 8 months.

- Dam

Prior to the river diversion, the excavation and the foundation treatment except for the river bed are performed on both banks at the first year. After the river diversion, the excavation and the grouting of the river bed are performed at the second year. After the works, embankment and concrete membrane works are performed over a period of 36 months.

- Spillway

Excavation should be carried out in parallel with the excavation for the dam abutment. After the excavation, concrete should be placed and the spillway gates be completed prior to the impoundment.

- Intake, Headrace and Penstock

The excavation of these structures is started at the second year. Concrete lining works of the headrace tunnel and the installation of the penstocks are started at the third year.

- Powerhouse, Tailrace and Switchyard

The powerhouse, tailrace and switchyard are almost entirely independent of the other civil works. However, the construction schedule is governed by the time necessary for the erection of the plant equipment. That is, 30 months from the installation of the draft-tube to commencement of operation.

Therefore, the construction work of the powerhouse should be started at the second year.

- Bottom Outlet

The diversion tunnel is changed to a bottom outlet during the last dry season within a 7-month period. A close coordination between civil works and equipment erection are to be required.

- Electro-mechanical Equipment

After installing a carrying-in crane and a overhead crane, the installation of the draft-tube are started at the third year. After the works, the turbines and generators are installed. The test of the equipment is performed at the end of the fourth year.

- Transmission Line and Mae Sariang Substation

The installation of the transmission line from the power station to the Mae Sariang substation is started at the third year and completed by the start of the operation of the power station.

(2) Mae Lama Luang Project

- Preparation Works

The preparation works are comprised of: the construction of the access roads to the dam site, and the constructions of the camp and site facilities including electricity supply and communications.

The works are to be started in the beginning of 1993.

- Diversion Tunnel

Since the river diver is a prerequisite for the start of dam work, it is necessary that the construction of the diversion tunnel is started at the first year. The tunnel should be excavated, lined and grouted within a period of 10 months.

- Dam

Prior to the river diversion, the excavation and the foundation treatment except for the river bed are performed on both banks at the first year. After the river diversion, the excavation and the grouting of the river bed are performed at the second year. After the works, the embankment are performed over a period of 36 months.

- Spillway

The excavation should be carried out in parallel with the excavation for the dam abutment. After the excavation, concrete should be placed and the spillway gates be completed prior to the impoundment.

- Intake, Headrace and Penstock

The excavation of these structures is started at the second year. Concrete lining works of the headrace tunnel and the installation of the penstock are started at the third year.

- Powerhouse, Tailrace and Switchyard

The powerhouse, the tailrace and the switchyard are almost entirely independent of the other civil works.

However, the construction schedule is governed by the time necessary for the erection of the plant equipment. That is, 30 months from the installation of the draft-tube to commencement of operation. Therefore, construction works of the powerhouse should be started at the second year.

- Bottom Outlet

The diversion tunnel is changed to a bottom outlet during the last dry season within a 7-month period. A close coordination between civil works and the equipment erection is to be required.

- Electro-mechanical Equipment

After installing a carrying-in crane and a overhead crane, the installation of the draft-tube are started at the third year. After the works, the turbines and generators are installed. The test of the equipment is performed at the end of the fourth year.

- Transmission Line

The installation of the transmission line from the power station to the Chiang Mai 3 substation is started at the third year and completed by the start of the operation of the power station.

