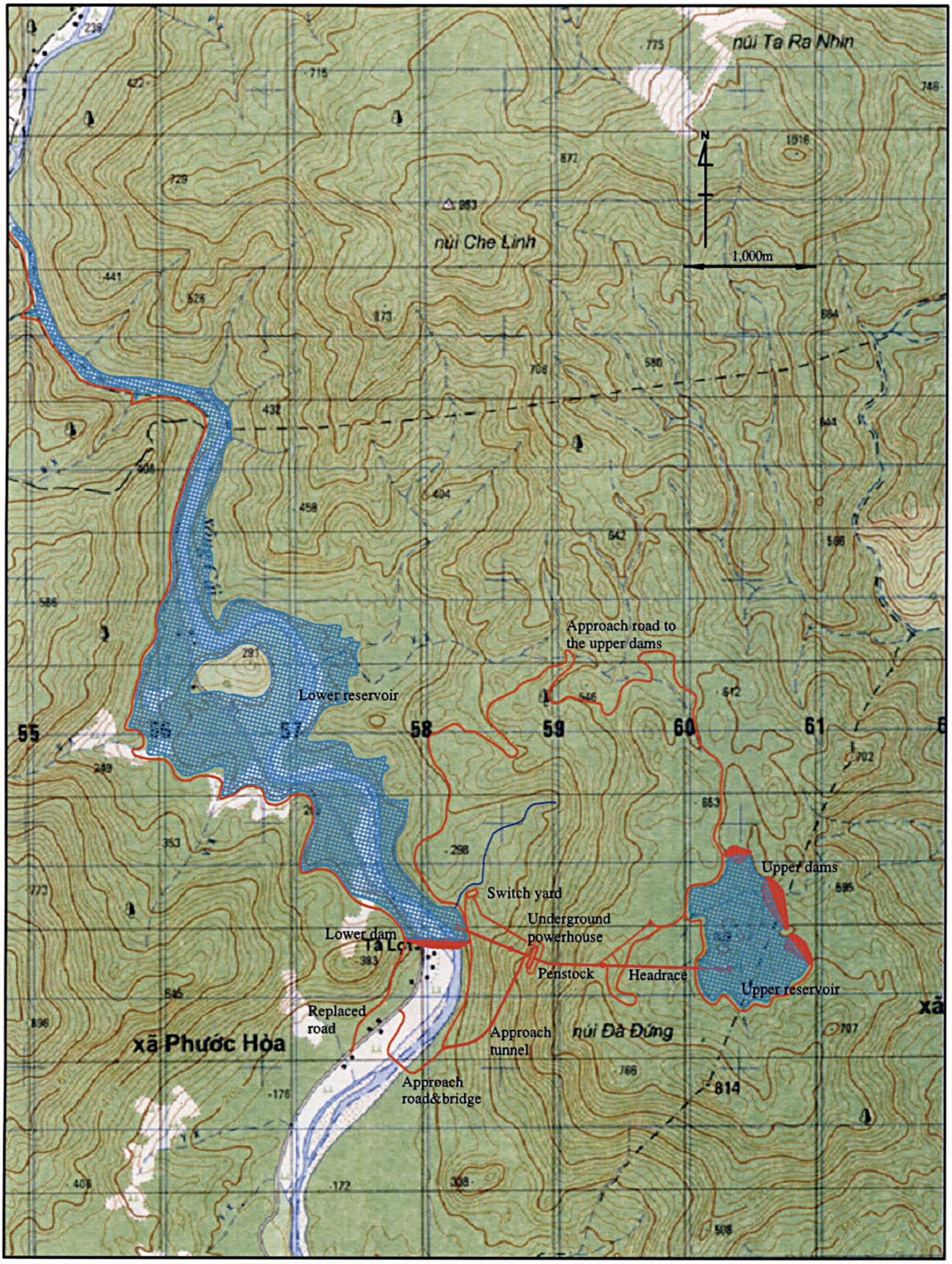


Figure 4-2-9 Layout of Bac Ai (JS6) project

(3) Prioritization of Three Projects

Prioritization of the three projects (JN3, JN5, JS6) was evaluated.

