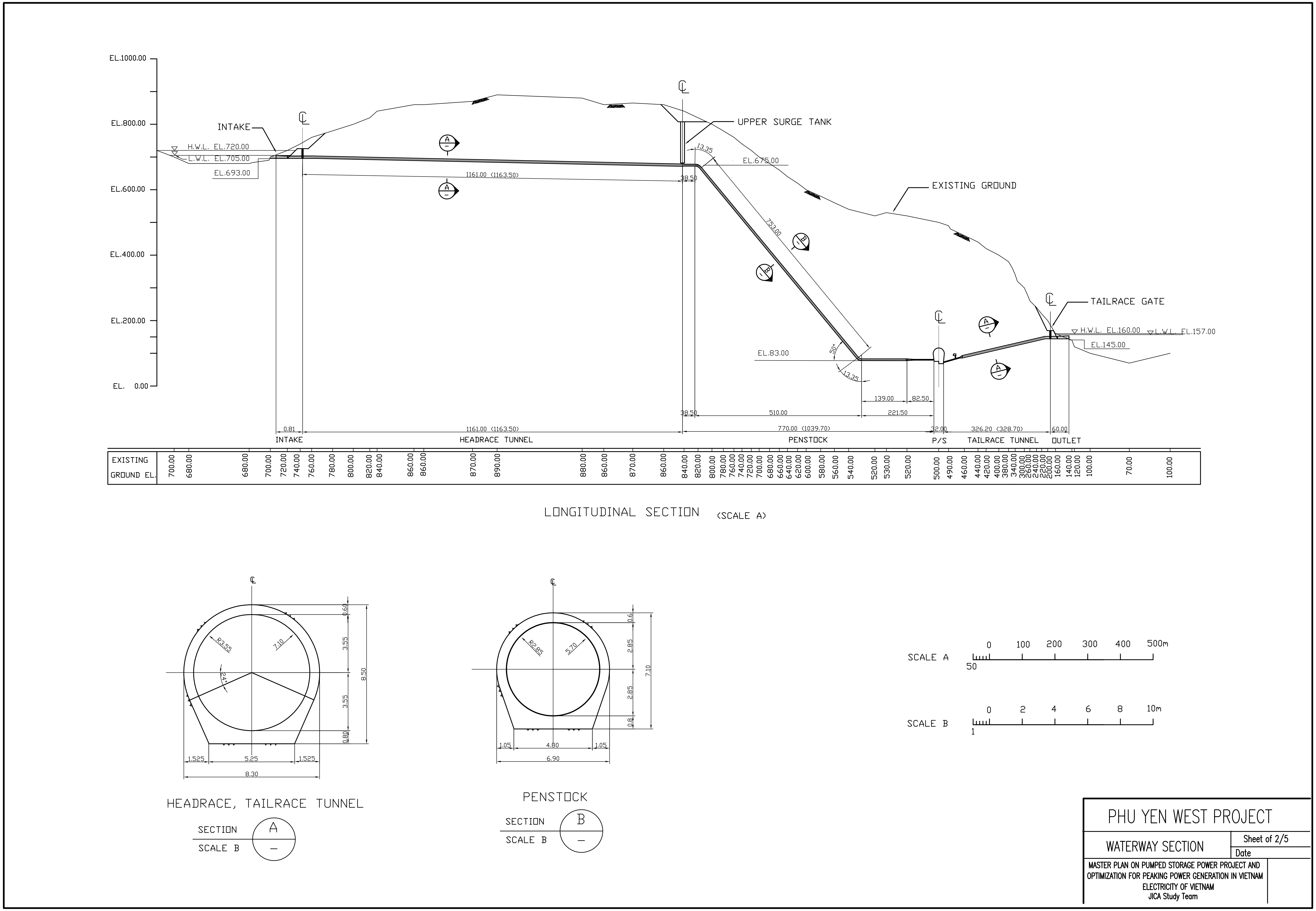


Figure 4-3-10 Waterway section of Phu Yen West site

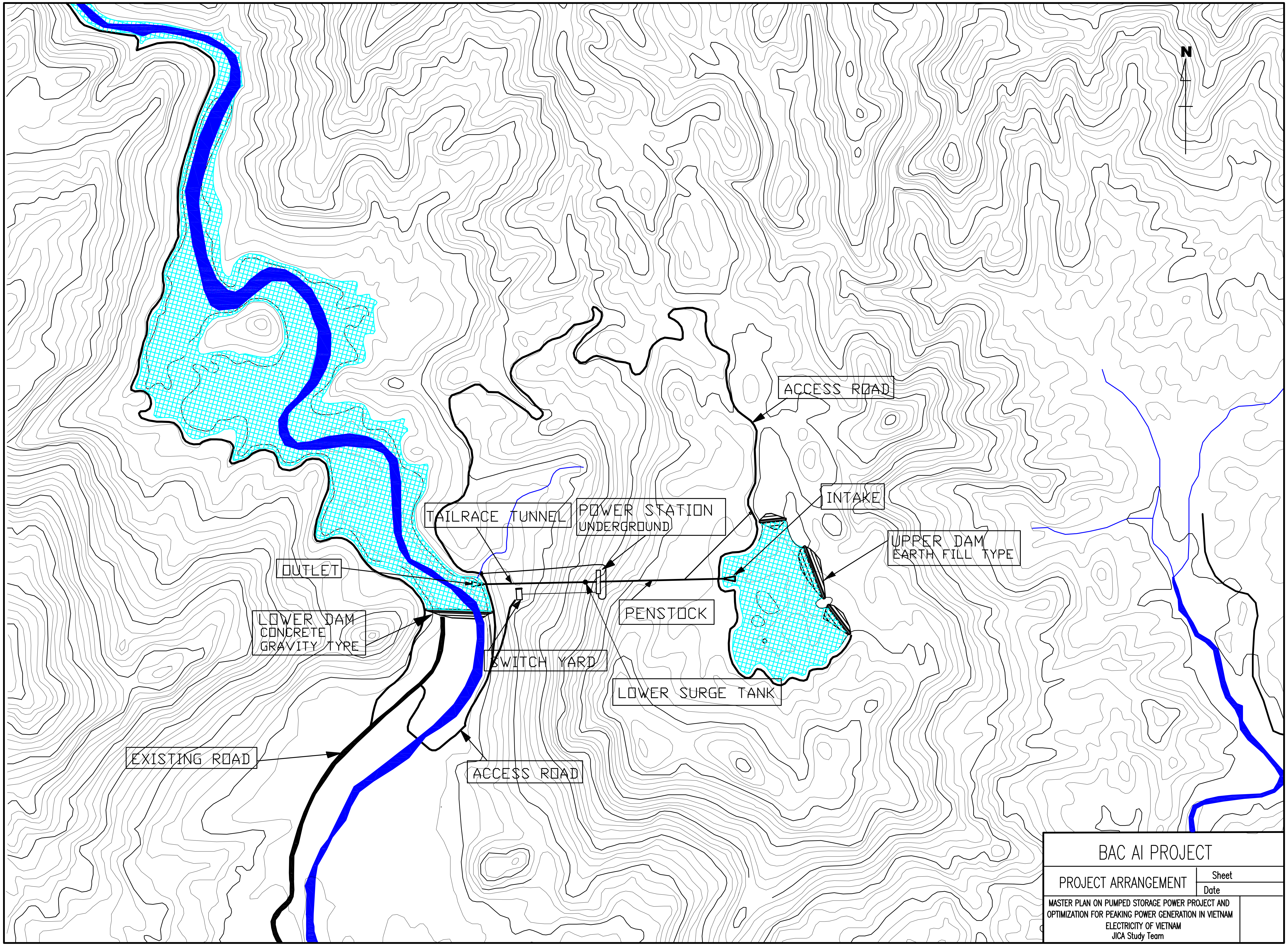


Figure 4-3-11 Project arrangement of Bac Ai site

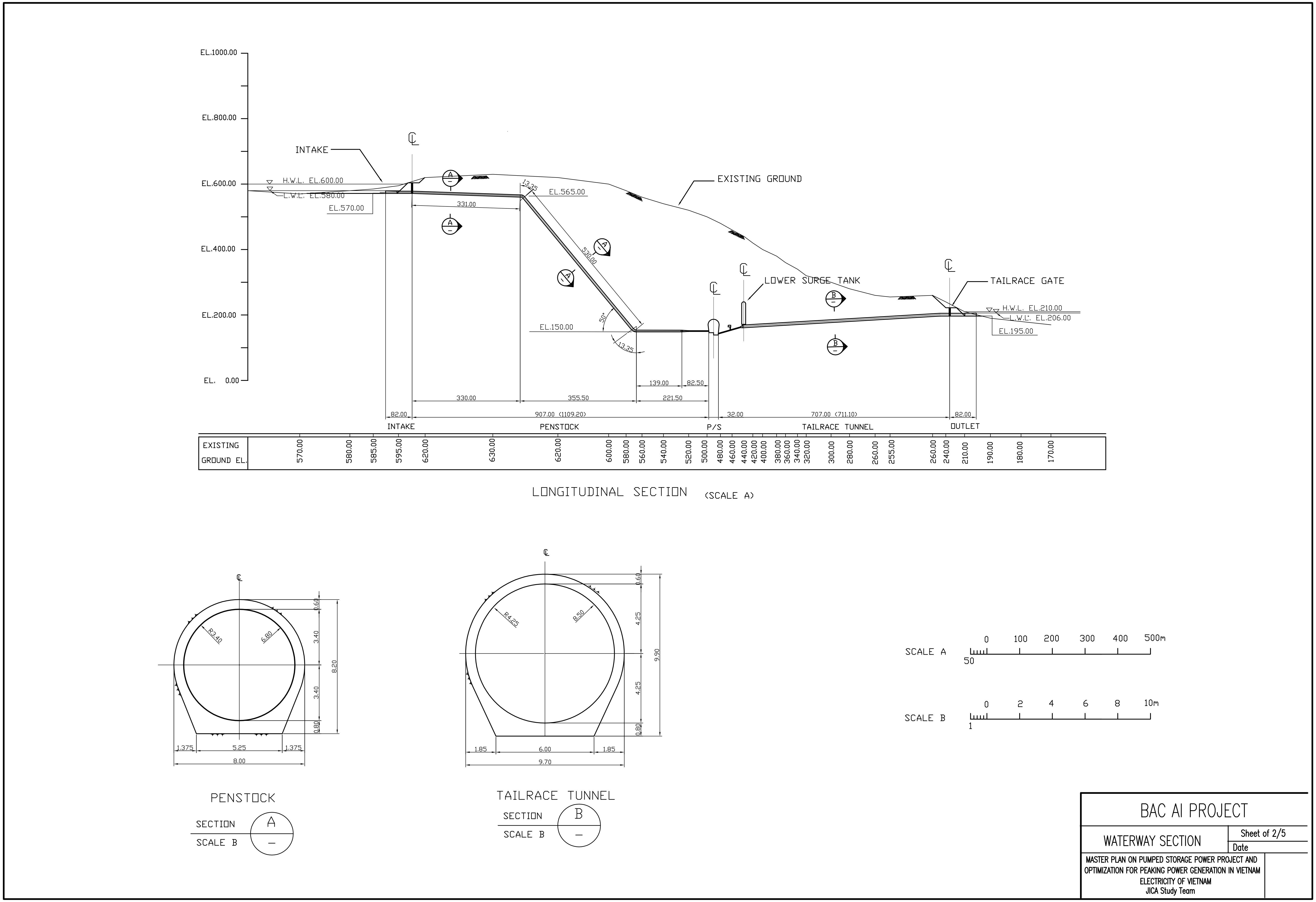


Figure 4-3-12 Waterway section of Bac Ai site

(2) Preliminary Cost Estimation

The preliminary cost estimations were carried based on the preliminary design. The results are presented in Table 4-3-11 and Appendix 4-8-2, 4-9-2.

Table 4-3-11 Cost Estimations of Phu Yen West, Bac Ai sites

(Unit; 1,000US$)

Cost Items	Phu Yen West	Bac Ai	Note
Ⅰ.Cnstruction Cost	581,659	547,659	
1.1 Preparation Works	30,622	19,370	
1.2 Civil Works	271,647	259,832	
1.3 Hydromechanical Works	42,630	31,697	
1.4 Hydroelectrical Works	236,760	236,760	
Ⅱ.Engineering Service	43,624	41,074	
Ⅲ.Administration Expense	2,908	2,738	
Ⅳ.Land Compensation and Resettlement	11,748	2,467	
Ⅴ.Others (VAT)	27,939	26,846	
Ⅵ.Physical Contingency	66,788	62,078	
Total Project Cost	734,666	682,862	Except transmission line
Construction Unit Cost (US$/kW)	700	650	Output; 1,050MW

(3) Proposed Development Schedule

Since the development scale of Phu Yen West and Bac Ai site are roughly equal to Phu Yen East site, the proposed implementation schedule refers to the Table 4-3-8.

CHAPTER 5 FEASIBILITY OFDEVELOPING PEAKING POWER SUPPLY

Chapter 5. Feasibility of Developing Peaking Power Supply

5.1 Feasibility of Developing Conventional Hydropower for Peaking Power Supply

5.1.1 Current Situations of the Existing Conventional Hydropower Plants and Purpose of the Study

In Vietnam, eight (8) large hydropower plants (the total capacity of about 3,945MW) are in operation. Some of them have to release water through a spillway without generation in the rainy season. This is called ineffective discharge. An example of ineffective discharge at the Tri An hydropower plant is shown in Figure 5-1-1. The graph indicates that 12% of the total flow from its reservoir corresponds to ineffective discharge. The Thac Mo hydropower plant also recorded the ineffective discharge of 11.8%. In addition, the Hoa Binh hydropower plant has significant ineffective discharge (Figure 5-1-2).

