JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE SOCIALIST REPUBLIC OF VIETNAM
MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

THE MASTER PLAN STUDY
ON
DONG NAI RIVER AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT

FINAL REPORT

VOLUME VI

APPENDIX V ENVIRONMENTAL EVALUATION

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NIPPON KOEI CO., LTD., TOKYO JAPAN

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FINAL REPORT

VOLUME VI

APPENDIX V HYDROPOWER GENERATION

AUGUST 1996

NIPPON KOEI CO., LTD., TOKYO JAPAN

This Report consists of

Volume I	Executive Summary	
Volume II	Main Report	
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The cost estimate was based on the December 1995 price level and expressed in US$ according to the exchange rate of US$ 1.00 = Vietnamese Dong 11,014 = Japanese Yen 101.53 as of December 15, 1995.

LIST OF ABBREVIATIONS

AFS	Agriculture and Forestry Service (PC)
CEMMA	Committee for Ethnic Minorities and Mountainous Areas
DCWSSS	Design Company for Water Supply and Sanitation System (HCMC-PC)
EA	Environment Assessment (Multi-lateral Lending Agencies)
ECSP	Evaluation Commission for State Projects
EIA	Environmental Impact Assessment
ENCO	Ho Chi Minh City Environmental Committee
EVN	*General Company of Electricity of Viet Nam (Abolished and renamed in November 1995 as Vietnamese Power Corporation)*
FIPI	Forest Inventory and Planning Institute (MOARD)
GCOP	Governmental Committee on Organization and Personnel
GDLA	General Department of Land Administration
GDMH	General Department of Meteorology & Hydrology
GOV	Government of Viet Nam
GSO	General Statistical Office
HCMC	Ho Chi Minh City
HEC	Ho Chi Minh Environment Committee (HCMC)
HIDC	Hydraulic Investigation and Design Company (MOARD)
HPC	Ho Chi Minh People's Committee (HCMC)
HSDC (or SDC)	Ho Chi Minh Sewerage and Drainage Company (HCMC)
HWSC (or WSC)	Ho Chi Minh Water Sypply Company (HCMC)
IDD	Irrigation and Drainage Department (MOARD)
IEE	Initial Environmental Examination
IER	Institute for Economic Research (HCMC-PC)
IHPH	Institute of Hygiene and Public Health (MOPH)
IM	Institute of Mines (MOID)
INVESCo	Investment Company for the Development of Water Sector (HCMC-PC/TUPWS)
IOE	Institute of Energy (MOID)
IURP	Institute of Urban and Rural Planning (HCMC-PC/Construction Service)
IWRE	Institute of Water Resources Economics (MOARD)
IWRP	Institute of Water Resources Planning (MOARD)
IWRR	Institute of Water Resources Research (MOARD)
JICA	Japan International Cooperation Agency (Japan)

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IWRP	Institute of Water Resources Planning (MOARD)
IWRR	Institute of Water Resources Research (MOARD)
JICA	Japan International Cooperation Agency (Japan)

MOAFI	*Ministry of Agriculture and Food Industry (Abolished and integrated into the new MOARD)*
MOAP	Ministry of Aquatic Products
MOARD (New)	Ministry of Agriculture and Rural Development (Created in October 1995 by the merger of the former Ministry of Water Resources, Ministry of Agriculture and Food Industry and Ministry of Forestry)
MOC	Ministry of Construction
MOCI	Ministry of Culture and Information
MOD	Ministry of Defence
MOE	*Ministry of Energy (Abolished and integrated into the new MOID)*
MOET	Ministry of Education and Training
MOFI	Ministry of Finance
MOFO	*Ministry of Forestry (Abolished and integrated into the new MOARD)*
MOFA	Ministry of Foreign Affairs
MOHI	*Ministry of Heavy Industry (Abolished and integrated into the new MOID)*
MOID(New)	Ministry of Industry (Created in November 1995 by the merger of the former Ministries of Heavy Industry, Light Industry and Energy)
MOJ	Ministry of Justice
MOIT	Ministry of Interior
MOLI	*Ministry of Light Industry (Abolished and integrated into the new MOID)*
MOLWISA	Ministry of Labour, War Invalids and Social Affairs
MOPH	Ministry of Public Health
MOPI (New)	Ministy of Planning and Investment (Formed from a merger of the former SPC amd SCCI)
MOSTE	Ministry of Science, Technology and Environment
MOTC	Ministry of Transport and Communications
MOT	Ministry of Trade
MOWR	*Ministry of Water Resources (Abolished and integrated into the new MOARD)*
MPAC	Ministrial Project Appraisal Committee
NEA	National Environment Agency
NGO	Non-Governmental Organization
NIAPP	National Institute for Agricultural Planning and Projection
NPAC	National Project Appraisal Committee
OECC	Overseas Environmental Cooperation Centre
OECF	Overseas Economic Cooperation Fund (Japan)
PC	People's Committee (executive arm of the People's Council)

PCC	Power Construction Company (VPC)
PIDC	Power Investigation and Design Company (VPC)
PPC	Provincial People's Committee (City People's Committee = CPC)
SBV	State Bank of Viet Nam
SCCI	*State Committee for Cooperation and Investment (Abolished and integrated into the new MOPI)*
SFEZ (or SFEA)	Southern Focal Economic Zone (or Southern Focal Economic Area)
SIWRP	Sub-Institute of Water Resources Planning (MOARD-IWRP)
SIWRR	Southern Institute of Water Resources Research (MOARD)
SPC	*State Planning Committee (Abolished and integrated into the new MOPI)*
SRV	Socialist Republic of Viet Nam
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Education Fund
UNIDO	United Nations Industrial Development Agency
VPC (New)	Vietnam Power Corporation (the former General Company of Electricity of Viet Nam = EVN)
WASECO	Water and Sewerage Construction Company (MOC)
WB	World Bank
WHO	World Health Organization
WPMI (IWRPM)	Water Planning and Management Institute (MOARD)
WRD(or WRS)	Water Resources Department or Water Resouce Service (PC)
WSC	Water Supply Company (under Construction Services of the PC)

Note : Abbreviations in *Italics* are no more existent (already abolished and integrated in November 1995).

Measurements

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer
ft	=	foot
yd	=	yard

Area

cm^2	=	square centimeter
m^2	=	square meter
ha	=	hectare
km^2	=	square kilometer

Volume

cm^3	=	cubic centimeter
l	=	litre
kl	=	kilolitre
m^3	=	cubic meter

Weight

g	=	gram
kg	=	kilogram
ton	=	metric ton

Time

s	=	second
min	=	minute
h	=	hour
d	=	day
y	=	year

Electric Measurements

V	=	Volt
A	=	Ampere
Hz	=	Hertz (cycle)
W	=	Watt
kW	=	kilowatt
MW	=	Megawatt
GW	=	Gigawatt

Other Measures

%	=	percent
PS	=	horsepower
^{0}	=	degree
10^3	=	thousand
10^6	=	million
10^9	=	billion

Derived Measures

m^3/s	=	cubic meter per second
kWh	=	Kilowatt hour
MWh	=	Megawatt hour
GWh	=	Gigawatt hour
kVA	=	kilovolt ampere

Currencies

US$	=	US Dollar
VND	=	Vietnamese Dong

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Appendix V

HYDROPOWER GENERATION

APPENDIX V

Hydropower Generation

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1. INTRODUCTION

The electric power supply regime in the nation is divided by the regions of the country to northern region (Power Company No. 1), central region (Power Company No. 3) and southern region (Power Company No. 2), and the Study Area occupies the major area of the southern region.

The demand/supply conditions differ substantially from one region to another, and it is the fact that the southern region has been suffering from the shortage of electricity supply especially in the dry season primarily due to reduction of energy generation by the existing hydropower plants. On the other hand, the northern region will continue to be a considerable excess of generation capacity, and in this respect the Government completed construction of a 500 kV single-circuit transmission line to interconnect the three regions in the year of 1994 and has started sending the surplus power from the northern region to the southern region.

Although the electricity supply network is now connected to the national power grid and the energy transfer from the northern region to the southern region is readily available, development of hydropower projects in the Study Area is still essential not only for reducing the power shortage but also for contributing to the environmental objectives such as alleviation of air pollution and foreign exchange earnings.

This Appendix V is prepared based on data/information collected and studies carried out during the Phase I, II and III study periods. The main objective of the Phase I was to identify potential hydropower schemes and to carry out the preliminary screening. In Phase II, the hydrology, the layout design and the cost estimate were reviewed and refined, and the second screening was carried out. The generation expansion planning study was carried out to confirm the development priority of projects, and the hydropower master plan projects were selected. In Phase III, the cross section survey and geological mapping were carried out for the selected master plan projects, and the design and the project costs were refined and modified. The economic evaluation and the initial environmental examination were furthermore carried out to confirm the economic as well as environmental viability of the selected projects.

In respect of the present power market and the demand forecast, JICA's latest report: "Master Plan Study on Electric Power Development in the Socialist Republic of Viet Nam" (Draft Final, July 1995), which contains the most updated data, is referred in preparing the relevant sections in this report.

2. PRESENT SITUATION OF ELECTRICITY SUPPLY

2.1 Present Situation of the Whole Country

The energy sector is substantially different in each of the three main regions of the country. In the north there is now an excess supply of hydropower along with the operations of coal-fired plants that are functioning at some 50 % of their capacity. The economy of the north has traditionally been coal-based and oriented towards heavy industry; it is growing relatively slowly compared to the southern region, and, in particular, the dynamic Ho Chi Minh City area. The central part of Viet Nam is generally less developed and less well-served by the electricity system; annual electricity consumption per capita is 52 kWh a year compared to 110 kWh a year in the north and the south. In terms of energy development, the southern region is characterized by shortage of electricity generation, particularly in the dry season. In general, electricity consumption has been constrained by supply limitations in the south and centre.

Three Power Companies, PC1, PC2 and PC3, provide bulk power supplies and operate three separate regional high voltage (220/110/66 kV) transmission and medium and low voltage distribution networks. The areas in and around Hanoi-Hai Phong are served by PC1 in the north, while PC2 is responsible for Ho Chi Minh City and the lower Mekong Delta region in the south. Da Nang and Hue areas in the central region are served by PC3. Both PC1's and PC2's 220/110 kV systems are gradually being extended to supply the central region, although currently there is 400 km separation between Da Nang and Nha Trang (the northernmost city supplied by PC2).

In the year 1994, Viet Nam had an installed generating capacity of over 4,470 MW with a total electricity production of 12,195 GWh or sales of 9,198 GWh. The existing installed capacity of 4,470 MW consists of 2,826 MW of hydropower plants and 1,644 MW of thermal power plants, however, the available capacity of the existing thermal power plants is estimated to be approximately 1,325 MW, since most of the fossil fuel plants are in poor condition due to age, lack of spare parts or inadequate maintenance. The gap between installed capacity and available capacity contributes to the power shortages in the central and southern areas.

One of notable issues in the electric power sector in Viet Nam is the imbalance of generation resources, characterized by surplus capacity in the north, while there is a growing energy deficiency in the south.