Fig. 11-1 Construction Schedule of Nam Ngao Project

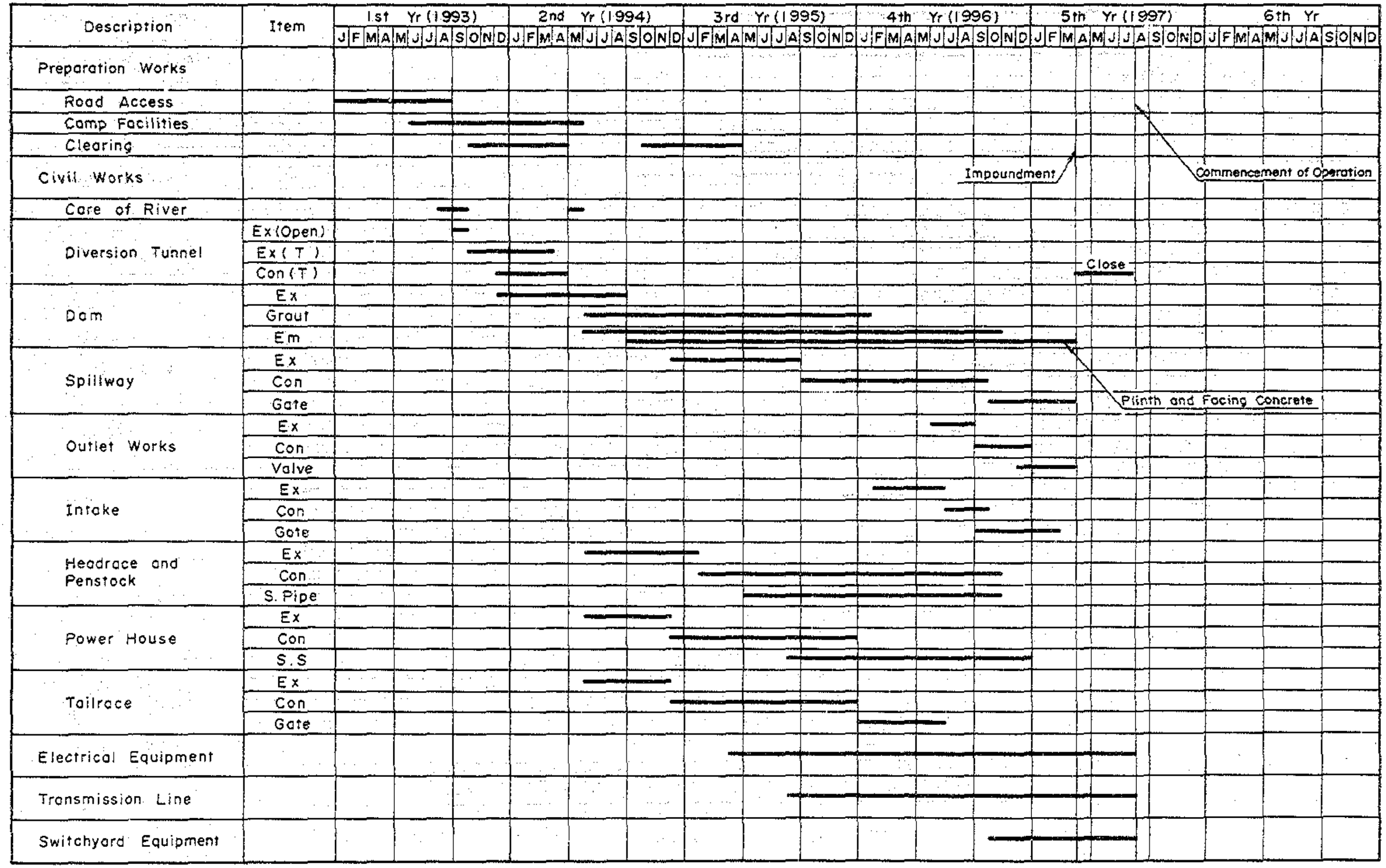
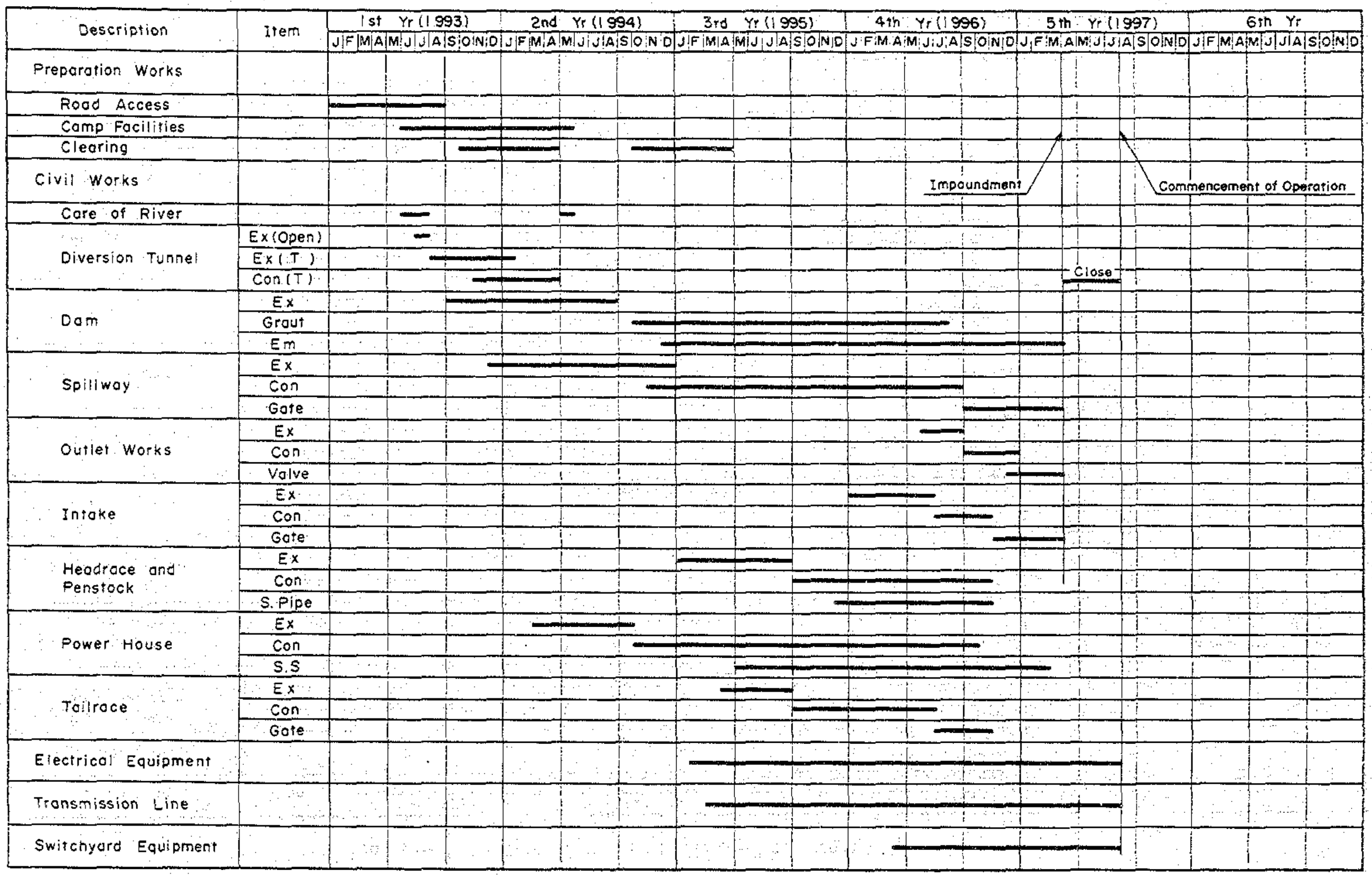


Fig. 11-2 Construction Schedule of Mae Lama Luang Project



11.2 Cost Estimate

The construction cost of the integrated development project was estimated taking into account the preliminary design based on the up-to-date engineering, construction methods, materials, products, geological conditions, local conditions and a scale of the construction works.

11.2.1 Basic Conditions

(1) Price Level and Currency Exchange Rate

Price Level : January 1989
Currency Exchange Rate: 1 US$ = 26 Baht

(2) Items of Cost Estimate

The items are as follows:

- Preparation Works : EGAT's camp and facilities, site preparation, access road, electric facilities

- Environmental Mitigation : resettlement and compensation in the reservoir area, relocation of road, mitigation for environmental impact

- Civil Works

  - River Diversion : diversion tunnel, coffer dam
  - Dam and Spillway : dam, spillway, outlet works
  - Waterway : intake, headrace, penstock
  - Powerhouse and Switchyard : civil works and architecture

- Hydraulic Equipment: gate, penstock, etc.

- Electro-mechanical Equipment: turbine, generator, transformer, telecommunication system, etc.

- Transmission Line : expense concerning transmission line

- Import Duties : import duties and tax

- EGAT Administration: administration cost concerning the project's construction

- Engineering Service: engineering fee for detail design and supervision

- Physical Contingency : contingency for unforeseen physical conditions

- Price Contingency : contingency for escalation

- Interest During Construction

(3) Condition for Cost Estimate

- Preliminary Works

Considering similar projects, construction cost of access roads and 5% of civil works are estimated as the cost of the preliminary works.

- Environmental Mitigation

Considering the examples of the existing projects similar to the Nam Ngao and Mae Lama Luang projects, relocation cost of national roads and 5% of the sum of civil works, hydraulic equipment, electro-mechanical equipment, transmission line, import duties, EGAT administration and engineering service are estimated as the environmental mitigation cost.

- Civil Works

The cost of civil works is estimated in accordance with the drawings of preliminary design and unit costs. The bill of quantities is as shown in Appendix.

The unit costs are derived from the assumed construction plans and methods, project site conditions and construction material availability referring to recent international contract bids and prices of hydroelectric projects in

Thailand. The detail of the major unit costs is attached in Appendix.

- Hydraulic Equipment and Electro-mechanical Equipment

The costs of hydraulic and electro-mechanical equipments are based on budget prices quoted by manufactures and contract or bid prices of recent similar projects, updated to January 1989 price. These equipments are imported from foreign countries.

