4. LAND AND WATER RESOURCES DEVELOPMENT PLAN

4.1 Plan Formulation

4.1.1 Methodology

The Khlong Yai dam has a nature of multiple-purpose areal-development project, since it is designed as an element of regional plan. It is one of the series of multiple-purpose dams to be developed in the Rayong river basin.

The existing Dok Krai dam has altered its main function from the irrigation water supply to Ban Khai existing area to the domestic and industrial water supply to Map Tha Phut-Sattahip area. The Nong Pla Lai dam has been formulated to replace the function of Dok Krai dam and to expand the irrigation area in the Rayong river basin. As revealed through the water demand and supply balance in Section 2.6, Nong Pla Lai dam is required to divert a part of its regulated water to Nong Kho reservoir to secure the domestic and industrial water demand in Laem Chabang-Pattaya area. As the consequence of the foregoing, Khlong Yai dam is projected to assure the irrigation water demand within the Rayong river basin. The irrigation water demand within the zone and the inter-zone water diversion to Nong Kho reservoir are, thus, ensured by development of Nong Pla Lai and Khlong Yai dams.

The land and water resources development comprises the irrigation and agricultural development, domestic and industrial water supply and development of Nong Pla Lai and Khlong Yai dams. The domestic and industrial water supply will be maintained at rates set forth in Section 4.2. The development scale of Nong Pla Lai dam has already been determined by the previous study, namely, "Main Report, the East Coast Water Resources Development Project, March 1982, JICA". Thus the optimum land and water resources development plan will be ascertained dealing with three variables; extent of irrigation area, cropping intensity and development scale of Khlong Yai dam.

In order to establish a relationship between the irrigation area, cropping intensity and storage capacity of Khlong Yai reservoir, a number of reservoir operation studies were conducted with the aid of degital computer. The study includes also the operating of Nong Pla Lai reservoir.

Based on the relationship, various development alternatives were arbitrarily evolved and their cost and benefit were estimated for economic comparative study. A development plan generating the maximum annual net benefit is recommended as proposed development plan.

The plan formulation on the land and water resources development is studied in detail as a part of water resources engineering as presented in Sectoral Report XI.

4.1.2 Reservoir Operation Study

The operations of Nong Pla Lai and Khlong Yai reservoirs were simulated at intervals of 10-day period during a 14-year period from April, 1968 to March, 1982. The study was processed in line with concepts described below. Fig. 25 illustrates a schematic water supply diagram with symbols adopted hereunder.

(1) Water balance points were set up at Khlong Yai weir and Ban Khai weir, where the irrigation waters are to be diverted.

(2) The Khlong Yai and Nong Pla Lai dams assures all the water demand during the simulation period.

(3) The domestic and industrial water to be diverted to Nong Kho reservoir (Qdw) is properly sustained by Nong Pla Lai reservoir.

(4) The water deficit at Ban Khai weir balance point should be met by release from Nong Pla Lai reservoirs.

(5) The domestic and industrial water demand within the basin (QDI) and river maintenance flow (QMF) are maintained at constant rate throughout the year.

(6) The irrigation water supply to the Ban Khai Extension Area will be served by both the Nong Pla Lai and Khlong Yai dams.

The flow chart of the reservoir simulation calculation is shown in Fig. 26. The simulations of Nong Pla Lai and Khlong Yai reservoirs are cited for the selected plan as shown in Figs. 27 and 28 respectively.

Based on the results of the reservoir operation study, the relationship between the irrigation area, cropping intensity and active storage capacity of Khlong Yai reservoir is developed as shown in Fig. 29. The cropping patterns and corresponding irrigation water requirements are compiled in Sectoral Report II, Agricultural Development Plan and Sectoral Report III, Irrigation Development Plan, respectively.

4.1.3 Development Alternatives

The relationship in Fig. 29 is carefully examined from the viewpoint of the land and water resources development and five development alternatives are arbitrarily established to sound their economic feasibility. The five alternatives are as under-listed.

Alternatives	Cropping Intensity (%)	Net irrigation Area (ha)		Reservoir Active Storage (10^6 m^3)	
		Ban Khai Existing	Ban Khai Extension	Nong Pla Lai	Khlong Yai
1-1	130	4,800	7,700	144.4	27
2-1	140	4,800	7,700	144.4	48
3-1	150	4,800	6,500	144.4	44
3-2	150	4,800	7,100	144.4	55
3-3	150	4,800	7,700	144.4	68

4.1.4 Economic Comparison

The project cost and benefit were calculated for the respective development alternative as described hereunder.

(1) Project cost

The land and water resources development is formed by the following components.

(1) Nong Pla Lai and Khlong Yai dams
(2) Nong Pla Lai water conveyance system
(3) Irrigation and drainage system in Ban Khai Extension Area

The construction cost, operation and maintenance cost and replacement cost were estimated for each project component at the price level of 1982. The construction cost of Khlong Yai dam is estimated based on the preliminary design, while that of Nong Pla Lai was obtained by updating the cost presented in the aforesaid report.

The construction cost was converted into annual equivalent cost at a discount rate of 8 % per annum with economic life of 50 years. The annual equivalent cost and operation, maintenance and replacement costs are shown in Table 16 for the respective develop- ment alternative.

(2) Project benefit

The project benefit is generated by the domestic and industrial water supply and land development. The water supply benefit is derived from the inter-zone water diversions to Map Ta Phut-Sattahip area and to Nong Kho reservoir. The land development benefit is accrued from the irrigation and agricultural development in Ban Khai Extension Area. More detailed discussion on benefit of each component is stated in Chapter 8.

The project benefit of each development alternative is as shown in Table 16.

The annual net benefit is defined as the annual benefit less the annual equivalent cost and OM & R cost. It is calculated for every development alternative as presented in Table 16 and is correlated to the active storage capacity of Khlong Yai reservoir as shown in Fig. 28.

As demonstrated in Fig. 30, Alternative 2-1 induces the maximum annual net benefit among 5 alternatives compared and therefore is justified to be the optimum land and water resources development plan.

4.2 Optimum Development Plan of Khlong Yai Dam Scheme

The plan formulation on the land and water resources development plan has clarified the optimum active storage of Khlong Yai reservoir, cropping intensity and irrigation area. Also the plan formulation on the flood mitigation plan has revealed the storage capacity requirement in the Khlong Yai reservoir for flood control. The development scale of Khlong Yai Dam Scheme in association with Nong Pla Lai dam is finally determined integrating the above study results as shown below.

(1) Multiple-purpose Dam

		Nong Pla Lai	Khlong Yai
Reservoir			
Gross storage capacity	:	200.7 x 10^6 m^3	7.15 x 10^6 m^3
Surcharge	:	43.5 x 10^6 m^3	16.9 x 10^6 m^3
Active storage capacity	:	144.4 x 10^6 m^3	48.0 x 10^6 m^3
Dead storage capacity	:	12.8 x 10^6 m^3	6.6 x 10^6 m^3
Flood water level	:	El. 47.0 m	El. 48.8 m
High water level	:	El. 45.0 m	El. 47.5 m
Low water level	:	El. 33.3 m	El. 40.6 m
Dam			
Crest elevation	:	El. 49.0 m	El. 50.8 m
Dam height, above the riverbed	:	31.0 m/1	17.3 m

/1: Above the cut-off bottom

(2) Land Development

Irrigation area	:	7,700 ha (Ban Khai Extension Area) 4,800 ha (Ban Khai existing area)
Proposed crops	:	Paddy, Groundnuts, Vegetables, Fruit Trees
Cropping intensity	:	140 %

(3) Domestic and Industrial Water Supply

Map Ta Phut-Sattahip Area	:	53.5×10^6 m^3/year
Nong Kho Reservoir	:	31.3×10^6 m^3/year

With development of Nong Pla Lai and Khlong Yai dams, the entire irrigable area in the Rayong river basin, consisting of 4,800 ha of Ban Khai existing area and 7,700 ha of Ban Khai Extension Area, can be cultivated with the proposed cropping pattern with 140 % of cropping intensity under the year-round irrigation water supply.

