KINGDOM OF THAILAND

MINISTRY OF AGRICULTURE AND COOPERATIVES

ROYAL IRRIGATION DEPARTMENT

THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT (PHASE II)

VOLUME 3

MAIN REPORT

FEASIBILITY STUDY ON

KHLONG YAI DAM SCHEME

AUGUST 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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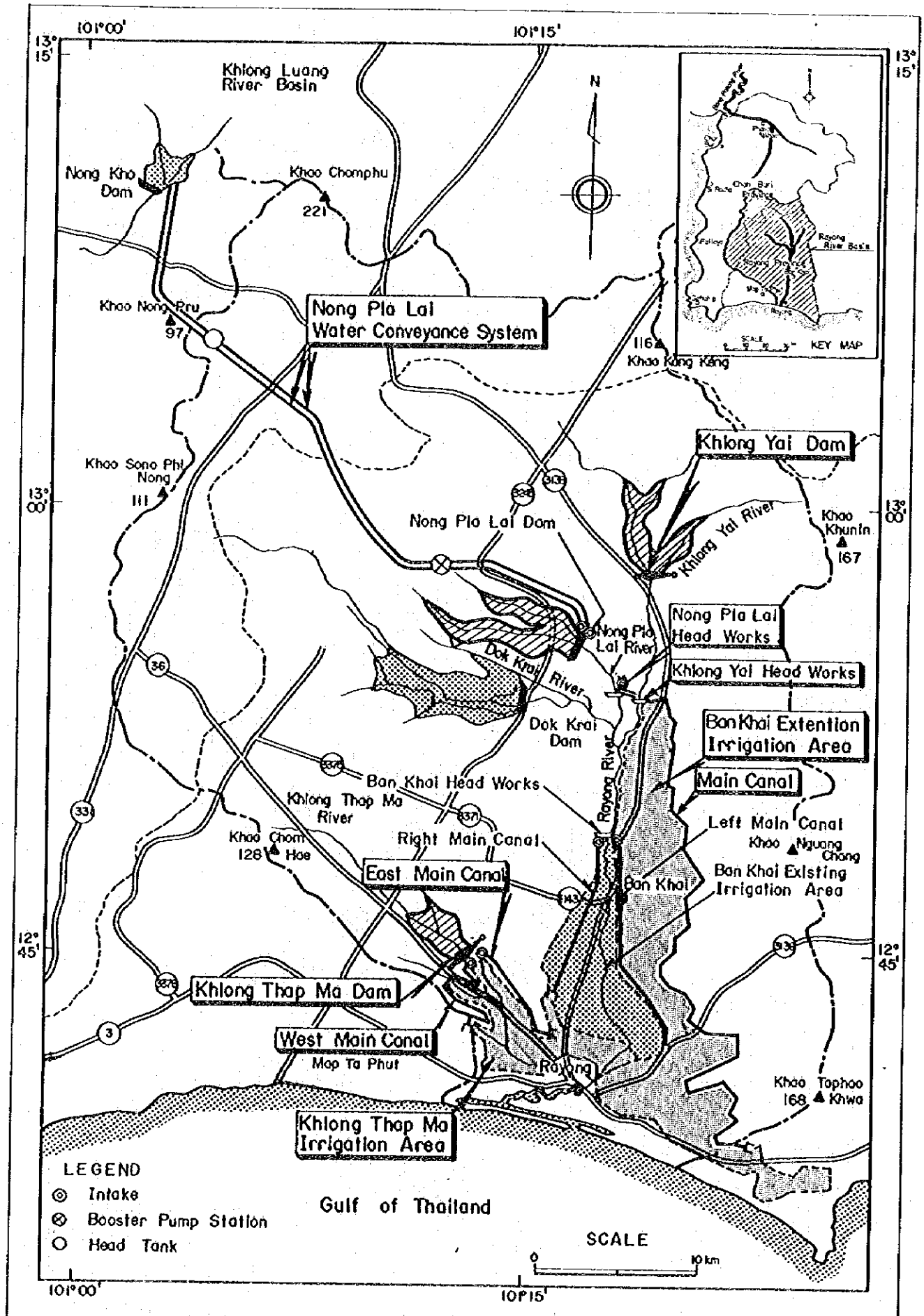


General Layout of Khlong Yai and Khlong Thap Ma Dam Schemes

SUMMARY OF CONCLUSION AND RECOMMENDATION

1. The Government of Kingdom of Thailand issued the Fifth National Economic and Social Development Plan (the Fifth National Plan), which covers a 5-year period from 1982 to 1986. The Fifth National Plan focuses to restore the nation's economic and financial stability, to improve the economic efficiency and to alleviate the poverty through the development of industry and increase of agricultural production.

2. The Eastern Seaboard Development is the spearhead of the nation's industrial development plan and aims at developing the basic industry based on natural gas. The development area extends over Chachoengsao, Chon Buri and Rayong Provinces. The majority of the development area are located along the coastal area in Chon Buri and Rayong Provinces.

3. The agricultural development is regarded to be promoted in the backward area of the industrial development area in order to create the balanced socio-economic situation throughout region and to increase the exportable quantity.

4. The East Coast Water Resources Development Project, Phase II (the Study) was launched by the Government to treat of increasing importance of land and water resources development for the industrial development and agricultural production.

   The objective area of the Study (the Study Area) covers Chon Buri and Rayong Provinces, except the Prasae river basin, and embraces the majority of the Eastern Seaboard Development Area.

5. The Study contains two subjects; (a) study for the long-term water demand and supply balance in the Study Area and (b) feasibility study for Khlong Luang, Khlong Yai and Khlong Thap Ma Dams.

6. The long-term water supply plan over the Study Area has been elaborated already and has pointed out clearly the significance of development of Khlong Yai Dam Scheme (the Scheme). The Scheme is distinguished as multiple-purpose areal-development project, since it is designed as an element in regional plan.

7. The Scheme is located in the Rayong river basin, which has a drainage area of 1,730 km^2. The population in the basin is 169,400 in 1981, of which about 75% resides in the rural area.

8. The lands and water resources of the basin remain almost untapped. There are approximately 14,900 ha of land suitable for cultivation of paddy, of which 4,800 ha is being irrigated under Ban Khai Irrigation Project and 2,400 ha is located in the Khlong Thap Ma river basin. The main crops are rice, cassava and sugarcane. The crop productivity is low due to lack of irrigation supply and agricultural input and inundation.

9. The pipe-water service is provided mainly for the urban areas. The existing three water works serve about 24 x 10^3 people, being only 15 % of the total population in the basin. The remaining people depend on groundwater or water-vender for their domestic use.

10. The alluvial plains are prone to inundation to a large extent, owing to flat topography and flooding of the Rayongriver. It is estimated that about 21,000 ha of lands were inundated in 1974.

11. The Scheme bears substantial portion of water deficit in Chon Buri - Pattaya area. The quantity of inter-zone water diversion is estimated to be 4.9 x 10^6 m^3 per year 1991, 14.2 x 10^6 m^3 per year in 1996 and 31.3 x 10^6 m^3 per year in 2001. The existing Dok Krai dam fully assures the domestic and industrial water demand in Map Ta Phut - Sattahip area. The annual water demand is projected to be 38.2 x 10^6 m^3 in 1986, 43.2 x 10^6 m^3 in 1991, 48.2 x 10^6 m^3 in 1996 and 53.5 x 10^6 m^3 in 2001.

12. The plan formulation study was conducted to ascertain the optimum development plan of the Scheme. It was performed in two steps each of which treats of various alternatives. The first step is directed to formulate the optimum land and water resources development plan, including the domestic and industrial water supply. The second step is led to formulate the optimum flood mitigation plan in the basin. As the results, the optimum development plan of the Scheme is determined.

13. The flood mitigation plan evolved the most favourable basic flood control plan for standard project flood with a 50-year recurrence interval. The basic plan is made up of combination of dam and river improvement works. The river improvement works, however, are not recommendable positively for the present, because of less technical feasibility.

14. The water conveyance system between Nong Pla Lai dam and Nong Kho reservoir will be implemented in two phases taking into account the growth of the domestic and industrial water demand. The first phase with system capacity of 0.65 m^3 per second must be realized in 1991 at the latest in order to release Chon Buri-Pattaya area from the water shortage. The system capacity will be expanded to 1.30 m^3 per second with completion of the second phase in 1996.

15. With development of Nong Pla Lai and Khlong Yai dams, the whole irrigable area extending along the main stream of the Rayong river, 12,500 ha, will be served with the year-round irrigation water supply. The area comprises Ban Khai existing area (4,800 ha) and Ban Khai Extension Area (7,700 ha). The Ban Khai Extension Area is extending along Left Main Canal of the Ban Khai existing area.

The recommended crops are rice, groundnuts, fruit trees and vegetables. The rice will be cultivated in the whole irrigation area during the wet season while it will be grown about 10 % of the area during the dry season. The groundnuts and vegetables will be grown during the dry season. Cropping intensity is 140 %

for both the Extension Area and existing area. The crop production will increase largely as shown below, resulting from the introduction of advanced farming practices and proper water management.