- Transmission Line

The cost of 230 kV transmission line between the Mae Lama Luang power station and the Chiang Mai 3 substation is included in the cost of the Mae Lama Luang project. The cost of the 115 kV transmission line between the Nam Ngao power station and the Mae Sariang substation and the cost of the substation are included in the cost of Nam Ngao project.

- Import Duties

Import duties are estimated by considering the foreign currency component; hydraulic equipment (20%), electromechanical equipment (25%), transmission line and communication system (10%).

- EGAT Administration and Engineering Service

The costs of EGAT's administration and engineering service are separately estimated at 3% and 5% respectively, of above mentioned costs from the preparation works to the transmission line.

- Physical Contingency

A physical contingency of 10% for all above mentioned costs from the preparation works to the hydraulic equipment, and 7% from electro-mechanical equipment to the transmission line is added to cover the cost of unforeseen physical conditions except price escalation.

- Price Contingency

A price contingency for all above mentioned costs from the preparation works to the transmission line is estimated on the basis of escalation rate as follows:

Escalation Rate

Fiscal Year	1989	'90	'91	'92	'93	'94	'95	'96 and onward
Escalation Rate (%)	6.3	1.5	3.6	3.6	3.6	3.6	3.6	4.6

(Source: IBRD Bangkok (Oct. '88))

- Interest During Construction

Interest during construction is estimated to be an 8% of annual interest rate on the foreign currency portion and 10% on 50% of the local currency portion applied to all above mentioned costs.

Further, commitment fee of 0.75% for the foreign currency is considered.

(4) Classification of Local and Foreign Currency Portion

Cement and reinforcement of domestic origin are used currency portion. Structural steel, spillway gates, and explosives are imported and are calculated in foreign currency.

Heavy equipment such as heavy dump trucks, bulldozers, wheel loaders, vibratory rollers for civil works, and temporary facility mechanical installations such as concrete plants, aggregate plants, are to be imported, and costs were calculated under foreign currency requirements.

Special types of equipment such as boring machines, grout pumps, compressors, etc. are imported and were calculated under foreign currency requirements.

Electromechanical equipment and transmission line equipment are included under foreign currency while their transportation costs in Thailand and installation costs are in local currency.

Import duty on the construction equipments for civil works to be imported and electromechanical equipment are included in the local currency.

11.2.2 Project Cost

(1) Project Cost

The project cost of the Integrated Development was estimated on the basis of the condition mentioned above.

Nam Ngao Project	6,470 Million Baht	(US$249 Million)
Mae Lama Luang Project	8,350 Million Baht	(US$321 Million)
Total	14,820 Million Baht	(US$570 Million)

The detail of the cost is shown in Table 11-1.

Further, the project cost of the Individual Development is attached in Appendix.

(2) Annual Expenditure

The annual expenditure of the project cost during construction is shown in Table 11-2 for the Nam Ngao project and Table 11-3 for the Mae Lama Luang project.

11.2.3 Economic Cost

(1) Economic Cost

The economic costs excluding the import duties, price contingency and interest during construction are as follows:

Nam Ngao Project	4,028 Million Baht	(US$155 Million)
Mae Lama Luang Project	5,103 Million Baht	(US$196 Million)
Total	9,131 Million Baht	(US$351 Million)

The detail of the economic costs is shown in Table 11-4.

The economic cost is used for the Economic Evaluation in Chapter 12.

(2) Annual Expenditure of the Economic Cost

The annual expenditure programme is shown in Table 11-5 for the Nam Ngao project and Table 11-6 for the Mae Lama Luang Project.

Table 11-1 Project Cost of Integrated Development Plan

(Million Baht)

I t e m	Nam Ngao Project			Mae Lama Luang Project			Overall Project		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
1. Preparation Works	0	102.0	102.0	0	133.0	133.0	0	235.0	235.0
Access Road	0	16.0	16.0	0	55.0	55.0			
Camp Facility & Others	0	86.0	86.0	0	78.0	78.0			
2. Environmental Mitigation	0	190.5	190.5	0	299.4	299.4	0	489.9	489.9
Relocation of Road	0	0	0	0	55.0	55.0		0	
Environmental Mitigation	0	190.5	190.5	0	244.4	244.4			
3. Civil Works	963.4	797.7	1,761.1	826.6	773.2	1,599.8	1,790.0	1,570.9	3,360.9
Care of River	87.8	89.4	177.5	114.0	113.1	227.1			
Dam	749.6	563.0	1,312.6	531.9	431.2	963.2			
Waterway	46.1	53.6	99.4	43.2	48.0	91.2			
Powerhouse and Switchyard	79.9	91.7	171.6	137.5	180.9	318.3			
4. Hydraulic Equipment	117.3	42.2	159.5	151.8	53.4	205.2	269.1	95.6	364.7
Gate, Screen and Valve	48.9	13.0	61.9	70.9	18.7	89.6			
Penstock	68.3	29.3	97.6	80.9	34.7	115.6			
5. Electro-mechanical Equipment	836.8	93.2	930.0	1,418.8	171.4	1,590.2	2,255.6	264.6	2,520.2
Turbine	320.6	44.2	364.8	549.0	75.8	624.8			
Generator	262.6	36.0	298.6	447.8	61.6	509.4			
Transformer and Others	253.6	13.0	266.6	422.0	34.0	456.0			
6. Transmission Line	228.0	74.0	302.0	458.0	93.0	551.0	686.0	167.0	853.0
230 kV Line	0	0	0	458.0	93.0	551.0			
115 kV Line	52.0	21.0	73.0	0	0	0			
Mea Sariang Sub-station	176.0	53.0	229.0	0	0	0			
7. Import Duties and Tax	0	340.0	340.0	0	531.8	531.8	0	871.8	871.8
8. EGAT Administration	0	103.4	103.4	0	131.3	131.3	0	234.7	234.7
9. Engineering Service	172.2	0	172.2	218.9	0	218.9	391.1	0	391.1
10. Physical Contingency	182.6	125.0	307.6	229.2	144.5	373.7	411.8	269.5	681.3
11. Price Contingency	596.4	440.3	1,036.7	804.9	553.7	1,358.6	1,401.3	994.0	2,395.3
12. Interest During Construction	741.6	323.4	1,065.0	954.1	403.0	1,357.1	1,695.7	726.4	2,422.1
13. Total Project Cost	3,838.3	2,631.7	6,470.0	5,062.3	3,287.7	8,350.0	8,900.6	5,919.4	14,820.0

Table 11-2 Annual Expenditure Schedule of Project Cost (Nam Ngao Project)

(Million Baht)