In order to utilize ineffective discharge, JETRO conducted a feasibility study of the Thac Mo extension project in the Be river system. As a result, an extension plan with the additional capacity of 75MW has been incorporated in the revised 5th master plan.

Utilization of ineffective discharge reduces consumption of fossil fuels by the use of renewable energy, resulting in contributing to the prevention of global warming. On the other hand, the use of river flow is not only for generation but also for other purposes including irrigation, water supply, and water transport. Thus, the concept of integrated water resource management is important for considering various aspects in developing, operating and maintaining hydropower plants. Especially when cascading hydropower development is anticipated, it is recommended to examine integrated water resource management of each river system, in addition to considering the necessary functions as a hydropower plant for peaking power supply.

PSPP, which is newly introduced in this Study, is an envisaged candidate of peaking power supply, which will be developed in future to meet the increasing electricity demand. The conventional hydropower is also a candidate for peaking power supply. In this Chapter, economic advantages of a large conventional hydropower plant planned for peaking supply is studied for the purpose of deciding development priority of the peaking power supply and of determining the timing of introducing PSPP.

Regarding feasibility of existing power station, the project reviewed in this Study should be selected from among the plants developed more than 5(five) years ago, which are the Tri An, Thac Mo and Hoa Binh. Because the hydropower plants that were recently developed have already considered the functions for peaking power supply. The extension of the Thac Mo has already studied. For the Hoa Binh, development such as Son La and Nam Nhun are planned in the same river, and the integrated water resource management of Da river system has been examined. Therefore the Tri An hydropower is selected for preliminary study on extension in this Study.

There are many new hydropower projects planned in Vietnam. In this Study, the cascade development projects of the Ban Chat and the Huoi Qiang hydropower are selected. These are planned for peaking power supply in the north area where peaking power sources are required to develop. Since these are located in the tributary of the Da river system, these peaking supply plants may operate without influences of the complicated water resource management of the international river. Therefore, these projects are the most likely conventional hydropower for peaking power supply.

In addition to the study on conventional hydropower plants, possibilities of introduction of the other type of power sources are studied in this chapter.

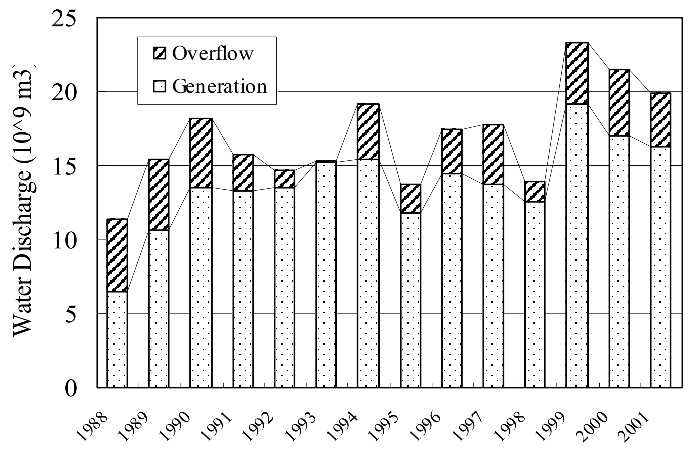


Figure 5-1-1 Ineffective Discharges at Tri An HPP

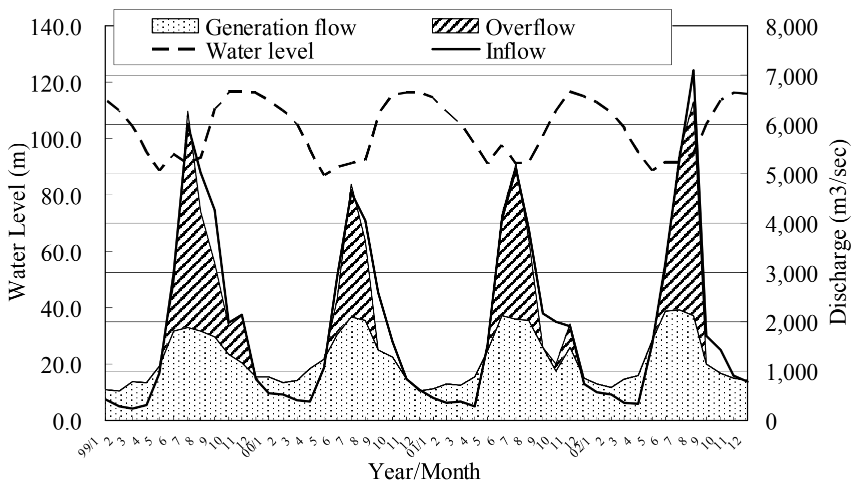


Figure 5-1-2 Ineffective Discharges at Hoa Binh HPP

5.1.2 Preliminary Study for Development of Peaking Power Supply by Extension regarding the Tri An Hydropower Station

a. Outline of the Existing Tri An Hydropower Station

The existing Tri An hydropower station (Tri An PS) is located in the middle reach of Dong Nai River in Dong Nai province as shown in Appendix 5-1. The Tri An PS has been operated in full capacity since 1991. The major features of the existing Tri An PS comprise of the main dam on the Dong Nai River together with a spillway, three earthfill dike dams, four underground penstocks and a 400 MW power station. The reservoir has a surface area of 323 km^2 and an effective storage capacity of 2,547million m^3.

Table 5-1-1 Main Project Feature of Existing Tri An PS

Installed capacity (MW)	400
Plant Discharge (m^3/s)	880
Effective head (m)	52
Annual generated energy (GWh)	1,700
Plant Factor (%)	49

b. Conditions to be Applied in the Study

1) Discharge Data Applied

Monthly discharge data at the existing Tri An dam site are estimated based on observation record at the Tri An PS, Ta Lai and Ta Pao streamflow gauging station for the period of 24-years from 1979 to 2002 and applied to reservoir operation study for estimate of power outputs from the extension project. Annual average discharge at the existing Tri An dam site are estimated as approximately 540m^3/s in this study.

2) Alternative Extension Capacity

In this study, installed capacity for the extension project is preliminary assumed to be 100MW, which is the same as one unit capacity in the existing Tri An PS (400MW= 4 units×100MW). The optimum installed capacity for the extension project will be decided by more detailed study in the future F/S stage.

3) Alternative Layout Plan

Through brief map study by 1/50,000 topographic maps, an alternative layout plan for the extension project is preliminary proposed as shown in Appendix 5-1. The alternative layout plan consists of intake, headrace tunnel, surge tank and penstock with total length of about 1.5km, powerhouse and tailrace.