(Unit: ton/year)

Crops	Extension Area			Existing Area		
	Without Project	With Project	Increment	Without Project	With Project	Increment
Rice						
- Local variety	6,790	5,680	-1,110	5,000	3,840	-1,160
- HYD	5,840	29,900	24,060	12,790	19,980	7,190
Groundnuts	30	4,330	4,300	-	2,730	2,730
Fruits	2,500	4,060	1,560	-	-	-
Vegetables	-	5,000	5,000	1,600	3,000	1,400

16. Preliminary designs were performed for the Khlong Yai dam, raw water conveyance system and irrigation and drainage system, respectively.

The dam is of homogeneous earth-fill type with the maximum height of 17.3 m above the river bed and the crest length of 3,980 m. The upstream and downstream slopes are 1 to 3.0 and 1:2.6 respectively. The total embankment volume is 2,495 x 10^3 m^3. The spillway is designed as a side-channel spillway with open channel chuteway based on inflow design flood with a peak discharge of 1,230 m^3/s (500-year recurrence interval). Its crest elevation and length are at El. 47.5 m and 70.0 m, respectively. The river outlet is designed for the maximum release of 8.7 m^3/s and is composed of intake, conduit pipe with ø 1,500 mm and Hollow-jet valve.

The water conveyance system connects the Nong Pla Lai dam with the Nong Kho dam with a total length of 53 km. The intake is located at the outlet of the river outlet of Nong Pla Lai dam and is equipped with 5 units of horizontal double suction volute pump,

each having a discharge capacity of 19.4 m^3 per min. The pipeline is designed by a combination of ø 900 mm pipe and ø 800 mm pipe and is installed in 2 rows. The boosting pump station and head tank are located at Ban Thap Thong and Ban Khao Khayai respectively.

Two headworks are proposed to be constructed to irrigate the Ban Khai Extension Area. The one is located in the Nong Pla Lai river and its diversion weir is 63 m in length and 3.56 m in height in fixed portion. The other is situated in the Khlong Yai river and its diversion weir is 4.1 m in height and 103 m in length. Both headworks are linked by diversion channel, which has a trapezoidal shape with a bottom width of 2.0 m. The design discharge of the diversion channel is 4.9 m^3/s. The main canal is originating from Khlong Yai headworks and has a total length of 45.2 km. It is designed with a trapezoidal cross-section with concrete lining. The total length of lateral canals is 123 km.

17. Environmental aspects of the Scheme is preliminarily evaluated according to the standard established by National Environmental Board. The standard comprises four categories namely, physical resources, ecological resources, human use values and quality of life values. It is clarified that the Scheme will induce positive impact on human use values and quality of life values greatly through the water resources development. Impact on such items as water quality and fauna and flora will be minimized or avoided by guaranteeing the river maintenance flow to the downstream of the river. It is recommended that detailed survey on environmental impacts of the Scheme will be conducted by the executive agency before the implementation of the Scheme.

18. The Scheme will be implemented in two stages. The first stage includes the construction of Nong Pla Lai and Khlong Yai dams, the first phase of water conveyance system and the development of irrigation and drainage system. The second stage is the construction of the second phase of the water conveyance system.

The first stage will extend over 8 years from 1984 to 1991. The construction period will be 6 years from 1985 to 1990 for the dams, 5 years from 1987 to 1991 for the first phase of the water conveyance system and 6 years from 1986 to 1991 for the irrigation and drainage system. The second stage will be implemented in a 5-year period from 1992 to 1996.

19. The total investment cost is estimated to be ฿ 7,579.8 x 10^6 comprising ฿ 3,154.0 x 10^6 of foreign currency portion and ฿ 4,425.8 x 10^6 of local currency portion as shown below:

(Unit: ฿ 10^6)

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

20. The benefit is accrued from the water supply, irrigation and drainage development and flood control and is estimated as follows for the full development stage:

(Unit: ฿ 10⁶)

Benefits	Annual Benefit
Water Supply	
Con Buri - Pattaya Area	539.8
Map Ta Phut - Sattahip Area	253.8
Irrigation and Drainage	198.2
Flood Control	
Nong Pla Lai Dam	37.2
Khlong Yai Dam	20.0
Total	1,049.0

The water supply benefit is measured by justifiable expenditure.

21. Economic feasibility of the Scheme is evaluated by economic internal rate of return (EIRR). EIRR is computed at 15.0 %, indicating the high economic soundness of the Scheme. From the view point of economic feasibility and urgent water demand in Chon Buri - Pattaya Area, the Scheme is highly recommended to be implemented at the earliest time possible.

22. Investment cost is allocated to the components by "Separable Cost - Remaining Benefit Method" and summarized as follows.

(Unit: ฿ 10⁶)

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

23. Financial aspect of the Scheme is evaluated by respective component paying particular attention to the repayability of the Scheme to the international loan. International loan is assumed to be financed with an interest rate of 3.5 % per annum and a term of 30 years including 10 years of grace period. Repayability is examined based on the project cost allocated to each project component and revenue expected to be collected through water tariff. Water tariff on domestic and industrial water supply is assumed to be ฿ 4.0/m^3. Water tariff on irrigation water is broadly estimated at ฿ 530/ha to recover annual O&M cost. International loan is expected to be repayed in due schedule, with Government subsidy given at the appropriate time.

24. Economic feasibility of the rehabilitation works in the Ban Khai Existing Area is evaluated by benefit - cost ratio (B/C). Investment cost is estimated to be B 390.5 x 10^6 comprising B 118.7 x 10^6 of foreign currency portion and B 271.8 x 10^6 of local currency portion. Benefit - cost ratio is estimated at 3.1. Rehabilitation works are highly recommended to be implemented in parallel withe the construction of the Nong Pla Lai Dam for the efficient and effective utilization of water.

25. RID will be responsible for implementation, operation and maintenance of dam and irrigation components. An appropriate agency would be appointed for the implementation, operation and maintenance of the raw water conveyance system. The Center for the Integrated Plan of Operation (CIPO) established within National Economic and Social Development Board (NESDB) will coordinate all the activities of the agencies with the activities related to the Eastern Seaboard Development.

PRINCIPAL FEATURES OF KHLONG YAI DAM SCHEME

1.	MULTIPLE-PURPOSE DAM		
1.1	Hydrology		
	(a)	Catchment area	218 km^2
	(b)	Annual average inflow	2.76 m^3/s
	(c)	Design flood for spillway (500-year flood)	1,230 m^3/s
	(d)	Extra-ordinary flood (Probable maximum)	1,950 m^3/s
1.2	Reservoir		
	(a)	High water level	El. 47.5 m
	(b)	Low water level	El. 40.6 m
	(c)	Flood water level	El. 48.8 m
	(d)	Extra-ordinary flood water level	El. 49.4 m
	(e)	Gross storage	71.5 x $10^6 m^3$
	(f)	Surcharge	16.9 x $10^6 m^3$
	(g)	Active storage	48.0 x $10^6 m^3$
	(h)	Dead storage	6.6 x $10^6 m^3$
	(i)	Reservoir area at HWL	11.9 km^2
1.3	Dam		
	(a)	Type	Homogeneous earthfill
	(b)	Crest elevation	El. 50.8 m
	(c)	Dam height above riverbed	17.3 m
	(d)	Crest length	3,980 m
	(e)	Crest width	8.0 m
	(f)	Slope, upstream	1 : 3.0
		downstream	1 : 2.6
	(g)	Embankment volume	
		Earthfill	2,051.000 m^3
		Filter	254,000 m^3
		Rock riprap	190,000 m^3

1.4 Spillway

(a)	Type	Non-gated side-channel weir
(b)	Overflow weir crest elevation	El. 47.5 m
(c)	Overflow weir width	70.0 m
(d)	Length of chuteway, including stilling basin	160.0 m

1.5 River Outlet

(a)	Design discharge	8.7 m^3/s
(b)	Diameter of conduit	ø1,500 mm
(c)	Length of conduit	90 m
(d)	Regulating gate	1.5m x 1.5m
(e)	Valve	Hollow-jet

2. WATER CONVEYANCE SYSTEM

		First Phase	Second Phase
2.1	Intake		
(a)	Location	Nong Pla Lai Dam	
(b)	Design discharge	19.4 m^3/min	19.4 m^3/min
(c)	Type of pump	Horizontal double suction volute pump	
(d)	Pump capacity	390 kW/unit	390 kW/unit
(e)	Number of unit	3	2
(f)	Floor area of pump station	259 m^2	
2.2	Pipeline		
(a)	Type of pipe	Coating steel pipe	
(b)	Inside diameter of pipe		
	Between intake and head tank	ø900 mm	ø900 mm
	Between head tank and Nong Kho Dam	ø800 mm	ø800 mm
(c)	Number of row	1	1
(d)	Length of pipeline		
	Between intake and head tank	30 km	30 km
	Between head tank and Nong Kho Dam	23 km	23 km

		First phase	Second phase
2.3	Booster Pump Station		
	(a) Location	Ban Thap Thong	
	(b) Design discharge	19.4 m^3/min	19.4 m^3/min
	(c) Type of pump	Horizontal double suction volute pump	
	(d) Pump capacity	3	2
	(f) Floor area of pump station	259 m^2	
2.4	Head Tank		
	(a) Location	Ban Khao Khayai	
	(b) Storage capacity	2,327 m^3	
	(c) High water level	El. 118.0 m	
	Low water level	El. 115.0 m	
3.	IRRIGATION AND DRAINAGE SYSTEM		
3.1	Net Irrigation Area	7,700 ha	
3.2	Nong Pla Lai Headworks		
	(a) Location	Nong Pla Lai river	
	(b) Design flood	200 m^3/s	
	(c) Flood water level	El. 27.05 m	
	(d) Design intake discharge	4.90 m^3/s	
	(e) Design intake water level	El. 25.46 m	
	(f) Type of diversion weir	Floating type	
	(g) Height of weir above riverbed	3.56 m	
	(h) Length of fixed weir	60 m	
	(i) Crest elevation of fixed weir	El. 25.56 m	
	(j) Width of scouring sluice	3.0 m	
	(k) Sill elevation of intake	El. 23.96 m	
	(l) Intake gate (B x H)	2.5m x 2.0m	
	(m) Number of intake gate	2	

