GOVERNMENT OF THE KINGDOM OF THAILAND

THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT

MAIN REPORT

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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P R E F A C E

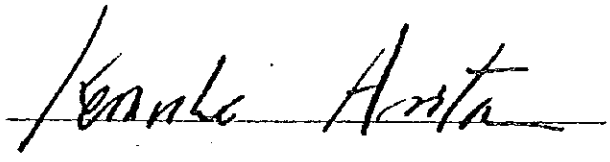
In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a feasibility study on the East Coast Water Resources Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Thailand a study team headed by Mr. Yuichi Katayama, the Joint Venture of CTI Engineering Co., Ltd., Sanyu Consultants Inc., and Nomura Research Institute from February to August, 1981.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the East Coast area. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

March, 1982



Keisuke Arita
President
Japan International Cooperation Agency

CONCLUSION AND SUMMARY

1. CONCLUSION

The project which comprises of Nong Pla Lai Sub-project and Ban Bung Sub-project has been formulated in order to support the incremental demand for municipal-industrial water as well as irrigation water for Changwats Rayong and Chon Buri in the East Coast Area.

It has been concluded that the sub-projects of Nong Pla Lai and Ban Bung are technically feasible and economically viable, and their social needs are very urgent. To meet the rapid increase of water demand arising from the execution of the Fifth Social and Economic Development Plan in the project area, the project is recommended to be implemented as soon as possible.

Nong Pla Lai Sub-project which comprises the construction of Nong Pla Lai Dam together with its water transmission and irrigation system has been judged the most essential in promoting the industrial development and in stabilizing the social welfare. Among the components of Nong Pla Lai Sub-project, the construction of water transmission system has to be implemented very urgently to expedite water supply arrangement toward Mab Ta Pud, since construction of natural gas separation plant is proposed there as a key project for the area's industrial development and its operation is scheduled to start in April, 1984.

Ban Bung Sub-project is meant for expansion of the present reservoir by construction of a new dam. While the unit cost of development of Ban Bung Dam is evaluated rather high, the Ban Bung area has been suffering from the chronic shortage of water so much so even drinking water is hardly obtainable. In view of answering this social need, it is recommended that the construction of Ban Bung Dam be implemented urgently.

2. SUMMARY

2.1 General

The Project is set up for the water resources development in a part of the eastern coast of Changwats Rayong and Chon Buri where a major target of the Fifth Social and Economic Development Plan has been assigned, and a tremendous volume of future water demand is anticipated.

The Project has been formulated on the basis of the existing Dok Krai Dam and the newly proposed four dams, namely Nong Pla Lai, Ban Bung, Khlong Yai and Thap Ma, to meet the industrial - municipal water demand in the year of 2000 as well as to supply irrigation water.

Within the framework of the above-stated plan, Nong Pla Lai and Ban Bung Sub-projects were given the first priority.

Nong Pla Lai Sub-project was planned to meet the water demand in four definite areas: Rayong, Sattahip and Laem Chabang areas for municipal-industrial water supply, and Nong Pla Lai area for irrigation water supply. In the course of the said plan, however, it has become clear that water conveyance to Laem Chabang would be very costly and also that alternative water source might as well be found in the vicinity of Laem Chabang area; thus there has arisen a possibility or desirability of dropping Laem Chabang area from the Sub-project's target areas.

From the above point of view, the formulation of the Sub-project excluding water supply to Laem Chabang has been also carried out (refer to APPENDIX I).

Ban Bung Sub-project which is meant for construction of a new dam, has been formulated to supply the municipal-industrial water to cover the chronic water shortage in the vicinity of Ban Bung city.

Water-shortage for non-agricultural purposes such as for drinking, cooking, bathing and washing as well as for cattles is very serious in Ban Bung city and its water supply during dry season depends mainly on distribution by tank-lorries which collect meager water on the bottom of the river.

2.2 COMPREHENSIVE WATER RESOURCES DEVELOPMENT PLAN

Water Demand

The future demand of municipal-industrial water is estimated at 72 MCM/year in 1990, 87 MCM/year in 1995 and 109 MCM/year in 2000 in the aforementioned target areas, namely Rayong, Sattahip, Laem Chabang and Ban Bung areas.

Breakdown of above estimation results is shown as follows:

(unit: MCM/year)

Area	Future Demand of Municipal-Industrial Water		
	1990	1995	2000
Rayong	36.0	38.4	56.0
Sattahip	17.6	19.4	24.0
Laem Chabang	12.9	22.2	29.3
Ban Bung	5.4	7.0	9.0
Total	71.9	87.0	109.3

As for irrigation water, demand will be arising towards Nong Pla Lai Irrigation Area with an irrigable area of 3,650 ha which will be newly developed by 1986, and further demand will be generated towards 6,400 ha-wide Thap Ma Irrigation Area which will be completed by 2000.

Water Resources Development Plan

In order to meet the incremental demand for water, surveys have already been carried out, and the following sites were selected for construction of new dams in the area concerned:

Proposed	Dam Location	Catchment Area (km^2)	Utilization Storage Capactiy (MCM)	Developed Water (MCM/year)
Nong Pla Lai	Changwat Rayong	426	144.4	116.0
Khlong Yai	Changwat Rayong	223	45.0	83.0
Thap Ma	Changwat Rayong	154	35.0	42.0
Ban Bung	Changwat Chon Buri	53	8.0	6.7

The water resources development plan deals with the existing Dok Krai Dam/1 and four newly proposed dams, and the following phasing of water supply is set up to meet the water demand until the target year 2000:

Stage 1: The surplus water of Dok Krai Dam is planned to be utilized to meet the urgent demand for municipal-industrial water by the year 1986 through equipment of appropriate water transmission system for the purpose.