4) Effective Head

It is assumed that about 47m of design head for the extension project can be obtained by the layout plan. It is noted that the design head of the extension project would be estimated to be 47m, which is 5m less than that of existing Tri An PS (52m). That is reason why each riverbed elevation on existing power plant and extension project is estimated to be different in consideration of 5 m difference in dam height between the exiting main dam and Suoirop dam.

c. Reservoir Operation Study for Estimate of Power Outputs

1) Conditions to be Applied

In order to estimate power outputs (=90% firm peak power and annual average energy) from the extension project, reservoir operation study for the Tri An reservoir are carried out on the following conditions.

There are following hydropower projects under operation, construction and planning stage in the Dong Nai River basin. These hydropower projects are supposed to directly affect reservoir operation on the Tri An PS.

- Ham Thuan - Da Mi hydropower projects ･･････････ under operation from 2001
- Dai Ninh hydropower project ･････････････････････ under construction
- Dong Nai No.3 & 4 hydropower project･･････････ currently being planned

Ham Thuan - Da Mi and Dong Nai No.3 & 4 hydropower project have a large reservoir to regulate the river flow in Dong Nai River annually at each dam site. These large reservoirs contribute to the stable river flow through the year in the Dong Nai River, that is, the river flow will increase in dry season and decrease in rainy season. Its effect will result in reduction of surplus spillway discharge in rainy season in the existing Tri An PS. Also Dai Ninh hydropower project accompanies river flow diversion from Dong Nai River to other river basin. Its effect will also result in reduction of surplus spillway discharge in rainy season in the existing Tri An PS.

Since effective use for the surplus spillway discharge in rainy season in the existing Tri An PS are basic concept of the Extension Project, these hydropower projects should be considered in the reservoir operation study to estimate power outputs from the extension project.

Consequently monthly discharge data at the Tri An dam site were estimated under following conditions:

- Discharge from effective catchment area of the Dai Ninh hydropower projects are taken out of discharge at the Tri An dam site.
- Discharge from effective catchment area of the Ham Thuan - Da Mi and Dong Nai No.3 & 4 hydropower project flow into the Tri An reservoir as "after-regulated discharge", which are calculated by reservoir operation study carried out for theses hydropower projects.

2) Results of the Reservoir Operation Study

First, 95% firm discharge of the Tri An reservoir was calculated with the differential mass curve, as shown in Appendix 5-1, and resulted in 327m^3/s.

Next the reservoir operation study was carried out for two cases of "Without Extension" and "With Extension" in order to estimate power outputs from each case. Results of the reservoir operation study are presented in the following table.

Table 5-1-2 Results of Reservoir Operation Study With and Without the Extension Project

	Without Extension	With Extension	Extension Project
95%Firm discharge (m^3/s)	327		
Min. operation hours (hours)	8.9	7.0	7.0
Installed capacity (MW)	400	500	100
Effective head (m)	52	52, 47	47
Maximum Discharge (m^3/s)	880	1,125	245
90% firm peak power (MW)	354	441	87
Generated energy (GWh/year)	1,863	1,952	89
Plant factor (%)	53	45	45
Rate of spillway discharge (%)※	9.4	3.4	3.4

※Rate of spillway discharge to total inflow volume

As shown in the above table, the annual average energy would increase from 1,863GWh without extension project to 1,952GWh with extension project in total. Consequently annual average energy from the extension project would be evaluated to be 89GWh as the difference between without and with the extension project. Also the plant factor of the existing Tri An PS would drop from 53%, whose value is over the design value of the existing plant, to 45% with the extension project.

With regard to the rate of spillway discharge in the above table, Attachment 5-1 shows monthly spillway discharge over the whole study period resulted from the reservoir operation study. The rate of spillway discharge to total river flow decreases from 9.4% to 3.4% with the extension project. Therefore it can be said that the extension project would contribute to more effective use of river flow with increase of the power energy (89GWh).

d. Project Cost Estimate

Project components of the extension project are almost same as that of Thac Mo extension project, which consists of intake, headrace tunnel, surge tank and penstock with total length of about 1.5km, powerhouse and tailrace.

Accordingly project cost of the extension project is preliminary estimated with reference to kW cost of 674USD, which was derived in the feasibility study on Thac Mo Hydropower extension project (Total project cost of 50.5millionUSD, Extension Capacity of 75,000kW). Consequently the project cost is estimated as 67.4 million USD by multiplying 100,000kW of the extension capacity by 674USD/kW.

e. Environmental Issues

In the extension project, there are no serious environmental impacts such as large-scale resettlements, destruction of wildlife ecosystem and so on. This is reason why the extension project is not only accompanied by construction of new dams and increase of reservoir-impounded area but also project site is already deforested to a certain extent.

f. Preliminary Project Evaluation

1) Economic Evaluation as Power Source for Peak Power Demand

Regarding Phu Yen East PSPP project, as described in the Section 4.3.2, economic viability was evaluated by means of the B/C method, in which Benefit (B) is regard as cost of the alternative thermal power (= gas turbine) and Cost (C) is regard as cost of the extension project. The same method was applied to economic evaluation of the extension project.

Based on the above study results, the B/C of the extension project is shown to be 1.42. The B/C value of 1.42 is almost same as that of 1.47 for Phu Yen East PSPP project.

2) Financial Evaluation

In addition to the function as power source for peak power demand, the extension project could generate annual average energy of 89GWh by effective use of surplus river flow discharged from the spillway in rainy season river at the existing Tri An reservoir. FIRR of the extension project was preliminary calculated by regarding power revenue (power tariff applied at 12US¢/kWh) from 89GWh as financial benefit[1] of the extension project which resulted in 9.1%[1].

The FIRR value of 9.1% is higher than that of 6.8% in the Thac Mo Extension project. Consequently it can be said that the extension project has high viability in terms of not only economic and also financial aspects.

3) Project Evaluation

Main project features of the extension project, resulted from the above preliminary study, are summarized in the following table.

Table 5-1-3 Main Features of the Extension Project

Installed capacity (MW)	100
Plant Discharge (m^3/s)	245
Effective head (m)	47
90% firm peak power	87
Annual average energy (GWh)	89
Min. operation hours (hours)	7.0
Plant factor (%)	45
Project cost (million USD)	67.4
B/C	1.42
FIRR at consumer's end (%)	9.1

Results of this preliminary study are summarized below. Consequently the extension project would be preliminary justified economically and environmentally.

- Since B/C of the extension project results in 1.42, the extension project is economically justified as the power source for peak power demand with the operation of more than 7.0 hours even in dry season. Also power generation during off-peak hour on the existing Tri An PS could be shifted to on-peak hours by the extension project. Accordingly its effects enhance the function as power source for peak demand of the Tri An PS.
- In addition to the function as power source for peak power demand, the extension project could generate annual average energy of 89GWh by effective use of surplus river flow discharged from the spillway in rainy season river at the existing Tri An

[1] All the conditions for the calculation of FIRR are same as conditions applied in feasibility study on Thac Mo extension project carried out by JETRO in 2002.

reservoir. FIRR of the extension project was preliminary calculated and then resulted in 9.1%. The FIRR value of 9.1% is higher than that of 6.8% in the Thac Mo Extension project. Consequently it can be said that the extension project has high viability in terms of not only economic and also financial aspects.

