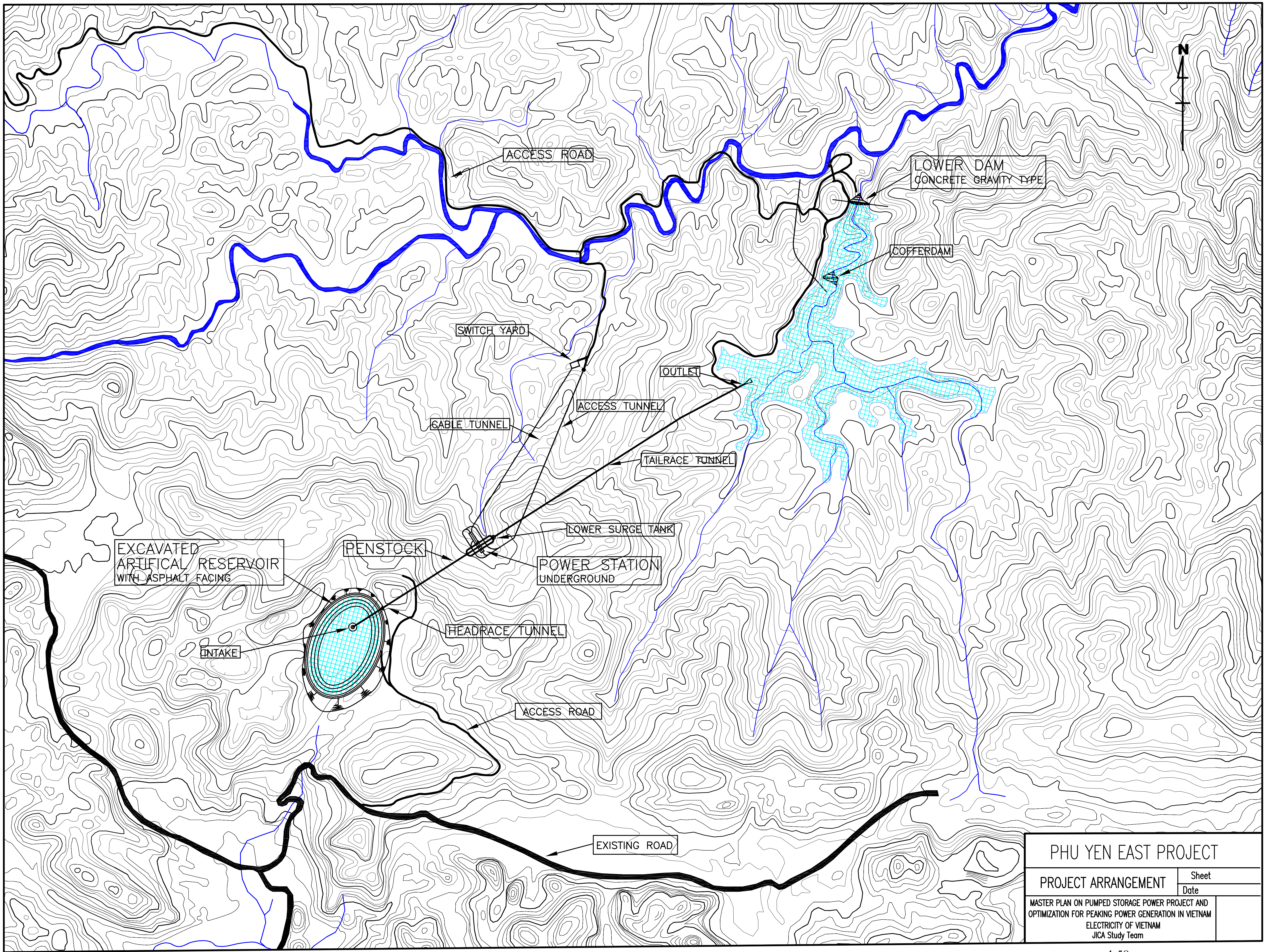


Figure 4-3-3 Project arrangement of Phu Yen East site

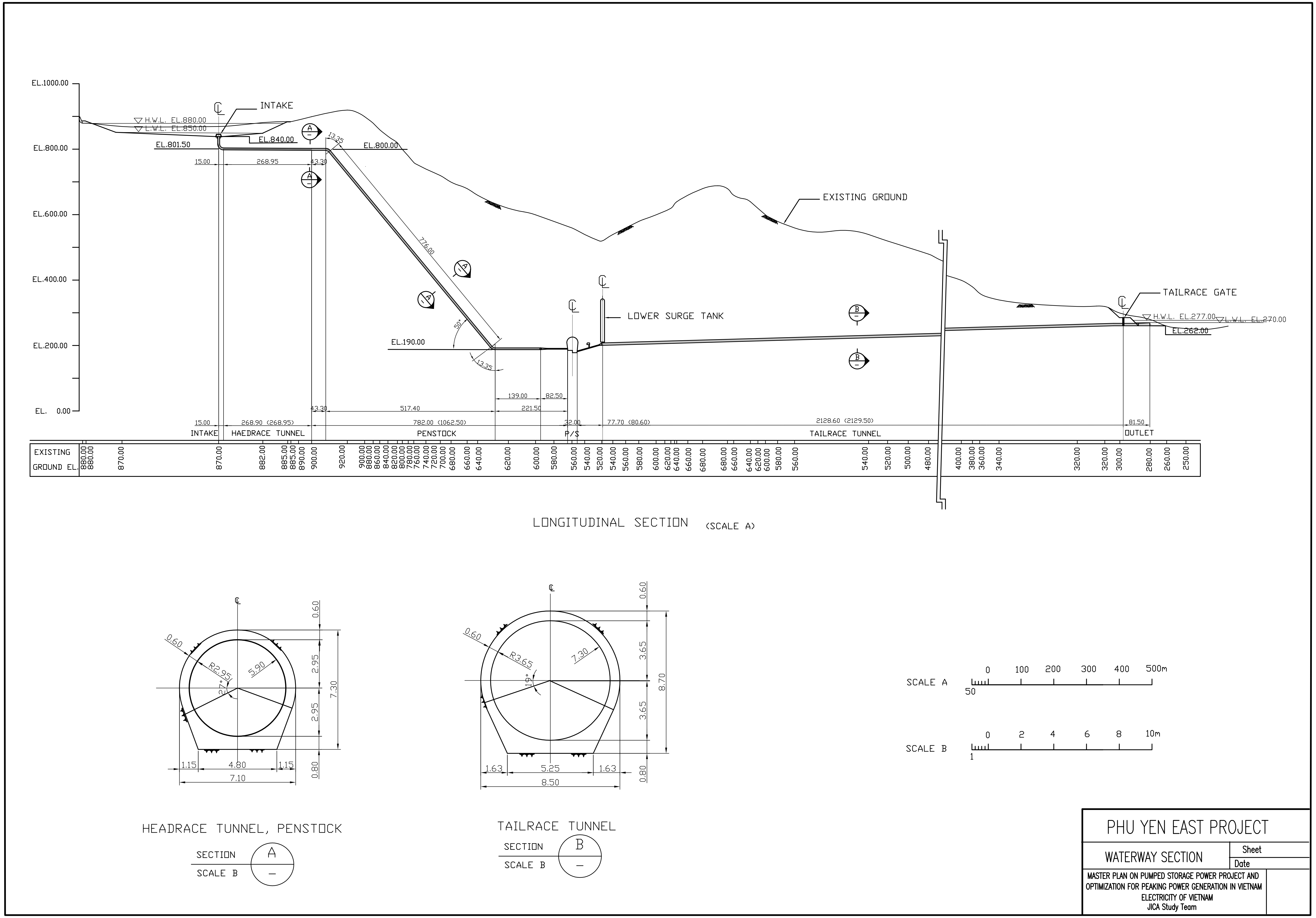


Figure 4-3-4 Waterway section of Phu Yen East site

(1) Design of Power Generation Planning

A power generation planning is an important matter to affect the design conditions of the PSPP's equipment. However, it is necessary from time to time to repeat reviewing the power generation planning in order to attain an optimal plan, since power plant features are changeable by the design of the structures.

The preliminary design was carried out according to the flowchart of Figure 4-3-5, and based on the topographical maps with the scale of 1/50,000.