	1st year		2nd year		3rd year		4th year		5th year		Total		
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	Total
1.Preparation Works	0	66.0	0	36.0	0	0	0	0	0	0	0	102.0	102.0
2.Environmental Mitigation	0	22.9	0	57.2	0	57.2	0	30.5	0	22.7	0	190.5	190.5
3.Civil Works	20.7	16.7	245.5	187.1	331.7	251.4	333.0	294.7	32.5	47.8	963.4	797.7	1,761.1
4.Hydraulic Equipment	0	0	0	0	45.1	18.7	46.3	16.8	25.9	6.7	117.3	42.2	159.5
5.Electro-mechanical Equipment	0	0	145.4	3.0	334.6	30.2	280.0	32.8	76.8	27.2	836.8	93.2	930.0
6.Transmission Line	0	0	0	0	114.0	22.3	91.4	37.0	22.6	14.7	228.0	74.0	302.0
Sub Total (1)	20.7	105.6	390.9	283.3	825.4	379.8	750.7	411.8	157.8	119.1	2,145.5	1,299.6	3,445.1
7.Import Duties	0	1.0	0	51.9	0	137.5	0	118.9	0	30.7	0	340.0	340.0
8.EGAT Administration	0	3.8	0	20.2	0	36.2	0	34.9	0	8.3	0	103.4	103.4
9.Engineering Service	6.3	0	33.7	0	60.3	0	58.1	0	13.8	0	172.2	0	172.2
Sub Total (2)	27.0	110.4	424.6	355.4	885.7	553.5	808.8	565.6	171.6	158.1	2,317.7	1,743.0	4,060.7
10.Physical Contingency	2.1	10.6	34.7	28.2	69.1	36.4	63.9	39.1	12.8	10.7	182.6	125.0	307.6
11.1 Escalation Ratio	(1.1580)	(1.1580)	(1.1997)	(1.1997)	(1.2429)	(1.2429)	(1.2877)	(1.2877)	(1.3469)	(1.3469)			
11.Price Contingency	4.3	17.4	84.8	71.0	215.1	134.4	232.7	162.7	59.5	54.8	596.4	440.3	1,036.7
Sub Total (3)	33.4	138.4	544.1	454.6	1,169.9	724.3	1,105.4	767.4	243.9	223.6	3,096.7	2,308.3	5,405.0
12.1 Interest	2.7	6.9	46.2	29.6	139.8	65.8	228.2	104.2	247.7	115.4	664.6	321.0	986.5
12.2 Commitment Fee	23.3		23.1		19.0		10.1		1.8		77.0	0	77.0
12.Interest During Construction	26.0	6.9	69.3	29.6	158.8	65.8	238.3	104.2	249.5	116.5	741.0	323.4	1,065.7
Total Project Cost	59.4	145.3	613.4	484.2	1,328.7	790.1	1,343.7	871.6	493.4	340.5	3,838.3	2,631.7	6,470.0

Table 11-3 Annual Expenditure Schedule of Project Cost (Mae Lama Luang Project)

(Million Baht)

	1st year		2nd year		3rd year		4th year		5th year		Total		
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	Total
1.Preparation Works	0	100.0	0	33.0	0	0	0	0	0	0	0	133.0	133.0
2.Environmental Mitigation	0	35.9	0	89.8	0	89.8	0	47.9	0	36.0	0	299.4	299.4
3.Civil Works	64.1	54.6	135.9	111.8	341.5	321.9	272.3	267.8	12.8	17.1	826.6	773.2	1,599.8
4.Hydraulic Equipment	0	0	0	0	8.1	3.5	101.6	39.0	42.1	10.9	151.8	53.4	205.2
5.Electro-mechanical Equipment	0	0	166.2	3.4	572.0	55.4	550.4	61.8	130.2	50.8	1,418.8	171.4	1,590.2
6.Transmission Line	0	0	0	0	229.0	28.3	182.6	46.5	46.4	18.2	458.0	93.0	551.0
Sub Total (1)	64.1	190.5	302.1	238.0	1,150.6	498.9	1,106.9	463.0	231.5	133.0	2,855.2	1,523.4	4,378.6
7.Import Duties	0	3.3	0	52.6	0	205.4	0	219.6	0	50.9	0	531.8	531.8
8.EGAT Administration	0	7.6	0	16.2	0	49.5	0	47.1	0	10.9	0	131.3	131.3
9.Engineering Service	12.7	0	27.0	0	82.5	0	78.5	0	18.2	0	218.9	0	218.9
Sub Total (2)	76.8	201.4	329.1	306.8	1,233.1	753.8	1,185.4	729.7	249.7	194.8	3,074.1	2,186.5	5,260.6
10.Physical Contingency	6.4	19.1	25.2	23.7	91.0	47.4	88.7	43.1	17.9	11.2	229.2	144.5	373.7
11.1 Escalation Ratio	(1.1580)	(1.1580)	(1.1997)	(1.1997)	(1.2429)	(1.2429)	(1.2877)	(1.2877)	(1.3469)	(1.3469)			
11.Price Contingency	12.1	31.8	65.7	61.3	299.5	183.1	341.0	209.9	86.6	67.6	804.9	553.7	1,358.6
Sub Total (3)	95.3	252.3	420.0	391.8	1,623.6	984.3	1,615.1	982.7	354.2	273.6	4,108.2	2,884.7	6,992.9
12.1 Interest	7.6	12.6	41.2	32.2	171.1	81.4	300.3	130.5	328.6	144.2	848.8	400.9	1,249.7
12.2 Commitment Fee	30.9		30.1		26.9		14.8		2.7		105.3	0	105.3
12.Interest During Construction	38.5	12.6	71.3	32.2	198.0	81.4	315.1	130.5	331.3	146.3	954.1	403.0	1,357.1
Total Project Cost	133.8	264.9	491.3	424.0	1,821.6	1,065.7	1,930.2	1,113.2	685.5	419.9	5,062.3	3,287.7	8,350.0

Table 11-4 Economic Cost of Integrated Development Plan

(Million Baht)

Item	Nam Ngao Project			Mae Lama Luang Project			Overall Project		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
1. Preparation Works	0	102.0	102.0	0	133.0	133.0	0	235.0	235.0
2. Environmental Mitigation	0	190.5	190.5	0	299.4	299.4	0	489.9	489.9
3. Civil Works	963.4	797.7	1,761.1	826.6	773.2	1,599.8	1,790.0	1,570.9	3,360.9
4. Hydraulic Equipment	117.3	42.2	159.5	151.8	53.4	205.2	269.1	95.6	364.7
5. Electro-mechanical Equipment	836.8	93.2	930.0	1,418.8	171.4	1,590.2	2,255.6	264.6	2,520.2
6. Transmission Line	228.0	74.0	302.0	458.0	93.0	551.0	686.0	167.0	853.0
7. EGAT Administration	0	103.4	103.4	0	131.3	131.3	0	234.7	234.7
8. Engineering Service	172.2	0	172.2	218.9	0	218.9	391.1	0	391.1
9. Physical Contingency	182.6	125.0	307.6	229.2	144.5	373.7	411.8	269.5	681.3
Economic Cost	2,500.3	1,528.0	4,028.3	3,303.3	1,799.2	5,102.5	5,803.6	3,327.2	9,130.8

