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 5.1 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 %)

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 distance. The second stage of the project completed in September 1994 with the maximum sending power capability of 500 MW to the south and tapping two substations in the central region (Da Nang and Play Ku).

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 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.

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.

5.2.3 Historical Trends of Power Consumption and Generation

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.

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 %

5.2.4 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.

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.

The demand forecast for the additional five years up to the year 2015 is then extrapolated for sector-by-sector in the southern region 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 for the Southern Region (PC2)

(Generation Basis)

(Unit: GWh)

		2000	2005	2010	2015
Generation	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	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

As seen from the Table, the power and energy demand in the year 2015 will be 7,900 MW and 42,000 GWh for the low case scenario, and 12,800 MW and 67,000 GWh for the high case scenario. This indicates that the power and energy demand in the target year of 2015 in the Study Area will be approximately 10 times larger than present condition.

To secure the high economic growth which is expected to be supported by the industry and service sectors in the future, the development of hydropower generation is essential not only for reducing the power and energy shortage but also for contributing to the environmental objectives such as alleviation of air pollution and saving of foreign exchange for importing fossil fuel.

5.3 Agriculture Development

5.3.1 National Strategy and Constraints

The economic liberalization policy under "Doi Moi" launched in the year 1988 shifted Viet Nam from rice importer to a net exporter of about 2 million tons paddy since the year 1989, being the second largest in the world at present. The national policy set in the Five-year Plan towards the year 2000 emphasizes in particular to two issues, i.e. continuing to increase food production for ensuring national food security and diversifying the farming structure for promoting market-oriented economy.

To encounter unavoidable population increase, Viet Nam has to increase the paddy production by about ten million tons for the next two decades from the present 23 million tons to the estimated 33.5 million tons with maintaining about 10 % export in the year 2015. This would not be an easy task in consideration of natural and physical constraints which will not allow the remarkable production increase in the Red and Mekong River deltas which bear a total of 70 % paddy production in the country. It implies that ensuring the national food security and earning of foreign exchange by rice production would meet difficulty in future. Consequently this calls for more investment of irrigation and drainage systems in the potential agricultural lands coupled with land and water resources developments as well as in the existing 5.39 million ha of cultivated area for annual crops, of which about 2.1 million ha is facilitated with irrigation systems.

While, high priority is being given to shifting the agriculture from the present paddy mono-culture into the diversified farming, which would improve and stabilize farm income, enhance rural agro-industry and diversify agricultural export income. To fulfill such policy requirement, attention should be given to the strengthening of agricultural supporting services such as extension, credit and market information besides providing sustained irrigation and on-farm investment.

5.3.2 Agriculture Development in the Study Area

The Study Area is divided into four regions, i.e. Mekong Delta, N-E Southland, South Central Coast and Central Highlands. The specific development objectives and strategies set by MOARD for the respective regions are as follows:

Mekong Delta region	- extension, intensification and export of rice; and - intensification of meat production particularly of pig meat and other crops such as pineapple, banana, coconuts, soybean, sugarcane and jute.
N - E Southland region	- intensification of food crops such as rice, and rubber production; and - extension of industrial crops such as soybean, groundnuts, sugar cane, tobacco and cotton and fruit tree cultivation such as coffee, pineapple, banana and cashew, and cattle raising for meat and milk.
South Central Coast region	- extension and intensification of rice and corn cultivation, and sugar cane cultivation including expansion of cane processing capacity; expansion of sericulture and animal industry; and development of bare or sandy land by growing perennial trees such as coconut, and pasture crops;
Central Highlands region	- expansion of coffee and rubber plantation, sericulture and dairy industry

The prime crop in the Study Area is paddy and the present 1.8 million tons paddy production satisfies around 60 % of its regional demand by the population of 11.4 million in the year 1993. The self-sufficiency of paddy in the Study Area should drop further to 30 % for the estimated 19.3 million population in the year 2015 if the present production level is maintained. To ensure stable food supply regionally and achieve the development objectives mentioned above, the further efforts for irrigated agricultural development is crucial in the Study Area. However, shortage of water is the prime constraint to the development in the Study Area in any case of paddy based and diversified agriculture despite the existence of the Dong Nai River basin having rich water resources.

The East Coast area, covering Ninh Thuan and Binh Thuan provinces, is fairly dry with less rainfall, and therefore cannot enjoy its large land potential for a wide range agriculture due to shortage of local water resources available in small river basins. A possible water diversion from the Dong Nai River basin to the East Coast is expected to improve such situation and enhance the regional socio-economy in this area. In HCMC-Long An delta area, the water resources presently available would not permit the expansion of dry season paddies, and the further development in the remaining potential lands suffering from acid soils and salinity intrusion will not be possible unless additional fresh water is conveyed to this area.

These conditions are impeding the expansion of irrigated agricultural development schemes, and the shortage of water in the dry season keeps the Study Area in low cropping intensity. Thus, poverty and high underemployment prevail in the rural area, while the industrialization is accelerating in the urban area centered at HCMC, and areal economic gap between the urban and rural area is widening. The investment for water resources development in the major river basins and its fair distribution will be the breakthrough to activate the rural economy and also to mitigate such social and economic disparity in the Study Area.

5.4 Development of Domestic and Industrial Water Supply

5.4.1 Domestic and Industrial Water Supply

As discussed in preceding Section 5.1, the Southern Focal Economic Area (SFEA) is emerging as a hot place of economic development with a land area of 12,400 km^2 and a population of 7.8 million. Domestic and industrial water constitutes a part of the most crucial elements to sustain the economic development. A study estimates that domestic and industrial water of an amount of 3.9 million m^3/day shall be developed by the year 2010 to sustain the economic development. Taking into account the present supply capacity of more or less 0.8 million m^3/day, water to be developed within coming 15 years becomes over 3 million m^3/day.

Large cities and towns such as HCMC, Bien Hoa, Vung Tau and so on are developed in the downstream reaches of the Dong Nai River near the estuary, where saline water intrudes. It is inevitable to mainly rely on the surface water as the water source of bulk demand (3.9 million m^3/day); that is, there would be a conflict between the requirements to meet the supply capacity and to satisfy the quality standard, which stipulates that raw water as drinking water shall be 0.25 g/l or lower in the salinity concentration. In other words, a large amount of maintenance flow should be released to secure the water source of domestic and industrial water supply.

In the Study Area, there are nine provinces and one city, which have 85 district and provincial towns in total. It is informed as a result of hearings and distribution of questionnaires to each water supply company of those nine provinces and one city that there still exist 26 district towns without any water supply system at present. This suggests that dissemination of water supply system to the district towns be also urgently sought besides the water supply to the SFEA.

There are some issues to overcome even for the district towns with water supply system such as limited distribution area, high distribution loss and so on. In particular, high water loss is mainly attributed to the old system, some of which were built in 19th Century by French colonial government.

5.4.2 Waste Water and Sewerage

According to the past experience of HCMC, industrial water use including commercial use accounts for 38 % of total use. If it is assumed that this rate is unchanged in future and that industrial water is not substantially consumed, an amount of some 1.5 million m^3/day (=3.9 million m^3/day x 0.38) is returned to the rivers as a total of industrial waste water in the SFEA.

At present, most of domestic sewage and industrial waste water is released to the rivers without any treatment. If the present condition, i.e. no treatment for waste water, continues even with increase of industrial water demands in future, it is quite easy to expect that riverine and estuarine environment deteriorates tremendously, causing menace to the healthy life of human being as well as to the eco-system in the lower reaches of the Dong Nai River.

5.5 Development of Rural Area

As discussed in preceding Section 5.1, the Southern Focal Economic Area including such large towns as HCMC, Bien Hoa, Vung Tau and so on is promised to be developed as a locomotive of economic development in the nation. On the other hand, the living condition of the highland areas and the east coast area covering Ninh Thuan and Binh Thuan provinces stays at a subsistence level. That is to say that there is considerably large economic disparity between urban and rural areas in the Study Area.

Economic disparity between two areas not only forces to the local people living in the rural area the low level life with such problems as malnutrition, poor social amenity and so on, but also causes migration of people seeking job opportunities from rural areas to large towns such as Ho Chi Minh City. This migration would have merits to supply labour force necessary for sustaining economic development of the SFEA. However, there is a more serious problem to deteriorate urban amenity as represented by squatters' houses built along the rivers and canals of the urban rivers.

Taking into account the living condition in the rural area, matters to be carried out for the socio-economic development in the Study Area most urgently are to improve social amenity and to create job opportunities in the rural area.

In terms of water resources development, enhancement of social amenity can be made by improving water supply in the rural area including district and major towns in the respective regions. On the other hand, creation of job opportunities will be made by improving and rehabilitating small scale irrigation projects scattered throughout the Study Area.

5.6 Management of Watershed and Water-related Issues

5.6.1 Flood Mitigation and Urban Drainage

As mentioned in preceding Sub-section 4.2.1, the Dong Nai River consists of six major tributaries with a total catchment area of 40,683 km^2; the main Dong Nai River (14,979 km^2), the La Nga River (4,093 km^2), the Be River (7,427 km^2), the Saigon River (4,717 km^2) and the East Vam Co (8,546 km^2) and West Vam Co (921 km^2: left bank area only inside the country) rivers. Of the total catchment area of 40,683 km^2, about 10 % is located outside the country, i.e. Cambodia. On the other hand, river basins lying in the coastal area are included in the Study Area. Some characteristics of these river system are briefed in terms of flooding.

Dong Nai Main

Channel profile of the Dong Nai River is unique with two steep slope reaches; the lower and upper rapids. Upstream of the rapid reaches, the channel slope is gentle. Flood-prone areas such as Cat Tien and Ta Lai (refer to Figure 5.1) are located in such a gentle slope area. On the other hand, in the lower reaches of the Dong Nai main where free meandering seems to prevail, flood-prone areas such as Tan Uyen/Vinh An, Long Thanh/Thu Duc and Nhon Trach are located.

La Nga River

Channel slope is steep in the lower reaches, and rapids and falls are seen in places. Upstream of steep reaches, an extensive plain extends. Flood-prone areas such as Tanh Linh and Duc Linh are located in such a plain.

Be River

The channel forms a wide valley with few settlements. Thus, flooding problems of the Be River are not deemed serious.

Saigon River

The river slope is very mild. The urban area of HCMC develops mostly on an isolated plateau ranging from +3 m to +10 m MSL. Flood-prone areas such as Thay Cai, Vin Loc A & B, Van Hai and Le Minh Xuan are located in the low-lying suburban areas lower than +2 m MSL. These areas are afflicted with the inundation caused by the inter-action of flood flow and high tides.

East and West Vam Co Rivers

The rivers are located on the eastern boundary of the Mekong delta and their slopes are markedly mild. Flooding in these areas is, in general, shallow in depth but extensive in area.

Coastal River Basins

There exist many rivers in the coastal area, generally flowing toward southeast and pouring into the South China Sea. Among these, major rivers which suffer from flood damages are the Phan Rang, Luy, Phan Thiet and Ca Ty river basins.

The rainy season in the Dong Nai River basin begins in April/May and ends in October/November. Runoff gradually increases from May and channel water level rises. The strong rainstorm occuring under these conditions would bring about large flood. The strong rainstorm with a wide rainfall area, which rarely occurs, is caused by typhoon and/or hovering front.

The cause of flooding in the Dong Nai River basin can be classified into three types, i.e. flooding due to flush runoff (1st type), flooding due to passage of flood flow through topographically insufficient sections (2nd type) and stagnancy of flood water due to high water level of trunk channel and sea tide (3rd type). Major flood-prone areas in the Dong Nai River basin shown in Figure 5.1 are classified into three types as follows:

1st-type

- Coastal rivers: Phan Rang, Luy, Phan Thiet and Ca Ty rivers;

2nd-type

- Upper Dong Nai River area: Cat Tien and Ta Lai areas,
- La Nga River area: Tanh Linh and Duc Linh areas, and
- Middle Dong Nai River area: Tan Uyen and Vinh An areas; and

3rd-type

- Lower Dong Nai River area: Long Thanh, Thu Duc and Nhon Trach areas,
- Suburban area of HCMC: Thay Cai, Vin Loc A & B, Van Hai and Le Minh Xuan areas, and
- Urban area of HCMC.

The Dong Nai River basin experienced large flooding in the year 1932, 1952, 1964 and 1978 since the year 1930, causing serious damages. Among them, the flood in the year 1952 is

considered as the recorded biggest and the 1978-flood as the biggest one in recent years. Markedly big floods have not been observed since the year 1978.

Since coastal rivers are short in length and have steep slope, floods in these rivers emerge and withdraw rapidly. Big flood rarely happens. But once it occurs, the flood always causes severe damages in the lower plains such as Phan Rang plain, Luy River plain, and Phan Thiet plain. The Phan Rang River experienced a historically big flood on December 17, 1964 along with another flood in the year 1979.

Ho Chi Minh City (HCMC), which is one of the most important economic and industrial centres in the country, has a total area of 2,029 km^2 and a population of 4.5 millions. Three-fourths of the population concentrate in 12 urban districts with a total area of 140 km^2, or 6.9 % of the whole city area.

Since the city is located in a low-lying land with many canals, drainage as well as sewage has been a problem since its establishment. In addition, rapid urbanization in recent years brought about damages and overload to drainage and sewerage facilities, causing a serious urban inundation along with water pollution.

5.6.2 Salinity Intrusion

The Dong Nai River multi-furcates into several branch channels in the deltaic estuary, forming a complicated channel network. Major inlets of sea water into the Study Area are the Dong Nai main, the Long Tau River and the Dong Tranh River. Sea water further intrudes into the tributaries of the Dong Nai River such as the Vam Co and the Saigon rivers. According to salinity observation carried out in the Study Area since the year 1977 by the Sub-Institute of Water Resources Planning (SIWRP), the maximum intrusion is recorded in the year 1977 and the minimum in the year 1989 as shown in Figure 5.2. The maximum extent of salinity intrusion ordinarily takes place at the end of April when the river flow falls to the lowest. The following Table shows the time period when the salinity concentration normally remains to be 4 g/l or more at each station:

Period of Salinity Concentration More than 4 g/l

Station	River	Period of 4 g/l or more
Nha Be	Dong Nai River	From Dec. 18 to Jul. 3
Cat Lai	Dong Nai River	From Jan. 15 to May 20
Phu An	Saigon River	From Feb. 10 to May 10
Ben Luc	East Vam Co River	From Feb. 2 to May 25
Tan An	West Vam Co River	From Feb. 10 to May 15

Due to the gentle slope and deep channel of rivers, sea water intrudes deeply into lands through the rivers and canals in the Study Area. The areas suffering from salinity intrusion are those in the lower reaches of the rivers and the canals connected with these rivers. The salinity intrusion has brought about adverse effects to the agricultural production and people's daily life in the areas.

5.6.3 Watershed Management

Deforestation in Viet Nam between the year 1943 and 1991 resulted in a reduction of forested area from 67 % to 29 %. In other words, the current rate of loss of forest cover exceeds 3,000 km^2/year. On the other hand, deforestation in the Study Area is indicated to have recorded a loss from 69 % to 29 % as shown in Table 5.2. More significantly from the biodiversity sustainability viewpoint are the losses in moist (evergreen) forests with the remaining area indicated to be 20 % or less. Similarly losses in lowland riverine habitats in the Study Area have been serious and detrimental to regional ecology and wildlife resources.