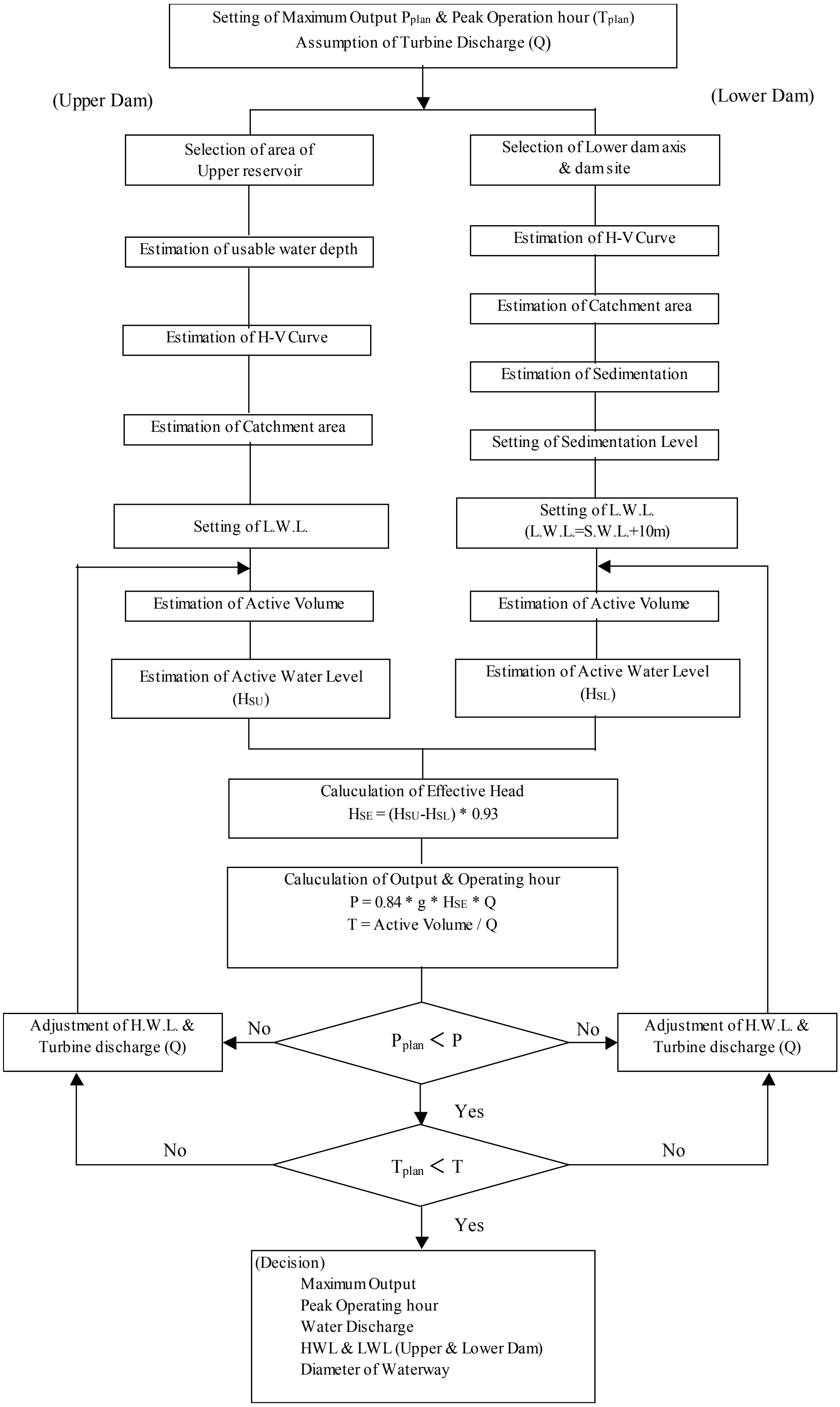


Figure 4-3-5 Flowchart of the Preliminary Design

(2) Design of the Main Structures

a. Civil Works

1) Upper Dam and Reservoir

(Upper Dam and Reservoir)

The rock around the upper reservoir is composed of clayish shale or limestone (D2mt, D2ebn, D2g-D3bc), which are hard and massive for a flat topography, and the thickness of the secondary sediments or weathering in the reservoir is about 5-10m.

Facing type poundage is suitable for this upper dam, of which H.W.L. is 880 m, considering the topographical condition.

There is a mountain of limestone in the west side of the reservoir, which has a very steep slant. It is necessary to build a bank keeping some distance from the skirts of the mountain to avoid the influences of collapse of the mountain. On the other hand, a small hill around EL.870m lies from north to south on the eastern side of the reservoir, which is not indicated in the topographic map. Location of the reservoir will be shifted west to use the hill as a bank of the reservoir.

The usable water depth of the upper reservoir has been planned with 30m, as the required storage volume (active storage) of the reservoir is 6,900,000m^3. The relation between the utilizing water depth and active storage capacity of the reservoir is presented in Figure 4-3-6.

The asphalt facing type is selected for the reservoir from the actual results of the existing hydropower projects in Japan, and the slope of the bank shall be 1:2.5 from the point of view of execution of asphalt facing. The bottom of the reservoir shall have a gentle slope to prevent pooling.

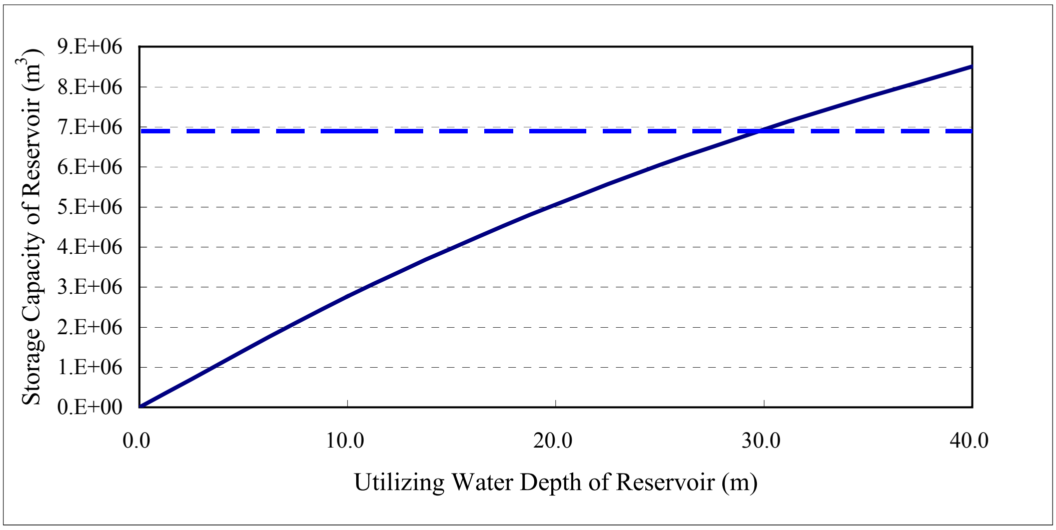


Figure 4-3-6 Storage Capacity Curve of the Upper Reservoir

(Intake Structure)