The regional power supply characteristics in the year 1994 are summarized as follows:

Power Supply Characteristics in the Year 1994

Description	Northern PC1	Central PC3	Southern PC2	Viet Nam Total
Population (million)	33,204 (47)	10,458 (15)	26,275 (38)	69,938 (100)
Available Hydro Capacity (MW)	2,028 (72)	85 (3)	713 (25)	2,826 (100)
Available Thermal Capacity (MW)	652 (49)	115 (9)	558 (42)	1,325 (100)
Available Total Capacity (MW)	2,680 (65)	200 (4)	1,271 (31)	4,151 (100)
Energy Generation (GWh)	7,142 (59)	253 (2)	4,800 (39)	12,159 (100)
Energy Sales (GWh)	4,186 (49)	764 (8)	4,248 (43)	9,198 (100)
Peak Load in 1993 (MW)	1,076 (52)	190 (9)	817 (39)	2,083 (100)

Note: Figures in parentheses show percent shares in the whole of the nation.

Both the central and southern regions are presently importing electricity from the northern region with rather high system losses in a range of 20 to 25 % in the country. Since the southern region has been showing the fast economic growth for last ten years and is expected to continue its economic growth as the major economic centre in the country in future, its power generation expansion planning aiming at self-sufficiency is one of the key factors to secure the stable national economic growth.

2.2 Present Situation in the Study Area

In the southern region, the total power generation in the year 1993 was 4,667 GWh, of which 2,790 GWh (60 %) was generated by the hydropower plants and the remaining consists of 1,140 GWh (24 %) of oil-fired thermal, 716 GWh (15 %) of gas turbine and 126 GWh (2 %) of diesel.

The annual growth rate of power consumption during last 10 years was approximately 10 %. Major demand sectors are the industrial sector (50 %) and the residential (household/lighting) sector (36 %), followed by the non-industrial (commercial/services) sector (10 %).

The existing capacity of power plants under PC2 in the year 1994 excluding power supply through 500 kV transmission line from the north is listed in Table 2.1 and is summarized as follows:

		Installed Capacity (MW)	Available Capacity (MW)	
a)	Hydropower	713	713	(56 %)
b)	Oil-fired Thermal	205	193	(15 %)
c)	Gas Turbine	388	287	(23 %)
d)	Diesel	201	78	(6 %)
	Total	1,507	1,271	(100 %)

Three major hydropower plants operating in the Study Area are as follows:

(1) Da Nhim Hydropower Plant

The Da Nhim Power Plant is located in the Da Nhim River, a tributary of the Dong Nai River, about 50 km northeast of Da Lat city. Its total capacity is 160 MW and the annual energy output is approximately 1,000 GWh since its commissioning in the year 1963. Its reservoir capacity is rather small but has a net head of 800 m attained by diverting water from the Da Nhim River to the Cai River in the east coast area.

(2) Tri An Hydropower Plant

The Tri An Power Plant was completed in the year 1989 and is located in the lower reaches of the Dong Nai River, 65 km northeast of Ho Chi Minh City. Its capacity is 400 MW with an annual energy output of 1,700 GWh. Due to the large capacity of the reservoir (effective storage of 2,543 million m^3), it significantly contributes to reducing flood damages in the downstream areas (refer to Appendix VIII) and to preventing salinity intrusion in the lower reaches of the river (refer to Appendix IX).

(3) Thac Mo Hydropower Plant

The Thac Mo Power Plant is located in the Be River, 120 km north of Ho Chi Minh City with a capacity of 150 MW. The annual energy output is 590 GWh and its commercial operation commenced in early 1995.

The Ham Thuan (300 MW)-Da Mi (172 MW) hydropower project is presently under the tender stage and the construction is expected to commence in the end of the year 1996 towards the target completion date in the year 2000. The feasibility study for the Dai Ninh hydropower project (300 MW) was completed by PIDC 2 and its commercial operation is expected to start in the year 2003 according to the "Master Plan Study-Fourth Stage (1995)" prepared by the Institute of Energy.

There are three major thermal power generation plants in the Study Area:

(1) Thu Duc Power Plant

The oil-fired Thu Duc Plant is located on the outskirts of Ho Chi Minh City with one 33 MW unit and two 66 MW units commissioned in the year 1966 and 1972, respectively. The Thu Duc Plant is the largest plant in the southern region. With these plants, five units of gas turbines were added in the year 1991/1992, and the total capacity is presently approximately 250 MW.

(2) Ba Ria Power Plant

The Ba Ria Power Plant is located in the Vung Tau district southeast of Ho Chi Minh City. Two units of old-type 22.5 MW gas turbines are not working well due to obsolescence. Five units of 37.5 MW gas turbines were additionally installed recently, and then the available capacity is now 160 MW.

(3) Tra Noc Power Plant

The Tra Noc Power Plant was commissioned in the year 1975 with one 33 MW oil-fired unit. This plant is located in the Mekong delta region, playing an important role in supplying power to the area. It also has two gas turbine units (28 MW), however, they are not in operation due to its obsolescence.

For the thermal plant expansion plan, the Phu My steam plant (200 MW x 3) is presently under the detailed design stage and its commercial operation is expected to take place in the year 1998.

2.3 Transmission Line System

The 500 kV transmission line began its first operation in June 1994 with the maximum sending power capability of 300 MW between the Hoa Binh substation in the north and the Phu Lam substation in the south with approximately 1,500 km long distance. The second stage of the project was completed in September 1994 with the maximum sending power capability of 500 MW to the south, tapping two substations in the central region (Da Nang and Play Ku). Its operation record in the year 1994 is as follows:

	Hoa Binh	Da Nang	Play Ku	Phu Lam
Energy (GWh)	990	106	14	770
Max. Power (MW)	574	121	49	418

In December 1994, it transmitted 256 GWh of energy in a month, which is equivalent to approximately 70 % of monthly load factor for the design transmission capability of 500 MW.

The maximum sending power of 630 MW was recorded at the Hoa Binh substation and the maximum receiving power of 478 MW at the Phu Lam substation in January 1995.

The central region with the Da Nang and Play Ku substations shifted its main power sources by the northern system from the 220 kV Hoa Binh-Dong Hoi transmission line to the 500 kV substations. Moreover, Vinh Son hydropower station commenced its operation as a supplier of peak demand in late 1994. With the proper arrangement of transmission line system, 500 kV transmission line is expected to contribute to the central power system until commissioning of promising large scale hydropower projects such as Yaly which is scheduled in the year 1999.

As described above, the power transmission network of each region is connected to the main trunk (national grid) through the 500 kV transmission line, and in this respect, more power and energy transmission from the north to the south will be expected. However it is also necessary to consider possible transmission loss due to the long distance of energy transmission. It is also to be noted that there is a possibility of system-wide blackout in the southern system due to technical reasons or tripping of the line due to typhoon damage and so on.

The transmission system, which covers the Study Area as well as the lower Mekong delta in the southern region, is shown in Figure 2.1.

The first 220 kV transmission line in the southern system was constructed between the Da Nhim hydropower station and the Thu Duc substation under the Da Nhim hydropower project in the year 1964. Three 220/110 kV substations were recently constructed at Long Binh, Hoc Mon and Phu Lam to reinforce the supply capacity to the Ho Chi Minh City area. Three new power stations, Tri An hydropower station, Thac Mo hydropower station and Ba Ria gas turbine station, have been connected to the power system with the 220 kV lines. The 220 kV line was extended to the Tra Noc substation near Can Tho power plant in the southern Mekong delta area.

The 110 kV transmission line systems deliver power to district cities and towns, and some of old 66 kV transmission systems are also still in operation in Ho Chi Minh City area. The 66 kV lines are mostly insulated for 132 kV and can be converted to an operating voltage of 110 kV for future upgrading.

3. POWER DEMAND AND SUPPLY BALANCE

3.1 Historical Trends of Power Consumption and Generation

(1) Whole Country

Table 3.1 shows the historical trends of power supply and demand in the whole of the country. The annual electric power demand (power sold) excluding companies' auxiliaries and the system losses increased from 2,218 GWh in the year 1976 to 2,670 GWh in the year 1980 and to 8,007 GWh in the year 1993. The demand for industrial sector in the year 1993 was 3,645 GWh, accounting for 46 % of the total demand, followed by residential sector (demand for household) which consumed 3,236 GWh (40 %).

Average annual growth rates (%) of the electricity demand by each sector are also shown in the Table. The growth rate per annum of the total demand over the time period of the year 1980 to 1993 was 8.81 %, where the growth rates of industrial, non-industrial, transport and household demand were 7.63 %, 7.84 %, 5.48 % and 10.51 % respectively. Leading drive force of the electricity consumption is therefore the rapid increase of household demand assumed to be mainly light demand.

The electric power generation increased from 2,965 GWh in the year 1976 to 3,559 GWh in the year 1980 and to 10,729 GWh in the year 1993 as shown in the same Table. Hydropower generation recorded 7,965 GWh, accounting for 74 % of the total power in the year 1993 (1,488 GWh, 42 % in the year 1980 and 5,369 GWh, 62 % in the year 1990). Such a large increase has been achieved by commissioning the Hoa Binh hydropower station (seven units installed as of the end of the year 1993 out of total 240 MW x 8 units) and the Tri An hydropower station (100 MW x 4 units).

Annual growth rates of power consumption are summarized as follows:

Year	1980/85	1985/90	1990/93	Average 1980/93
Whole Country	7.70 %	9.85 %	8.97 %	8.81 %
Northern Region	8.74 %	8.03 %	7.02 %	8.07 %
Central Region	13.62 %	9.64 %	13.66 %	12.08 %
Southern Region	5.38 %	12.38 %	10.48 %	9.20 %

(2) Southern Region

Tables 3.2 and 3.3 show the historical trends of power demand and generation by source in the southern region.

Electricity demand in the region increased from 1,111 GWh in the year 1980 to 3,491 GWh in the year 1993. The industrial sector consumed 1,740 GWh a year, accounting 50 % of the total. The residential (household) sector was 1,263 GWh a year (36 %), followed by non-industrial (360 GWh, 10 %), agricultural (96 GWh, 3 %) and transport sector (32 GWh, 0.9 %) in the year 1993.

The growth rate per annum of the total demand over the period of the year 1980 to 1993 was 9.2 %, and that of industrial, non-industrial, transport, agricultural and household demands was 8.12 %, 13.26 %, 12.86 %, 11.36 % and 9.7 % respectively.

Power generation also increased from 1,544 GWh in the year 1980 to 4,668 GWh in the year 1993, in which hydropower generation shared approximately two-thirds of the total. The second largest power source is oil-fired thermal, which accounts for 24 % of the total in the year 1993.

3.2 Load Curve

Monthly peak load curves (the year 1985, 1988, 1990, 1992 and 1993) and typical daily load curves (April 1993 and November 1994) in the southern region are shown in Figure 3.1.

As seen from the Figure, there is no significant fluctuation in respect of the monthly peak load throughout the year. On the other hand, the daily peak load varies significantly from the lowest (500 MW) around 3:00 AM to the highest (1,100 MW) at 18:00 PM according to the daily load curve recorded in November 1994. Electricity consumption in the peak time is inferred to accrue from the lighting demand necessary through meal preparation in households.

Electricity consumption during the day time (9:00 to 17:00 o'clock) is supposed to be raised by the industrial/commercial sector demand. In the southern region, the share of light industries and service/commercial sector is expected to expand rapidly, and such instantaneous peak demand will gradually be diminished as the daily total demand increases.

3.3 Power Demand Forecast

In the "Master Plan Study on Electric Development in the Socialist Republic of Viet Nam", Draft Final Report, July, 1995, prepared by JICA, an econometric approach was adopted for the power demand forecasting model and the power demand was forecast up to the year 2010.

