(6) The reservoir secures all the water demand throughout the study periods for 14 years from April, 1968 to March, 1982 when meteo-hydrological data are available.

The basic equation for reservoir operation is

$$dS / dt = O - I$$

where dS : a differential of reservoir capacity between time intervals dt,

O : an outflow,

I : an inflow

The simulation of reservoir operation is adapted to a digital computer, since many trials were necessary to get the relationship between irrigation area, cropping intensity and reservoir active storage capacity. The flow chart of computation procedure is shown on Fig. 27 with simulation parameters described above. As a result of the operation study, the relationship of the three variables is shown on Fig. 28.

5.2.2 Economic Comparison

Based on the relationship between irrigation area, cropping intensity and reservoir active storage capacity shown on Fig. 28, twelve development alternatives were arbitrary selected to establish an optimum scheme. The twelve alternatives are tabulated below.

Alternatives	Cropping Intensity (%)	Net Irrigation Area (ha)	Reservoir Active Storage (10^6 m^3)
1-1	130	5,900	89
1-2	130	6,700	103
1-3	130	7,200	119
1-4	130	7,400	135
2-1	140	5,300	89
2-2	140	6,100	103
2-3	140	6,600	119
2-4	140	6,800	135
3-1	150	4,500	89
3-2	150	5,300	103
3-3	150	5,800	119
3-4	150	6,000	135

An optimum scheme was selected from the alternatives by benefitcost analysis. An alternative generating the maximum annual net benefit was selected as an optimum development plan. For the calculation of the annual net benefit, project cost and benefit were estimated.

Project Cost

Construction costs of dam, irrigation facilities and water conveyance system were estimated on the basis of the preliminary layout design at the price level in the end of 1982. The basic conditions on the cost estimate were assumed as follows:

(1) Direct construction costs are estimated at 90 % of those financial cost from which tax is deducted.

(2) Engineering service is 10 % of direct cost for dam works, 13 % for irrigation facilities and 8 % for water conveyance system.

(3) Government administration is 2 % of direct cost for dam works, 5 % for irrigation facilities and 4 % for water conveyance system.

(4) Physical contingency is 15 % of the base cost which consists of each direct cost, engineering service and government administration costs.

(5) Annual operation and maintenance (O&M) costs are 0.5 % of direct cost for dam works and irrigation facilities and ฿ 15.2 x 10^6 for water conveyance system.

(6) Replacement cost is estimated for irrigation facility and water conveyance system. Replacement cost of irrigation facility is ฿ 3,400 per ha for gates of which economic life is 25 years and ฿ 3,500 per ha for O&M equipments of which economic life is 10 years. As for water conveyance system, it is 100 % of direct cost except civil works.

Project Benefit

The economic benefits concerned herein are those by domestic and industrial water supply and irrigation water supply.

The domestic and industrial water supply benefit was estimated to be equivalent to alternative cost. The annual cost of alternative was estimated at ฿ 68.8 x 10^6, assuming that a specific purpose dam would be constructed at the same damsite.

The irrigation benefit was evaluated by increase in farm products and was estimated as follows:

Cropping Intensity (%)	Annual Benefit (฿/ha)
130	25,224
140	27,358
150	30,577

The land located in upstream from the damsite will be submerged after the construction of Khlong Luang dam. Therefore the production foregone was taken into account as negative benefit. It was estimated from the value of farm products in the submerged area as described in detail in the Sectoral Report III, Irrigation Development Plan. It was summarized below.

Elevation (m)	Production Foregone (Ø 10^3/yr)
25.4	0
32.0	3,445
34.0	11,157
36.0	21,922
38.0	31,082
40.0	41,027
42.0	51,479

All the cost and benefit were converted into annual equivalent cost and benefit at a discount rate of 8 % with economic life of 50 years. Economic comparison of alternative development scales is shown in Table 31. The relationship between annual net benefit and active storage is shown on Fig. 29.

The alternative 2-3 indicates the maximum annual net benefit among the twelve alternatives. Therefore the alternative 2-3 was justified to be the optimum development plan. The result of the operation study of alternative 2-3 is shown on Fig. 30. The calculation data are collected in the Data Book. They revealed that the critical drawdown cycle was 8 years. The meteo-hydrological data from April, 1968 to March, 1972 were adopted to those after 1982 because the critical drawdown occured around August, 1985 and was recovered in 1986 in this manner. The outline of the Khlong Luang dam scheme is summarized as follows:

(1)	Dam Crest Elevation	El. 42.5 m
(2)	Reservoir H.W.L.	El. 39.5 m
(3)	Reservoir L.W.L.	El. 33.8 m
(4)	Active Storage	119×10^6 m^3
(5)	Water Supply for D&I Demand	0.56 m^3/s
(6)	Irrigation Area	6,600 ha
(7)	Cropping Intensity	140 %

5.3 Optimization of Khlong Yai Dam Scheme

5.3.1 Reservoir Operation Study

The reservoir operation of Khlong Yai dam was simulated at 10-day time intervals based on the operating rule as follows:

(1) The reservoir is operated in association with the Nong Pla Lai dam which is under planning.

(2) Balance points to determine the quantity of water release from these dams are set at Ban Khai weir and proposed Khlong Yai weir which will be constructed about 7 km upstream from the Ban Khai weir.

(3) The role of Dok Krai dam is to be converted to domestic and industrial water supply for Zone Nos. 7 through 9 from irrigation water supply for Ban Khai irrigation existing project in Zone No. 10. Therefore the river maintenance flow from Dok Krai dam, QINd at the rate of 0.1 m^3/s and stream-flow from residual basin, QINr are utilized at first for Ban Khai irrigation existing project, domestic and industrial water supply in Zone No. 10, QDI1 and maintenance flow at Ban Khai weir, QMF.

(4) If the deficit occures at Ban Khai weir balance point, Nong Pla Lai reservoir supplies water for it. Nong Pla Lai reservoir also supplies diversion water, QDW at the constant rate of 0.99 m^3/s to Nong Kho reservoir for the water shortage in the coastal area of Zone Nos. 2 to 5.

(5) The Khlong Yai and Nong Pla Lai dams jointly supply diversion water, QIR2 for Ban Khai irrigation extention project.

(6) Domestic and industrial water, QDI in Zone No. 10 and the river maintenance flow, QMF at Ban Khai weir is supplied at the constant rate of 0.5 m^3/s and 0.38 m^3/s respectively throughout the years.

(7) Effective precipitation, QRAIN and evapolation loss, QEVAP are taken into account as a function of reservoir area. The data of precipitation at Nong Pla Lai gauge station and the data of evapolation at Ban Nong Mapring gauge station are adopted to those at Khlong Yai and Nong Pla Lai damsites.

(8) The historical streamflow sequence at Ban Pak Phraek gauge station and Nong Pla Lai gauge station were adopted to those at Khlong Yai damsite, QINy and Nong Pla Lai damsite, QINn respectively. But QINy was adjusted by the ratio of basin area at Ban Pak Phraek gauge station, 161 km^2 and Khlong Yai damsite, 218 km^2.

(9) The Khlong Yai dam and Nong Pla Lai dam secure all the water demand throughout the study periods for 14 years from April, 1968 to March, 1982 for which streamflow records are available.

Schematic outline of Rayong river basin is illustrated on Fig. 31 with simulation parameters described above. The flow chart of computation procedure is shown on Fig. 32. As a result of the operation study, the relationship between irrigation area, cropping intensity and reservoir active storage capacity was derived as shown on Fig. 33.

According to the result of operation study under the condition without Khlong Yai dam or diversion water to Nong Kho reservoir, Nong Pla Lai dam could supply irrigation water sufficiently for potential irrigable area of Ban Khai irrigation project in case that cropping intensity was less than 150 %. Therefore Khlong Yai dam should be constructed only to supply water for the irrigation area, where Nong Pla Lai could not supply because it began to supply diversion water to the Nong Kho reservoir in such case as cropping intensity was less than 150 % as shown on Fig. 33.

5.3.2 Economic Comparson

Five development alternatives were arbitrary selected to establish an optimum scheme based on the relationship of the three variables as shown on Fig. 33. The five alternatives are tabulated below.

Alternatives	Cropping Intensity (%)	Net Irrigation Area (ha)	Reservoir Active Storage (10^6 m^3)
1-1	130	7,700	27
2-1	140	7,700	48
3-1	150	6,500	44
3-2	150	7,100	55
3-3	150	7,700	68

An annual net benefit was calculated to ascertain the economic characteristics of the respective alternatives. An alternative generating the maximum annual net benefit was selected as an optimum development plan.

For the calculation of the annual net benefit, project cost and benefit were estimated as fofllows.

Project Cost

Construction costs of dams, irrigation facilities and water conveyance system were estimated respectively based on the preliminary design. Construction cost of the Nong Pla Lai dam was updated as the same way as made for the Khlong Yai dam. The basic conditions on the cost estimate were assumed as same as those of the Khlong Luang dam.

Project Benefit

The economic benefits concerned herein are those by domestic and industrial water supply and irrigation water supply.

The domestic and industrial water supply benefit was estimated to be equivalent to alternative cost. The alternative cost consisted of specific purpose dam which would be constructed at the same damsite and water conveyance system. The alternative dams at Nong Pla Lai damsite for Zone Nos. 7 through 9 and Khlong Yai damsite for Zone Nos. 2 through 5 were taken into account. The benefit by domestic and industrial water supply was estimated at ฿ 211 x 10^6.

The irrigation benefit was evaluated by increase in farm products and was estimated as follows:

Cropping Intensity (%)	Annual Benefit (฿/ha)
130	23,331
140	25,744
150	28,181

The land located in upstream from the damsite will be submerged after the construction of Khlong Yai and Nong Pla Lai dams. Therefore the production foregone was taken into account as negative benefit. It was estimated from the value of farm products in the submerged area as shown below.

Khlong Yai Dam

Elevation (m)	Production Foregone (฿ 10^3/yr)
34.5	0
40.0	2,127
42.0	4,466
44.0	7,213
46.0	9,802
48.0	13,490

Nong Pla Lai Dam

Elevation (m)	Production Foregone (฿ 10^3/yr)
20.0	0
34.0	5,976
36.0	8,847
38.0	11,749
40.0	14,760
42.0	17,460
44.0	20,409
46.0	23,763

All the cost and benefit were converted into annual equivalent cost and benefit at a discount rate of 8 % with economic life of 50 years. Economic comparison of alternative development scales is shown in Table 32. The relationship between annual net benefit and active storage is shown on Fig. 34.

The alternative 2-1 indicates the maximum annual net benefit among the five alternatives. Therefore the alternative 2-1 was justified to be the optimum development plan. The result of the operation study of alternative 2-1 is shown on Fig. 35. The calculation data are shown in the Data Book. They revealed that the critical drawdown cycle was 3 years. The meteo- hydrological data from April, 1968 to March, 1971 were used to those after April, 1982. The critical drawdown of Khlong Yai dam occured in April, 1980 and was recovered in August, 1981 in this manner. The operation study of Nong Pla Lai reservoir is also shown on Fig. 36. The outline of the Khlong Yai and Nong Pla Lai dams are summarized below.

		Khlong Yai Dam	Nong Pla Lai Dam
(1)	Dam Crest Elevation	El. 50.8 m	El. 49 m
(2)	Reservoir H.W.L.	El. 47.5 m	El. 45 m
(3)	Reservoir L.W.L.	El. 40.6 m	El. 33.3 m
(4)	Active Storage	48 x 10^6 m^3	144.4 x 10^6 m^3
(5)	D&I Water Supply	0.99 m^3/s /1 +	0.46 m^3/s /2
(6)	Irrigation Area		
	Existing	4,800 ha	
	Extention	7,700 ha	
(7)	Cropping Intensity	140 %	

/1: To be diverted to Nong Kho reservoir

/2: To be consumed within the Rayong river basin

5.4 Optimization of Khlong Thap Ma Dam Scheme

5.4.1 Reservoir Operation Study

The reservoir operation of Khlong Thap Ma dam was simulated at 10-day time intervals based on the operating rule as follows:

(1) The reservoir provides diversion water, QIR for Thap Ma irrigation project.

(2) The river maintenance flow, QMF is sustained at the constant rate of 0.33 m^3/s throughout the years.

(3) Effective precipitation, QRAIN and evapolation loss, QEVAP are taken into account as a function of reservoir area. The data of precipitation at Ban Khai gauge station and the data of evapolation at Ban Nong Mapring gauge station were adopted to those at damsite.

(4) The historical streamflow sequence at Dok Krai dam was applied to those at Khlong Thap Ma damsite, QIN taking into account the ratio of catchment area at Dok Krai and Khlong Thap Ma damsites.

(5) The Khlong Thap Ma dam secures all the water demand throughout the study periods for 14 years from April, 1968 to March, 1982 for which meteo-hydrological data are available.

The flow chart of computation procedure is shown on Fig. 37 with simulation parameters described above. As a result of the operation study, the relationship between irrigation area, cropping intensity and reservoir active storage capacity was derived as shown on Fig. 38.

5.4.2 Economic Comparson

Twelve development alternatives were arbitrary selected to establish an optimum scheme based on the relationship of the three variables as shown on Fig. 38. The twelve alternatives are tabulated below.

Alternatives	Cropping Intensity (%)	Net Irrigation Area (ha)	Reservoir Active Storage (10^6 m^3)
1-1	150	1,900	31.0
1-2	150	2,100	35.5
1-3	150	2,400	42.5
2-1	160	1,900	35.5
2-2	160	2,200	42.5
2-3	160	2,400	49.5
3-1	170	1,500	31.0
3-2	170	2,000	42.5
3-3	170	2,400	56.1
4-1	180	1,500	35.5
4-2	180	2,000	49.5
4-3	180	2,400	68.5

An annual net benefit was calculated to ascertain the economic characteristics of the respective alternatives. An alternative generating the maximum annual net benefit was selected as an optimum development plan.

For the calculation of the annual net benefit, project cost and benefit were estimated as fofllows:

Project Cost

Construction costs of dam and irrigation facilities were estimated respectively based on the preliminary designat the price level in the end of 1982. The basic conditions on the cost estimate were assumed as same as those of the Khlong Luang dam scheme.

Project Benefit

The economic benefits concerned herein is irrigation water supply benefit. The irrigation benefit was evaluated by increase in farm products and was estimated as follows:

Cropping Intensity (%)	Annual Benefit (฿/ha)
150	28,071
160	30,986
170	34,021
180	37,191

The land located in upstream from the damsite will be submerged after the construction of Khlong Thap Ma dam. Therefore the production foregone was taken into account as negative benefit. It was estimated from the value of farm products in the submerged area as shown below.

Elevation (m)	Production Foregone (฿ 10^3/yr)
9.0	0
16.0	475
18.0	1,018
20.0	1,482
22.0	1,977
24.0	2,551
26.0	3,186
28.0	3,852

All the cost and benefit were converted into annual equivalent cost and benefit at a discount rate of 8 % with economic life of 50 years. Economic comparison of alternative development scales is shown in Table 33. The relationship between annual net benefit and active storage is shown on Fig. 39.

The alternative 3-3 indicates the maximum annual net benefit among the twelve alternatives. Therefore the alternative 3-3 was justified to be the optimum development plan. The result of the operation study of alternative 3-3 is shown on Fig. 40. The calculation data are collected in the Data Book. They revealed that the critical drawdown cycle was 5 years. The meteo-hydrological data from April, 1968 to

March, 1972 were adopted to those after April, 1982. The critical drawdown of Khlong Yai dam occured in April, 1982, because the critical drawdown occured around September, 1980 and was recovered in June, 1982 in this manner. The outline of the Khlong Thap Ma dam is summarized as follows:

(1)	Dam Crest Elevation	El. 28.9 m
(2)	Reservoir H.W.L.	El. 25.7 m
(3)	Reservoir L.W.L.	El. 16.2 m
(4)	Active Storage	56.1×10^6 m^3
(5)	Irrigation Area	2,400 ha
(6)	Cropping Intensity	170 %

6. PRELIMINARY DESIGN

6.1 Design Criteria

6.1.1 General

Design criteria and methods of analysis of dam design dealt in this study are as follows:

(1) Design floods,
(2) Reservoir water levels,
(3) Dam crest elevation (non-overflow section),
(4) Stability of dam body,
(5) Seepage analysis, and
(6) Spillway design

6.1.2 Design Floods

In accordance with the design criteria of RID, the design inflow floods are determined to be a 100-year probable flood for service spillway and a 500-year probable flood for emergency spillway respectively. Spillway structures shall have enough capacity to discharge the design discharges under the condition that the effect of reservoir regulation can be counted.

The extra-ordinary flood is based on the probable maximum flood (P.M.F). Spillway structures shall be safe against the P.M.F with the same condition as above. In addition the case of sequential floods shall be examined. Considering the propaties of floods at the proposed damsite, a sequence of the each flood with 1-hour interval is to be examined. The effect of reservoir regulation was calculated by the following equation.

$$\frac{S}{t} = \frac{I_t + I_{t+\Delta t}}{2} - \frac{O_t + O_{t+\Delta t}}{2} \quad \text{------------} \quad (1)$$

where, Δt : unit time of calculation in this study, 1 hour

ΔS : increase or decrease of reservoir storage during t

I_t : inflow at time t

O_t : outflow at time t

6.1.3 Reservoir Water Levels

The reservoir water levels are minutely described in Section 5, Optimization Study and are summarized as follows.

(1) High water level

High wter level is defined as the highest water level in normal operation and the overflow crest elevation of spillway weir is the same with this water surface.

(2) Design flood water level

Design flood water level is defined as the water level of Hd, which is overflow depth above the crest elevation of spillway weir to regulate the 500-year inflow discharge taking into consideration of reservoir regulation effect.

(3) Extra-ordinary flood water level

It is defined as the highest water surface in reservoir due to regulating the extra-ordinary flood.

(4) Low water level

Low water level is the lowest water surface in normal operation. It is set at the surface of sediment deposit in 100-year after inpoundment. The entrance of intake structure shall be designed to be capable of releasing the designed rate of flow at this water level.

6.1.4 Dam Crest Elevation (Non-overflow Section)

The elevation of non-overflow section of fill type dam with uncontrolled spillway is equal to the highest among the following four cases.

(1)	H.W.L + hw + he + ha	(if hw + he $<$ 1, hw + he = 1.0)
(2)	$D.F.W.L_1 + hw + \frac{he}{2} + ha$	(if $hw + \frac{he}{2} < 1$, $hw + \frac{he}{2} = 1.0$)
(3)	$D.F.W.L_2 + hw + ha$	(if hw $<$ 1, hw = 1.0)
(4)	E.F.W.L + hw	(if hw $<$ 1, hw = 1.0)

where,

H.W.L	:	high water level
$D.F.W.L_1$	:	design flood water level for a 100-year probable flood
$D.F.W.L_2$	:	design flood water level for a 500-year problem flood
E.F.W.L	:	extra-ordinary flood water level
hw	:	height of wave due to wind (given as function of the related wind velocity and fetch distance combined by S.B.M method and Saville's method)
hs	:	height of wave due to earthquake (given by S. Sato's formula as follows)

$$hs = \frac{k\tau}{2\pi}\sqrt{gho} \quad \text{---------} \quad (2)$$

where, k : horizontal seismicity
τ : duration of seismic waves in second
g : acceleration due to force of gravity
ho: depth of reservoir water

It is study, k=0.05 and τ =1 sec were adopted

ha : allowance of fill type dams

6.1.5 Stability Analysis

Determination of the optimum slope gradients of dam body is based on the stability analysis of the maximum section of dam body. The stability analysis is usually examined by the slip-circle method. The safety factor against sliding for an assumed circle is given by the following equation.

$$S.F = \frac{\sum(C \cdot L + (N-U-Ns)\ \tan\phi\ )}{\sum(T + Te)} \quad \text{----------} \quad (3)$$

where,

S.F	:	safety factor
C	:	cohesion of material
L	:	length of arch of slip circle
N	:	normal forces along the arc
U	:	uplift forces due to pore pressure along the arc
Ns	:	seismic force along the arc
ϕ	:	internal friction angle of material
T	:	tangential forces along the arc
Ts	:	tangential seismic forces along the arc

Computations shall be repeated for various combinations of center and radius to minimize the safty factor.

Three cases of the reservoir water level are examined as design conditions as follows.

(1) Reservoir water level = high water level
(2) Reservoir empty after completion
(3) Reservoir water level = low water level

For cases of (1) and (3) normal and seismic conditions are examined. In case of (2) only normal condition except seismic condition is done taking into consideration that no earthquake occurs on condition of reservoir empty after completion. For all the cases, the sliding of foundation layer is also done.

In reservoir operation of three dam schemes, rapid drawdown of reservoir water from H.W.L to L.W.L is not taken into account. Some pore-water pressure is anticipated to be remained in dam body when reservoir water is lowered up to low water level. The stability analysis of dam body in L.W.L therefore is examined on condition that the magunitude of static water head in H.W.L acts as uplift pressure head to dam body.

The minimum allowable safety factor is determined to be 1.2 for these equations. Computation are done for selected gradients with 0.1 of interval and the adopted slopes are those giving the smallest safety factor but bigger than 1.2 among these selected gradients.

The horizontal seismicity (k) at the proposed dam sites was estimated at 0.05 on the basis of study done by RID.

6.1.6 Seepage Analysis

The purpose of seepage analysis is to examine safety of a dam body and its foundation against failures due to seepage forces such as quick sand, piping and boiling.

The subsurface flow through a dam body and its foundation is analysed by applying the Finite Element Method of a computer program developed by the Study Team. In the computer program, the dam body and the foundation are divided into meshes of some hundreds elements and the vector of flow and pressure head at each node are analysed.

The final products of the analysis are the maximum flow velocity and the total seepage amount through the dam body and the foundation.

The safety of dam against seepage failure is usually evaluated by the critical velocity method. Several equations have been proposed for the method. Among them a theoretical formula after Justin and an experimental formula after Koslova are employed.

(a) Justin's equation

$$Vc = \sqrt{2/3\ (Gs - 1)\ d \cdot g} \quad \text{----------} \quad (4)$$

where,
- Vc : critical velocity (cm/sec)
- d : grain size of soil (cm)
- g : gravity acceleration (cm/sec^2)
- Gs : specific gravity of soil

(b) Koslova's equation

$$Vc = 0.26\, d^2 \left(1 + 1000\frac{d^2}{D^2}\right) \quad \text{----------- (5)}$$

where, D : mean grain size of soils

In addition it is foreseeable the large quantity of seepage water leak through the dam body and foundation in view of reservoir storage effect. Therefore, possible total leakage rate through the above is determined to be less than one percent of the annual average inflow rate into reservoir and less than 0.05 percent of gross storage capacity of reservoir for the daily leakage quantity.