The intake structure of the excavated artificial reservoir shall be located at the bottom of the reservoir so as to use the storage volume effectively. It shall be of a morning glory type by reinforced concrete. The tunnel portion of the intake structure shall be steel lined and be jointed to the penstock tunnel.

The top of the intake shall be less than 3m of L.W.L. (EL.850m) to prevent a whirlpool and avoid air to go dragged into the waterway. Invert concrete shall be placed at the area of about 30m diameters for the purpose of preventing erosion by water flow at the bottom of the reservoir.

2) Underground Structure

Generally speaking, the shortest route shall be selected between the upper reservoir and the lower reservoir for the tunnel alignment of the waterway, based on the topographical and geological conditions. The lined profile of the waterway shall be circular in order to prevent the concentrating stress.

(Penstock)

The penstock tunnel has been designed as the shortest route between the intake and the underground powerhouse. A shaft at 50 degrees inclination, which has the actual results in Japan, was selected from the point of view of the excavation rocks.

The maximum velocity of 10m/sec in the penstock is estimated from actual results from existing hydropower projects. The detailed design is as follows:

- The penstock tunnel is approximately 1,500m long with a horse-shoe section of 7.1m diameter.
- The average diameter of the penstock is 5.9m, and the apertures between the penstock and the bedrock shall be filled with the concrete after the penstock is set up.
- At a flat place immediately upstream of the underground powerhouse, a trifurcation of the penstock is set up to be connected with the three turbines. .

(Underground Powerhouse)

Basically, the location and direction of the cavern are determined after excavating the exploratory headings and investigating the geological condition such as initial ground pressure and rock mass characteristics etc. In this study, the location of the underground powerhouse has been selected by the topographical maps with the scale of 1/50,000, the published geological maps and the criteria for PSPP finding indicated in Table 4-2-1.

An egg-shape type, which has actual results in Japan, was selected as the cavern form, from the point of view of dynamic advantage. The cavern dimension was designed according to TEPCO's PSPP results of the 1,000MW class.

As a lasting tunnel required for an underground power plant, an access tunnel (1,500m), a cable tunnel (1,250m) and a drainage tunnel (1,700m) were planned as permanent facilities based on the topographical maps with the scale of 1/50,000.

(Lower Surge Tank)

A lower surge tank shall be designed at the upstream end of the tailrace, since the tailrace tunnel is estimated to be about 2,300m long in total.

Considering its maximum discharge and tailrace length, the volume of the lower surge tank was designed according to the previous results of equal scale. In short, the upper surge water level has been determined to be 50m above H.W.L. of the lower reservoir.

(Tailrace)

Reinforced concrete shall be used for the tailrace liner from the economical point of view.

The maximum velocity in the concrete lining is estimated at 6.5m/sec with the inner diameter of 7.3m, following the actual data of the existing hydropower projects. An optimal diameter shall be determined based on the economic evaluations in the basic design stage.

The detailed design is as follows;

- The tailrace tunnel is approximately 2,300m long with a horse-shoe section of 8.5m diameter.
- The tailrace is 7.3m of diameter, and the concrete lining (thickness: 600mm) will be designed after tunnel excavation is completed.
- The contact and /or consolidation grouting are necessary in order to exert the pre-stress on the lining concrete.

(Outlet)

The location of the outlet is selected at the ridge, where the centerline of the outlet intersects the contour vertically, based on the criteria of the distance to the other side, sedimentations and the shortest waterway length.

The outlet structure shall be of a side outlet type by reinforced concrete according to the Japanese existing results (including the hydraulic model tests) (D×1.1＋2.5, D; the diameter of the tailrace).

3) Lower Dam and Reservoir

(Lower Dam and Reservoir)

The geology in the whole area of the lower reservoir/dam site is mainly of gently sloped clayish shale and limy shale in partial (D1st), and partially exposed limestone is found in the riverbed, of which elevation is 210 m. The planned lower dam site represents topography of steep slope and narrow width of the river, which is suitable for a concrete gravity type dam. No features of weak zone or strongly weathered zone around the reservoir and dam axis has been found.

The river flow in the lower dam site is as little as 0.3-0.4 m^3/s at the time of the site investigation (the dry season). If the lower dam site is planned in the main river, not only construction cost becomes higher, but also environmental issues are bigger. Therefore, the hydrological survey will be required in the next stage (F/S), and it is important to judge whether the pumping facilities from the main river will be construct or not.