4.3 Domestic and Industrial Water Supply

The Khlong Yai Dam Scheme bears the water supply to the coastal area. According to the water demand and supply balance, Chon Buri-Pattaya area will encounter with a huge quantity of water shortage; 5.3×10^6 m^3 in 1991, 19.7×10^6 m^3 in 1996 and 42.3×10^6 m^3 in 2001. The long-term water supply plan endorsed the inter-zone water diversion plan. The water shortage will be solved by water diversion from both the Khlong Luang and Rayong river basins, in proportion to their run-off coefficients and availabilities of water. Water diversion from the Khlong Yai Dam Scheme is computed by the following equation;

$$Qn = WD \times [k(2) \times AD(2)]/[k(1) \times AD(1) + k(2) \times AD(2)]$$

$$AD(1) = ND(1) - DI(1) - MF(1)$$

$$AD(2) = ND(2) - DI(2) - MF(2)$$

where,

Qn: annual water diversion from the Nong Pla Lai dam
Wd: annual water shortage in Chon Buri-Pattaya area
k : run-off coefficient of river
ND: annual regulated outflows from the reservoirs
DI: domestic and industrial water demand in the basin
MF: river maintenance flow
Suffixes (1) and (2) mean the Khlong Luang river basin and the Rayong river basin respectively.

The Khlong Yai Dam Scheme diverts the domestic and industrial water into Chon Buri-Pattaya area at a rate of 4.9×10^6 m^3 in 1991, 14.2×10^6 m^3 in 1996 and 31.3×10^6 m^3 in 2001.

Water withdrawal in Map Ta Phut-Sattahip area will be totally supplied by Dok Krai reservoir through Dok Krai Pipeline Project. The quantity of annual water supply is projected at 38.2×10^6 m^3 in 1986, 43.2×10^6 m^3 in 1991, 48.2×10^6 m^3 in 1996 and 53.5×10^6 m^3 in 2001.

The total inter-zone water diversion from the Rayong river basin is summarized as follows;

(Unit: 10^6 m^3/yr)

Water Conveyance System	1986	1991	1996	2001
Nong Pla Lai system	-	4.9	14.2	31.3
Dok Krai system	38.2	43.2	48.2	53.5
Total	38.2	48.1	62.4	84.8

Domestic and industrial water demand within the zone will be supplied by Dok Krai reservoir through Ban Khai pipeline system.

4.4 Agricultural Development Plan

4.4.1 Proposed Irrigation Area

According to the results of plan formulation on land development, the entire Ban Khai Extension Area is planned to be provided with a systematic irrigation and drainage system. The area is 7,700 ha in a net and lies along Left Main Canal of Ban Khai existing area as shown in DWG No. 3-1.

In addition rehabilitation of existing irrigation facilities in Ban Khai existing area is recommended to be carried out for effective and efficient use of water as noted in Section 9.3. The irrigation area of Ban Khai existing area is shown in DWG No. 3-2.

4.4.2 Proposed Cropping Pattern

The proposed cropping pattern with 140 % of cropping intensity is shown in Fig. 15 for Ban Khai Extension Area and in Fig. 16 for Ban Khai existing area.

Rice will be cultivated predominantly as the nation's principal food and export commodity. The Government has been emphasizing in its Fifth National Plan an increase of rice production to cope with future population increase and to improve the international trade balance. The high yielding varieties will be predominant among rice varieties in future and will be planted for 87 % and 80 % of the rice planting areas during the wet season for the extention are and existing area respectively. The traditional varieties will also be grown in the remaining area during the wet season for the sake of distribution of risk and choice in taste.

Rice will also be grown during the dry season in about 10 % of the proposed irrigation area in both the Ban Khai Extension and existing areas.

Groundnuts will be cultivated during the dry season. They are selected from the viewpoints of soil conservation and farmer's cash income.

Vegetables will also be cultivated during the dry season in relatively large area. Consumption of vegetables are predicted to be increased with a leap in the coastal area resulting from the induced population.

The future land use in the proposed irrigation area will be as follows.

(Unit: ha)

Crops	Ban Khai Existing Area		Ban Khai Extention Area	
	Wet Season	Dry Season	Wet Season	Dry Season
Rice				
- Local varieties	960	-	1,420	-
- High yielding varieties	3,840	540	5,700	850
Groundnuts	-	1,080	-	1,730
Vegetables	-	300	-	500
Fruit Trees	-	-	(580)	580
(Cropping intensity)	140 %		140 %	

4.4.3 Proposed Farming Practices

In line with development of advanced irrigation and drainage system, the improved farming practices will naturally be introduced into the area to attain and maintain the high crop productivity. The proposed farming practices by major crop are described hereunder.

(1) Rice

The distribution of seeds of the high quality is essential to increase the crop yield as expected. The RD varieties such as RD-7, RD-9 and RD-25 are recommended as high yielding varieties.

The fertilization is also significant to increase the yield. The fertilizer application rates are proposed as follows:

Varieties of Rice	Application Rate (kg/ha)	
	Nitrogen	Phosphate
High Yield	80 - 100	30 - 50
Local	30 - 40	20 - 30

For plant protection, intensive application of agro-chemicals will be adopted to control insects (stemborers and plant hoppers) and disease (blast). It is recommended to carry out the spraying systematically through the farmer's group.

The proper water management is indispensable for cultivation of rice, particularly the high yielding varieties. Water will be supplied deep in depth during the rooting period of seedlings and critical period for the punicle development and fertilization stage of rice plants.

(2) Groundnuts

To maintain the expected yields of groundnuts, good land preparation, careful pulverizing, optimum application of fertilizers and partinent spraying of agro-chemicals should always be sustained. The recommended fertilizer applications are as follows.

Fertilizer	Application Rate (kg/ha)
Nitrogen	7 to 13
Phosphate	7 to 13
Potassium	10 to 20

4.4.4 Farm Input

(1) Labour Requirement

The labour force requirements are estimated for "without project" and "with project" conditions respectively, as tabulated below.

(Unit: 10^3 man-day)

Month	Ban Khai Existing Area			Ban Khai Extention Area		
	Labour Requirement		Available family labour	Labour Requirement		Available family labour
	Without project	With project		Without project	With project	
Jan.	52.5	50.1	105.6	30.4	29.4	148.2
Feb.	22.2	25.5	93.4	6.6	13.7	131.1
Mar.	1.6	18.1	105.6	6.3	9.0	148.2
Apr.	26.1	33.7	101.6	8.7	16.8	142.5
May	12.7	17.8	93.4	3.7	7.5	131.1
Jun.	6.8	16.1	101.6	10.4	10.0	142.5
Jul.	59.0	66.9	101.6	81.5	44.2	142.5
Aug.	52.8	121.6	97.5	73.0	81.1	136.8
Sep.	11.0	24.9	81.3	16.8	15.8	114.0
Oct.	18.4	38.4	89.4	28.2	25.0	125.4
Nov.	31.5	102.0	105.6	44.9	68.0	148.2
Dec.	44.3	47.4	105.6	53.1	282.2	148.2
Total	338.9	562.0	1,182.2	363.6	348.7	1,658.7

The family labour fully satisfies the labour force requirement.

(2) Material Requirements

The requirements of farming materials such as seed, fertilizers and agro-chemicals will increase substantially due to introduction of advanced farming practices. The annual material requirements are estimated as follows for the full development stage.

Farming Materials	Unit	Quantity	
		Existing Area	Extention Area
Seed			
Rice, local varieties	t	29	43
high yielding varieties	t	131	197
Groundnuts	t	33	52
Vegetables	t	9	10
Fertilizer			
Compound (N:16, P:20, K:0)	t	1,370	2,050
(N:15, P:15, K:15)	t	240	570
(N:13, P:13, K:21)	t	120	190
Urea	t	430	540
Agro-chemicals			
Insecticides, Fungicides	kg	10,100	16,570
Herbicides	l	11,940	18,120
Rodenticides	kg	24,250	36,300

4.4.5 Anticipated Yield and Production

The target yields are projected referring to the results of experiments in the Agricultural Experimental Stations and the other information from the Agricultural Extension Office in Rayong. The target crop yields and productions are shown below.