6.1.7 Spillway Design

Because of the rapid rise of floods at dam sites, control of flood flow by gates is very difficult. Thus, uncontrolled overflow type weir is adopted to these damsites. The elevation of the crest overflow weir is set at the high water level and floods above the water level will be automatically controlled by the weir.

The flow capacity of spillway shall be designed to be enough for releasing not only the design floods for a 100-year and a 500-year probable floods but also the extra-ordinary flood with the sufficient allowance as given in Section 6.1.4.

The optimum combination of depth and width of overflow section is determined so as to minimize the cost of dam and spillway as well as flood mitigation effect.

6.2 Khlong Luang Dam Scheme

6.2.1 Optimum Development Plan

In compliance with the recommendation in Chapter 5, Optimization Study, the optimum development plan of Khlong Luang dam scheme was selected to be alternative 2-3, which was appraised to be the most economical plan among twelve alternatives.

The water surfaces were determined at EL. 39.5 m and EL. 33.8 m for the high water level and the low water level respectively. The storage capacity of the reservoir was individually 134.8 x 10^6 m^3 and 15.8 x 10^6 m^3 for the above water level. Fig. 6 shows the area-storage curve of Khlong Luang reservoir, which were based on 1:20,000 topographic map.

6.2.2 Flood Control Space

(1) Design flood water level

According to Spillway design in Section 6.2.5, the design inflow flood was adopted to be the 500-year probable flood of which the peak inflow discharge is 1,460 m^3/sec.

The flood regulation of reservoir for the design inflow flood was calculated by the equation (1) given in Section 6.1.2.

The overflow depth for this flood (1,460 m^3/sec) was determined to be 1.0 m which is minimal in the construction cost including costs of spillway and dam embankment. Thus, since the surcharge is allocated above the normal operation space, the design flood water level was set at EL. 40.5 m, or 1.0 m above the high water level.

Fig. 41 shows the inflow and outflow hydrographs of the 100-year and the 500-year probable floods respectively.

(2) Extra-ordinary flood water level

It is defined as the highest water level due to regulation of extra-ordinary flood.

Fig. 41 shows the inflow and outflow hydrographs of the extra-ordinary flood. The highest reservoir level thus calculated was EL. 40.9 m, or 1.4 m above the crest of spillway weir.

Thus, the space of surcharge was as large as 34.3 x 10^6 m^3 between EL. 39.5 m and EL. 40.5 m, compared with the volume of the extra-ordinary flood of 49.7 x10^6 m^3. The regulated outflow discharge is 150 m^3/sec which is 10 % of the peak discharge of the inflow hydrograph of 1,460 m^3/sec. In case of the extra-ordinary flood of 2,520 m^3/sec the regulated outflow discharge is 250 m^3/sec which is also 10 % of the peak discharge of the extra-ordinary flood.

6.2.3 Dam Crest Elevation

The free board of non-overflow section of Khlong Luang dam was calculated as follows in accordance with the design criteria given in Section 6.1.4.

(a) Height of wave due to wind : hw

Assuming 9.5 km of fetch distance and 20 m/sec of mean wind velocity, hw = 1.0 m was obtained by method combined S.M.B and Saville.

(b) Height of wave due to earthquake : he

$$he = \frac{k\tau}{2\pi}\sqrt{gho}$$

and
$k = 0.05$
$\tau = 1$ sec.
$ho = 17$ m (dam height)
$g = 9.8$ m/sec^2

Then, he = 0.1 m

(c) Allowance of fill type dam

$$ha = 1.0 \text{ m}$$

Thus, the non-overflow crest height is given as the highest among the following four.

(1) H.W.L + hw + he + ha
$= 39.5 + 1.0 + 0.1 + 1.0 \qquad = \text{EL. } 41.6 \text{ m}$

(2) $D.F.W.L_1 + hw + \frac{he}{2} + ha$
$= 40.3 + 1.0 + 0.05 + 1.0 \qquad = \text{EL. } 42.35 \text{ m}$

(3) $D.F.W.L_2 + hw + ha$
$= 40.5 + 1.0 + 1.0 \qquad = \text{EL. } 42.5 \text{ m}$

(4) E.F.W.L + hw
$= 40.9 + 1.0 \qquad = \text{EL. } 41.9 \text{ m}$

Consequently, the height of non-overflow section was set at EL. 42.5 m which is 3.0 m above the high water level or 2.0 m above design flood water level.

6.2.4 Design of Dam

Design of dam was carried out as explained hereunder, taking into account geological and topographic conditions, availability of embankment materials such as earth, rock, sand and gravel including these transportation distance and the preliminary design executed by RID.

(1) Dam axis selection

The axis of Khlong Luang dam was adopted to be the same as proposed in PRELIMINARY REPORT, KHLONG LUANG RESERVOIR PROJECT reported by RID, May 1968. The length of dam crest of adopted dam axis is 3,820 m.

(2) Type of dam

Foundation geology and topography allow to build only a fill type dam at the proposed damsite. The expected height of dam is 20.5 m at the maximum cross section above the excavated bottom.

According to the material survey, earth material can be enough obtained from borrow area in the neighborhood of the proposed damsite without mixing with other materials. On the other hand rock, sand and gravel materials cannot be got around the proposed damsite. Therefore, these materials will be produced in and transported from Ban Non Thakhian and Khao Bo Kwang Thong quarry sites where are located at about 30 km southwest of the proposed damsite. Unit cost of these materials will be become great. Thus, a homogeneous earthfill dam type is selected from the viewpoint of the above.

In compliance with Sectoral Report VIII, Geology, permeability shows low value in the order of 10^{-5} cm/sec for the flood plain deposits and colluvial and terrace deposits lying to about 3 - 7 m in depth below the ground surface. On the contrary it shows value in order of 10^{-4} cm/sec for the above deposits from 7 m to 20 m in depth and to be virtually impervious layer below 20 m. It is deemed not reasonable to sink an impervious earth cut-off up to 20 m of depth, while the height of dam is only 14 m above the river bed.

Accordingly the appropriate method for leakage control is to spread an artificial earth blanket on upstream from the earth embankment of the dam. It is designed to be 2 m of thickness and 60 m of length at maximum based on the seepage analysis described later. The dam foundation is excavated to the bottom of the flood plain deposits, to 3 - 7 m in depth in the colluvial and terrace deposits at minimum and to about 3 m on both the abutments. Dam body is homogeneously embanked with earth material and a filter zone with thickness of 2.5 m is continuously arranged as wall in dam body for drain. Upstream slope is surfaced with a rock riprap and downstream slope with sodding. Typical cross section of dam is shown in DWG NO. 1-2 of Main Report Volume 2, Feasibility Study on Khlong Luang Dam Scheme.

(3) Cross section of dam (Stability analysis)

The optimum slope gradients of dam body were determined after the stability analysis (method is explained in Section 6.1.5). The stability of dam body against sliding was examined by the slip-circle method given in equation (3) of Section 6.1.5. The status of reservoir water level selected for this analysis was:

(1) High water level,
(2) Reservoir empty after completion, and
(3) Low water level.

Table 34 summarizes the resulting minimum safety factor of the adopted gradients. The allowable safety factor is 1.2. Figs. 44 to 46 show the design values of materials for the calculation and the sliding circles to be minimum safety factor in some selected cases of calculation which were drawn by a computer.

According to the above analysis, sliding circle by seismic force is critical for the upstream slope in the case of low water level and sliding circle by normal force is critical for downstream slope in the case of reservoir empty after completion. The safety factors for sliding of dam body and foundation are 1.24 for upstream slope gradient of 1:2.6 and 1.26 for downstream slope gradient of 1:2.4 (see Figs. 45 and 46). The cross section of Khlong Luang dam determined after stability analysis is shown in DWG NO. 1-2 of Volume 2.

(4) Seepage analysis

Seepage through dam body and foundation layers was calculated by applying the Finite Element Method. Table 35 gives the design values of dam body and foundation materials.

The total leakage rate through the dam body and its foundation was obtained to be 43.3 l/sec in case of the no artificial earth blanket which is more than 1 % of the annual average inflow into Khlong Luang reservoir, 39.7 l/sec. Therefore, it is designed that the artificial earth blanket is continuously spread on upstream from the earth embankment of the dam, thickness of 2 m and length of 60 m at maximum, which is generally to be taken 5 or 6 times of the water head.

Fig. 53 shows the mesh of input and Figs. 54 and 55 show the potential flow line, flow function, uplift pressure head and vector of flow velocity, respectively. Table 36 summarizes the results of seepage analysis. The total leakage rate through the dam body and its foundation is reduced to 30.6 l/sec, meaning about 0.7 % of the annual average inflow. The daily leakage quantity is 2,660 m^3/day, which is within a limit compared with gross storage capacity of the reservoir.

The critical flow velocity by Justin's equation is calculated as follows:

$$Vc = \sqrt{2/3 \times (Gs-1)\ d \cdot g} \quad \text{(cm/sec)} \quad \text{---------- (6)}$$

where, $d = 0.001$ cm
$g = 980$ cm/sec^2
$Gs = 2.75$

then, $Vc = 1.07$ cm/sec (actual velocity)

The actual velocity by Justin's equation was 1.07 cm/sec and the mean maximum velocity is given as follows:

$$\bar{V}c = Vc \times \beta$$

$$\beta = 1 - (1 - n)^{\frac{2}{3}}$$

where, $\bar{V}c$: mean velocity (cm/sec)
Vc : actual velocity (cm/sec)
n : porosity = 0.46

then, $\bar{V}c = 4.92 \times 10^{-1}$ cm/sec (mean velocity)

On the other hand Koslova's equation gives the following value of the critical velocity:

$$\bar{V}c' = 0.26\ d^2\ (1 + 1000\ d^2/D^2)\ \text{(cm/sec)}$$

where, $d = 0.01$ mm
$D = 0.1$ mm

then, $\bar{V}c' = 2.86 \times 10^{-4}$ cm/sec (mean velocity)

The mean maximum velocity obtained by F.E.M analysis was 7.18×10^{-5} cm/sec. The flow velocity of dam body and foundation thus calculated is sufficiently small compared with the critical values calculated by these equations as follows.

	Justin's equation	Koslova's equation	F.E.M analysis
Critical velocity (cm/sec)	4.92×10^{-1}	2.86×10^{-4}	7.18×10^{-5}

Accordingly, the dam body and foundation will be safe enough against the seepage forces as far as the design values are kept.

6.2.5 Other Structures

(1) Spillway

The spillway structures were arranged on the left abutment of the main dam as shown in DWG NO. 1-3 of Volume 2. No other alternatives would be conceivable because of the topography of the damsite.

Uncontrolled overflow type weir is adopted so as to release automatically water in the reservoir from the weir whenever the reservoir water level exceeds high water level of EL. 39.5 m. A side-channel spillway is selected as the most suitable type to the proposed damsite in viewpoint that this type evolves relatively narrow chute-way width compared with a strait center overflow spillway.

The differances in overflow depth between the 100-year flood and the 500-year probable flood is only 15 cm - 20 cm for a same weir length varied from 50 m to 90 m. Therefore, the spillway structures were designed with a 500-year probable flood for the overflow weir and the approach channel up to control section and with a 100-year probable flood for stilling basin. The spillway structures designed as the above have capacity to regulate the extra-ordinary flood in safety.

The crest elevation of overflow weir was set at EL. 39.5 m which was the same as the high water level. The length of overflow weir was 70 m and no piers were provided on the weir. The width of side channel was gradually expanded from 7 m at upstream end to 9 m at downstream end. The approach channel, the chute-way and the stilling basin were width of 9 m and length of 200 m in total.

(2) Diversion system

During the construction of the main dam, the river flow should be diverted through a diversion water way. A tunnel water way system is not suitable for the proposed damsite because of the gently sloping topography and low height and extra-ordinary length of dam.

The open channel water ways were arranged in each river, which is Khlong Luang river and Khlong Huai Sung river. The excavation and embankment in the river bed portion up to original ground surface will be constructed during the first dry season. The diversion flood of the 10-year probable flood with peak discharge of 860 m^3/sec will be flowed on these portions with the overflow deth of about 5 m at maximum. In the last dry season during the construction period, these water ways will be closed and embanked with the impounding of reservoir, though inflow discharge is little in dry season.

(3) Saddle dam

There is a low saddle on the rim of the reservoir area, which is located about 1.5 km south of the left abutment of dam. The lowest part of the saddle is a little higher than EL. 35 m which is 4 m lower than the proposd high water level.

According to Sectoral Report VIII, Geology, the saddle dam foundation is excavated about 2 m thick organic layer in the surface and earth cut-off is to be sunk up to 5 m of depth below surface. A saddle dam designed is 12.5 m high above excavated bottom and 2,250 m long. It is a homogeneous earth fill dam type to be the same as main dam with 1:2.6 and 1:2.4 of upstream and downstream slope gradients, respectively.

6.2.6 Quantity of Construction Works

The work quantities of Khlong Luang dam is shown in Table 37. The total embankment volume of dam body is estimated at 3,271,000 m^3 including 2,972,000 m^3 of main dam and 299,000 m^3 of saddle dam. The embankment of main dam consist of core, blanket, filter as drain, and riprap to be 2,158,000 m^3, 447,000 m^3, 213,000 m^3 and 154,000 m^3 in volume, respectively. The excavation volume of dam foundation will be 2,179,000 m^3.

The concrete volume of the spillway is 6,800 m^3 in total. The excavation volume of spillway will be 75,000 m^3.

The proposed quarry site is located at about 30 km southwest of the damsite. There is no alternative for transporting the rock, sand and gravel including concrete materials. It is use of dump trucks from quarry site to damsite, though the truck transportation will require a construction of hauling road of about 15 km long.

6.3 Khlong Yai Dam Scheme

6.3.1 Optimum Development Plan

In compliance with the recommendation in Chapter 5, Optimization Study, the optimum development plan of Khlong Yai dam scheme was selected to be alternative 2-1, which was appraised to be the most economical plan among five alternatives.

The water surfaces were determined at EL. 47.5 m and EL. 40.6 m for the high water level and the low water level respectively. The storage capacity of the reservoir was individually 54.6 x 10^6 m^3 and 6.6 x 10^6 m^3 for the above water level. Fig. 19 shows the area-storage curve of Khlong Yai reservoir, which were based on 1:20,000 topographic map.

6.3.2 Flood Control Space

(1) Design flood water level

According to Spillway design in Section 6.3.5, the design inflow flood was adopted to be the 500-year probable flood of which the peak inflow discharge is 1,230 m^3/sec.

The flood regulation of reservoir for the design inflow flood was calculated by the equation (1) given in Section 6.1.2.

The overflow depth for this flood (1,230 m^3/sec) was determined to be 1.3 m which is minimal the construction cost including costs of spillway and dam embankment. Thus, since the surcharge is allocated above the normal operation space, the design flood water level was set at EL. 48.8 m, or 1.3 m above the high water level.

Fig. 42 shows the inflow and outflow hydrographs of the 100-year and the 500-year probable floods respectively.

(2, Extra-ordinary flood water level

It is defined as the highest water level due to regulation of extra-ordinary flood.

Fig. 42 shows the inflow and outflow hydrographs of the extra-ordinary flood. The highest reservoir level thus calculated was EL. 49.4 m, or 1.9 m above the crest of spillway weir.

Thus, the space of surcharge was as large as 16.9×10^6 m^3 between EL. 47.5 m and EL. 48.8 m, compared with the volume of the extra-ordinary flood of 26.1×10^6 m^3. The regulated outflow discharge is 220 m^3/sec which is 18 % of the peak discharge of the inflow hydrograph of 1,230 m^3/sec. In case of the extraordinary flood of 1,950 m^3/sec the regulated outflow discharge is 400 m^3/sec which is 20 % of the peak discharge of the extra-ordinary flood.

6.3.3 Dam Crest Elevation

The free board of non-overflow section of Khlong Yai dam was calculated as follows in accordance with the design criteria given in Section 6.1.4.

(a) Height of wave due to wind : hw

Assuming 5 km of fetch distance and 20 m/sec of mean wind velocity, hw = 0.8 m was obtained by method combined S.M.B and Saville.

(b) Height of wave due to earthquake : he

$$he = \frac{k\tau}{2\pi}\sqrt{gho}$$

and
$k = 0.05$
$\tau = 1$ sec.
$ho = 16$ m (dam height)
$g = 9.8$ m/sec2

Then, he = 0.1 m

(c) Allowance of fill type dam

$ha = 1.0$ m

Thus, the non-overflow crest height is given as the highest among the following four.

(1) H.W.L + hw + he + ha
$= 47.5 + 1.0 + 1.0$ = EL. 49.5 m
(if $hw + he < 1$, $hw + he = 1.0$)

(2) $D.F.W.L_1 + hw + \frac{he}{2} + ha$
$= 48.6 + 1.0 + 1.0$ = EL. 50.6 m
(if $hw + he/2 < 1$, $hw + he/2 = 1.0$)

(3) $D.F.W.L_2 + hw + ha$
$= 48.8 + 1.0 + 1.0$ = EL. 50.8 m
(if $hw < 1$, $hw = 1.0$)

(4) E.F.W.L + hw
$= 49.4 + 1.0$ = EL. 50.4 m
(if $hw < 1$, $hw = 1.0$)

Consequently, the height of non-overflow section was set at EL. 50.8 m which is 3.3 m above the high water level or 2.0 m above design flood water level.

6.3.4 Design of Dam

Design of dam was carried out as explained hereunder, taking into account geological and topographic conditions, availability of embankment materials such as earth, rock, sand and gravel including these transportation distance and the preliminary design executed by RID.

(1) Dam axis selection

The axis of Khlong Yai dam was adopted to be the same as proposed in PRELIMINARY REPORT, KHLONG YAI RESERVOIR PROJECT reported by RID, May 1968. The length of dam crest of adopted dam axis is 3,980 m.

(2) Type of dam

Foundation geology and topography allow to build only a fill type dam at the proposed damsite. The expected height of dam is 26 m at the maximum cross section above the excavated bottom.

According to the material survey, earth material can be enough obtained from borrow area in the neighborhood of the proposed damsite without mixing with other materials. On the other hand rock, sand and gravel materials cannot be got around the proposed damsite. Therefore, these materials will be produced in and transported from Ban Non Thakhian and Khao Bo Kwang Thong quarry sites where are located at about 30 km northwest of the proposed damsite. Unit cost of these materials will be become great. Thus, a homogeneous earthfill dam type is selected from the viewpoint of the above.

In compliance with Sectoral Report VIII, Geology, dam and reservoir area is widely covered by terrace and colluvial deposits with 5 to 15 m thick. Standard penetration tests give varied N-value for the unconsolidated deposits, ranging from 3 to more than 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. In one hand, coeficient of permiability shows value in order of 10^{-4} cm/sec for the terrace and colluvial deposits and in order of 10^{-5} cm/sec for the weathered gneissose granite lying below the former deposits.

Accordingly the foundation of earthfill dam is excavated to the bottom of the flood plain deposits and to 3-5 m in depth in the terrace and colluvial deposits. The foundation treatment for leakage control is designed as to sink an impervious earth cut-off wall to a level in weathered gneissose granite, where coefficient of permiability is within the magnitude of 10^{-5} cm/sec. This level of cut off wall bottom 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 from the ground surface) under the Khlong Ma Mui valley.

On the abutment slopes on both banks, the weathered granite interface 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. Because of relatively low permeability of the deposits, the cut off wall is extended length of 50 m from the end of the dam crest in order to decrease total seepage through a wing. Dam body is homogeneously embanked with earth material and a filter zone with thickness of 2.5 m is continuously arranged as wall in dam body for drain. Upstream slope is surfaced with a rock riprap and downstream slope with sodding. Typical cross section of dam is shown in DWG NO. 1-2 of Main Report Volume 3, Feasibility Study on Khlong Yai Dam Scheme.

(3) Cross section of dam (Stability analysis)

The optimum slope gradients of dam body were determined after the stability analysis (method is explained in Section 6.1.5). The stability of dam body against sliding was examined by the slip-circle method given in equation (3) of Section 6.1.5. The status of reservoir water level selected for this analysis was:

(1) High water level,
(2) Reservoir empty after completion, and
(3) Low water level.

Table 34 summarizes the resulting minimum safety factor of the adopted gradients. The allowable safety factor is 1.2. Figs. 47 to 49 show the design values of materials for the calculation and the sliding circles to be minimum safety factor in some selected cases of calculation which were drawn by a computer.

According to the above analysis, sliding circle by seismic force is critical for the upstream slope in the case of low water level and sliding circle by normal force is critical for downstream slope in the case of reservoir empty after completion. The safety factors for sliding of dam body and foundation are 1.22 for upstream slope gradient of 1:3.1 and 1.25 for downstream stope gradient of 1:2.6 (see Figs. 48 and 49). The cross section of Khlong Yai dum determined after stability analysis is shown in DWG NO. 1-2 of Volume 3.

(4) Seepage analysis

Seepage through dam body and foundation layers was calculated by applying the Finite Element Method. Table 35 gives the design values of dam body and foundation materials.

Fig. 56 shows the mesh of input and Figs. 57 and 58 show the potential flow line, flow function, uplift pressure head and vector of flow velocity, respectively. Table 36 summarizes the results of seepage analysis. The total leakage rate through the dam body and its foundation is reduced to 18.9 l/sec, meaning about 0.7 % of the annual average inflow, 2.76 m^3/sec, into Khlong Yai reservoir. The daily leakage quantity is 1,630 m^3/day, which is within a limit compared with gross storage capacity of the reservoir.

The critical flow velocity by Justin's equation is calculated as follows:

$$Vc = \sqrt{2/3 \times (Gs-1)\ d\ .\ g} \quad \text{(cm/sec)} \text{ ---------- } (6)$$

where, d = 0.001 cm
g = 980 cm/sec^2
Gs = 2.75

then, Vc = 1.07 cm/sec (actual velocity)

The actual velocity by Justin's equation was 1.07 cm/sec and the mean maximum velocity is given as follows:

$$\bar{V}c = Vc \times \beta$$

$$\beta = 1 - (1 - n)^{\frac{2}{3}}$$

where, $\bar{V}c$: mean velocity (cm/sec)
Vc : actual velocity (cm/sec)
n : porosity = 0.46

then, $\bar{V}c = 4.92 \times 10^{-1}$ cm/sec (mean velocity)

On the other hand Koslova's equation gives the following value of the critical velocity:

$$\bar{V}c' = 0.26\ d^2\ (1 + 1000\ d^2/D^2)\ \text{(cm/sec)}$$

where, $d = 0.01$ mm
$D = 0.1$ mm

then, $\bar{V}c' = 2.86 \times 10^{-4}$ cm/sec (mean velocity)

The mean maximum velocity obtained by F.E.M analysis was 9.08×10^{-5} cm/sec. The flow velocity of dam body and foundation thus calculated is sufficiently small compared with the critical values calculated by these equations as follows.