The sedimentation volume of the lower dam is determined by multiplying the catchment area ratio by dam durability (100 years) based on the sedimentation data of Hoa Binh Lake.

The bottom elevation or the top of sedimentation is designed 10m below L.W.L. (270m), as the required storage volume (active storage) of the upper reservoir is 6,900,000m^3,and the usable water depth of the lower reservoir is planned with 7m (H.W.L.277m).

The relation between the water level and the effective storage capacity of the reservoir is presented in Figure 4-3-7.

The lower dam is of a concrete gravity type with the upstream slope of 1:0.1 and the downstream slope of 1:0.8, and is 80m high, giving an allowance of 3.0m from the H.W.L.

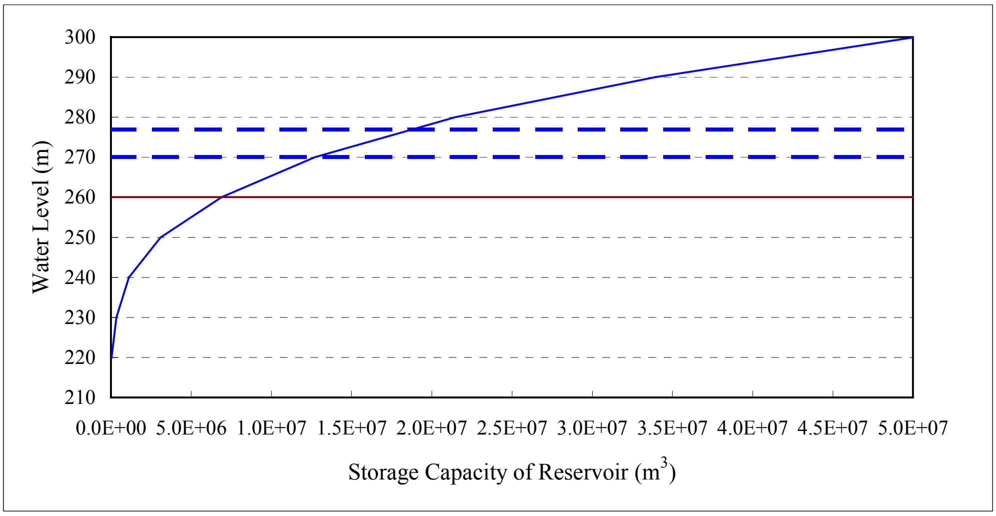


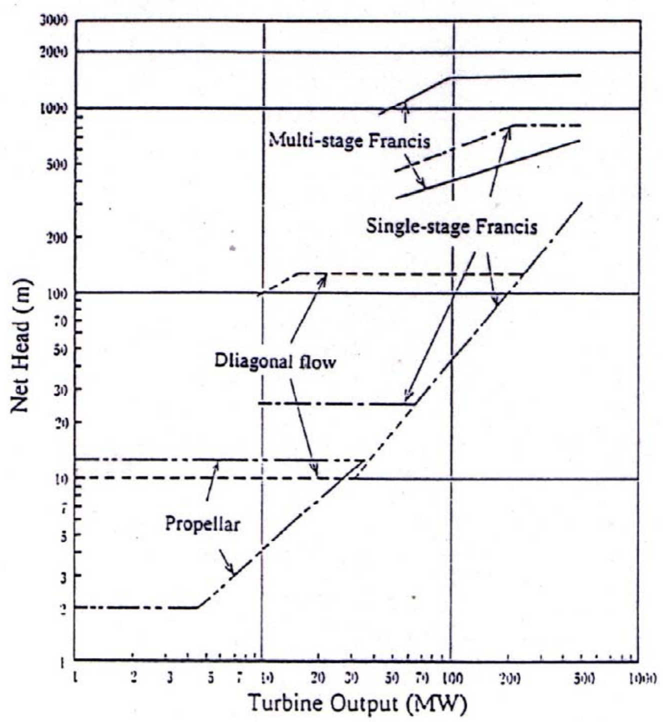
Figure 4-3-7 Storage Capacity Curve of the Lower Reservoir

b. Mechanical and Electrical Equipment

The optimal development scale has been studied in (2) in 4 cases between 750MW (250MW*3units) and 1,200MW (400MW*3units). Selection of unit size involves several technical and economical considerations. Main elements that influence the selection of the number and size of the units are:

- cost of initial installation,
- cost of operation and maintenance,
- reliability, flexibility and efficiency for plant operation,
- share by unit size in the power system,
- level of current manufacturing technology, and
- restrictions on weight and dimension in the methods and routes of transportation

Francis turbine has been adopted as the suitable type for Phu Yen East site, based on the site conditions (effective head; about 560m, unit output; 250MW～400MW) (refer to the Figure 4-3-8).



Reference;

Feasibility Study for the Upper Cisokan Pumped Storage Hydroelectric Power Development Project, JICA, March 1995.

Figure 4-3-8 Criteria for the Pump-turbine Type

c. Hydromechanical Works

1) Penstock

The penstock tunnel shall link the intake and the underground powerhouse, and the apertures between the penstock and the section of the tunnel shall be filled with concrete.