Deforestation has resulted from several activities including:

a) Removal of forest cover for agricultural land development based on irrigation (lowland area), shifting cultivation (highland area) and the tree crops at varying elevations, e.g. rubber, cashews, coffee and tea,

b) Logging, both legal and illegal, with some controls put into law and regulation in the year 1989, remaining ineffective against continued cutting for firewood and fuelwood and taking of selected valuable species, e.g. rosewood and local timber production,

c) Destruction of forests by spraying of defoliants, broadscale clearing and burning during the Viet Nam war (the year 1968 to 1975) including substantial areas in parts of Tay Ninh, Song Be and western Dac Lac provinces close to the Cambodian border, and

d) Fires particularly in the peat swamp area between the East Vam Co and West Vam Co rivers and in the pine forests in the Da Lat area.

Data analysis for the Tropical Forest Action Plan (TFAP) indicated an annual breakdown of the deforestation for the Northeast of Mekong Zone (most of the Study Area) as follows (TFAP, 1991):

a)	Shifting cultivation	-	3,000 ha	(5 %)
b)	Firewood and charcoal	-	32,000 ha	(54 %)
c)	Logging/timber production	-	13,000 ha	(22 %)
d)	Fire damage	-	11,000 ha	(19 %)
	Total	-	59,000 ha.	

The dominance of deforestation for fuel, i.e. firewood and charcoal in the Study Area, is further shown in Table 5.3 which indicates the Northeast of Mekong zone being responsible for 15 % of Viet Nam's firewood and 40 % of its charcoal consumption. Since a large component of this is for urban areas, particularly Ho Chi Minh City, forest areas of Song Be, Tay Ninh and Dong Nai provinces are in effect being deforested for supply of fuel to urban areas. The above figures reflect an untenable situation in terms of forest resource sustainability on a long term basis for the Study Area.

Deforestation is also directly linked to erosion problem and indirectly to sedimentation transport in local rivers which are of direct concern to proposed reservoir projects. Erosion rates from upland rice growing areas for Viet Nam have been estimated as follows :

- 100 to 150 tonnes/ha/year for land slopes of 5 to 6 %
- 250 to 300 tonnes/ha/year for land slopes of 15 to 20 %
- 350 tonnes/ha/year for land slopes > 30 %.

Most of the uplands in the Study Area considered susceptible to erosion have been designated as Class I. In other words, the least susceptible area to erosion (289 km^2) is only 0.6 % of total the area of 48,500 km^2.

6. WATER RESOURCES DEVELOPMENT POTENTIAL

6.1 Principal Approaches of Water Resources Development

Needs for water resources development in the Study Area have been discussed in the preceding Chapter 5. To meet the requirement of each need, water available in the Dong Nai River basin is desired to be fully mobilized in an optimal way. The principal approaches formulating the optimal water allocation in the Dong Nai River basin are represented as follows:

a) Water development in the major potential area with creation of reservoirs - Dong Nai and Be River basins,

b) Agricultural development in the east coast area with water diverted from the Dong Nai River basin, and

c) Agricultural development in the HCMC-Long An Delta area with water transfer from the Be River basin.

It would be necessary to create a reservoir with a long diversion tunnel in the upstream reaches of the Dong Nai River for realizing the plan to divert the Dong Nai River water to the east coast for the development of irrigation schemes. Water transfer to the HCMC-Long An Delta area would also require construction of a reservoir with a diversion facility in a proper place of the Be River for diverting its water to the Saigon River through the existing Dau Tieng reservoir, the function of which is to warrant the stable irrigation water supply to each beneficiary area widely spreading in the HCMC-Long An Delta along with the reservoir to be built in the Be River.

Diversion of water to the east coast area and the HCMC-Long An Delta naturally reduces the flow of the Dong Nai main stream, in particular in the dry season, with large water demand centres in its downstream reaches. This situation encourages to build reservoirs in the Dong Nai main stream for meeting the water demand in its downstream reaches along with the maintenance flow for salinity intrusion. The primal objective of the reservoirs to be built in the Dong Nai River main stream is hydropower generation, even if such a flow regulation function is included in the development objectives. Taking into consideration the strategies mentioned above as well as the needs sought to water resources development in the Study Area, discussions how to develop water resources potential available in the Study Area are dealt with in this Chapter.

6.2 Hydropower Generation

6.2.1 Characteristics of the Basins

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 the La Nga, one of its major tributaries, shows a low hilly plateau climbing up to about El. 50 to 125 m. The western part of the Dong Nai 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.

6.2.2 Identification of Hydropower Potential

The potential damsites are identified using the topographical maps with a scale of 1/100,000 and 1/50,000 based on the information provided by SIWRP.

The river profiles together with the identified schemes are shown in Figure 6.1. As seen from Figure 6.1, 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 6.2.

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 with 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.

Projects in the Main Stream

Principal features of these projects are summarized in Table 6.1 and the brief description of each project is as follows:

(1) Dai Ninh

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 (active 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 PIDC2, 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.

(2) Dong Nai No. 1, No. 2 and No. 3

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 active 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.

(3) Dong Nai No. 4 and No. 5

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 that of the Da Nhim and the Dai Ninh

project. Damsites of both projects are located in a relatively narrow valley and are favourable for constructing a high dam to create high head. However, the active 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 active 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.

(4) Dong Nai No. 6 and No. 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 projects.

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 active 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 the firm energy output of the existing Tri An hydropower plant located downstream.

(5) Can Don and Fu Mieng

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 an 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.

(6) Bao Loc and La Nga No. 3

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.

Projects 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 6.2.

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.

These high head projects with a relatively short waterway will 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, 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.

6.2.3 Project Evaluation and Screening

The project evaluation and the screening of the identified potential schemes are carried out through First Screening, Second Screening and Environmental Considerations described below.

(1) First Screening

For the first screening of the identified potential projects, capacity and energy of each project are preliminarily calculated by assuming that only the particular project is independently developed in future with the existing and that committed projects below are being "in operation":

Existing projects : Da Nhim project (160 MW), Tri An 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).

In the first screening stage, 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.

For the preliminary economic evaluation to select promising hydropower projects which can be candidates for the second screening, Specific Capacity Cost (SCC) and Specific Generation Cost (SGC) 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 types 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 6.3.

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 Sections.

(2) Second Screening

During the Phase II study period, the basic layout study of candidate projects selected in the first screening was carried out, and the preliminary layout drawings are prepared as shown in Figures 6.3 to 6.10, and the principal features of each project are shown in Table 6.4.

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. 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.

In respect of the energy output estimate, 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", and these additional energy is assumed to be the benefit of these candidate projects.

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

Increase of power output with existence of 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.

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. The results are shown in Table 6.5 and 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 million/year) or single development of Dong Nai No. 4 (US$ 9.5 million/year) is considered to be economically viable, however, the expected annual net 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 with US$ 9.5 million/year or Dong Nai No. 3 with 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 %.

(3) Environmental Consideration

National Park

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 PIDC2) 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.

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 very 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 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.

(4) Results of Second Screening

Through the first and second screening carried out with the economic comparison as well as preliminary environmental consideration, 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 enables 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 viable, 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 justifiable.

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 multipurpose.

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, based on the generation expansion planning study in the next Section.

6.2.4 Generation Expansion Planning Study

In the previous Sections, 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 with the preliminary environmental considerations.

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 time horizon and 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 value of all the relevant construction and operation costs needed to satisfy the forecast customer demand including prescribed overall system reliability.

The main results are described hereunder (For the detailed explanation of the model structure, constraints, input data, etc., refer to Appendix V : Hydropower Generation).

(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. 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 input timing of the selected hydropower projects is shown Table 6.6 (Base Case) and the results are summarized as follows:

	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 multipurpose development of Fu Mieng are 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. It is however to be noted that Can Don will be required in the year 2013, if the capital cost of the combined cycle plant is increased by 20 %, according to the sensitively study carried out.

(3) 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.

The summary of the screening process in respect of first screening, second screening and the generation expansion study is summarized in Table 6.7.

6.3 Irrigated Agricultural Development

6.3.1 Classification and Basic Concept of Irrigation Development

All the irrigation schemes in the Study Area are categorized broadly into three groups, i.e. (A) existing irrigation schemes, (B) on-going and planned irrigation schemes and (C) potential irrigation schemes, and further classified into some sub-groups as shown below:

Code	Classification of Schemes Main	Sub		Name of Schemes
A.	Existing Irrigation Schemes	A.1	Large and Medium Irrigation Schemes (Area larger than 2,000 ha)	Vo Xu, Phan Rang, Song Pha, Dai Don, Quan Hiep/Tyuen Lam and Phuoc Chi (6 schemes)
		A.2	Small Irrigation Schemes (Area larger than 100 ha and smaller than 2,000 ha)	161 schemes in total
		A.3	Extension or Proposed Small Irrigation Schemes	65 schemes in total
B.	On-going and Planned Irrigation Schemes			Dau Tieng, Phuoc Hoa, Hoc Mon-Bac Binh Chanh and Song Quao (4 schemes)
C.	Potential Irrigation Schemes	C.1	Potential Schemes in HCMC-Long An Delta (Deltatic and saline water affected area)	HCMC Long An province : Duc Hue, Duc Hoa, Ben Luc, Can Giouc, Can Duoc, Tran Tru, Thu Thua, Thanh Hoa and Moc Hoa (9 irri. blocks)
		C.2	Potential Schemes in East Coast expecting water resources diverted from Dong Nai River basin	Phan Ri Plain, Phan Thiet Plain and Ham Tan Plain (3 schemes)
		C.3	Potential Schemes in La Nga River and other river basins	Lower La Nga Plain (Ta Pao and Vo Dat), Phan Rang Plain (Extension), Tuy Phong Plain, Song Phan Plain, Song Ray Plain and Song Dinh Plain (7 schemes)

All the irrigation schemes in the Study Area are discussed in this Master Plan Study on a category-wise basis as classified with regard to the study objectives and items listed in Table 6.8, and on the basis of planning concepts described below.

The irrigation water requirements are calculated for indicative cropping patterns on a diversified farming basis, which introduces more cash crops such as sugarcane, cotton and various winter-spring upland crops like groundnuts with a cropping area of 40 % in general, while sharing 60 % for paddy. The maximum diversion water requirement ranges from 1.1 to 1.2 lit./sec/ha and takes place in January to May depending upon climatic conditions in the respective regions. It would be able to ensure proper irrigation against possible changes of cropping in future. Water balance made to the respective schemes is based on the river flow with a 75 % exceeding probability (75 % runoff).

6.3.2 Existing Irrigation Schemes

The irrigation area in the Study Area is estimated at about 243,000 ha in total, occupying about 28 % of the annual cropping area as shown in Table 6.9 and summarized below:

Province	Agricultural Area (ha)			Irrigation Schemes and Designed Area	
	Annual Crops	Perennial Crops	Total	Scheme No.	Area (ha)
1. Lam Dong	40,952	42,316	83,268	155	16,308
2. Dac Lac	4,461	1,552	6,013	12	394
3. Ninh Thuan	39,525	2,000	41,525	51	21,300
4. Binh Thuan	82,512	17,619	100,131	153	28,655
5. Song Be	79,300	139,400	218,700	50	5,587
6. Dong Nai	181,607	153,142	334,749	49	18,322
7. Ba Ria-Vung Tau	44,019	64,934	108,953	24	8,885
8. Tay Ninh	182,707	93,393	276,100	4	52,915
9. HCMC	80,822	12,424	93,246	6	31,330
10. Long An	139,696	-	139,696	9	59,200
Total	875,601	526,780	1,420,381	513	242,896

The cropping intensity in the irrigation schemes is estimated at 112 % on an average, and the area actually irrigated would be less than 40 % against the designed irrigation area. The top five problems involved in running irrigation schemes identified through the inventory survey are:

- Insufficient development in on-farm irrigation systems;
- Inadequate or defective design of irrigation systems;
- Water shortage;
- Damages and deterioration of irrigation systems; and
- Poor operation and maintenance.

The above facts reveal the necessity of rehabilitation and improvement of the existing irrigation schemes. Although the provincial administrations have heavy stress in shortage of fund for

maintenance and repair of the existing schemes, they have strong intention to implement those rehabilitation including development new small irrigation schemes. Aiming mainly at narrowing down the economic disparity between urban and rural areas, it is proposed to formulate and implement Rural Agricultural Development Project (RADP) through the rehabilitation of these small existing and new irrigation schemes as one of the urgent development programmes in the Study Area. The objective schemes of RADP would cover 229 small irrigation schemes, consisting of 164 existing ones and 65 new ones scattered through the Study Area.

6.3.3 On-going and Planned Irrigation Schemes

Four on-going and planned irrigation schemes are identified, i.e. on-going Dau Tieng and Song Quao and planned Phuoc Hoa and Hoc Mon-Bac Binh Chanh. The results of review and updating of these schemes are briefly described below except for the Song Quao irrigation scheme which is separately discussed in connection with the Phan Ri-Phan Thiet irrigation project.

(1) Dau Tieng Irrigation Scheme

The Dau Tieng scheme has a designed irrigation area of 93,390 ha situated in Tay Ninh province and HCMC fed by the Dau Tieng reservoir constructed in the Saigon River in the year 1985. An area of 45,000 ha has been facilitated with irrigation system and is in operation, however the rest 48,390 ha, tentatively called "Dau Tieng Extension irrigation scheme" is still left behind un-irrigated. The water balance of Dau Tieng reservoir reveals that it would not permit the irrigation in the Dau Tieng scheme of more than 50,000 ha besides the water supply for domestic use and salinity repulsion in HCMC, unless supplemental water would be diverted from the Be River.

The annual economic cost of irrigation development of Dau Tieng Extension is estimated at US$ 130/ha covering construction of 2nd/3rd irrigation canals, on-farm facilities and small pump stations for the area of 35,940 ha in total. While, the annual incremental benefit is estimated at US$ 1,128/ha. The development of Dau Tieng Extension area is considered to be economically viable, provided that the irrigation water enough to feed the entire scheme would be secured.

The development of Dau Tieng Extension irrigation scheme by the trans-basin diversion from the Be River will involve the water supply to 15 existing and new small irrigation schemes with a total area of 29,400 ha located in the right bank of the East Vam Co River, named the Tay Ninh riparian schemes. Although included in the RADP, these schemes are taken into consideration in the study of optimum water allocation.

(2) Phuoc Hoa Irrigation Scheme

The Phuoc Hoa irrigation scheme is proposed to irrigate an area of 45,680 ha in the southern part of Song Be province by constructing the proposed Phuoc Hoa dam. The proposed crops to be irrigated are paddy and upland crops including groundnut, beans, maize, tobacco, sugarcane and fruits. A total area of about 7,200 ha for cashew cultivation is to be converted to annual crops including sugarcane. The Phuoc Hoa dam is proposed in the Be River about 23.8 km upstream of the Phuoc Hoa bridge of National Highway No. 13. The catchment area at the damsite is 5,247 km^2, and the mean annual flow is 205 m^3/sec regulated by the recently completed Thac Mo reservoir. The Phuoc Hoa reservoir has an active storage volume of about 67 million m^3. The total length of main and secondary irrigation canals is about 210 km. Seven booster pump stations are to be constructed on the upper reaches of the main canal to irrigate the elevated lands in the scheme area.