	Justin's equation	Koslova's equation	F.E.M analysis
Critical velocity (cm/sec)	4.92×10^{-1}	2.86×10^{-4}	9.08×10^{-5}

Accordingly, the dam body and foundation will be safe enough against the seepage forces as far as the design values are kept.

6.3.5 Other structures

(1) Spillway

The spillway structures were arranged on the right abutment of the main dam as shown in DWG NO. 1-3 of Volume 3. No other alternatives would be conceivable because of the topography of the damsite.

Uncontrolled overflow type weir is adopted so as to release auto- matically water in the reservoir from the weir whenever the reservoir water level exceeds high water level of EL. 47.5 m. A side-channel spillway is selected as the most suitable type to the proposed damsite in viewpoint that this type evolves relatively narrow chute-way width compared with a strait center overflow spillway.

The differances in overflow depth between the 100-year flood and the 500-year probable flood is only 15 cm - 20 cm for a same weir length varied from 50 m to 90 m. Therefore, the spillway structures were designed with a 500-year probable flood for the overflow weir and the approach channel up to control section and with a 100-year probable flood for stilling basin. The spillway structures designed as the above have capacity to regulate the extra-ordinary flood in safety.

The crest elevation of overflow weir was set at EL. 47.5 m which was the same as the high water level. The length of overflow weir was 70 m and no piers were provided on the weir. The width of side channel was gradually expanded from 7 m at upstream end to 10 m at downstream end. The approach channel, the chute-way and the stilling basin were width of 10 m and length of 830 m in total.

(2) Diversion system

During the construction of the main dam, the river flow should be diverted through a diversion water way. A tunnel water way system is not suitable for the proposed damsite because of the gently sloping topography and low height and extra-ordinary length of dam.

The open channel water ways were arranged in each river, which is Khlong Yai river, Khlong Nong Ai Run river and Khlong Ma Mui river. The excavation and embankment in the river bed portion up to original ground surface will be constructed during the first dry season. The diversion flood of the 10-year probable flood with peak discharge of 720 m^3/sec will be flowed on these portions with the overflow depth of about 5 m at maximum. In the last dry season during the construction period, these water ways will be closed and embanked with the impounding of reservoir, though inflow discharge is little in dry season.

(3) River outlet facilities

Intake structure were not arranged at the proposed damsite because water for irrigation is taked into at the more distant downstream of damsite. River outlet facilities were located at the right abutment in the dam body in order to flow out water impounded in reservoir. The facilities were design so as to have capacity to flow out the maximum discharge of 8.7 m^3/sec in L.W.L, comprising inlet channel of length of 80 m, steel conduit with valve of length of 90 m and diameter of 1.5 m and outlet channel of length of 270 m. The conduit will be constructed with concrete backfill around steel pipe and protected with concrete cut off wall with 5 m interval toward upstream side from dam axis for leakage control.

6.3.6 Quantity of Construction Works

The work quantities of Khlong Yai dam is shown in Table 38. The total embankment volume of dam body is estimated at 2,495,000 m^3. The embankment of dam body consist of core, filter as drain, and riprap to be 2,051,000 m^3, 254,000 m^3 and 190,000 m^3 in volume, respectively. The excavation volume of dam foundation will be 1,331,000 m^3.

The concrete volume of the spillway is 13,000 m^3 in total and the excavation volume will be 275,000 m^3.

The proposed quarry site is located at about 30 km northwest of the damsite. There is no alternative for transporting the rock, sand and gravel including concrete materials. It is use of dump trucks from quarry site to damsite, though the truck transportation will require construction of new hauling road of about 30 - 50 km long.

6.4 Khlong Thap Ma Dam Scheme

6.4.1 Optimum Development Plan

In compliance with the recommendation in Chapter 5, Optimization Study, the optimum development plan of Khlong Thap Ma dam scheme was selected to be alternative 3-3, which was appraised to be the most economical plan among twelve alternatives.

The water surfaces were determined at EL. 25.7 m and EL. 16.2 m for the high water level and the low water level respectively. The storage capacity of the reservoir was individually 60.8 x 10^6 m^3 and 4.7 x 10^6 m^3 for the above water level. Fig. 18 shows the area-storage curve of Khlong Thap Ma reservoir, which were based on 1:20,000 topographic map.

6.4.2 Flood Control Space

(1) Design flood water level

According to Spillway design in Section 6.4.5, the design inflow flood was adopted to be a 500-year probable flood of which the peak inflow discharge is 920 m^3/sec.

The flood regulation of reservoir for the design inflow flood was calculated by the equation (1) given in Section 6.1.2.

The overflow depth for this flood (920 m^3/sec) was determined to be 1.2 m which is minimal the construction cost including costs of spillway and dam embankment. Thus, since the surcharge is allocated above the normal operation space, the design flood water level was set at EL. 26.9 m, or 1.2 m above the high water level.

Fig. 43 shows the inflow and outflow hydrographs of the 100-year and the 500-year probable floods respectively.

(2) Extra-ordinary flood water level

It is defined as the highest water level due to regulation of extra-ordinary flood.

Fig. 43 shows the inflow and outflow hydrographs of the extra-ordinary flood. The highest reservoir level thus calculated was EL. 27.5 m, or 1.8 m above the crest of spillway weir.

Thus, the space of surcharge was as large as 13.5 x 10^6 m^3 between EL. 25.7 m and EL. 26.9 m, compared with the volume of the extra-ordinary flood of 21.6 x 10^6 m^3. The regulated outflow discharge is 140 m^3/sec which is 15 % of the peak discharge of the inflow hydrograph of 920 m^3/sec. In case of the extra-ordinary flood of 1,540 m^3/sec the regulated outflow discharge is 270 m^3/sec which is also 17 % of the peak discharge of the extra-ordinary flood.

6.4.3 Dam Crest Elevation

The free board of non-overflow section of Khlong Thap Ma dam was calculated as follows in accordance with the design criteria given in Section 6.1.4.

(a) Height of wave due to wind : hw

Assuming 3 km of fetch distance and 20 m/sec of mean wind velocity, hw = 0.6 m was obtained by method combined S.M.B. and Saville.

(b) Height of wave due to earthquake : he

$$he = \frac{k\tau}{2\pi}\sqrt{gho}$$

and
$k = 0.05$
$\tau = 1$ sec.
$ho = 19$ m (dam height)
$g = 9.8$ m/sec^2

Then, he = 0.1 m

(c) Allowance of fill type dam

ha = 1.0 m

Thus, the non-overflow crest height is given as the highest among the following four.

(1) H.W.L + hw + he + ha
= 25.7 + 1.0 + 1.0 = EL. 27.7 m
(if hw + he < 1, hw + he = 1.0)

(2) $D.F.W.L_1 + he + \frac{he}{2} + ha$
= 26.7 + 1.0 + 1.0 = EL. 28.7 m
(if hw + he/2 < 1, hw + he/2 = 1.0)

(3) $D.F.W.L_2 + hw + ha$
= 26.9 + 1.0 + 1.0 = EL. 28.9 m
(if hw < 1, hw = 1.0)

(4) E.F.W.L + hw
= 27.5 + 1.0 = EL. 28.5 m
(if hw < 1, hw = 1.0)

Consequently, the height of non-overflow section was set at EL. 28.9 m which is 3.2 m above the high water level or 2.0 m above design flood water level.

6.4.4 Design of Dam

Design of dam was carried out as explained hereunder, taking into account geological and topographic conditions, availability of embankment materials such as earth, rock, sand and gravel including these transportation distance and the preliminary design executed by RID.

(1) Dam axis selection

The axis of Khlong Thap Ma Dam was adopted to be the same as proposed in PRELIMINARY REPORT, KHLONG THAP MA RESERVOIR PROJECT reported by RID, May 1968. The length of dam crest of adopted dam axis is 810 m.

(2) Type of dam

Foundation geology and topography allow to build only a fill type dam at the proposed damsite. The expected height of dam is 34 m at the maximum cross section above the excavated bottom.

According to the material survey, earth material can be enough obtained from borrow area in the neighborhood of the proposed damsite without mixing with other materials. On the other hand rock, sand and gravel materials cannot be got around the proposed damsite. Therefore, these materials will be transported from Kong Ton Po sand borrow area and Ban Pak Than quarry site where are located at about 20 km southeast of the proposed damsite. Unit cost of these materials will be become great. Thus, a homogeneous earth fill dam type is selected from the viewpoint of the above.

In compliance with Sectoral Report VIII, Geology, geological and geotechnical feature of the reservoir area is essentially similar to those of Khlong Yai dam scheme. Dam and reservoir area is widely covered by terrace and colluvial deposits with 5 to 15 m thick. Standard penetration tests give varied N-value for the unconsolidated deposits, ranging from 2 to more than 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. In one hand, coefficient of permeability shows value in order of 10^{-3} cm/sec for the terrace and colluvial deposits and in order of 10^{-5} cm/sec for the weathered gneissose granite lying below the former deposits.

Accordingly the foundation of earthfill dam is excavated to the bottom of the flood plain deposits, to 3-5 m in depth in the terrace and colluvial deposits and to about 3 m on both the abutments. The foundation treatment for leakage control is designed as to sink an impervious earth cut off wall to a level in weathered gneissose granite, where coefficient of permeability is within the magnitude of 10^{-5} cm/sec. This level of cut off wall bottom lies at EL. -5 m (about 15 m deep from the ground surface) under the Khlong Thap Ma valley. Dam body is homogeneously embanked with earth material and a filter zone with thickness of 2.5 m is continuously arranged as wall in dam body for drain. Upstream slope is surfaced with a rock riprap and downstream slope with sodding. Typical cross section of dam is shown in DWG NO. 1-3 of Main Report Volume 4, Feasibility Study on Khlong Thap Ma Dam Scheme.

(3) Cross section of dam (Stability analysis)

The optimum slope gradients of dam body were determined after the stability analysis (method is explained in Section 6.1.5). The stability of dam body against sliding was examined by the slip-circle method given in equation (3) of Section 6.1.5. The status of reservoir water level selected for this analysis was:

(1) High water level,
(2) Reservoir empty after completion, and
(3) Low water level.

Table 34 summarizes the resulting minimum safety factor of the adopted gradients. The allowable safety factor is 1.2. Figs. 50 to 52 show the design values of materials for the calculation and the sliding circles to be minimum safety factor in some selected cases of calculation which were drawn by a computer.

According to the above analysis, sliding circle by seismic force is critical for the upstream slope in the case of low water level and sliding circle by normal force is critical for downstream slope in the case of reservoir empty after completion. The safety factors for sliding of dam body and foundation are 1.21 for upstream slope gradient of 1:3.1 and 1.25 for downstream slope gradient of 1:2.6 (see Figs. 51 and 52). The cross section of Khlong Thap Ma dam determined after stability analysis is shown in DWG NO. 1-3 of Volume 4.

(4) Seepage analysis

Seepage through dam body and foundation layers was calculated by applying the Finite Element Method. Table 35 gives the design values of dam body and foundation materials.

Fig. 59 shows the mesh of input and Figs. 60 and 61 show the potential flow line, flow function, uplift pressure head and vector of flow velocity, respectively. Table 36 summarizes the results of seepage analysis. The total leakage rate through the dam body and its foundation is only 6.7 l/sec, meaning about 0.4 % of the annual average inflow, 1.75 m^3/sec, into Khlong Thap Ma reservoir. The daily leakage quantity is 580 m^3/day, which is within a limit compared with gross storage capacity of the reservoir.

The critical flow velocity by Justin's equation is calculated as follows:

$$Vc = \sqrt{2/3 \times (Gs-1)\, d \cdot g} \quad (cm/sec) \text{ ---------- } (6)$$

where,
$d = 0.001$ cm
$g = 980$ cm/sec^2
$Gs = 2.75$

then, $vc = 1.07$ cm/sec (actual velocity)

The actual velocity by Justin's equation was 1.07 cm/sec and the mean maximum velocity is given as follows:

$$\bar{V}_c = V_c \times \beta$$

$$\beta = 1 - (1 - n)^{\frac{2}{3}}$$

where,
$\bar{V}c$: mean velocity (cm/sec)
Vc : actual velocity (cm/sec)
n : porosity = 0.46

then, $\bar{V}c$: 4.92×10^{-1} cm/sec (mean velocity)

On the other hand Koslova's equation gives the following value of the critical velocity:

$$\bar{V}c' = 0.26\ d^2\ (1 + 1000\ d^2/D^2)\ \text{(cm/sec)}$$

where, $d = 0.01$ mm
$D = 0.1$ mm

then, $\bar{V}c' = 2.86 \times 10^{-4}$ cm/sec (mean velocity)

The mean maximum velocity obtained by F.E.M. analysis was 1.18×10^{-4} cm/sec. The flow velocity of dam body and foundation thus calculated is sufficiently small compared with the critical values calculated by these equations as follows.

	Justin's equation	Koslova's equation	F.E.M analysis
Critical velocity (cm/sec)	4.92×10^{-1}	2.86×10^{-4}	1.18×10^{-4}

Accordingly, the dam body and foundation will be safe enough against the seepage forces as far as the design values are kept.

6.4.5 Other Structures

(1) Spillway

The spillway structures were arranged on the left abutment of the main dam as shown in DWG NO. 1-4 of Volume 4. No other alternatives would be conceivable because of the topography of the damsite.

Uncontrolled overflow type weir is adopted so as to release automatically water in the reservoir from the weir whenever the reservoir water level exceeds high water level of EL. 25.7 m. A side-channel spillway is selected as the most suitable type to the proposed damsite in viewpoint that this type evolves relatively narrow chute-way width compared with a strait center overflow spillway.

The differences in overflow depth between the 100-year flood and the 500-year probable flood is only 15 cm - 20 cm for a same weir length varied from 30 m to 70 m. Therefore, the spillway structures were designed with a 500-year probable flood for the overflow weir and the approach channel up to control section and with a 100-year probable flood for stilling basin. The spillway structures designed as the above have capacity to regulate the extra-ordinary flood in safety.

The crest elevation of overflow weir was set at EL. 25.7 m which was the same as the high water level. The length of overflow weir was 50 m and no piers were provided on the weir. The width of side channel was gradually expanded from 4 m at upstream end to 8 m at downstream end. The approach channel, the chute-way and the stilling basin were width of 8 m and length of 270 m in total.

(2) Diversion system

During the construction of the main dam, the river flow should be diverted through a diversion water way. A tunnel water way system is not suitable for the proposed damsite because of the gently sloping topography and low height and extra-ordinary length of dam.

The open channel water way was arranged in river, which is Khlong Thap Ma river. The excavation and embankment in the river bed portion up to original ground surface will be constructed during the first dry season. The diversion flood of the 10-year probable flood with peak discharge of 540 m^3/sec will be flowed on the portion with the overflow depth of about 5 m at maximum. In the last dry season during the construction period, this water way is closed and embanked with the impounding of reservoir, though inflow discharge is little in dry season.

(3) Saddle dam

There is a low saddle on the rim of the reservoir area, which is located about 0.8 km north of the left abutment of dam. The lowest part of the saddle is a little higher than EL. 25 m which is only 0.7 m lower than the proposed high water level.

According to Sectoral Report VIII, Geology, the saddle dam foundation is excavated about 2 m thick organic layer in the surface and earth cut-off is to be sunk up to 5 m of depth below surface. A saddle dam designed is 9 m high above excavated bottom and 410 m long. It is a homogeneous earth fill dam type to be the same as main dam with 1:3.1 and 1:2.6 of upstream and downstream slope gradients, respectively.

6.4.6 Quantity of Construction Works

The work quantities of Khlong Thap Ma dam is shown in Table 39. The total embankment volume of dam body is estimated at 1,392,400 m^3 including 1,345,000 m^3 of main dam and 49,000 m^3 of saddle dam. The embankment of main dam consist of core, filter as drain, and riprap to be 1,182,000 m^3, 92,000 m^3 and 71,000 m^3 in volume, respectively. The excavation volume of dam foundation will be 568,000 m^3.

The concrete volume of the spillway is 12,000 m^3 in total. The excavation volume of spillway will be 101,000 m^3.

The proposed sand borrow area and quarry site are located at about 10 km or 20 km southeast of damsite respectively. There is no alternative for transporting the sand, rock and gravel including concrete materials. It is use of dump trucks from quarry site to damsite, though the truck transportation will require a construction of hauling road of about 5 km long.

7. CONSTRUCTION PLAN AND COST ESTIMATE

7.1 Construction Plan

7.1.1 Basic Conditions

The construction plans for the three dams, Khlong Luang dam, Khlong Yai dam and Khlong Thap Ma dam, are formulated in this chapter taking into account the local availability of construction materials, require- ment for machinery and equipment, climate condition, accessibility of the project sites and other related factors.

In this construction plans, the construction period to be required is minimized as plactical as possible for the efficient execution and acquiring the expected benefit soon.

7.1.2 Construction Materials

Embankment Materials

The three (3) dam construction works will require approximately 7.2 million m^3 of embankment works, of which 3.3 million m^3 will be for the Khlong Luang dam and its appurtenant facilities, 2.5 million m^3 for the Khlong Yai dam and 1.4 million m^3 for the Khlong Thap Ma dam and its appurtenant facilities.

Investigation has shown that impervious core including blanket fill, filter and riprap materials for the dam embankment are all available from area within 1 - 70 km from the damsite, each quarry site and sand borrow area as shown in Fig. 62 and 63.

The estimated yield of core materials from the proposed borrow area is sufficient for the requirement. For final assessment of the borrow areas, however, further detailed investigation will be required in the subsequent design stage. Selected riprap materials from the each quarry site will be also utilized for the embankment of dam. Table 40 shows the required quantity and total yield capacity of embankment materials in each quarry site and borrow area.

Concrete Materials

Estimated total quantity of concrete work for three dam constructions is about 52,000 m^3 including temporary facilities works. Aggregate will be supplied from the each quarry site and sand borrow area. It is presumed that the deposit will yield about 104,000 ton of fine aggregate and coarse aggregate.

Construction cost estimated in this report assumes that cement will be supplies with domestic production. Required quantity of cement will be about 18,500 tons for the above works. Reinforcing steel bars of about 1,100 tons will be also supplies with domestic production.

Mechanical and Electrical Equipment

Most of the hardware and equipment required for the work such as structural equipment and major electrical equipment, will have to be imported. Other supplies such as steel sheets, wires, lighting equipment and fixtures are available in local market.

Local Materials

Local materials will be utilized to the maximum extent. The major item are wooden materials, bricks, stone-blocks, oil products, etc.

7.1.3 Construction Facilities

Construction facilities include residential quarters, offices, warehouses, workshops, motor pool and repair shop, concrete and aggregate production plants, raw aggregate stockpiles, core materials stockpiles and various construction roads.

Office and Quarters

The government office and quarters will be built on the construction area, about 600 m^2. The quarters will be provided with permanent construction as accommodation of future operation personnel after the completion of the works.

Access Road and Bridges

Most of the construction materials, equipment and supplies will be transported by road from Sattahip to the damsite.

Some of them appear not to have sufficient capacity for the passing of the project goods (40 tons maximum). Reinforcement of the existing bridges will be a primary work item to be performed before the commencement of main works.

Road Relocation near Damsite

The existing road on the construction area of the damsite is to be relocated at an early period of the construction.

7.1.4 Construction Plant and Equipment

The dam construction work requires about 25 items of construction plant and equipment. Construction production facilities will be one aggregate screening plant and one concrete batching plant, 80 ton/hour and 20 m^3/hour capacity respectively. Major items of heavy equipment will be 1.8 - 3.2 m^3 class shovels, 16 - 30 ton bulldozer and 8 - 15 ton dump trucks. Tables 41 to 43 show the item and required number of plant and equipment for dam construction works. However, it is assumed that equipment for the road relocation work will be procured locally.

Aggregate screening plant power will be supplies from a diesel engine generating plant of 150 kW capacity. Pumping station will supply construction water to various sites including office and residential quarters. The peak requirement of water supply is estimated to be about 6.7 m^3/min.

Water Supply System

Water is taken from the river, pumped up to head tanks through 200 mm dia. pipe line, and distributed to each delivery points. For the main supply system on the construction area, centrifugal pump equipped with 75 kW motor will be installed at the pump station. Construction water requirement is estimated as follows:

Location	Requirement (m^3/min)
- Repair shop	0.8
- Motor pool & storage yard	1.0
- Warehouses and shops	0.2
- Office	0.1
- Government living quarters	0.2
- Contractor's living camp	0.1
- Labur camp	0.3
- Damsite work area	2.0
- Diesel generating plant	1.0
- Others	1.0
Total	6.7 m^3/min

Power Supply System

Electric power generated by 2 units of 300 kW diesel generator is distributed to each site by 400 V distribution line.

The peak requirement of power is totaled to be 150 kW assuming the power demand factor of 0.45. In usual case, one generator can supply enough power to the work sites. Power demand required is shown as follows.

Location	Power Requirement (kW)
- Water supply	80
- Lighting, damsite and road	50
- Repair shop	20
- Motor pool & work shops	50
- Office & quarters	20
- Dewatering pump	50
- Other	50
Total	320 kW

Fuel Supply System

Daily fuel consumption of equipment and mobiles is estimated to be 20,000 liters for light oil and 1,000 liters for gasoline at the peak construction time. Fuel storage and supply facilities will be provided, of which required volume is estimated to be three times of daily consumption.

(i)	Fuel tank on ground (light oil)	20,000 liters x 3 tanks (each project)
(ii)	Fuel tank on ground (gasoline)	1,000 liters (each project)

Fuel tank will be installed at diesel generator plant. It is erected on ground for convenience of gravity supply to the plant.

7.1.5 Construction Plan and Schedule

Work Plan

Construction work will be generally carried out by conventional method. Excavation will be mostly by blading and ripping with bulldozers, loading by shovels, wheel loader and hauling by dump trucks. Concrete is produced by forced mixing plant of 18 cft x 1 unit and delivered to each placing site by agitator trucks.

Monthly average embankment of the dam will be about 14,000 m^3. In the placement of fill materials, impervious core zone and filter zone will be placed in 25 - 30 cm layer and compacted by vibration roller. Core and filter embankment will be almost suspended during the wet season, mid May to mid November.

Excavation and concrete works for the spillway will be divided in 3 areas, i.e. overflow weir, chuteway and stilling basin areas. Excavation in the overflow weir and upstream part of chuteway will precede and concreting will progress intermittently in parallel with the other works.