Table 11-5 Annual Expenditure Schedule of Economic Cost (Nam Ngao Project)

(Million Baht)

	1st year		2nd year		3rd year		4th year		5th year		Total		
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	Total
Preparation Works	0	66.0	0	36.0	0	0	0	0	0	0	0	102.0	102.0
Resettlement and Compensation	0	22.9	0	57.2	0	57.2	0	30.5	0	22.7	0	190.5	190.5
Civil Works	20.7	16.7	245.5	187.1	331.7	251.4	333.0	294.7	32.5	47.8	963.4	797.7	1,761.1
Hydraulic Equipment	0	0	0	0	45.1	18.7	46.3	16.8	25.9	6.7	117.3	42.2	159.5
Electro-mechanical Equipment	0	0	145.4	3.0	334.6	30.2	280.0	32.8	76.8	27.2	836.8	93.2	930.0
Transmission Line	0	0	0	0	114.0	22.3	91.4	37.0	22.6	14.7	228.0	74.0	302.0
EGAT Administration	0	3.8	0	20.2	0	36.2	0	34.9	0	8.3	0	103.4	103.4
Engineering Service	6.3	0	33.7	0	60.3	0	58.1	0	13.8	0	172.2	0	172.2
Sub Total	27.0	109.4	424.6	303.5	885.7	416.0	808.8	446.7	171.6	127.4	2,317.7	1,403.0	3,720.7
Physical Contingency	2.1	10.6	34.7	28.2	69.1	36.4	63.9	39.1	12.8	10.7	182.6	125.0	307.6
Economic Cost	29.1	120.0	459.3	331.7	954.8	452.4	872.7	485.8	184.4	138.1	2,500.3	1,528.0	4,028.3

Table 11-6 Annual Expenditure Schedule of Economic Cost (Mae Lama Luang Project)

(Million Baht)

	1st year		2nd year		3rd year		4th year		5th year		Total		
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	Total
Preparation Works	0	100.0	0	33.0	0	0	0	0	0	0	0	133.0	133.0
Resettlement and Compensation	0	35.9	0	89.8	0	89.8	0	47.9	0	36.0	0	299.4	299.4
Civil Works	64.1	54.6	135.9	111.8	341.5	321.9	272.3	267.8	12.8	17.1	826.6	773.2	1,599.8
Hydraulic Equipment	0	0	0	0	8.1	3.5	101.6	39.0	42.1	10.9	151.8	53.4	205.2
Electro-mechanical Equipment	0	0	166.2	3.4	572.0	55.4	550.4	61.8	130.2	50.8	1,418.8	171.4	1,590.2
Transmission Line	0	0	0	0	229.0	28.3	182.6	46.5	46.4	18.2	458.0	93.0	551.0
EGAT Administration	0	7.6	0	16.2	0	49.5	0	47.1	0	10.9	0	131.3	131.3
Engineering Service	12.7	0	27.0	0	82.5	0	78.5	0	18.2	0	218.9	0	218.9
Sub Total	76.8	198.1	329.1	254.2	1,233.1	548.4	1,185.4	510.1	249.7	143.9	3,074.1	1,654.7	4,728.8
Physical Contingency	6.4	19.1	25.2	23.7	91.0	47.4	88.7	43.1	17.9	11.2	229.2	144.5	373.7
Economic Cost	83.2	217.2	354.3	277.9	1,324.1	595.8	1,274.1	553.2	267.6	155.1	3,303.3	1,799.2	5,102.5

CHAPTER 12

ECONOMIC EVALUATION

CHAPTER 12 ECONOMIC EVALUATION

CONTENTS

Page

List of Tables

List of Figures

CHAPTER 12 ECONOMIC EVALUATION

12.1 Methodology and Basic Conditions

12.1.1 Methodology

In general, economic evaluation of a development project is designed to measure its socio-economic impact on the country as a whole by comparing two cases; the project is implemented and the project is not implemented.

The economic evaluation employs indices such as net present value of the project, benefit/cost ratio and economic internal rate of return which are calculated from benefits and costs of the project using the "Discounted Cash Flow method".

To determine benefits and costs of a project, market prices obtained should be converted to real benefits and costs, since these are generally distorted due to taxes, government subsidies, import control, import duties, public charges, minimum wages, and other government intervention and monopolistic pricing.

The World Bank and other international financing organizations employ international market prices to estimate real project costs and benefits. The method of economic evaluation employed by the World Bank and other international financing organizations may be summarized as shown in Fig. 12-1.

Phase 1: To exclude items to be transferred to national income from market prices.

Phase 2: To convert market prices for trade goods, non-trade goods, skilled labor, unskilled labor and other items to real (border) prices.

Phase 3: To determine the internal rate of return on the basis of real benefits and costs, and compare it with opportunity cost of capital in the country.

Phase 4: To carry out a socio-economic evaluation considering national saving and income distribution.

For this project, economic evaluation up to Phase 3 is carried out (See Fig. 12-1).

In economic evaluation of hydroelectric power development projects, it is more realistic to measure and compare benefits and costs of the project using the long-term marginal cost method or the tariff system method, if benefits can be accounted for.

However, if benefits cannot be easily accounted for and the project is incorporated in a long range electric power development program which is a part of a national socio-economic development policy to satisfy future power demand (i.e., if the project is not implemented, other means of power supply is to be substituted for it.), an alternative plant approach will be employed to measure and evaluate economic costs of the proposed project and the alternative project.

For this project, the alternative plant approach is employed. Usually, the capacity benefit of a hydro power plant is evaluated at the fixed cost of an appropriate alternative thermal power plant which has an equivalent capacity to the firm capacity of the hydro power plant. The energy benefit is taken to be equal to the variable cost of an alternative thermal power plant which produces an equal amount of energy.

12.1.2 Basic Conditions

The basic conditions for confirming the economic justification of this project are as follows:

(1) Construction Cost

The economic cost eliminating interest during construction, import duty, taxes and other public charges. The cost estimates are based on price levels as of January 1989.

(2) Exchange Rate of Currency

The construction cost is estimated using an exchange rate of US$1 = 26 Baht.

(3) Operation and Maintenance Costs of the Hydroelectric Power Plant

Dam and Reservoir	:	1% of the construction cost
Hydro Power Station	:	2% of the construction cost
Transmission Line	:	1% of the construction cost

(4) Service Life of the Hydroelectric Power Plant

Dam and reservoir	:	50 years
Generating facilities	:	25 years
Transmission facilities	:	40 years

(5) Station Service Rate, Scheduled Outage Rate and Forced Outage Rate of the Hydroelectric Power Plant

Station Service Rate
kW : 0.8%
kWh : 1.0%
Scheduled Outage Rate : 2.0%
Forced Outage Rate : 0.5%

(6) Discount Rate

The discount rate shall be set at 12%.