The Phuoc Hoa dam is presently designed to divert part of the Be River flow to the Saigon River with the maximum discharge of 42 m^3/sec for the purposes of supplemental water supply to the Hoc Mon-Bac Binh Chanh scheme and riparian and deltatic agricultural land in HCMC as well as water supply. Having reviewed water balance at the Phuoc Hoa reservoir, the maximum discharge diverted to the Saigon River increases to about 50 m^3/sec.

As a result of updating the construction cost of the Phuoc Hoa irrigation scheme, there is a considerable gap in the cost estimates between that estimated in the pre-feasibility study made by the MOARD in the year 1995 and updated in this Study. The small weir and pump station as an alternative headworks instead of the Phuoc Hoa reservoir gives the lowest investment cost. The annual incremental benefit is estimated at US$ 1,174/ha, consisting of US$ 750/ha from irrigation and US$ 424/ha from water supply to the southern part of Song Be province. While, the annual economic cost of the Phuoc Hoa scheme including O&M cost is estimated at US$ 571/ha in case of Phuoc Hoa reservoir and US$ 502/ha in case of pump irrigation.

(3) Hoc Mon-Bac Binh Chanh Irrigation Scheme

The Hoc Mon-Bac Binh Chanh irrigation scheme aims to improve the drainage and irrigation conditions for an area of 12,197 ha located in the centre of HCMC-Long An Delta. The main source of water for the scheme is the Saigon River through Rach Tra canal connecting between the Saigon River and the East Vam Co River. The main crops of the scheme are paddy, groundnut, vegetables, sugarcane and fruits with a cropping intensity of 178 %. The scheme is evaluated with an economic rate of return of 12 % in its feasibility study, and has started the construction towards the completion in the year 2000.

6.3.4 Potential Irrigation Schemes in HCMC-Long An Delta

The potential irrigation area in the HCMC-Long An Delta is estimated at 100,000 ha in total, consisting of 46,000 ha irrigated by the Saigon River including the on-going Hoc Mon-Bac Binh Chanh irrigation scheme (HCMC Delta) and 54,000 ha irrigated by the East Vam Co River (Long An Delta) as shown in Figure 6.11 and schematically illustrated in Figure 6.12.

The major crops to be introduced are paddy, groundnut, vegetables, sugarcane and fruits with a cropping intensity of 180 % on an average. The annual economic costs including O & M costs are estimated at US$ 253/ha in HCMC Delta and US$ 233/ha in Long An Delta, while the annual incremental benefits are estimated at US$ 474/ha and US$ 457/ha, respectively. The irrigated agricultural development in HCMC-Long An Delta is considered economically viable, subject to making irrigation water available including salinity control.

6.3.5 Potential Irrigation Schemes in East Coast Area and La Nga River and Other River Basins

(1) Identification of Potential Irrigation Schemes

Over the past three decades in Viet Nam, the various studies have been made by the Government for formulating many potential irrigated agricultural development projects in the East Coast area and the La Nga River and other river basins. A total of ten potential irrigation schemes are identified in these area as shown in Figure 6.13 on the basis of the land suitability maps prepared in this Master Plan Study together with various planning reports available. The result of inventory survey for irrigation systems and the availability of water resources is listed in Table 6.10 and is summarized below:

Unit : ha

Potential Scheme	Potential Irrigation Area		Area with existing irrigation facilities	Potential irrigable area
	Gross	Net		
East Coast Area				
Phan Ri Plain	56,700	32,000	6,113	25,887
Phan Thiet Plain	46,680	24,400	11,605	12,795
La Nga River Basin (Lower La Nga Plain)				
Ta Pao	29,330	23,000	10,235	12,765
Vo Dat	22,920	15,000	0	15,000
Other River Basin				
Phan Rang Plain	21,350	15,400	5,075	10,325
Tuy Phong Plain	4,700	4,200	2,150	2,050
Song Phan Plain	7,100	5,030	0	5,030
Ham Tan Plain	27,450	8,000	1,210	6,790
Ray River Plain	19,600	13,710	4,050	9,660
Dinh River Plain	6,800	4,740	1,950	2,790
Total	242,630	145,480	42,388	103,092

(*1) : Estimated

(*2) : Estimated without existing Phan Rang and Song Pha irrigation schemes

As a result of reviewing and updating all the above potential schemes, two projects of Phan Ri-Phan Thiet irrigation project and Lower La Nga plain irrigation project are proposed as candidates for the master plan projects, while the rest schemes are omitted due mainly to insufficient availability of water resources and low economic viability as described in the subsequent Sub-section 6.3.6. The formulation of development plan for the former two schemes is described below.

(2) Phan Ri-Phan Thiet Irrigation Project

Water with a constant discharge of 24.5 m^3/sec from the Dong Nai River basin through the Dai Ninh power station would accommodate the irrigation for the entire 29,700 ha area in the Phan Ri plain by constructing the Luy reservoir in conjunction with water resources of the Luy River basin, which moreover gives surplus water of about 11 m^3/sec on an annual average. This surplus water can be topographically conveyed to the eastern part of the Phan Thiet plain of 18,000 ha for the use of its supplemental irrigation. Since an area of 8,000 ha is to be irrigated by the Song Quao reservoir which is under construction, an area of 39,700 ha in both the Phan Ri and Phan Thiet plains would be irrigated by the project with the proposed Luy reservoir having an active storage volume of about 110 million m^3.

The Luy River in conjunction with the water from the Dai Ninh power station, Ca Giay reservoir being planned and other small existing irrigation systems would be able to irrigate an area of about 24,300 ha without the proposed Luy reservoir. While, the existing agricultural land in the project area is estimated at 30,000 ha in total. Consequently the Phan Ri-Phan Thiet irrigation project would be implemented on a stagewise development basis with the following

possible development steps, i.e. (i) construction of an intake on the Luy river and irrigation system for the existing agricultural lands in the Phan Ri plain, (ii) extension of main canal to and construction of irrigation system in the Phan Thiet plain, and (iii) construction of the Luy reservoir and land reclamation of newly development land.

The annual economic cost including O & M costs of the project is estimated at US$ 456/ha, while the annual incremental benefits are estimated at US$ 990/ha in the Phan Ri plain and US$ 962/ha in the Phan Thiet plain, respectively. Therefore, the Phan Ri-Phan Thiet irrigation project is considered economically viable.

(3) Lower La Nga Plain Irrigation Project

The potential irrigation area in the Lower La Nga plain is estimated at 38,000 ha in total, sub-divided into two schemes of the Ta Pao irrigation scheme of 23,000 ha and the Vo Dat irrigation scheme of 15,000 ha, respectively. The Ta Pao irrigation scheme will involve the existing Vo Xu pump irrigation scheme with a designed area of 5,000 ha, and also low-lying flood-prone areas along the Lower La Nga River.

Two diversion weirs of Ta Pao and Vo Dat are to be constructed on the main stream of the La Nga River. The water balance at both the proposed weir sites, subject to river flow regulated by the Ham Thuan and Da Mi reservoirs which are under implementing, results in that the Ta Pao irrigation scheme is fully irrigated, while the Vo Dat irrigation scheme is marginally irrigated by taking the return flow from the Ta Pao scheme area into consideration.

The annual economic costs including O & M costs of the project are estimated at US$ 306/ha for Ta Pao and US$ 445/ha for Vo Dat, while the annual incremental benefits are estimated at US$ 828/ha and US$ 975/ha, respectively. Therefore, the Lower La Nga irrigation project is considered economically viable. However, its scale is subject to the assessments of flood protection, water resources available and possible effect to power generation of Tri An hydropower station situated downstream of the Dong Nai River, and consequently should be sought in the study of optimum water allocation discussed in the subsequent Chapter.

6.3.6 Selection of Candidate Master Plan Projects

(1) Proposed Strategy of Irrigation Development

With the national policies for irrigation development and the present conditions of the irrigated agriculture in the Study Area confirmed by data and information obtained through the field reconnaissance and inventory survey for the existing irrigation schemes, it seems appropriate to take the following approaches for formulating a master plan of irrigation development in the Study Area, coupled with strategy for agricultural development:

- Placing the prime purpose of irrigation development on stabilization of agricultural production, it will be formulated comprehensively in association with environmentally sound improvement and upgrading of socio-economic conditions of rural areas that ultimately aim to enhance the living standard of people and to narrow down the regional gap of socio-economic conditions;

- As an immediate irrigated agricultural development in the Study Area, the highest priority will be given to the Rural Agricultural Development Project which is based on the rehabilitation and upgrading of the existing irrigation schemes including the exploitation of additional water resources, followed by completion of on-going schemes and technically and economically viable schemes among the presently proposed small irrigation schemes; and

- Parallelly, water resources development projects will be promoted for the potential irrigation schemes by giving the highest priority to the exploitation of locally available but untapped rivers, and to technically and economically viable water diversion schemes from other river basins in coordination with hydropower development and water supply schemes.

(2) Screening of Candidate Schemes for Master Plan Projects

On the basis of the results of individual studies above mentioned, the following factors are adopted to the screening of candidate schemes for master plan projects:

- Water resources, either Dong Nai River including diversion or surrounding basin;
- Availability of water;
- Maturity of planning;
- Social impacts;
- Natural environmental impacts; and
- Economic viability.

The screening matrix incorporating the above factors is shown in Table 6.11, and results in selecting the following schemes as the candidates for the master plan projects:

a) Rural Agricultural Development Project consisting of small irrigation schemes including 164 existing schemes of 65,185 ha in total and 65 new schemes of 65,472 ha;

b) Remaining development area of 48,390 ha of the Dau Tieng irrigation scheme (Dau Tieng Extension);

c) Phuoc Hoa irrigation scheme of 45,680 ha;

d) Irrigated agricultural development schemes in the HCMC-Long An Delta with an area of 100,000 ha in total, consisting of HCMC Delta of 46,000 ha and Long An Delta of 54,000 ha;

e) Phan Ri-Phan Thiet diversion scheme with an area of 39,700 ha in total, consisting of Phan Ri irrigation scheme of 29,700 ha and Phan Thiet irrigation scheme of 10,000 ha; and

f) Ta Pao irrigation scheme of 23,000 ha and Vo Dat irrigation scheme of 15,000 ha in La Nga River basin.

6.4. Domestic and Industrial Water Supply

6.4.1 Present Water Supply Condition and Future Balance

According to the service criteria, urban water supply is defined as the project to supply domestic, commercial and industrial water to the areas with population more than 15,000, agriculture involvement ratio of less than 25 % in terms of the number of households and population density higher than 100 persons per hectare.

A survey based on hearings and distribution of questionnaires to each of the nine provinces and one city was carried out in the field work of Phase I to prepare an inventory of water supply projects and to grasp the current water supply situation in the Study Area. In the field work of Phase II, a survey to visit water supply companies of each province in the Study Area was continued not only to confirm the collected information and data on water supply projects, but also to collect data and information necessary for water demand projection and future water balance studies.

Table 6.12 summarizes the survey results to show the present situation and future plans of water supply for the provincial and district towns including some other towns (refer to Figure 3.1 for their identification) in the Study Area, telling that there still exist 26 district towns without any water supply system out of 85 provincial and district towns in the Study Area at present as mentioned in preceding Section 5.4 and furthermore that the water supply of the remaining district towns except for the provincial towns is very limited just relying on the small scale development of groundwater.

Most of provincial towns in the Study Area have a water supply system with a scale of thousands to some ten thousands m^3/day except for Ho Chi Minh City with a supply capacity of 680,000 m^3/day at present. Most of those towns suffer from chronic water shortage.

Future water demand, which is the base to calculate the capacity to the developed in future, for the urban areas of nine provinces and one city in the Study Area is estimated in the year 2000 and 2015 as summarized in Table 6.13 based on the projected population and the conditions set for water demand projection, reaching a level of 1.6 million m^3/day in the year 2000 and 4.3 million m^3/day in the year 2015 as the total of the Study Area. As for HCMC, the demand will grow to a level of 1.0 million m^3/day in the year 2000 and 2.1 million m^3/day in the year 2015. The industrial development area along National Highway No. 51 including such towns as Bien Hoa, Tam Phuoc, Long Thanh and Nhon Trach in Dong Nai province and Vung Tau, Ba Ria, Long Son, Long Hai, Phuoc Tinh, Long Dien, Dat Do, Phuoc Hai and Phu My in Ba Ria-Vung Tau province will need to develop domestic and industrial water with an amount of 0.4 million m^3/day by the year 2000 and 1.7 million m^3/day by the year 2015 as summarized below:

Province	District and Major Towns	Water Demand, m^3/day 2000	2015
Dong Nai	Bien Hoa	158,000	353,487
	Tam Phuoc	20,895	243,938
	Long Thanh	3,803	15,103
	Nhon Trach	55,440	368,776
Ba Ria-Vung Tau	Vung Tau	65,122	270,275
	Ba Ria	11,393	61,383
	Long Son	3,675	14,871
	Long Hai	4,594	15,215
	Phuoc Tinh	3,675	10,897
	Long Dien	5,145	14,990
	Dat Do	5,145	14,990
	Phuoc Hai	2,756	9,785
	Phu My	83,950	330,704
	Total	423,593	1,724,414

For future water demand predicted as given Table 6.13, present water supply capacity including future plans for extension is summarized as given in Table 6.12. The balance between them is computed as deficit to be developed as given in Table 6.14, requiring an amount of 0.22 million m^3/day by the year 2000 and 1.13 million m^3/day by the year 2015 as the sum of the Study Area.

In this water balance study, a few to several towns in a province are treated as one water supply system as follows:

Province	Towns in a System
Tay Ninh	Tay Ninh and Hoa Thanh
Song Be	Thu Dau Mot, Di An and Lai Thien
Ninh Thuan	Phan Rang, Thap Cham, Ninh Chu and Dong Hai
Binh Thuan	Bac Binh and Phan Ri Cua
Ba Ria-Vung Tau	Vung Tau, Ba Ria, Long Son, Long Hai, Phuoc Tinh, Long Dien, Dat Do and Phuoc Hai
Dong Nai	Bien Hoa and Tam Phuoc

It is noted that the towns and cities developed along Natural Highway No. 51 would seek a water source to the Dong Nai River along with water sources available in and around the area as a system.

In HCMC, there are several proposed projects to develop domestic and industrial water as listed in Table 6.12. If all the projects listed are developed, the supply capacity will far exceed the demand. Taking into consideration this situation, following schemes are assumed to be developed to meet water demand in HCMC by the year 2000 and 2015:

Development Year	Project	Development Amount, m^3/day
by 2000	Hoa An Rehabilitation	100,000
	Hoa An Extension	150,000
	Bin An Under-construction	50,000
	Phu Cuong Under-construction	300,000
	Hoc Mon Groundwater	20,000
	Total	620,000
by 2015	Hoa An Extension	600,000
	Bin An Extension	100,000
	Total	700,000

The last interest on the domestic and industrial water development in the Study Area is to estimate the construction cost to be invested by the year 2000 and 2015. The cost to be invested for the future development of the domestic and industrial water supply in the Study Area is estimated to require an amount of US$ 337 million by the year 2000 and US$ 683 million between the year 2000 and 2015. HCMC will need an investment of US$ 160 million by the year 2000 and US$ 190 million by the year 2015, whilst US$ 99 million by the year 2000 and US$ 353 million by the year 2015 for the towns and cities along National Highway No. 51 from Bien Hoa to Vung Tau.