The model includes the relationships among power consumption, GDP in each sector which consists of industry, agriculture, residence and others, and electrification ratio. Using the regression analysis and taking into consideration the development scenario of each sector, mathematical equations were established to estimate future power demand.

Since the target year for this Dong Nai Water Resources Master Plan is 2015, demands are extrapolated for the additional five-year period of the year 2011 to 2015 based on an assumption that the macro economic and social indicators will not vary and that the growth rate for the total GDP growth rate (%), the population growth rate (%), the electrification ratio and so on in the said time period of the year 2011 to 2015 will remain the same as that for the time period of the year 2006 to 2010.

Demand forecast for the additional five years up to the year 2015 is then extrapolated for sector-by-sector in the southern region. The detailed forecast for three cases (low, base and high scenario) together with the assumed growth rates is shown in Tables 3.4, 3.5 and 3.6, and the summary is tabulated below:

Summary of Power Demand Forecast for the Southern Region (PC2)
(Demand Basis)

(Unit : GWh)

	Year	2000	2005	2010	2015
Industry	Low Case	4,640	8,546	13,991	22,842
	Base Case	5,327	10,444	18,128	31,353
	High Case	5,736	11,894	21,857	40,021
Agriculture	Low Case	181	223	263	309
	Base Case	186	240	308	395
	High Case	186	240	308	395
Others	Low Case	776	929	1,062	1,211
	Base Case	829	1,008	1,159	1,330
	High Case	864	1,070	1,239	1,431
Residence	Low Case	2,611	4,304	6,519	9,821
	Base Case	2,869	4,989	7,859	12,293
	High Case	2,998	5,403	8,730	13,989
Total	Low Case	8,208	14,002	21,835	34,183
	Base Case	9,211	16,681	27,454	45,371
	High Case	9,784	18,607	32,134	55,837

Summary of Power Generation and Peak Load (PC2)

(Generation Basis)

		2000	2005	2010	2015
Generation (GWh)	Low Case	10,261	17,286	26,306	41,184
	Base Case	11,514	20,595	33,077	54,663
	High Case	12,231	22,972	38,715	67,273
Peak Load (MW)	Low Case	1,952	3,289	5,005	7,836
	Base Case	2,191	3,918	6,293	10,400
	High Case	2,327	4,371	7,366	12,799

In the "Master Plan Study on Electric Power Development in Viet Nam (Fourth Stage)" prepared by the Institute of Energy (IEV) under the then Ministry of Energy in January 1995, the electricity requirement (generation base) up to the year 2010 in the country is projected as follows for reference:

Year	Whole of the country	North	Central	South
2000	25,309 - 27,465	9,780 - 10,695	2,279 - 2,442	13,250 - 14,328
2005	40,495 - 43,712	15,182 - 16,419	3,283 - 3,632	22,030 - 23,681
2010	68,369 - 75,203	24,183 - 27,003	5,267 - 6,021	38,919 - 42,179

Note: Figures above show the base and high cases with a unit of GWh.

The forecast demand for the southern region up to the year 2010 by the Institute of Energy is higher than that of JICA's by 10 to 17 %, and such difference is inferred to be due to the demand forecasting methodology applied.

4. IDENTIFICATION OF HYDROPOWER POTENTIAL SCHEMES

4.1 Characteristics of the River Basins

Viet Nam has a considerable amount of hydropower potential. This potential derives essentially from water resources of the three major river systems which dominate the country's hydrology: the Red River Delta in the north, the Mekong Delta and the Dong Nai River in the south. The Dong Nai River is the major river in the Study Area, and its efficient use of available water resources is essential to secure the sustainable and stable growth of the Study Area.

In general, river flows show a strong imbalance between rainy and dry seasons with as much as 80 % of water discharge taking place during the six-month rainy season (from May to October) on an average. While the amount of firm energy varies from plant to plant, the power development programme will need to feature sufficient thermal capacity to supplement the output of hydropower plants during the dry season.

The rainfall over the Dong Nai River basin is approximately 2,000 mm/year on an average, varying considerably from location to location. The wettest part of the basin is the area in and around Di Linh where the rainfall averages around 2,700 to 2,800 mm/year. Dry parts of the basin are the areas of the Da Dung and Da Nhim sub-basins and the western part of the Study Area (Saigon and Vam Co sub-basins) which receive only between 1,500 and 2,000 mm/year.

The topography varies rather widely in the Dong Nai River basin. The basin east of Di Linh constitutes a hilly plateau with elevations ranging from El. 1,000 to 1,400 m. The central and central northern part of the Dong Nai River basin, i.e. the area in and around Bao Loc and Gia Nghia, also forms a hilly plateau but with elevations ranging between El. 600 and 1,000 m. The central southern part of the basin, i.e. the area around the confluence of the Dong Nai and one of its major tributaries, the La Nga, shows a low hilly plateau climbing up to about El. 50 to 125 m. The western part of the Dong Nai River basin, i.e. the greater part of the basin of the Dong Nai's main tributary, the Be River, is hilly with elevations ranging from El. 10 m in the south to about 200 m in the north.

For further detail, reference is made to Appendix II (Topography and Geology), Appendix III (Meteorology and Hydrology) and Appendix IV (Natural Environment).

4.2 Identification of Hydropower Potential

In the Phase I Study, each potential dam site is identified together with SIWRP using the topographical maps with a scale of 1/100,000 and 1/50,000.

The river profiles together with the identified schemes are shown in Figure 4.1. As seen from the Figure, the average gradient of the Dong Nai main stream, in which identified cascade projects are located, is approximately 1/250. Projects in the Be River are located on the stretches with its gradient of less than 1/1,500. Although the river slope is rather gentle, their drainage areas are large, resulting in large discharge. On the other hand, the river stretches with their slope steeper than 1/50, at which construction of run-of-river type and/or pumped storage type power generation is empirically considered to be favourable, are very limited and can be found only at tributaries of the above main stream with a rather limited catchment area.

The location of the identified projects is shown in Figure 4.2.

From the viewpoint of hydropower generation planning, the projects identified in the Study Area are classified into two groups; one consists of projects located on the main streams of the Dong Nai and Be rivers, which generally require large storage capacity to fully utilize water available from large catchment areas but have rather limited head with the exception of Dai Ninh Project which involves inter-basin transfer of water and creates high head. The other group consists of projects located on the tributaries of the main streams with limited catchment areas but with high head for power generation.

Following Sections describe the projects identified and classified into the two groups.

4.3 Hydropower Potential in the Main Stream

The Dai Ninh project is a basin transfer project which diverts water of the Dong Nai upstream basin to the Luy River in the east coast area (Phan Ri). The project has high head with relatively large storage (effective storage: 252 million cum), contributing to not only the hydropower development but also the irrigation and water supply development in the east coast area. The feasibility study for the project was completed by PIDC 2, and its commercial operation is expected to be commenced in the year 2003 according to the Master Plan Study (Fourth Stage) prepared by the Institute of Energy in the year 1995, following the completion of the Ham Thuan-Da Mi project which is scheduled to be in the year 2000. In this Master Plan Study these two projects are therefore assumed to be the committed (existing) projects.

Other projects such as Dong Nai No. 1 to No. 8, Can Don, Fu Mieng, Bao Loc and La Nga No. 3 are mainly cascade projects with a reservoir aiming to fully utilize the potential head available in the main river courses of the Dong Nai, Be and La Nga river systems.

Table 4.1 summarizes principal features of these projects, and their locations are shown in Figures 4.3 to 4.11.

Brief description of the identified projects is as follows:

(1) Dong Nai No. 1, No. 2 and No. 3 (refer to Figures 4.3 and 4.4)

These projects are located in the upstream reaches of the Dong Nai main stream with their catchment area from 1,869 km^2 to 2,428 km^2, which excludes the catchment area of the Da Nhim project (775 km^2) and the Dai Ninh project (1,158 km^2), and large reservoir storage volume is available. The dead storage deposited by sediment inflow has a rather small impact on the gross storage volume, and thus its effective storage of 1,500 million to 2,500 million m^3 can be secured. Due to such a large storage volume, their inflow regulating efficiency (firm discharge against natural inflow) is quite high and will contribute to the downstream water resources development by its "firming up effect".

It is noted that Dong Nai No. 1 and No. 2 are mutually exclusive projects for the construction.

(2) Dong Nai No. 4 and No. 5 (refer to Figures 4.5 and 4.6)

These projects are located in the middle reaches of the Dong Nai main stream with their catchment area of 2,597 km^2 to 4,263 km^2 excluding the Da Nhim and the Dai Ninh project. Dam sites of both projects are located in a relatively narrow valley and is favourable for constructing a high dam to create high head. However, the effective storage is very limited ranging from 50 million m^3 to 300 million m^3, and consequently the regulating efficiency is small, resulting in rather limited firm energy production. The sediment inflow volume will significantly affect to secure the effective storage.

It is considered that these projects will become attractive only after a reservoir type dam such as Dong Nai No. 3 is constructed in the upstream reaches; that is, these high heads can fully and effectively be utilized with the flow regulation by the upstream projects.

With its topographical advantage, Dong Nai No. 4 is designed to utilize an additional head by short-cutting the natural river bent with a relatively short length of the headrace tunnel, and therefore highly efficient hydropower development can be realized. Dong Nai No. 5 has a larger catchment area approximately 65 % larger than that of Dong Nai No. 4, but has no topographic advantage in the hydraulic head.

For both schemes, depending upon their geological conditions, a concrete gravity type dam may be considered.

(3) Dong Nai No. 6 and No. 8 (refer to Figures 4.7 and 4.8)

These projects are located in the flat area extending in the downstream reaches of the Dong Nai main stream, and high head is not available topographically. However, an abundant runoff of 160 to 270 m^3/sec in annual mean can be expected from their large catchment areas of 5,118 km^2 and 7,889 km^2, which exclude the catchment areas of the Da Nhim and Dai Ninh project.

Due to the topographic restriction, the dam construction requires long crest length in the range of 3,000 m to nearly 8,000 m with many saddle dams.

Dong Nai No. 6 has a large effective storage of 2,400 million m^3 compared with 820 million m^3 of Dong Nai No. 8, and in this respect, the flow regulation efficiency is higher.

It is to be noted that all the potential projects, Dong Nai No. 1 to No. 8, will contribute to increasing firm energy output of the existing Tri An hydropower plant located downstream.

(4) Can Don and Fu Mieng (refer to Figure 4.11)

Can Don and Fu Mieng are located on the Be River with a catchment area of 3,440 km^2 and 4,110 km^2 respectively, and can fully utilize an advantage of the regulated flow from the existing Thac Mo hydropower plant. With relatively low dams in terms of investment, both projects can generate sizable power and energy.

Fu Mieng also has a topographic advantage which enables diverting water of the Be River to the Saigon River through the existing Dau Tieng reservoir with approximately 7 km long channel. Since water transfer from the Be River to the HCMC-Long An delta area for the irrigation development is one of the most focal issues in this study, the optimum allocation of available water for the diversion purpose (irrigation) and power generation purpose shall carefully be studied.

(5) Bao Loc and La Nga No. 3 (refer to Figures 4.9 and 4.10)

Bao Loc site, which is located on the La Nga River upstream of the Ham Thuan-Da Mi projects, will be able to increase the power generation of the Ham Thuan-Da Mi projects as well as the Tri An hydropower plant with its firm-up effect.