3.3 Diversion Channel

(a)	Design discharge	4.9 m^3/s
(b)	Type	Trapezoidal, lined with concrete
(c)	Bottom width	2.0 m
(d)	Length	1,800 m

3.4 Khlong Yai Headworks

(a)	Location	Khlong Yai river
(b)	Design flood	280 m^3/s
(c)	Flood water level	El. 26.57 m
(d)	Design intake discharge	11.09 m^3/s
(e)	Design intake water level	El. 25.00 m
(f)	Type of diversion weir	Floating type
(g)	Height of weir above riverbed	4.1 m
(h)	Length of fixed weir	95.0 m
(i)	Crest elevation of fixed weir	El. 25.1 m
(j)	Width of scouring sluice	8.0 m
(k)	Sill elevation of intake	El. 23.0 m
(l)	Intake gate (B x H)	4.0 m x 3.0 m
(m)	Number of intake gate	2

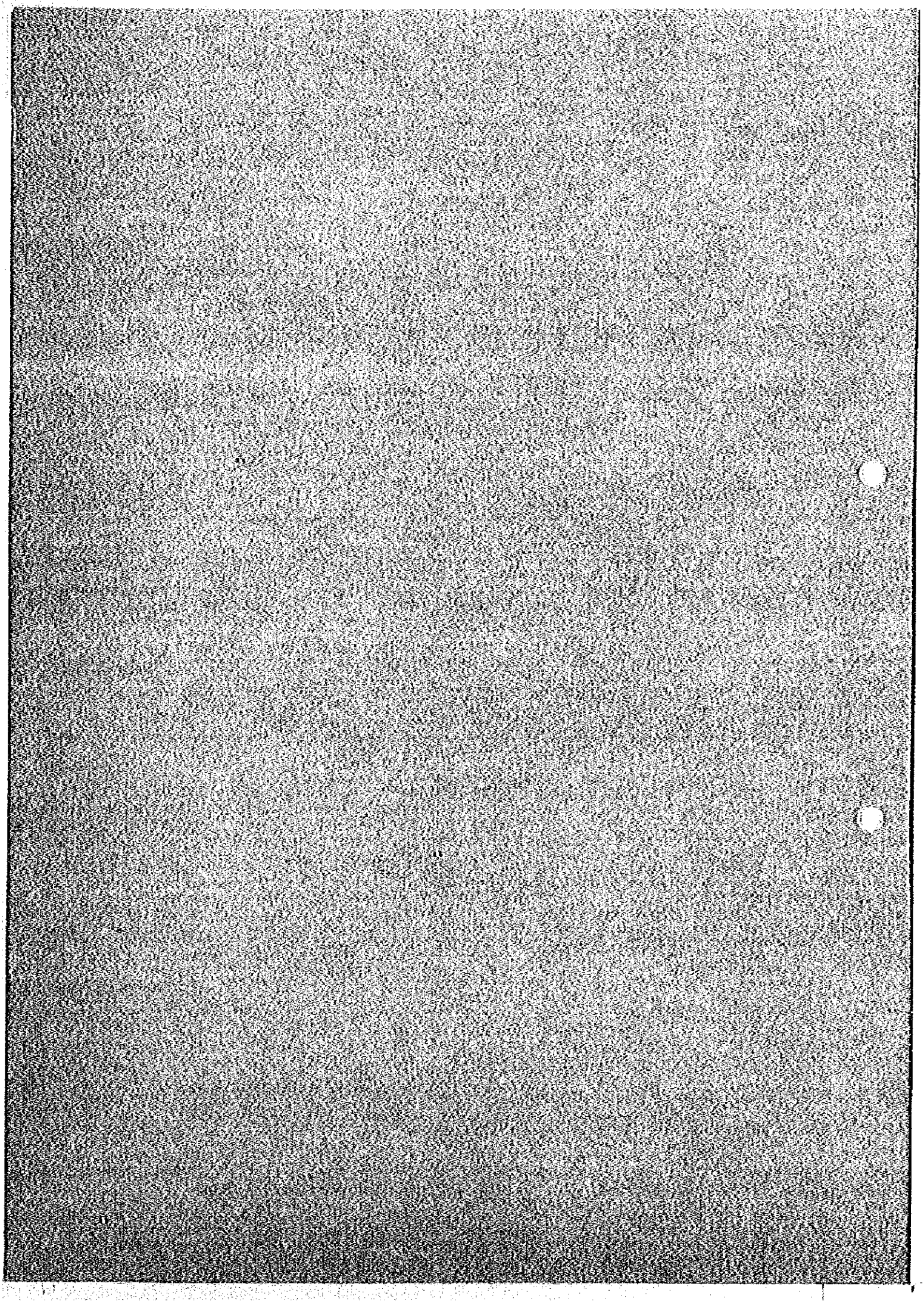
3.5 Main Canal

(a)	Type of canal	Trapezoidal, lined with concrete
(b)	Side slop	1:1.5
(c)	Effective width of inspection road	5.0 m
(d)	Length	45.2 km

3.6 Lateral and Sub-Lateral Canals

(a)	Type of canal	Trapezoidal, unlined
(b)	Side slop	1:1.5
(c)	Effective width of inspection road	3.0 m
(d)	Total length	123 km

3.7	Canal Structures	503 nos.
3.8	Drainage	
	(a) New drains	81 km
	(b) Improved drains	43 km
	(c) Structures	59 km



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ABBREVIATIONS AND LOCAL TERMS

A. ABBREVIATION OF MEASURES

(1) Length
- mm = millimetre
- cm = centimetre
- m = metre
- km = kilometre

(2) Area
- m^2 = square metre
- ha = hectare = $10^4 m^2$
- km^2 = square kilometre = $10^6 m^2$
- rai = 0.16 ha

(3) Volume
- lit, l = litre = 1,000 cm^3
- kl = kilolitre = 1 m^3
- m^3 = cubic metres
- MCM = million cubic metres = 1,000,000 m^3

(4) Weight
- mg = milligramme
- g = gramme
- kg = kilogramme
- t = ton = 1,000 kg
- qwt = quintal = 100 kg

(5) Time
- s = second
- min = minute
- h = hour
- d = day
- yr = year

(6) Money
- ฿ = Baht (unit of Thai currency US$ 1 = ฿ 22.9)
- $ = US dollar
- ¥ = Japanese Yen

(7) Electric Measures
- kV = kilovolt
- kW = kilowatt
- MW = megawatt = 1,000 kW
- kWh = kilowatt hour
- kVA = kilovolt Ampere

(8) Other Measures
- mmho = micromho = conductance
- ppm = parts per million
- ppb = parts per billion
- % = per cent
- LCD = litre per capita per day
- PS = 0.736 kW
- pH = scale for acidity
- ° = degree
- ' = minute
- " = second
- °C = degree centigrade
- 10^3 = thousand
- 10^6 = million
- 10^9 = billion (milliard)

(9) Derived Measures Based on the Same Symbols
- m^3/s = cubic metre per second
- ton/ha = ton per hectare
- $10^6 m^3/yr$, MCM/yr = million cubic meter per year

B. OTHER ABBREVIATIONS

- GDP = gross domestic product
- GRP = gross regional product
- El. = elevation
- HWS = high water surface
- SD = sanitary district
- DA = development area
- ESS = Eastern Seaboard Study
- FOB = free on board
- CIF = cost, insurance and freight
- WHO = World Health Organization

C. ABBREVIATION OF ORGANIZATIONS

MOAC	Ministry of Agriculture and Cooperatives
RID	Royal Irrigation Department
DOF	Department of Fisheries
LDD	Land Development Department
NESDB	National Economic and Social Development Board
NEB	National Environment Board
NSO	National Statistical Office
MOI	Ministry of Industry
DMR	Department of Mineral Resources
DIW	Department of Industrial Works
MOC	Ministry of Communications
HD	Harbor Deparment
DHW	Department of Highways
DOH	Department of Health
RTN	Royal Thai Navy
PWWA	Public Water Works Authority
MD	Meteorology Department
DOLA	Department of Local Administration
TAT	Toursim Authority of Thailand

D. LOCAL TERMS

Changwat	:	Province
Amphoe	:	District (Township)
Tambon	:	Township (Town)
Muban	:	Village
Muang	:	Administrative Center of Province
King Amphoe	:	Sub-district
Mae Nam	:	River
Khwae	:	Main tributary of a river
Huai	:	Stream, creek or small tributary
Khlong	:	Canal
Khao	:	Mountain

1. INTRODUCTION

1.1 Authority

The Feasibility Study on East Coast Water Resources Development Project, Phase II (the Study) was carried out in accordance with Implementation Arrangement, Technical Cooperation for Feasibility Study on East Coast Water Resources Development Project (Phase II), Khlong Luang, Khlong Yai and Khlong Thap Ma Dams (the Implementation Arrangement), which was concluded in the date of February 22, 1982 between Japan International Cooperation Agency (JICA), an executive agency of the Government of Japan and Royal Irrigation Department (RID), Ministry of Agriculture and Cooperatives, an executive agency of the Government of Kingdom of Thailand. The objective area of the Study (the Study Area) extends over Chon Buri and Rayong Provinces, excluding the Prasae river basin.