The basic conditions of alternative thermal power generating facilities are described in section 12.2.

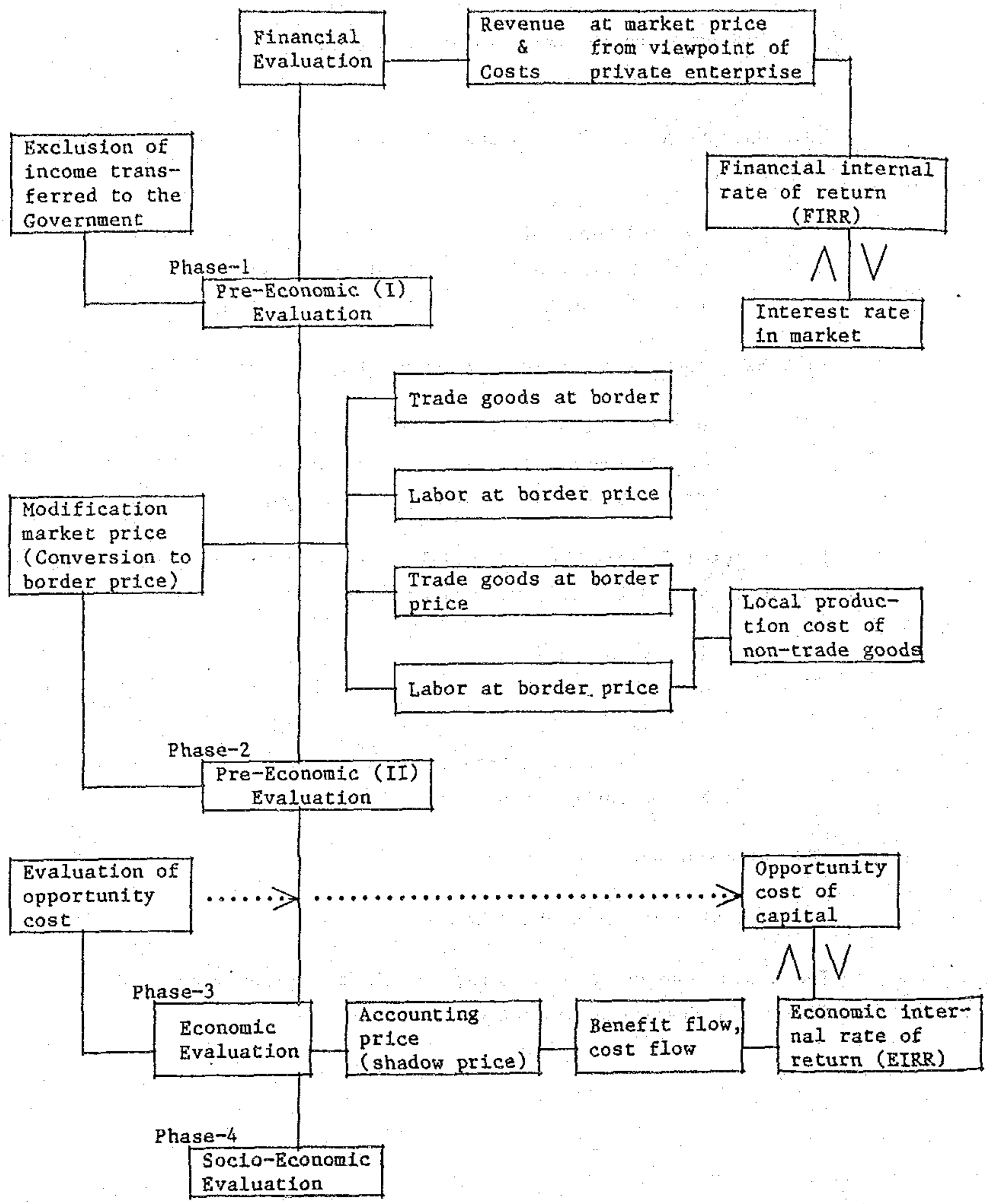


Fig. 12–1 Flow Chart of Economic Evaluation of Project

12.2 Alternative Thermal Power Generating Facilities

Several types of thermal power plants, such as a gas turbine plant, a combined cycle plant, an oil-fired or coal-fired steam thermal power plant, etc. are to be considered for the evaluation of the benefit of this Project.

As is well known, these thermal power plants have their own characters. In case of gas turbine, for example, capital cost per KW is lower but fuel cost per KWH is higher, so it is usually suited for supplying peak energy.

On the contrary in case of the high efficiency thermal power plant, the cost relationship is reversed, hence it is generally committed to assume the base load portion. The combined cycle plant stands between these two. In addition, these thermal power plants should be operated within certain specified ranges of capacity factors.

In other words, each type of thermal power plant has its own range of allowable operation hours in a year (hence for its whole life) within which the most economical operation of the plant will be attained.

Combinations of the following three types of thermal power plants were adopted as the appropriate alternative thermal plants for the evaluation of the benefit of this project. The most suitable alternative thermal power plant having a similar generation characteristic and capacity factor to this Project shall be selected using the "Screening Curve Method". The annuitized cost of each type of thermal power plant (Y) consists of the annuitized fixed cost and variable cost (fuel cost) in proportion to capacity factors (annual operation hours: X), and a linear function as follows is stood up between Y and X:

Annuitized Cost (Y) = Annuitized Fixed Cost + Variable Cost x
Annual Operation Hours (X)

The boundary points of the economical ranges of capacity factors for each type of thermal power plant can be decided by calculating intersection points of cost curves of the three types of thermal power plants as shown on Fig. 12-2.

- Gas Turbine Plant

  Fuel: Natural gas for the first 25 years and diesel oil for the second 25 years

- Steam Thermal Power Plant

  Fuel: Natural gas for the first 25 years and imported coal for the second 25 years

- Lignite Thermal Power Plant

  Fuel: Lignite for the whole 50 years

Basic economic criteria and basic costs of these thermal plants are as shown on Table 12-1.

Based on these criteria, the annuitized fixed cost and variable cost for each of these thermal plants were calculated using the annual cost method as shown on Table 12-2 through Table 12-4.

The results are summarized as follows:

	kW-cost ฿/kW.a	kWh-cost ฿/kWh
Gas turbine	1,788.6	1.1612
Steam thermal	3,590.1	0.9619
Lignite	4,969.0	0.5756

(Price level: January 1989)

The boundary points of the economical ranges of capacity factors for the three types of thermal power plants, are 103.2% and 62.0% between gas turbine and steam thermal, and gas turbine and lignite, respectively as shown on Table 12-5.

Judging from the above, the gas turbine plant was selected as the alternative thermal power plant for the evaluation of this project which is designed to supply peak energy for Region 4.