6.4.2 Water Supply for the Economic Triangle Zone

An area, which includes HCMC and the corridor between Bien Hoa and Vung Tau along with the southern part of Song Be province, i.e. Thu Dau Mot and Thuan An, is emerged as a locomotive to propel economic development of the nation, called the economic triangle zone. Future water demands of the area in the year 2015 are projected by district or town as given in Table 6.13, reaching a level of 3.8 million m^3/day as summarized below:

Area	Water Demand in 2015, m^3/day
Song Be Province	
1. Thu Dau Mot-Thuan An	90,000
Ba Ria-Vung Tau Province	
2. Ba Ria Vung Tau including nearby towns	410,000
3. Go Dau-Phu My-Thi Vai	330,000
Dong Nai Province	
4. Bien Hoa-Ho Nai	350,000
5. Tam Phuoc-An Phuoc	240,000
6. Nhon Trach-Long Thanh	380,000
Ho Chi Minh City	
7. 17 Districts	2,000,000
Total	3,800,000

Sources for the water supply systems of the above towns and cities are mainly sought to the Dong Nai River and the Saigon River, even if there are alternative sources such as groundwater and local rivers.

Table 6.15 shows a summary of development requirement to seek water sources to the Dong Nai River and the Saigon River to meet the above mentioned demand in the said area in the year 2015 under the condition that the existing and planned projects given in Table 6.12 are under operation. It indicates that an amount of 3,187,000 m^3/day equivalent to 36.8 m^3/sec is sought to the Dong Nai River, whilst 940,000 m^3/day (10.9 m^3/sec) for the Saigon River. Such a amount of water shall be guaranteed at Hoa An for the Dong Nai River and Phu Cuong for the Saigon River, where the proposed intake sites are located. It is however to be noted that there are the Song Ray and other reservoirs besides the Dong Nai River as alternative sources of water supply to the major towns along National Highway No. 51 in Ba Ria-Vung Tau province, but that those are excluded in computing water amount to be secured (water right) to the Dong Nai River as a source of water supply projects.

Water demand of HCMC and the corridor towns along National Highway No. 51 is estimated to reach a level of 3.8 million m^3/day in the year 2015, which accounts for 88 % of total water demand (4.3 million m^3/day) in the Study Area. Taking into consideration the fact that water supply projects for HCMC and the corridor towns along National Highway No. 51 will play

an important role for the economic development in the region, both water supply projects are proposed as the candidates of master plan projects to be selected in the optimal water allocation study (refer to subsequent Chapter 8).

Domestic and industrial water is not substantially consumed through their use, since those water is mainly used for bathing, cloth washing, industrial processing and so on. This implies that water with an amount of more or less 3.8 million m^3/day used for domestic and industrial purposes in HCMC and the corridor area is returned to the rivers with degraded quality, thus required treatment.

HCMC has combined sewer systems with a total length of 661.6 km, but most of domestic sewage and waste water is released to the rivers without any treatment. If the present condition, i.e. no treatment for waste water, continues even with increase of domestic and industrial water demands in future, it is quite easy to expect that riverine and estuarine environment deteriorates tremendously, causing menace to the healthy life of human being as well as to the eco-system in the lower reaches of the Dong Nai River.

It is not realistic to recommend to build extensive sewer systems with sewage treatment judging from the present situation in HCMC. However, based on the argument that such systems are necessary to protect natural environment as well as to keep social amenities as basic human needs, a proposal here is to install waste water treatment plants to the industrial development zones where release of waste water is concentrated with the lower quality than that of domestic sewage. A rough estimate for constructing such treatment plants is made, requiring an amount of US$ 1,030 million by the year 2000 and US$ 2,510 million by the year 2015.

6.4.3 Rural Water Supply

As discussed in the preceding Sub-section 6.4.1, domestic water supply in the Study Area is in an incipient stage except for large cities and towns such as Ho Chi Minh City and Bien Hoa. This fact implies that any systematic water supply projects have rarely been established in the rural areas of the Study Area. In fact, people living in the rural areas rely on small wells privately dug, sand filtration system, rain water tanks (roof catchment) and so forth as a drinking water source.

Small wells manually dug in the rural areas are normally shallow with a depth of 20 m to 30 m, showing less reliability on supply in the dry season probably due to the fact that water level in the well rapidly draws down in coincidence with rapid falling of river water level starting from the beginning of dry season. Dry-up of wells in the dry season makes local people have no alternatives but to buy for getting drinking water. In particular, the long lasting dry season in the year 1995 made most of shallow wells drilled on the rural area dried up,

resulting in serious shortage of drinking water as reported for example that hundreds of patients and the staff of the Health Care Centre of Bu Dang district, Song Be province, have to share a well, which only had a supply capacity of 1 m^3/day. Even if wells are barely available for use, there is a hygienic problem, since there are high chances that the release of water used for daily life including toilet water to the ground would contaminate the well.

It can be said that the life of people, who have wells even if those are not good in quality, is rather easy compared with those who do not have wells. They have to collect drinking water from the nearby river or canal no matter how water quality is, or to buy it. In case of buying drinking water, local people have to buy it with the price 10 to 100 times higher than that of tap water.

Based on the rural water supply situation in Viet Nam mentioned above, UNICEF (United Nations Children's Fund) with the assistance of Central Rural Water Supply Project, Ministry of Labour, War-invalids & Social Affairs, which was in charge of rural water supply projects in the Vietnamese Government at that time, commenced in the year 1980 their assistance to improve the rural water supply in Viet Nam in aiming to protect children's life by raising hygienic level in the rural area. Its assistance spurred based on the proclamation of the International Drinking Water and Sanitation Decade (the year 1981 to 1990) by the United Nations (UN). As at the end of the year 1994, UNICEF has developed 15,448 water sources for rural water supply in the Study Area; 3,949 for Ho Chi Minh City, 3,410 for Binh Thuan, 1,959 for Ninh Thuan, 655 for Ba Ria-Vung Tau, 336 for Dong Nai, 493 for Song Be, 598 for Tay Ninh, 564 for Lam Dong, 20 for Dac Lac and 3,464 for Long An as summarized in Table 6.16. It is noted that rural water supply projects in Dac Lac and Long An provinces show the performance of two and seven districts respectively lying in the Study Area.

As at the end of the year 1994, only a fraction of 27.6 % of people living in the rural part of the Study Area is computed to receive the benefit of rural water supply projects compared with the national average of 35 % under the condition that the number of beneficiaries is 120 persons for a water source and that annual increase rate of population is 2.68 % between the year 1989 and 1994. By province, Tay Ninh, Song Be, Dac Lac and Dong Nai lie in the area with the poorest performance rate of lower than 10 %. Two provinces, Lam Dong and Ba Ria-Vung Tau, show a slightly higher performance rate of 14 % to 18 %, whilst three provinces, Ninh Thuan, Binh Thuan and Long An, performed rural water supply projects with a higher rate of more than 60 %.

Identification of the communes, which are the smallest administrative unit lying under the district and urgently require rural water supply projects with a small distribution system, is made by distributing a questionnaire from the office of Central Water Supply Project to each provincial office in charge of rural water supply projects except for Ho Chi Minh City, where the piped water is expected to be supplied in most of its administrative area. Based on the

distribution of questionnaire to the provincial offices of rural water supply projects, a list of communes to require rural water supply project urgently is prepared as summarized in Table 6.17; nine communes in Tay Ninh province, 11 communes in Song Be province, 19 communes in Dac Lac province, 29 communes in Lam Dong province, nine communes in Ninh Thuan province, 25 communes in Binh Thuan province, 20 communes in Ba Ria-Vung Tau province, 18 communes in Dong Nai province and 30 communes in Long An province (170 communes in total).

The number of rural water supply projects with a small distribution system required for the above communes is estimated by putting some conditions. As a result, a total of 1,207 rural water supply projects with a small distribution system are estimated to be implemented for the 170 communes by the year 2015 as summarized in Table 6.17. Taking into consideration the importance of rural water supply projects in enhancing the rural amenity, a plan to implement 1,207 rural water supply projects is selected as the candidate for the master plan projects of this study.

7. WATER AND WATERSHED MANAGEMENT

7.1 Flood Mitigation and Urban Drainage

Present conditions on flood and urban drainage in the Study Area as well as the issues to be solved are dealt with in preceding Section 5.6. In this Section, discussions are focused on measuring the flood mitigation effects by existing and proposed structural measures. In case where floods are not well mitigated even with such measures, further recommendations for flood mitigation will be made.

7.1.1 Study on Flood Discharge

The study on flood discharge starts with the preparation of runoff simulation model, followed by the evaluation of flood mitigation effects by simulating the runoff model under the with-and-without condition of structural measures.

(1) Preparation of Runoff Simulation Model

Storage function method is applied as the simulation model of flood runoff analysis. The Dong Nai River basin is divided into sub-basins to apply the storage function model, and a runoff system diagram is prepared based on the sub-basins so divided (refer to Figure 7.1). The flood runoff model is calibrated so that the simulated flood hydrograph well coincides with the recorded one. Figure 7.2 shows the comparison between the simulated runoff hydrograph and the recorded one. Judging from the comparison of those two hydrographs, it can be said that the runoff simulation model is well established.

(2) Basic Flood Discharge

Flood mitigation effects with structural measures are evaluated by comparing with the basic flood discharge, which shows the flood condition without structural measures. The basic flood discharge is estimated for various return periods as shown in Table 7.1, whilst Figure 7.3 depicts 100- and 20-year floods.

(3) Flood Discharge with Existing and Proposed Reservoirs

There are four (4) existing reservoirs and three (3) proposed reservoirs in the Study Area as follows:

a) Dong Nai Main Stream: Dong Nai No. 3 (proposed), Dong Nai No. 4 (proposed) and Tri An (existing) reservoirs,
b) La Nga River: Ham Thuan (under construction) reservoir,

c) Be River: Thac Mo (existing) and Fu Mieng (proposed) reservoirs, and
d) Saigon River: Dau Tieng (existing) reservoir.

Flood runoff is analyzed under the conditions with four existing reservoirs and with seven reservoirs including three proposed ones by applying 20- through 100-year probable rainfalls. Results of runoff analysis are also shown in the said Table 7.1. Flood mitigation effects with the structural measures are discussed in the following Sub-section by flood-prone area, which is identified in Figure 5.1.

7.1.2 Study on Flood Mitigation

Flood mitigation effects are discussed for following three flood-prone areas:

a) Cat Tien-Ta Lai area,
b) La Nga River area, and
c) Lower Dong Nai and related rivers.

(1) Cat Tien-Ta Lai Area

Cat Tien-Ta Lai area, the location of which is identified in Figure 7.4, suffers from long-lasting flooding. The flood brings about damages to settlers' houses, paddy fields and fruit farms due to flooding and river bank erosion. Causes of flooding in this area are mainly flood runoff from the vast Dong Nai River basin and shortage of channel capacity (only 20 % of the 2-year flood discharge).

It is expected that about 33 % of basic flood discharge would be retained by the proposed Dong Nai No. 3 and No. 4 reservoirs. However, the peak flood discharge is still much bigger than the existing channel capacity.

Cat Tien-Ta Lai area has been designated as a reserved national park, and intensive flood mitigation measures are not acceptable. In addition, the existing flooding areas contribute as natural flood retention areas for the downstream reaches.

In view of the above, a layout plan clearly showing the boundaries of park area to be reserved and other areas for settlement and farming should be established as soon as possible prior to the establishment of flood mitigation plan for this area. In order to fulfill the immediate need of the area, local dikes to protect the existing settlement areas and farm lands are also advised to be constructed by paying due attention to the reserved national park.

(2) La Nga River Area

La Nga River area, the location of which is shown in Figure 7.5, suffers from long-lasting flooding for 10 to 15 days. Agricultural crops such as paddy, maize and sugarcane are subject to flood damages. Causes of flooding in this area are mainly flush flood runoff from the steep upper basin as well as depressed topography. Channel capacity is markedly small, being about 150 m^3/s and 350 m^3/s in the lower and upper flood-prone areas, respectively (refer to Figure 7.6).

Owing to the runoff retention effect of Ham Thuan reservoir which is now under construction, the 20-year discharge would be lowered to about 73 % of the basic discharge, and the 5-year discharge under the present condition would be raised up to the return period of 20 years. However, flood runoff is still far bigger than the channel capacity.

The La Nga River area also includes a part of reserved national park. Drastic changes of inundation conditions in the reserved areas would not be allowed. On the other hand, some part of the area has already been developed as fertile agricultural lands with mechanical irrigation systems, and the area still has high potential for agricultural development in future.

In consideration of the above, a layout plan should be prepared to clarify the areas to be reserved and to be developed. The areas to be developed would need flood mitigation measures by means of channel improvement such as diking systems. The flood mitigation should be planned and implemented in complying with the regional development scheme such as agricultural development. These development and flood mitigation activities should be implemented by paying due attention to conservation of the reserved park area.

(3) Lower Dong Nai and Related Rivers

Areas along the lower reaches of the Dong Nai, Saigon and East and West Vam Co rivers (refer to Figure 7.7) are flat and low-lying, suffering from river flooding and inundation due to local heavy rains and high tides. The areas experienced big floods in the year 1932, 1952, 1964 and 1978. Causes of these floods were typhoon or stationing south-west monsoon. These floods brought about serious damages to private houses and properties, public facilities, agricultural crops and livestock.

Average capacity of the existing channel is estimated as follows (refer to Figure 7.8):

- Dong Nai River upstream of the confluence with the Saigon River : 6,200 m^3/s
- Saigon River upstream of the confluence with the Rach Tra canal : 890 m^3/s
- East Vam Co River upstream of Xuan Khanh : 650 m^3/s
- West Vam Co River upstream of Tuyen Nhon : 330 m^3/s.

Tri An, Thac Mo and Dau Tien reservoirs play an important role for the flood mitigation in this area. With these reservoirs, safety of the existing Dong Nai River has been raised up to about 15-year probable discharge and the Saigon River up to 20-year probable flood or more. The past major floods mentioned above are those occurred before the commissioning of these reservoirs.

Since flooding problems in this area have been substantially solved, major problems remained are inundation due to local heavy rains and high tides as well as the channel with a capacity of partly lower than the 20-year discharge. The sites which need measures should be investigated in detail based on the topographic survey and verbal information from the local resident.

River and channel system in the area are complicated, sharing various functions such as floodway, drainage, water supply, irrigation and navigation. Functions of these rivers and canals should be investigated and clarified for planning flood mitigation measures. Continuous diking system with sluices would be a primary measure of this area, planned in consideration of the functions of the rivers and canals.

(4) Suburban Areas of HCMC

Suburban areas of HCMC such as Tay Cai, Van Hai, Le Minh Xuan and Vinh Loc A and B are located in the topographically depressed area and have been suffering from long-lasting inundation caused by local heavy rains and spring tides. The inundation occurs every year in thousands hectares of lands and loses mostly agriculture production such as paddy, sugarcane and pineapple.

Improvement of canals with diking system and sluice would be a primary measure. Drainage improvement in this area should be planned in complying with the development schemes of the area as proposed in the Hoc Mon-Bac Binh Chanh irrigation project. The drainage plan should be implemented by giving top priority to this area.

7.1.3 Urban Drainage of HCMC

Since the urban area of HCMC is located in a low land surrounded by rivers and canals, drainage as well as sewage and waste water has been a problem since its establishment.