La Nga No. 3 is located downstream of the Ham Thuan-Da Mi projects, and with its topographic advantage water in the reservoir can be transferred to the east coast area for irrigation development in Phan Thiet. However, such diversion will reduce not only power output of the project itself but also will decrease energy output of the Tri An hydropower plant.

4.4 Hydropower Potential in the Tributaries

The projects identified on the tributaries of the main streams have relatively small catchment areas, however, they are topographically favourable in respect of high head with a short distance of the envisaged waterway.

Principal features of the projects identified under this group are summarized in Table 4.2, and their preliminary layouts are shown in Figures 4.12 and 4.13.

As an indicator for the preliminary evaluation of hydraulic efficiency of projects, the length of waterway is divided by the static head (L/H=Length of waterway/Static Head), and the results are given as follows:

	Catchment Area (km^2)	Static Head (m)	Length of Waterway (m)	L/H
Da M'Bri	211	460	6,600	14.3
Dak R'Tih-Da R'Keh-Anh Kong	868 (=89+61+718)	370	3,400*	9.2
Dak R'Tih (Single **)	718	200	3,000	15.0
Da Siat	115	320	2,500	7.8

Note: * : Connecting tunnel of 12 km long as an optional case

** : This project is optional to Dak-Da R'Keh-Anh Kong.

Brief project features are described as follows:

(1) Da M'Bri (refer to Figure 4.12)

The dam site drains a catchment area of 211 km^2, and a 70 m high dam can have an effective storage of approximately 50 million m^3 by setting FSL at El. 605 m. Diverting water from the Da M'Bri River to the Da Te River through an approximately 6,600 m long water way will create an available static head of 460 m. This high head is attractive, and power generation of 50 to 70 MW can be expected. Since it has a sizable storage, possibility of constructing a pumped storage plant with the supplementary runoff will also be sought.

(2) Da R'Keh-Anh Kong-Dak R'Tih (refer to Figure 4.13)

Da R'Keh and Anh Kong dam sites are both located on the western part of the plateau on the north bank of the middle Dong Nai with their catchment areas of 89 km^2 and 61 km^2 respectively. The primary advantage of the project (both reservoirs to be connected by non-pressure tunnel of approximately 1 km long) is the creation of head of approximately 370 m by diverting water to the Dong Nai main stream (just downstream of Dong Nai No. 5) with a 3,400 m long waterway. For supplementing water for energy generation, it is possible to develop Dak R'Tih dam, which lies on the upstream reaches of the Da Nong River with its catchment area of 718 km^2, and to connect Dak R'Tih reservoir to the Da R'Keh River by a connecting tunnel of approximately 12 km long. With an additional firm discharge of 15 to 20 m^3/sec available from Dak R'Tih dam, a power of 200 to 250 MW can be generated.

As an alternative to the above, without diverting water from the Da Nong River to the Da R'Keh River (without constructing a connecting tunnel of 12 km long), Da R'Keh and Anh Kong dams can be developed as an upper pond for a pumped storage project utilizing available high head, and thus Dak R'Tih dam can be developed separately as an independent hydropower project utilizing a head of 200m within the Da Nong River basin.

(3) Da Siat (refer to Figure 4.13)

Da Siat dam site with a catchment area of 115 km^2 drains a small plateau on the south bank of the Dong Nai main stream and falls in the main stream. By constructing a small dam with a height of 30 to 40 m and a waterway of approximately 2,500 m long, a head of approximately 300 m can be created.

Although annual energy production is limited due to the small catchment area, its topographic advantage of high head with a relatively short waterway is considered suitable for constructing a pumped storage plant.

These high head projects with a relatively short waterway can be attractive as those to generate peak power for the limited high demand time, however, their annual energy output is limited due to its small catchment area. In this respect these projects are not subject to further study in this Master Plan, however, it is recommended to be developed as a pumped storage hydropower plant.

A pumped storage hydropower plant is designed to generate power during the peak load time by discharging water pumped up to the upper reservoir with cheap-cost surplus energy made available at an off-peak time from power plants such as nuclear and coal-fired power plants.

At present moment, such an off-peak time surplus energy is not available in the Study Area (southern region), and the overall system is under the premature level for developing pumped storage type hydropower plants yet.

However in the year 2010 to 2015, thermal power plant will become the major energy source, say 70 to 80 % of the total generation, in the overall system (refer to generation expansion planning study in Chapter 7), and the off-peak time surplus energy is then expected to be available with relatively cheap cost. Therefore it is worthy to study these high head projects as the pumped storage projects to be implemented after the year 2010 to 2015.

5. FIRST SCREENING OF POTENTIAL PROJECTS

5.1 Power Output

For the first screening of the identified potential projects, capacity and energy of each project are preliminarily calculated on condition that only the particular project is independently developed in future and that the existing and commited projects below are being "in operation" (The energy calculation taking into account the downstream and/or mutual effects to the other projects is carried out in Chapter 6):

Existing projects : Da Nhim project (160 MW), Tri Ân project (400 MW) and Thac Mo project (150 MW);

Project to be implemented in the year 2000: Ham Thuan-Da Mi projects (300 and 172 MW respectively); and

Project to be implemented in the year 2003 : Dai Ninh project (300 MW).

Three cases by effective storage are assumed for each project, except for some projects for which alternatives are considered to be topographically impractical, so that the cost sensitivity to capacity setting is properly assessed.

Data and assumptions adopted for the calculation are as follows:

(1) Runoff

Monthly runoff of 30 years at the selected key gaging stations provided by SIWRP in the Phase I stage is provisionally used to estimate monthly inflow at respective project sites.

(2) Sediment

A denudation rate of 1 mm/km^2/year is assumed for the 50-year project life (refer to Appendix III)

(3) Evaporation loss

Evaporation loss from the reservoir surface is assumed at 3 mm/day.

(4) Dam height-reservoir area-storage volume curve

Using 1/50,000 topographic maps, the reservoir area curve and the storage volume curve are prepared as shown in Table 5.1.

(5) Minimum Operating Level (MOL or LWL)

MOL = DWL + 2 x diameter of headrace tunnel + 1 m

where,

DWL: dead water level estimated from the horizontal formation of total sediment volume (50 years)

(6) Velocity in headrace tunnel

Velocity in the headrace tunnel is assumed at 3.0 m/sec.

(7) Dependability

Firm energy is defined as the energy to be guaranteed for the period covering 95 % of the total simulation period.

(8) Rated head (Design head)

Rated Head = FSL - 1/3 x (FLS - MOL) - TWL - head loss

where,

FSL (or HWL)	:	Full supply level
TWL	:	Tailwater level

(9) Installed capacity

Pi = 9.8 x 0.85 x 4 x firm discharge x rated head

where,

Combined efficiency of turbine and generator: 0.85

Plant discharge: 6-hour peaking operation is assumed.

Calculation results are summarized in Table 5.2.

5.2 Preliminary Cost Estimate

In the first screening carried out, only the major project component cost is estimated, and costs for the access roads, transmission lines and land acquisition/compensation are not considered for preliminary screening purpose. The cost data available from Ham Thuan-Da Mi hydropower project are referred to, and the projects are assumed to be implemented under the international competitive bidding basis.

Based on the past experience and simplified and/or empirical formulae described below, the major cost components are estimated for (1) civil works, (2) electro-mechanical equipment and (3) hydraulic equipment, and the total project cost is estimated for three cases by changing the dam height (effective storage).

(1) Civil Works

a) Dam

Total embankment volume is calculated by using a simplified formula with the parameters of height, crest length, slopes and so on as follows:

$$V = 1/2 \times B \times H \times (L1+L2)+1/6 \times (m+n) \times H^2 \times (L1+2 \times L2)$$

where,

V : Total embankment volume (m^3)
B : Crest width (m)
H : Dam height (m)
L1: Length of crest (m)
L2: Width of river bed (m)
m : Upstream slope
n : Downstream slope.

The proportions of core, filter and rock materials for embankment are referred to Ham Thuan-Da Mi project as follows:

	Rockfill	Earthfill
Embank material		
Core	15 %	85 %
Filter	5 %	5 %
Rock	80 %	10 %
Excavation		
Common	36 %	10 %
Rock	4 %	0 %

Other cost components such as foundation treatment including grouting, drainage system and so on are estimated at 15 % of the dam cost; that is, no special consideration is given to the geological characteristics at each dam site.

b) Spillway

Construction cost for the spillway is estimated based on an empirical formula with the parameters of design flood and length of spillway.

c) Diversion (Care of River)

For care of the river during the time of dam embankment, construction of diversion tunnels is basically assumed, except for Dong Nai No. 8, Fu Mieng and La Nga No. 3, for which a half portion of the dam is constructed by releasing flood discharge with the remaining half portion.

d) Headrace

Assuming an average velocity of 3 m/sec, a typical cross section is assumed, and the unit cost per one meter including excavation, reinforcement and lining, which is applied to the total length, is estimated by the following equation:

Unit Cost of Tunnel (US$/m)

$$= 50 \times (Dia - 3.99)^2 + 1{,}310 \times (Dia - 3.99) + 3{,}330$$

where,

Dia: internal diameter of tunnel (m).

As other miscellaneous costs, 15 % of direct costs is added to the total cost. A surge tank with a restricted orifice type is provided when the total length of headrace exceeds 500 m.

e) Penstock

Based on the length of penstock, costs for excavation and concrete works excluding metal works estimated below are estimated.

f) Powerhouse

Cost for civil works is estimated by taking into consideration the installed capacity and the number of units as follows:

$$TSV = 7.89 \times (Inst)^{0.653}$$

where,

TSV: total structural volume (m^3)

Inst: installed capacity (kW)

$$Unr = 3230 \times (TSV)^{(-0.216)}$$

where,

Unr: unit rate per structural volume (US$/$m^3$).

(2) Generating Equipment

Cost for generating equipment and its auxiliary system is estimated based on an empirical formula using hydraulic head and installed capacity as follows:

$$G/E = 0.111 \times (P/(h)^{0.5})^{0.648}$$

where,

G/E : total cost of generating equipment and auxiliary

P : installed capacity (kW)

h : rated head (m).

(3) Gates and Metal Works

Radial gates are assumed for the spillway gates. The total tonnage inclusive of main body, guide frame, hoisting equipment and so on is estimated based on the height, width and number of units. Unit rate of construction cost is referred to the Ham Thuan-Da Mi project. Costs for other metal works such as intake gates, screen and so on are also estimated on the basis of the total tonnage and the unit rate.

Economic diameter of penstock to estimate the cost of metal works is empirically obtained by following formula:

$$Dia = 0.71 \times P^{0.43} / h^{0.65}$$

where,

Dia : economic diameter of penstock (m)

P : installed capacity (kW)

h : rated head (m).

Taking into consideration the minimum design thickness of penstock, total weight is estimated, and then a unit rate of US$ 7,000/ton is applied for cost estimate.

(4) Others

Estimates for others are as follows:

Preparatory Works: 10 % of cost for civil works,

Administration & Engineering: 12 % of costs for civil, electrical and metal works, and

Physical Contingency: 15 % of total costs.

The total project costs with break-down for each case of respective projects are estimated as summarized in Table 5.3.

5.3 Results of First Screening

For the preliminary economic evaluation to select promising hydropower projects to proceed to the second screening, Specific Capacity Cost (SCC) and Specific Generation Cost (SGC) for the identified projects are estimated.