- The extension project would not cause any serious impacts on natural and social environment, because the reservoir-impounded area is not increased, and additional construction of the extension facilities is minimal.

5.1.3 Power Extension of Conventional Hydropower Plant in the Northern Region

(1) Power Development Plan for the Da River Basin

The Da River is the largest tributary of the Red River, which flows into the Gulf of Tonkin through Hanoi city, and occupies 37% of the catchment area of the Red River. The length of the Da River is 980km, of which the downstream 540km spreads in Vietnam's territory, and the upstream 440km lies in Chinese territory. The hydro energy potential of the Da River is about 31.6 billion kWh of annual electric power generation, or 6,258MW in terms of output, which accounts for about forty (40) percent of that of the whole country.

On the other hand, the Da River causes flood. According to the statistics during 1971 through 1996, the volume of the Da River's flood accounted for from 42% to 78% of that of the Red River. Thus the Hoa Binh Dam keeps a storage capacity of 6 billion m^3 for flood control during the flood season.

For the power development plan of the Da River, four (4) new dams as shown in Table 5-1-4 are planned for power development including the Son La dam, the largest project in Da river basin, of which a development plan has practically been decided. In the plan, 4 billion m^3 of flood storage capacity is bore by Son La after commencement and 3 billion m^3 is designed to Hoa Bin dam.

Table 5-1-4 Power Development plan for Da River Basin

Project Name	unit	Hoa Binh (Existing)	Son La	Nam Nhun	Ban Chat	HuoiQuang
River System	-	Da	Da	Da	Nam Mu	Nam Mu
Province	-	Hoa Binh	Son La	Lai Chau	Lao Cai	Lao Cai
Catchment Area	km^2	51,700	43,760	26,000	2,017	2,930
Installed Capacity	MW	1,920	2,400	1,200	200	560
Annual Energy	GWh	9,298	8,892	4,423	734	1,957
Effective head	m	109	99	96	96	181
Effective capacity of reservoir	10^6m^3	5,650	5,871	759	1,380	126
Flood capacity	10^6m^3	3,000	4,000	0	0	0
Dam type	-	Rock/Earth	Concrete	Concrete	Concrete	RCC

Source: PECC1

(2) Optimum Installed Capacity for the Ban Chat and Huoi Quang Hydropower Projects

a. Development Plan of the Ban Chat and Huoi Quang Hydropower Projects

Ban Chat and Huoi Quang hydropower projects are located on the Nam Mu River, which joins the Da River upstream of the planned Son La dam site, and are planned for simultaneous development.

Huoi Quang project is a dam-and-conduit type power project. The location of the power station is planned at the upstream end of the Son La dam reservoir. Ban Chat project is of a dam type power station and is planned at about 30km upstream of the Huoi Quang dam. The Feasibility Study of Huoi Quang project and the Pre-Feasibility Study of Ban Chat project were finished at September 2003. The main features of the projects are shown in Table 5-1-5.

Table 5-1-5 Main Features of Huoi Quang, Ban Chat Power Project

	Unit	Ban Chat PS	Huoi Quang PS
Installed Capacity	MW	200 (100MW x2)	540 (180MW x3)
Annual Energy Generation	GWh	710	1,822
Total water head	m	82	149
Max. Power discharge	m^3/s	279	411
Catchment Area	km^2	2,017	2,930
Dam height	m	127	151
Dam type	-	Concrete gravity	Concrete gravity
Effective Storage	10^6m^3	1,380	173
Resettled households	-	1,340	305
Total project cost	10^9VND	4,244	8,268

Source: PECC1

b. Simulation Study of Dam Operation for Optimization of the Plan

Ban Chat and Huoi Quang hydropower projects are planned on the same river. The power station located downstream is affected by the dam operation of the upstream power station. Accordingly, optimization studies are required not for the individual projects, but as an integrated optimization plan based on a consistent use of the river basin, for the assessment of validity of the plan as a whole.

Evaluation study by simulation to confirm the optimum installed capacity of Ban Chat and Huoi Quang hydro projects was carried out based on the latest plans and river discharge data during the past thirty years, which are from 1966 to 1995, and are converted from Nam Mu river discharge data to the dam sites using basin area ratio. River discharge and evaporation of each month are shown in Table 5-1-6, 5-1-7.

Table 5-1-6 Average River Discharge at Huoi Quang / Ban Chat Dam Site (1966-1995)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Ban Chat	234	354	271	154	79	49	30	25	22	20	33	97
Huoi Quang	339	514	394	223	115	71	44	37	32	30	48	141

(Unit : m^3/s)

Table 5-1-7 Evaporation at Huoi Quang / Ban Chat Dam Site

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Evaporation	12.4	11.8	9.9	10.5	11.8	10.7	11.7	13.2	16.3	22.1	20.8	18.8

(Unit: mm)

1) Case of Simulation

Installed capacity of Ban Chat in the current plan is 200MW(100MW×2units), and that of Huoi Quang is 540MW (180MW×3units). In this study, dam operation is simulated and power generation is calculated for each case of increase and decrease of power units of the two power stations. The combination of the simulation cases is selected as shown in Table 5-1-8. Here, the purpose of both of the dams is only for power generation and they do not have flood storage.

The optimization study of the dams is not carried out. In this study, the location of the dams and the reservoirs areas are the same as the current plan.

Table 5-1-8 Case of Simulation

Huoi Quang PS / Ban Chat PS	No develop -ment	1 unit, 180MW	2 units, 360MW	3 units, 540MW	4 units, 720MW
No development	—	—	—	○	—
1 unit, 100MW	—	—	—	○	—
2 units, 200MW	○	○	○	◎	○
3 units, 300MW	—	—	—	○	—
4 units, 400MW	—	—	—	○	—

Legend ○ : simulation case, ◎ : current plan of PECC1

2) Reservoir Operation Study

First, a 95%firm discharge of the upstream Ban Chat was calculated with the differential mass curve. Then reservoir operation study was carried out to estimate monthly generation during the thirty years. The calculation of firm discharge and reservoir operation study for the downstream Huoi Quang reservoir were carried out in the same way.

The monthly inflow of Huoi Quang reservoir has been defined as the value of the outflow of

Ban Chat Dam Power Station (as a result of simulation), added with the inflow of tributaries between the dams, taking into consideration the river discharge at Huoi Quang Dam site in case of an independent development (no development of Ban Chat Station), and the regulation of the Ban Chat Dam in case of a cascade development (development of both of Ban Chat and Huoi Quang stations). In other words, the total of outflow of Ban Chat and inflow of the tributaries between the dams should be used for the inflow of the Huoi Quang reservoir.