The JICA entrusted the Study to Nippon Koei Co., Ltd., associated with Nikken Consultant Inc. (the Study Team).

The Study Team conducted the field investigation and study during the period from July, 1982 to July, 1983 with the counterpart support provided by the Government of Kingdom of Thailand (the Government). This report is one of draft final report and presents the findings and recommendations on the Khlong Yai Dam Scheme.

1.2 Historical Background

Thailand is embarking in a new era of industrialization with enforcement of the Fifth National Economic and Social Development Plan (the Fifth National Plan), which covers a 5-year period from 1982 to 1986. The Fifth National Plan places a great emphasis on Eastern Seaboard Development as the keystone of industrialization. It involves not only industrial development but also urban development and associated infrastructural development. The agricultural development is also given high priority in the Fifth National Plan. So far as the Study Area is concerned, the agricultural development deserves particular attention.

It must be promoted positively in the backward area of the industrial development areas so as to create the balanced socio-economic situation throughout the Study Area.

In order to cope with the rapidly increasing water demand due to the above-mentioned development activities, the Government launched the East Coast Water Resources Development Project (the Phase I Study), objective of which was to conduct the feasibility study of Nong Pla Lai and Ban Bung Dams. The Phase I Study was carried out by JICA in compliance with request made by the Government during the period from February, 1981 to March, 1982.

The NESDB conducted Eastern Seaboard Study (the ESS) and issued an Interim Report in July, 1982. The report contains a comprehensive study relevant to Eastern Seaboard Development, including economic, infra- structural, social and urban development programme, implementation, finance and impact of development.

The Government further requested the Government of Japan to extend the technical cooperation on the Study in September, 1981. The Government of Japan decided to execute the technical cooperation and entrusted thereof to JICA. The JICA dispatched a Preliminary Survey Team to Thailand during the period from February 9 to 23, 1982 to finalize the technical cooperation and concluded the Implementation Arrangement with RID as aforementioned.

1.3 Scope of Study

The Study is to conduct the feasibility study on the water resources development of the Khlong Luang river and Rayong river, especially centering the construction of dams, namely Khlong Luang, Khlong Yai and Khlong Thap Ma dams. The Scope of Work contains two studying subjects as follows;

Part A: Study for the long-term water demand and supply balance in the Study Area.

Part B: Feasibility study for Khlong Luang, Khlong Yai and Khlong Thap Ma Dams.

For the purpose of the Study, target years have been set forth; 1991 as intermediate target year and 2001 as final target year.

The study for the long-term water demand and supply balance has been completed already during the field investigation period and "Study Report on Long-Term Water Supply Plan" was issued in January, 1983. The report points out clearly the significance of development of Khlong Yai Dam Scheme (the Scheme). The Scheme is distinguished as multiple-purpose areal-development project, since it is designed as an element in regional plan. The feasibility study of the Scheme deals with;

(1) Khlong Yai multiple-purpose dam development,

(2) Irrigation and agricultural development,

(3) Raw water conveyance system development, and

(4) Flood mitigation plan

2. BACKGROUND

2.1 Socio-Economy of Thailand

2.1.1 Land and Population

The territory of Thailand is approximately 514 x 10^3 km^2, being located between $5^o20'$ and $20^o40'$ north in latitude and between $97^o20'$ and $105^o40'$ east in longitude. Administratively the country is divided into 72 provinces. Each province is further divided into more or less 10 districts. Each district is further subsegmented into several townships which are composed of a number of villages. Map of Thailand is shown in Fig. 1.

Thailand lies in tropical monsoon zone and is blessed with fairly rich land and water resources. Approximately 177 x 10^3 km^2, corresponding to 34 % of the nation's land, are used for agricultural purpose, of which about 118 km^2 are paddy fields.

The national population was 44.3 x 10^6 in 1980, of which 4.7 x 10^6 people reside in Bangkok Metoropolis. The population density in 1980 was 86.3 persons per km^2 on the average, ranging from 52.7 in North Region to 137.5 in Central Region. The population growth was 2.6 % per annum during a 10-year period from 1970 to 1980.

2.1.2 Economic Performance

The economy of Thailand has achieved a continuous expansion, through its five-year national development plans, of which the period is 1962 - 1966 for the first plan, 1967 - 1971 for the second plan, 1972 - 1976 for the third plan and 1977 - 1981 for the fourth plan, respectively. The GDP increased from ฿ 140 x 10^9 in 1971 to ฿ 315 x 10^9 in 1981 at 1972 constant price, or from B 3,6Ø2 per capita to B 6,6Ø6 per capita. The average growth rate was 9.5 % per annum in 1971 - 1976 and 7.4 % per annum in 1977 - 1981.

The 1981 GDP is composed of ฿ 151 x 10^9 in service sector, ฿ 88 x 10^9 in manufacturing sector and ฿ 76 x 10^9 in agricultural sector. The share of the manufacturing sector increased from 16 % in 1971 to 21 % in 1981, while that of the agricultural sector declined from 28 % to 24 %.

The export of goods and services increased sharply from ฿ 17 x 10^9 in 1971 to B 15฿ x 10^9 in 1981, while the import of goods and services also increased from B 27 x 10^9 in 1971 to B 217 x 10^9 in 1981. The most dominant export and import commodities are rice and petroleum, respectively. Rice export was 3,036 x 10^3 tons in 1981 and earned ฿ 26 x 10^9, corresponding to 17 % of the total export value. The import of petroleum and lubricant amounted to B 6฿ x 10^9 in 1981, which nearly coincides with the deficit in the foreign trade.

The socio-economy of Thailand is reported in more detail in Sectoral Report I, Socio-Economy.

2.2 The Fifth National Plan

The Government issued in October, 1981, the Fifth National Plan, which was established reflecting the performance in the preceding national plans during the last two decades. The Fifth National Plan contemplates to accomplish the following national policy objectives;

(1) To restore the nation's economic and financial stability by mobilizing more saving and building up the national and economic discipline in both the public and private sectors.

(2) To adjust the economic structure and to improve the economic efficiency in order to magnify the economic activities in the rural area, to earn more foreign exchange with expansion of export and to be consistent with the world's economic changes.

(3) To develop the social structure and to improve the social services such as education, health, justice and other basic needs in the rural area.

(4) To alleviate poverty in backward area.

(5) To coordinate consistently economic development activities with the national security management.

The economic target of the Fifth National Plan is presented in Table 1 in comparison with that of the Fourth National Plan.

More detailed explanation on the Fifth National Plan is presented in Sectoral Report I, Socio-Economy.

2.3 Eastern Seaboard Development

The Fifth National Plan sets forth the following policy measures with respect to industrial activity:

(1) To switch from import substitution to exports.
(2) To decentralize the industrial activities to the provincial areas.
(3) To develop the basic industry, practically based on natural gas.
(4) To develop labour intensive industry and technology in export industry.

The Fifth National Plan sets forth the following targets for the industrial activities:

	Description	Average Growth Rate (%/yr)
(1)	Manufacturing output	7.6
	Export industry	15.0
	Domestic consumption	5 - 6
(2)	Employment increase	7.6
(3)	Consumption of petroleum product (max. level)	4.0

The Eastern Seaboard Development will make a great contribution to the national policy objectives. Firstly, it will spearhead to change the industrial structure from import substitution to exports, based on local resources, particularly on a natural gas. Secondly it will become a major employment generator in North and East Regions. Thirdly, in the long term, it will serve decentralization of economic and industrial activities from Central Region.

The ESS proposes seven strategic development areas in the eastern seaboard; Chon Buri, Si Racha-Laem Chabang, Pattaya, Sattahip, Map Ta Phut-Rayong, Chachoengsao and Ban Phe. Out of these, Chachoengsao and Ban Phe are located outside the Study Area. Fig. 2 shows the map of the Study Area, including the development areas.

Six industrial development zones have been designated by the ESS as tabulated hereunder together with development area and plan.

Proposed Zone	Area (ha)	Proposed Industrial Development
Chon Buri	160	Urban service industries
Laem Chabang	480	Export processing and light industry
Sattahip	40	Ship repairs and services and transhipment
Map Ta Phut	800	Heavy industry, polluting industry and construction materials
Rayong	80	Agro-industry
Chachoengsao	80	Agro-industry

The development of infrastructures is an integral part of industrialization. The infrastructure development plan has also been worked out by the ESS as presented in Table 2.

The Eastern Seaboard Development will certainly create additional employments and induce migrants from the outside of the Eastern Seaboard.

The additional employments and induced population have been projected to be 130,200 and 201,550, respectively, by the ESS for a 20-year period from 1981 to 2001. The ESS predicts that approximately 71 % of the additional employment occurs in three development areas, Si Racha-Laem Chabang, Pattaya and Rayong-Map Ta Phut.

2.4 Agricultural Development

The agriculture still plays an important role in the economy of Thailand. It sustains the self-sufficiency of staple food and the employment absorption. It also makes a great contribution to foreign trade; share of agricultural products accounts for 52 % of the total export value in 1980. Major crops are rice, rubber, maize and cassava.