Evaluation items are selected as follows.

- Natural environment impact
- Construction cost (power station, transmission line and including compensation)

The comprehensive rank of three projects was evaluated by two steps.

At first, the projects were evaluated by item and given the rank order. Next, comprehensive rank was decided by taking two kind of rank order into consideration.

Here, land compensation / resettlement cost for social environment impact is counted into construction cost.

Comprehensive evaluation of priority PSPP is shown in Table 4-2-13.

Evaluation of environmental impacts is as follows;

a. Social Environment

Impacts on the social environments could be evaluated quantitatively. Quantitative figures are indicated in the following table however it should be noted that the following figures are very rough estimation and are subject to more detailed survey.

Only those who receive direct impacts are considered in the following assessment. The impacts include resettlement, compulsory land purchase (e.g. lost of rice filed) and others (e.g. social unrest by outsiders). It should be noted that one of the villages which receive direct impacts at JN5 moved to the current area when Hoa Binh dam project was implemented. Therefore it is likely that the PSPP project gives negative impacts on them psychologically, and this issue should be handled carefully.

The secondary affected people are excluded from the assessment because the survey did not cover these people well due to time constraints. At the next stage (e.g. feasibility study), it is therefore necessary to conduct more detailed survey on people who are expected receive secondary impacts and to propose adequate mitigation measures.

b. Natural Environment

It is difficult to quantitatively estimate scale of impacts on natural environment. After intensive and comprehensive survey, one may quantitatively estimate the scale. However, the survey may take at least one year (or a couple of years), and may not produce expected data.

Regarding this project, time was limited and little information is available. It is, therefore, inappropriate to quantitatively estimate the scale of impacts. In the following table, the direct impacts of the ecosystem at each site are described comparing each site.

Table 4-2-13 Comprehensive Evaluation of Priority PSPP

Evaluation items		Phu Yen East (JN3)	Phu Yen West (JN5)	Bac Ai (JS6)
Environmental Impacts	Social Environment	Number of households (population) which receive direct impacts: **74** households (**385** persons).	Number of households (population) which receive direct impacts: About **300** households (**1,700** persons).	Number of households (population) which receive direct impacts: **63** households (**330** persons).
	Natural Environment	**Direct impacts on the natural environment are limited.** One tributary of Mua river receives significant impacts by the lower dam but the scale is limited due to its small basin. Upper reservoir site is located in agricultural land.	**Direct impacts on the aquatic ecosystem may be significant.** The lower dam will disturb the aquatic ecosystem of Sap river. The river has a large basin and its current status of the aquatic ecosystem is not studied. Impacts may be significant and irreversible.	**Direct impacts on the aquatic ecosystem will be significant.** There is no dam in the entire length of Cai river. The lower dam will separate the river, which clearly will give significant impacts on the aquatic ecosystem of the river. The impacts may reach to the downstream of the river. Although direct impacts on the terrestrial environment are expected to be limited, it is important to note that the site is part of the area recognized as a globally important area.
Project Cost	P/S Cost	US$ 630 / kW	US$ 700 / kW	US$ 660 / kW
	T/L Cost	US $ 40 mln.	US$ 45 mln.	US$ 50 mln.
	Distance to S/S	70 km	80 km	90 km
Environment impact rank		①	②	③
Construction cost rank		①	③	②
Comprehensive rank		①	②	②

Remarks） JN3: Thung Land and Manh villages are considered. Lan village should be included but number of households and its population was collected.

JN5: Keo Lan, Xa, Na Nay and Phieng Luong villages are considered.

JS6: Ta Lot village is considered.