Crops	Existing Area		Extention Area	
	Target Yield (t/ha)	Production (t)	Target Yield (t/ha)	Production (t)
Rice				
- Local varieties	4.0	3,840	4.0	5,680
- High yield varieties				
Dry season	4.5	17,280	4.5	25,650
Wet season	5.0	2,700	5.0	4,250
Groundnuts	2.5	2,730	2.5	4,330
Vegetables	10.0	3,000	10.0	5,000
Fruit Trees	-	-	7.0	4,060

A five-year period will be required to reach the target yields by reasons of strengthening of agricultural support service systems.

4.5 Irrigation Development Plan

4.5.1 Irrigation Requirement

The irrigation requirement was calculated at intervals of 10-day to perform the plan formulation and to determine the design discharge for the irrigation facilities. The calculation method is briefly described below.

Reference crop evapotranspiration was calculated based on the Modified Penman Method for the respective crop. The climatological records at Chon Buri station was applied for the calculation.

Effective rainfall was derived from a rainfall - effective rainfall relationship, which was developed by RID. The rainfall records observed at Ban Khai rain gauge were adopted.

Irrigation efficiency is determined as shown below.

Description	Canal Conveyance Efficiency	Canal Operation Efficiency	Combined Efficiency
Field canal duty	90	95	86
Lateral canal duty	95	95	77
Main canal duty	95	95	70

The maximum diversion requirements were calculated at 1.44 and 1.56 l/s/ha for Ban Khai Extention Area and Ban Khai existing area respectively. These figures will be employed as design discharge for preliminary design of irrigation facilities.

4.5.2 Drainage Requirement

The drainage improvement will be planned so as to remove within 72 hours excess water resulting from the maximum 3-day continuous rainfall expected to occur at a frequency of 10 years. Three-day ten-year frequency rainfall is 208 mm according to the rainfall records observed at Ban Khai rain gauge. Drain design discharge is calculated at 5.7 l/s/ha for both the Ban Khai existing area and Ban Khai Extention Area.

4.5.3 Irrigation and Drainage Systems

The Ban Khai Extension Area with a net area of 7,700 ha is located along the Left Main Canal of the Ban Khai existing area as shown in DWG No. 3-1. The irrigation water for both the Ban Khai existing and Extension areas are planned to be supplied from both the Nong Pla Lai and Khlong Yai dams.

The irrigation water to the Ban Khai Extension Area is led through two headworks, a diversion channel and main canal. The regulated release of Nong Pla Lai dam is diverted at Nong Pla Lai headworks into the Khlong Yai river through the diversion channel. Then it is taken into the main canal at Khlong Yai headworks together with the regulated

release from Khlong Yai dam. The main canal is 45.2 km in length and runs along the eastern periphery of the irrigaton area.

The irrigation area is divided into adequate numbers of lateral and/or sub-lateral units, each of which is further sub-divided into a number of tertiary units. The maximum command areas of the lateral and tertiary units will be limited to 500 ha and 20 ha respectively. The total length of lateral canals is 123 km.

Systematic drainage system will be provided over the irrigation area. Excess water will be evacuated from the irrigated land principally by natural channels but many of the channels will need improvement. Artificial drains would also be constructed in some areas. The total length of drains is also roughly estimated at 124 km, comprising 81 km of new drains and 43 km of improved drains.

5. FLOOD MITIGATION PLAN

5.1. Formulation of Basic Flood Control Plan

5.1.1 Basic Principles

As explained in Section 3.5, flooding have incurred damages on agricultural product, house and housing effects, public facilities and utilities, etc. It could be expected that flood hazards to life and health will increase as population expands, and intensified use and occupancy of flood plain lands will result in incresed property damage from future floods.

An appropriate flood protection measure will be essential for enhancement and prosperity of economic activity, conservation of land, increase of agricultural productivity and assurance of human life and health. Such protective measure, however, should be established in view of long-term perspective.

In the Rayong river basin, Dok Krai dam has been constructed and Nong Pla Lai dam is being contemplated to be implemented within several years. In addition Khlong Yai and Khlong Thap Ma dams are expected to be developed one after another after completion of Nong Pla Lai dam. By these 4 dams, out of 1,730 km^2 of the entire Rayong river basin, about 1,075 km^2 or 62 % would be kept under control.

A basic flood control plan is elaborated taking into account the above water resources development sequence as a guide in establishment of flood mitigation measure and plan of flood protection works. The plan is based on a standard project flood, which has a recurrence interval of 50 years. The basic flood control plan of the Rayong river basin are thoroughly explained in Sectoral Report XIII, Flood Mitigation Engineering.

5.1.2 Basic Flood Control Alternatives

The basic flood control planning was processed through two steps. The first step is to lay out the optimum plan with a combination of

three dams (Dok Krai, Nong Pla Lai and Khlong Yai dams) and river improvement. The second step is to work out the appropriate flood control plan properly for the Khlong Thap Ma river by a combination of Khlong Thap Ma dam and river improvement. The overall basic flood control plan of the Rayong river basin is given by the results of Steps "1" and "2".

Herein reported are the study result concerned with the Step "1". As for Step "2", details are stated either in Sectoral Report XIII, Flood Mitigation Engineering and in Volume IV, Feasibility Study of Khlong Thap Ma Dam Scheme.

For Step "1", the under-listed, three alternatives are arbitrarily selected for comparison. Since features of Dok Krai and Nong Pla Lai dams have been fixed, spillway width of Khlong Yai dam is adopted as variable function. The surcharge volume of Khlong Yai dam and river improvement works vary with width of the spillway.

Structures	Unit	Alternatives		
		1	2	3
Dok Krai Dam				
Surcharge volume	10^6 m^3	20.0	20.0	20.0
Spillway diameter	ϕ, m	10.0	10.0	10.0
Nong Pla Lai Dam				
Surcharge volume	10^6 m^3	43.5	43.5	43.5
Spillway width	m	120.0	120.0	120.0
Khlong Yai Dam				
High water level	El.m	47.5	47.5	47.5
Flood water level	El.m	48.9	48.8	48.7
Surcharge volume	10^6 m^3	18.6	16.9	15.6
Spillway width	m	50.0	70.0	90.0
River Improvement Work				
Length	km	47.3	47.3	47.3
Earth work	10^3 m^3	3,880	3,910	3,950

The high water level of Khlong Yai reservoir has been determined at El. 47.5 m through the land and water resources development plan. The spillway is designed as a side-channel spillway without gate and its crest elevation is the same with the high water level. The surcharge volume and flood water level are decided by routing the 500-year inflow flood.

The requirement of the river improvement work was worked out subsequent to flood routings by reservoirs and according to the flood run-off simulation model presented in Section 3.5. Preliminary design of channel improvement work is carried out based on the criteria recommended by Ministry of Construction, Japan. The quantity of earth work, practically dike embankment indicates only slight difference among the alternatives, since flood run-offs from the sub-basins in downstream from the dam is so large compared to critical channel capacities.

The construction cost of each structure is estimated for cost comparison among the alternatives. The construction cost of Khlong Yai dam attributable to flood control is presumed to correspond to dam embankment cost above the high water level and spillway cost. The estimated costs are as follows.

(Unit: ฿/10^6)

Structures	Alternatives		
	1	2	3
Khlong Yai Dam	298.5	295.0	298.7
River improvement work	1,187.2	1,190.4	1,192.3
Total	1,485.7	1,485.4	1,491.0

5.1.3 Proposed Basic Flood Control Plan

The constructions of the three alternatives are almost even. The Alternative 2, however, indicates the minimum cost and its total dam construction cost is also the lowest among the three. Therefore the Alternative 2 is proposed as the basic flood control plan.

The Khlong Yai dam retains the surcharge volume of 16.9 x $10^6 m^3$ between HWL 47.5 m and FWL 48.8 m. The spillway width is determined at 70.0 m and its crest is set at El. 47.5 m.