The agricultural development during the last two decades was characterized by diversification of crops and expansion of cultivation area. During a 10-year period from 1972 to 1981, planted areas were expanded year after year with a considerably high rate; 15.3 % per annum for upland crops, 40.0 % per annum for oil crops, 16.2 % per annum for perennial crops and 3.4 % per annum for paddy. The increase in production was mainly resulted from such rapid expansion of planted areas. However, an increase in crop yield remained as low as 2.0 % per annum on an overall average during the Fourth National Plan.

The Fifth National Plan puts forward the following targets and supporting policy measures, in order to achieve the short-run objectives of a rapid economic recovery and a greater degree of economic stability:

(1) To attain the target of about 7 % increase in GDP, the value in agricultural sector is projected as,

(a) overall target: annual increase by 4.5%
(b) crop production: annual increase by 4.7%
(c) livestock production: annual increase by 4.2%
(d) fisheries production: annual increase by 5.4%
(e) forestry production : annual increase by 0.3%.

(2) More emphasis will be placed on the conservation of forest and watershed. The forests and national park, totalling about 10.4 x 10^6 ha, should carefully be conserved by proper rehabilitation works and the reafforestation should be implemented at a rate of about 48,000 ha per annum. Hence, expansion of farmland will be limited over the 5-year period. In this context, the strategy of agricultural development has to emphasize structural improvement within the sector.

(3) In order to raise productivity of agriculture, the priority is given to development of irrigation system and expansion of on-farm facilities as well as water resources development. An emphasis will be placed on soil improvement and strengthening the agricultural support services.

Sectoral Report I, Socio-Economy presents in more detail the issues and policy measures of agricultural development in Thailand.

2.5 Pipe-Water Supply Services

The pipe-water supply services are mainly administerd by MWWA and PWWA. The MWWA is responsible solely for Bangkok Metropolis and the PWWA assumes a direct responsibility for 117 townships, 707 sanitary districts and 2,000 villages throughout the country.

The PWWA has been endeavouring to expand the pipe-water supply services along its two basic programmes; large scale water supply programme and rural water supply programme. The former focuses on the municipalities and sanitary districts with more than 5,000 population and is executed under full responsibility of PWWA. The latter is promoted for sanitary districts and rural communities with 1,500 - 5,000 population and is mainly implemented by the local administrative authorities under financial and technical assistance from PWWA, OARD and DMR.

According to the information obtained from PWWA, the pipe-water supply situation in 1982 are as follows.

Water Supply Programme	Nos. of Supply System (nos)	Water Supply Capacity (10^3 m^3/day)	Served Population (10^6)
Large Scale	169	849	3.7
Rural	663	378	2.1
Total	832	1,227	5.8

As is clear from the above table, the pipe-water served population is only 13 % of the national population. The water supply per capita is 210 l/day on the average.

In line with the policy measures set forth in the Fifth National Plan, the PWWA established its Five-Year Plan. It stipulates the following basic objectives;

(1) The water supply capacity in the urban area will be augmented from 849 x 10^3 m^3 per day in 1981 to 1,414 x 10^3 m^3 per day in 1986. Pipe-water supply population will be 4.4 x 10^6 m^3 in 1986.

(2) The rural water supply programme will also be emphasized in order to alleviate a gap in standard of living between the urban area and the rural area. The objective is to develop and expand the water supply system for 150 communities and to construct the new water supply system for 250 communities. These will bring about an additional water supply capacity of 35 x 10^6 m^3 per annum.

According to the Five-Year Plan of PWWA, the total investment cost is estimated at ฿ 7,665 x 10^6, comprising ฿ 1,577 x 10^6 for the rural water supply programme and ฿ 6,088 x 10^6 for the large scale water supply programme.

2.6 Long-Term Water Supply Plan

2.6.1 General

In order to meet the rapidly increasing water demand due to industrial and urban development and agricultural development, long-term water supply plan has been worked out for the Study Area as one of the objectives of the present study. The proposed development plan is reported in Study Report on Long-Term Water Supply Plan. Herein contained are the outline of the plan.

The long-term water supply plan is, in principle, formulated aiming at satisfying all the water demands in the Study Area in Target Year 2001. The Target Year is determined in due consideration of periods of the national five-year development plans and development period of Eastern Seaboard Development.

Pursuant to principle of water resources management, the Study Area is basically divided into 10 zones as shown in Fig. 2. Each zone consists of a single river basin or a couple of river basins. The water supply plan over the Study Area is formulated primarily based on the result of water demand and supply balance of the respective zone.

It should, however, be kept in mind that the water supply plan presented in this report is a little different from that originally proposed in the Study Report on Long-Term Water Supply or other relevant sectoral reports. The water diversion from New Ban Bung dam, which was an integral part of the original plan, has been cancelled in due consideration of the RID's policy amendment. In the revised plan, corresponding amount of water is supplied from the Bang Phra dam by means of reduction of a rate of river maintenance flow. The reduction of the river maintenance flow is judged allowable for the following reasons.

(1) The Bang Phra dam is located only at 2.5 km distance to estuary. There is neither intake nor water user inbetween the dam and the river mouth.

(2) The Bang Phra dam has never been releasing regularly the water to the downstream for unspecified use, according to its operation record. The unspecified release is rarely possible, since the Bang Phra reservoir is 2.4 times as much as the average annual inflow.

(3) Under the present reservoir operation practices, any particular adverse effect on aquatic ecology has not been identified.

(4) The river maintenance flow is still sustained at a rate of 1.1×10^6 m^3 per year. The aquatic ecology and riparian lands would, therefore, be preserved at the same status as the present.

The water demand and supply balance and alignment of raw water conveyance systems have been adjusted accordingly in this report.

2.6.2 Water Demand

The water demand comprises the domestic use, industrial use and irrigation use. In addition, a concept of river maintenance flow is introduced. The projection of the water demand is discussed in detail in Sectoral Report IV, Domestic and Industrial Water Demand, and III, Irrigation Development Plan.

(1) Domestic Water Demand

In compliance with the pipe-water supply programme set forth in the Five-Year Plan of PWWA, each zone is classified into urban area and rural area. The urban area is defined as municipality and sanitary district with more than 5,000 population by Target Year 2001 and is further classified into development area and non-development area in accordance with Eastern Seaboard Development Plan.

The domestic water demand is projected based on the projected population, water consumption per capita and service factor for every 5-year period, namely, 1986, 1991, 1996 and 2001. The projected population and domestic water demand are shown in Table 3.

(2) Industrial Water Demand

The industrial water demand has been projected by ESS in line with the industrial development plan described in the preceding Section 2.3. The industrial water demand projected by ESS accrues only from the development areas.

Presently several enterprises are extracting groundwater or water from reservoirs by their own facilities. For enterprises located outside the development area, the same quantity of water as being consumed needs to be guaranteed. This water supply was carefully investigated and is added to the industrial water demand projected by ESS to produce the real industrial water demand. The estimated industrial water demand is presented in Table 4.

(3) Irrigation Water Demand

In the Study Area, there are two major irrigation areas at present. They are Bang Phra irrigation area with a net irrigation area of 1,120 ha in Zone 2 and Ban Khai irrigation area with 4,800 ha in Zone 10.

In addition, three irrigation development schemes are envisaged to be newly realized in association with development plan of Khlong Luang, Khlong Yai and Khlong Thap Ma dams. The irrigation area of the respective scheme is tentatively determined based on the preliminary water balance study. The development programme was set up in conjunction with water resources development requirement for the domestic and industrial water supply.

The irrigation water requirement is estimated based on the provisional cropping pattern with 150 % of cropping intensity and approximated irrigation area. The irrigation area and water requirement applied for water balance study are given below,

Irrigation Scheme	Irrigation Area (ha)	Irrigation Water Requirement (10^6 m^3/yr)			
		1986	1991	1996	2001
Khlong Luang	4,700	0	60.1	60.1	60.1
Bang Phra	1,120	15.4	15.4	15.4	15.4
Ban Khai	4,800	65.8	65.8	65.8	65.8
Ban Khai Extension	5,400	75.1	75.1	75.1	75.1
Thap Ma	2,200	0	0	30.6	30.6
Total	18,220	156.3	216.4	247.0	247.0

It should be noted that the above agricultural development plan is provisional. They will finally be determined through optimization study of the land and water resources development of the respective development shceme.

(4) River Maintenance Flow

The reduction of river flow due to intensified water use will result in adverse effect to various water users, if it exceeds a certain amount. It is therefore proposed to introduce the concept of the river maintenance flow. The river maintenance flow is the minimum discharge which is able to maintain water depth, flow velocity, water quality, channel stability, aquatic ecosystem and scenery to the extent necessary for navigation, fish catch, operation and maintenance of intakes, maintenance of river facilities, sea water repulsion, prevention of estuary clogging, conservation of groundwater, preservation of riparian land and people's amenity.

In the Study, in principle, the rate of the river maintenance flow is tentatively assessed to be equal to 90 % dependable monthly run-off at balance point. The river maintenance flow thus assessed is shown in Table 5.

(5) Overall Water Demand

The overall water demand of the respective zone is presented in Tables 6 through 9. The followings are the overall water demand expressed in terms of source water demand for the whole Study Area.