The existing drainage system given in Figure 7.9 has seriously been degraded mainly due to rapid urbanization and budgetary constraints for drainage works. Inundation occurs frequently in places in the urban area and causes hazard to economic activities as well as people's livelihood, damages to public structures and facilities, and deterioration of living and sanitary environment of the city.

Water quality of the city including the economic triangle zone is probably the most serious environmental issue in this area. Almost all of the domestic sewage and industrial waste water is being released to the canals and rivers without treatment. According to the appraisal of river water pollution conducted in the year 1990/91, Tan Hoa-Lo Gom canal, Nhieu Loc-Thi Nghe canal and upper half of Tham Luong canal are appraised to be badly polluted.

Recently a master plan study on urban drainage of HCMC was carried out by using full local funds. The study is, however, limited to the basic survey of the existing drainage facilities and preparation of repair and improvement programme for secondary and tertiary drains.

Taking into account the situation mentioned above, it is recommended to conduct a master plan study for improving urban drainage of HCMC. The study should cover the drainage and water pollution problems, and the plan to be proposed should be discussed from the overall viewpoint, including main drainage canal systems as well as considering future development of the city. Considering the recent rapid urbanization of the city, the master plan study should be implemented as soon as possible.

7.1.4 Flooding of the Coastal Rivers

There exist many rivers in the coastal area (refer to Figure 7.10). Among these, major rivers suffering from flood damages are the Phan Pang, Luy, Phan Thiet and Ca Ty river basins. Floods in the coastal river basins are characterized by:

- Sharp flood peak with a short duration,
- Rare occurrence of big flood, but extensive damage once occurred, and
- Flood runoff caused by heavy rainfall in the upper basin with less rainfall in the flooding areas.

Runoff retention by reservoir would be effective for this type of floods. Channel improvement by diking system and river training structure will augment the mitigation effects to protect the town areas and agricultural lands from flooding.

7.2 Salinity Intrusion

7.2.1 Field Observation of Salinity Intrusion

A field observation for salinity intrusion was programmed and carried out by the JICA Study Team in February and March, 1995, aiming to measure the salinity concentration by electric conductivity (EC) through the following three kinds of observation:

a) Sectional observation: Measurement of salinity at various points of a section to delineate cross-sectional distribution of salinity concentration;

b) Longitudinal observation: Measurement of salinity at various sections along river channel to delineate longitudinal distribution of salinity concentration; and

c) Consecutive observation: Hourly measurement of salinity of river water consecutively during a cycle of tidal movement (25 hours).

The observation and its locations are shown in Figure 7.11. Date and time for the observation are decided by considering the conditions of tidal movement based on the tide table. Major findings through the observation are presented below.

Cross-sectional Salinity Observation

In order to clarify the distribution of CL-values, defined to be ‰ or number of grams of salt in kilogram of sample, in a channel section, CL-values were measured at 25 points set on five verticals and five points on respective verticals. As a result, it is found that sectional distribution of CL-values is rather uniform for the whole sections. This result tells that the salinity intrusion in the Study Area falls under the category of strong mixture type, and thus the dispersion model shall be adopted for salinity intrusion analysis.

Longitudinal Salinity Observation

From the observation results, it is seen that the East Vam Co River is inducing the salinity into the land, while the Saigon and Dong Nai rivers push down the salinity. The Kinh Moi-Ben Luc River connecting the channels laterally plays an important role to level off the salinity.

Consecutive Salinity Observation

The 25-hour consecutive salinity observation was conducted simultaneously at 20 sections to observe the effect of tidal movement to the salinity and its propagation. The observation was made twice during neap tide and spring tide. During the spring tide observation, hourly discharge measurements by current meters were also carried out at the selected sections.

Results of the consecutive salinity observation are shown in Figure 7.12 by selecting the sections where CL-values exceed 0.5g/l.

7.2.2 Salinity Intrusion Analysis

(1) Preparation of Salinity Intrusion Model

A salinity intrusion model in the lower Dong Nai, Saigon, East Vam Co and West Vam Co rivers (Dong Nai System) is prepared to simulate:

- Unsteady flow under the change of sea tide and channel discharge,
- Channel discharge distribution in the complicated channel network, and
- Salinity intrusion of dispersion type.

The salinity intrusion model is calibrated using the consecutive salinity observation data collected on March 18/19, 1995. Figure 7.13 shows the result of calibration for some selected sections, illustrating the simulated water level, discharge and salinity in comparison with the observed values.

Salinity concentration and its distribution at various sections of interest were calculated using the simulation model for a time period of 15 days from March 5 with a time step of 30 minutes. The same boundary conditions used for the calibration are adopted principally for the simulation except for the case requiring the modification of the boundary conditions.

There is a standard on salinity concentration in using river water as a water source of domestic and irrigation supply as follows:

a) CL < 4 g/l: For an irrigation water source according to the practice in the Study Area and the Mekong delta, and

b) CL < 0.25 g/l: For a municipal water source according to Provisional Environmental Criteria, 1993; Ministry for Science, Technology and Environment.

The result of simulation for salinity intrusion will be used for judging the suitability as a water source of water supply and irrigation projects.

(2) Channel Flow Requirement in the Dong Nai and Saigon Rivers

An existing municipal water intake for HCMC is located at Hoa An along the Dong Nai River, and another municipal water intake for the town of Thu Dau Mot exists near the town along the Saigon River. A new municipal water intake for HCMC is under construction at Ben Than (Phu Cuong) site about 1.7 km upstream of the Thu Dau Mot intake along the Saigon River.

Salinity concentration of river water at these intake sites should be kept below 0.25 g/l throughout the year.

According to the present operation of Dau Tieng reservoir, maintenance flow released for salinity prevention is 20 m^3/s. Including flow from the Thi Thinh River which is one of main tributaries of the Saigon River lying downstream of the Dau Tieng reservoir, discharge at Thu Dau Mot would be about 25 m^3/s in the dry season.

Salinity at the Hoa An site along the Dong Nai River and three sites along the Saigon River is calculated by the simulation model under various combinations of river flows of the Dong Nai and Saigon rivers as summarized in Figure 7.14. The simulated results clarify the following:

a) Hoa An site: Salinity at the Hoa An site is estimated to be less than the allowable limit (0.25 g/l) even for the discharge combination of 50 m^3/s in the Dong Nai River and 10 m^3/s in the Saigon River.

b) Thu Dau Mot site: Salinity at the Thu Dau Mot site is estimated to be less than 0.25 g/l for any cases more than 20 m^3/s in the Saigon River. The same result is obtained when the flow of the Dong Nai River is greater than 200 m^3/s.

c) Salinity for the case of D100S25 (refer to Figure 7.15): For the discharge combination of 100 m^3/s in the Dong Nai River and 25 m^3/s (existing maintenance flow) in the Saigon River, salinity at the Hoa An and Thu Dau Mot sites is estimated at 0.05 g/l and 0.23 g/l, respectively, both satisfying the allowable limit.

(3) Channel Flow Requirement in the East Vam Co River

Discharge records are not available in the reaches of the East Vam Co River for the salinity study, since the river is located in the tide-affected area. According to verbal information obtained from SIWRP, the low flow discharge of the East Vam Co River itself is 10 m^3/s, and the supply from Dau Tieng reservoir is also 10 m^3/s. The low flow discharge at Xuan Khanh is, therefore, assumed to be 20 m^3/s under the present condition.

A relationship between discharge and salinity at Xuan Khanh is obtained as illustrated in Figure 7.16. According to the simulation study, salinity concentration at Xuan Khanh is summarized for various channel flow conditions as follows:

a) Estimated salinity concentration at Xuan Khanh is lower than the allowable limit (4 g/l) even for the low flow discharge of 10 m^3/s.

b) Salinity is estimated at 2.0 g/l for a discharge of 10 m^3/s which corresponds to discharge from the East Vam Co River without supply from Dau Tieng reservoir.

c) Salinity is estimated at 1.7 g/l for a discharge of 20 m^3/s which corresponds to the existing low flow discharge consisting of 10 m^3/s from the East Vam Co River and 10 m^3/s from Dau Tieng reservoir.

Salinity concentration at Xuan Khanh is lower than the allowable limit of 4 g/l even for the low flow discharge of 10 m^3/s. Taking into consideration the facts that the boundary conditions given for the West Vam Co River involve uncertainties by the influence from the Mekong River and that an allowable limit of salinity concentration of 4 g/l requires rather strict conditions for irrigated agriculture development, a flow of 20 m^3/s is set as the boundary condition of the East Vam Co River at Xuan Khanh.

(4) Study on Influence of Channel Improvement for Inland Navigation

Channel improvement works for inland navigation by deepening and widening the river channel in the deltaic estuary may affect the salinity intrusion. From this viewpoint, existing conditions and plans of the inland navigation are reviewed, and then the affect of channel improvement to the salinity intrusion is evaluated.

Existing Inland Navigation

HCMC is a key port for inland navigation in this area. According to Network of Inland Waterways and Highways in the Lower Mekong Delta by WATCO and information obtained from Saigon Port Authority, there are seven (7) primary waterways for navigation in the Study Area.

Navigation Improvement Plan

As a component project of Mekong delta master plan, recovery and improvement of the existing route from HCMC to My Tho/Mekong delta via the Kinh Te Canal, Cay Kho River, Can Giuoc River and Vam Co River were proposed. According to the plan, the river reaches of the Can Giuoc River between two confluences with the Vam Co River and the Cay Kho River will be improved with a canal depth of 3 m and a canal bed width of 90 m, whilst the river reaches of the Cay Kho River-Kinh Te Canal from the Can Giuoc River to the Saigon River will be dredged with a canal depth of 2 m and a canal bed width of 70 m.

Influence of Channel Improvement

Simulation analysis for the salinity intrusion is made for the following three cases to evaluate the influence of channel implement:

- Case-0: Existing channel,
- Case-1: Improved channel proposed by the Mekong delta master plan, and
- Case-2: Channel improvement for the Cay Kho River-Kinh Te Canal with the same standard section as the improved Can Giuoc River.

For both the cases, i.e. Cases 1 and 2, channel improvement will be made mainly for the Cay Kho River and Kinh Te Canal, since the Case-1 works are of small scale. According to the result of simulation, changes in salinity are slight, and adverse effects brought about by these channel improvement will not be substantial for both the cases. Distribution of the estimated maximum salinity for Case-2 is shown in Figure 7.17 in comparison with Case-0.

7.3 Watershed Management

7.3.1 Reservoir and Watershed Management Issues

The issue of reservoir-related watershed management in the Study Area is integrally linked and is complicated by the fact that many of the boundaries between provinces follow the main rivers. For example, the Dong Nai River is the boundary between Dong Nai and Dac Lac and Song Be provinces in vicinity of the Dong Nai No. 3, 4, 5 and 6 projects (refer to Figure 6.2). Responsibility for management of key resources such as forestry is on a provincial basis, so a comprehensive watershed management plan could require the cooperation of three or four Provincial Forestry Departments and 10 to 12 District People's Committees. Likewise the controls on non-forestry land use in any reservoir's catchment area could be divided among a similar number (or more) of provincial or district authorities and state enterprises.

Due to the above situation, controls on deforestation and remedial measures for controlling erosion and sedimentation would need to be planned and implemented involving numerous agencies. Consequently, the planning, programming and budgeting for watershed management programmes would need to be completed and to be included as an integral part of project planning, programming and budgeting. This would probably require an annual allocation of project revenue from electricity generation in order to effectively implement watershed management requirements over the long term.

Provisions under the policies of the Ministry of Agriculture and Rural Development relating to Protection Forests and leasing of Production Forest for private establishment, maintenance and scheduled harvesting would also need to be considered in the preparation of watershed management plans for any individual or a series of reservoir projects. Similarly, some proportion of any watershed management budget should be allocated for the "protection roles" of Special Use Forests such as National Parks and Nature Reserves included in any specific watershed management plan.

With the progress being made in Viet Nam lease controlled land to individuals on a long term basis (i.e. 10 to 15 ha/household) by assigning Forestry Department, there should be good

opportunities for implementing effective watershed management programmes in the long term. The opportunity for reforestation of natural forest areas as an integral part of watershed management plans should also be possible if properly planned and negotiated with Forestry Department through the Forestry Inventory and Planning Institute (FIPI). Further details and recommendations relating to reservoir and watershed management are referred to Appendix IV.

7.3.2 Protected Areas and Management

As of the year 1992, there were 87 Protected Areas (PA) or Special Use Forests (SUF) covering about 3 % of Viet Nam's land area or about 993,000 ha. Recent assistance to the Ministry of Agriculture and Rural Development by conservation-oriented NGO's, particularly the IUCN, has recommended expansion and consolidation of Protected Areas into a more representative system covering Viet Nam's natural resource base and diversity and to include at least 2 million ha covering approximately 6 % of the country.

The Protected Areas located in the Study Area are presented in Figure 7.18. The most important factors evident at this time relating to Protected Areas and their management and water resource developments recommended as "priority projects" include:

a) The middle and upper parts of the Dong Nai River and Be River catchments have residual forested areas including designated Protected Areas which are key components of the country's representative ecosystems and biodiversity.

b) Specific designated Protected Areas such as the Cat Tien National Park are considered internationally significant (e.g. as proposed Man and the Biosphere (MAB) Reserves) and could be critical habitat for preservation of some water-related endangered fauna in Viet Nam (e.g. freshwater crocodile, otters, selected birds (White-winged duck, cranes and stork) and tortoises).

c) There is considerable overlap of areas designated for Protected Areas for different purposes (e.g. Bien Lac and Cat Tien swamps are designated as both "wetland reserves" and "forest reserves"), but these allocations will be sorted out during rationalisation of the revised Special Use Forest or Protected Area system by the Forest Inventory and Planning Institute (FIPI) and the Ministry of Agriculture and Regional Development in conjunction with their international NGO advisers on wildlife and conservation issues.

d) There is a lack of a consolidated data base relating to Protected Areas and their overall significance to Viet Nam and to the Dong Nai, Be, Saigon, Vam Co and coastal river basins, with information being largely specific to particular areas of varying reliability and

of very limited extent relating to areas to be affected by priority projects for reservoir and irrigation development.

e) Previously constructed reservoirs such as Da Nhim, Tri An and are included in the Biodiversity Action Plan's proposed Wetland Reserve programme.

Wetland ecosystems in Viet Nam contain at least 30 genera of flora due to the presence of the Mekong Delta and inland riverine swamps and are indicated as having a greater biodiversity than those of other Southeast Asia ecosystems (e.g. Thailand (24 genera) and Philippines (19 genera)). Of particular ecological and economic values are the Melaleuca leucadendron or "tram" forests (acid coastal and Mekong Delta swamps); coastal mangroves (Rhizophora, ascilata or "duoc"; Avicennia alba or "nam quan" and A. intermedia or "nam den") and the tidal zone river fringing plant Nipa fruticans or "dua nuoc". Likewise there are several rare or endangered wildlife species associated with these wetlands. Since a comprehensive system of Wetland Reserves has been proposed to the then Ministry of Forestry by the IUCN, a programme to conserve the Protected Areas shall intensively and extensively be implemented in terms of preservation of natural environment.

8. FORMULATION OF WATER RESOURCES DEVELOPMENT IN THE STUDY AREA

8.1 Principal Approaches for Water Allocation

Needs for water resources development in the Study Area are discussed in detail in preceding Section 5.1. To meet those requirements, in particular for item a) to d), the limited water available in the Dong Nai River system is desired to be allocated in an optimal way. The items, e) to g), are also very important issues, however, the development strategies for these items are not directly related to the water allocation of the Dong Nai River system, and can be developed in parallel with development of the former group.