4.3 Preliminary structural Design of the Priority PSPP

To conduct a preliminary structural design and to identify a rough development cost for the most preferred site among the candidate PSPPs selected in Section 4.2.6. The design of Phu Yen East site was carried out based on topographical maps on a scale of 1/50,000.

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 like Phu Yen East.

4.3.1 Evaluation of the Scale of the Priority PSPP

The most suitable development scale has been evaluated with respect to the most preferred PSPP site, Phu Yen East.

(1) Methodology

Evaluation of the size of the priority PSPP was conducted by applying the B/C method taking a GT thermal power plant as an alternative.

The B/C method compares the benefits and costs resulted from the development. In this study, the Cost and Benefit correspond to the total development costs of PSPP and GT thermal respectively. The following equations were used for calculating the Cost and Benefit.

$C = C1 + C2$

$= I_P \times a_P + P_P \times H \times F_P / \eta_P$

$C1$; annual costs of PSPP generation

$C2$; annual costs for pumping

I_P ; construction costs of PSPP

a_P ; annual cost factor

P_P ; peak generation capacity

H ; annual equivalent hours for continuous peak generation (800hr)

F_p ; fuel costs for pumping (coal thermal, conventional hydro)

η_P ; total efficiency of PSPP generation (70%)

$B = B1 + B2$

$= Y_A \times I_A \times a_A + P_P \times H \times F_A$

$B1$; kW values of alternative power plant

$B2$; kWh values of alternative power plant

Y_A ; effective generation capacity (installed capacity－latent capacity)

I_A ; construction unit costs of alternative power plant

a_A ; annual cost factor of alternative power plant

H ; annual equivalent hours for continuous peak generation (800hr)

F_A ; fuel costs of alternative power plant

(2) Latent Capacity

A PSPP cannot always operate at its full capacity, since its daily operation is influenced by peak generation hours and generation capability for pumping during off-peak hours. Thus, full operation cannot meet operation hours required for the system-wise demand and supply, when daily maximum generation capability, which is determined by the volume of stored water for generation, is insufficient, and the PSPP has to be operated at partial load. The reduction of output capacity caused by such a situation is generally called as "latent capacity".

Since latent capacity depends largely on system operation and poundage size, the required peak generation hours on operation were calculating by the simulation. Therefore, this time, it was determined as 7 hours, which the following equation was used for calculating the effective capacity.

$$Y_A = P_P \times h / (\text{ required peak generation hours} = 7 \text{ hr}) \qquad (h < 7 \text{ hr})$$

$$= P_P \qquad (h \geqq 7 \text{ hr})$$

Y_A ; effective capacity (peak generation capacity－latent capacity)

P_P ; peak generation capacity

h ; peak generation hours (6, 7, 8 hrs)

(3) Input Parameters

Interest, depreciation, and O&M costs were taken as fixed costs, and fuel prices in 2020 were considered as variable costs in evaluating the scale of PSPP development. For calculating fuel costs, operations of alternative GT thermal and coal thermal for pumping were also considered incorporating changes of thermal efficiency with plant factor. Input parameters are shown in Table 4-3-1.

Table 4-3-1 Input Parameters

Power source	Construction cost	Plant life	Annual O&M cost factor	Fuel cost	
PSPP	650US$/kW	40	1.0%	Hydro: 0 ¢ /kWh	Coal: 2.1 ¢ /kWh
GT thermal	400US$/kW	20	5.0%	3.9 ¢ /kWh	
Coal thermal	938US$/kW	30	3.5%	1.5 ¢ /kWh	

(4) Comparative study of the Optimal Development Scale and the Analysis Results

a. Comparative Study of the Optimal Development Scale and the Construction Costs

The optimal development scale (Output capacity and Operation hour) for PSPP from an economical point of view has been studied. The comparative study cases, which make the output capacity and the operation hours into a parameter, are shown in Table 4-3-2.