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

Water Demand	1986	1991	1996	2001
Domestic	33.1	45.4	66.7	91.5
Industrial	56.6	71.2	77.4	88.5
Irrigation	156.3	216.4	247.0	247.0
River maintenance flow	21.0	21.0	31.5	31.5
Total	267.0	354.0	422.6	458.5

2.6.3 Water Resources Development Potentials

As varified in the succeeding sub-section 2.6.4, under the present water resources development conditions, water shortage of about 57 x 10^6 m^3 is foreseen to occur in Target Year 2001. A new water resources development plan is indispensable to satisfy the whole water demand for the successful implementation of Eastern Seaboard Development and agricultural development.

The water resources development potentials in the Study Area are studied primarily based on the data and information so far collected by RID as reported in detail in Sectoral Report XI, Water Resources Engineering.

As listed hereunder, there are 8 dams either existing or under construction or under planning as shown in Fig. 2 and Table 10.

Out of dams in operation, both the Phluta Luang and Khlong Bang Phai dams are used exclusively for Sattahip Naval Base. Thus they are not taken into consideration in the formulation of the long-term water supply plan.

Six dams, Bang Phra, Map Prachan, Dok Krai, Nong Kho, New Ban Bung and Nong Pla Lai dams have the active storage capacity of 339.7 x 10^6 m^3 in total and produce the net regulated outflow of 227.5 x 10^6 m^3 per year in such drought year as 1979.

There have been identified 9 potential damsites, including Khlong Luang, Khlong Thap Ma and Khlong Yai damsites, in the Study Area. Out of these, five damsites are located in small rivers in the coastal area as shown in Fig. 2. It is foreseeable that the anticipated water shortage will be met by development of several dams among the potential damsites.

Water supply capacity of the respective potential damsite is obtained based on storage-draft relationships of Khlong Luang, Dok Krai, Nong Pla Lai and Khlong Yai damsites, where streamflow observation records are available for a 14-year period from April, 1968 to March, 1982. The said storage-draft relationships are shown in Fig. 3. A relationship between storage ratio and unit development cost of water is then developed for the respective potential damsite as shown in Fig. 4.

The relationships shown in Fig. 4 expresses two elements. Firstly, Khlong Luang, Khlong Yai and Khlong Thap Ma damsites are incomparably superior to the other potential damsites in terms of unit development cost of water. Secondly development scale is the most economical within a range of 80 - 100 % in terms of storage ratio. For the purpose of water balance study, development scale is tentatively determined to be 100 % in terms of the storage ratio for Khlong Luang, Khlong Yai and Khlong Thap Ma damsites and 80 % for the remaining 6 pontential damsites. Table 11 shows the salient features and water supply capacity of the respective potential dams at the pre-determined development scale.

2.6.4 Water Balance

The water balance study was performed in order to determine the water resources development requirement as reported in detail in Sectoral Report X, Water Balance Study.

The representative river is selected in each zone, in which a balance point is located for the water balance study. The balance point is, in principle, set up at the lowest intake site. The representative river and balance point of the respective zone are as shown in Table 5.

The water demand and supply balance was calculated zone by zone at intervals of 10-day period during a 12-month period from May, 1979 to April, 1980, which is the driest year among a 14-year period from 1968 to 1981.

At first water withdrawal was computed as the water demand deducted by the available local water resources. The water withdrawal means the net reduction in river flow which is required to meet the water demand. The water deficit is then calculated as the water withdrawal less the natural run-off at the balance point under the following presumptions.

(a) The Dok Krai Pipeline Project fully supplies the water withdrawals in Zones 7 through 9.

(b) As to Zone 2, natural run-off of the representative river is negligibly small compared to the domestic and industrial water demand. Therefore the whole domestic and industrial water demand is determined to be met by inter-zone water diversion.

The water demand and supply balance was initially calculated under the present water resources development condition. The Nong Kho and Nong Pla Lai dams are treated as existing one. The result is given hereunder.

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

Year	Water Demand	Water Withdrawal	Water Deficit	Supply by Dams	Balance
1986	267.0	264.9	214.0	218.0	-4.0
1991	354.0	351.9	283.1	218.0	+65.1
1996	422.6	420.5	335.3	218.0	+117.3
2001	458.5	456.4	367.5	218.0	+149.5

As shown in the above, the water supply runs short as a whole. The water demand and supply balance situation varies largely from zone to zone, depending on the magnitude of water demand and the availability of water resources. The integrated development of water resources and inter-zone water diversion system is ascertained to be most appropriate measure to overcome the shortage of water supply.

A set of four water supply alternatives were drawn up for Target Year 2001 to ascertain the most optimal plan. The water demand and supply balance was further computed for the respective water supply alternative. The water demand and supply balance under the proposed water supply plan is given in Tables 6 to 9 and is summarized below.

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

Year	Water Demand	Water Withdrawal	Water Deficit	Supply by Dams	Balance
1986	267.0	264.9	214.0	227.5	-13.5
1991	354.0	351.9	306.2	369.7	-63.5
1996	422.6	420.5	371.5	411.0	-39.5
2001	458.5	456.4	404.0	411.0	-7.0

The water balances for the intermediate years are calculated referring to the development sequence of the proposed water supply plan.

2.6.5 Proposed Long-Term Water Supply Plan

All the water supply alternatives were examined in detail from the viewpoint of investment requirement, technical soundness and social problems. As the results, the water supply plan shown in Figs. 5 to 8 is determined to be most promissing plan. The fundamentals of the proposed water supply plan for Target Year 2001 are as follows;

(1) Development of water resources facilities

Khlong Luang, New Ban Bung, Khlong Thap Ma and Khlong Yai dams

(2) Development of water conveyance systems

Khlong Luang, Ban Bung, Nong Kho, Nong Pla Lai, Bang Lamung, Huai Yai, Dok Krai and Ban Khai systems

(3) Water diversion from the inland area to the coastal area

Khlong Luang river basin to Chon Buri Pattaya area: 11.0 x 10^6 m^3/yr
Rayong river basin to Chon Buri-Pattaya area: 31.3 x 10^6 m^3/yr
Rayong river basin to Sattahip-Map Ta Phut area: 54.8 x 10^6 m^3/yr.

Water demand and supply balance until the target year 2001 is shown in Fig. 9.

Investment requirement for the proposed water supply plan is roughly estimated to be ฿ 8,827 x 10^6, consisting of ฿ 3,602 x 10^6 for water resources development, ฿ 4,205 x 10^6 for water conveyance system and ฿ 1,020 x 10^6 for irrigation development.

3. KHLONG YAI RIVER BASIN

3.1 Natural Conditions

3.1.1 Location and Topography

The Khlong Yai Dam Scheme is one of a series of water resources development projects in the Rayong river basin.

The Rayong river is situated in the eastern part of the Study Area and has a drainage area of approximately 1,730 km^2. The proposed Khlong Yai damsite is located in the Khlong Yai river, a tributary of the Rayong river.

The Khlong Yai river takes its origin in Mt. Khao Liang Khwai (El. 179 m) and flows down almost southward. It joins with the main stream of the Rayong river at about 10 km downstream from the proposed damsite. A drainage area of the Khlong Yai river is 218 km^2 at the proposed damsite.

The Rayong river embraces a vast alluvial plain in the downstream from the confluence of the Khlong Yai and Rayong rivers. According to the land use, soils and land capability assessments, there is approximately 14,900 ha of lands suitable for cultivation of paddy in the Rayong river basin. Out of this 4,800 ha has been irrigated under Ban Khai Irrigation Project by streamflow regulated by Dok Krai reservoir and another 2,400 ha lies in the Khlong Thap Ma river basin, a tributary of the Rayong river. The remaining 7,700 ha of lands is named Ban Khai Extension Area and extends over outside of the Ban Khai Irrigation Project area on the left bank of the Rayong river. The area is, at present, used for cultivation of paddy and upland crops such as cassava and sugarcane without irrigation.

The alluvial plains have a slope of more or less one per cent and are prone to inundation to a large extent. The ground height is for the most parts lower than El. 100.0 m.

3.1.2 Climate

Details of climate over the Study Area are reported in Sectoral Report VII, Meteorology and Hydrology.

The climate over the Rayong river basin is tropical and monsoonal. There are two distinct seasons in a year. Dry season with the north-east monsoon lasts from November to April, while the wet season with the southwest monsoon extends from May to October. The climatological data at Chon Buri, Sattahip and Ban Nong Mapring stations are presented in Table 12.

Air temperature varies only slightly from the annual average of 29°C. The average annual basin rainfall is approximately 1,300 mm, of which more than 80 % occurs during the wet season. The relative humidity is almost constant throughout the year, 93 % on the average.

3.1.3 Hydrology

The stream flow of the Khlong Yai river has been recorded at Ban Pak Phraek stream gauge, which is located at approximately 2 km down-stream from the proposed Khlong Yai damsite. The drainage area of the Khlong Yai river is 161 km^2 at the stream gauge. The catchment area of the proposed damsite is 218 km^2, including the Khlong Nong Ai Run river and Khlong Ma Mui river basins.

The run-offs at the proposed damsite were estimated at 10-day intervals for a 14-year period from April, 1968 to March, 1982. Table 13 shows the monthly mean run-offs at the damsite. The average annual run-off is 2.76 m^3/s, ranging from 0.85 m^3/s in 1979 to 3.52 m^3/s in 1969.