Construction Schedule

Construction period of the dam and reservoir works will extend over a period of about 4 - 5 years. Construction work will be proceeded throughout the year with maintaining 2 working shifts except during the peak wet period. The construction time schedules for each dam project are presented in Figs. 64 to 66.

7.2 Investment Cost

7.2.1 Basic Condition

The investment cost consist of direct construction 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 construction 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 was 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, etc,
- Fuel, oil and lubricant,
- Cement,
- Small gate and reinforcement steel bars,
- Inland transportation cost.

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

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

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

The compensation and land acquisition cost was referred to the result of the compensation survey, which was directly conducted by RID in 1982. The administration cost of the executive agencies was assumed to be 2 % of the direct cost. The cost of engineering service was assumed to be 10 % of the direct cost for the dam components. The physical contingency was 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.

7.2.2 Investment Cost

The investment cost of each dam is presented in Tables 44 to 47 with Nong Pla Lai dam cost which was updated as the same way as made for the other dams. They are summarized as follows:

(Unit: ฿ 10^3)

Dam Scheme	Foreign currency portion	Local currency portion	Total
Khlong Luang dam	752,790	1,716,760	2,469,550
Khlong Yai dam	707,460	1,377,460	2,084,920
Nong Pla Lai dam	713,170	1,612,810	2,325,980
Khlong Thap Ma dam	294,490	981,470	1,275,960

The detailed construction cost estimates are respectively shown in Priced Bill fo Quantities. The above investment costs are estimated on the international competitive bid basis, based on which economic evaluation of the project is conducted. However, apart from the above, the investment cost on basis of force account construction were also estimated for the purpose of reference as shown in Tables 48 to 50 and its procurement cost were shown in Tables 51 to 53 respectively.

7.2.3 Annual Disbursement Schedule

The annual disbursement schedule of investment cost of each dam project was worked out as shown in Tables 54 to 56, based on the construction time schedule. The annual disbursement schedule of economic construction cost of each dam was also shown in Tables 57 to 60.

7.3 Operation and Maintenance Costs

The annual operation and maintenance costs include the salaries of operation and maintenance office staffs, the materials and labour costs for repair and maintenance of dam facilities and running cost of dam facilities. The operation and maintenance costs were estimated based on the assumption to be 0.5 % of direct construction cost. The annual operation and maintenance costs for each dam project are summarized as follows:

(Unit: ฿ 10^3)

Dam Scheme	Annual O&M Cost
Khlong Luang dam	5,050
Khlong Yai dam	4,830
Nong Pla Lai dam	5,880
Khlong Thap Ma dam	2,140

REFERENCES

1. EAST COAST WATER RESOURCES DEVELOPMENT PROJECT (PHASE II), PRELIMINARY REPORT, MAY 1982, JICA
2. REPORT ON SUITABILITY OF WATER SUPPLY TO PATTAYA AND BANG LAMUNG, AUGUST 1979, NESDB
3. STUDIES OF WATER RESOURCES MANAGEMENT ORGANIZATION OF THAILAND, NESDB
4. RECONNAISSANCE REPORT FOR BANG PAKONG RIVER BASIN DEVELOPMENT, ENGINEERING CONSULTANTS, INC
5. THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT , MARCH 1982, JICA
6. GENERAL IRRIGATION OF EAST COAST OF GULF OF THAILAND, 1968, RID
7. PRACHIN RIVER DEVELOPMENT PROJECT AND EAST COAST WATER RESOURCES DEVELOPMENT PROJECT, FEBRUARY 1967, RID
8. PRELIMINARY REPORT, KHLONG LUANG RESERVOIR PROJECT, MAY 1968, RID
9. PRELIMINARY REPORT, BAN BUNG (EXTENDED) RESERVOIR PROJECT, RID
10. PRELIMINARY REPORT, KHLONG THAP MA RESERVOIR PROJECT, AUGUST 1979, RID
11. EASTERN SEABOARD STUDY, INTERIM REPORT 5 TRANSPORT WATER AND UTILITIES, JULY 1982
12. HANDBOOK OF APPLIED HYDROLOGY, VEN TE CHOW, McGRAW-HILL BOOK COMPANY
13. FREEBOARD ALLOWANCE FOR WAVES INLAND RESERVOIR, 1962, J. SAVILLE
14. DESIGN CRITERIA FOR LARGE DAM, 1978, JAPAN CONFERENCE OF LARGE DAM
15. DESIGN OF SMALL DAMS, U.S. BUREAU OF RECLAMATION

TABLES

Table 1 CHARACTERISTICS OF ZONES

Zone No.	Total Area of Zone	Name of Zones	Rivers	Catchment Area	River Length
	(km^2)			(km^2)	(km)
1	2,118/1	Khlong Luang	Khlong Luang	1,925	85.0
2	168	Chon Buri	Khlong Yai Cheng	30.1	8.8
			Huai Nong Khang Khok	20.4	10.0
			Khlong Bang Prong	27.8	13.6
			Others	89.7	-
3	128	Bang Phra	Huai Sukhrip	128	17.5
4	361	Laem Chabang	Khlong Bang Lamung	301	31.9
			Others	60.0	-
5	142	Pattaya	Huai Nong Pru	100	17.8
			Others	42.0	-
6	135	Huai Yai	Huai Yai	119	18.9
			Others	16.0	-
7	422	Sattahip	Khlong Bang Phai	181	28.5
			Others	241	-
8	109	Ban Chang	Khlong Phayun	31.8	13.1
			Khlong Phala	18.8	9.5
			Khlong Nam Tok	18.7	9.5
			Others	39.7	-
9	120	Map Ta Phut	Khlong Huai Yai	120	18.0
10	1,776	Rayong	Rayong	1,726	91.0
			Others	50	-

Note : Distance and area was measured in 1/50,000 topographic maps.

Remarks : /1 : Including 193 km^2 of the Bang Pakong river basin.

TABLE 2 SALIENT FEATURES OF DAMS IN OPERATION, UNDER CONSTRUCTION AND PROPOSED

Description	Unit	Existing						Under construction	Proposed	
		Bang Phra	Map Prachan	Dok Krai	Ban Bung	Phluta Luang	Khlong Bang Phai	Nong Kho	Ban Bung	Nong Pla Lai
1. Purpose		D & I, A	D & I, A	D & I, A, F	D & I, A	D & I	D & I	D & I, A	D & I, A	A, F
2. Year of completion		1975	1979	1975	1958	N.A	N.A	-	-	-
3. River basin No.		3	5	10	1	7	7	4	1	10
4. Name of river		Huai Sukhrip	Huai Nong Pru	Khlong Dok Krai	Ban Bung	Phluta Luang	Khlong Bang Phai	Huai Nong Kho	Ban Bung	Nong Pla Lai
5. Catchment area	km^2	123	37.9	291	51.2			48.3	51.2	408
6. Average annual inflow	$10^6 m^3$	43.9 /1	13.5 /1	103.8	12.2 /1			17.2 /1	12.2 /1	126.1
7. Reservoir										
Gross storage capacity	$10^6 m^3$	120.0	17.0	70.8	2.9			26.0	21.9	200.7
Surcharge capacity	$10^6 m^3$	10.0	2.2	20.0	1.0			7.0	7.8	43.5
Active storage capacity	$10^6 m^3$	104.0	14.0	46.8	0.4			18.0	12.5	144.4
Dead storage capacity	$10^6 m^3$	6.0 /2	0.8	4.0	1.5			1.0	1.6	12.8
Flood water surface	El.m	30.6	45.7	52.6	77.1			66.5	84.3	47.0
High water surface	El.m	30.0	45.0	50.6	76.3			65.0	82.1	45.0
Low water surface	EL.m	18.6 /3	36.0	38.6 /3	75.8			57.5	76.1	33.3
Reservoir surface area of HWS	km^2	15.8	2.8	8.8	1.2			4.4	3.2	20.2
8. Dam										
Type		Earth-fill	Earth-fill	Earth-fill	Earth-fill			Earth-fill	Earth-fill	Earth-fill
Height	m	24.0	17.0	24.6	8.5			17.0	21.5	31.0
Crest elevation	El.m	31.5	47.0	54.6	78.8			68.0	86.3	49.0
Crest length	m	1,720	2,060	1,500	1,400			2,000	2,800	4,000
Volume	$10^6 m^3$	N.A	N.A	N.A	N.A				1.4	3.2
9. Spillway										
Type		Morning glory	Morning glory	Morning glory	Open Chute			Open chute	Open chute	Open chute
Discharge capacity	m^3/s	65.0	37.0	N.A.	N.A.			108	125	700
Crest elevation of overflow section	EI.m	300	45.0	50.6	76.3			65.0	82.1	38.0
Crest length of overflow section	m	N.A	ø6 m	ø10.0	-			40	20.0	20.0

/1 : Estimated from Dok Krai

/2 : Derived from the area-storage curve prepared by RID

/3 : Estimated assuming sediment deposits in horizontal layor.

Note; N.A. : Not available

D & I : Domestic and industrial water supply

A : Irrigation

F : Flood control

Table 3 HISTORICAL WATER SUPPLY

Water Source Facilities		Water Uses		Amount of Water Supply (MCM/yr)				
Facilities	Zone No.	Zone No.	Water Uses	1977	1978	1979	1980	1981
1. Reservoirs								
Ban Bung	1	1	Industrial	1.3	0.9	2.4	1.7	3.7
		1	Irrigation	0.8	0.4	0.4	0.6	1.1
		1	Others	0.0	0.0	0.0	0.0	0.0
			Total	2.1	1.3	2.8	2.3	4.8
Bang Phra	3	2	Domestic	8.8	8.8	8.8	8.8	8.8
		2	Irrigation	9.5	4.8	9.6	1.8	6.3
		3	Industry	0.3	0.3	0.3	0.3	0.3
		4	Industry	1.1	1.1	1.2	1.1	1.3
		3	Others	0.1	0.1	0.1	0.1	0.1
			Total	19.8	15.1	20.0	12.1	16.8
Map Prachan	5	5	Industry	-	-	-	-	0.0
		5	Domestic	-	-	-	-	1.2
		5	Irrigation	-	-	-	-	0.1
			Total	-	-	-	-	1.3
Dok Krai	10	10	Irrigation	47.8	55.0	38.9	26.1	45.9
2. Intakes of Urban Water Works /1								
Ban Bung	1			0.1	0.1	0.1	0.1	0.1
Phanat Nikhom	1			0.3	0.4	0.2	0.3	0.4
Rayong /2	10			1.3	1.5	1.8	1.8	2.1
Total				71.4	73.4	63.8	42.7	71.4

/1 Not including the intakes of rural water works, since no data is available

/2 Including a part of water supplied by Dok Krai reservoir

Data Source : RID, PWWA

Table 4 MONTHLY MEAN RUN-OFF AT KHLONG LUANG DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.28	0.83	0.88	0.35	6.71	5.45	6.99	0.26	0.02	0.01	0.01	0.02	1.82
1969	0.02	0.08	0.08	0.07	2.36	20.28	6.25	0.58	0.01	0.01	0.01	0.05	2.48
1970	0.48	0.97	7.55	6.40	5.15	7.66	4.64	0.28	0.08	0.00	0.00	0.01	2.77
1971	0.02	0.19	1.85	0.53	7.62	19.36	14.89	2.72	0.11	0.01	0.03	0.00	3.95
1972	0.39	0.09	8.02	1.57	0.47	21.49	24.00	2.05	0.65	0.09	0.02	0.05	4.91
1973	0.04	0.53	1.30	5.97	6.61	22.50	9.53	0.92	0.15	0.15	0.27	0.41	4.03
1974	1.22	1.92	1.24	2.45	6.95	12.97	59.36	10.81	1.09	0.45	0.86	0.29	8.30
1975	0.32	1.86	1.04	6.80	3.16	20.79	24.49	3.78	0.46	0.26	0.59	0.47	5.34
1976	0.84	1.50	2.02	1.59	6.74	16.73	14.29	9.93	0.47	0.25	0.22	0.25	4.57
1977	0.21	0.91	1.10	3.02	4.14	4.08	6.30	0.79	0.24	0.17	1.57	0.54	1.92
1978	2.46	11.39	4.55	9.34	4.68	26.87	10.99	1.13	0.32	0.23	0.20	0.17	6.03
1979	0.73	2.64	1.20	0.46	0.77	1.65	4.10	0.19	0.16	0.12	0.05	0.51	1.04
1980	0.38	0.22	8.50	3.08	13.20	10.88	6.75	1.48	0.22	0.19	0.15	0.20	3.77
1981	9.76	3.83	1.05	1.75	2.51	23.26	9.23	4.18	0.49	0.12	0.09	0.05	4.70
Mean	1.23	1.92	2.88	3.10	5.08	15.28	14.41	2.79	0.32	0.15	0.29	0.22	3.98

River System : Khlong Luang

Catchment Area : 526 km^2

Zone No. : 1

Table 5 MONTHLY MEAN RUN-OFF AT PA DAENG DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.03	0.08	0.09	0.04	0.69	0.56	0.71	0.03	0.00	0.00	0.00	0.00	0.19
1969	0.00	0.01	0.01	0.01	0.24	2.07	0.64	0.06	0.00	0.00	0.00	0.01	0.25
1970	0.05	0.10	0.77	0.65	0.53	0.78	0.47	0.03	0.01	0.00	0.00	0.00	0.28
1971	0.00	0.02	0.19	0.05	0.78	1.98	1.52	0.28	0.01	0.00	0.00	0.00	0.40
1972	0.04	0.01	0.82	0.16	0.05	2.20	2.45	0.21	0.07	0.01	0.00	0.01	0.50
1973	0.00	0.05	0.13	0.61	0.68	2.30	0.97	0.09	0.02	0.02	0.03	0.04	0.41
1974	0.12	0.20	0.13	0.25	0.71	1.33	6.07	1.11	0.11	0.05	0.09	0.03	0.85
1975	0.03	0.19	0.11	0.70	0.32	2.13	2.50	0.39	0.05	0.03	0.06	0.05	0.55
1976	0.09	0.15	0.21	0.16	0.69	1.71	1.46	1.02	0.05	0.03	0.02	0.03	0.47
1977	0.02	0.09	0.11	0.31	0.42	0.42	0.64	0.08	0.02	0.02	0.16	0.06	0.20
1978	0.25	1.16	0.47	0.95	0.48	2.75	1.12	0.12	0.03	0.02	0.02	0.02	0.62
1979	0.07	0.27	0.12	0.05	0.08	0.17	0.42	0.02	0.02	0.01	0.01	0.05	0.11
1980	0.04	0.02	0.87	0.31	1.35	1.11	0.69	0.15	0.02	0.02	0.02	0.02	0.39
1981	1.00	0.39	0.11	0.18	0.26	2.38	0.94	0.43	0.05	0.01	0.01	0.01	0.48
Mean	0.13	0.20	0.29	0.32	0.52	1.56	1.47	0.29	0.03	0.02	0.03	0.02	0.407

River System : Khlong Luang
Catchment Area : 53.8 km^2
Zone No. : 1

Table 6 MONTLHLY MEAN RUN-OFF AT BAN BUNG DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.37	1.32	1.59	0.90	0.56	0.61	1.59	0.97	0.28	0.27	0.11	0.12	0.73
1969	0.05	0.25	0.43	0.28	0.35	1.13	1.46	1.26	0.36	0.18	0.38	0.12	0.52
1970	0.30	1.43	1.04	0.42	0.31	0.43	1.20	0.37	1.90	0.46	0.23	0.22	0.69
1971	0.33	0.41	0.27	0.09	0.19	0.78	1.58	0.76	0.27	0.13	0.18	0.11	0.42
1972	0.95	0.17	0.16	0.04	0.01	2.47	3.23	1.43	0.51	0.18	0.19	0.24	0.80
1973	0.10	0.59	0.72	0.67	0.70	1.16	1.65	0.83	0.32	0.16	0.12	0.16	0.60
1974	0.65	0.61	0.25	0.17	0.34	1.01	2.37	1.31	0.43	0.33	0.27	0.20	0.66
1975	0.21	0.54	0.64	0.22	0.27	0.49	2.72	1.46	0.62	0.16	0.18	0.16	0.64
1976	0.28	0.60	0.12	0.05	1.06	0.89	1.44	1.59	0.44	0.19	0.15	0.07	0.57
1977	0.25	0.47	0.18	0.41	0.32	0.22	2.02	0.51	0.13	0.11	0.17	0.09	0.41
1978	0.26	0.93	0.39	0.63	0.40	0.73	1.31	0.64	0.16	0.11	0.08	0.04	0.48
1979	0.06	0.17	0.36	0.07	0.10	0.66	0.40	0.12	0.11	0.03	0.20	0.07	0.20
1980	0.08	0.11	0.60	0.22	0.28	0.30	2.26	1.10	0.29	0.07	0.30	0.25	0.49
1981	0.46	1.31	0.56	0.40	0.40	0.88	1.43	2.09	0.70	0.21	0.11	0.17	0.73
Mean	0.31	0.64	0.52	0.33	0.33	0.84	1.76	1.03	0.47	0.19	0.19	0.14	0.57

River System : Khlong Luang
Catchment Area : 51.2 km^2
Zone No. : 1

Table 7 MONTHLY MEAN RUN-OFF AT BANG PHRA DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.88	3.18	3.83	2.16	1.34	1.46	3.82	2.34	0.68	0.65	0.28	0.30	1.74
1969	0.12	0.60	1.03	0.67	0.83	2.71	3.50	3.03	0.87	0.44	0.91	0.28	1.25
1970	0.71	3.44	2.51	1.00	0.75	1.02	2.88	0.88	4.55	1.11	0.54	0.54	1.66
1971	0.80	0.99	0.65	0.22	0.45	1.86	3.78	1.83	0.64	0.32	0.42	0.42	1.02
1972	2.29	0.42	0.39	0.11	0.03	5.93	7.75	3.45	1.23	0.44	0.46	0.58	1.92
1973	0.24	1.41	1.72	1.62	1.68	2.79	3.96	2.00	0.77	0.38	0.30	0.37	1.44
1974	1.56	1.46	0.60	0.42	0.82	2.44	5.70	3.14	1.03	0.79	0.66	0.48	1.59
1975	0.50	1.31	1.55	0.54	0.66	1.18	6.54	3.51	1.48	0.39	0.42	0.37	1.54
1976	0.68	1.45	0.28	0.13	2.55	2.15	3.46	3.83	1.06	0.45	0.35	0.17	1.38
1977	0.59	1.14	0.44	0.98	0.77	0.52	4.86	1.23	0.31	0.26	0.41	0.21	0.98
1978	0.63	2.24	0.94	1.51	0.97	1.76	3.15	1.54	0.39	0.28	0.19	0.11	1.14
1979	0.14	0.41	0.88	0.16	0.24	1.59	0.97	0.29	0.26	0.08	0.48	0.17	0.47
1980	0.19	0.28	1.44	0.53	0.68	0.73	5.42	2.63	0.70	0.17	0.72	0.60	1.18
1981	1.10	3.15	1.34	0.96	1.08	2.11	3.45	5.01	1.69	0.50	0.28	0.41	1.76
Mean	0.74	1.53	1.26	1.26	0.92	2.02	4.23	2.48	1.12	0.45	0.46	0.35	1.36

River System : Huai Sukhrip

Catchment Area : 123 km^2

Zone No. : 3

Table 8 MONTHLY MEAN RUN-OFF AT NONG KHO DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.35	1.25	1.50	0.85	0.53	0.57	1.50	0.92	0.27	0.26	0.11	0.12	0.68
1969	0.05	0.23	0.40	0.26	0.33	1.06	1.37	1.19	0.34	0.17	0.36	0.11	0.49
1970	0.28	1.35	0.98	0.39	0.29	0.40	1.13	0.35	1.79	0.44	0.21	0.21	0.65
1971	0.31	0.39	0.26	0.09	0.18	0.73	1.49	0.72	0.25	0.12	0.17	0.11	0.40
1972	0.90	0.16	0.15	0.04	0.01	2.33	3.04	1.35	0.49	0.17	0.18	0.23	0.76
1973	0.10	0.55	0.68	0.64	0.66	1.10	1.56	0.79	0.30	0.15	0.12	0.15	0.56
1974	0.61	0.57	0.24	0.16	0.32	0.96	2.24	1.23	0.41	0.31	0.26	0.19	0.62
1975	0.19	0.51	0.61	0.21	0.26	0.47	2.57	1.38	0.58	0.15	0.17	0.15	0.60
1976	0.27	0.57	0.11	0.11	0.05	1.00	0.84	1.50	0.42	0.18	0.14	0.07	0.54
1977	0.23	0.45	0.17	0.38	0.30	0.20	1.91	0.48	0.12	0.10	0.16	0.08	0.38
1978	0.25	0.88	0.37	0.59	0.38	0.69	1.24	0.61	0.15	0.11	0.08	0.04	0.45
1979	0.06	0.16	0.34	0.06	0.09	0.62	0.38	0.11	0.10	0.03	0.19	0.07	0.19
1980	0.08	0.11	0.56	0.21	0.27	0.29	2.13	1.03	0.28	0.07	0.28	0.23	0.46
1981	0.43	1.24	0.53	0.38	0.42	0.83	1.35	1.97	0.66	0.20	0.11	0.16	0.69
Mean	0.29	0.60	0.49	0.31	0.36	0.79	1.66	0.97	0.44	0.18	0.14	0.14	0.54

River System : Khlong Bang Lamung

Catchment Area : 48.3 km^2

Zone No. : 4

Table 9 MONTHLY MEAN RUN-OFF AT HUAI BUNG DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.49	1.77	2.13	1.20	0.74	0.82	2.13	1.30	0.38	0.36	0.16	0.17	0.97
1969	0.07	0.33	0.57	0.37	0.46	1.51	1.95	1.69	0.48	0.24	0.51	0.16	0.69
1970	0.40	1.92	1.40	0.56	0.42	0.57	1.60	0.49	2.54	0.62	0.30	0.30	0.93
1971	0.45	0.55	0.36	0.12	0.25	1.04	2.11	1.02	0.36	0.18	0.24	0.15	0.57
1972	1.27	0.23	0.21	0.06	0.02	3.30	4.32	1.92	0.69	0.24	0.25	0.33	1.07
1973	0.13	0.78	0.96	0.90	0.94	1.56	2.21	1.12	0.43	0.21	0.17	0.21	0.80
1974	0.87	0.81	0.34	0.23	0.46	1.36	3.18	1.75	0.57	0.44	0.37	0.27	0.89
1975	0.28	0.73	0.86	0.30	0.37	0.66	3.64	1.95	0.82	0.22	0.24	0.21	0.86
1976	0.38	0.81	0.16	0.07	1.42	1.20	1.93	2.13	0.59	0.25	0.20	0.10	0.77
1977	0.33	0.63	0.24	0.54	0.43	0.29	2.71	0.69	0.17	0.14	0.23	0.12	0.54
1978	0.35	1.25	0.52	0.84	0.54	0.98	1.75	0.86	0.22	0.15	0.11	0.06	0.64
1979	0.08	0.23	0.49	0.09	0.13	0.89	0.54	0.16	0.15	0.05	0.27	0.09	0.26
1980	0.11	0.15	0.80	0.30	0.38	0.41	3.02	1.47	0.39	0.09	0.40	0.33	0.65
1981	0.61	1.75	0.75	0.53	0.60	1.18	1.92	2.79	0.94	0.28	0.15	0.23	0.98
Mean	0.41	0.86	0.70	0.44	0.51	1.12	2.36	1.38	0.62	0.25	0.25	0.19	0.76