Although the principal approaches formulating the optimal water allocation in the Dong Nai River basin are also discussed in preceding Section 6.1, those are presented here again for the model formulation as follows:

a) Water development in the major potential area with creation of reservoirs-Dong Nai and Be River basins,

b) Agricultural development in the east coast area with water diverted from the Dong Nai River basin, and

c) Agricultural development in the HCMC-Long An Delta area with water transferred from the Be River basin.

The schematic diagram of basin model is shown in Figure 8.1 and the above three principal approaches are further explained as follows:

Water development in the major potential area

As for the alignment of the reservoirs to be created in the Dong Nai River main stream, the combined development of Dong Nai No. 3 and No. 4 projects with the reservoirs would be most promising in view of electricity generation as well as domestic and industrial water supply in the downstream area, particularly the SFEA.

Others, such as No. 1, No. 2, No. 6 and No. 8 are omitted from the list of schemes to be implemented by the target year 2015 because of low economic indices and social and environmental reasons. While further details are referred to Appendix IV, Natural Environment and Appendix V, Hydropower Generation, Table 6.7 summarizes the screening process of reservoirs to be added to the mathematical model of water allocation.

Dong Nai No. 3 project has a large active storage capacity of 899 million m^3, the creation of which makes it possible to increase not only the installed capacity of Dong Nai No. 4 (up to

double of the independent development of No. 4) but also its firm energy generation. It also contributes to increasing the firm energy generation of Tri An project and the river flow in the dry season at the downstream reaches of Tri An project. Thus, simultaneous combined development of the Dong Nai No. 3 and No. 4 is desirable, but in case where Dong Nai No. 4 is developed before Dong Nai No. 3, the design of the project should be made in consideration of future expansion.

In the Be River, Fu Mieng multipurpose project with the reservoir is promising in view of electricity generation and diversion of water to the HCMC-Long An Delta through the existing Dau Tieng reservoir. Besides the reservoirs mentioned above, i.e. one existing reservoir of Tri An and three proposed reservoirs of Dong Nai No. 3, Dong Nai No. 4 and Fu Mieng, following reservoirs are to be incorporated in the mathematical model of water allocation study; Dau Tieng, Thac Mo, Ham Thuan-Da Mi, Da Nhim, Dai Ninh and Song Luy. Dau Tieng is the existing reservoir built for the irrigation development in the Saigon and Vam Co river basins. Since Thac Mo, Da Nhim and Ham Thuan-Da Mi, which is under construction but is treated as existing project in the model, are the existing reservoirs constructed in the upper reaches of the Be, Dong Nai and La Nga rivers respectively, simulated outflows from those three reservoirs are treated as inflow to the mathematical model of the water allocation study. Dai Ninh and Song Luy are the reservoirs proposed as part of diversion to the east coast area as discussed below.

Agricultural development in the east coast area

Creation of the Dai Ninh reservoir in the upper Dong Nai River will be the core component to divert water from the Dong Nai River to the east coast area. Water diversion will make it possible to generate an electric power of 300 MW and then to expand the irrigation schemes in the Phan Ri and Phan Thiet plains. While further details are referred to Appendix VI, Agricultural Development and Irrigation, Table 8.1 summarizes the screening process of potential irrigation projects to be added to the mathematical model of water allocation besides the existing irrigation projects.

Diverted water would be capable of irrigating a cultivated land of about 40,000 ha which covers the Phan Ri plain (29,700 ha out of a total potential area of 32,000 ha) and an east part of the Phan Thiet plain (10,000 ha) in conjunction with the water resources available in the east coast area even if actual irrigation area is changed with diversion amount. La Nga No. 3 diversion project to irrigate additional potential irrigation area in Phan Thiet plain was initially considered, however, since economic viability of the scheme is low, this diversion concept is canceled. The maximum irrigable area in Phan Thiet plain which is to be supplied with water from the Dai Ninh reservoir through the Phan Ri plain is limited to be 10,000 ha because of the topographical constraint. To regulate local flow and to re-regulate the outflow from the Dai Ninh power plant, the Luy reservoir is also proposed to be built.

Agricultural development in the HCMC-Long An Delta area

The beneficiary area of the HCMC-Long An Delta to receive diverted water from the Be River through the existing Dau Tieng reservoir is delineated as an area spreading between the West Vam Co River and the Saigon River. Potential irrigation projects as well as the existing one are Dau Tieng existing (45,000 ha), Dau Tieng extension (48,390 ha), Tay Ninh lower (14,300 ha), Long An Delta-Rach Tram (54,000 ha), and HCMC (46,000 ha).

As diversion measures, both the Fu Mieng reservoir and the Phuoc Hoa reservoir are possible spots from where water can be diverted to the Dau Tieng reservoir through an open channel. Although the Fu Mieng reservoir has a physical advantage for diversion rather than the Phuoc Hoa, the diversion of water before power generation brings the loss of energy output. Taking into account the above condition, following two development scenarios are considered as the alternatives to select the optimal diversion scheme from the Be River to the Dau Tieng reservoir as schematically depicted in Figure 8.2:

Scenario-A : Fu Mieng multipurpose project with a diversion channel of 7 km long, and Phuoc Hoa irrigation project with a low intake weir for the pump intake; and

Scenario-B : Fu Mieng hydropower project and Phuoc Hoa irrigation project with the Phuoc Hoa dam with a diversion channel of 16 km long.

Besides the irrigation development by inter-basin water transfer discussed above, following irrigation areas are to be incorporated in the mathematical model of water allocation; Phuoc Hoa (45,680 ha), Ta Pao (23,000 ha), Vo Dat (15,000 ha), Tay Ninh Upper (15,100 ha) and Dong Nai riparian existing (23,400 ha). It is noted here that Tay Ninh Upper and Tay Ninh Lower schemes are not one large scale irrigation project, but an integration of small scale irrigation schemes.

8.2 Model Analysis of Water Allocation

8.2.1 Mathematical Model

In order to formulate a mathematical model to seek the optimal allocation of water resources available in the Study Area, one of the operations research methods, Mixed Integer Programming Method, has been applied as the overall mathematical diagram is shown in Figure 8.3.

The model structure is briefly described below (for further detail, refer to Appendix X) :

Candidate Projects for the Study Area

The candidate projects for hydropower, irrigation and water supply, which have been selected through the screening process under each sector, including the recently developed and committed ones are as follows:

- Site 1: Dai Ninh reservoir and hydropower (committed);
- Site 2: Dong Nai No. 3 reservoir and hydropower (planned);
- Site 3: Dong Nai No. 4 reservoir and hydropower (planned);
- Site 4: Tri An reservoir and hydropower (existing);
- Site 5: Fu Mieng reservoir, hydropower and diversion (planned);
- Site 6: Phuoc Hoa irrigation and diversion (planned);
- Site 7: Dau Tieng reservoir (existing), irrigation and diversion (planned);
- Site 8: Phan Ri reservoir, irrigation and diversion (planned);
- Site 9: Phan Thiet irrigation (planned);
- Site 10: Ta Pao irrigation (planned);
- Site 11: Vo Dat irrigation (planned);
- Site 12: Dau Tieng irrigation (existing) and diversion;
- Site 13: Tay Ninh upper irrigation (planned);
- Site 14: Tay Ninh lower irrigation (planned);
- Site 15: Dong Nai riparian irrigation (on-going);
- Site 16 Long An Delta-Rach Tram irrigation (planned);
- Site 17 HCMC irrigation (planned);
- Site 18 Hoa An water supply intake (existing and planned); and
- Site 19 Phu Cuong water supply intake (on-going and planned).

Objective Function

The objective function utilized in the Dong Nai Mixed Integer Programming Model is to maximize the net benefit, which is the difference between the annual economic benefit and cost given for each site as expressed below:

Net Benefit = Total Benefit-Total Cost

where total benefit includes benefit which will be obtained by hydropower generation, irrigation development and water supply. Total cost in the objective function includes construction costs for the proposed dam, irrigation development, diversion channel and water supply facilities as well as the operation and maintenance cost for them.

Estimated Inflow

Monthly discharge at each project site is prepared from inflows at major observation stations estimated by Tank Model, and by multiplying the ratio of catchment area and mean annual rainfall by respective sites.

The monthly flow at the Hoa An intake for a duration of 29 water-years with assumption that the Tri An power station is operating is considered to be the initial condition at the strategic point of this Master Plan Study, and the water-year in the year 1974, i.e. from November 1973 to October 1974, is selected as the representative 4-year drought inflow for each candidate project site in order to coincide with the design criteria for planning irrigation development schemes.

For further detail, reference is made to Appendix III, Meteorology and Hydrology, and Appendix X, Formulation of Master Plan Project.

Groundwater for Water Supply

Cities and towns developed and to be developed in the downstream reaches of the Dong Nai and Saigon rivers, i.e. HCMC and the corridor towns between Bien Hoa and Vung Tau, are assumed to seek water to those two main rivers as their main water sources to meet the domestic and industrial water demand, since their water demands of those areas are too large to rely on the water sources such as groundwater.

Taking into account the fact that drinking water is one of basic human needs for daily life, water requirements of HCMC and the corridor towns between Bien Hoa and Vung Tau are to be treated as the constraint to be met in the mathematical model of the water allocation study.

Water demands of scattered rural areas including districts and major towns in the Study Area are not included in the mathematical model, however the demand is expected to grow rapidly in future, and groundwater will be a main source to meet their demands. This issue is further discussed in subsequent Section 8.3.

Irrigation and Water Supply Parameters

In Dong Nai Mixed Integer Programming Model, monthly water requirements and maximum irrigable areas are obtained for sites 6, 7, 8, 9, 10, 11, 13, 14, 16, and 17. These water requirements are presented in Table 8.2. For the existing irrigation at Dau Tieng (45,000 ha) and Dong Nai riparian area (23,400 ha), water requirements have been incorporated in the Model as mandatory demand in order to secure the current irrigation condition in the area.

Furthermore, it should be noted here that for Site 9, Phan Thiet, the maximum irrigable area is defined to be 10,000 ha. This value is obtained based on the assumption that water required for irrigation is obtained from the natural inflow to Phan Thiet and diversion from Song Luy

dam at Phan Ri. Therefore, the right bank of the Ca Ty River in the Phan Thiet plain is not included in the maximum irrigable area (refer to Appendix VI, Agricultural Development and Irrigation).

Water supply requirements at the Hoa An intake for HCMC and the economic triangle zone and at the Saigon intake (Phu Cuong) for HCMC are also obtained based on demand projection of the municipality and industrial sites as well as the implementation programme of water supply projects as follows:

Site	Requirements, m^3/sec	
Hoa An	36.8	(3,187,000 m^3/day)
Saigon	10.9	(940,000 m^3/day)

A requirement of 36.8 m^3/sec at Hoa An is estimated under the condition that all the towns along National Highway No. 51 along with HCMC seek to the Dong Nai River as a primary water source to meet their water demands. These requirements are treated as mandatory release (constraints) in the model. It is noted here that water demands in the year 2015 are estimated at 2.1 million m^3/day for HCMC and 1.7 million m^3/day for the towns along National Highway No. 51. Details of the demand calculation are presented in Appendix VII.

Environmental Constraints for Salinity Intrusion, Maintenance Flow and other Parameters

Salinity intrusion is one of major adverse factors for the agricultural development and water supply in the areas lying in the downstream reaches of the Dong Nai, Saigon and Vam Co rivers. An intensive study to assess the amount of maintenance flow not to cause any adverse effects to agricultural development and water supply by salinity intrusion is undertaken in Appendix IX.

According to the Vietnamese standard, salinity concentration of drinking water is stipulated to be 0.25 g/l or less. Simulation of salinity intrusion discussed in Appendix IX reveals that an amount of 100 m^3/s be secured at Site 18, Hoa An intake for water supply, as maintenance flow of the Dong Nai River to keep the salinity concentration to the stipulated level, whilst 25 m^3/s at Site 19, Phu Cuong intake for water supply, as maintenance flow of the Saigon River.

Similarly, the minimum flow required for the Vam Co River is defined from the result of the salinity intrusion simulation study at Xuan Khanh where the intake of irrigation canal for Long An Delta-Rach Tram exists. At this point, since water is utilized for the agricultural development only, a salinity concentration of 4.0 g/l is utilized as the standard to maintain, and

20 m^3/s has been determined to be the discharge to release for preventing the East Vam Co River from salinity intrusion.

Minimum flow required at the Cai River in the east coast area has been defined so as to maintain 10 percent of the natural inflow (4-year drought flow) to the site for each month at a point just downstream of the Phan Thiet irrigation water intake. Similarly, the minimum stream flow just downstream of Phan Ri damsite in the Luy River is set at 10 percent of the natural inflow (4-year drought flow to the site for each month).

Furthermore, maintenance flow released from the Dau Tieng reservoir to the Saigon River is set at 20 m^3/s, while requirement downstream of the Phuoc Hoa pump station has been set at 18.6 m^3/s, which is the historical minimum flow obtained from 30-year Tank Model simulation at the Phuoc Hoa gauging station.

Parameters for Water Diversion

Diversion schemes within the Study Area are considered at sites 1, 5, 6, 7, 8 and 12. For sites 5 and 6, alternative schemes (Fu Mieng diversion and Phuoc Hoa diversion) are incorporated in the model together with five maximum diversion capacity alternatives for each site. Similarly, a total of five alternatives for the maximum diversion capacity at the sites 7 and 12 are incorporated. For Site 8 (Phan Ri to Phan Thiet diversion), the maximum diversion capacity of the channel is defined at 40 m^3/s. For Site 1 (Dai Ninh), the maximum diversion capacity has to follow the maximum plant discharge of 57.0 m^3/s which is the maximum turbinable flow.

Costs and Benefits for Objective Function

The objective function explained above requires cost and benefit functions of all the water resources development projects included in the model such as reservoir, hydropower, water diversion, irrigation and water supply.

Construction costs related to existing facilities, such as Tri An, Ham Thuan-Da Mi, Thac Mo and Dau Tieng, are treated as sunk cost and are not included in the model.

It is to be noted here that all the costs and benefits given for each alternative scheme are based on the study result of Phase II for the mathematical optimization purpose, and the further detailed study to estimate the specific benefits and costs for the selected master plan projects is carried out through Phase III, in which the individual project evaluation is carried out and the results are discussed in subsequent Chapter 9.