The flood analysis was made by means of unit hydrograph method. The synthesized probable floods at the damsite are as follows:

Return Period (year)	Peak Discharge (m^3/s)
10	718
50	932
100	1,040
500	1,230
Probable Max.	1,950

The sediment yield from the basin area is evaluated to be 300 $m^3/km^2/year$.

The run-off and flood analyses and sediment transport are discussed in detail in Sectoral Report VII, Meteorology and Hydrology.

3.1.4 Groundwater

The reconnaissance survey on groundwater resources was carried out as explained in Sectoral Report IX, Groundwater Resources.

Local phreatic aquifers are found in flood plains, which consists of silty sand, sandy clay and rare gravelly sand layers. The aquifers are recharged by rivers and paddy fields. Remarkable descent of groundwater level in the aquifers takes place during the dry season. The aquifers are encountered with salt water intrusion. The salt water is detected in Ban Khai, about 13 km upstream from the estuary.

Regional confined or unconfined aquifers are ascertained to be existent to a very small extent, due to high clay content and resultant low permeability and also low storage capacity in the terrace deposits. The groundwater in the terrace deposits appears to be recharged by vertical infiltration of rainfalls.

According to the inventory and sampling surveys, approximately 80 % of rural population are dependent on shallow dug-wells for their domestic water. The annual groundwater abstraction through the shallow dug-wells are roughly estimated at 4.1×10^6 m^3, all of which is presumed to be domestic use. There are 5 tube-wells in the Rayong river basin at present. They produce 0.2×10^6 m^3 of groundwater annually, of which 40 % are exclusive use for manufacturing.

The groundwater development potential is concluded to be quite low owing to the salt water intrusion deep into the alluvial plains and poor hydraulic characteristics of the terrace deposits.

3.1.5 Geology

The Rayong river basin, including the Khlong Yai river basin, is situated in the geologic province of the pre-Cambrian metamorphic rocks. Gneiss and gneissose granites are cropped out around the eastern divide of the basin, whereas the Triassic intrusive granites are widely developed on the western side of the basin. Small patches of crystalline schists and phyllites are located in the Khlong Thap Ma valley.

The terrace and collunial deposits of Quaternary period are widespread in the basin, covering the metamorphic bedrocks. The river alluvial deposits and flood deposits cover the central parts of the basin, along the river valley.

The Rayong river basin is generally characterized by topography of peneplain in the late stage of erosion. The terrain is flattened by erosion into low undulating hills and wide open valleys. Some isolated hills with rather steep slopes remain only at places. The bedrocks crop out almost solely on those isolated hills.

The Sectoral Report VIII, Geology displays in more detail the geological condition of the Rayong river basin and proposed damsites.

3.1.6 Soils

Soils and land capability explained herein are for the whole irrigable areas in the Rayong river basin, consisting of Ban Khai existing area (4,800 ha) and Ban Khai Extension Area (7,700 ha). Figs. 10 and 11 shows the detailed soil map and land capability map, respectively.

Major soil groups in the area are the soils of alluvium and soils of transported materials and residuum from granite and geneiss. They are classified into a number of soil series by LDD. Table 14 and 15 present the distribution of soils by soil series for Ban Khai Extension Area and Ban Khai existing area. The predominant soil series are alluvial soils poorly drained complexes (AC-pd) series, Khok Khian (KO) series and Huai Pong (Hp) series. The generalized brief descriptions on these soil series are as follows.

Alluvial Soils, Poorly Drained Complexes (AC-pd): These soils are typical alluvial soils on the low-lying alluvial plain developed along the Rayong river and its tributaries. These soils are characterized by gleic horizon and/or layer. The soils have, in general, fine texture and strong acid reaction. Inherent fertility of the soil is low. The drainage conditions are externally and internally poor, due to flat or depressed topography and fine soil texture.

Khok Khian Series (KO): Khok Khian series are typical wet soils characterized by a thick, mottled, gray argillic horizon. They are formed from relatively old alluvium and occur on the lower parts of terraces. Relief is flat to almost flat. The soils have medium texture, deep effective soil depth and mottled profile. PH values show very strong acid to strong acid. The lands are poorly drained with slow surface runoff. Khok Khian series are correlated with Low Humic Gley Soils (National) or Typic Paleaquults (USDA).

Huai Pong Series (Hp): Huai Pong series are light coloured and freely drained soils which have developed on the low and middle terraces. They are derived from sandy alluvium which consists of the materials transported granite and gneiss. The lands covered with these soils mainly extend over the hilly zone. The soils are deep, slightly acid to moderately alkaline. Drainage condition is well to somewhat poor.

The land capability is referred to Land Capability Map published by LDD and is presented in Fig. 11. According to the LDD's classification, land capability is broadly divided into two categories, namely, "Suitable" and "Not Suitable". A category of "Suitable" is further sub-divided into (1) Class I, highly suitable, (2) Class II, moderately suitable, (3) Class III, suitable and (4) Class IV, marginally suitable. Nearly 65 % of the irrigable area is ascertained to be Class II.

3.2 Administrative Division and Population

The Rayong river basin falls in with Rayong Province and includes 29 townships. Major town/city is Rayong and Ban Khai. The administrative divisions are shown in Fig. 12.

The total population in the basin is 169,400 in 1981, of which 75 % resides in rural area. The urban population is 42,500 in 1981; 37,300 in Rayong and 5,200 in Ban Khai.

3.3 Infrastructure

3.3.1 Transportation

The Rayong river basin is served with well-developed road network systems. One primary, one inter-regional and one secondary national highways and one provincial highway run through the basin as shown in Fig. 12.

National highway Route 3 runs along the southern coastal area, connecting Rayong with Sattahip and then goes up to the north passing though Pattaya, Laem Chabang, Chon Buri and finally connects to Bangkok. Rayong is connected with Ban Lamung located on the eastern coastal area by Route 36 which runs in the inland area northwesternwards to Ban Lamung with the distance of around 55 km. Rayong is also connected with Chon Buri by Route 3138 which goes through inland hilly area toward the north passing through Ban Khai with the approximate distance of 100 km.

Rural roads are spread over the basin area. Most of the rural roads are laterite-paved with two lanes.

3.3.2 Pipe-water Supply

There are one large scale water works and two rural water works in the Rayong river basin as listed below.

Types	Water Works	Plant Capacity (m^3/day)
Large Scale	Rayong	7,680
Rural	Ban Khai	480
	Pulak Daeng	240
	Total	8,400

The pipe-water served population is roughly estimated at 24.3×10^3 in 1981, comprising 20.3×10^3 under large scale water work and 4.0×10^3 under rural water works. The pipe-water service factor is, therefore, approximately 15 %. Majority of people rely on groundwater and water vender for their domestic use. Per capita water supply is estimated to be about 220 l/day for 1981.

The Sectoral Report XII, Water Conveyance Engineering compiles more information and data on the pipe-water supply.

3.3.3 Irrigation and Drainage

The RID has been endeavoring to develop the irrigation systems and to improve the drainage condition. The following irrigation and drainage projects have been realized by RID in the Rayong river basin, up to date.

(1) Ban Khai Irrigation Project

Ban Khai Irrigation Project was completed in 1960 by RID. Its area extends along the both banks of the Rayong river with a net irrigation area of 4,800 ha. It is provided with two main canals with the length of 11.4 km and 12.7 km, respectively.

The project area is served by regulated flow by Dok Krai reservoir. The regulated flow is diverted to the irrigation area at the Ban Khai diversion weir located 4 km upstream of the northern tip of the irrigation area. Lateral canals and the farm ditches have been constructed in 50% of the whole area and the remaing areas are irrigated by plot-to-plot system. There is no systematic drainage system and excess irrigation water is evacuated mainly by primitive drain ditches constructed by farmers themselves.

(2) Bung Ton Chan Irrigation Project

The project area of 1,280 ha is located immediately east of the left main canal of the Ban Khai Irrigation Project. It is served by a run-of-river irrigation system. The unregulated flow of the Khlong Hin Dat river is diverted at the diversion weir. A very primitive feeder canal have been provided and distribution is made by plot-to-plot system.

(3) Khlong Yai Da Irrigation Project

The project area is located about 10 km east of Rayong and its area of 320 ha is being irrigated by unregulated flow of the

Khlong Yai Dai river by the run-of-river system. Two main canals with the length of 100 m were constructed by RID in 1977.

(4) Rayong Flood Protection Project

The project was implemented aiming at protecting the paddy fields and Rayong from inundation. Three diversion channels with regulating gates were constructed in 1962 by RID.

The locations of the above-mentioned projects are shown in Fig. 13. The Sectoral Report III, Irrigation Development Plan presents more detailed descriptions.

3.3.4 Dams

The surface water resources of the Rayong river basin have been developed partly. There is one existing dam, Dok Krai Dam and one dam under planning, Nong Pla Lai Dam in the basin. Salient features of the two dams are presented in Table 10.

Dok Krai dam was constructed in 1975. Its reservoir has a gross storage capacity of 70.8 x 10^6 m^3. The Dok Krai dam has altered its function from the irrigation water supply to the domestic and industrial water supply. Nong Plan Lai dam is primarily planned to inherit Dok Krai dam's function and to further expand the irrigation area in the Rayong river basin. Its reservoir has a gross storage capacity of 200.7 x 10^6 m^3.