Fig. 31 shows the flood discharge distribution over the Rayong river basin with Dok Krai, Nong Pla Lai and Khlong Yai dams in operation. The flood discharge distribution under "with Khlong Thap Ma dam" condition is also prepared as presented in Fig. 31. Fig. 31 also shows the plan and profile of the river improvement works in the Rayong river basin under "with Khlong Thap Ma dam" condition.

The construction cost of the river improvement works would be reduced to ฿ 972.8 x 10^6 under "with Khlong Thap Ma dam" condition.

5.2. Flood Control Effects by Dams

5.2.1 Flood Regulation by Reservoir

The reservoir retains temporarily a large quantity of flood run-off, resulting in reduction of a rate of peak discharge as shown in Fig. 32. The flood regulation effects by the reservoirs are worked out for various probable floods by applying the simulation model. According to the results, flood frequency curves of relevant channel reaches were modified as shown in Fig. 21.

5.2.2 Flood Control Benefit by Dams

The flood control benefits due to dam was measured as the difference between the annual damages under unregulated conditions of flooding and those with the reservoir in operation. The annual flood control benefit of the respective dam is estimated based on the modified flood frequency curves and flood damage curves as shown below.

(Unit: ฿ 10^6)

Conditions	Residual damage	Benefit
(1) Unregulated	147.2	-
(2) Dok Krai dam	111.8	35.4
(3) Dok Krai & Nong Pla Lai dams	74.6	37.2
(4) Dok Krai, Nong Pla Lai, Khlong Yai dams	54.6	20.0
(5) Dok Krai, Nong Pla Lai, Khlong Yai and Khlong Thap Ma dams	35.1	19.5

The annual flood control benefits due to Nong Pla Lai and Khlong Yai dams are estimated at ฿ 37.2×10^6 and ฿ 20.0×10^6, respectively.

5.3. Economic Comparison of River Improvement Works

The river improvement plan involved in the basic flood control plan is established for a long-range objective and will be realized as a mean of final flood control resort, since flow capacity of existing channel is exessively small compared to magnitude of flood. It, however, would be planned to be executed in a stage-wise in due consideration of flood damage severities.

Economic viabilities of river improvement work were testified respectively for three different risk levels, namely, 10-year, 30-year and 50-year in terms of recurrence interval of flood. The construction cost was estimated based on the preliminary layout design and converted into annual equivalent cost at an assumed discount rate of 8 % per annum. The operation and maintenance cost was also estimated for each measure.

The annual benefit was estimated from the modified flood frequency curves and flood damage curves. The estimated annual cost and benefit are as shown below. Case 1 means the river improvement works under Dok Krai, Nong Pla Lai and Khlong Yai dams in operation and Case 2 under four dams including Khlong Thap Ma dam in operation.

(Unit: ¥ 10^6)

River Improvement Works	Annual Cost	Annual Benefit	Annual Net Benefit
Case 1			
Risk Level : 10-year	104.7	48.4	-56.3
Risk Level : 30-year	120.3	52.2	-68.1
Risk Level : 50-year	125.0	53.1	-71.9
Case 2			
Risk Level : 10-year	90.9	30.5	-60.4
Risk Level : 30-year	97.4	33.3	-64.1
Risk Level : 50-year	102.2	33.9	-68.3

As shown in the above, the river improvement works are not economically attractive. However, it is recommendable to execute the flood protective work in some local areas, where flood hazards are serious. It would also be recommended to conduct systematic flood damage statistical survey so that economic and financial losses in the basin will be realistically clarified.

6. PRELIMINARY DESIGN

6.1 Dam and Reservoir

6.1.1 Reservoir

According to the plan formulation studies, the gross storage capacity of the reservoir is determined at 71.5 x 10^6 m^3, consisting of 6.6 x 10^6 m^3 of dead storage, 48.0 x 10^6 m^3 of active storage and 16.9 x 10^6 m^3 of surcharge. The dead storage is decided taking into account sediment deposit over 100 years. The flood water level, high water level and low water level are El. 48.8 m, El. 47.5 m and El. 40.6 m, respectively. The flood water level is determined against a 500-year probable flood. The reservoir water level rises to El. 49.4 m, when probable maximum flood should occur.

DWG No. 1-1 shows the map of reservoir area. Fig. 33 shows the area-storage curve of the reservoir.

6.1.2 Dam

Preliminary design of Khlong Yai multiple-purpose dam is shown in DWG No. 1-2. The dam sits astride three streams; the Khlong Yai river, the Khlong Nong Ai Run river and the Khlong Ma Mui river.

(1) Dam Crest Elevation

Crest elevation of dam is set at El. 50.8 m allowing 2.0 m of freeboard above the flood water level. Dam height is 17.3 m above the river bed.

(2) Geological and Geotechnical Evaluation

In order to supplement the existing data, additional geological investigation was carried out. The results of the investigation are compiled in Sectoral Report VIII, Geology.

The proposed axis of the dam is identical with that selected by the previous study and has approximately 4,000 m of length across the above-said three rivers. As shown in Fig. 34, dam and reservoir areas are widely covered by terrace and colluvial deposits which are composed largely of silty to clayey sand. Bottom of the river valleys is filled with alluvial flood deposits consisting of sand with gravels. The geological map of the dam-site is shown in Fig. 35 and geological profile along the proposed dam axis is presented in Fig. 36.

Bed rock is gneissose granite, which is intensively weathered up to 30 m of depth or more. None of the twenty two previous drillings has reached to fresh rock zone. The intensively weathered gneissose granite shows N-value in the standard penetration test higher than 50 in general. Permeability measured in three bore holes, BY-1 to -3, shows lower value than 5×10^{-5} cm/sec in the zone deeper than 10 m from the level of the river beds. The terrace and colluvial deposits are 5 to 15 m thick and composed of silty to clayey sand with gravels, ranging in the penetration N-value from 4 to 50. Some irregular variations of the N-value are often observed, while it is commonly low in the surfacial zone within a few meters of depth. Strength as foundation is estimated in the proximity of 2.5 t/m^2 for cohesion and 28° for internal friction angle when N-value be 20. Three to five-meter deep excavation is required to remove the surfacial looser zone for foundation of the earth-fill dam.

A conceivable way of foundation treatment is to sink an impervious earth cut-off wall to a level in the intensively weathered gneissose granite, where coefficient of permeability is within the magnitude of 10^{-5} cm/sec. This level lies at El. 25 m (about 10 m deep from the ground surface) under the Khlong Yai valley and El. 30 m (also 10 m deep underground) under the Khlong Ma Mui valley.

On the abutment slopes on both banks, the weathered granite interface under the terrace/colluvial deposits or the talusdeposit does not rise parallel to the ground surface, but develops nearly horizontally or in very low gradient at the height several meters lower than H.W.L. This situation makes it unable for the dam in its higher part to abut to the bedrock. It is thereby necessitated to construct the impervious earth cut-off walls inserted long into the terrain of the abutment slopes. Because of relatively low prmeability of the deposits, it is estimated that the cut-off wall extending 50 m from the end of the dam crest would be able to decrease total seepage through a wing of unconsolidated deposits to less than 20 l/min.

(3) Type of Dam

Geological and topographic conditions allow to build only a fill type dam at the proposed damsite. A homogeneous earth fill type dam is selected from the viewpoint of the availability of embankment materials such as earth, rock, sand and gravel.

According to the material survey, earth borrow area is selected on the left abutment of the main dam. The soils are composed of terrace and colluvium deposits. Riprap and sand and gravel will be produced in Ban Non Thakhian quarry site, which is located at about 30 km northwest of the proposed damsite. The Sectoral Report VIII, Geology contains the result of the material survey.

(4) Zoning

Typical dam section is shown in DWG No. 1-2. Dam body is embanked with homogeneous earth material. A chimney drain with a thickness of 2.5 m is arranged in dam body for drainage. The dam foundation is excavated to 3-5 m in depth in the terrace deposits and the flood plain deposits. The upstream slope is surfaced with a rock riprap and downstream slope with sodding.