River System : Khlong Bang Lamung

Catchment Area : 68.5 km^2

Zone No. : 4

Table 10 MONTHLY MEAN RUN-OFF AT HUAI TAKHIAN TIA DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.24	0.85	1.03	0.58	0.41	0.39	1.02	0.63	0.18	0.17	0.07	0.08	0.47
1969	0.03	0.16	0.28	0.18	0.22	0.73	0.94	0.81	0.23	0.12	0.24	0.07	0.33
1970	0.19	0.92	0.67	0.27	0.20	0.27	0.77	0.24	1.22	0.30	0.15	0.14	0.45
1971	0.21	0.26	0.18	0.06	0.12	0.50	1.01	0.49	0.17	0.09	0.11	0.07	0.27
1972	0.61	0.11	0.10	0.03	0.01	1.59	2.08	0.92	0.33	0.12	0.12	0.16	0.52
1973	0.07	0.38	0.46	0.43	0.45	0.75	1.06	0.54	0.21	0.10	0.08	0.10	0.39
1974	0.42	0.39	0.16	0.11	0.22	0.65	1.53	0.84	0.28	0.21	0.18	0.13	0.43
1975	0.13	0.35	0.42	0.14	0.18	0.32	1.76	0.94	0.40	0.11	0.11	0.10	0.41
1976	0.18	0.39	0.08	0.03	0.68	0.58	0.93	1.03	0.28	0.12	0.09	0.05	0.37
1977	0.16	0.31	0.12	0.26	0.21	0.14	1.30	0.33	0.08	0.07	0.11	0.06	0.26
1978	0.17	0.60	0.25	0.40	0.26	0.47	0.84	0.41	0.11	0.07	0.05	0.03	0.31
1979	0.04	0.11	0.24	0.04	0.06	0.43	0.26	0.08	0.07	0.02	0.13	0.05	0.13
1980	0.05	0.07	0.39	0.14	0.18	0.20	1.45	0.71	0.19	0.04	0.19	0.16	0.32
1981	0.30	0.85	0.36	0.26	0.26	0.57	0.92	1.34	0.45	0.13	0.07	0.11	0.47
Mean	0.20	0.41	0.34	0.21	0.25	0.54	1.14	0.66	0.30	0.12	0.12	0.09	0.37

River System : Khlong Bang Lamung

Catchment Area : 33.0 km^2

Zone No. : 4

Table 11 MONTHLY MEAN RUN-OFF AT KHLONG NA KLUA DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.16	0.58	0.69	0.39	0.24	0.27	0.69	0.42	0.12	0.12	0.05	0.05	0.32
1969	0.02	0.11	0.19	0.12	0.15	0.49	0.63	0.55	0.16	0.08	0.16	0.05	0.23
1970	0.13	0.62	0.45	0.18	0.14	0.19	0.52	0.16	0.83	0.20	0.10	0.10	0.30
1971	0.14	0.18	0.12	0.04	0.08	0.34	0.69	0.33	0.12	0.06	0.08	0.05	0.18
1972	0.41	0.08	0.07	0.02	0.01	1.07	1.40	0.62	0.22	0.08	0.08	0.11	0.35
1973	0.04	0.26	0.31	0.29	0.30	0.51	0.72	0.36	0.14	0.07	0.05	0.07	0.26
1974	0.28	0.26	0.11	0.08	0.15	0.44	1.03	0.57	0.19	0.14	0.12	0.09	0.29
1975	0.09	0.24	0.28	0.10	0.12	0.21	1.19	0.64	0.27	0.07	0.08	0.07	0.28
1976	0.12	0.26	0.05	0.02	0.46	0.39	0.63	0.69	0.19	0.08	0.06	0.03	0.25
1977	0.11	0.21	0.08	0.18	0.14	0.09	0.88	0.22	0.06	0.05	0.07	0.04	0.18
1978	0.11	0.41	0.17	0.27	0.16	0.32	0.57	0.28	0.07	0.05	0.04	0.02	0.21
1979	0.03	0.08	0.16	0.03	0.04	0.29	0.18	0.05	0.05	0.01	0.09	0.03	0.08
1980	0.04	0.05	0.26	0.10	0.12	0.13	0.98	0.48	0.13	0.03	0.13	0.11	0.21
1981	0.20	0.57	0.24	0.17	0.16	0.38	0.62	0.91	0.31	0.09	0.05	0.08	0.32
Mean	0.13	0.28	0.23	0.14	0.17	0.37	0.77	0.45	0.20	0.08	0.08	0.06	0.25

River System : Huai Nong Pru

Catchment Area : 22.3 km^2

Zone No. : 5

Table 12 MONTHLY MEAN RUN-OFF AT MAP PRACHAN DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.27	0.98	1.18	0.66	0.41	0.45	1.18	0.72	0.21	0.20	0.09	0.09	0.54
1969	0.04	0.18	0.32	0.21	0.26	0.83	1.08	0.93	0.27	0.13	0.28	0.09	0.38
1970	0.22	1.06	0.77	0.31	0.23	0.32	0.89	0.27	1.40	0.34	0.17	0.17	0.52
1971	0.25	0.30	0.20	0.07	0.14	0.57	1.17	0.56	0.20	0.10	0.13	0.08	0.31
1972	0.70	0.13	0.12	0.03	0.01	1.83	2.39	1.06	0.38	0.13	0.14	0.18	0.59
1973	0.07	0.43	0.53	0.50	0.52	0.86	1.22	0.62	0.24	0.12	0.09	0.11	0.44
1974	0.48	0.45	0.19	0.13	0.25	0.75	1.76	0.97	0.32	0.24	0.20	0.15	0.49
1975	0.15	0.40	0.48	0.17	0.20	0.36	2.02	1.08	0.46	0.12	0.13	0.11	0.47
1976	0.21	0.45	0.09	0.04	0.79	0.66	1.07	1.18	0.33	0.14	0.11	0.05	0.43
1977	0.18	0.35	0.13	0.30	0.24	0.16	1.50	0.38	0.10	0.08	0.13	0.07	0.30
1978	0.19	0.69	0.29	0.46	0.30	0.54	0.97	0.48	0.12	0.08	0.06	0.03	0.35
1979	0.04	0.13	0.27	0.05	0.07	0.49	0.30	0.09	0.08	0.02	0.15	0.05	0.14
1980	0.06	0.08	0.44	0.16	0.21	0.23	1.67	0.81	0.22	0.05	0.22	0.18	0.36
1981	0.34	0.97	0.41	0.29	0.33	0.65	1.06	1.54	0.52	0.15	0.08	0.13	0.54
Mean	0.23	0.47	0.39	0.24	0.28	0.62	1.30	0.76	0.35	0.14	0.14	0.11	0.42

River System : Huai Nong Pru
Catchment Area : 37.9 km^2
Zone No. : 5

Table 13 MONTHLY MEAN RUN-OFF AT HUAI CHAK NOK DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.13	0.47	0.56	0.32	0.20	0.22	0.56	0.34	0.10	0.10	0.04	0.04	0.26
1969	0.02	0.09	0.15	0.10	0.12	0.40	0.51	0.45	0.13	0.06	0.13	0.04	0.18
1970	0.11	0.51	0.37	0.15	0.11	0.15	0.42	0.13	0.67	0.16	0.08	0.08	0.25
1971	0.12	0.14	0.10	0.03	0.07	0.27	0.56	0.27	0.09	0.05	0.06	0.04	0.15
1972	0.34	0.06	0.06	0.02	0.00	0.87	1.14	0.51	0.18	0.06	0.07	0.09	0.28
1973	0.04	0.21	0.25	0.24	0.25	0.41	0.58	0.29	0.11	0.06	0.04	0.05	0.21
1974	0.23	0.21	0.09	0.06	0.12	0.36	0.84	0.46	0.15	0.12	0.10	0.07	0.23
1975	0.07	0.19	0.23	0.08	0.10	0.17	0.96	0.52	0.22	0.06	0.06	0.05	0.23
1976	0.10	0.21	0.04	0.02	0.38	0.32	0.51	0.56	0.16	0.07	0.05	0.03	0.20
1977	0.09	0.17	0.06	0.14	0.11	0.08	0.72	0.18	0.05	0.04	0.06	0.03	0.14
1978	0.09	0.33	0.14	0.22	0.14	0.26	0.46	0.23	0.06	0.04	0.03	0.02	0.17
1979	0.02	0.06	0.13	0.02	0.03	0.23	0.14	0.04	0.04	0.01	0.07	0.02	0.07
1980	0.03	0.04	0.21	0.08	0.10	0.11	0.80	0.39	0.10	0.02	0.11	0.09	0.17
1981	0.16	0.46	0.20	0.14	0.16	0.31	0.51	0.74	0.25	0.07	0.04	0.06	0.26
Mean	0.11	0.23	0.18	0.12	0.13	0.30	0.62	0.36	0.16	0.07	0.07	0.05	0.20

River System : Huai Yai

Catchment Area : 18.1 km^2

Zone No. : 6

Table 14 MONTHLY MEAN RUN-OFF AT HUAI YAI DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.47	1.70	2.05	1.15	0.72	0.78	2.04	1.25	0.36	0.35	0.15	0.16	0.93
1969	0.06	0.32	0.55	0.36	0.45	1.45	1.87	1.62	0.46	0.23	0.49	0.15	0.67
1970	0.38	1.84	1.34	0.53	0.40	0.55	1.54	0.47	2.44	0.60	0.29	0.29	0.89
1971	0.43	0.53	0.35	0.12	0.24	1.00	2.03	0.98	0.34	0.17	0.23	0.14	0.55
1972	1.23	0.22	0.21	0.06	0.02	3.17	4.15	1.85	0.66	0.23	0.25	0.31	1.03
1973	0.13	0.75	0.92	0.87	0.90	1.50	2.12	1.07	0.41	0.20	0.16	0.20	0.77
1974	0.84	0.78	0.32	0.22	0.44	1.30	3.05	1.68	0.55	0.42	0.35	0.26	0.85
1975	0.26	0.70	0.83	0.29	0.35	0.63	3.51	1.88	0.79	0.21	0.23	0.20	0.82
1976	0.36	0.78	0.15	0.07	1.37	1.15	1.85	2.05	0.57	0.24	0.19	0.09	0.74
1977	0.32	0.61	0.23	0.52	0.41	0.28	2.60	0.66	0.17	0.14	0.22	0.11	0.52
1978	0.34	1.20	0.50	0.81	0.52	0.94	1.69	0.83	0.21	0.15	0.10	0.06	0.61
1979	0.08	0.22	0.47	0.08	0.13	0.85	0.52	0.15	0.14	0.04	0.26	0.09	0.25
1980	0.10	0.15	0.77	0.29	0.36	0.39	2.90	1.41	0.38	0.09	0.39	0.32	0.63
1981	0.59	1.69	0.72	0.51	0.58	1.13	1.85	2.69	0.91	0.27	0.15	0.22	0.94
Mean	0.40	0.82	0.67	0.42	0.49	1.08	2.27	1.33	0.60	0.24	0.25	0.19	0.73

River System : Huai Yai

Catchment Area : 65.9 km^2

Zone No. : 6

Table 15 MONTHLY MEAN RUN-OFF AT KHLONG THAP MA DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	1.13	4.08	4.91	2.77	1.72	1.88	4.90	3.00	0.87	0.84	0.36	0.38	2.25
1969	0.15	0.77	1.32	0.86	1.07	3.48	4.49	3.89	1.11	0.56	1.17	0.36	1.60
1970	0.92	4.42	3.22	1.28	0.96	1.31	3.70	1.13	5.85	1.43	0.69	0.69	2.15
1971	1.03	1.27	0.84	0.28	0.58	2.39	4.86	2.35	0.82	0.41	0.54	0.34	1.31
1972	2.94	0.54	0.49	0.14	0.04	7.61	9.95	4.43	1.59	0.56	0.59	0.75	2.47
1973	0.31	1.81	2.21	2.08	2.16	3.59	5.09	2.57	0.99	0.49	0.38	0.48	1.85
1974	2.01	1.87	0.78	0.54	1.05	3.13	7.32	4.03	1.32	1.01	0.84	0.62	2.05
1975	0.64	1.68	1.99	0.69	0.84	1.52	8.40	4.51	1.90	0.50	0.54	0.48	1.98
1976	0.87	1.86	0.36	0.16	3.28	2.76	4.44	4.91	1.36	0.58	0.45	0.22	1.78
1977	0.76	1.46	0.56	1.25	0.99	0.66	6.24	1.58	0.40	0.33	0.53	0.27	1.26
1978	0.81	2.87	1.21	1.93	1.24	2.26	4.05	1.98	0.50	0.35	0.25	0.14	1.47
1979	0.18	0.53	1.12	0.20	0.30	2.04	1.24	0.37	0.34	0.10	0.61	0.22	0.60
1980	0.25	0.35	1.85	0.68	0.87	0.94	6.96	3.38	0.90	0.21	0.92	0.77	1.51
1981	1.41	4.05	1.72	1.23	1.38	2.71	4.43	6.44	2.17	0.65	0.35	0.53	2.26
Mean	0.96	1.97	1.61	1.00	1.18	2.59	5.43	3.18	1.44	0.58	0.59	0.45	1.75

River System : Rayong

Catchment Area : 158 km^2

Zone No. : 10

Table 16 MONTHLY MEAN RUN-OFF AT NONG PLA LAI DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	1.92	5.14	8.66	4.99	3.62	5.38	12.20	5.53	1.75	1.48	0.74	0.71	4.34
1969	0.50	2.47	2.47	1.61	2.90	11.60	15.60	10.70	3.01	1.52	1.62	0.95	4.58
1970	3.02	7.41	8.77	5.69	3.45	3.54	7.95	3.00	5.82	2.14	1.48	1.93	4.52
1971	2.00	4.07	2.89	1.21	3.74	7.89	10.80	4.00	1.75	1.01	2.37	1.75	3.62
1972	7.59	2.06	3.09	1.21	0.40	9.77	14.00	10.10	4.18	1.48	1.33	1.71	4.74
1973	0.81	4.76	5.81	5.47	5.69	9.45	13.40	6.78	2.62	1.28	1.00	1.25	4.86
1974	5.29	4.93	2.04	1.42	2.77	8.24	19.30	10.60	3.49	2.66	2.22	1.63	5.38
1975	1.55	3.64	2.14	2.06	2.28	11.10	14.50	8.48	3.36	1.56	1.59	1.61	4.49
1976	2.29	4.91	2.36	0.93	3.67	14.90	10.40	10.70	3.22	1.52	1.19	0.59	4.72
1977	1.03	2.69	2.09	2.42	1.70	1.25	5.24	2.22	0.89	0.88	2.25	0.71	1.95
1978	2.13	8.65	5.73	7.12	3.49	7.23	9.49	3.22	1.33	0.93	0.67	0.36	4.20
1979	0.85	2.65	3.06	0.84	0.62	3.59	3.46	0.78	0.51	0.26	0.75	0.79	1.51
1980	0.66	0.94	5.93	3.14	3.32	3.16	13.20	5.48	2.09	0.89	1.14	1.31	3.44
1981	3.38	8.55	4.19	3.24	3.30	8.14	9.76	8.50	4.45	1.57	1.21	1.40	4.81
Mean	2.36	4.49	4.23	2.95	2.93	7.52	11.40	6.44	2.75	1.37	1.40	1.19	4.083

River System : Rayong

Catchment Area : 408 km^2

Zone No. : 10

Table 17 MONTHLY MEAN RUN-OFF AT KHLONG YAI DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
1968	0.61	2.90	6.59	2.76	1.67	3.13	11.33	3.26	4.59	0.41	0.14	0.14	3.13
1969	0.07	0.91	0.92	0.46	1.18	10.47	16.70	9.21	1.25	0.42	0.47	0.20	3.52
1970	1.26	5.16	6.73	3.40	1.54	1.61	5.77	1.23	3.53	0.73	8.53	0.62	2.67
1971	0.65	2.00	1.16	0.30	1.76	5.70	9.34	1.95	0.53	0.22	0.85	0.53	2.09
1972	5.36	0.69	1.25	0.30	0.05	7.99	13.82	8.40	2.02	0.41	0.34	0.51	3.43
1973	0.16	2.56	3.52	3.20	3.40	7.57	13.13	4.48	1.00	0.32	0.22	0.31	3.32
1974	3.03	2.71	0.68	0.38	1.10	6.11	23.32	9.10	1.57	1.03	0.77	0.47	4.18
1975	0.43	1.68	0.73	0.69	0.80	9.83	14.89	6.39	1.48	0.45	0.46	0.46	3.20
1976	0.81	2.69	0.85	0.19	1.71	15.61	8.87	9.17	1.38	0.42	0.28	0.09	3.51
1977	0.23	1.04	1.62	3.18	1.08	1.00	7.27	0.89	0.20	0.11	0.93	0.18	1.48
1978	0.41	8.42	3.32	4.59	1.92	6.39	5.81	1.04	0.22	0.22	0.05	0.01	2.69
1979	0.35	0.34	0.54	1.18	0.22	2.53	4.21	0.18	0.08	0.03	0.03	0.54	0.85
1980	0.31	0.28	2.61	1.87	2.99	1.18	9.48	3.43	0.27	0.11	0.11	0.09	1.90
1981	1.92	4.55	2.52	3.21	2.61	7.64	4.48	4.25	0.88	0.24	0.16	0.07	2.71
Mean	1.11	2.57	2.36	1.84	1.57	6.20	10.60	4.50	1.35	0.37	0.38	0.30	2.76

River System : Rayong
Catchment Area : 218 km^2
Zone No. : 10

Table 18 MONTHLY MEAN RUN-OFF AT DOK KRAI DAMSITE

(Unit: m^3/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1968	2.08	7.52	9.05	5.10	3.16	3.46	9.03	5.53	1.60	1.54	0.66	0.70	4.12
1969	0.28	1.41	2.43	1.59	1.97	6.41	8.27	7.17	2.05	1.03	2.15	0.66	2.95
1970	1.69	8.14	5.93	2.36	1.77	2.42	6.81	2.09	10.77	2.63	1.28	1.27	3.93
1971	1.89	2.33	1.54	0.51	1.06	4.41	8.95	4.32	1.51	0.75	1.00	0.63	2.41
1972	5.41	0.99	0.91	0.25	0.08	14.02	18.33	8.15	2.92	1.03	1.08	1.38	4.55
1973	0.57	3.33	4.07	3.83	3.98	6.61	9.37	4.74	1.83	0.90	0.70	0.88	3.40
1974	3.70	3.45	1.43	0.99	1.94	5.76	13.49	7.42	2.44	1.86	1.55	1.14	3.76
1975	1.17	3.09	3.66	1.27	1.55	2.80	15.48	8.30	3.50	0.93	1.00	0.88	3.64
1976	1.60	3.43	0.66	0.30	6.04	5.08	8.18	9.05	2.51	1.07	0.83	0.41	3.26
1977	1.40	2.69	1.03	2.31	1.82	1.22	11.50	2.91	0.73	0.61	0.97	0.50	2.31
1978	1.49	5.29	2.22	3.56	2.29	4.16	7.45	3.65	0.93	0.65	0.46	0.25	2.70
1979	0.34	0.98	2.07	0.37	0.56	3.76	2.29	0.68	0.62	0.19	1.13	0.40	1.12
1980	0.46	0.65	3.40	1.26	1.61	1.73	12.82	6.23	1.66	0.39	1.70	1.41	2.78
1981	2.60	7.45	3.17	2.26	2.55	5.00	8.15	11.86	4.00	1.19	0.65	0.98	4.16
Mean	1.76	3.63	2.97	1.85	2.17	4.77	10.01	5.86	2.65	1.06	1.08	0.82	3.22

Note : River System : Rayong
Catchment Area : 291 km^2
Zone No. : 10

Table 19 COMPENSATION AND RELOCATION COST

	Descriptions	Unit	Nong Kho /1	Map Prachan /1	Khlong Luang /2	Khlong Thap Ma /2	Khlong Yai /2
(1)	Compensation cost for land	฿ 10^6	60.54	31.75	161.6	129.6	26.25
(2)	Compensation cost for crops, housings, trees, other assets	฿ 10^6	92.42	24.41	63.89	131.31	29.39
(3)	Land acquired	ha	569.6	508	3,232	1,152	560
(4)	Reservoir surface area at HWS	ha	440	280	3,280	1,160	1,680
(5)	Unit cost for land, (1)/(3)	฿10^3/ha	106.3	62.5	50.0	112.5	46.9
(6)	Unit cost for land (1)/(4)	฿10^3/ha	137.6	113.4	49.3	124.6	15.6
(7)	Unit cost for crops, housing, etc., (2)/(4)	฿10^3/ha	210.0	87.2	19.5	113.2	17.5
(8)	Average cost, (1)+(2)/(4)	฿10^3/ha	347.6	200.6	68.7	224.6	33.1

/1 Actual data

/2 Estimated, according to the preliminary survey

Data Source : RID

Table 20 FORMAT FOR PRELIMINARY CONSTRUCTION COST ESTIMATE

Cost Items	
1. Preparatory Works	1 % of Item (2)
2. Dam and Spillway	
Dam, excavation	
embankment	
others	20 % of excavation plus embankment
Spillway, excavation	
concrete	
reinforcement bar	
others	20 % of excavation, concrete and reinforcement bar
Miscellaneous	3 % of dam and spillway cost
3. Compensation & Relocation	
4. General Expenses	12 % of the sum of Items (1) through (3)
5. Contingency	20 % of the sum of Items (1) through (4)
6. Interest during Construction Period	0.4 x T/1 x i/2 x (1+2+3+4+5)
Total	

/1 Construction period, assumed to be 3 years

/2 Interest rate, assumed to be 8 % per year.