3.4 Regional Agriculture

3.4.1 Farm Population and Households

Agriculture over the Ban Khai existing area and Ban Khai Extension Area is described herein. The Sectoral Report II, Agricultural Development Plan describes the regional agriculture over the Rayong river basin.

The population and number of household in the Ban Khai existing irrigation area are 9,300 and 1,840, respectively and in the Ban Khai Extension Area 15,610 and 2,730 respectively, according to the statistic data obtained from Agricultural Extension Office in Rayong. The average family size is 5.1 for the existing area and 5.7 for the extention area.

The number of the farm household and farm population are estimated at 1,625 and 8,300 respectively for the existing area and 2,280 and 13,000 respectively for the extention area. Potential farm labor force is presumed to be 2 to 3 persons per farm household.

3.4.2 Land Holding and Land Tenure

The average land holding size is 3.3 ha for the existing area and 3.9 ha for the extension area. According to the Agricultural Census Report, 1978, the households with land holding size of less than 1.0 ha account for 6.8 % of the total in Rayong Province. The households of 1.0 to 4.0 ha are most predominant, occupying about 48 % of the total.

Approximately 90 % of farms are owner operator and 4 % tenant in Rayong Province, according to the above-said report. Approximately 91 % of the entire farm holding lands is occupied by the owner operators.

3.4.3 Land Use

The land use in the proposed irrigation area was ascertained by land use map in a scale of 1 to 250,000 and field survey. The land use map is shown in Fig. 14.

In the Ban Khai existing irrigation area rice is cultivated in 4,640 ha in the wet season, of which 60 % is irrigated. Rice is also grown in the dry season in about 1,900 ha under irrigation. Some upland crops and vegetables are cultivated during the dry season.

In the Ban Khai Extention Area, rice is cultivated in 6,300 ha or 70 % of the total area under rainfed condition in the wet season. Upland crops and perennial crops are cultivated in 1,900 ha and 580 ha respectively.

3.4.4 Cropping Pattern

The cropping patterns prevailing over the extension and existing areas are shown in Figs. 15 and 16.

Wet season rice is planted from the beginning of July to the middle of August and is harvested from the beginning of November to the middle of December. Dry season rice is transplanted during a period from the middle of January to the end of February and is harvested during the period from the middle of April to the end of May.

Cassava is cultivated in rather limited area. Its planting extends over two and half months from the middle of October to the end of December and harvesting lasts also two and half months from the middle of August to the end of October.

Sugarcane is cultivated in the limited area. Planting of plant cane takes place during the period from the middle of December to the end of April. It is harvested during the period from the middle of December to the end of April.

The cropping intensity is 100 % in the extension area and 160 % in the existing area under the present condition.

3.4.5 Farming Practices

Various varieties of rice are cultivated in the existing and extension areas, all of which are of non-glutinous type. The high yielding varieties have been spread over about 40 % of paddy cultivation area. Applications of fertilizers and agro-chemicals are rarely practiced. Transplanting and harvesting are done still manually. Harvested paddy is threshed mainly by means of trampling of buffaloes.

Cassava is mainly grown for industrial use. Native variety designated as "Rayong" is predominantly cultivated. Fertilizing is generally not carried out. Planting is made manually at a rate of one set per square meter; 10,000 sets per ha.

Sugarcane is planted with a spacing of 1.3 m by 0.3 m, 25,600 sets per ha. Earthing is done two times during the growing period; the first is one to one and a half month after planting and the second two to three months after planting. Ratooning is commonly practiced. Fertilizers are applied at a rate of 310 kg per ha of compound fertilizer (N:15 - P:15 - K:15).

3.4.6 Crop Yield and Production

Yields of crops remain low because of lack of enough on-farm facilities and irrigation water supply and less supply of agricultural requisite. Productions of crops vary from year to year, characterized by climatological conditions. Crop yield and production for 1981 are given below.

Description	Yield (t/ha)		Production (t)	
	Existing Area	Extention Area	Existing Area	Extention Area
Rice, wet season				
- Local varieties	1.8	1.8	5,000	6,790
- High yielding varieties	3.2	2.3	5,950	5,840
Rice, dry season				
- High yielding varieties	3.6	-	6,840	-
Groundnuts	-	1.3	-	30
Cassava	16.0	16.0	15,840	24,960
Sugarcane	-	43.0	-	13,760
Fruits	-	5.0	-	2,500
Vegetable	5.0	-	1,600	-

3.5 Flood Problems

3.5.1 Flood Characteristics

The Rayong river flows through broad alluvial plains subject to frequent overflow, in a reach between the proposed damsite and the estuary. The reach is characterized by flat bed slopes, meandering channels of very small flow capacity, and low banks. The average fall of the reach is 0.4 m per kilometer.

According to the stream gauging records of Ban Khai station, the Rayong river basin has been experiencing numerous floods over the years. The recent devastating floods were observed in 1974 and 1981, respectively.

The floods generally occur during the months of September and October, although it rarely happens in the months of August and November.

3.5.2 Channel Capacity

Critical channel capacities were analyzed for all river reaches pertinent to flood control study. Critical or bankful flows were computed by means of non-uniform flow formula based on the longitudinal profile and cross-sectional survey data along the main stem of the Rayong river. Figs. 17 and 18 show the critical channel capacities along the Khlong Yai and Rayong rivers respectively.

The average bankfull flow is 23 m^3/s for the Khlong Yai river and 160 m^3/s for the middle reach of the Rayong river. The magnitude of the floods exceed far beyond the critical channel capacity, causing flood damage.

3.5.3 Flood Magnitude and Frequency

In the Rayong river basin, flood records are available for a short period at three stream gauges. Thus flood run-off analysis was performed by means of flood run-off simulation model in order to reveal

the magnitude of flood and establish a relationship among frequency, magnitude of flood and flood damage. The simulation model consists of three basic elements, i.e., (i) flood run-off calculation by sub-basin, (ii) channel routing calculation and (iii) flood regulation by dam.

For the analysis, the Rayong river basin including the Khlong Thap Ma river basin is divided into 9 sub-basins as shown in Fig. 19. Further main stem of the Rayong river is divided into 6 blocks and the Khlong Thap Ma river is treated as one block. The simulation model is then formed as presented in Fig. 20.

The flood run-off of the respective sub-zone is synthesized by means of unit hydrograph method. The basin rainfall of the sub-zone is obtained based on a relationship between the point rainfall and the areal rainfall. A rate of direct flood run-off is estimated to be 65% based on the past flood run-off records.

The routing through river channel is computed by applying the storage function method.

The flood run-off at the upstream end of the respective reach was simulated by a combination of the flood run-off calculation and channel routing calculation. Flood frequency curve thus obtained is shown in Fig. 21.

The flood run-off analysis is discussed in Sectoral Report VII. Meteorology and Hydrology.

3.5.4 Flood Prone Area

Because of insufficient channel capacity, the middle and lower Rayong river basin has been sufferred from floodings. The floodings pose a severe hazard to the population and exert a negative effect on economic growth of the area.

In order to grasp the extent of flooding and the character of flood losses, the flood damage survey was carried out during the period from August to October, 1982 in collaboration with RID. The survey was conducted through interview survey, which was conducted at 27 spots in the basin. As the results, flood inundation area has been revealed for the 1974- and 1981-floods as shown in Figs. 22 and 23. The inundation area is estimated to be 21,000 ha for the 1974-flood and 17,000 ha for the 1981-flood. The 1974- and 1981-floods have recurrence intervals of 18.0-year and 3.6-year, respectively, according to the flood frequency curve at Ban Khai gauge.

The inundation areas are classified into four land use categories as shown below, according to the topographic map and land use map.

Land Use	Inundated Area (ha)	
	1974-flood	1981-flood
Paddy field	11,300	10,400
Uplands	4,000	1,800
Village area	1,600	1,200
Other lands	4,100	3,600
Total	21,000	17,000

The number of houses subject to flood damage is estimated at 16,570 for the 1974-flood and 12,420 for the 1981-flood.

3.5.5 Flood Damages

The flood damages in the basin have been broadly grouped into four categories, namely, (i) rice, (ii) upland crops, (iii) house and household effects and (iv) livestock. Other tangible losses such as impairment of public facilities and utilities and buiseness and financial losses are assumed to be 20 % of the above damages. Intangible losses are not taken into account.

The damage rate was determined for each damage category depending on the seasonal occurence and frequency of flooding and the characteristics of flooding such as depth and duration. The damageable value is also determined for each category. The damageable values of rice and upland crop are based on their yields and prices prospected to 1990 and are estimated to be ฿ 14,090 per ha and ฿ 14,510 per ha respectively. The damageable values of house and household effects and livestock are estimated to be ฿ 39,600 per household and ฿ 1,164 per household respectively.

The flood damage was calculated based on the damageable value and damage rate for each damage category and flood damage curve is prepared for each river reach as shown in Fig. 24. The flood damages of the 1974- and 1981-floods are estimated for the whole Rayong river basin as shown below.

(Unit: ฿ 10^6)

Damage Categories	1974-flood	1981-flood
Rice	48.6	34.2
Upland crops	15.1	6.4
House and household effects	21.2	15.0
Livestock	9.8	7.6
Other tangible	18.9	12.6
Total	113.6	75.8

The average annual flood damage in the basin is estimated to be ฿ 147.1 x 10^6 based on the flood damage curves.

Thorough study on flood damage is compiled in the Sectoral Report XIII, Flood Mitigation Engineering.