The penstock thickness is calculated by the following expression:

$t = P \times D / 2 \sigma_r \times (1 - \lambda)$

t ; thickness of penstock

P ; hydraulic pressure at a place to determine stress

D ; internal diameter

σ_r ; stress

λ ; sharing ratio of internal pressure by bedrock

In this study, the sharing ratio of internal pressure by bedrock is not used since there is no information regarding the bedrock surrounding the penstock.

2) Gate

The gate is installed at the outlet. The slide gate is planned as a suitable type for the outlet.

d. Access Road

The lasting roads and the temporary roads were planned as the access roads when the main structures were redesigned. As a result, the new approach roads and the temporary roads for the works are estimated to be about 27km long in total. A definite plan shall be drafted based on the detailed specifications and the working schedule, which are to be studied from now on.

(3) Preliminary Cost Estimation for PSPP Site

The JICA study team developed an efficient method for estimating the preliminary cost of the PSPP project, based on the information and data obtained from the 1/50,000 topographic maps and from the results of the site survey already implemented. The analysis results are shown in Table 4-3-6 and Appendix 4-7-2.

Table 4-3-6 Cost Estimation of Phu Yen East PSPP

(Unit; 1,000US$)

Cost Items	Cost	Note
Ⅰ.Construction Cost	575,574	
1.1 Preparation Works	17,125	
1.2 Civil Works	259,016	
1.3 Hydromechanical Works	43,123	
1.4 Hydroelectrical Works	256,310	
Ⅱ.Engineering Service	43,168	
Ⅲ.Administration Expense	2,878	
Ⅳ.Land Compensation and Resettlement	2,898	
Ⅴ.Others (VAT)	29,943	
Ⅵ.Physical Contingency	65,446	
Total Project Cost	719,907	Except transmission line
Construction Unit Cost (US$/kW)	600	Output; 1,200MW

a. Construction Cost

1) Preparatory Works

The construction cost of preparatory works includes access roads and bridges, base camp, construction power and water supply facilities and so on. The quantities of access roads and bridges are roughly estimated by using the 1/50,000 topographical maps. Site installation costs are estimated at 5% of the above cost.

2) Civil Works

The data obtained from the main counterpart, Son La PMB has been applied for calculating the unit prices by each kind of construction regarding the civil works. Some examples of hydropower projects in Vietnam are reflected on these unit prices.. As regards the items with no instances in Vietnam, proper unit prices are determined by referring to the instances adopted in Malaysia.

The quantities of excavation (clay, rock), concrete, reinforcing bar and so on are roughly estimated by each main structure, by using the preliminary design drawing based on the 1/50,000 topographical maps and the site survey results. Site installation costs are estimated at 10% of the above cost.

3) Hydromechanical Works

The data obtained from the main counterpart, Son La PMB has also been applied for calculating the construction unit prices of the hydromechanical work such as penstock and gate. Site installation costs are estimated at 16% of the above cost.

4) Mechanical and Electrical Equipment

As mentioned earlier, the Francis type turbine was judged to be the right type for Phu Yen East site. The turbine shall be transported from Japan.

The total cost of the generation equipment by each case of study includes mechanical and electrical equipment costs, transportation costs and installation costs as summarized in Table 4-3-7.

Table 4-3-7 Cost of the Generation Equipment

Total Plant Capacity (MW)	Unit Capacity (MW)	Number of Units	Total Cost (Mil. US$)
750	250	3	192.54
900	300	3	217.13
1,050	350	3	236.76
1,200	400	3	256.31

b. Engineering Services

The cost of engineering services, comprising detailed design, procurement works and site supervision, have been estimated at 7.5%of the above construction cost.

c. Administration Expenses

Administration expenses of the project owner (EVN) are also estimated at 0.5% of the construction cost.

d. Land Compensation

The expenses per household obtained from the main counterpart, Son La PMB, have been applied for the compensation expenses of land for the power plant structures. The number of households is derived from the results of the second field survey.

e. Others

Ten percent of the mechanical and electrical equipment costs has been estimated as customs duties of imported products, as mechanical and electrical equipment have to be imported from foreign countries. .

f. Tax (VAT)

In this study, value added tax (VAT) is estimated at 10% of the total amount of the items “a.～ e.” above-mentioned.

(4) Proposed Development Schedule for PSPP Project

Proposed development schedule for PSPP project is shown in Table 4-3-8.

The entire implementation period of the project will take approximately 14 years at the earliest after the start of the Feasibility Study. The sequence of activities leading to the commissioning of the project is as follows;

a. Preliminary study for Feasibility Study (F/S)

Preliminary study for F/S is estimated at 1 year.

b. Feasibility Study (F/S)

Topographical, geological and hydrological survey will be taken approximately 1 year from Japanese experience. And evaluation of the above survey results will be taken approximately 1 year. Thus, Feasibility Study is estimated at 2 years.