Table 21 FEATURES AND CONSTRUCTION COST OF KLONG LUANG DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km^2	526.0	526.0	526.0	526.0	526.0
Average annual run-off	$10^6 m^3$	125.2	125.2	125.2	125.2	125.2
High water surface	El.m.	36.0	38.0	39.0	40.0	42.0
Low water surface	El.m.	33.8	33.8	33.8	33.8	33.8
Gross storage capacity	$10^6 m^3$	45.9	90.3	119.0	150.7	228.2
Active storage capacity	$10^6 m^3$	30.1	74.5	103.2	134.9	212.4
Dead storage capacity	$10^6 m^3$	15.8	15.8	15.8	15.8	15.8
Reservoir surface area at HWS	km^2	18.4	26.0	30.0	34.0	43.1
Regulated outflow	$10^6 m^3$	32.8	56.8	71.6	78.5	84.8
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	39.0	41.0	42.0	43.0	45.0
Length of dam crest	m.	3,330.0	3,740.0	3,760.0	3,740.0	3,860.0
Height of dam	m.	16.0	18.0	19.0	20.0	22.0
Dam volume	$10^3 m^3$	1,147.0	1,592.0	1,861.0	2,159.0	2,873.0
100-year probable flood	m^3/s	878.0	878.0	878.0	878.0	878.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	3.8	4.9	5.6	6.4	8.3
2.2 Dam & Spillway	฿ 10^6	375.5	489.6	560.7	638.8	825.1
2.3 Compensation and relocation cost	฿ 10^6	158.2	210.4	237.9	268.1	327.9
2.4 General expenses	฿ 10^6	64.5	84.6	96.5	109.6	139.4
2.5 Contingency	฿ 10^6	120.4	157.9	180.1	204.5	260.1
2.6 Interest during construction period	฿ 10^6	69.4	91.0	103.8	117.8	149.8
Total	฿ 10^6	791.8	1,038.4	1,184.6	1,344.6	1,710.6

Table 22 FEATURES AND CONSTRUCTION COST OF PA DAENG DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km²	53.8	53.8	53.8	53.8	
Average annual run-off	$10^6 m^3$	18.8	18.8	18.8	18.8	
High water surface	El.m.	64.3	65.4	66.0	66.7	
Low water surface	El.m.	61.7	61.7	61.7	61.7	
Gross storage capacity	$10^6 m^3$	6.7	10.6	14.4	17.0	
Active storage capacity	$10^6 m^3$	5.1	9.0	12.8	15.4	
Dead storage capacity	$10^6 m^3$	1.6	1.6	1.6	1.6	
Reservoir surface area at HWS	km²	3.1	4.2	4.8	5.6	
Regulated outflow	$10^6 m^3$	6.9	9.1	10.7	11.6	
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	
Dam crest	El.m.	67.3	68.4	69.0	69.7	
Length of dam crest	m.	1,480.0	1,660.0	1,760.0	1,880.0	
Height of dam	m.	12.8	13.9	14.5	15.2	
Dam volume	$10^3 m^3$	347.0	442.0	502.0	578.0	
100-year probable flood	m³/s	240.0	240.0	240.0	240.0	
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	1.2	1.4	1.6	1.8	
2.2 Dam & Spillway	฿ 10^6	116.3	140.2	157.4	179.2	
2.3 Compensation and relocation cost	฿ 10^6	111.7	149.9	170.7	198.6	
2.4 General expenses	฿ 10^6	27.5	35.0	39.6	45.6	
2.5 Contingency	฿ 10^6	51.3	65.3	73.9	85.0	
2.6 Interest during construction period	฿ 10^6	29.6	37.6	42.5	49.0	
Total	฿ 10^6	337.6	429.4	485.7	559.2	

Table 23 FEATURES AND CONSTRUCTION COST OF HUAI BUNG DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km^2	68.5	68.5	68.5	68.5	68.5
Average annual run-off	$10^6 m^3$	23.9	23.9	23.9	23.9	23.9
High water surface	El.m.	26.9	27.7	28.4	29.0	30.0
Low water surface	El.m.	22.3	22.3	22.3	22.3	22.3
Gross storage capacity	$10^6 m^3$	14.9	19.2	23.5	27.8	35.4
Active storage capacity	$10^6 m^3$	12.8	17.1	21.4	25.7	33.3
Dead storage capacity	$10^6 m^3$	2.1	2.1	2.1	2.1	2.1
Reservoir surface area at HWS	km^2	4.9	5.6	6.3	6.9	8.1
Regulated outflow	$10^6 m^3$	12.9	14.8	16.4	17.4	18.6
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	29.9	30.7	31.4	32.0	33.0
Length of dam crest	m.	2,610.0	2,700.0	2,760.0	2,820.0	2,900.0
Height of dam	m.	13.4	14.2	14.9	15.5	16.5
Dam volume	$10^3 m^3$	627.0	717.0	798.0	874.0	1,004.0
100-year probable flood	m^3/s	280.0	280.0	280.0	280.0	280.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	2.0	2.2	2.5	2.7	3.0
2.2 Dam & Spillway	฿ 10^6	198.4	223.8	246.4	267.6	303.6
2.3 Compensation and relocation cost	฿ 10^6	173.8	198.2	222.5	243.3	281.6
2.4 General expenses	฿ 10^6	20.9	23.8	26.7	29.2	33.8
2.5 Contingency	฿ 10^6	79.0	89.6	99.6	108.6	124.4
2.6 Interest during construction period	฿ 10^6	45.5	51.6	57.4	62.5	71.7
Total	฿ 10^6	529.6	589.2	655.1	713.9	818.1

Table 24 FEATURES AND CONSTRUCTION COST OF HUAI TAKHIAN TIA DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km^2	33.0	33.0	33.0	33.0	33.0
Average annual run-off	$10^6 m^3$	11.5	11.5	11.5	11.5	11.5
High water surface	El.m.	29.4	30.1	30.6	31.0	31.5
Low water surface	El.m.	25.0	25.0	25.0	25.0	25.0
Gross storage capacity	$10^6 m^3$	7.2	9.2	11.3	13.4	15.4
Active storage capacity	$10^6 m^3$	6.2	8.2	10.3	12.4	14.4
Dead storage capacity	$10^6 m^3$	1.0	1.0	1.0	1.0	1.0
Reservoir surface area at HWS	km^2	2.4	2.7	2.9	3.1	3.4
Regulated outflow	$10^6 m^3$	6.3	7.3	7.9		8.5
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	32.4	33.1	33.6	34.0	34.5
Length of dam crest	m.	1,770.0	1,870.0	1,940.0	2,000.0	2,060.0
Height of dam	m.	12.9	13.6	14.1	14.5	15.0
Dam volume	$10^3 m^3$	476.0	545.0	598.0	644.0	701.0
100-year probable flood	m^3/s	175.0	175.0	175.0	175.0	175.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	1.5	1.7	1.8	1.9	2.1
2.2 Dam & Spillway	฿ 10^6	145.5	165.3	180.5	193.2	209.0
2.3 Compensation and relocation cost	฿ 10^6	85.0	95.5	102.4	109.4	119.8
2.4 General expenses	฿ 10^6	27.8	31.5	34.2	36.5	39.7
2.5 Contingency	฿ 10^6	52.0	58.8	63.8	68.2	74.1
2.6 Interest during construction period	฿ 10^6	29.9	33.9	36.7	39.3	42.7
Total	฿ 10^6	341.9	386.7	419.4	448.5	487.4

Table 25 FEATURES AND CONSTRUCTION COST OF KLONG NA KLUA DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km^2	22.3	22.3	22.3	22.3	22.3
Average annual run-off	$10^6 m^3$	7.8	7.8	7.8	7.8	7.8
High water surface	El.m.	30.0	30.7	31.6	32.2	37.0
Low water surface	El.m.	25.0	25.0	25.0	25.0	25.0
Gross storage capacity	$10^6 m^3$	4.9	6.3	7.7	9.1	23.0
Active storage capacity	$10^6 m^3$	4.2	5.6	7.0	8.4	22.3
Dead storage capacity	$10^6 m^3$	0.7	0.7	0.7	0.7	0.7
Reservoir surface area at HWS	km^2	1.55	1.75	2.0	2.2	3.55
Regulated outflow	$10^6 m^3$	4.1	4.7	5.4	5.7	6.0
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	33.0	33.7	34.6	35.2	40.0
Length of dam crest	m.	1,320.0	1,370.0	1,430.0	1,470.0	1,610.0
Height of dam	m.	13.5	14.2	15.1	15.7	20.5
Dam volume	$10^3 m^3$	461.0	518.0	595.0	651.0	1,135.0
100-year probable flood	m^3/s	127.0	127.0	127.0	127.0	127.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	1.4	1.5	1.7	1.9	3.1
2.2 Dam & Spillway	฿ 10^6	135.2	150.8	171.5	186.6	312.8
2.3 Compensation and relocation cost	฿ 10^6	56.3	66.8	73.7	80.7	129.3
2.4 General expenses	฿ 10^6	23.1	26.3	29.6	32.3	53.4
2.5 Contingency	฿ 10^6	43.2	49.1	55.3	60.3	99.7
2.6 Interest during construction period	฿ 10^6	24.9	28.3	31.9	34.7	57.4
Total	฿ 10^6	284.1	322.8	363.7	396.5	655.7

Table 26 FEATURES AND CONSTRUCTION COST
OF HUAI CHAK NOK DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km²	18.1	18.1	18.1	18.1	18.1
Average annual run-off	$10^6 m^3$	6.3	6.3	6.3	6.3	6.3
High water surface	El.m.	13.6	14.4	15.1	15.7	17.0
Low water surface	El.m.	10.0	10.0	10.0	10.0	10.0
Gross storage capacity	$10^6 m^3$	4.0	5.1	6.2	7.3	9.7
Active storage capacity	$10^6 m^3$	3.4	4.5	5.6	6.7	9.1
Dead storage capacity	$10^6 m^3$	0.6	0.6	0.6	0.6	0.6
Reservoir surface area at HWS	km²	1.3	1.46	1.65	1.8	2.25
Regulated outflow	$10^6 m^3$	3.4	4.0	4.4	4.5	4.7
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	16.6	17.4	18.1	18.7	20.0
Length of dam crest	m.	1,300.0	1,370.0	1,430.0	1,480.0	1,600.0
Height of dam	m.	10.1	10.9	11.6	12.2	13.5
Dam volume	$10^3 m^3$	313.0	369.0	423.0	473.0	594.0
100-year probable flood	m³/s	107.0	107.0	107.0	107.0	107.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	0.9	1.1	1.2	1.4	1.7
2.2 Dam & Spillway	฿ 10^6	93.2	108.6	123.5	137.3	170.1
2.3 Compensation and relocation cost	฿ 10^6	47.2	54.1	61.1	65.4	79.3
2.4 General expenses	฿ 10^6	17.0	19.7	22.3	24.5	30.1
2.5 Contingency	฿ 10^6	31.7	36.7	41.6	45.7	56.2
2.6 Interest during construction period	฿ 10^6	18.2	21.1	24.0	26.3	32.4
Total	฿ 10^6	208.2	241.3	273.7	300.6	369.8

Table 27 FEATURES AND CONSTRUCTION COST OF HUAI YAI DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km^2	65.9	65.9	65.9	65.9	65.9
Average annual run-off	$10^6 m^3$	23.0	23.0	23.0	23.0	23.0
High water surface	El.m.	24.3	25.2	26.0	26.7	30.0
Low water surface	El.m.	19.9	19.9	19.9	19.9	19.9
Gross storage capacity	$10^6 m^3$	14.4	18.5	22.6	26.7	51.6
Active storage capacity	$10^6 m^3$	12.4	16.5	20.6	24.7	49.6
Dead storage capacity	$10^6 m^3$	2.0	2.0	2.0	2.0	2.0
Reservoir surface area at HWS	km^2	3.6	4.2	4.9	5.5	8.8
Regulated outflow	$10^6 m^3$	12.9	14.8	16.4	17.4	18.6
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	27.3	28.2	29.0	29.7	33.0
Length of dam crest	m.	3,520.0	3,610.0	3,660.0	3,730.0	4,400.0
Height of dam	m.	12.8	13.7	14.5	15.2	18.5
Dam volume	$10^3 m^3$	1,579.0	1,810.0	2,023.0	2,227.0	3,469.0
100-year probable flood	m^3/s	270.0	270.0	270.0	270.0	270.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	4.3	4.9	5.4	6.0	9.2
2.2 Dam & Spillway	฿ 10^6	429.9	489.2	543.5	595.3	915.1
2.3 Compensation and relocation cost	฿ 10^6	137.5	158.4	182.7	203.9	325.3
2.4 General expenses	฿ 10^6	68.6	75.1	87.8	96.6	150.0
2.5 Contingency	฿ 10^6	128.1	145.5	163.9	180.3	279.9
2.6 Interest during construction period	฿ 10^6	73.8	83.8	94.4	103.9	161.2
Total	฿ 10^6	842.2	956.9	1,077.7	1,185.7	1,840.7

Table 28 FEATURES AND CONSTRUCTION COST OF KHLONG YAI DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km^2	218.0	218.0	218.0	218.0	
Average annual run-off	$10^6 m^3$	87.0	87.0	87.0	87.0	
High water surface	El.m.	46.0	48.0	50.0	52.0	
Low water surface	El.m.	40.6	40.6	40.6	40.6	
Gross storage capacity	$10^6 m^3$	38.0	60.1	89.3	125.8	
Active storage capacity	$10^6 m^3$	31.4	53.5	82.7	119.2	
Dead storage capacity	$10^6 m^3$	6.6	6.6	6.6	6.6	
Reservoir surface area at HWS	km^2	9.3	12.8	16.4	20.1	
Regulated outflow	$10^6 m^3$	35.3	47.6	59.9	67.8	
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	
Dam crest	El.m.	49.0	51.0	53.0	55.0	
Length of dam crest	m.	3,770.0	3,970.0	4,080.0	4,180.0	
Height of dam	m.	17.0	19.0	21.0	23.0	
Dam volume	$10^3 m^3$	1,418.0	1,890.0	2,456.0	3,120.0	
100-year probable flood	m^3/s	550.0	550.0	550.0	550.0	
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	4.2	5.4	6.8	8.5	
2.2 Dam & Spillway	฿ 10^6	416.5	538.9	682.9	850.1	
2.3 Compensation and relocation cost	฿ 10^6	57.1	68.7	80.6	92.8	
2.4 General expenses	฿ 10^6	57.3	73.6	92.4	114.2	
2.5 Contingency	฿ 10^6	107.0	137.3	172.5	213.1	
2.6 Interest during construction period	฿ 10^6	61.6	79.1	99.4	122.8	
Total	฿ 10^6	703.7	903.0	1,134.6	1,401.5	

Table 29 FEATURES AND CONSTRUCTION COST OF KHLONG THAP MA DAM SCHEME

Description	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
1. Features of Scheme						
1.1 Reservoir						
Catchment area	km²	158.0	158.0	158.0	158.0	158.0
Average annual run-off	$10^6 m^3$	55.2	55.2	55.2	55.2	55.2
High water surface	El.m.	22.0	24.0	26.0	28.0	30.0
Low water surface	El.m.	16.2	16.2	16.2	16.2	16.2
Gross storage capacity	$10^6 m^3$	29.2	44.6	64.1	88.0	116.9
Active storage capacity	$10^6 m^3$	24.5	39.9	59.4	83.3	112.2
Dead storage capacity	$10^6 m^3$	4.7	4.7	4.7	4.7	4.7
Reservoir surface area at H.W.L.	km²	6.7	8.7	10.8	13.1	15.8
Regulated outflow	$10^6 m^3$	28.7	36.6	42.3	47.3	46.7
1.2 Dam & Spillway						
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest	El.m.	25.0	27.0	29.0	31.0	33.0
Length of dam crest	m.	750.0	770.0	790.0	820.0	840.0
Height of dam	m.	16.5	18.5	20.5	22.5	24.5
Dam volume	$10^6 m^3$	571.0	721.0	898.0	1,130.0	1,390.0
100-year probable flood	m³/s	458.0	458.0	458.0	458.0	458.0
2. Construction Cost						
2.1 Preparatory works	฿ 10^6	1.6	2.0	2.5	3.1	5.8
2.2 Dam & Spillway	฿ 10^6	164.4	204.0	250.2	311.3	378.5
2.3 Compensation and relocation cost	฿ 10^6	161.9	210.0	254.0	304.8	366.5
2.4 General expenses	฿ 10^6	39.4	49.9	60.8	74.3	89.9
2.5 Contingency	฿ 10^6	73.5	93.2	113.5	138.7	167.7
2.6 Interest during construction cost	฿ 10^6	42.3	53.7	65.4	79.9	96.6
Total	฿ 10^6	483.1	612.8	746.4	912.1	1,103.0

Table 30 FEATURES AND CONSTRUCTION COST OF SELECTED DEVELOPMENT SCALE

	Unit	Khlong Luang	Pa Daeng	Huai Bung	Huai Takhian Tia	Khlong Na Klua	Huai Chak Nok	Huai Yai	Khlong Thap Ma	Khlong Yai
1. Features of Scheme										
1.1 Reservoir										
Catchment area	km^2	526.0	53.8	68.5	33.0	22.3	18.1	65.9	158.0	218.0
Average annual run-off	10^6m^3	125.2	18.8	23.9	11.5	7.8	6.3	23.0	55.2	87.0
High Water surface	El.m.	39.7	66.6	28.0	30.3	31.1	14.7	25.6	25.6	50.3
Low water surface	El.m.	33.8	61.7	22.3	25.0	25.0	10.0	19.9	16.2	40.6
Reservoir storage capacity										
Gross storage	10^6m^3	141.0	16.6	21.2	10.2	6.9	5.6	20.4	59.9	93.6
Active storage	10^6m^3	125.2	15.0	19.1	9.2	6.2	5.0	18.4	55.2	87.0
Dead	10^6m^3	15.8	1.6	2.1	1.0	0.7	0.6	2.0	4.7	6.6
Reservoir surface area at HWS	km^2	32.8	5.4	5.9	2.8	1.8	1.5	4.6	10.4	16.8
Net regulated outflow	10^6m^3	80.4	11.6	16.0	7.8	5.2	4.3	15.6	41.3	62.4
1.2 Dam and Spillway										
Type of dam		Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill	Earth-fill
Dam crest elevation	El.m.	42.7	69.6	31.0	33.3	34.1	17.7	28.6	28.6	53.3
Length of dam crest	m.	3,790.0	1,880.0	2,730.0	1,900.0	1,400.0	1,410.0	3,720.0	770.0	4,090.0
Dam height	m.	19.7	15.1	14.5	13.8	14.6	11.2	14.1	20.1	21.3
Dam volume	10^3m^3	2,070.0	578.0	760.0	570.0	560.0	400.0	1,910.0	870.0	2,570.0
Spillway design discharge	m^3/s	878.0	240.0	280.0	175.0	127.0	107.0	270.0	458.0	550.0
2. Construction Cost										
2.1 Preparatory works	฿ 10^6	6.1	1.8	2.4	1.7	1.6	1.2	5.1	2.4	7.1
2.2 Dam and spillway	฿ 10^6	614.5	179.1	235.5	173.3	161.9	120.1	514.5	242.5	711.4
2.3 Compensation and relocation cost	฿ 10^6	257.1	191.6	205.1	98.9	66.8	52.1	159.9	244.6	81.9
2.4 General expenses	฿ 10^6	105.3	44.7	53.2	32.9	27.6	20.8	81.5	58.7	96.1
2.5 Contingency	฿ 10^6	196.6	83.4	99.2	61.4	51.6	38.8	152.2	109.6	179.3
2.6 Interest during construction	฿ 10^6	113.2	48.1	57.2	35.3	29.7	22.4	87.7	63.2	103.3
Total	฿ 10^6	1,292.8	548.7	652.6	403.5	339.2	255.4	1,000.9	721.0	1,179.1

Table 31 ECONOMIC COMPARISON OF ALTERNATIVES, KHLONG LUANG DAM SCHEME

(Unit: ฿ 10^6)

Alternatives	1-1	1-2	1-3	1-4	2-1	2-2	2-3	2-4	3-1	3-2	3-3	3-4
Features												
Dam Crest El. (m)	41.5	42	42.5	43	41.5	42	42.5	43	41.5	42	42.5	43
H.W.L. (m)	38.5	39	39.5	40	38.5	39	39.5	40	38.5	39	39.5	40
Active Storage (10^6 m^3)	89	103	119	135	89	103	119	135	89	103	119	135
Irrigation Area (ha)	5,900	6,700	7,200	7,400	5,300	6,100	6,600	6,800	4,500	5,300	5,800	6,000
Cropping Intensity (%)	130	130	130	130	140	140	140	140	150	150	150	150
Cost												
1. Dam Works	772.20	823.68	880.11	923.67	772.20	823.68	880.11	923.67	772.20	823.68	880.11	923.67
2. Irrigation Facilities	321.75	345.51	370.26	380.16	304.92	326.70	339.57	349.47	284.13	304.92	318.78	323.73
3. Pipeline System	399.17	399.17	399.17	399.17	399.17	399.17	399.17	399.17	399.17	399.17	399.17	399.17
4. Engineering Service	150.98	159.22	168.08	173.72	148.79	156.77	164.09	169.73	146.09	153.94	161.39	166.39
5. Government Administration	47.50	49.72	52.08	53.45	46.66	48.78	50.55	51.91	45.62	47.69	49.51	50.63
Base Cost	1,691.60	1,777.29	1,869.70	1,930.17	1,671.74	1,755.10	1,833.48	1,893.95	1,647.21	1,729.40	1,808.95	1,863.58
6. Physical Contingency	253.74	266.59	280.45	289.53	250.76	263.26	275.02	284.09	247.08	259.41	271.34	279.54
Project Cost	1,945.34	2,043.89	2,150.15	2,219.69	1,922.50	2,018.36	2,108.51	2,178.05	1,894.29	1,988.80	2,080.29	2,143.12
Annual Equivalent Cost	159.02	167.07	175.76	181.44	157.14	164.99	172.35	178.03	154.85	162.57	170.05	175.19
7. O & M Cost	20.67	21.05	21.45	21.72	20.59	20.95	21.30	21.57	20.48	20.84	21.19	21.44
8. Replacement Cost	38.43	39.10	39.52	39.69	37.93	38.60	39.02	39.19	37.25	37.93	38.35	38.51
(I) Annual Cost	218.12	227.22	236.73	242.85	215.66	224.54	232.67	238.79	212.58	221.34	229.59	235.14
Benefit												
9. Irrigation Benefit	148.82	169.00	181.61	186.66	145.00	166.88	180.56	186.03	137.60	162.06	177.35	183.46
10. Water Supply Benefit	165.96	165.96	165.96	165.96	165.96	165.96	165.96	165.96	165.96	165.96	165.96	165.96
11. Production Foregone	33.57	36.06	38.54	41.03	33.57	36.06	38.54	41.03	33.57	36.06	38.54	41.03
(II) Annual Benefit	281.22	298.91	309.03	311.59	277.39	296.79	307.98	310.97	269.99	291.97	304.77	308.40
(III) Net Benefit (B-C)	63.10	71.69	72.30	68.74	61.73	72.26	75.31	72.18	57.41	70.63	75.18	73.26
(IV) Benefit-Cost Ratio (B/C)	1.29	1.32	1.31	1.28	1.29	1.32	1.32	1.30	1.27	1.32	1.33	1.31