Table 12-1 Economic Criteria and Basic Cost of Thermal Power Plants

		Unit	Hydro Power Plant	Gas Turbine		Thermal		Lignite (50 years)	
				Natural Gas (1st 25 years)	Diesel Oil (2nd 25 years)	Natural Gas (1st 25 years)	Imported Coal (2nd 25 years)		
	Installed capacity	MW	H	G	G	T	T	L	
a.	Standard unit capacity	MW		100	100	600	600	600	
b.	Standard plant factor	%	Xh	X_g	X_g	X_t	X_t	X_ℓ	
c.	Economic life length adopted	Years	50	15	15	20	25	25	
d.	Station service rate	%	1	2	2	7	7	7	
e.	Scheduled outage rate	%	2	4	4	12	12	12	
f.	Forced outage rate	%	0.5	4	4	10	12	12	
g.	Annual fixed O&M rate	%	*	3	3	2.5	3	2	
h.	Unit construction cost (Economic Cost)	฿/kW		9,100	9,100	15,800	22,400	22,400	
	(Fuel)			Natural gas	Diesel oil	Natural gas	Imported coal	Lignite	
i.	Fuel calorific value			1,000 Btu/cu.ft	8,900 kcal/Lit	1,000 Btu/cu.ft	5,700 kcal/kg	2,900 kcal/kg	
j.	Thermal efficiency	%		25	25	36	36	36	
k.	Energy equivalence	kcal/kWH		3,440 kcal/kWH	3,440 kcal/kWH	2,388.9kcal/kWH	2,388.9kcal/kWH	2,388.9kcal/kWH	
l.	Plant heat value	Btu/kWH		13,651 Btu/kWH	13,651 Btu/kWH	9,480 Btu/kWH	9,480 Btu/kWH	9,480 Btu/kWH	
m.	Fuel consumption			13.651 cu.ft/kWH	0.3865 Lit/kWH	9.480 cu.ft/kWH	0.4191 kg/kWH	0.8238 kg/kWH	
n.	Unit fuel price			0.0745 ฿/cu.ft	3.9384 ฿/Lit	0.0745 ฿/cu.ft	1.0959 B/kg	0.4961 ฿/kg	
o.	Unit fuel cost	B/kWH		1.0170	1.5222	0.7063	0.4593	0.4087	
p.	Effective capacity	MW	0.98H	0.92G	0.92G	0.78T	0.76T	0.76L	100-(e+f)/100xInstalled capa.
q.	Send-out capacity	MW	0.97H	0.90G	0.90G	0.73T	0.71T	0.71L	p x (1-d/100)
r.	Energy production	MWH		GX_gH_r	GX_gH_r	TX_tH_r	TX_tH_r	$LX_\ell H_r$	
s.	Send-out energy	MWH	0.97 HX_hH_r	$0.90GX_gH_r$	$0.90TX_tH_r$	$0.73TX_tH_r$	$0.71TX_tH_r$	$0.71LX_\ell H_r$	
t.	Capital investment cost	฿		9,100G	9,100G	15,800T	22,400T	22,400L	h x installed capacity
u.	Annual O&M cost	฿		273	273	395	672	672	t x g
v.	Daily O&M cost	฿		0.7479	0.7479	1.0822	1.8411	1.8411	u/365
w.	Fuel cost	฿		$1.0170GX_gH_r$	$1.5222GX_gH_r$	$0.7063TX_tH_r$	$0.4593TX_tH_r$	$0.4087LX_\ell H_r$	r x o

* Dam & Reservoir : 1%
Hydro Power Station : 2%

Table 12-2 Cost Stream of Alternative Gas Turbine (Natural gas —— Diesel oil)

Year	Single payment worth factor 1)	Capital investment cost					O&M	Fuel Cost		
		Plant 1	Plant 2	Plant 3	Plant 4	Total		for the 1st 25 years	for the 2nd 25 years	Total
n	i = 12%	GMW	GMW	GMW	GMW					
0	1.000	9,100G								
1							273.0G	$1.0170GXgH_r$		
15	0.182696		9,100G							
30	0.033378			9,100G						
45	0.006098				9,100G					
50	0.003460				$-\frac{10}{15}$ 9,100G				$1.5222GXgH_r$	
Present value factor		1.000	0.182696	0.033378	0.006098 0.003460			7.843139 2)	0.461359 3)	
Present value		9,100G	1,662.5G	303.7G	55.5G -21.0G	11,100.7G		$7.9765GXgH_r$	$0.7023GXgH_r$	$8.6788GXgH_r$
Capital recovery factor		0.1204167 4)								
Annuitized cost						1,336.7G	273.0G			$1.0451GXgH_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	1,336.7G	
O&M	฿	273.0G	
Fuel	฿		$1.0451GXgH_r$
Total	฿	1,609.7G	$1.0451GXgH_r$

	Unit	Cost	
KW-benefit	฿/KW	1,788.6	1,609.7G/0.90G
KWH-benefit	฿/KWH	1.1612	$1.0451GXgH_r/0.90GXgH_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... Yg = 1,788.6 + 1.1612 x 8760Xg = 1,788.6 + 10,172.1Xg

Daily cost ...... Yg = 1,788.6/365 + 1.1612 x 24Xg = 4.9003 + 27.8688Xg

1) Present worth factor $1/(1+i)^n$

2) Annuity cost factor = $\frac{(1+i)^n-1}{i(1+i)^n}$

i = 0.12 n = 25 7.843139

3) $\frac{(1+i)^{50}-1}{i(1+i)^{50}} - \frac{(1+i)^{25}-1}{i(1+i)^{25}}$

= 8.304498 − 7.843139 = 0.461359

4) Annuity factor $\frac{i(1+i)^n}{(1+i)^n-1}$

Table 12-3 Cost Stream of Alternative Steam Thermal (Natural gas —— Imported coal)

Year	Single payment worth factor 1)	Capital investment cost				O&M cost			Fuel cost		
		Plant 1 Natural gas	Plant 2 Natural gas	Plant 3 Imported coal	Total	Plant 1 & Plant 2	Plant 3	Total	for the 1st 25 years	for the 2nd 25 years	Total
n	i = 12%	T MW	T MW	T MW							
0	1.000	15,800T									
1						395T			$0.7063X_tH_r$		
20	0.103667		15,800T			↓			↓		
25	0.058823		$-\frac{15}{20}$ 15,800T	22,400T		↓			↓		
							672T			$0.4593TX_tH_r$	
50	0.003460						↓			↓	
Present value factor		1.000	0.103667 0.058823	0.058823		7.843139	0.461359		7.843139	0.461359	
Present value		15,800T	1,637.9T	1,317.6T		3,098.0T	310.0T		$5.5396TX_tH_r$	$0.2119TX_tH_r$	
			-697.1T		18,058.4T			3,408.0T			$5.7515TX_tH_r$
Capital recovery factor		0.1204167									
Annuitized cost					2,174.5T			410.4T			$0.6926TX_tH_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	2,174.5T	
O&M	฿	410.4T	
Fuel	฿		$0.6926TX_tH_r$
Total	฿	2,584.9T	$0.6926TX_tH_r$