Environmental Impact Assessment is also estimated at 2 years.

c. Establishing a Finance Schedule

In the case where the project financing is sought from international organizations, it will take approximately 1 year from the application of Engineering Service and construction to conclusion of Loan agreement.

d. Financing Study for Engineering Service (ES)

Financing study for ES is estimated at 1 year.

e. Preparation of the Detailed Design and Tender Documents

Preparation of the detailed design and tender documents is estimated at 1.5 years based on the guidelines for procurement under JBIC. This includes detailed design studies, additional topographical and geological survey, and preparation of thunder documents for construction.

f. Fund Procurement for Construction, Examination and Decision of Bids and Contracts

The bidding and construction awards for all Contracts will be performed at the same time. Therefore, this stage is estimated at 1.25 year based on the guidelines for procurement under JBIC.

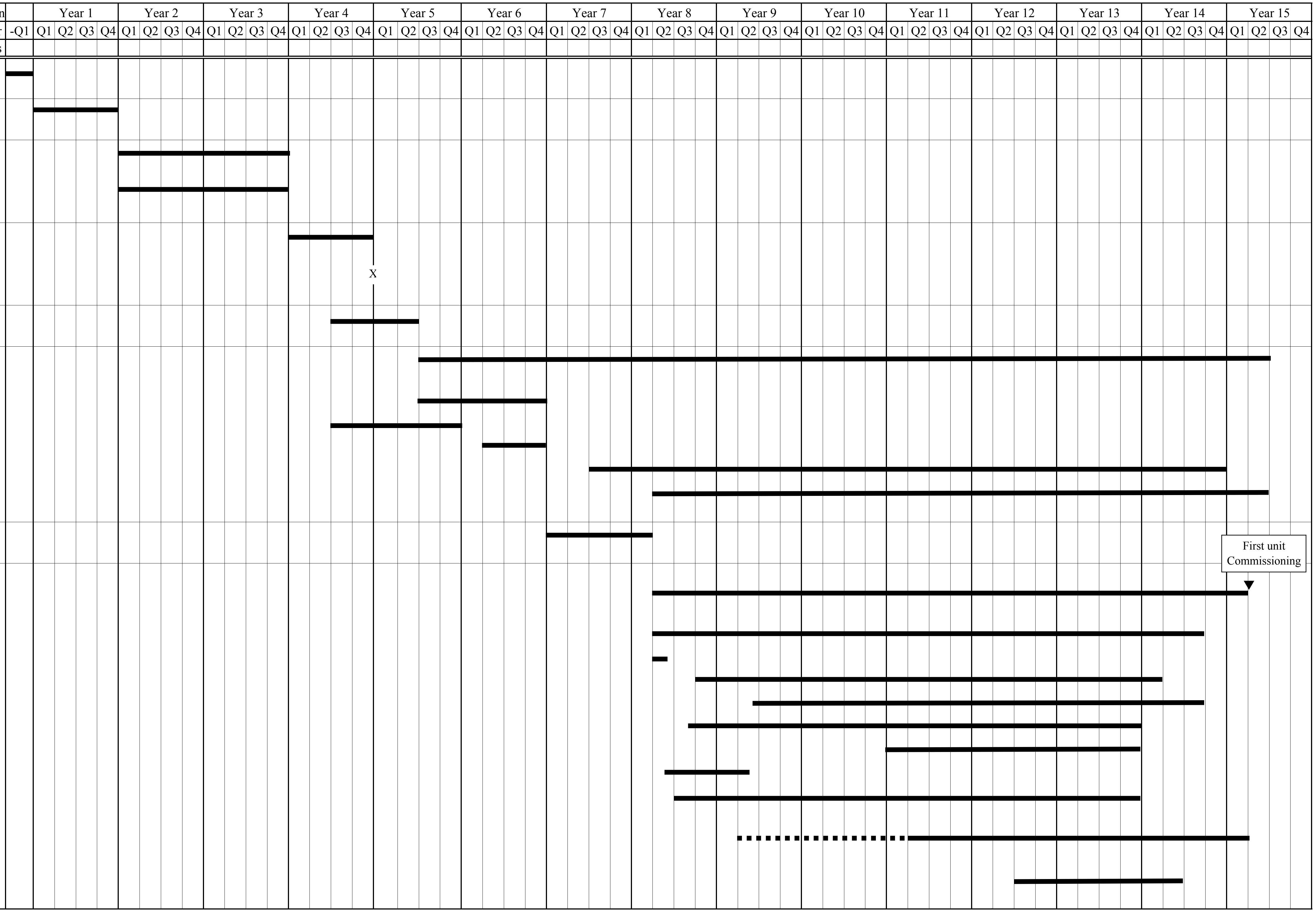
g. Construction Works

The period for executing tests on power generating equipment and metal works will be included in this step. The detailed schedule, which takes approximately 7 years, is shown in Table 4-3-8.

Provided that the selection of consultant for the Feasibility Study will be started in the next year following the completion of this master plan study, the completion will be in 2019 and the operation of the first power plant will be commenced in the same year.