Table 32 ECONOMIC COMPARISON OF ALTERNATIVES, KHLONG YAI DAM SCHEME

(Unit: ฿10⁶)

Alternatives	1-1	2-1	3-1	3-2	3-3
Features					
Dam Crest El. (m)	48.8	50.8	50.5	51.4	52.4
H.W.L. (m)	45.5	47.5	47.2	48.1	49.1
Active Storage (10^6 m^3)	26.9	47.5	43.8	54.8	67.6
Irrigation Area (ha)	7,700	7,700	6,500	7,100	7,700
Cropping Intensity (%)	130	140	150	150	150
Cost					
1. Dam Works	1,708.74	1,843.38	1,822.59	1,906.74	1,990.89
2. Irrigation Facilities	478.17	478.17	382.14	425.70	478.17
3. Pipeline System	606.28	606.28	606.28	606.28	606.28
4. Engineering Service	281.54	295.00	280.44	294.52	309.75
5. Gov. Administration	82.33	85.03	79.81	83.67	87.98
Base Cost	3,157.06	3,307.86	3,171.26	3,316.90	3,473.07
6. Physical Contingency	473.56	496.18	475.69	497.54	520.96
Project Cost	3,630.62	3,804.03	3,646.94	3,814.44	3,994.03
7. O & M Cost	45.93	46.61	46.02	46.66	47.35
8. Replacement Cost	51.38	51.38	51.30	51.34	51.38
(I) Annual Cost	394.10	408.95	395.44	409.81	425.21
Benefit					
9. Irrigation Benefit	179.65	193.23	183.18	200.09	216.99
10. Water Supply Benefit	327.17	327.17	327.17	327.17	327.17
11. Production Foregone	31.25	34.68	34.12	35.79	37.69
(II) Annual Benefit	475.57	490.72	476.22	491.46	506.47
(III) Net Benefit (B-C)	81.48	81.78	80.79	81.65	81.26
(IV) Benefit-Cost Ratio (B/C)	1.21	1.20	1.20	1.20	1.19

Table .33 ECONOMIC COMPARISON OF ALTERNATIVES, KHLONG THAP MA DAM SCHEME

(Unit: ฿ 10^6)

Alternatives	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3
Features												
Dam Crest El. (m)	26.2	26.8	27.7	26.8	27.7	28.4	26.2	27.7	28.9	26.8	28.4	30
H.W.L. (m)	22.8	23.4	24.3	23.4	24.3	25.1	22.8	24.3	25.7	23.4	25.1	26.8
Active Storage (10^6 m^3)	31	35.5	42.5	35.5	42.5	49.5	31	42.5	56.1	35.5	49.5	68.5
Irrigation Area (ha)	1,900	2,100	2,400	1,900	2,200	2,400	1,500	2,000	2,400	1,500	2,000	2,400
Cropping Intensity (%)	150	150	150	160	160	160	170	170	170	180	180	180
Cost												
1. Dam Works	303.93	318.78	342.54	318.78	342.54	359.37	303.93	342.54	371.25	318.78	359.37	436.59
2. Irrigation Facilities	95.04	105.93	128.70	95.04	111.87	128.70	80.19	100.98	128.70	80.19	100.98	128.70
3. Engineering Service	42.75	45.65	50.99	44.23	48.80	52.67	40.82	47.38	53.86	42.30	49.06	60.39
4. Government Administration	10.83	11.67	13.29	11.13	12.44	13.62	10.09	11.90	13.86	10.39	12.24	15.17
Base Cost	452.55	482.03	535.51	469.18	515.65	554.36	435.03	502.80	567.67	451.66	521.65	640.85
5. Physical Contingency	82.88	88.35	97.88	86.43	94.90	102.35	80.25	92.97	105.10	83.80	97.45	118.63
Project Cost	535.43	570.39	633.39	555.61	610.55	656.71	515.28	595.77	672.77	535.46	619.10	759.47
Annual Equivalent Cost	43.77	46.63	51.77	45.41	49.91	53.68	42.12	48.70	54.99	43.77	50.61	62.07
6. O & M Cost	1.99	2.12	2.36	2.07	2.27	2.44	1.92	2.22	2.50	1.99	2.30	2.83
7. Replacement Cost	1.60	1.76	2.02	1.60	1.85	2.02	1.26	1.68	2.02	1.26	1.68	2.02
(I) Annual Cost	47.36	50.51	56.15	49.08	54.03	58.14	45.30	52.60	59.51	47.02	54.59	66.92
Benefit												
8. Irrigation Benefit	53.33	58.95	67.37	58.87	68.17	74.37	51.03	68.04	81.65	55.79	74.38	89.26
9. Production Foregone	2.21	2.38	2.65	2.38	2.65	2.90	2.21	2.65	3.09	2.38	2.90	3.45
(II) Annual Benefit	51.13	56.57	64.72	56.49	65.52	71.47	48.82	65.40	78.56	53.41	71.48	85.81
(III) Net Benefit (B-C)	3.77	6.06	8.58	7.41	11.49	13.33	3.52	12.80	19.05	6.38	16.89	18.88
(IV) Benefit-Cost Ratio (B/C)	1.08	1.12	1.15	1.15	1.21	1.23	1.08	1.24	1.32	1.14	1.31	1.28

Table 34 STABILITY ANALISYS

Status of Reservoir Water Level	Minimum Safety Factor	
	Normal	Seismic
1. Khlong Luang Dam		
a) H.W.L.		
a-1) Upstream slope (1:2.6)	2.531	2.106
a-2) Downstream slope (1:2.4)	1.963	1.632
b) Reservoir empty		
b-1) Upstream slope (1:2.6)	1.350	-
b-2) Downstream slope (1:2.4)	1.258	-
c) L.W.L.		
c-1) Upstream slope (1:2.6)	1.483	1.238
c-2) Downstream slope (1:2.4)	1.864	1.572
2. Khlong Yai Dam		
a) H.W.L.		
a-1) Upstream slope (1:3.0)	2.820	2.104
a-2) Downstream slope (1:2.6)	1.806	1.480
b) Reservoir empty		
b-1) Upstream slope (1:3.0)	1.397	-
b-2) Downstream slope (1:2.6)	1.246	-
c) L.W.L.		
c-1) Upstream slope (1:3.0)	1.477	1.216
c-2) Downstream slope (1:2.6)	1.685	1.371
3. Khlong Thap Ma Dam		
a) H.W.L.		
a-1) Upstream slope (1:3.1)	2.576	2.088
a-2) Downstream slope (1:2.6)	1.792	1.537
b) Reservoir empty		
b-1) Upstream slope (1:3.1)	1.350	-
b-2) Downstream slope (1:2.6)	1.251	-
c) L.W.L.		
c-1) Upstream slope (1:3.1)	1.464	1.213
c-2) Downstream slope (1:2.6)	1.836	1.567

Table 35 DESIGN VALUES FOR SEEPAGE ANALYSIS

Unit: cm/sec

Material	Coefficient of Permeability	
	KH	KV
1. Khlong Luang Dam		
Core	1×10^{-6}	1×10^{-7}
Blanket	1×10^{-6}	1×10^{-6}
Filter as drain	5×10^{-3}	5×10^{-3}
Terrace/colluvial deposits	7×10^{-4}	7×10^{-4}
2. Khlong Yai Dam		
Core	1×10^{-6}	1×10^{-7}
Filter as drain	5×10^{-3}	5×10^{-3}
Terrace/colluvial deposits	1×10^{-3}	1×10^{-3}
Weathered gneissose granite	5×10^{-5}	5×10^{-5}
3. Khlong Thap Ma Dam		
Core	1×10^{-6}	1×10^{-7}
Filter as drain	5×10^{-3}	5×10^{-3}
Terrace/colluvial deposits	5×10^{-3}	5×10^{-3}
Weathered gneissose granite	5×10^{-5}	5×10^{-5}

Table 36 SEEPAGE ANALYSIS

Description	Specifications Requirements	F.E.M. Analysis
1. Khlong Luang Dam		
a) Leakage rate per unit width	-	8.0×10^{-3} l/sec m
b) Leakage rate from total width		
For per unit time /1	less than 39.7 l/sec	30.6 l/sec
For daily leakage /2	less than 67,400 m^3/day	2,660 m^3/day
c) Maximum flow velocity		
Justin's equation	4.92×10^{-1} cm/sec	7.18×10^{-5} cm/sec
Koslona's equation	2.86×10^{-4} cm/sec	7.18×10^{-5} cm/sec
2. Khlong Yai Dam		
a) Leakage rate per unit width	-	4.7×10^{-3} l/sec m
b) Leakage rate from total width		
For per unit time /1	less than 27.6 l/sec	18.9 l/sec
For daily leakage /2	less than 27,300 m^3/day	1,600 m^3/day
c) Maximum flow velocity		
Justin's equation	4.92×10^{-1} cm/sec	9.08×10^{-5} cm/sec
Koslona's equation	2.86×10^{-4} cm/sec	9.08×10^{-5} cm/sec
3. Khlong Thap Ma Dam		
a) Leakage rate per unit width	-	7.8×10^{-3} l/sec m
b) Leakage rate from total width		
For per unit time /1	less than 17.50 l/sec	6.7 l/sec
For daily leakage /2	less than 33,650 m^3/day	580 m^3/day
c) Maximum flow velocity		
Justin's equation	4.92×10^{-1} cm/sec	1.18×10^{-4} cm/sec
Koslona's equation	2.86×10^{-4} cm/sec	1.18×10^{-4} cm/sec

Note, /1 : It is difined to be less than 1 percent of annual average inflow rate into reservoir.

/2 : It is difined to be less than 0.05 percent of gross storage capacity of reservoir.

Table 37 WORK QUANTITY OF KHLONG LUANG DAM

Item	Unit	Quantity
Main dam		
Excavation,	m^3	1,971,000
Common, for foundation	m^3	1,524,000
Common, for blanket	m^3	447,000
Embankment,	m^3	2,972,000
Core	m^3	2,158,000
Blanket	m^3	447,000
Filter	m^3	213,000
Riprap	m^3	154,000
Reinforced concrete	m^3	1,500
Sod facing, for downstream slope	m^2	95,000
Asphalt facing, on dam crest	m	3,900
Saddle dam		
Excavation,	m^3	208,000
Common, for dam foundation	m^3	148,000
Common, for trench cut-off	m^3	60,000
Embankment,	m^3	299,000
Core	m^3	215,000
Filter	m^3	53,000
Riprap	m^3	31,000
Reinforced concrete	m^3	1,000
Sod facing, for downstream slop	m^2	16,000
Asphalt facing, on dam crest	m	2,300
Spillway		
Excavation, common	m^3	75,000
Backfill with excavated materials	m^3	10,000
Reinforced concrete	m^3	6,800

Table 38 WORK QUANTITY OF KHLONG YAI DAM

Item	Unit	Quantity
Main dam		
Excavation,	m^3	1,331,000
Common, for foundation	m^3	873,000
Common, for trench cut-off	m^3	458,000
Embankment,	m^3	2,495,000
Core	m^3	2,051,000
Filter	m^3	254,000
Riprap	m^3	190,000
Reinforced concrete	m^3	1,500
Sod facing, for downstream slope	m^2	102,000
Asphalt facing, on dam crest	m	4,100
Spillway		
Excavation, common	m^3	275,000
Backfill with excavated materials	m^3	32,000
Reinforced concrete	m^3	13,000
River outlet		
Excavation, common	m^3	19,000
Backfill with excavated materials	m^3	5,300
Reinforced concrete	m^3	1,100
Steel pipe	t	50
Inlet gate including trash rack	set	1
River outlet valve	set	1

Table 39 WORK QUANTITY OF KHLONG THAP MA DAM

Item	Unit	Quantity
Main dam		
Excavation,	m^3	568,000
Common, for foundation	m^3	508,000
Common, for trench cut-off	m^3	60,000
Embankment,	m^3	1,345,000
Core	m^3	1,182,000
Filter	m^3	92,000
Riprap	m^3	71,000
Reinforced concrete	m^3	300
Sod facing, for downstream slope	m^2	43,000
Asphalt facing, on dam crest	m	850
Saddle dam		
Excavation,	m^3	39,000
Common, for foundation	m^3	27,000
Common, for trench cut-off	m^3	12,000
Embankment,	m^3	49,000
Core	m^3	35,000
Filter	m^3	9,000
Riprap	m^3	5,000
Reinforced concrete	m^3	200
Sod facing, for downstream slope	m^2	2,500
Asphalt facing, on dam crest	m	420
Spillway		
Excavation, common	m^3	101,000
Backfill with excavated materials	m^3	28,000
Reinforced concrete	m^3	12,000

Table 40 REQUIRED QUANTITY AND TOTAL YIELD CAPACITY OF EMBANKMENT MATERIALS

Unit: m^3

Location	Required quantity	Total yield capacity	Remarks
Borrow area			
Khlong Luang	2,820,000	3,700,000	Core and blanket
Khlong Yai	2,051,000	2,670,000	Core
Khlong Thap Ma	1,217,000	1,585,000	Core
Rock quarry (A)			
Ban Non Thakhian (Khlong Luang dam & Khlong Yai dam)			
Sand material & fine aggregate	539,000	701,000	Filter & concrete aggregate
Coarse aggregate	18,000	24,000	Concrete aggregate
Rock material	190,000	247,000	Riprap
Rock quarry (B)			
Khao Bo Kwang Thong (Khlong Luang dam)			
Rock material	185,000	240,000	Riprap
Rock quarry (C)			
Ban Pak Than (Khlong Thap Ma dam)			
Coarse aggregate	8,000	11,000	Concrete aggregate
Rock material	76,000	99,000	Riprap
Sand borrow			
Kong Ton Po (Khlong Thap Ma dam)			
Sand material & fine aggregate	109,000	142,000	Filter & concrete aggregate

Table 41 MAJOR CONSTRUCTION PLANT AND EQUIPMENT OF KHLONG LUANG DAM

Item	Capacity	Quantity
Aggregate plant	80 tons/hr	1 set
Concrete plant	18 cft x 1	1 set
Bulldozer W/R	32 tons	5 nos.
Bulldozer	32 tons	5 nos.
- do -	21 tons	5 nos.
- do -	16 tons	5 nos.
Back hoe	1.2 m^3	8 nos.
- do -	0.7 m^3	2 nos.
Power shovel	1.2 m^3	4 nos.
Tractor shovel	2.2 m^3	7 nos.
- do -	1.8 m^3	1 no.
Wheel loader	3.2 m^3	2 nos.
- do -	2.2 m^3	1 no.
- do -	1.8 m^3	2 nos.
Dump truck	15 tons	57 nos.
- do -	8 tons	100 nos.
Vibration roller	10 tons	5 nos.
Diesel engine generator	150 kW	2 nos.
Agitator truck	3.2 m^3	4 nos.
Motor grader	3.7 m	2 nos.
Road roller	8/10 tons	4 nos.
Hydraulic crane	25 tons	1 no.
Water tanker	8 m^3	6 nos.
Asphalt spreader	30 l/min	6 nos.
Tractor & trailer	30 tons	1 no.
Spare parts	-	L.S.

Table 42 MAJOR CONSTRUCTION PLANT AND EQUIPMENT OF KHLONG YAI DAM

Item	Capacity	Quantity
Aggregate plant	80 tons/hr	1 set
Concrete plant	18 cft x 1	1 set
Bulldozer W/R	32 tons	7 nos.
Bulldozer	32 tons	5 nos.
- do -	21 tons	5 nos.
Back hoe	1.2 m^3	6 nos.
- do -	0.7 m^3	4 nos.
Power shovel	1.2 m^3	5 nos.
Tractor shovel	3.2 m^3	6 nos.
- do -	2.2 m^3	4 nos.
- do -	1.8 m^3	1 no.
Wheel loader	3.2 m^3	3 nos.
- do -	1.8 m^3	1 no.
Dump truck	15 tons	75 nos.
- do -	8 tons	95 nos.
Vibration roller	10 tons	5 nos.
Diesel engine generator	150 KVA	2 nos.
Agitator truck	3.2 m^3	4 nos.
Motor grador	3.7 m	2 nos.
Road roller	8/10 tons	4 nos.
Hydraulic crane	25 tons	1 no.
Water tanker	8 m^3	6 nos.
Asphalt spreader	30 l/min	6 nos.
Tractor and trailer	30 tons	1 no.
Spare parts	-	L.S.

Table 43 MAJOR CONSTRUCTION PLANT AND EQUIPMENT OF KHLONG THAP MA DAM

Item	Capacity	Quantity
Concrete plant		1 set
Bulldozer W/R	32 tons	5 nos.
Bulldozer	32 tons	3 nos.
- do -	21 tons	4 nos.
- do -	16 tons	5 nos.
Back hoe	1.2 m^3	3 nos.
- do -	0.7 m^3	3 nos.
Power shovel	1.2 m^3	2 nos.
Tractor shovel	3.2 m^3	3 nos.
- do -	2.2 m^3	2 nos.
- do -	1.8 m^3	1 no.
Wheel loader	3.2 m^3	1 no.
- do -	2.2 m^3	1 no.
- do -	1.8 m^3	1 no.
Dump truck	15 tons	60 nos.
- do -	8 tons	58 nos.
Vibration roller	10 tons	4 nos.
Agitator truck	3.2 m^3	4 nos.
Motor grader	3.7 m	2 nos.
Road roller	8/10 tons	4 nos.
Hydraulic crane	25 tons	1 no.
Water tanker	8 m^3	6 nos.
Asphalt spreader	30 l/min	6 nos.
Tractor & trailer	30 tons	1 no.
Spare parts	-	L.S.

Table 44 INVESTMENT COST OF KHLONG LUANG DAM
(Contract Basis)

(Unit: ฿10³)

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Works	12,860	21,380	34,240
2.	Care of River	3,210	5,340	8,550
3.	Dam	313,780	510,920	824,700
4.	Spillway	7,600	23,480	31,080
5.	Contractor's Administration Cost	11,810	19,640	31,450
6.	Contractor's Profit	21,930	36,470	58,400
7.	Tax	-	30,550	30,550
	Sub-total	371,190	647,780	1,018,970
8.	Compensation & Relocation	-	272,020	272,020
9.	Engineering Services	71,330	30,570	101,900
10.	Administration Cost of Executive Agency	-	20,380	20,380
	Sub-total	442,520	970,750	1,413,270
11.	Physical Contingency	66,380	145,610	211,990
	Sub-total	508,900	1,116,360	1,625,260
12.	Price Contingency	243,890	600,400	844,290
	Total	752,790	1,716,760	2,469,550

Table 45 INVESTMENT COST OF KHLONG YAI DAM
(Contract Basis)

(Unit: ฿10^{3})

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Works	12,120	20,320	32,440
2.	Care of River	3,030	5,080	8,110
3.	Dam	275,950	448,020	723,970
4.	Intake	7,170	7,540	14,710
5.	Spillway	19,990	52,550	72,540
6.	Contractor's Administration Cost	11,140	18,670	29,810
7.	Contractor's Profit	20,690	34,680	55,370
8.	Tax	-	28,960	28,960
	Sub-total	350,090	615,820	965,910
9.	Compensation & Relocation	-	87,800	87,800
10.	Engineering Services	67,610	28,980	96,590
11.	Administration Cost of Executive Agency	-	19,320	19,320
	Sub-total	417,700	751,920	1,169,620
12.	Physical Contingency	62,660	112,790	175,450
	Sub-total	480,360	864,710	1,345,070
13.	Price Contingency	227,100	512,750	739,850
	Total	707,460	1,377,460	2,084,920

Table 46 INVESTMENT COST ON NONG PLA LAI DAM
(Contract Basis)

(Unit: ฿10³)

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Works	14,180	25,710	39,890
2.	Care of River	82,410	155,710	238,120
3.	Dam	232,230	378,390	610,620
4.	Spillway	32,420	103,260	135,680
5.	Intake	7,490	5,420	12,910
6.	Contractor's Administration Cost	12,910	23,400	36,310
7.	Contractor's Profit	23,970	43,450	67,420
8.	Tax	-	35,260	35,260
	Sub-total	405,610	770,600	1,176,210
9.	Compensation & Relocation	-	242,290	242,290
10.	Engineering Services	82,330	35,290	117,620
11.	Administration Cost of Executive Agency	-	23,520	23,520
	Sub-total	487,940	1,071,700	1,559,640
12.	Physical Contingency	73,190	160,760	233,950
	Sub-total	561,430	1,232,460	1,793,590
13.	Price Contingency	152,040	380,350	532,390
	Total	713,170	1,612,810	2,325,980

Table 47 INVESTMENT COST OF KHLONG THAP MA DAM (Contract Basis)

(Unit: ฿10^{3})

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Work	5,140	9,250	14,390
2.	Care of River	1,290	2,310	3,600
3.	Dam	118,130	189,830	307,960
4.	Spillway	10,270	40,700	50,970
5.	Contractor's Administration Cost	4,720	8,470	13,190
6.	Contractor's Profit	8,760	15,740	24,500
7.	Tax	-	12,820	12,820
	Sub-total	148,310	279,120	427,430
8.	Compensation & Relocation	-	294,300	294,300
9.	Engineering Services	29,920	12,820	42,740
10.	Administration Cost of Executive Agency	-	8,550	8,550
	Sub-total	178,230	594,790	773,020
11.	Physical Contingency	26,740	89,220	115,960
	Sub-total	204,970	684,010	888,980
12.	Price Contingency	89,520	297,460	386,980
	Total	294,490	981,470	1,275,960

Table 48 CONSTRUCTION COST OF KHLONG LUANG DAM
(Force Account Construction)