Specific Capacity Cost (SCC) is a simple economic index which represents a unit capacity cost and is calculated by dividing the total project cost by the installed capacity (US$/kW). This value is assumed to represent the economic value of power and is utilized as one of indexes for the evaluation of hydropower projects.

Specific Generation Cost (SGC) is defined as a preliminary cost of one unit of energy generation (1 kWh), and is utilized to evaluate the economic value of the energy.

For the calculation of annual equivalent cost, a capital recovery factor of 0.1009, which is gained by applying a discount rate of 10 % for a project life of 50 years, is multiplied by the economic cost assumed at 85 % of the total project cost.

There are two type of energy; one is firm energy guaranteed throughout the year with 95 % reliability and the other is secondary energy which can be generated at the time only when abundant water is available during the rainy season with lower reliability. The economic value of the secondary energy is usually considered to be lower than that of the firm energy, and therefore in this Study, the SGC is calculated by assuming that 20 % of the secondary energy cannot be sold; that is, the value of secondary energy is 80 % of the firm energy in terms of monetary value.

The calculation results of SCC and SGC are summarized in Table 5.4.

In the first screening stage, the projects with Specific Generation Cost of more than US Cent 11 per kWh or Specific Capacity Cost of more than US$ 4,000 per kW are judged to be "economically less attractive", and based on this criteria, Dong Nai No. 1, Dong Nai No. 2, Dong Nai No. 5 and Bao Loc are screened out and excluded for further studies in the second screening stage.

For Fu Mieng and La Nga No. 3, these projects involve possible diversion to other basins for irrigation purpose and cannot be assessed by the above simple economic indexes which assume single purpose hydropower generation. These projects are thus further assessed in the subsequent Chapter by using cost allocation method and are also discussed in Appendix VI (Agricultural Development and Irrigation).

6. SECOND SCREENING OF POTENTIAL PROJECTS

6.1 Project Layout and Cost Estimate

During the Phase II study period, following topographical maps became available for the projects selected from the first screening:

Scale	Project Site
1/10,000	Dong Nai No. 3, No. 4 and No. 8
1/25,000	Can Don
1/50,000	Dong Nai No. 6, Fu Mieng and La Nga No. 3.

Using these maps and data/information obtained during the field inspections, the basic layout study of these candidate projects was carried out, and the preliminary layout drawings are prepared as shown in Figures 6.1 to 6.8, and the principal features of each project are shown in Table 6.1.

For Dong Nai No. 3, there is a site which may be suitable for constructing a concrete gravity dam approximately 1 km downstream of the original dam axis, and thus the preliminary drawing as an alternative is prepared as given in Figure 6.2. Since there is no detailed data regarding the geological conditions at the dam site at present, its geological investigation is strongly recommended to be carried out for assessing the feasibility of constructing a concrete gravity dam so that the most economical solution for the project configuration can be obtained.

Based on the refined project layout and the design, the work quantities for major project components such as (1) civil works, (2) electro-mechanical equipment and (3) hydraulic equipment are reviewed and readjusted, and the total project cost is estimated. Since the construction of Dong Nai No. 3 will significantly contribute to increasing the power output of the downstream projects such as Dong Nai No. 4, No. 6 and No. 8, the total cost for such projects with the increased capacity is also estimated.

For the land compensation and the resettlement cost, the draft final report for "The Master Plan Study on Electric Power Development" prepared by JICA (July 1995) is referred to, and a unit cost of US$ 400,000 /km^2 is assumed for the compensation of the inundated area and the relevant sites for the major project components.

The total project cost for each candidate project is shown in Table 6.2.

6.2 Power Output and Economic Comparison

(1) Energy Increase at Tri An Project

In the second screening stage, the hydrological data of the Study Area were reviewed with supplementary data obtained during Phase II Field Study, and a 29-year consecutive series of monthly runoff data is established at each prospective damsite (refer to Appendix III, Meteorology and Hydrology, for further detail).

The development of such projects as Dong Nai No. 3, No. 4, No. 6, No. 8 and La Nga No. 3 located upstream of existing Tri An hydropower project is expected to increase the energy output (firm energy) of the Tri An project by their "firm-up effect", resulting in the increase of daily operating hours of Tri An power plant.

The expected additional energy output of the Tri An project by constructing upstream projects is therefore calculated by simulating the 29-year consecutive series of monthly runoff data and is counted on as the total power output of the upstream project.

(2) Effect of Combined Development

In case of Dong Nai No. 4 and No. 8, the firm-up effect of Dong Nai No. 3 for these projects is significant and should be taken into consideration in their economic evaluation, since these projects have relatively small effective storage against their annual inflow, resulting in limited capacity and firm energy output if they are developed independently.

Dong Nai No. 6 has sufficient regulating efficiency with the large effective storage, and therefore only marginal impact in terms of firm-up effect is expected from Dong Nai No. 3.

To analyze the positive impact of the upstream development to the downstream projects lying in the Dong Nai main stream, following development cases (development combination) are studied:

Basic case	: Tri An only (present condition)
Case 1	: Tri An and Dong Nai No. 3
Case 2	: Tri An and Dong Nai No. 4
Case 3	: Tri An and Dong Nai No. 8
Case 4	: Tri An, Dong Nai No. 3 and Dong Nai No. 4
Case 5	: Tri An, Dong Nai No. 3 and Dong Nai No. 8
Case 6	: Tri An, Dong Nai No. 3, No. 4 and No. 8.

Table 6.3 shows the results of the combined effect on power and energy output, clearly telling that Dong Nai No. 3 will significantly contribute to the improvement of the power output of Dong Nai No. 4 and No. 8 as summarized below:

Increase of power output by Dong Nai No. 3		
	Installed Capacity, MW	Firm Energy, GWh/year
Dong Nai No. 4	from 147 to 318	from 320 to 682
Dong Nai No. 8	from 134 to 210	from 292 to 456

The development sequence of these three projects is not determined yet, however, it can be said that combined development (similar to the development sequence of the Ham Thuan-Da Mi project) of Dong Nai No. 3 and No. 4 should positively be considered. In case where Dong Nai No. 4 or Dong Nai No. 8 is developed before Dong Nai No. 3, the design of these projects should reserve a margin for capacity expansion (almost double) by taking into account the future development of Dong Nai No. 3.

(3) Economic Comparison

For the economic comparison purpose, Economic Annual Net Benefit is calculated in addition to Specific Capacity Cost (SCC) and Specific Generation Cost (SGC) so that the capacity value and the energy value can jointly be assessed.

For the estimate of economic annual benefit, a coal-fired thermal power plant is assumed for the least cost or second best alternative to the candidate projects by taking into account the various capacity size of candidate projects (60 MW to 448 MW). The capacity value, energy value and O&M are set for benefit calculation as follows:

Unit capital cost : US$ 1,250 / kW
Unit fuel cost : US $ Cent 1.563
kW adjustment factor : 1.2207
kWh adjustment factor : 1.0318
O & M cost : 5.0 % for coal-fired plant and 0.5 % (more than 100 MW) and 1 % (less than 100 MW) for hydropower.

For estimating annual equivalent benefit and cost, a capital recovery factor of 0.1009 is applied.

For the assessment of possible multipurpose projects such as Fu Mieng and La Nga No. 3, cost allocation is made in accordance with the proportion of the firm discharge to be utilized for hydropower generation and irrigation use.

Table 6.4 shows the power and energy output and the economic index of each project, and the results are summarized as follows:

Economic Index of Project

	Capacity (MW)	SCC ($/kW)	SGC (Cent/kWh)	Annual Net Benefit (Mil. $/Year)
Dong Nai No. 3	130	2,654	8.2	4.6
Dong Nai No. 4	147	2,571	5.4	9.5
Dong Nai No. 6	322	3,363	14.4	-9.0
Dong Nai No. 8	134	6,067	11.4	-32.5
Combined No. 3 and 4	448	1,842	6.1	47.4
Combined No. 3 and 8	340	3,541	8.9	-11.5
Can Don	80	2,375	6.3	5.5
Fu Mieng	60 (126)	2,001 (1,960)	4.9 (5.5)	5.9 (12.9)
La Nga No. 3	62 (73)	3,476 (3,055)	12.5 (8.0)	-3.7 (-0.4)

Note: Figures in the parentheses show the economic indexes of hydropower single purpose.

From the Table, it is confirmed that:

a) Single development of Dong Nai No. 3 (US$ 4.6 milliion/year) or single development of Dong Nai No. 4 (US$ 9.5 million/year) is considered to be economically viable, however, the expected annual benefit is rather limited.

b) Dong Nai No. 3 will significantly increase the economic viability of Dong Nai No. 4. The combined development of Dong Nai No. 3 and No. 4 generates an annual net benefit of US$ 47.4 million/year against the single development of Dong Nai No. 4 to generate US$ 9.5 million/year or Dong Nai No. 3 to gain US$ 4.6 million/year. This result mainly accrues from the capacity increase gained in the combined development. Therefore, the combined development of Dong Nai No. 3 and No. 4 is judged to be given the development priority.

c) Fu Mieng is considered to be economically viable for both multipurpose development and single purpose development as far as a simple cost allocation method is applied, and further study is to be made from the viewpoint of the irrigation development scheme discussed in Appendix VI and the optimal water resources allocation study as discussed in Appendix X.

d) Can Don is considered to be economically viable, however, its expected benefit is rather small and its contribution to the overall power demand in the Study Area is limited.

e) Dong Nai No. 6, Dong Nai No. 8, La Nga No. 3 (with and/or without diversion) and combined development of Dong Nai No. 3 and No. 8 are economically less attractive in terms of the annual net benefit gained by applying a discount rate of 10 %.

6.3 Environmental Consideration

(1) Natural Reserve

There are several protected areas, and conservation activities are being undertaken by the Ministry of Agriculture and Rural Development (MOARD) and the provincial Forest Protection Departments. Of all the forest areas which are currently under some sorts of MOARD management in that region, Nam Cat Tien National Park in Dong Nai province and Cat Loc Nature Reserve in Lam Dong province, which are collectively known as "Cat Tien National Park", are the top priority for conservation.

Cat Tien National Park lies within a global "biodiversity hotspot", and the conservation of this area is also critical for maintaining its value for global biodiversity. Cat Tien National Park supports populations of two bird species endemic to Viet Nam, breeding populations of eight species of globally threatened birds, and mainland Asia's only known surviving population of Javan Rhinoceros (Rhinoceros sondaicus annamensis), which is described as a sub-species distinct from the population of Javan rhinos resident in Ujung Kulon National Park in Indonesia. These features clearly make the conservation for Cat Tien most important.

Although the exact boundaries of the national park and the adjacent forest reserves have not been identified at this stage, the southern half of the entire reservoir area of Dong Nai No. 6 is located within the Cat Tien National Park, and this fact suggests that the Dong Nai No. 6 cause significant direct environmental impacts by submerging portions of the river and forest habitats lying inside the boundaries.

In case of Dong Nai No. 8, FSL is currently set at El. 120 m (El. 125 m according to the latest study being carried out by PIDC 2) and its reservoir area appears to intrude in some downstream parts of the park. Therefore further confirmation for the boundaries and the elevation of the park is required and its management policy needs to be clarified.