8.2.2 Model Solution

Given the structured problem and the constraints as stated above, the model is solved using the General Algebraic Model (GAMS) incorporating Optimization Subroutine Library (OSL) solver. The optimal solution obtained from the model is presented in Table 8.3 and Figure 8.4, from which the following can be read:

(1) Water Diversion from the Be River to Dau Tieng Reservoir

It can be said that the water resources in the Study Area are relatively abundant and that diversion of water from the Be River to the Saigon and Vam Co rivers would enable additional irrigation development in the latter area. In order to compare the potential irrigation development scenario of diverted-case and non-diverted case, the model is applied by enforcing integer variables at both Fu Mieng and Phuoc Hoa diversion alternatives to be zero; that is, no diversion scheme is considered from the Be River to Saigon River. Constraints incorporated in the model, such as boundary conditions at the Dong Nai River at Hoa An, the Saigon River at Phu Cuong and the Vam Co River, have been kept the same. The result of this analysis is as follows:

Unit: ha

Site	Project	Max. Irrig. Area	Diversion	No Diversion
Site 6	Phuoc Hoa	45,680	45,680	45,680
Site 7	Dau Tieng (Extension)*	48,390	48,390	37,264
Site 8	Phan Ri	29,700	29,700	29,700
Site 9	Phan Thiet	10,000	10,000	10,000
Site 10	Ta Pao	23,000	19,000	23,000
Site 11	Vo Dat	15,000	12,617	15,000
Site 12	Dau Tieng (Existing)	45,000	45,000	45,000
Site 13	Tay Ninh Upper	15,100	10,825	10,825
Site 14	Tay Ninh Lower	14,300	14,300	14,300
Site 15	Dong Nai Riparian	23,400	23,400	23,400
Site 16	Long An Delta*	54,000	31,170	0
Site 17	HCMC*	46,000	46,000	0
	Total	369,570	336,082	274,169

Note: * Beneficiary areas by diversion from the Be River.

The above result presents the fact that it is not possible to irrigate a total of 88,300 ha (entire irrigation area of HCMC-Long An Delta and part of Dau Tieng Extension) without the water diversion from the Be River, although the case without diversion shows a favour for Ta Pao and Vo Dat. Water resources in the Study Area are abundant, as noted above, however, utilization of water in the Study Area would not be optimally allocated unless water is diverted from the Be River to the Saigon River.

(2) Incremental Paddy Production in the Study Area

In respect of the paddy production in the Study Area to compare with the demand growth at the planning target year 2015, the following Table is presented to analyze the incremental paddy production in the Study Area:

Incremental Paddy Production

Site	Project	Development Area (ha)	Present Production (ton)	Future Production (ton)	Production Increment (ton)
Site 6	Phuoc Hoa	45,680	39,630	139,360	99,730
Site 7	Dau Tieng (Extension)	48,390	181,460	235,660	54,200
Site 8	Phan Ri	29,700	41,440	182,660	141,220
Site 9	Phan Thiet	10,000	22,230	61,500	39,270
Site 10	Ta Pao	19,000	51,950	150,510	98,560
Site 11	Vo Dat	12,620	1,750	107,100	105,350
Site 12	Dau Tieng (Existing)	45,000	168,750	168,750	0
Site 13	Tay Ninh Upper	10,830	40,590	124,490	83,900
Site 14	Tay Ninh Lower	14,300	53,630	164,450	110,820
Site 15	Dong Nai Riparian	23,400	70,200	70,200	0
Site 16	Long An Delta	31,170	53,200	192,070	138,870
Site 17	HCMC	46,000	55,800	221,630	165,830
Total		336,090	780,630	1,818,380	1,037,750

With an increased irrigation area of 267,690 ha (i.e. 336,090 ha minus 68,400 ha of existing Dau Tieng and Dong Nai Riparian) by irrigated agricultural development, the incremental paddy production is estimated to be 1.04 million tons per annum in the year 2015.

While the requirement of paddy to meet the population increase by 7.3 million in the Study Area from the year 1995 to 2015 is estimated to be about 2.1 million tons by assuming a per capita consumption of 285 kg/year, it is confirmed that the irrigation development to the full extent under the optimum utilization of water resources in the Dong Nai and surrounding river basins would be still in short for the self- sufficiency but definitely contribute to the stable food supply in the Study Area.

This irrigation development matches to the agricultural development policy in the Study Area to intensify food crops such as rice by taking into consideration the present situation that food production can only satisfy 50 % of demands in food stuffs. By doing such endeavour in agricultural development, there would still fall short of food supply, which would have to be supplemented by the increased paddy production through the rehabilitation and extension of the existing irrigation schemes and import of paddy mainly from the Mekong Delta as currently being practiced.

(3) Comparison of Diversion Schemes at Phuoc Hoa and at Fu Mieng

It is worth mentioned that the diversion scheme of Fu Mieng is selected as the optimal diversion scheme when compared with the Phuoc Hoa scheme. As a comparison, the model is set so as to enforcing the selection of Phuoc Hoa diversion scheme.

The result of the analysis reveals that the net benefit of the model when Phuoc Hoa diversion scheme is selected would become US$ 491 million while that of Fu Mieng diversion scheme is US$ 492 million. While the difference of net benefit between two schemes is marginal, the model concludes that Fu Mieng diversion scheme is more beneficial and therefore it is included in the optimal set of solutions. Further studies to select the optimal one between two alternatives are discussed in subsequent Section 9.2.

(4) Development of East Coast Area by Dai Ninh Diversion

From the optimal set of solutions presented, it is found that diverted water from Dai Ninh to the east coast area would fully be utilized by constructing the Song Luy reservoir and by re-diverting water to the Cai River for the full development of Phan Thiet and Phan Ri plains. To realize these irrigation development, the active storage capacity of 110 million m^3 is required for the Song Luy reservoir.

(5) Development of Hydropower Damsites

The results indicate that the reservoir development at Dong Nai No. 3 and Dong Nai No. 4 is not required. It should be noted that, however, this result came from the constraints incorporated in the Model, such as underestimated energy output due to adoption of 4-year draught year, which was required in conformity with the irrigation planning criteria, and the limitation of the model which cannot incorporate the electricity demand by the target year 2015, hence no consideration is made for capacity value assessment.

Hydropower development in the Study Area is studied in Appendix V, Hydropower Generation, in which the generation expansion planing study is separately carried out, and it confirmed that the combined development of Dong Nai No. 3 and No. 4 is necessary in the year 2006 to 2008. It is also obvious that the reservoir development such as Dong Nai No. 3 and Dong Nai No. 4, would create further positive impacts to the downstream flow, especially in the dry season. Therefore, the optimal set of solutions obtained by the water allocation study should concurrently be considered.

(6) Water Requirement at the Hoa An Intake and Future Development of the Dong Nai River Basin beyond the Target Year 2015

The minimum flow requirement at the Hoa An intake for the salinity intrusion is set at 100 m^3/s, whilst water supply requirements for HCMC and the towns along National Highway No. 51 are 36.8 m^3/s.

Since the minimum monthly firm discharge at Tri An is set at 230 m^3/s, the balance between water actually released from the Tri An power plant and water requirements for water supply and salinity intrusion is counted as the future potential for development. Following is the discharge secured at Hoa An before the abstraction of requirements for water supply:

(Unit in m^3/s)

Jan.	Feb.	Mar	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
414	234	241	243	468	294	472	1,015	500	1,237	674	295

The above Table suggests the fact that a further development of some 100 m^3/s (i.e. 234 - 36.8 - 100 m^3/s) be possible beyond the target year 2015 at the downstream reaches of the Dong Nai River, provided that the minimum flow of 100 m^3/s is kept at the Hoa An intake for salinity intrusion and that the minimum monthly firm discharge at Tri An is kept at 230 m^3/s.

Direct diversion from Bien Hoa of the Dong Nai River to the Saigon River and further through the Rach Tra canal to the East Vam Co River would be considered as one of development alternatives beyond the year 2015 for further development of low-lying areas extending in HCMC and Long An province. Such a proposed diversion route is shown in Figure 8.5.

Figure 8.6 shows the comparison of flow of the Dong Nai River at Hoa An between that in the Model Solution after abstraction of water requirements for water supply, irrigation and diversion for the Master Plan Projects, and the natural flow with only the Tri An reservoir is in operation (as the present condition) but without implementing any Master Plan Project.

Similarly, discharge secured at Phu Cuong of the Saigon River, where the minimum flow is set at 25 m^3/s for salinity intrusion, after the abstraction of requirements for water supply is as follows:

(Unit in m^3/s)

Jan.	Feb.	Mar	Apr.	May	Jun.	July	Aug.	Sep	Oct.	Nov.	Dec.
25	25	25	25	37	83	42	25	52	75	60	25

For the East Vam Co River, discharge secured just downstream of Xuan Khanh, where the minimum flow is set at 20 m^3/s for salinity intrusion, after the abstraction of water

requirements for irrigation for Long An Delta-Rach Tram is also presented as follows for reference:

(Unit in m^3/s)

Jan.	Feb.	Mar	Apr.	May	Jun.	July	Aug.	Sep	Oct.	Nov.	Dec.
20	20	20	20	22	59	32	62	59	183	54	26

8.2.3 Sensitivity Test

A 4-year drought flow estimated at Hoa An is used to gain the optimal water allocation of the Dong Nai River basin, since the Hoa An site is considered to be the most appropriate place to measure hydrological regime of the whole of the Dong Nai River basin.

However, there is an argument that hydrological regime does not necessarily coincide between the Dong Nai main stream and the Be River, which is the crucial water source for the diversion scheme to the Saigon and East Vam Co river areas. Indeed, a careful assessment of discharge data at the Phuoc Hoa station, which is the representative discharge gauge in the Be River basin, shows the 4-year drought in the 1969 water year, i.e. November 1968 to October 1969, against the 1974 water year at Hoa An.

A sensitivity test is carried out to see the change of irrigable area, in particular in the Saigon and East Vam Co river basin, by applying flow data of the 1969 water year to each interesting site.

Following shows the result of sensitivity test and compares the irrigable areas gained by applying 1969 and 1974 water year data for each scheme:

Irrigation Scheme	Irrigable Area, ha		
	Maximum	1974 Water Year	1969 Water Year
Site 6 Phuoc Hoa	45,680	45,680	45,680
Site 7 Dau Tieng (Extension)	48,390	48,390	48,390
Site 8 Phan Ri	29,700	29,700	29,700
Site 9 Phan Tiet	10,000	10,000	10,000
Site 10 Ta Pao	23,000	19,000	19,000
Site 11 Vo Dat	15,000	12,617	8,915
Site 12 Dau Tieng (Existing)	45,000	45,000	45,000
Site 13 Tay Ninh Upper	15,100	10,825	8,926
Site 14 Tay Ninh Lower	14,300	14,300	1,4300
Site 15 Dong Nai Riparian (Existing)	23,400	23,400	23,400
Site 16 Long An Delta	54,000	31,170	23,773
Site 17 HCMC	46,000	46,000	40,752
Total	369,570	336,082	317,836

The above sensitivity test tells the tendency that the irrigable area, in particular Long An Delta and HCMC, reduces as the flow of the Be River decreases. Taking into consideration the uncertainties involved in return flow, cropping pattern and maintenance flow of the Saigon and East Vam Co rivers, the result obtained by using hydrological data of the 1974 water year is treated as a prime result, whilst reference for the result gained by the 1969 data.

8.3 Development of Rural Area

The mathematical model solutions discussed in Section 8.2 deal with only large scale development projects in respect of the optimal water allocation of the Dong Nai main river system such as the Dong Nai River main stream, the La Nga River, the Be River, the Luy River, the Saigon River and Vam Co River. It is however to be stressed that there are rural areas where they cannot receive any benefits (or indirectly or partially only) from implementing these large scale projects due to their topographical locations such as isolated areas, remoteness from major demand centres, and rather small development scale.

Migration of people seeking job opportunities from rural areas to large towns such as Ho Chi Minh City, called mechanical increase, not only has merits to supply labour force necessary for sustaining economic development of the SFEA, which is a locomotive of national economic development, but also brings side-effects to deteriorate urban amenity as represented by squatters' houses built along the rivers and canals.

Excessive migration of people to urban areas mainly results from the living standard of rural area staying at a subsistence level. This severe lives in the rural area may be inferred from the performance of rural water supply projects in the Study Area as dealt with in Appendix VII, Domestic and Industrial Water Supply; that is, the work to collect drinking water still shares a large part of daily life of women and children in the rural area.

Taking into account the living condition in the rural area, matters to be carried out for the socio-economic development in the Study Area most urgently are to improve social amenity and to create job opportunities in the rural area, which should be carried out in parallel with developing the large scale projects under the long term objectives, and which is one of the principal policies adopted for this Master Plan Study to realize the most efficient and balanced development programme in the Study Area.

In terms of water resources development, enhancement of social amenity can be made by improving water supply in the rural area including district and major towns in the respective regions. As discussed in Appendix VII, a total of 1,207 rural water supply projects are

proposed to be implemented within the coming 20 years as parts of the work to enhance social amenity.

On the other hand, creation of job opportunities will be made by improving and rehabilitating small scale irrigation projects scattered throughout the Study Area. As discussed in Appendix VI, Agricultural Development and Irrigation, a total of 229 small scale irrigation schemes are identified in the Study Area, consisting of 164 improvement and rehabilitation schemes and 65 new schemes. As part of creating job opportunities in the rural area, actions to realize the improvement and rehabilitation of those 164 existing schemes as well as the implementation of 65 new schemes are urgently required.

Following is the summary of small scale projects to be implemented for the rural development in the Study Area :

Province	Small Scale Irrigation Projects				Rural Water Supply Projects	
	Existing Rehabilitation Projects		New Proposed Projects			
	Number of Projects	Total Area (ha)	Number of Projects	Total Area (ha)	Number of Communes	Number of Projects
Lam Dong	25	10,809	3	3,050	29	93
Dac Lac	1	120	0	0	19	46
Ninh Thuan	15	3,932	3	6,400	9	47
Binh Thuan	56	20,033	2	608	25	193
Ba Ria-Vung Tau	15	8,080	18	8,450	20	239
Dong Nai	33	16,930	7	9,770	18	190
Song Be	16	4,581	20	11,094	11	78
Tay Ninh	3	3,260	12	21,870	9	119
Long An	0	0	0	0	30	202
Total	164	67,745	65	61,242	170	1,207

The promotion of small scale irrigation schemes has effects not only to create job opportunities through direct employment or participation, but also to enhance the induction of agro-based industry and to improve chronic malnutrition common in the rural area.

It is true that it takes much time to complete the rural water supply programme and the improvement and rehabilitation programme of small irrigation projects due to their numerous number. However, implementation of one rural water supply project or small scale irrigation scheme generates quick effect to the beneficial area. Thus, it is considered urgent to make an implementation programme of rural water supply and small irrigation projects to carry out step by step. For expediting the implementation of such rural development, some financial

assistance from foreign countries will be required to reduce the financial burden to the government.

8.4 Selection of Master Plan Projects

The optimal allocation study of water resources available in the Study Area as discussed above has presented various significant points of consideration for the integrated development of the Study Area. Based on the result of the optimization study in Section 8.2 as well as the discussions to enhance the living standard in the rural area in Section 8.3, master plan projects to be implemented within coming 20 years, i.e. by the year 2015, in the Study Area are proposed as given below:

(1) Improvement and rehabilitation of 164 small scale irrigation projects as well as the implementation of 65 new ones as the rural agricultural development project,

(2) A total of 1,207 rural water supply projects,

(3) Two hydropower projects with reservoir (420 MW in total);
Dong Nai No. 3: 180 MW
Dong Nai No. 4: 240 MW,

(4) The Be-Saigon diversion project (a diversion amount of 60 m^3/sec to the existing Dau Tieng in the Saigon River basin),

(5) Eight (8) irrigation projects (242,560 ha in total) including Song Luy irrigation reservoir porject (110 million m^3 in active storage); Phuoc Hoa (45,680 ha), Dau Tieng Extension (48,390 ha), Phan Ri (29,700 ha), Phan Thiet (10,000 ha), Ta Pao (19,000 ha), Vo Dat (12,620 ha), Long An Delta (31,170 ha) and HCMC (46,000 ha),

(6) Water supply project along National Highway No. 51 (1.7 million m^3/day in demand), and

(7) Strengthening of the organization on water-related institutions.