Results of the reservoir operation study are presented in Table 5-1-9. In this table, the values of 90% firm output are given assuming a peak duration time of seven (7) hours, which is the requirement of power system.

Table 5-1-9 Results of the Reservoir Operation

		Independent		Cascade development							
				BC constant				HC constant			
		HQ	BC	A-1	BASE	A-2	A-3	B-1	B-2	BASE	B-3
Installed Capacity	BC	-	200	**100**	**200**	**300**	**400**	200	200	200	200
	HQ	540	-	540	540	540	540	**180**	**360**	**540**	**720**
(MW)	Total	540	200	640	740	840	940	380	560	740	920
95% Firm discharge	BC	-	93	93	93	93	93	93	93	93	93
(m^3/s)	HQ	49	-	115	115	115	115	115	115.3	115	115
Annual Generation	BC	-	723	673	723	722	725	723	723	723	723
	HQ	1,723	-	1,856	1,853	1,849	1,849	1,425	1,775	1,853	1872
(GWh)	Total	1,723	723	2,529	2,576	2,571	2,574	2,148	2,498	2,576	2595
90% firm peak power	BC	-	177	88	177	201	206	145	177	177	177
	HQ	128	-	499	499	499	499	172	354	499	499
(MW)	Total	128	177	587	676	700	705	317	531	676	676
Plant Factor	BC	-	41	77	41	27	21	41	41	41	41
	HQ	36	-	39	39	39	39	90	56	39	30
(%)	Total	36	41	45	40	35	31	65	51	40	32

Legend BC: Ban Chat PS, HQ: HuoiQuang PS, (*) capital recovery factor11％

c. Estimation of the Project Costs

The project cost of Ban Chat and Huoi Quang hydropower stations has been calculated firstly by counting the design quantities of each structure based on the latest project drawings of the Ban Chat 200MW(100MW×2units) / Huoi Quang 540MW (180MW×3units) projects and the total project costs were estimated by applying the unit costs used in the calculation for that of pumped storage.

Secondly, the total project cost for each of generation scales for comparison were estimated by calculating the work volume and adding/ taking the expenses according to the increase or decrease of the power units. The estimated project costs for each scale of the development are shown in Table 5-1-10. The calculated project costs have turned out to be higher than those calculated for F/S and pre-F/S. It has be decided, however, that the project costs, which have been calculated this time in the same method as those for a pump storage power station, should be adopted for the economic evaluation of the projects, allowing easier comparison with a pump storage power station, as optimization of the peak capacity has been the purpose of this study.

Table 5-1-10 Estimated Project Cost

	Ban Chat PS				Huoi Quang PS			
	1 unit 100 MW	2 units 200 MW	3 units 300 MW	4 units 400 MW	1 unit 180 MW	2 units 360 MW	3 units 540 MW	4 units 720 MW
I Construction Cost	**203,100**	**236,000**	**275,800**	**314,400**	**354,200**	**399,100**	**441,600**	**487,500**
1.1 Preparatory Works	40,700	40,700	40,700	40,700	27,900	27,900	27,900	27,900
1.2 Civil Work	135,400	141,500	155,100	166,200	290,400	307,800	322,800	341,200
1.3 Hydromechanical Works	4,000	8,000	12,000	16,000	8,200	8,200	8,200	8,200
1.4 Hydroelectrical Works	23,000	45,800	68,000	91,500	27,700	55,200	82,700	110,200
II Engineering Service	**15,200**	**17,700**	**20,700**	**23,600**	**26,600**	**29,900**	**33,100**	**36,600**
III Administration Expense	**1,000**	**1,200**	**1,400**	**1,600**	**1,800**	**2,000**	**2,200**	**2,400**
IV Land compensation and Resettlement	**52,500**	**52,500**	**52,500**	**52,500**	**11,900**	**11,900**	**11,900**	**11,900**
V Others (Tax)	**2,700**	**5,400**	**8,000**	**10,800**	**3,600**	**6,300**	**9,100**	**11,800**
VI Physical Contingency	**27,500**	**31,300**	**35,800**	**40,300**	**39,800**	**44,900**	**49,800**	**55,000**
Total Project Cost	**302,000**	**344,100**	**394,200**	**443,200**	**437,900**	**494,100**	**547,700**	**605,200**

d. Optimum Installed Capacity

1) Economic Evaluation by B/C Method

Economic evaluation was carried out using B/C method, which was the same way for pumped storage and the Tri An hydro power. Here the Benefit (B) is regarded as the cost of the alternative thermal power (combined cycle), and the Cost (C) as the cost of construction of hydropower.

So far in Vietnam, annual peak generation hours of forty hundred (Tmax = 4,000) have been a rough guideline for selection of installed capacity of a hydropower station.

$A = P_{max} \times T_{max}$ here、 A : Annual generated energy（MWh）
Pmax : Installed Capacity (MW)
Tmax : Annual peak generation hours (hr)

Annual peak generation hours (Tmax) is an index like Capacity Factor (CF). Relation of these is shown as the next formula.

$$T_{max} = A / P = 8{,}760\text{hr} \times (\text{CF}(\%)/100)$$

Accordingly, Annual generation hour (Tmax) 4,000hr accounts for Capacity Factor (CF) of 45.7%, and Tmax 3,000 hr for CF34.2% likewise.

Relationship between annual cost of candidate generations and capacity factor are shown in Fig. 5-1-3, which figure is presented for screening analysis described in Chapter 6. Annual cost of the cascade project of Ban Chat and Huoi Quang, and the Son La hydropower are shown in the figure.

Combined cycle was chosen as the alternative generation of the B/C method for economic evaluation of Ban Chat and Huoi Quan hydropower. In the figure, line for combined cycle thermal indicates the cost at every capacity factor, which means the benefit (B). Line for Ban Chat and Huoi Quang hydropower, which means the cost (C). Accordingly the difference between the two lines correspond to the (B-C). Thus the case of which capacity factor maximizes the difference, indicates the optimum installed capacity for the hydropower.

There is a wide range of difference of construction costs with every hydropower because of the difference of site conditions. Further, there are other reasons to make difference of the project cost, that is river discharge, design of reservoir capacity and installed capacity. Accordingly annual generation does not increase in proportion to the increase of installed capacity.

Therefore, optimum installed capacity is not determined by annual generation hours (Tmax) alone. It is necessary to evaluate by B/C method considering the properties of the project.