(2) Inundation Area and Power Output

As a simple index for preliminary environmental impact assessment, the inundation area of each project is divided by the power output as follows:

Inundation Area per One Kilowatt Capacity

	Capacity (MW)	Inundation Area at FSL (km^2)	Area / Capacity (m^2 per kW)
Dong Nai No. 3	130	48	369
Dong Nai No. 4	147	11	75
Dong Nai No. 6	322	77	239
Dong Nai No. 8	134	122	910
Combined No. 3 and 4	448	59	132
Combined No. 3 and 8	340	170	500
Can Don	80	30	375
Fu Mieng	60 (126)	71	566 (563)
La Nga No. 3	62 (73)	21	288 (287)

It is noted that figures given in parentheses show the area/capacity index of hydropower single purpose and that the index in case of multipurpose is calculated by the rate of firm discharge shared between hydropower and irrigation, i.e. the index for Fu Mieng (= 71 x 55/115) and for La Nga No. 3 (= 21 x 56/66).

The index, "area/capacity", represents a conceptual value of area to be inundated for the creation of one kilowatt, and it is to be noted that the value neither takes into consideration the number of people affected (population density) nor ethnic group distribution, land utilization and so on. However, it can be generally said that Dong Nai No. 8 has a high value and is likely to involve significant land compensation and resettlement problems.

Fu Mieng also has a relatively high value if the project is assessed in respect of power generation purpose only. However, as a multipurpose development project, the benefit of irrigation development resulting from the diversion which makes it possible to irrigate an additional area of 88,300 ha in HCMC-Long An delta compared with the without-diversion case (refer to Appendix X for further discussion) should be also considered at the same time.

Dong Nai No. 4 itself has the smallest value, giving the least impact as far as the compensation and resettlement problems are concerned. The value of combined development of Dong Nai No. 3 and No. 4 is the second least among the candidates.

For further detailed discussions on the environmental issue including the initial environmental examination, reference is made to Appendix IV, Natural Environment.

6.4 Results of Second Screening

Through the economic comparison discussed in preceding Section 6.2 and the environmental considerations discussed in above Section 6.3, following assessments are made:

a) Dong Nai No. 4 as a single (independent) development has environmentally the least adverse impact among candidate projects and is economically viable, however, the expected net benefit is rather small mainly due to its limited regulating capacity of the reservoir. The capacity (installed capacity) and the firm energy output of Dong Nai No. 4 can be doubled if Dong Nai No. 3 is constructed as a combined project.

b) Although the economic index of Dong Nai No. 3 as a single (independent) development is low, the combined development of Dong Nai No. 3 and No. 4 will generate the highest annual net benefit of approximately US$ 47.4 million in comparison with US$ 9.5 million for the single development of Dong Nai No. 4 only. Therefore, from the viewpoint of optimizing the overall development benefit for the hydropower projects, priority should be given to the combined development of Dong Nai No. 3 and No. 4. In case where Dong Nai No. 4 is developed prior to Dong Nai No. 3, the design should reserve a margin for the capacity expansion (almost double) by taking into account the future development of Dong Nai No. 3.

   In respect of the environmental adverse impact, the combined development of Dong Nai No. 3 and No. 4 has the second least value among the candidate projects, and therefore the compensation and resettlement problem is judged to be in "acceptable", even if further detailed examination is required through the coming feasibility study.

c) Fu Mieng is economically viable as a single purpose as well as a multipurpose project. Since Fu Mieng is considered to be one of the promising projects to divert water from the Be River to the HCMC-Long An delta area through the existing Dau Tieng reservoir and enable to develop an additional irrigation area of 88,300 ha, it is recommended to develop the project as a multipurpose project.

   Nevertheless, it is to be noted that the inundation area is relatively large and may involve a considerable compensation and resettlement problem, and therefore that the project should carefully be implemented by taking into consideration the multi-benefit nature and the environmental issue.

d) Can Don is considered to be economically vaible, however, its net benefit is small. The environmental adverse impact is also judged to be medium among candidate projects. The project has a rather small scale in development capacity, resulting in the limited contribution to the overall system demand in the Study Area.

e) Dong Nai No. 6 and No. 8 are judged to be economically less attractive in terms of the annual economic net benefit with a discount rate of 10 %. The former also seems to have significant adverse environmental impacts on the biodiversity in the Cat Tien National Park, and the latter has the largest inundation area for creating a unit power output among candidate projects, implying that the large scale resettlement and compensation will be involved for the implementation.

f) La Nga No. 3 is judged to be economically less attractive for both of single purpose and multipurpose projects (diversion for irrigation). As discussed in Appendix VI, the advantage of diverting water to the east coast area (Phan Thiet) is not economically justified.

g) Based on the above assessment, following four projects and a plan are selected as the ones to pass the Second Screening:

- Dong Nai No. 3 (Single Development)
- Dong Nai No. 4 (Single Development)
- Combined development of Dong Nai No. 3 and No. 4
- Can Don
- Fu Mieng Multi-purpose.

Viability of four projects and a plan is further confirmed by assessing their input timing to be added to the overall power system within the time horizon up to the target year of 2015. This generation expansion planning study is discussed in subsequent Chapter 7.

7. GENERATION EXPANSION PLANNING STUDY

7.1 Introduction

In the previous Chapters, hydropower projects are preliminarily evaluated and screened based on the simple economic evaluation method which considers only the annual power output and the project cost. Eventually as presented in preceding Section 6.4, four projects and a plan are selected as promising ones for development.

However in the actual situation, management decisions must weigh not only such simple economic evaluation results, but also short- and long-term policies for supplying electric power so as to meet growing electricity demand which has prescribed load profile requiring appropriate system reliability.

Generation expansion planning, which deals with the optimal installation timing of promising projects to be added to the power supply system, should consider competing factors such as the availability of generation resources, uncertainties in fuel prices, capital costs, system reliability requirement, growth of electricity demand and so on. To deal with these complex factors, the generation expansion planning study is carried out by using the computer software package "EGEAS: Electric Generation Expansion Analysis System" developed by the Massachusetts Institute of Technology, U.S.A.

The planning has an objective of satisfying electricity demand over the planning horizon up to the target year 2015 in the most efficient and least costly manner, assuming that the decisions for investment relating to the electric power development should be made on the premise of minimizing the present cost of all the relevant construction and operation costs needed to satisfy the forecast customer demand including prescribed overall system reliability.

7.2 Model Structure

EGEAS is designed to be responsive to the wide range of capacity expansion options, and Dynamic Programming (DP) is applied to handle the sub-year production costing and reliability analysis for the Study. DP is capable of enumerating all of the possible planning alternative combinations in each year of the planning horizon and selecting the minimum cost transitions from one year to the next by utilizing the coarse grid DP technique. The overview of the model is summarized below:

(1) Objective Function

The objective function is to seek the least cost of capital and operating costs invested during the planning and extension periods. All the costs are discounted to the base year 1995. Capital costs of existing and committed units are not included since they are treated as sunk costs in planning purposes. Operating costs of existing and committed as well as new units are determined in the programme via detailed probabilistic production cost simulation and are included as part of costs.

(2) Constraints and Reliability

There are three reliability constraints implemented on each year of the planning horizon as follows:

a) Minimum reserve margin ≤ 20 % of peak load
b) Loss of load probability ≤ 87.4 hours per year (1%)
c) Expected unserved energy ≤ 1% of customer demand.

(3) Decision and Input Variables

Decision variables in the DP programme are integer variables representing the number of units of each alternative installed in each year of the planning period. Thus, the optimal plan consists of whole unit capacity additions.

Input variables can be grouped into three categories; general and load data, generating unit data, and DP programme-specific data. The general data include specifications of the base year for cost discounting and system reliability requirement. In this study, all the costs are discounted to the base year 1995 by applying a discount rate of 10 %. The load data include load curves of each year and system demand data. The generating unit data specify capabilities and costs of generating units. The DP programme-specific data include information on the years included in the planning horizon (the year 1995 to 2015), the length of extension period (25 years) that accounts for terminal effects, maximum number of States to be analyzed in DP, maintenance scheduling and other relevant data.

(4) Handling of Terminal Effects

Terminal effects arise because of the finite planning horizon in the expansion planning model. The costs and benefits associated with plans continue to accrue in the years beyond the planning horizon. A consideration of total costs beyond the planning horizon could well lead to an expansion plan different from the one indicated by an analysis based on the only costs accrued in the planning horizon. These and the related factors constitute the terminal effects which should be taken into account in the search for an optimal expansion plan.

In EGEAS, an extension period is formulated as the period that units installed during the planning horizon are replaced in kind. Committed and existing units that are not retired by the end of the planning horizon are assumed to operate throughout the extension period of 25 years. All of the years in the extension period are assumed to have the same load characteristics as those of the last year of the planning horizon. Operating costs during the extension period are discounted to the base year. Likewise, fixed charges for capacity installed during the extension period are discounted to the base year.

7.3 Input Data

(1) Planning Years and Power and Energy Demand

The planning horizon is 21 years from the base year 1995 to the target year 2015 with the extension period being further 25 years, and each year is subdivided into four sub-years to represent the seasonal variation of hydropower energy availability.

Investment and operating costs of planning alternatives, which have an assumed escalation rate of 3% per year, are discounted to the base year 1995 at a discount rate of 10 %.

The power and energy demand in the Study Area, i.e. southern region, for this study is estimated as discussed in preceding Chapter 3.

(2) Load Curve

Daily and monthly load curve data are given as shown in Figure 3.1.

As seen from the Figure, the monthly load variation is negligibly small and in the simulation study the monthly peak load is assumed to be constant thorough the year. For the daily load curve, the load curve of April in the year 1994 is assumed to be the typical daily load pattern through the year. Since the forecast peak demand and annual energy are user's specified inputs in the EGEAS programme, a linear transformation is automatically applied to the hourly loads so that the peak load and energy derived from the transformed loads will match the input values.

The sample output of the peak load and energy with the transformed load duration curve in the year 2015 for Base Case is shown in Table 7.1.

(3) Existing and Planned Alternatives

Existing thermal power plants and their assumed available capacities are:

Thu Duc oil thermal; 156 MW

Tra Noc oil thermal;	32 MW
Ba Ria gas turbine;	195 MW
Thu Duc gas turbine;	98 MW
Diesel;	65 MW.

Existing hydropower plants are:

Da Nhim;	160 MW
Tri An;	400 MW
Thac Mo;	150 MW.

Committed thermal projects are:

Phu My gas turbine;	600 MW (1998)
Ba Ria combined cycle;	58 MW (1997)

It is noted that the figure in the parentheses shows the expected commissioning year.

Committed hydropower projects are:

Ham Thuan-Da Mi;	472 MW (2000)
Dai Ninh;	300 MW (2003)

It is noted that the figure in the parentheses shows the expected commissioning year.

Planning alternatives for hydropower projects are:

Dong Nai No. 3 (Single);	130 MW
Dong Nai No. 4 (Single);	147 MW
Combined Dong Nai No. 3/4;	448 MW
Can Don;	80 MW
Fu Mieng multipurpose;	60 MW.

Planning alternatives for thermal plants are:

Coal thermal plant;	300 MW
Combined cycle plant;	300 MW.

The detailed data such as capital and operation costs, assumed equivalent forced outage rate, heat rate and so forth are summarized in Table 7.2.

Taking into consideration the seasonal variation of energy output from hydropower projects, the energy output on sub-yearly basis (every three months) is assumed as shown in Table 7.3.

The seasonal maximum energy output is then distributed/restricted based on these multipliers gained as the ratio to the annual energy output.

The maintenance cycle is assumed to be one week per year for hydropower plant and six weeks for thermal power plant.