The master plan projects proposed in the Study Area are summarized in Table 8.4 and shown in Figure 8.7 except for Item 7, which is the institutional proposal to smoothly implement the projects mentioned in Items 1 to 6 and is discussed in subsequent Section 10.2.

The supplemental notes on the above plans and projects are as follows:

Rural Development for Small Scale Irrigation and Water Supply Projects

In order to raise the living condition and create job opportunities in the rural area, it is proposed that the rural water supply projects and small-scale irrigation projects be incorporated as a set of master plan projects.

Noting the urgent demand which must be responded by the Government, these small-scale irrigation projects and rural water supply projects are critical for the overall increase of the living standard in the rural area. This set of master plan projects would not only create job opportunities but also focus on the improvement of social amenity and reduction of poverty in the rural area. In other words and most importantly, it would contribute to the sustainable development of the rural area. While the scale of each project within this set of master plan projects is small, the significance of the impacts of these projects which will contribute to the rural area cannot be neglected.

Hydropower Projects

In view of the future electric supply situation in which the electric power demand is expected to grow some 10 times greater than the present level within coming 20 years as discussed in Appendix V, and from viewpoint of efficient utilization of the indigenous resource which is environmentally clean and renewable, and contributing to saving foreign exchange earnings for importing fossil fuel at the same time, hydropower projects shall be developed as much as possible.

These projects will create further positive impacts to the downstream flow, especially in the dry season. Considering the full development of SFEA and further demand which will be created by future expansion of Economic Triangle Zone, HCMC and its vicinities beyond the target year of 2015 to the mid-21 century, the positive impacts of the combined scheme of Dong Nai No. 3 and Dong Nai No. 4 cannot be neglected and this scheme is thus incorporated as the master plan projects.

It is to be noted that the power output of Dong Nai No. 3 , No. 4 and Fu Mieng was initially assumed to be 130 MW, 318 MW and 60 MW respectively during the Phase II study period. However, based on the topographic survey, geological mapping and the further optimization study carried out in the Phase III Study, the capacities of these projects are modified to be 180 MW, 240 MW and 55 MW respectively.

Large Scale Irrigation Projects

In view of the integrated regional development, a total of eight irrigation projects out of ten projects are incorporated as the master plan projects with large scale, and Tay Ninh Upper

(10,825 ha) and Tay Ninh Lower (14,300 ha) which were components of the mathematical water allocation model, are categorized under the improvement and rehabilitation of small scale irrigation projects since those two areas are a cluster of small scale irrigation projects. As noted above, the irrigation development to the full extent under the optimal utilization of water resources in the Dong Nai and surrounding river basins would contribute to the stable food supply in the Study Area.

Furthermore, the optimal allocation study has also revealed the fact that, in order to support the full development of potential irrigation area, three key projects: 1) Dai Ninh hydropower/diversion for the inter-basin transfer of water resources of the upper Dong Nai River basin for the development of east coast area; 2) inter-basin transfer of water resources of the upper Be River basin for the development of the Saigon and East Vam Co river basins; and 3) Song Luy irrigation reservoir for the full utilization of water resources to be made available by the construction of Dai Ninh for the east coast area are indispensable. Taking into consideration that the Dai Ninh project is already given the priority to be developed in early 2000s by the Vietnamese Government, the project is treated as a committed project, i.e. exclusion from the list of master plan projects, and Be-Saigon diversion project and Song Luy reservoir projects are included in the list of this master plan projects.

Water Supply Projects Along National Highway No. 51

Development of domestic and industrial water, as discussed in detail in Appendix VII, is important not only for meeting the basic human needs in the Study Area, but also for economic development in the southern Viet Nam including SFEA which is considered as a locomotive area for future national economic development.

While many districts and major towns scattered in the Study Area still have such a scale that their water demands can be met with the development of groundwater, HCMC and the corridor area along National Highway No. 51 between Bien Hoa and Vung Tau are needed to seek a water source of domestic and industrial water supply to surface water such as the Dong Nai River due to a large future demand of 2.1 million m^3/day for the former and 1.7 million m^3/day for the latter in the year 2015.

Water supply projects for HCMC and the corridor area along National Highway No. 51 are thus considered to be two candidates for master plan projects by taking into account the development scale as well as the influence to the economic development in the nation.

Currently, a master plan study has been completed with funds from the Asian Development Bank to make a concrete development plan for the water supply of HCMC. On the other hand, the corridor area along the National Highway No. 51 consisting of five demand zones (refer to Appendix VII) does not so far have a clear plan for water supply in an integrated manner, even

if studies for a few specific projects are independently carried out by the Vietnamese Government.

Taking into consideration the situation mentioned above, the water supply project along National Highway No. 51 is selected as the master plan project of water supply.

Flood Mitigation

Flood mitigation study discussed in Appendix VIII identifies the flood prone-areas in the Study Area such as Cat Tien and Ta Lai area in the upper Dong Nai, Ta Pao and Phu Dien area in the La Nga River and the lower Dong Nai and Saigon River areas. Since flood simulation study reveals that flood damages in the said areas are substantially solved with flood retardation effects of the existing and proposed reservoirs, flood mitigation projects are not included in the list of master plan projects. However, in case where the proposed irrigation master plan projects are still susceptible to flooding, in particular, local flooding, a flood mitigation plan shall be studied as part of irrigation development for those projects.

Overall Planning, Coordination and Management

Finally, the result of the optimal allocation study of water resources available in the Study Area has emphasized the importance of integrated approach to the water resources development.

Most of the development projects reviewed in this master plan study, although some are newly identified during the study period, have been studied previously by line ministries and agencies or by provincial governments. However, while some of these projects have been found feasible as an individual project, feasibility in terms of the Dong Nai River and surrounding river basins as a whole has never been analyzed.

It is considered that the overall and integrated planning, coordination and management of the water resources development in the Study Area will be the key factor for the successful implementation of the proposed master plan projects by the year 2015. To realize this, a regional level institutional framework and management unit for continuing the project-related activities of the Dong Nai Master Plan is recommended to be organized. For further detail, reference is made to Chapter 10.

9. PRELIMINARY BASIC DESIGN AND EVALUATION FOR THE SELECTED MASTER PLAN PROJECTS

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

9.1.1 Project Layout and Preliminary Basic Design

The project layout including the reservoir water levels of the combined development of Dong Nai No. 3 and No. 4 is 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.

Based on the power optimization study, it is confirmed 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 (for further details, refer to Appendix X: Hydropower Generation).

The principal features of the project are summarized in Table 9.1, and the basic layout and design prepared based on the cross section survey results are shown in Figures 9.1 and 9.2.

9.1.2 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 of 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.

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

9.1.3 Initial Environmental Examination

Project Area

The proposed reservoir areas are virtually undisturbed and would involve flooding of riverine fringe forests with relatively high wildlife habitat values and adjacent areas which are bamboo forests in the case of Dong Nai No. 3 and bamboo and evergreen in the case of Dong Nai No. 4 Project. All these ecosystems are widely distributed in Central Viet Nam with equivalent habitats both upstream and downstream along the Dong Nai River, including in Cat Tien National Park. The general distribution of wildlife in the project areas would be also similar to that in Cat Tien National Park, however, it is indicated through discussions with local communities that the Javan Rhinoceros areas do not exist in the proposed reservoir area.

There are only limited communities located in and near the areas affected by the projects, and the nearest villages to the damsite/reservoir in each case are of the order of 4 to 8 km away. The villages indicated to be immediately upstream of the Dong Nai No. 3 damsite have been relocated to ridge sites in the B'sre area above proposed reservoir level. Continued use of these areas and the groups involved and their customary rights to the areas in the reservoir area need to be confirmed. Human use of the area is limited at present to opportunities for exploitation of forest, fruits and leaves, bamboo, rattan, wildlife (hunting and trapping) and fish. No local communities are entirely dependent on the forests of the proposed reservoir areas for their subsistence or income.

Aquatic Ecology Aspects

The water quality of the Dong Nai No. 3 and No. 4 reservoirs would be entirely dependent on the extent to which clearing of vegetation is undertaken. With relatively small reservoir areas, it

may be possible to log and extract forest products from the majority of the reservoir areas. Rafting of bamboo for recovery filling may also need to be considered due to topography constraints in both the reservoir area. Prediction of Dissolved Oxygen (DO) levels should be undertaken for the EIA study based on forest inventory/biomass surveys and assumptions regarding the effective extent of clearing.

The annual productivity and potential yields for reservoir fisheries could be limited due to several factors including:

- Relatively narrow deep reservoirs characterized by drawdowns of 25 to 30 m (Dong Nai No. 3),
- Low primary productivity due to limited nutrients present in river inflows and cooler water temperatures in the reservoirs,
- Potential thermal or chemical stratification during the winter season due to ambient temperatures and decaying biomass from seasonally exposed drawdown zones.

Socioeconomic and Resettlement Aspects

The main communities in the vicinity of project areas are as follows:

Dong Nai No. 3

B'sre (90 to 100 families) east of the damsite and Dak Plao (225 families) near the top end of the reservoir are located well above proposed reservoir FSL of El. 570 m. The extent to which Route 724 south from the Dong Nai River to Dinh Trang Tuong would be flooded needs to be verified by topographical survey.

Dong Nai No. 4

Quang Khe consisting of 250 to 260 families plus several outlying hamlets to the north along Route 724 and to the east toward the damsite is all located above the reservoir level, however, their requirement of access routes needs to be clarified and confirmed.

Compensation and resettlement requirement as presently indicated for the Dong Nai No. 3 and No. 4 are considered to be acceptable. The situation could alter however between now and project construction due to ongoing influx of people to the general area. A "land freeze" on permanent occupation and allocation of land in the reservoir and their immediate tributary catchment within 3 to 4 km of the reservoir margins should be considered. It is possible that Dac Nong's Dak Plao community of 225 households may need to be relocated for the Dong Nai No. 3 Project, however no communities presently exist in the southern sector of the reservoir in Di Linh district.

The main potential socioeconomic effects of the Dong Nai No. 3 and No. 4 projects would include:

- Economic expansion of the two district centres nearest the projects: Di Linh to the south in Lam Dong province and Dak Nong to the north in Dac Lac province,

- Upgrading of Route 724, eventually to be National Highway No. 8 linking Dak Nong and Di Linh as well as associated effects particularly relating to:

  i. Improved access for existing communities to local and regional market,
  ii. Localized benefit to existing and new business along the road, and
  iii. Secondary benefits to local community for access to schools, health facilities and services.

- Adverse effects on land and forest resources due to further pressure for land development and forest area exploitation and in-migration due to employment opportunities,

- Opportunities to consolidate regional and area development plans due to improved infrastructures, communications and diversification of the local economy.

Conclusion and Recommendations

The combined development of the Dong Nai No. 3 and No. 4 projects, although located in relatively remote areas, could be constructed and operated in an environmentally acceptable way. The main environmental adverse effects would relate to further losses in riverined habitat of the Dong Nai River system. This could be acceptable, provided the extent of losses of the habitat type does not extend completely along the Dong Nai River through cascade type dam and reservoir development. It is considered that socioeconomic benefits would accrue in the long term relating to local, district and regional development, provided in-migration for land development in the catchment is controlled.

The exact elevation of the Dak Plao community and its associated hamlets as well as traditional lands used by the minority groups (Mnong) and the project effect on this community require special attention (including anthropological survey) at an early stage so that a comprehensive Resettlement or Indigenous People Action Plan can be prepared to comply with any multilateral lending agency's requirement.

9.1.4 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 9.2 and 9.3.

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 an assumption that the least cost alternative for the combined development of Dong Nai No. 3 and No. 4 is a combined cycle power plant with a capacity of 450 MW.

Table 9.4 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 electric power supply system in these days is required to maintain high quality in voltage and frequency control due to recent increase in utilizing electronic computers and relevant equipment. 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 sizable peak power output, the combined development of Dong Nai No. 3 and No. 4 is recommended to install an auto-frequency control system, when developed.

9.2 Fu Mieng Multipurpose Project

9.2.1 Project Layout and Preliminary 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 9.1.

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. The power output is thus revised accordingly, 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 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 approximately 10 km long river section immediately downstream of the 7 km diversion channel to receive the diverted water without causing 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 active 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 9.3, and the breakdown of the total project cost estimated based on the design so prepared is summarized in Table 9.5.

9.2.2 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 strong enough 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).

9.2.3 Initial Environmental Examination

Project Area

The entire reservoir area and much of its surrounds were zones of intensive fighting in the 1968 to 1975 period with most of the villages/hamlets being destroyed and of extensive areas subjected to defoliation spraying and destruction of plantations and native forests by burning. No major villages have been re-established in the reservoir area, but land clearing and cultivation for rice paddy, upland crops and cashew have been ongoing since the early 1980's. It is estimated that some 500 to 550 families now reside in scattered locations throughout the proposed reservoir area or close to the diversion channel alignment.

Most of the residual land in the reservoir area not subject to recent re-occupation or used for upland crops on a seasonal basis is covered with scrub bamboo regrowth. Only scattered pockets of riverine forest remain along the main Be River and tributary streams.

As with the project area, much of the region in Binh Long and Phuoc Long districts was subjected to destruction during the 2nd Indochina War. Presently, redevelopment of upland rubber plantations is being undertaken by district (State) enterprises, and private farm development is proceeding slowly with controls on irrigation and land allocation still in place by authorities due to security requirements.

Subsistence (i.e. rice and maze) and cash crops (e.g. cashews) are most practical at this time due to constraints of land capabilities, farm access and distance to market. Due to the subsistence level of living in the area, use of residual forest and wildlife resources occurs extensively, including use by persons employed in State enterprise rubber plantations.

Aquatic Ecology Aspects

Water quality problems are unlikely to occur in Fu Mieng reservoir and its diverted waters due to the limited biomass of natural vegetation in the area of impoundment. Also most of the areas surrounding the reservoir margins are rubber plantation or regrowth forest lands. Further land clearing in the immediate reservoir zone would improve water quality in the reservoir to some extent, but the reservoir is located far enough downstream of Thac Mo that incoming flows would be re-aerated and diluted substantially.

An aquatic community similar to Tri An, Thac Mo and Dau Tieng reservoirs should evolve at Fu Mieng reservoir including its fisheries resources. In fact, this reservoir could have a basically better aquatic ecology due to good water quality because of limited decaying vegetation. Nutrient inflows would be the critical factors, however due to the limited agricultural development potentials (e.g. tree crops such as rubber or plantation forest and limited population) thus trophic conditions are unlikely to occur.

Fisheries potentials in the reservoir should be good for development of both open water capture fisheries and aquaculture with an average surface area of 50 to 60 km^2. A preliminarily estimated yield of 125 to 150 tones per year from open water plus 50 to 60 tones per year from aquaculture activities should be possible with limited management inputs.

Resettlement and Socioeconomic Aspects

Potential effects related to compensation, resettlement and socioeconomic activities include:

- The reservoir area has been severely degraded due to destruction of previous villages as well as the natural vegetation and tree crops during the 1968 to 75 period.

- People have been moving back into the area since the mid 1980's, establishing a few villages and cultivating upland rice and tree crops, mainly cashews and coffee, with some pepper vines.

- The standard of living is mainly at the subsistence level with limited development of access road and other infrastructure such as schools and health posts to date.