Teble 4-3-8 Proposed Implementation Schedule for Pumped Storage Hydroelectric Project

Description	Duration (Months)
Evaluation M/P Study	4
Preliminary Study for F/S	12
Feasibility Study	24
Environmental Impact Assessment	24
Project Financing Procurement	12
Preject Approval to Proceed	0
Financing Study for ES	12
Engineering Services	120
1.Tender Design	18
2.Additional Investigation	18
3.Preparation of Tender Documesnts	9
4.Detailed Design	66
5.Construction Supervision	75
Tender Procedure	15
Construction	72
(Civil Works)	66
1.Mobilization	2
2.Upper Dam & Reservoir	54
3.Waterway & Underground Structure	50
4.Service Tunnel	52
5.Switch Yard	24
6.Road Works	12
7.Lower Dam & Reservoir	54
(E & M Works)	48
(Transmission Line)	18



; Manufacture/Shipping

(5) Financial Evaluation for PSPP Project

In addition to the function of a power source for peak power demand, Phu Yen East PSPP project could generate annual average energy of 960GWh. FIRR of the PSPP project was preliminary calculated by observing power revenue (power tariff applied at 12 ¢/kWh) from 960GWh as the financial benefit of its project. The input conditions are shown in the Table 4-3-9.

FIRR resulted in 6.1 in the coal case for pumping energy and resulted in 7.8 in the conventional hydropower case for pumping energy. Consequently, it can be said that PSPP project has high viability in financial aspects. The results of calculation are presented in Appendix 4-7-3.

Table 4-3-9 Conditions Applied for Calculation of FIRR

Items	Unit	Applied in this study	Remarks
Annual Energy Outputs	GWh	960	1,200MW*800hrs/yr
Construction cost	Mil. US$	799.6	Including escalation; 1.0%
O & M cost ratio	%	1.0	
Pumping energy; Caol	¢/kWh	2.1	
; Hydropower	¢/kWh	0	
Selling & General Expenses	¢/kWh	1.0	
Resource tax & VAT	%	12.0	
Power Tariff	¢/kWh	7.0	for Off-peak hours
	¢/kWh	12.0	for peak hours

Source ; F/S on Thac Mo Hydropower Station Extension Project, JETRO, March 2003

4.3.3 Preliminary Design of Phu Yen West and Bac Ai Sites

The design and the cost estimation of Phu Yen West and Bac Ai sites were carried out based on the condition that output is 1,050MW.

(1) Preliminary Design

The preliminary design of the main structures was carried out in the same as Section 4.3.2.

The outline of the main features is shown in Table 4-3-10, and structural drawings of the PSPP are presented in Figure 4-3-9～4-3-12 and Appendix 4-8-1, 4-9-1.

Table 4-3-10 Outline of the Main Features of Phu Yen West and Bac Ai Sites

Description			Unit	Phu Yen West	Bac Ai
General	Installed Capacity	P	MW	1,050	1,050
	Designed Discharge	Qd	m^3/s	253	362
	Effective Head	Hd	m	524	365
	Peak Duration Hours		hrs	7	7
Upper Reservoir	Type			Concrete Gravity	Rockfill
	Height	H	m	85	55+55+55
	Crest Length	L	m	385	420+270+200
	Dam (Bank) Volume	V	mln. m^3	530	670+200+250
	Excavation Volume	Ve	mln. m^3	150	400
	Reservoir Area	Ra	km^2	0.6	0.7
	Catchment Area	Ca	km^2	3.5	3.4
	H.W.L.		m	720	600
	L.W.L.		m	705	580
	Usable Water Depth		m	15	20
	Effective Reservoir Capacity		mln. m^3	6.4	9.2
Lower Dam and Reservoir	Type			Concrete Gravity	Concrete Gravity
	Height	H	m	105	55
	Crest Length	L	m	250	525
	Dam (Bank) Volume	V	mln. m^3	670	860
	Reservoir Area	Ra	km^2	2.5	3.2
	Catchment Area	Ca	km^2	420.0	720.0
	H.W.L.		m	160	210
	L.W.L.		m	157	206
	Usable Water Depth		m	3	4
	Effective Reservoir Capacity		mln. m^3	6.4	9.2
Waterway	Headrace	L (m) × n	m	7.1×1,250×1	—
	Penstock	L (m) × n	m	5.7 ×1,050×1	6.8 ×1,250×1
	Tailrace	L (m) × n	m	7.1×400×1	8.5×850×1
	Total Length	Lt	m	2,700	2,100
Powerhouse	Type			Egg-shape (Underground)	Egg-shape (Underground)
	Overburden		m	350	350
	Height		m	49	49
	Width		m	32	32
	Length		m	165	165
	Cavern Volume		m^3	185,000	185,000
Turbine	Type			Single-Stage Francis	Single-Stage Francis
	Number		unit	3	3
	Single generating capacity		MW	350	350
Lt / Hd				5.2	5.8