	Unit	Cost	
KW-benefit	฿/KW	3,590.1	2,584.9T/0.72T
KWH-benefit	฿/KWH	0.9619	$0.6926TX_tH_r/0.72TX_tH_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... Y_t = 3,590.1 + 0.9619 x 8760X_t = 3,590.1 + 8,426.2X_t

Daily cost ...... Y_t = 3,590.1/365 + 0.9619 x 24X_t = 9.8359 + 23.0856X_t

Table 12-4 Cost Stream of Alternative Steam Thermal (Lignite)

Year	Single payment worth factor 1)	Capital investment cost			O&M cost			Fuel cost		
		Plant 1	Plant 2	Total	Plant 1	Plant 2	Total	for the 1st 25 years	for the 2nd 25 years	Total
n	i = 12%	L MW	L MW					Lignite	Lignite	
0	1.0	22,400L								
1					672L ↓		672L ↓	$0.4087LX_1H_r$ ↓		$0.4087LX_1H_r$ ↓
25	0.058823		22,400L			672L ↓			$0.4087LX_1H_r$ ↓	
50										
Present value factor		1.0	0.058823							
Present value		22,400L	1,317.6L	23,717.6L						
Capital recovery factor		0.1204167								
Annuitized cost				2,856.0L			672L			$0.4087LX_1H_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	2,856.0L	
O&M	฿	672L	
Fuel	฿		$0.4087LX_1H_r$
Total	฿	3,528.0L	$0.4087LX_1H_r$

	Unit	Cost	
KW-benefit	฿/KW	4,969.0	3,528.0L/0.71L
KWH-benefit	฿/KWH	0.5756	$0.4087LX_1H_r/0.71LX_1H_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... $Y_1 = 4,969.0 + 0.5756 \times 8760X_1 = 4,969.0 + 5,042.3X_1$

Daily cost ...... $Y_1 = 4,969.0/365 + 0.5756 \times 24X_1 = 13.6137 + 13.8144X_1$

Table 12-5 Intersection Points of Cost Curves

Cost curve of gas turbine

$$y_g = 4.9003 + 27.8688\ X_g \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

Cost curve of thermal

$$y_t = 9.8359 + 23.0856\ X_t \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

Cost curve of lignite

$$y_\ell = 13.6137 + 13.8144\ X \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

Intersection point of (1) and (2),

$$X_{g,t} = \frac{9.8359 - 4.9003}{27.8688 - 23.0856} = 1.0319\ (103.2\%)$$

Intersection point of (2) and (3)

$$X_{t,\ell} = \frac{13.6137 - 9.8359}{23.0856 - 13.8144} = 0.4075\ (40.8\%)$$

Intersection point of (1) and (3)

$$X_{g,\ell} = \frac{13.6137 - 4.9003}{27.8688 - 13.8144} = 0.6200\ (62.0\%)$$

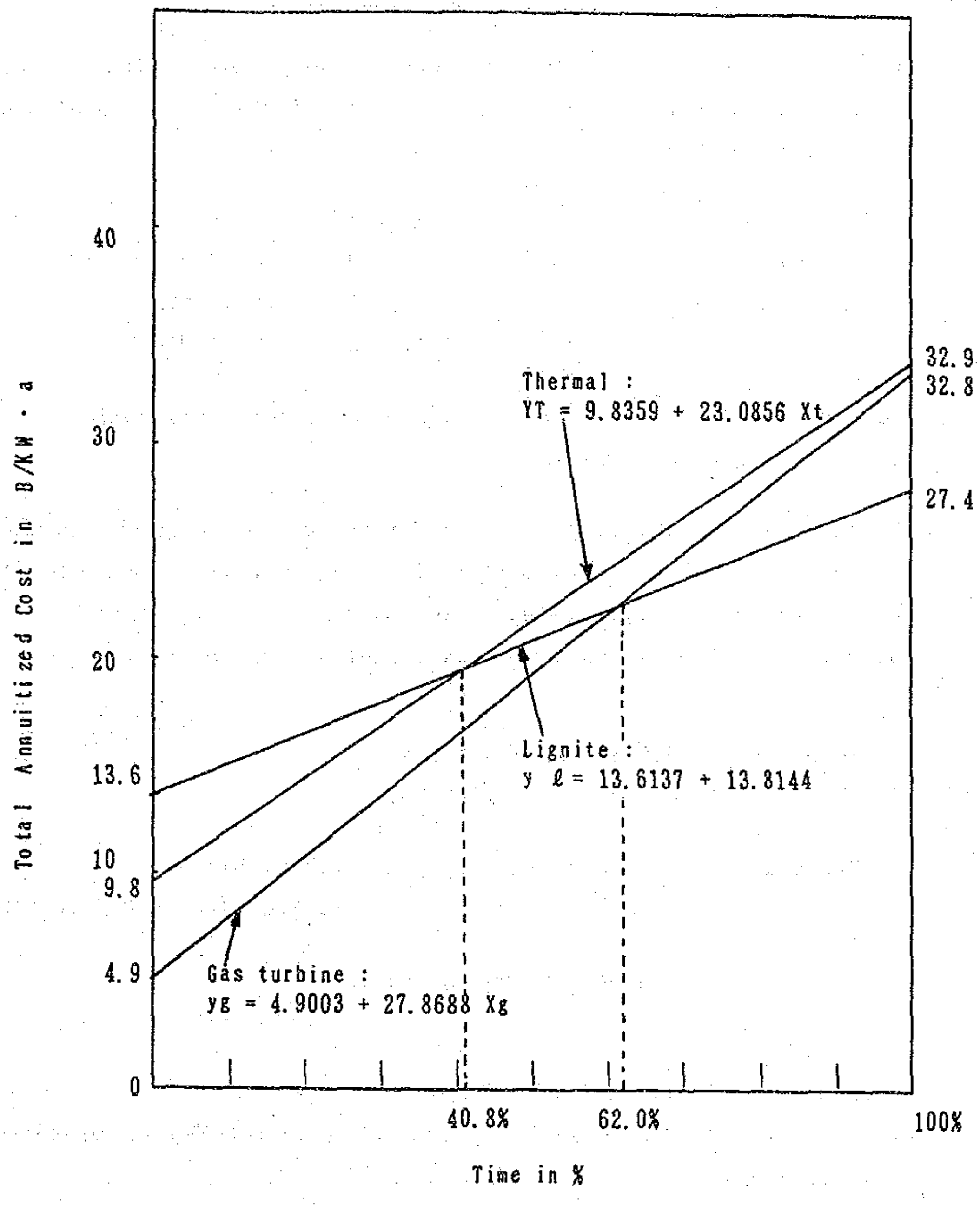


Fig 12-2 Relation between Annuitized Cost and Capacity Factor of Alternative Thermal Power Plants