(4) Power Interchange

In this study, the energy import from the northern and central regions through the 500 kV transmission line is assumed to have the maximum capacity of 500 kV with an approximate plant factor of 80 % (20 hours per day). It is noted that after the completion of Yaly and other projects in the central region, the major energy supplier to the south will be shifted from the north to the central region.

(5) Earliest Input Timing

In consideration of the lead time required for project implementation such as detailed investigation, detailed studies, detailed design, financial arrangement, tendering processes, construction schedule and so on, the earliest input timing for each planning alternative is assumed as shown in Table 7.4.

(6) Planning Alternatives for Thermal Plant

For the planning alternatives for thermal plant, oil-fired thermal plant and diesel plant are not considered taking into account the latest international practice for global energy conservation and environmental protection policy. Two alternative energy sources assumed in this study are coal-fired thermal and combined cycle plant as follows:

	Capacity	Capital Cost	Heat Rate	Fuel Cost
Coal-fired thermal	300 MW	US$ 1,250/kW	10,100 BTU/kWh	$1.6/MBTU
Combined cycle	300 MW	US$ 800/kW	7,600 BTU/kWh	$2.5/MBTU

(7) Unserved Energy

Because generating units have the possibility to be unavailable due to forced outages, there is usually a certain amount of customer load which cannot be served all the time. In the study, this expected unserved energy value is assumed to be US$ 700/MWh (US Cent 70 per kWh) which is approximately 10 times of the assumed long run marginal cost, US Cent 7.0 per kWh.

7.4 Results of Generation Expansion Planning Study

(1) Combined Development of Dong Nai No. 3 and No. 4

For the development scenario of Dong Nai No. 3 and Dong Nai No. 4 in the Dong Nai River, significant capacity increase for Dong Nai No. 4 is expected due to the flow regulation effect by Dong Nai No. 3 as explained in Chapter 6. In the generation expansion plan study, three development scenarios are considered for the planning horizon of the year 1995 to 2015 as follows:

Scenario A: Only Dong Nai No. 3 of 130 MW is developed.
Scenario B: Only Dong Nai No. 4 of 147 MW is developed.
Scenario C: Dong Nai No. 3 of 130 MW and No. 4 with an extended capacity of 318 MW are developed.

The simulation results indicate that neither scenario A nor B will give the least cost option for the overall system. This means that single development of Dong Nai No. 3 (130 MW) or single development of Dong Nai No. 4 (147 MW without Dong Nai No. 3) is not competitive against thermal power plant, and that only the combined development of Dong Nai No. 3 and No. 4 (total capacity of 448 MW) will be the most economical solution from the viewpoint of the least cost investment option for the overall generation expansion plan in the Study Area.

(2) Input Timing of Selected Projects

The least cost generation expansion plans for three cases, i.e. low, base and high demand cases, are generated by EGEAS, and the results are tabulated in Tables 7.5, 7.6 and 7.7.

Input timing of the selected hydropower projects is summarized as follow:

	Input Year (Commissioning Year)
1. Low Case Demand Forecast (7,836 MW & 41,184 GWh in the year 2015)	
Dong Nai No. 3 & No. 4	2008 (448 MW)
Fu Mieng Multipurpose	2009 (60 MW)
Combined Cycles	after 1997 (21 units and 6,300 MW in total)
2. Base Case Demand Forecast (10,400 MW & 54,663 GWh in the year 2015)	
Dong Nai No. 3 & No. 4	2006 (448 MW)
Fu Mieng Multipurpose	2005 (60 MW)
Combined Cycles	after 1997 (32 units and 9,600 MW in total)
3. High Case Demand Forecast (12,800 MW & 67,273 GWh in the year 2015)	
Dong Nai No. 3 & No. 4	2008 (448 MW)
Fu Mieng Multipurpose	2005 (60 MW)
Combined Cycles	after 1997 (42 units and 12,600 MW in total)

From the above, it is confirmed that combined development of Dong Nai No. 3 and No. 4, and Fu Mieng multipurpose is attractive and promising under any demand forecast conditions and that the former combination should be developed between the year 2006 and 2008, and the latter project should be developed in the year 2005 to 2009.

Can Don is not required within the time horizon up to the year 2015 under any demand case on condition that the cost of combined cycles is remained the same throughout the planning year.

It is to be noted that the share of the hydropower projects to be developed will be approximately 15% of the total system in the southern region in the year 2015.

(3) Sensitivity Analysis for Can Don and Coal-fired Thermal

In the generation expansion study above, Can Don and coal-fired thermal plant are not selected, since they are assumed to be economically less competitive to the combined cycle plant. To clarify the sensitivity of the possible development of Can Don and/or the coal-fired thermal plant to the relevant cost of the combined cycle plant, following two cases are studied:

Case 1: Construction cost (capital cost) of combined cycle plant increased by 20 % from US$ 800/kWh to US$ 960/kWh, and

Case 2: Fuel cost for combined cycle plant increased by 20 % from US$ 2.5/MBTU to US$ 3.0/MBTU.

Tables 7.8 and 7.9 show the capacity expansion plans for Cases 1 and 2 respectively.

Tables suggest for Case 1 that Dong Nai No. 3 and No. 4 be committed in the year 2005, whilst the year 2006 for Fu Mieng multipurpose and the year 2013 for Can Don. This implies that Can Don will become competitive to the combined cycle plant if the construction cost of the combined cycle plant is increased by 20 %.

For Case 2, in which the operation cost (fuel cost) of the combined cycle plant is assumed to increase by 20 %, Can Dong will not be required within the planning horizon up to the target year 2015, however, the number of the coal-fired thermal plant will be increased to 17, whilst that of combined cycle plant will be reduced to 15.

The results of above analysis tell that Can Dong (hydro) and coal-fired thermal plant (thermal) as planning alternatives for the generation expansion planning study in the Study Area are marginally competitive, whilst Dong Nai No. 3 and No. 4 and Fu Mieng are confirmed to be quite competitive for the combined cycle plant.

(4) Summary of Generation Expansion Plans

a) In the generation expansion planning period up to the target year 2015, the combined development of Dong Nai No. 3 and No. 4 and Fu Mieng multipurpose are most attractive and promising under any demand forecast conditions. The former combination should be developed between the year 2006 and 2008, and the latter project should be developed in the year 2005 to 2009.

b) Can Don is less competitive to the above hydropower projects and the combined cycle plant, and it is confirmed that the project is not required within the time horizon up to the year 2015. However, it is to be noted that if the construction cost for the combined cycle plant is increased by 20 %, Can Don will be then required in the year 2013.

c) Based on the above, the combined development of Dong Nai No. 3 and No. 4 and Fu Mieng multipurpose are listed as candidates to the master plan projects to be selected based on the optimal water allocation study discussed in Appendix X.

d) Can Don is not selected as a candidate to the master plan projects based on a result of generation expansion study. However, it is recommended to be retained in the list of hydropower project development options. In consideration of its sizable scale, BOT development by the private investors as envisaged by the Vietnamese Government could be one of the development options.

8. HYDROPOWER MASTER PLAN PROJECTS

8.1 Selected Hydropower Master Plan Projects

Based on the optimal water allocation study carried out in Appendix X, the candidate projects selected in Chapter 7, i.e. combined development of Dong Nai No. 3 and No. 4 and Fu Mieng as one of the most promising alternatives of the Be-Saigon diversion project, are confirmed to be the hydropower master plan projects to be developed within the time horizon up to the target year 2015. Furthermore, it is confirmed through the optimization study that Fu Mieng project should be developed as the multipurpose project, which diverts an amount of water of 60 m^3/sec from the Be River to the Dau Tieng reservoir, enabling to irrigate an additional area of 88,300 ha extending in HCMC-Long An delta area.

In the Phase III study, major efforts were directed toward topographical and geological survey work at the sites of the selected hydropower master plan projects, and based on such survey work the project layout, design and estimated cost were reviewed, refined and updated. The extent of survey is as follows:

	Dong Nai No. 3	Fu Mieng
(1) Topographic survey work Cross section survey - Work quantity (m):	1,600	3,800
(2) Geological survey work Geological mapping - Work quantity(km^2):	2.6	18.0

For Dong Nai No. 4, the feasibility level study was previously carried out by the Vietnamese Government in the year 1993, and thus some topographical and geological data are available.

Following Sections describe the design review results including the economic evaluation of Dong Nai No. 3 and No. 4 projects (combined development) and Fu Mieng multipurpose project.

8.2 Combined Development of Dong Nai No. 3 and No. 4

(1) Project Layout and Basic Design

The project layout and the reservoir water levels of the combined development of Dong Nai No. 3 and No. 4 are reviewed from the viewpoint of optimum utilization of the head available within this particular river stretches, based on the cross section survey results obtained during the Phase III study period.

Taking into consideration a rather steep river profile lying downstream of the Dong Nai No. 3, extension of the headrace tunnel is envisaged as an alternative to efficiently utilize available head, and accordingly FSL of Dong Nai No. 4 is reduced from El 480 m to El 440 m. In case of setting FSL El 440 m, the layout for the dam and spillway of Dong Nai No. 4 becomes more compact and is improved for construction. The alternative layouts of Dong Nai No. 3 and Dong Nai No. 4 are shown in Figures 8.1 and 8.2.

For power optimization study purpose, FSL of Dong Nai No. 4 is selected for two cases, El. 480 m and 440 m, and three FSL alternatives for each case of Dong Nai No. 3, El. 580, 570 and 560 m, are proposed to estimate the total project output. Table 8.1 shows the results of optimization study.

As seen from the Table, it is concluded that the combination of Dong Nai No. 3 (180 MW) with FSL of El. 570 m and Dong Nai No. 4 (240 MW) with FSL of El. 440 m is found to be the best combination.

Two sites are identified as the damsite alternative of Dong Nai No. 3. The upstream alternative is for a rockfill dam, while there is a possibility to construct a concrete gravity dam, which may be an attractive option in respect of the project cost, for the downstream site. However, there is an old landslide area at the right bank slope between the downstream and upstream alternative sites, possibly activated after reservoir impounding. It is therefore recommended that the downstream alternative be investigated and studied more intensively in the coming feasibility study stage.

For the Dong Nai No. 4 dam site, no significant problem is identified for constructing a rockfill dam at the site identified through the feasibility study carried out by the Vietnamese Government. In case of the alternative with a lower reservoir water level such as El. 440 m for FSL, an alternative damsite is identified approximately 300 m upstream of the presently proposed damsite, so the length of diversion tunnel can be shortened and the general layout of dam and spillway becomes more compact.

The principal features of the project are summarized in Table 8.2, and the basic layout and design prepared based on the cross section survey results are shown in Figures 8.3 and 8.4.

(2) Site Geology

Project areas of Dong Nai No. 3 and No. 4 are located in the comparatively narrow valleys with 100m to 150m width and are under the similar geological conditions. Basement rocks of the project area consist of mainly dark-gray shale interbedded by fine to medium grained sandstone of Ban Don Formation in the Mesozoic-Jurassic. The bedding planes strike N45-60 E and dip 50-70 S.

For the geology of both damsites, hard and massive fresh rocks outcrop widely at the riverbed of each dam site with a few small shear zones parallel to bedding planes and joints. No major fault can be found at both the damsites. Colluvium deposits in the Quaternary distribute at the foot and on the gentle slopes of each bank. The thickness of weathered layers is expected to be more or less 20 m and partially 40 m at both right bank and left bank abutments of Dong Nai No. 4 and to be around 10 to 20 m at Dong Nai No. 3. Basaltic rocks in the Neogene-Quaternary are situated on the top of mountain higher than El. 500 m to 650 m overlying the basement rocks.