(5) Stability Analysis

Based on the stability analysis, the upstream and downstream slopes of dam are determined at 1:3.0 and 1:2.6 respectively. The minimum allowable safety factor is set at 1.2. The design values of materials, results of the stability analyses and sliding circles are shown in Fig. 37.

The preliminary design of dam and its appurtenant structure is attained as a part of water resources engineering as presented in Sectoral Report XI.

(6) Seepage Analysis

As a result of geological and geotechnical evaluation, the foundation treatment for leakage control is required as to sink an impervious earth cut-off wall to a level in weathered gneissose granite.

The analysis of seepage through dam body and foundation was attained by applying the Finite Element Method. Detailed analysis data such as mesh of input, potential flow line, flow function, uplift pressure head and vector of flow velocity are compiled in Sectoral Report XI, Water Resources Engineering.

The earth cut-off wall is designed so as to reduce the quantity of seepage water less than one per cent of the average annual inflow, namely 27.6 l/s.

6.1.3 Spillway

The spillway is located on the right abutment of the dam as shown in DWG No. 1-3.

In accordance with the design criteria of RID a 500-year probable flood, of which peak discharge is 1,230 m^3/s is adopted as design inflow flood. The design of spillway is made taking into account the retardation effect of the reservoir.

A side-channel spillway is selected as the most suitable type to the proposed damsite. Its crest length is determined at 70 m from the viewpoint of flood mitigation plan as explained in Chapter 5. The crest elevation is set at El. 47.5 m, the same elevation as the high water level. The maximum outflow from the spillway is 220 m^3/s at flood water level El. 48.8 m. The flood regulation by the reservoir is shown in Fig. 32.

In case of occurrence of the probable maximum flood with a peak discharge of 1,950 m^3/s, the reservoir water level rises to El. 49.4m and the spillway discharges 400 m^3/s at the maximum.

The side-channel spillway is connected to chuteway with a total length of 80 m. A stilling basin is provided at the downstream end of chuteway to dissipate the excess energy of flow.

6.1.4 River Outlet Facilities

River outlet is located at the right abutment and is to release the irrigation water. The facilities were designed for the maximum discharge of 8.7 m^3/sec, and are composed of inlet channel with a length of 80 m, steel conduit with a length of 90 m and inside diameter of 1.5 m and outlet channel with a length of 270 m. The conduit will be constructed with concrete backfill around steel pipe and protected with concrete cutoff collar at 5 m intervals for leakage control.

6.2. Water Conveyance System

6.2.1 Pipeline

The water conveyance system is planned to be implemented in two phases so that system capacity can be adjusted to possible increase or decrease in water demand. The design of the water conveyance system is thoroughly described in Sectoral Report XII, Water Conveyance Engineering.

The intake is located at the outlet of the river outlet of the Nong Pla Lai dam and raw water is conveyed to the Nong Kho reservoir through 53 km long pipeline. The pipeline is aligned in 2 rows along rural road as shown in DWG No. 2-1. The pipeline is divided into 3 reaches characterized by hydraulic conditions as shown below.

Reach	Length (km)	Discharge (m^3/s)		Pipe Dia. (mm)	
		1st Phase	2nd Phase	1st Phase	2nd Phase
Intake Booster P/S	11.0	1.29	1.29	900	900
Booster P/S - Head Tank	22.0	1.29	1.29	900	900
Head Tank - Nong Kho	20.0	1.29	1.29	800	800

Design discharge is determined at 1.29 m^3 per second for each pipeline, taking into account the plant factor of 1.3.

The most economical combination of pump capacity and pipe size is selected through comparative study of several alternatives.

The pipes are of coating steel pipe having an allowable stress of 10 kg/cm^2. In hydraulic design, static head is confined at 8 kg/cm^2 at the maximum for the sake of water hammer. The hydraulic design of the system is shown in Fig. 38.

6.2.2 Intake

The intake is composed of pump well and pumping and electric stations as shwon in DWG No. 2-2.

Pump well has a capacity of 288 m^3 between HWL 27.8 m and LWL 24.8 m. Five double suction volute pumps with ø 400 mm are installed, of which one unit is the standby. Each pump has a discharge capacity of 19.4 m^3 per minute and pumping height of 85 m in gross. Out of five units of pumps, three units will be installed in the first phase.

6.2.3 Booster Pump Station

The booster pump station is located at Ban Thap Thong. It is equipped with 5 units of double suction volute pump with ϕ 350 mm, including a standby, each of which has a discharge capacity of 19.4 m^3 per minute with total head of 65 m. The associated pump well has a capacity of 2,327 m^3 between HWL 91.7 m and LWL 88.7 m. Three pumps including a standby will be installed in the initial stage.

The preliminary design of the booster pump station is shown in DWG No. 2-3.

6.2.4 Head Tank

A head tank is situated at Ban Khao Khayai, highest position along the proposed pipeline route. It will be constructed in a full scale in the first stage and has a storage capacity of 2,327 m^3 between HWL 118.0 m and LWL 115.0 m. Preliminary design of head tank is shown in DWG No. 2-4.

6.3 Irrigation and Drainage System

6.3.1 Headworks

Two headworks, named as Nong Pla Lai and Khlong Yai headworks are proposed to be constructed in the Nong Pla Lai river and Khlong Yai river respectively. Main components of both headworks are concrete diversion weir, embankment dike and intake. Principal features are as follows.

Description	Unit	Nong Pla Lai Headworks	Khlong Yai Headworks
(1) Diversion Weir			
Design flood	m^3/s	200	280
Design flood water level	El.m	27.05	26.57
Type		Floating	Floating
Crest elevation	El.m	25.56	25.10
Length, fixed portion	m	60.0	95.0
scouring sluice	m	3.0	8.0
Height above the riverbed	m	3.56	4.10
Scouring sluice gate (BxH)	m	3.0x4.0	3.0x4.4
Nos. of sluice gate	nos.	1	2
(2) Embankment Dike			
Crest elevation	El.m	28.0	27.5
Crest width	m	5.0	5.0
Total length	m	1,090	181
(3) Intake			
Design discharge	m^3/s	4.90	11.09
Design intake water level	El.m	25.46	25.00
Sill elevation of inlet	El.m	23.96	23.00
Intake gate (BxH)	m	2.5x2.0	4.0x3.0
Nos. of gate	nos.	2	2

Both diversion weirs are provided with fish ladder. For under-seepage control, steel sheetpiles with a length of 3.0 m are driven along the upstream and downstream cut-off. The adopted design flood is corresponding to an outflow of dam spillway in case of occurence of a 50-year probable flood.

Preliminary designs of headworks and diversion channels are shown DWG Nos. 3-3 and 3-4.

The diversion channel between the both headworks is designed for the maximum diversion requirement of 4.90 m^3/s. It has a total length of 1,800 m and bottom width of 2.0 m. The channel is lined with concrete and its bottom gradient is in 1 to 5,000.

6.3.2 Irrigation Canal and Canal Structures

The alignment of the irrigation canals is shown in DWG No. 3-1.

For design of canal, the maximum and minimum velocities are set at 1.2 m/s and 0.6 m/s respectively for concrete-lined canal and at 0.7 m/s and 0.4 m/s respectively for earth canal. The main canals are lined with 7 cm thick plain concrete for their entire reach and have a trapezoidal cross-section with a side slope of 1:1.5. The longitudinal profile of the main canal is shown in DWG No. 3-5.

The irrigation system is associated with various canal structures such as culvert, inverted siphon, drop structure, check gate, turnout, spillway, cross-drain, aqueduct and bridge.

6.3.3 Drainage Canal and Related Structures

The drainage network in the irrigation development area is shown in DWG No. 3-1. The natural streams and existing local drains are incorporated into the drainage system as much as possible.

6.3.4 Inspection Road

The inspection road is classified into main inspection road and lateral inspection road. The main inspection roads run along the main canals and have an effective width of 5 m paved with laterite. The lateral inspection roads are aligned almost along with the lateral canals and is 3 m in width.

6.4 Environmental Aspects

6.4.1 NEB Standard

Impacts of the Scheme on environmental conditions are preliminarily evaluated in the present study. The standard established by National Environmental Board (NEB standard) is applied to the evaluation.