Table 4-3-2 Comparative Study of the Optimal Development Scale（Phu Yen East）

Max. Capacity (MW)	Operation Hour (hr)	Active Storage (1,000m3)	Effective Head (m)	Turbine Discharge (m3/s)	Upper Dam HWL LWL (El. m)	Upper Dam Height (m)	Lower Dam HWL LWL (El. m)	Lower Dam Height (m)	Underground Structure Tunnel Dia. (m)	Underground Structure Penstock Dia. (m)	Underground Structure Power Station (m, m3)
750 (250*3)	6	3,700	563	168	880 867	13.0	274 270	72.0	5.8	4.7	B=21 H=44 L=125m V=116,000
	7	4,300	563	168	880 863	17.0	275 270	73.0			
	8	4,900	563	168	880 860	20.0	275.5 270	73.5			
900 (300*3)	6	4,400	561	203	880 860	20.0	275 270	73.0	6.4	5.1	B=25 H=47 L=140m V=116,000
	7	5,200	561	203	880 858	22.0	275.5 270	73.5			
	8	5,900	561	203	880 856	24.0	276 270	74.0			
1,050 (350*3)	6	5,200	560	237	880 858	22.0	275.5 270	73.5	6.9	5.5	B=27 H=50 L=155m V=147,000
	7	6,000	560	237	880 856	24.0	276 270	74.0			
	8	6,900	560	237	880 850	30.0	277 270	75.0			
1,200 (400*3)	6	5,900	559	271	880 856	24.0	276 270	74.0	7.3	5.9	B=30 H=51 L=170m V=182,000
	7	6,900	559	271	880 850	30.0	277 270	75.0			
	8*)	7,800	559	271	880 840	40.0	278 270	76.0			

*) The case of 1,200 MW and 8hrs cannot secure the amount of active storage of the upper dam due to the present topographical condition.

Construction unit cost of each case is shown in Table 4-3-3 and Figure 4-3-1.

The construction unit cost changes between 582US$ and 742US$, and it reduces with a larger output capacity by the scale merit. Also, the difference of the construction unit cost by operation hour is not so remarkable.

Table 4-3-3 Construction Unit Cost of Each Case

Operation hr	6hr				7hr				8hr		
Output (MW)	750	900	1,050	1,200	750	900	1,050	1,200	750	900	1,050
Total project cost ($\times 10^6$US$)	534.7	591.7	642.8	698.8	553.8	602.0	656.3	721.9	556.2	614.1	676.8
Construction unit cost (US$/kW)	713	657	612	582	738	669	625	602	742	682	645