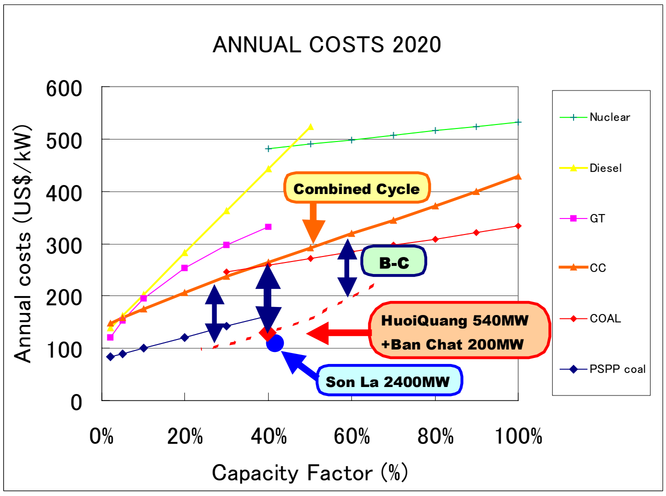


Fig.5-1-3 Optimum Case in B/C Method

2) Properties of Ban Chat, Huoi Quang Hydropower Stations

River discharge is stored to the dam reservoir during the wet season for the use of power generation in the dry season. Since the stored volume limits the available amount of the water for generation, it is necessary to generate systematically. In many cases, the economical efficiency of a downstream power station in a cascade development is better than that of an independent development, as the operation of the lower dam can be benefited by the regulation of the river discharge at the upper dam.

Based on the results of simulation of base case of cascade development, peak operation hours in the dry season are 8 hours for Ban Chat and 6.6 hours for Huoi Quang. During the wet season, however, there are wide variances of the river discharge. In some years, the generators could work full time of a day, but in a drought year, power stations may generate only the same hours as in a dry season.

The planned capacity of reservoirs for the dams seems too small to regulate most of the river discharge in the wet season and to use it at an averaged volume through the year. But if the dams are elevated for enlarging the reservoir scale, that may bring about increase of years when the designed full supply level is not reached due to relatively short river discharge for the enlarged reservoirs even in the wet season. Considering that increase of operating hours in the dry season is not to be anticipated, the dam/ reservoir capacity of the present plan may be reasonable. It means both of Ban Chat and Huoi Quang hydropower stations are better to be used as peak/middle generations.

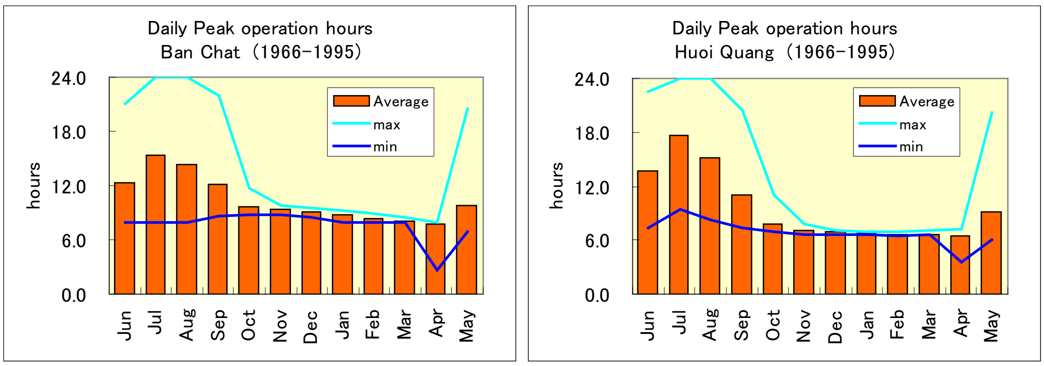
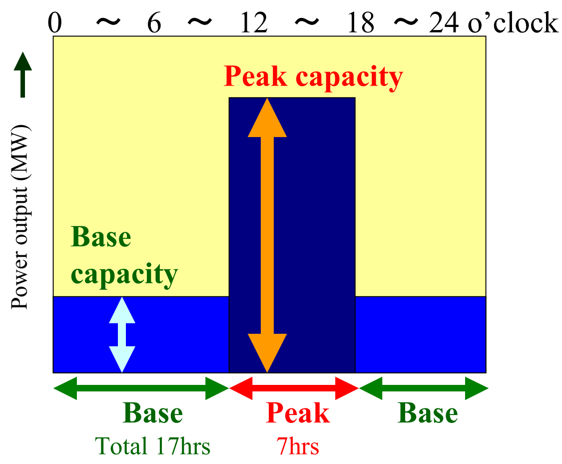


Fig. 5-1-4 Available Peak Generation Hours of Each Month (Base Case)

The monthly average capacity is shown in the Figure 5-1-5 for a peaking supply using the reserved water that is allotted for each month. (The idea of peak operation is shown on the right.)



As is described in details in Chapter 6, the generating capacity available within the volume of reserved water has been calculated assuming the daily peak operation to be 7 hours, as the peak duration requirement for peaking power generations is 7 hours, taking the future demand pattern into consideration. Besides, an average capacity of generation during the off-peak hours (17 hours/day) is calculated using the remaining reserved water, which is also shown in the Figure 5-1-5.

In this figure, most of the available storage for each month of dry season is used for peak generation. During the wet season, there is more abundant water available, so that the remaining water after peak generation is used for off-peak generation as base operation. When the base capacity is higher, the adjusting range of load following capability that is difference of peak and base capacity is smaller. It means operation of these stations during wet season is like a middle supply. However, when peak power for the adjusting range of load following capability is required, it may be possible by releasing surplusage without generation, although annual generation will be decreased a lot. Therefore the property of these hydropowers is basically of peaking supply, but sophisticated operation plan should be designed for them especially for wet season from the viewpoint of efficient use of reserved water.

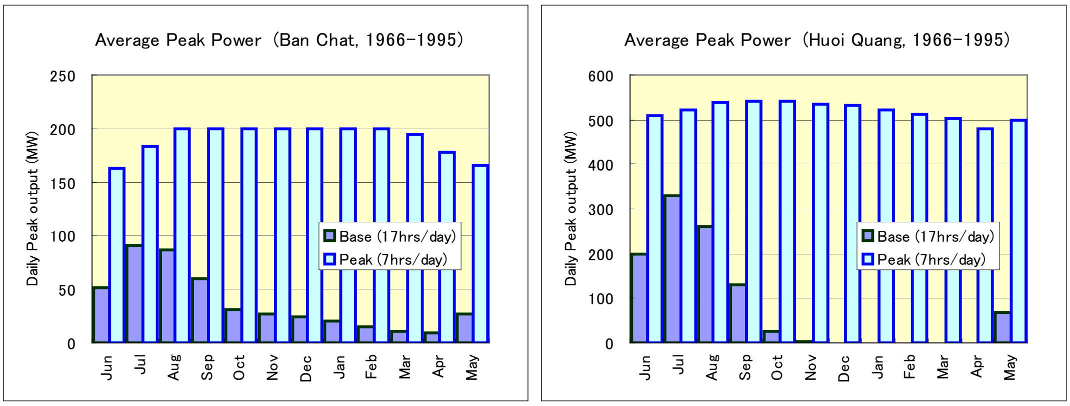


Fig. 5-1-5 Available Peak/Base Capacity of Each Month (Base Case)

3) Optimum Installed Capacity

In the above clause, the peak duration hours for peaking supply is defined as seven (7) hours for future demand in Vietnam. In this clause, the effect of change of the peak duration hours on the optimization of installed capacity is presented. Economic evaluation results using B/C method are shown in Fig.5-1-6 for three cases of peak duration hours, which are seven (7), six (6) and five (5) hours.