It should be noted for the downstream alternative damsite (concrete dam) of Dong Nai No. 3 that a trace of old large-scale landslide is observed in the reservoir area at the right bank 500 m upstream from the damsite. However, the damsite itself consisting of fresh rocks free from weathering seems to have sufficient strength and is expected to show impermeability for an around 100 m high concrete gravity dam due to no large fractured zone and well contacted bedding planes and joints. Therefore this alternative should be investigated in more detail in the coming feasibility study stage.

Regarding construction materials, strongly weathered layers of the basaltic rocks and the sedimentary rocks as well as colluviam deposits can be used for core materials. Some excavated materials produced during construction may also be available for the core materials. Fresh basaltic rocks and massive sandstone, which can be used as rock materials, can be identified around the damsites. Crushed basalt and sandstone should be designated for the filter and concrete aggregates because of only small sand and gravel deposition at the edge of river course.

For further detailed assessment, reference is made to Appendix II (Topography and Geology).

(3) Cost Estimate and Economic Evaluation

Work quantity of major structures is estimated on the basis of the basic design prepared. The unit prices of each work item are established with reference to the price data available from recent project, Ham Thuan-Da Mi hydropower project, by assuming that the project will be implemented under an international competitive bidding basis and that the cost estimate is made at the price level of December 1995.

Direct cost consists of preparatory works, civil works, hydraulic equipment, metal works, electro-mechanical equipment and transmission line. On the other hand, indirect cost comprises compensation cost, administration cost, engineering services and contingency.

The breakdown of the total project cost so estimated is shown in Tables 8.3 and 8.4.

To confirm the economic viability of the project, economic evaluation is made by the present worth method as well as the economic internal rate of return (EIRR) method based on following assumptions and conditions for assessing the benefits and costs:

a) Least cost or second best alternative for the combined development of Dong Nai No. 3 and No. 4 is assumed to be a combined cycle power plant with a capacity of 450 MW.

b) Unit capital cost: US $ 800 / kW
Unit fuel cost: US Cent 1.896

c) Capacity adjustment factor: 1.2207
Generation adjustment factor: 0.9846

d) Service life and O & M

	Service life (year)	O & M (%)
Combined cycle plant	20	5.0
Hydropower	50	0.5

e) Economic cost of Dong Nai No. 3 and No. 4 is assumed at 85 % of the total project cost by taking into consideration the transfer payments and opportunity costs.

f) Present value is calculated by applying a discount rate of 10 %.

Table 8.5 shows a cash flow for the economic evaluation.

As seen in Table, a net benefit of US$ 81.8 million and an EIRR of 11.41 % are gained. Thus, it is confirmed that the combined development of Dong Nai No. 3 and No. 4 is economically viable.

It is to be noted that the environmental adverse impact of the projects is likely to be small since the value represented by the inundation area per unit capacity development is the second least (next to the single development of Dong Nai No. 4) among the candidate projects.

Another noticeable point is that electric power to be supplied these days is required to maintain high quality since electronic computers, which are one of essential tools for sustaining economic development, need to use high quality electricity for their operation. In this context, some of plants to be developed in future shall have a function of frequency control to maintain the high electric quality. Taking advantage of the characteristics of hydropower plant which can easily correspond without time delay to electric power demand varying time to time as well as the development capacity of 420 MW, the combined development of Dong Nai No. 3 and No. 4 is recommended to install a function of frequency control, when developed.

8.3 Fu Mieng Multipurpose Project

(1) Project Layout and Basic Design

The project layout and the design of Fu Mieng multipurpose project are reviewed based on the cross section survey carried out during Phase III field work. The principal features are summarized in Table 8.2.

The Tail Water Level (TWL) of the project was initially assumed at El. 40 m using the topographical map with a scale of 1/50,000, however, it is raised by 5 m to El. 45 m based on the cross section survey results. Power output is accordingly revised, and the installed capacity is adjusted at 55 MW.

The diversion channel from the Fu Mieng to the Ton Le Tru River which flows into the Dau Tieng reservoir has to have the maximum flow capacity of 60 m^3/sec based on the result of the optimal water allocation study discussed in Appendix X. It is envisaged that some river improvement works may be required for the 10 km long river section immediately downstream of the 7 km diversion channel to receive the diverted water without artificial flooding. In this respect, the flow capacity of the Ton Le Tru River should be further studied with detailed topographical survey and investigation in the coming feasibility study stage.

FSL is set at El. 77 m with an effective storage of 462 million m^3 to secure the diversion flow to the Dau Tieng reservoir as well as the flow for the power generation and the irrigation development of Phuoc Hoa project according to the optimal water allocation study. On the other hand, it is informed that TWL of Can Don is being proposed to be variable around El. 77 m or less in the feasibility study presently being carried out by the Vietnamese Government. This may cause a possible conflict between the two projects. Therefore it is recommended to clarify and adjust the design during the feasibility study stage of the two projects.

The basic layout and design prepared based on the cross section survey results and the above considerations are shown in Figure 8.5, and the breakdown of the total project cost estimated based on the design so prepared is summarized in Table 8.6.

(2) *Site Geology*

The damsite is located in the gentle hill, and basement rocks distributed at the damsite consist of mainly fissile shale and sandstone of Ban Don Formation in the Mesozoic-Jurassic. Small outcrops are recognized on the brink of the present river course sporadically at and around the place 500 m upstream of the damsite. The bedding planes striking N30-E and dipping nearly vertical are in a direction of right angles to the river course. Basaltic rocks of the Neogene-Quaternary cover the top of both banks higher than El 80 m. No fault characterized by fractured zone can be found around the damsite.

From the viewpoint of engineering geology, the foundation condition at the proposed damsite is not sufficient for a concrete gravity dam because of existence of the alluvium and colluvium unconsolidated deposits and extensively weathered layers thicker than 20 m. Fresh rocks are considered impermeable compared with the weathered layers with open cracks. It is evaluated that possibility of the leakage from the reservoir flowing out through the basaltic rocks is small because the distribution boundary between basaltic layer and the basement rocks is higher than FSL of El. 77 m. Regarding construction materials, no proper rock material and concrete aggregates can be found near the damsite, so earthfill dam is adequate for the damsite. Colluvial deposits and weathered layers of both sedimentary rocks and basaltic rocks are available from the nearby area of the damsite for embankment materials of earthfill dam.

For further detailed assessment, reference is made to Appendix II (Topography and Geology).

(3) Issue Relevant to the Phuoc Hoa Irrigation Dam and Diversion Scheme

According to the optimal water allocation study, it is confirmed that water diversion of an amount of 60 m^3/sec from the Be River to the Dau Tieng reservoir will make it possible to irrigate an area of 88,300 ha extending in the HCMC-Long An delta.

As an alternative to divert water from the Fu Mieng multipurpose reservoir, the Phuoc Hoa irrigation dam with the diversion channel to the Dau Tieng reservoir is conceivable as shown in Figure 8.6.

The superiority between the Fu Mieng diversion and the Phuoc Hoa diversion is compared in the water allocation study discussed in Appendix X, however, the difference in the economic net benefit between the two schemes was marginal, even if Fu Mieng shows more attractiveness, and furthermore costs used for the optimal water allocation study were relied on the rather preliminary ones estimated in Phase II.

To clarify and confirm this issue, economic evaluation is made for following three envisaged schemes based on the refined design and estimated cost :

Scheme A : Fu Mieng multipurpose dam and Phuoc Hoa irrigation low weir with a pumping station

Scheme B : Fu Mieng hydropower (single purpose) and Phuoc Hoa dam (high weir) with a diversion channel

Scheme C : Phuoc Hoa dam (high weir) and diversion channel without Fu Mieng.

For the preparation of the cash flow for irrigation development at Phuoc Hoa, Dau Tieng and HCMC-Long An delta, the irrigation costs and benefits of the above schemes discussed in Appendix VI are referred to.

For the calculation of economic cost and benefit of the power generation, following assumptions are made:

a) Least cost or second best alternative power plant is a coal-fired thermal power plant with a capacity of 55 MW for Fu Mieng multipurpose and 110 MW for the single purpose.

b) Unit capital cost : US $ 1,250 / kW
Unit fuel cost : US Cent 1.563

c) Capacity adjustment factor : 1.2207
Generation adjustment factor : 1.0318

d) Service life and O & M

	Service life (year)	O & M (%)
Coal-fired thermal plant	20	5.0
Hydropower	50	1.0

e) Economic cost is assumed at 85 % of the total project cost by taking into consideration the transfer payments and opportunity costs.

f) Present values of benefits and costs are calculated at a discount rate of 10 %.

On the above basis, the present value of economic net benefit and the EIRR for three schemes are calculated and shown in Tables 8.7 to 8.9 and the results are summarized as follows:

	Present Value, million US$	EIRR, %
Scheme A :	114.5	11.38
Scheme B :	77.7	10.85
Scheme C :	21.1	10.27

From the above, it is confirmed that Scheme A is the best option among the three schemes; that is, Fu Mieng diversion is more attractive than that of Phuoc Hoa.

(4) Economic Evaluation of Fu Mieng Multipurpose Project

The economic evaluation of the Fu Mieng multipurpose project itself without Phuoc Hoa irrigation scheme is carried out, in the same manner as discussed in the above Section. Once the Fu Mieng multipurpose project is implemented, Phuoc Hoa irrigation scheme can be implemented separately by constructing a small weir and a pumping station, and therefore Phuoc Hoa irrigation scheme is considered to be independent of Fu Mieng.

Therefore, the project costs and benefits gained from an incremental irrigation area of 88,300 ha in Dau Tieng, HCMC-Long An delta are counted for the evaluation, but those for Phuoc Hoa irrigation scheme are excluded.

The cash flow for the analysis is shown in Table 8.10.

As seen from Table, the net benefit at a discount rate of 10 % is US$ 67.8 million and the EIRR is 11.32 %. Thus, it is confirmed that the Fu Mieng multipurpose project is economically viable as the diversion alternative of the Be-Saigon diversion project (the final selection between Fu Mieng and Phuoc Hoa as the diversion alternative will be made in further detailed study in future).

However in respect of the environmental aspect of the project, it is to be noted that the inundation area of the project is relatively large and may involve possible compensation and resettlement problems, and therefore the implementation of the project should carefully be judged taking into consideration the large-scale socio-economic benefits contributing to the regional development gained from an incremental irrigation of 88,300 ha as well as the possible environmental issue.

8.4 Implementation Schedule

The implementation schedule of the combined development of Dong Nai No. 3 and No. 4, projects and the Fu Mieng multipurpose project as the diversion alternative of the Be-Saigon diversion project is prepared and shown in Figure 8.7.

The commissioning timing of the former is assumed to be at the begining of the year 2008 according to the generation expansion study results discussed in Chapter 7, and that of the latter is determined to be at the begining of the the year 2010 taking into account the irrigation development scenario discussed in Appendix VI (Agricultural Development and Irrigation).

Further discussions for the selected hydropower master plan projects such as fund management, administrative management system and selection of priority projects are given in Appendix X. In fact, the combined development of Dong Nai No. 3 and No. 4 is selected as one of the priority projects to proceed to the feasibility study stage taking into account the input timing and its project scale, and therefore Terms of Reference (TOR) for the feasibility study is prepared as attached in Appendix X.