Unit: 10^3 Baht

Item	Unit	Quantity	Foreign Currency	Local Currency	Total
1. Preparatory Works	L.S.		-	34,240	34,240
2. Care of River	L.S.		-	8,550	8,550
3. Main Dam					
Excavation					
Common, for foundation	m^3	1,524,000	-	38,060	38,060
Common, for blanket	m^3	447,000	-	11,160	11,160
Embankment					
Core	m^3	2,158,000	-	140,920	140,920
Blanket	m^3	447,000	-	29,190	29,190
Filter	m^3	213,000	-	38,840	38,840
Riprap	m^3	154,000	-	66,100	66,100
Reinforced concrete	m^3	1,500	-	3,540	3,540
Sod facing	m^2	95,000	-	590	590
Asphalt facing	m	3,900	-	2,620	2,620
4. Saddle Dam					
Excavation					
Common, for foundation	m^3	148,000	-	3,700	3,700
Common, for cut off trench	m^3	60,000	-	1,850	1,850
Embankment					
Core	m^3	215,000	-	13,440	13,440
Filter	m^3	53,000	-	9,650	9,650
Riprap	m^3	31,000	-	13,280	13,280
Reinforced concrete	m^3	1,000	-	2,360	2,360
Sod facing	m^2	16,000	-	100	100
Asphalt facing	m	2,300	-	1,540	1,540
5. Spillway					
Excavation, common	m^3	75,000	-	1,870	1,870
Backfill	m^3	10,000	-	650	650
Reinforced concrete	m^3	6,800	-	16,050	16,050
6. Procurement	L.S.		388,260	2,580	390,840
(Sub-total 1-6)			(388,260)	(440,880)	(829,140)
7. Compensation and Relocation	L.S.		-	272,020	272,020
8. Administration	L.S.		-	20,380	20,380
9. Engineering Service	L.S.		71,330	30,570	101,900
(Sub-total 7-9)			(71,330)	(322,970)	(394,300)
10. Physical Contingency	L.S.		68,940	114,580	183,520
Total			528,530	878,430	1,406,960

Table 49 CONSTRUCTION COST OF KHLONG YAI DAM
(Force Account Construction)

Unit: 10^3 Baht

Item	Unit	Quantity	Foreign Currency	Local Currency	Total
1. Preparatory Works	L.S.		-	32,440	32,440
2. Care of River	L.S.		-	8,110	8,110
3. Dam					
Excavation					
Common, for foundation	m^3	873,000	-	21,210	21,210
Common, for cut off trench	m^3	458,000	-	12,350	12,350
Embankment					
Core	m^3	2,051,000	-	172,860	172,860
Filter	m^3	254,000	-	33,410	33,410
Riprap	m^3	190,000	-	79,970	79,970
Feinforced concrete	m^3	1,500	-	3,690	3,690
Sod facing	m^2	102,000	-	640	640
Asphalt facing	m	4,100	-	3,950	3,950
4. Spillway					
Excavation, common	m^3	275,000	-	6,680	6,680
Backfill	m^3	32,000	-	2,700	2,700
Reinforced concrete	m^3	13,000	-	32,000	32,000
5. River Outlet					
Excavation, common	m^3	19,000	-	460	460
Backfill	m^3	5,300	-	450	450
Reinforced concrete	m^3	1,100	-	2,710	2,710
Gate & trashrack	set	1	670	190	860
Steel pipe	t	50	4,750	1,290	6,040
River outlet valve	set	1	-	1,500	1,500
6. Procurement	L.S.		429,010	1,820	430,830
(Sub-total 1-6)			(434,430)	(418,430)	(852,860)
7. Compensation and Relocation	L.S.		-	294,290	294,290
8. Administration	L.S.		-	19,320	19,320
9. Engineering Service	L.S.		67,610	28,980	96,590
(Sub-total 7-9)			(67,610)	(342,590)	(410,200)
10. Physical Contingency	L.S.		75,310	114,150	189,460
Total			577,350	875,170	1,452,520

Table 50 CONSTRUCTION COST OF KHLONG THAP MA DAM
(Force Account Construction)

Unit: 10^3 Baht

Item	Unit	Quantity	Foreign Currency	Local Currency	Total
1. Preparatory Works	L.S.		-	14,390	14,390
2. Care of River	L.S.		-	3,600	3,600
3. Main Dam					
Excavation					
Common, for foundation	m^3	508,000	-	10,160	10,160
Common, for cut off trench	m^3	60,000	-	1,250	1,250
Embankment					
Core	m^3	1,182,000	-	71,310	71,310
Filter	m^3	92,000	-	18,150	18,150
Riprap	m^3	72,000	-	26,970	26,970
Reinforced concrete	m^3	300	-	770	770
Sod facing	m^2	43,000	-	270	270
Asphalt facing	m	850	-	440	440
4. Saddle Dam					
Excavation					
Common, for foundation	m^3	27,000	-	590	590
Common, for cut off trench	m^3	12,000	-	300	300
Embankment					
Core	m^3	35,000	-	2,840	2,840
Filter	m^3	9,000	-	1,830	1,830
Riprap	m^3	5,000	-	1,990	1,990
Reinforced concrete	m^3	200	-	520	520
Sod facing	m^2	2,500	-	20	20
Asphalt facing	m	420	-	220	220
5. Spillway					
Excavation, common	m^3	101,000	-	2,020	2,020
Backfill	m^3	28,000	-	1,690	1,690
Reinforced concrete	m^3	12,000	-	30,880	30,880
6. Procurement	L.S.		317,740	1,000	318,740
(Sub-total 1-6)			(317,740)	(191,210)	(508,950)
7. Compensation and Relocation	L.S.		-	294,300	294,300
8. Administration	L.S.		-	8,550	8,550
9. Engineering Service	L.S.		29,920	12,820	42,740
(Sub-total 8-9)			(29,920)	(315,670)	(345,590)
10. Physical Contingency	L.S.		52,150	76,030	128,180
Total			399,810	582,910	982,720

Table 51 PROCUREMENT COST OF KHLONG LUANG DAM

Unit: 10^3 Baht

Item	Capacity	Quantity	Foreign Currency	Local Currency	Amount
Aggregate plant	80 t/hr.	1 set	17,388	339	17,727
Concrete plant	18 cft x 1	1 set	3,014	184	3,198
Bulldozer W/R	32 tons	5 nos.	23,454	150	23,604
Bulldozer	32 tons	5 nos.	19,875	135	20,010
- do -	21 tons	5 nos.	13,985	90	14,075
- do -	16 tons	5 nos.	9,036	75	9,111
Back hoe	1.2 m^3	8 nos.	28,833	192	29,025
- do -	0.7 m^3	2 nos.	3,787	36	3,823
Power shovel	1.2 m^3	4 nos.	15,840	96	15,936
Tractor shovel	2.2 m^3	7 nos.	15,920	126	16,046
- do -	1.8 m^3	1 no.	1,270	12	1,282
Wheel loader	3.2 m^3	2 nos.	5,239	48	5,287
- do -	2.2 m^3	1 no.	1,849	18	1,867
- do -	1.8 m^3	2 nos.	2,843	24	2,867
Dump truck	15 tons	57 nos.	78,127	309	78,436
- do -	8 tons	100 nos.	69,041	288	69,329
Vibration roller	10 tons	5 nos.	7,361	30	7,391
Diesel engine generator	150 kW	2 nos.	2,092	48	2,140
Agitator truck	3.2 m^3	4 nos.	3,046	12	3,058
Motor grader	3.7 m	2 nos.	3,046	36	3,082
Road roller	8/10 tons.	4 nos.	3,168	24	3,192
Hydraulic crane	25 tons.	1 no.	2,437	90	2,527
Water tanker	8 m^3	6 nos.	4,569	17	4,586
Asphalt spreader	30 l/min	6 nos.	183	11	194
Tractor & trailer	30 tons.	1 no.	2,538	11	2,549
Spare parts	-	L.S.	50,311	180	50,491
Total			388,252	2,581	390,833

Table 52 PROCUREMENT COST OF KHLONG YAI DAM

Unit: 10^3 Baht

Item	Capacity	Quantity	Foreign Currency	Local Currency	Amount
Aggregate plant	80 t/hr.	1 set	17,388	309	17,697
Concrete plant	18 cft x 1	1 set	3,014	164	3,178
Bulldozer W/R	32 tons	7 nos.	32,836	140	32,976
Bulldozer	32 tons	5 nos.	19,875	90	19,965
- do -	21 tons	5 nos.	13,985	60	14,045
Back hoe	1.2 m^3	6 nos.	21,626	96	21,722
- do -	0.7 m^3	4 nos.	7,573	40	7,613
Power shovel	1.2 m^3	5 nos.	19,794	80	19,874
Tractor shovel	3.2 m^3	6 nos.	20,774	96	20,870
- do -	2.2 m^3	4 nos.	9,098	48	9,146
- do -	1.8 m^3	1 no.	1,315	8	1,323
Wheel loader	3.2 m^3	3 nos.	7,859	36	7,895
- do -	1.8 m^3	1 no.	1,421	8	1,429
Dump truck	15 tons	75 no.s	102,800	270	103,070
- do -	8 tons	95 nos.	65,590	144	65,734
Vibration roller	10 tons	5 nos.	7,361	20	7,381
Diesel engine generator	150 kW	2 nos.	2,092	16	2,108
Agitator truck	3.2 m^3	4 nos.	3,046	8	3,054
Motor grador	3.7 m	2 nos.	3,046	16	3,062
Road roller	8/10 tons	4 nos.	3,165	16	3,181
Hydraulic crane	25 tons	1 no.	2,437	6	2,443
Water tanker	8 m^3	6 nos.	4,569	12	4,581
Asphalt spreader	30 l/min	6 nos.	183	12	195
Tractor & trailer	30 tons	1 no.	2,538	7	2,545
Spare parts	-	L.S.	55,621	120	55,741
Total			429,006	1,822	430,828

Table 53 PROCUREMENT COST OF KHLONG THAP MA DAM

Unit: 10^3 Baht

Item	Capacity	Quantity	Foreign Currency	Local Currency	Amount
Concrete plant	18 cft x 1	1 set	30,140	141	30,281
Bulldozer W/R	32 tons	5 nos.	23,454	81	23,535
Bulldozer	32 tons	3 nos.	11,925	44	11,969
- do -	21 tons	4 nos.	11,188	46	11,234
- do -	16 tons	5 nos.	9,036	49	9,085
Back hoe	1.2 m^3	3 nos.	10,803	39	10,842
- do -	0.7 m^3	3 nos.	5,681	29	5,710
Tractor shovel	3.2 m^3	3 nos.	10,387	39	10,426
- do -	2.2 m^3	2 nos.	4,549	20	4,569
- do -	1.8 m^3	1 no.	1,756	7	1,763
Power shovel	1.2 m^3	2 nos.	7,917	26	7,943
Wheel loader	3.2 m^3	1 no.	2,620	11	2,631
- do -	2.2 m^3	1 no.	1,848	10	1,858
- do -	1.8 m^3	1 no.	1,422	8	1,430
Dump truck	15 tons	60 nos.	82,240	176	82,416
- do -	8 tons	58 nos.	40,042	91	40,133
Vibration roller	10 tons	4 nos.	5,889	13	5,902
Agitator truck	3.2 m^3	4 nos.	3,046	6	3,052
Motor grader	3.7 m	2 nos.	3,046	20	3,066
Road roller	8/10 tons	4 nos.	3,168	13	3,181
Hydraulic crane	25 tons	1 no.	2,437	6	2,443
Water tanker	8 m^3	6 nos.	4,569	9	4,578
Asphalt spreader	30 l/min	6 nos.	183	6	189
Tractor & trailer	30 tons	1 no.	2,538	10	2,548
Spare parts	-	L.S.	37,860	98	37,958
Total			317,744	998	318,742

Table 54 DISBURSEMENT SCHEDULE OF INVESTMENT COST, KHLONG LUANG DAM

(Unit: ฿ 10^3)

Item	Summary			1985		1986		1987		1988		1989		1990	
	Total	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.
1. Preparatory Works	34,240	12,860	21,380	-	-	10,120	16,830	2,740	4,550	-	-	-	-	-	-
2. Care of River	8,550	3,210	5,340	-	-	-	-	1,530	2,560	840	1,390	840	1,390	-	-
3. Dam	824,700	313,780	510,920	-	-	-	-	83,460	133,080	100,400	161,230	102,230	174,400	27,690	42,210
4. Spillway	31,080	7,600	23,480	-	-	-	-	-	-	-	-	4,920	15,190	2,680	8,290
5. Contractor's Administration Cost	31,450	11,810	19,640	-	-	360	590	3,070	4,900	3,540	5,700	3,780	6,680	1,060	1,770
6. Contractor's Profit	58,400	21,930	36,470	-	-	660	1,090	5,710	9,110	6,580	10,570	7,010	12,420	1,970	3,280
7. Tax	30,550	-	30,550	-	-	-	920	-	7,750	-	8,970	-	10,160	-	2,750
8. Compensation & Relocation	272,020	-	272,020	-	136,010	-	136,010	-	-	-	-	-	-	-	-
Sub-total	1,290,990	371,190	919,800	-	136,010	11,140	155,440	96,510	161,950	111,360	187,860	118,780	220,240	33,400	58,300
9. Engineering Services	101,900	71,330	30,570	11,890	5,090	13,310	5,710	12,360	5,100	14,270	5,910	15,220	6,930	4,280	1,830
10. Administration Cost of Executive Agency	20,380	-	20,380	-	3,030	-	3,460	-	3,580	-	4,150	-	4,870	-	1,290
Sub-total	1,413,270	442,520	970,750	11,890	144,130	24,450	164,610	108,870	170,630	125,630	197,920	134,000	232,040	37,680	61,420
11. Physical Contingency	211,990	66,380	145,610	1,780	21,620	3,670	24,690	16,330	25,590	18,850	29,690	20,100	34,810	5,650	9,210
Sub-total	1,625,260	508,900	1,116,360	13,670	165,750	28,120	189,300	125,200	196,220	144,480	227,610	154,100	266,850	43,330	70,630
12. Price Contingency	844,290	243,890	600,400	2,280	34,810	7,300	62,660	45,130	91,070	67,810	138,960	90,440	205,890	30,930	67,010
Grand Total	2,469,550	752,790	1,716,760	15,950	200,560	35,420	251,960	170,330	287,290	212,290	366,570	244,540	472,740	74,260	137,640

Table 55 DISBURSEMENT SCHEDULE OF INVESTMENT COST, KHLONG YAI DAM

(Unit: ฿ 10^3)

Item	Summary			1985		1986		1987		1988		1989		1990	
	Total	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.
1. Preparatory Works	32,440	12,120	20,320	-	-	9,460	15,870	2,660	4,450	-	-	-	-	-	-
2. Care of River	8,110	3,030	5,080	-	-	80	140	1,210	2,030	800	1,340	800	1,340	140	230
3. Dam	723,970	275,950	448,020	-	-	-	-	88,430	137,370	89,680	140,150	69,330	122,720	28,510	47,780
4. Intake	14,710	7,170	7,540	-	-	-	-	-	-	-	-	7,170	7,540	-	-
5. Spillway	72,540	19,990	52,550	-	-	-	-	-	-	4,990	13,140	15,000	39,410	-	-
6. Contractor's Administration Cost	29,810	11,140	18,670	-	-	340	560	3,230	5,040	3,340	5,410	3,230	5,980	1,000	1,680
7. Contractor's Profit	55,370	20,690	34,680	-	-	620	1,040	6,000	9,350	6,210	10,050	6,000	11,120	1,860	3,120
8. Tax	28,960	-	28,960	-	-	-	870	-	8,030	-	8,500	-	8,950	-	2,610
9. Compensation & Relocation	87,800	-	87,800	-	43,900	-	43,900	-	-	-	-	-	-	-	-
Sub-total	1,053,710	350,090	703,620	-	43,900	10,500	62,380	101,530	166,270	105,020	178,590	101,530	197,060	31,510	55,420
10. Engineering Services	96,591	67,610	28,980	11,270	4,830	12,620	5,410	13,070	5,220	13,520	5,600	13,070	6,180	4,060	1,740
11. Administration Cost of Executive Agency	19,320	-	19,320	-	3,130	-	3,520	-	3,520	-	3,790	-	4,180	-	1,180
Sub-total	1,169,620	417,700	751,920	11,270	51,860	23,120	71,310	114,600	175,010	118,540	187,980	114,600	207,420	35,570	58,340
12. Physical Contingency	175,450	62,660	112,790	1,690	7,780	3,470	10,700	17,190	26,250	17,780	28,200	17,190	31,110	5,340	8,750
Sub-total	1,345,070	480,360	864,710	12,960	59,640	26,590	82,010	131,790	201,260	136,320	216,180	131,790	238,530	40,910	67,090
13. Price Contingency	739,840	227,100	512,750	2,160	12,520	6,910	27,150	47,510	93,410	63,980	131,980	77,340	184,040	29,200	63,650
Grand Total	2,084,910	707,460	1,377,460	15,120	72,160	33,500	109,160	179,300	294,670	200,300	348,160	209,130	422,570	70,110	130,740

Table 56 DISBURSEMENT SCHEDULE OF INVESTMENT COST, KHLONG THAP MA DAM

(Unit: ₱ 10^3)

Item	Summary			1985		1986		1987		1988		1989	
	Total	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.
1. Preparatory Works	14,390	5,140	9,250	-	-	4,050	7,270	1,090	1,980	-	-	-	-
2. Care of River	3,600	1,290	2,310	-	-	-	-	760	1,360	530	950	-	-
3. Dam	307,960	118,130	189,830	-	-	-	-	50,730	78,770	41,890	63,330	25,510	47,730
4. Spillway	50,970	10,270	40,700	-	-	-	-	-	-	2,070	8,220	8,200	32,480
5. Contractor's Administration Cost	13,190	4,720	8,470	-	-	140	250	1,840	2,870	1,560	2,540	1,180	2,810
6. Contractor's Profit	24,500	8,760	15,740	-	-	260	470	3,420	5,340	2,890	4,710	2,190	5,220
7. Tax	12,820	-	12,820	-	-	-	380	-	4,580	-	3,990	-	3,870
8. Compensation & Relocation	294,300	-	294,300	-	147,150	-	147,150	-	-	-	-	-	-
Sub-total	721,730	148,310	573,420	-	147,150	4,450	155,520	57,840	94,900	48,940	83,740	37,080	92,110
9. Engineering Services	42,740	29,920	12,820	4,990	2,140	5,580	2,390	7,780	2,910	6,580	2,560	4,990	2,820
10. Administration Cost	8,550	-	8,550	-	2,180	-	2,300	-	1,430	-	1,260	-	1,380
Sub-total	773,020	178,230	594,790	4,990	151,470	10,030	160,210	65,620	99,240	55,520	87,560	42,070	96,310
11. Physical Contingency	115,960	26,740	89,220	750	22,720	1,510	24,030	9,840	14,890	8,330	13,130	6,310	14,450
Sub-total	888,980	204,970	684,010	5,740	174,190	11,540	184,240	75,460	114,130	63,850	100,690	48,380	110,760
12. Price Contingency	386,980	89,520	297,460	960	36,580	3,000	60,980	27,200	52,970	29,970	61,470	28,390	85,460
Grand Total	1,275,960	294,490	981,470	6,700	210,770	14,540	245,220	102,660	167,100	93,820	162,160	76,770	196,220

Table 57 ECONOMIC CONSTRUCTION COST OF KHLONG LUANG DAM

(Unit: ฿ 10^3)

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Works	12,860	18,170	31,030
2.	Care of River	3,210	4,540	7,750
3.	Dam	313,780	434,280	748,060
4.	Spillway	7,600	19,960	27,560
	Sub-total	337,450	476,950	814,400
5.	Contractor's Overhead	11,810	16,690	28,500
6.	Contractor's Profit	21,930	31,000	52,930
	Sub-total	371,190	524,640	895,830
7.	Engineering Services	71,330	25,980	97,310
8.	Administration Cost of Executive Agency	-	17,920	17,920
	Sub-total	442,520	568,540	1,011,060
9.	Physical Contingency	66,380	85,280	151,660
	Total	508,900	653,820	1,162,720

Table 58 ECONOMIC CONSTRUCTION COST OF KHLONG YAI DAM

(Unit: ฿ 10^3)

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Works	12,120	17,280	29,400
2.	Care of River	3,030	4,320	7,350
3.	Dam	275,950	380,820	656,770
4.	Intake	7,170	6,410	13,580
5.	Spillway	19,990	44,660	64,650
	Sub-total	318,260	453,490	771,750
6.	Contractor's Overhead	11,140	15,870	27,010
7.	Contractor's Profit	20,690	29,480	50,170
	Sub-total	350,090	498,840	848,930
8.	Engineering Services	67,610	24,640	92,250
9.	Administration Cost of Executive Agency	-	16,980	16,980
	Sub-total	417,700	540,460	958,160
10.	Physical Contingency	62,660	81,080	143,740
	Total	480,360	621,540	1,101,900

Table 59 ECONOMIC CONSTRUCTION COST OF NONG PLA LAI DAM

(Unit: ฿ 10^3)

	Description	Foreign Currency Portion	Local Currency Portion	Total
1.	Preparatory Works	14,180	21,850	36,030
2.	Diversion & Coffer	82,410	132,350	214,760
3.	Dam	232,230	321,630	553,860
4.	Intake	7,490	4,610	12,100
5.	Spillway	32,420	87,770	120,190
	Sub-total	368,730	568,210	936,940
6.	Contractor's Overhead	12,910	19,890	32,800
7.	Contractor's Profit	23,970	36,930	60,900
	Sub-total	405,610	625,030	1,030,640
8.	Engineering Services	82,330	30,000	112,330
9.	Administration Cost of Executive Agency	-	20,610	20,610
	Sub-total	487,940	675,640	1,163,580
10.	Physical Contingency	73,190	101,350	174,540
	Total	561,130	776,990	1,338,120

Table 60 ECONOMIC CONSTRUCTION COST OF KHLONG THAP MA DAM

(Unit: ฿ 10^3)

Description	Foreign Currency Portion	Local Currency Portion	Total
1. Preparatory Works	5,140	7,860	13,000
2. Care of River	1,290	1,960	3,250
3. Dam	118,130	161,360	279,490
4. Spillway	10,270	34,590	44,860
Sub-total	134,830	205,770	340,600
5. Overhead	4,720	7,200	11,920
6. Profit	8,760	13,380	22,140
Sub-total	148,310	226,350	374,660
7. Engineering Services	29,920	10,900	40,820
8. Administration Cost of Executive Agency	-	7,490	7,490
Sub-total	178,230	244,740	422,970
9. Physical Contingency	26,740	36,710	63,450
Total	204,970	281,450	486,420