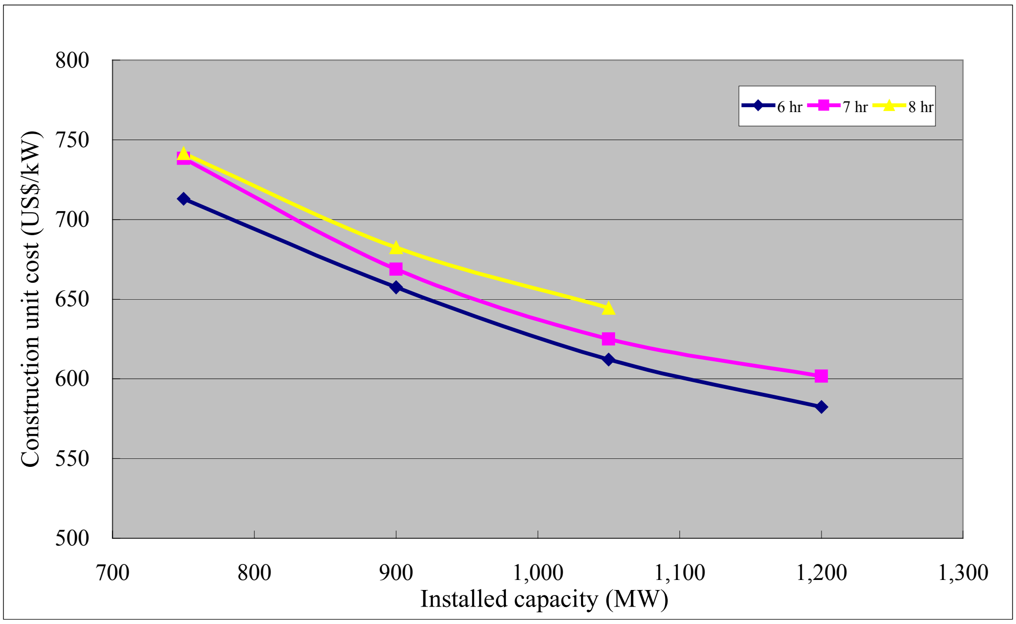


Figure 4-3-1 Construction Unit Cost of Each Case

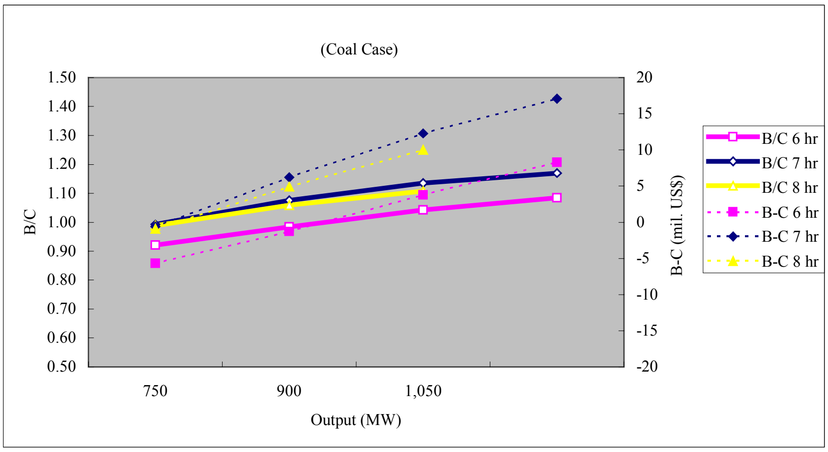
b. Analysis Results of the Optimal Development Scale

The project's Benefit/Cost (B/C) ratio and Benefit- Cost (B-C) of each case are shown in Table 4-3-4 and Figure 4-3-2.

The comparative study of the optimal development scale was carried out in two alternative cases, which are coal and conventional hydropower cases for the pumping energy. It is natural that B/C value of the conventional hydropower case is higher than that of the coal case.

Table 4-3-4 Results of the Optimal Development Scale

Operating hr		6hr				7hr				8hr		
Output (MW)		750	900	1,050	1,200	750	900	1,050	1,200	750	900	1,050
Effective Output (MW)		645	770	900	1,030	750	900	1,050	1,200	750	900	1,050
Coal	Benefit (B)	66.4	79.7	93.0	106.3	73.6	88.4	103.1	117.8	73.6	88.4	103.1
	Cost (C	72.1	81.0	89.2	98.0	74.2	82.2	90.8	100.7	74.5	83.5	93.1
	B/C	0.92	0.98	1.04	1.08	0.99	1.08	1.14	1.17	0.99	1.06	1.11
	B-C	-5.7	-1.3	3.8	8.3	-0.6	6.2	12.3	17.1	-0.9	4.9	10.0
Hydro	Benefit (B)	66.4	79.7	93.0	106.3	73.6	88.4	103.1	117.8	73.6	88.4	103.1
	Cost (C	59.3	65.6	71.2	77.4	61.4	66.7	72.8	80.1	61.7	68.0	75.1
	B/C	1.12	1.21	1.31	1.37	1.20	1.33	1.42	1.47	1.19	1.30	1.37
	B-C	7.1	14.1	21.8	28.9	12.2	21.7	30.3	37.7	11.9	20.4	28.0