The left graphs show the optimum installed capacity of Huoi Quang hydropower when the capacity of Ban Chat hydropower is 200MW. The right graphs show the optimum installed capacity of Ban Chat hydropower when the capacity of Huoi Quang hydropower is 540MW.

According to the graphs on the left side, the optimum installed capacity moves to the right (the direction in which the optimum installed capacity becomes bigger) as the peak duration hours reduce from 7 hours. However when the peak duration hours are kept above six hours, the installed capacity 540MW of Huoi Quang becomes optimum.

From the graphs on the right side, the same results are seen as the left graphs on the relation between peak duration hours and optimum installed capacity. The installed capacity of Ban Chat 200MW also becomes optimum when the peak duration hours is maintained for above six hours.

In conclusion, the respective installed capacities of the current development plan, which are 200MW of Ban Chat and 540MW of Huoi Quang, are deemed the best choice, considering the future proportion of power demand.

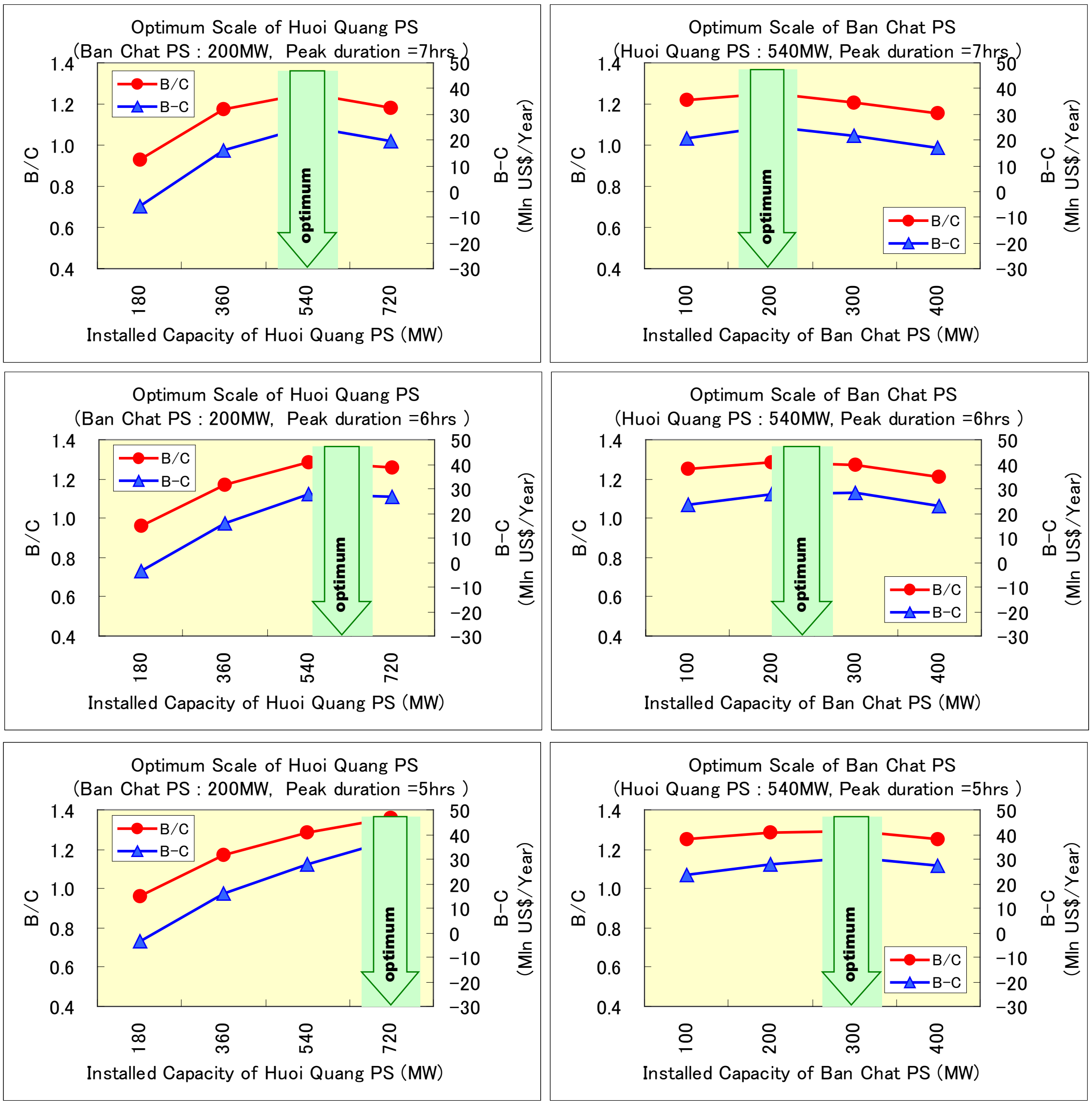


Fig.5-1-6 Optimum Installed Capacity for Ban Chat, Huoi Quang in Case Peak Duration is 7, 6, 5hours

The results of the simulation in case of 7 hours of peak duration hours are presented in Table 5-1-11. Cascade development is desirable, although independent development cases of Ban Chat and Huoi Quang are shown in the table, as both of the cases are economically less feasible.

Table 5-1-11 Results of Economic Evaluation

		Independent		Cascade development							
				HQ constant				BC constant			
		HQ	BC	A-1	BASE	A-2	A-3	B-1	B-2	BASE	B-3
Installed Capacity	BC	-	200	100	200	300	400	200	200	200	200
	HQ	540	-	540	540	540	540	180	360	540	720
(MW)	Total	540	200	640	740	840	940	380	560	740	920
Unit Cost	BC	-	1,721	3,020	1,721	1,314	1,108	1,721	1,721	1,721	1,721
	HQ	1,015	-	1,015	1,015	1,015	1,015	2,433	1,373	1,015	841
(US$/kW)	Total	1,015	1,721	1,328	1,206	1,122	1,054	2,058	1,497	1,206	1,032
Generation Cost	BC	-	5.2	4.9	5.2	6.0	6.7	5.2	5.2	5.2	5.2
	HQ	3.5	-	3.2	3.3	3.3	3.3	3.4	3.1	3.3	3.6
(UScent/kWh)	Total	3.5	5.2	3.7	3.8	4.0	4.2	4.0	3.7	3.8	4.0
Economic Evaluation	B/C	0.87	0.44	1.22	1.25	1.21	1.15	0.93	1.17	1.25	1.18
(mln US$)	B-C	-7.6	-42.7	20.6	25.2	21.7	16.9	-5.9	15.9	25.2	19.3

Legend BC: Ban Chat PS, HQ: HuoiQuang PS