The NEB is the responsible agency for preservation of the nation's environment and making recommendations to the Government on environmental impacts of projects. NEB standard was prepared in 1979 and includes evaluation standard for dam and reservoirs.

6.4.2 Environmental Impact Evaluation

Four categories are presented as to be evaluated for water resources development project, as listed below.

(1) Physical resources
(2) Ecological resources
(3) Human use values
(4) Quality of life values

Each category includes more specific items to be examined.

The following table presents the result of the evaluation focused on the items considered to be related to the Khlong Yai Dam Scheme.

Environmental Resources	Item	Grade	
		Dam and Reservoir	Irrigation System
Physical Resources	Water Quality	2 (1)	(1)
	Soils	-	(2)
Ecological Resources	Fisheries	2 (1)	1
	Fauna & Flora	(1)	2
	Forests	(1)	-
	Fertilizer & Agro Chemical	-	(1)
Human Use Value	Water Supply	3	3
	Flood Control	3	-
Quality of Life Values	Socio-economy	3	3
	Public Health	2	1
	Recreation	3	1

Grade is expressed by figures 3, 2, 1 indicating the beneficial impact of major, intermediate and minor, while figures with parentheses indicate adverse effect; (3), (2) and (1) mean major, intermediate and minor adverse effect.

According to the result, the Khlong Yai and Nong Pla Lai dams induce positive effect on the most items in human use value and quality of life values. The Scheme contributes to the improvement of sanitary condition, economic situation and recreational opportunities of the local population either directly or indirectly through water resources development and resultant industrialization and agricultural development of the area.

Although the Scheme poses to induce a little adverse effect on several items of physical resources and ecological resources, it is expected that they will be limited to the minimum level by guaranteeing the river maintenance flow to the downstream of the river. As already

explained in sub-section 2.6.2, the concept of river maintenance flow is introduced in the present study in order to minimize or avoid the adverse effect of the water resources development on such items as water quality, fauna and flora and fishery.

6.4.3 Recommendations

Environmental impacts of the Scheme is evaluated preliminarily in the present study. It is proposed that detailed study will be conducted according to the NEB standard at the implementation stage of the Scheme.

Following actions are recommended to be taken by the executive agency before the implementation of the scheme.

(1) Detailed survey on the environmental conditions in the Scheme area.

(2) Establishment of specific counter measures against possible adverse effect

(3) Establishment of regular monitoring system on water quality, fauna and flora etc.

7. COST ESTIMATE

7.1 Investment Cost

7.1.1 Basic Conditions

The Scheme comprises three components; multiple-purpose dams, raw water conveyance system and irrigation and drainage system. The investment cost of the respective component consists of the direct cost, compensation and relocation cost, administration cost of executive agencies, engineering service, physical contingency and price contingency. It was estimated based on the 1982 price level. The followings are the basic conditions for the direct cost estimate.

(1) The currency exchange rates were assumed;
US$ 1 = Baht 23 = Japanese Yen 240

(2) All the construction works will be executed by contractors selected through international competitive bidding.

(3) Unit price of each work item included direct cost such as personnel and labour expenses, material costs and operation and depreciation costs of construction equipment. The unit price is divided into foreign currency portion and local currency portion in accordance with the following classification.

Foreign Currency Portion

- Depreciation cost of construction plant and equipment,
- Large gate and valve,
- Electrical equipment,
- Hydro-mechanical equipment,
- Steel pipe and valve,

Local Currency Portion

- Labour wages,
- Sand, gravel, timber, board,
- Fuel, oil, lubricant,
- Cement,
- Small gate, reinforcement steel bars,
- Inland transportation cost.

(4) The contractor's overhead and profit was estimated in accordance with the Government's guideline issued in July 30, 1982.

(5) Income taxes to be levied by the Government is also included in accordance with the above guideline.

(6) Import tax and duty on the equipment, plants and materials imported by contractors were not taken into account.

The compensation and relocation cost is referred to the result of the compensation survey, which was directly conducted by RID in 1982.

The administration cost of the executive ageancies was assumed to be 2 %, 4 % and 5 % of the direct cost for dam, water conveyance and irrigation component respectively.

The costs of engineering services was assumed to be 10 % of the direct cost for the dam component, 8 % for the water conveyance component and 13 % for the irrigation component respectively.

The physical contingency is assumed to be 15 % of the sum of the direct cost, compensation and relocation cost, administration cost of the executive agencies and cost of engineering services.

The price contingency was estimated assuming broadly a price escalation of 10 % per annum for the local currency portion and of 8 % per annum for the foreign currency portion.

7.1.2 Investment Cost

The investment cost estimate is presented in Table 17 and is summarized as follows:

(Unit: ฿ 10^6)

Component	Foreign Currency Portion	Local Currency Portion	Total
First Stage			
Nong Pla Lai Dam	713.2	1,612.8	2,326.0
Khlong Yai Dam	707.4	1,377.5	2,084.9
Water Conveyance System	585.8	248.3	834.1
Irrigation and Drainage System	380.4	911.2	1,291.6
Sub-total	2,386.8	4,149.8	6,536.6
Second Stage			
Water Conveyance System	767.2	276.0	1,043.2
Sub-total	767.2	276.0	1,043.2
Total	3,154.0	4,425.8	7,579.8

The detailed construction cost estimate of the dam, water conveyance and irrigation components are compiled in the Bill of Quantities attached to the report.

The above investment cost is estimated on the international competitive bid basis, based on which economic evaluation of the Scheme is conducted. However, apart from the above, the investment costs on the basis of force account construction are estimated for the dam and irrigation components respectively for the purpose of reference. They are compiled in Sectoral Report XI, Water Resources Engineering and Sectoral Report III, Irrigation Development Plan, respectively.

7.2 Operation and Maintenance Cost

The operation and maintenance cost of the respective project component is assumed to be 0.5 %, 1.0 % and 0.5 % of construction cost for dam, water conveyance system and irrigation and drainage systems respectively. For the water conveyance system, electrical charge is added at the rate of ฿ 1.19 per kWh.

The annual operation and maintenance cost is estimated to be ฿ 4.8 x 10^6 for the Khlong Yai Dam, ฿ 5.9 x 10^6 for Nong Pla Lai Dam, ฿ 7.0 x 10^6 for the water conveyance system and ฿ 2.6 x 10^6 for the irrigation and drainage system.

7.3 Replacement Cost

Some facilities and equipment need to be replaced periodically. Economic life and replacement cost are estimated as follows:

Facilities and Equipment	Economic Life (year)	Replacement Cost (฿ 10^6)	
		First Stage	Second Stage
Water Conveyance System			
Hydro-mechanical equipment	16	15.8	9.0
Electrical equipment	16	27.6	6.0
Pipeline	40	306.8	306.9
Irrigation and Drainage System			
Gate	25	25.8	-
O&M equipment	10	24.1	-

7.4 Implementation Schedule

The implementation schedule of the Scheme is shown in Fig. 39. The implementation of the Scheme is divided into two stages, since the water conveyance system is completed in two phases in accordance with the growth of water demand.

The first stage includes the construction works of the multiple-purpose dams, irrigation and drainage system, the first phase of the water conveyance system and the procurement of O&M equipment for irrigation services. The commencement of the first stage is assumed to be the beginning of fiscal year 1984. The construction period by the project component is scheduled as follows:

Nong Pla Lai Dam	:	1985 to 1987
Khlong Yai Dam	:	1986 to 1990
Water conveyance system, 1st phase	:	1987 to 1991
Irrigation and drainage system	:	1986 to 1991

The second stage is the implementation of the second phase of the water conveyance system. It will take place in 1992. The construction period will extend over 3 years from 1993 to 1996.

Disbursement schedule of investment cost is presented in Table 18.

7.5 Major Construction Equipment

The major construction plant and equipment required by the project component are listed as shown in Table 19.