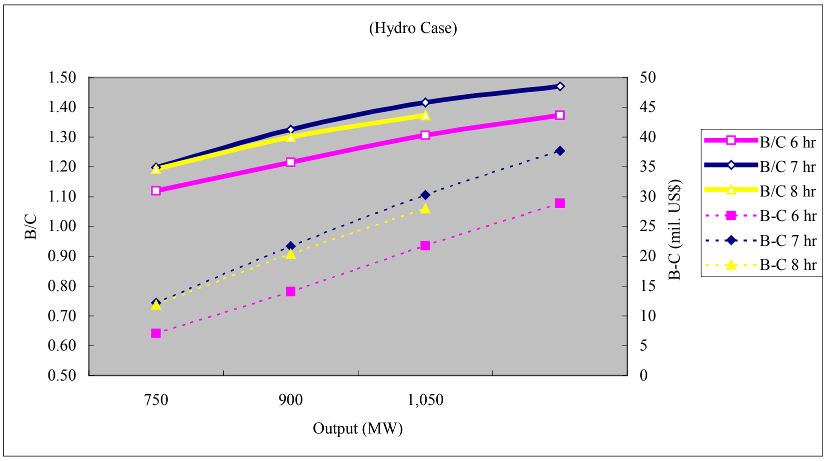


Figure 4-3-2 Results of the Optimal Development Scale (Coal Case, Hydro Case)

The case of 1,200MW (400MW*3units) and 7 hours (active storage) indicated in the above table for Phu Yen East site was selected as the optimal development scale, since it has the maximum B/C values (coal; 1.17, conventional hydropower; 1.47).

4.3.2 Preliminary Design for the Promising PSPP Site

The preliminary design of Phu Yen East site was carried out with the above graph.

The outline of the main features is shown in Table 4-3-3, and structural drawings of the PSPP are presented in Figure 4-3-3, 4-3-4 and Appendix 4-7-1.

The difference of the previous design is as follows.

1) The shortest route was selected between the upper reservoir and the lower reservoir for the tunnel alignment of waterway.
2) The location of the underground powerhouse was shifted the upstream in order to minimize the overburden of it.
3) According to the 2), the penstock became shorter.

Table 4-3-5 Main Features of Phu Yen East PSPP

Description			Unit	Phu Yen East PSPP
General	Installed Capacity	P	MW	1,200
	Designed Discharge	Qd	m^3/s	271
	Effective Head	Hd	m	559
	Peak Duration Hours		hrs	7
Upper Reservoir	Type			Full Face Pond (Asphalt)
	Height	H	m	35
	Crest Length	L	m	2,000
	Dam (Bank) Volume	V	m^3	4,500,000
	Excavation Volume	Ve	m^3	4,800,000
	Reservoir Area	Ra	km^2	0.3
	Catchment Area	Ca	km^2	0.3
	H.W.L.		m	880
	L.W.L.		m	850
	Usable Water Depth		m	30
	Effective Reservoir Capacity		mln. m^3	6.9
Lower Dam and Reservoir	Type			Concrete Gravity
	Height	H	m	80
	Crest Length	L	m	150
	Dam (Bank) Volume	V	m^3	200,000
	Reservoir Area	Ra	km^2	1.1
	Catchment Area	Ca	km^2	16.0
	H.W.L.		m	277
	L.W.L.		m	270
	Usable Water Depth		m	7
	Effective Reservoir Capacity		mln. m^3	6.9
Waterway	Penstock	L (m) × n	m	5.9 ×1,400×1
	Tailrace	L (m) × n	m	7.3×2,300×1
	Total Length	Lt	m	3,700
Powerhouse	Type			Egg-shape (Underground)
	Overburden		m	350
	Height		m	49
	Width		m	32
	Length		m	165
	Cavern Volume		m^3	185,000
Turbine	Type			Single-Stage Francis
	Number		unit	3
	Single generating capacity		MW	400
Lt / Hd				6.6