8. BENEFIT

8.1 Domestic and Industrial Water Supply Benefit

8.1.1 Unit Water Supply Benefit

Domestic and industrial water supply benefit of the Khlong Yai Dam Scheme accrues from the D&I water supply to Chon Buri-Pattaya area and Map Ta Phut-Sattahip area. Benefit is evaluated by the cost of alternative facilities with the single purpose of supplying domestic and industrial water. Alternative facilities include the dams, which are assumed to be located at the same location as the proposed Khlong Yai and Nong Pla Lai Dams and the Nong Pla Lai water conveyance system. Benefit is estimated at Nong Kho reservoir which is the terminal point of the Nong Pla Lai water conveyance system and at Nong Pla Lai Dam.

Unit D&I water supply benefit is obtained by the following formula.

$$\sum_{n=1}^{n} \frac{C_{1(n)} + C_{2(n)}}{(1+i)^n} = \sum_{n=1}^{n} \frac{\alpha \cdot Sn}{(1+i)^n}$$

where, $C_{1(n)}$; Construction cost of alternative facilities (฿10^6)

$C_{2(n)}$; OM & R cost of alternative facilities (฿10^6)

α ; Unit D&I water supply benefit (฿/m^3)

Sn ; Water supply volume (10^6 m^3/year)

i ; Discount rate which corresponds to internal rate of return

Parameters are summarized as follows,

Construction Cost of Alternative Facilities (฿10^6)

Nong Pla Lai Dam	1,243.9
Khlong Yai Dam	783.9
Water Conveyance System	845.9
Total	2,873.7

O&M Cost of Alternative Facilities (฿10^6)

	1991	1996	2001
Nong Pla Lai Dam	4.7	4.7	4.7
Khlong Yai Dam	3.0	3.0	3.0
Water Conveyance System	7.7	18.9	34.0
Total	15.4	26.6	41.7

Water Supply Volume (10^6 m^3)

Chon Buri - Pattaya Area	4.9	14.2	31.3
Map Ta Phut - Sattahip Area	43.2	48.2	53.5

Replacement cost of water conveyance system is as shown in section 7.3.

Unit D&I water supply benefit by different discount rate is as shown below.

Discount Rate	Unit Benefit (฿/m^3)	
	Chon Buri Pattaya	Map Ta Phut Sattahip
8.0	7.97	2.38
10.0	10.14	3.00
12.0	12.69	3.67
14.0	15.63	4.38
16.0	18.97	5.12

Unit D&I water supply benefit is estimated at ฿ 17.25/m^3 and ฿ 4.74/m^3 for water supply to Chon Buri - Pattaya Area and to Map Ta Phut-Sattahip Area respectively at the discount rate of 15.0% which corresponds to internal rate of return of the Scheme.

8.1.2 Water Supply Benefit

Total D&I water supply benefit is obtained by multiplying the unit water supply benefit by annual water supply for domestic and industrial use. It is presented for every five year period as shown below.

Year	D&I Water Supply Benefit (฿10^6)		
	Chon Buri Pattaya	Map Ta Phut Sattahip	Total
1991	84.5	204.9	289.4
1996	244.9	228.7	473.6
2001	539.8	253.8	793.6

Domestic and industrial water supply benefit will reach the maximum level at 2001 and thereafter will be kept constant.

8.2 Agriculture Benefit

8.2.1 Agricultural Production

In the Ban Khai Extension and Existing areas, groundnuts will be newly introduced as second crop after rice. Agricultural production of each crop under "without project" and "with project" conditions is summarized as follows.

(Unit: t/yr)

Crop	Extension Area			Existing Area		
	Without Project	With Project	Increment	Without Project	With Project	Increment
Rice						
- Local	6,790	5,680	-1,110	5,000	3,840	-1,160
- High Yield (wet)	5,840	25,650	19,810	5,950	17,280	11,330
(dry)	-	4,250	4,250	6,840	2,700	-4,140
Groundnuts	30	4,330	4,300	-	2,730	2,730
Vegetable	-	5,000	5,000	1,600	3,000	1,400
Sugarcane	13,760	-	-13,760	-	-	-
Cassava	24,960	-	-24,960	15,840	-	-15,840
Fruit Trees	2,500	4,060	1,560	-	-	-

Figures in the above table are the annual production at the full development stage. Build-up period is assumed to be five years.

8.2.2 Price Prospect

Economic prices of major agricultural commodities and products are estimated in terms of the international market price prospected for the year 1990 in the 1982 constant price. Prices after 1991 is assumed to be constant. International market price, which is CIF and FOB prices at Bangkok or CIF price at other international port, is adjusted to farm gate price by taking into account costs for inland transportation, handling charge and processing etc.

Financial price of agricultural input and output is obtained from available data at government agencies and local offices and based on the farm survey conducted by the Study Team. Both economic and financial prices are presented in Table 20.

8.2.3. Benefit

Benefit created by agricultural development is indicated by the net incremental benefit. It is the difference in net production value between with project condition and without project condition. Net production value of each case is obtained by subtracting production cost from gross production value. Total incremental benefit of the Scheme is estimated at ฿ 198.2 x 10^6 per annum as shown in Table 21.

Agriculture benefit of the Ban Khai Existing Area is not counted as the benefit of the Khlong Yai Dam Scheme.

8.3. Flood Control Benefit

Annual flood control benefits by the Nong Pla Lai and Khlong Yai Dams are estimated at ฿ 37.2 x 10^6 and ฿ 20.0 x 10^6 respectively as shown in sub-section 5.2.2.

9. PROJECT EVALUATION

9.1 Economic Evaluation

9.1.1 Basic Assumptions

The economic feasibility of the Scheme is evaluated by economic internal rate of return (EIRR). Further, sensitivity analysis is conducted to assess the impact of possible changes in economic conditions on the economic soundness of the Scheme.

The following assumptions are established in the evaluation.

(1) The implementation period is 12 years from 1984 to 1996.

(2) Only direct benefit is counted in the evaluation and any indirect or intangible benefit is not taken into account.

(3) Economic price is expressed in terms of the 1982 constant price.

(4) Economic useful life of the project is assumed to be 50 years.

9.1.2 Object of the Evaluation

Economic evaluation of the Khlong Yai Dam Scheme is conducted based on the costs and benefits of the following components.

	Cost	Benefit
(1)	Khlong Yai Dam	D&I water supply to Chon Buri-Pattaya area
(2)	Nong Pla Lai Water Conveyance System	
(3)	Nong Pla Lai Dam	D&I water supply to Map Ta Phut-Sattahip area
(4)	Ban Khai Extension Irrigation System	Irrigation system development in the Ban Khai Extension Area

9.1.3 Economic Cost

Economic cost is derived by subtracting transfer payment from financial cost. Transfer payment includes tax, compensation and relocation cost and price escalation. In addition, 15 % of local currency portion is deducted as transfer payment.

Land cost of the reservoir area is estimated by the opportunity cost of land which is the annual agricultural production foregone. Production foregone is the net production value of crops under without project condition. Annual production foregone is estimated to be ฿ 12.6 x 10^6 for Khlong Yai Dam and ฿ 25.3 x 10^6 for Nong Pla Lai Dam respectively. It is extracted from the net incremental benefit.

Economic investment costs of dams, raw water conveyance system and irrigation facilities are presented below.

(Unit: ฿ 10^6)

Component	Foreign Currency Portion	Local Currency Portion	Total
FIRST STAGE			
Nong Pla Lai Dam	561.1	777.0	1,338.1
Khlong Yai Dam	480.4	621.5	1,101.9
Water Conveyance System (First Phase)	359.5	94.3	453.8
Irrigation System	246.6	397.9	644.5
Sub-total	1,647.6	1,890.7	3,538.3
SECOND STAGE			
Water Conveyance System (Second Phase)	320.4	71.7	392.1
Sub-total	320.4	71.7	392.1
Total	1,968.0	1,962.4	3,930.4

Disbursement schedule of economic investment cost is presented in Table 22.

9.1.4 Benefit-Cost Stream

Based on the implementation plan and estimated annual benefit, benefit-cost stream of the Khlong Yai Dam Scheme is established as shown in Table 23.

9.1.5 Economic Internal Rate of Return

Economic Internal Rate of Return (EIRR) is computed based on the benefit-cost stream for several cases and presented as below.

(Unit : %)

Condition		EIRR
(1)	Standard	15.0
(2)	10 % of Cost Increase	11.3
(3)	10 % of Benefit Decrease	11.0
(4)	(2) + (3)	8.6
(5)	Delay in Construction for 2 years	9.1

It was proved by the economic evaluation that the Scheme bears the sound economic feasibility. Besides, Chon Buri - Pattaya Area is prospected to suffer from the severe water deficit after 1986 as clarified in Chapter 2. Considering these conditions, it is highly recommended that the Khlong Yai Dam Scheme will be started as soon as possible and completed before 1991.

9.2 Financial Evaluation

9.2.1 Cost Allocation

Investment cost and O&M cost of dams are allocated to the domestic and industrial water supply component, irrigation water supply component and flood control component respectively, in order to clarify the size of investment cost to be borne by each related agency.

Investment cost is allocated by "Separable Cost - Remainig Benefit Method". The investment cost by project component is summarized as follows.

(Unit: ₱ 10^6)

Component	Foreign Currency	Local Currency	Total
D&I Water Supply	2,355.9	2,644.3	5,000.2
Irrigation	593.4	1,359.8	1,953.2
Flood Control	204.7	421.7	626.4
Total	3,154.0	4,425.8	7,579.8

Allocated cost for flood control component will be borne by the government subsidy.

9.2.2 Financial Evaluation of Domestic and Industrial Water Supply

Investment cost for domestic and industrial water supply is assumed to be financed under the following conditions.

a. Foreign currency portion of the investment cost is financed through international loan with an annual interest rate of 3.5 % and a term of 30 years including grace period of 10 years.

b. Local currency portion is borne by the Government.

Disbursement schedule of allocated investment cost for domestic and industrial water supply is presented in Table 24.

Allocated operation and maintenance cost is estimated to be ₱ 42.6 x 10^6 annualy. Replacement cost is directly derived from the replacement cost of raw water conveyance system as presented in Section 7.3.

Recovery of the foreign currency portion of investment cost, O&M cost and replacement cost is planned under the condition that O&M cost and 10 % of the total investment cost and replacement cost is recovered by water tariff collected from water users.

Most of the investment cost is borne by the government, since the dam and water conveyance system for domestic and industrial water supply is one of the most essential infrastructure for the industrial development of the area. Under the above conditions, the water tariff is assumed to be ฿ 4/m^3 including ฿ 2.5/m^3 for management cost of PWWA including O&M cost of purification and distribution system and ฿ 1.5/m^3 for O&M cost of raw water conveyance and 10 % of investment cost and replacement cost.

Cash flow statement of domestic and industrial water supply is presented in Table 25.

9.2.3 Financial Evaluation of Irrigation System Development

Investment cost for irrigation system development is assumed to be financed the following conditions.

a. Foreign currency portion of the investment cost is financed through international loan with an annual interest rate of 3.5 % and a term of 30 years including 10 years of grace period.

b. Local currency portion is borne by the Government.

Disbursement schedule of allocated investment cost is presented in Table 24.

O & M cost is estimated to be ฿ 4.1 x 10^6 annualy. Replacement cost is same as those presented in section 7.3.

Recovery of investment cost, O&M cost and replacement cost is planned under the following conditions.

a. O&M cost is recovered by water tariff collected from beneficiaries.

b. Investment cost and replacement cost is borne by the Government.

Cash flow statement is presented in Table 26.

9.2.4 Farm Budget Analysis

Farm budget analysis is conducted to assess the impact of the Scheme on the economy of farm household. Farm households which own gross land area of 1.8 ha and 3.2 ha are taken up as typical farms.

Annual income and outgo under the "with project" and "without project" condition are estimated as below.

(Unit: ฿)

Typical Farm	Without Project			With Project			Increment of Reserve
	Income	Outgo	Reserve	Income	Outgo	Reserve	
1.8 ha	21,240	21,240	0	38,820	32,550	6,270	6,270
3.2 ha	29,590	25,910	3,680	67,770	40,970	26,800	23,120

With the implementation of the Scheme, farmer's income is expected to grow remarkably. It is considerd that the farmers will have enough capacity to pay for the water tariff induced on irrigation water use. Annual water tariff is broadly estimated to be ฿ 530 per ha which is equivalent to the annual O&M cost.

9.3 Evaluation of Irrigation Rehabilitation Works in the Ban Khai Existing Area

Economic feasibility of the rehabilitation works of the Ban Khai existing area is evaluated independently of the Khlong Yai Dam Scheme.

Preliminary design was performed for the rehabilitation works and presented in the Sectoral Report III, Irrigation Development Plan.

Investment cost of the rehabilitation works is estimated to be ฿ 390.5 x 10^6, comprising ฿ 118.7 x 10^6 of foreign currency portion and ฿ 271.8 x 10^6 of local currency portion as shown in Table 27.

Agriculture benefit is derived from net incremental benefit and estimated at ฿ 71.0 x 10^6 per annum as presented in Table 28.

Economic feasibility of the rehabilitation works in the Ban Khai Existing Area is evaluated by benefit-cost ratio (B/C). Investment cost is adjusted to annual equivalent cost with 8 % of discount rate and 50 years of economic life.

Annual cost and benefit and benefit-cost ratio are as follows.

(1)	Annual Cost	:	฿ 23,260
	- Annual Equivalent Construction Cost	:	฿ 21,010
	- Annual OM&R Cost	:	฿ 2,250
(2)	Annual Incremental Benefit	:	฿ 71,040
(3)	Benefit-Cost Ratio (B/C)	:	3.1
(4)	Annual Net Benefit (B-C)	:	฿ 47,780

Benefit-Cost Ratio is estimated at 3.1 indicating the high economic soundness of the rehabilitation works in the Ban Khai Existing Area. It is highly recommended that the rehabilitation works of the Ban Khai Existing Area will be implemented in parallel with the construction of Nong Pla Lai Dam, so that the regulated flow of Nong Pla Lai will be utilized effectively and efficiently.

10. ORGANIZATION AND MANAGEMENT

10.1 Related Organizations

The water administration in Thailand is directed by the Water Resources Committee although several ministries, government agencies and autonomous institutions have responsibilities and interest in water resources development and conservation.

The RID is engaged in water resources development relevant to agricultural land development. The organization chart of RID is shown in Fig. 40. The RID has 11 Regional Offices. Each regional office assumes a responsibility for construction, operation and maintenance of water resources, irrigation and drainage facilities in its administrative area. The Rayong river basin is within a territorial area of Regional Office No. IX.

The PWWA is an autonomous agency and is responsible for the pipe-water supply in the area outside of Bangkok Metoropolis.

The PWD of the Ministry of Interior has a responsibility mainly for infrastructure development in rural area, such as electrification, road, minor pipe-water supply, etc. The PWWA was formerly a division within PWD. The organization chart of PWD is presented in Fig. 41.

The proposed development activities are deeply concerned with the Eastern Seaboard Development. The Eastern Seaboard Development Committee (the Committee) is chaired by the Prime Minister and is empowered to rule on behalf of the Cabinet. Fig. 42 shows the organization chart of the Committee. The function of the Committee is the overall control of the development programme related to policy issues.

The NESDB is a part of the Office of the Prime Minister responsible for advising on the economic and social development of Thailand. The Center for the Integrated Plan of Operation is a

technical division within NESDB and is the Secretariat Office of the Committee. The CIPO assumes responsibility for preparing the details of the development operation as well as coordinating and monitoring the implementation programmes of all government agencies concerned.

10.2 Executive Agencies

Two executive agencies will directly be involved in the implementation of the Khlong Yai Dam Scheme.

The RID will be responsible for the implementation as well as operation and maintenance of the dam and irrigation components. The project manager will be appointed by RID and he will take the whole responsibility to the RID for the proper implementation of the dam and irrigation components.

An appropriate agency will be appointed for the proper implementation, operation and maintenance of water conveyance system.

The CIPO will coordinate all activities of the agencies with other activities related to the Eastern Seaboard Development.