Stage 2: Nong Pla Lai Dam which will be equipped with the biggest capacity among the proposed dams is planned to be completed in 1986 to meet the municipal-industrial and irrigation water demand of its project area until 1995. Ban Bung Dam is also planned to be completed in 1986 to meet the required municipal-industrial water demand of Ban Bung area until the year 2000.

Stage 3: Khlong Yai and Thap Ma Dams, both with rather small reservoir capacity, will be built to support and cover additional water demand until the year 2000.

/1: There presently exists Dok Krai Dam on Dok Krai River, tributary of Rayong River, which has water utilization storage capacity of 49.0 MCM (water supply volume being 80 MCM/year.) This dam was meant for supply of irrigation water to Ban Khai area but the water developed by this dam is not fully utilized because of insufficient facilities of the irrigation system.

2.3 Project Formulation

Shortage of municipal-industrial water will cause a serious problem in the project area and, in view of coping with such problem, the two Sub-projects of Nong Pla Lai and Ban Bung have been taken up for project formulation as below:

Nong Pla Lai Sub-Project

Nong Pla Lai Sub-project comprises Nong Pla Lai Dam, water transmission system and Nong Pla Lai Irrigation and Drainage system.

The arrangement for developing water resources by the above system and the main features of system facilities are described as follows:

1) Arrangement for Water Development

The existing surplus water of 22.8 MCM/year at Dok Krai Dam will be supplied to Mab Ta Pud by the newly constructed water pipeline system to meet the municipal-industrial water demand in 1986, before completion of Nong Pla Lai Dam.

After Nong Pla Lai Dam will be completed, Dok Krai Dam will have its function altered and start supplying municipal-industrial water to the volume of 80 MCM/year towards Rayong (including Mab Ta Pud), Sattahip and Laem Chabang, until the year 1995. In case supply system to Laem Chabang area should be excluded from the Sub-Project, Dok Krai Dam can meet the said water demand until the year 2000, and the volume of water to Laem Chabang will be supplied to Rayong area via Rayong River.

Nong Pla Lai Dam will specialize at supply of irrigation water, to the volume of 116 MCM/year, to satisfy the vested right in Ban Khai Irrigation Area, on the one hand, and towards Nong Pla Lai Irrigacion Area having 3,650 ha, on the other. Nong Pla Lai Dam may also have some flood control effect by using its surcharge capacity on the lower reaches of Rayong River.

2) Features of System Facilities

The proposed Nong Pla Lai Dam-site is located in the upper reaches of Rayong River with the catchment area of 426 km^2. The reservoir of the dam (earth-fill type, maximum dam height - 31 m) will have a total storage capacity of 200.7 MCM, which accommodate the water utilization storage (144.4 MCM), the surcharge storage (43.5 MCM) and the sediment storage (12.8 MCM). The spillway of the dam will have the side overflow type weir with emergency gate (roller gate) and the flow capacity of 700 m^3/s at H.W.L. The vertical type tower is adopted for intake of the resevoir water and the jet flow gate (D=1,500 mm) is equipped for its outlet meant for irrigation water.

The proposed water transmission system is composed of three routes of pipeline, namely Dok Krai - Mab Ta Pud (L=27.6 km, D=1,350 mm), Mab Ta Pud - Sattahip (L=21.9 km, D=1,000 mm), and Dok Krai - Laem Chabang (L=53.0 km, D=900 - 1500 mm). As for the route of Dok Krai - Mab Ta Pud, the pumped-up water at Dok Krai Reservoir is transmitted to the receiving well at Ban Chak Luk Ya by pipeline along Routes 3191 and 3. As for the route of Dok Krai - Laem Chabang, the pumped-up water at Dok Krai Reservoir is transmitted by pipeline to the head tank along Route 3191 and then to the receiving well near Ban Thung Suk La along Route 3.

In the irrigation system, the water (69.4 MCM/year) toward Nong Pla Lai Irrigation Area (3,650 ha) is planned to be diverted at Ban Nong Bau diversion weir. The main irrigation canal (concrete lined with 46.2 km length) is aligned along the hillside on the left bank of Rayong River.

Ban Bung Sub-project

1) Arrangement for Water Development

Ban Bung Dam will supply the newly developed water of 6.7 MCM/year to meet the future municipal-industrial water demand until the year 2000 at Ban Bung city and its vicinity.

Ban Bung Dam may also have some flood control effect for the lower reaches of Ban Bung River by using the surcharge capacity.

2) Features of System Facilities

The proposed Ban Bung Dam site is located in the upper reaches of Ban Bung River with the catchment area of 53 km^2. The reservoir of the dam (earth fill type, max. dam height = 21.5 m) will have a total storage capacity of 21.9 MCM, which accomodate the water utilization storage (12.5 MCM), the surcharge storage (7.8 MCM) and the sediment storage (1.6 MCM). The spillway of the dam will have the type of overflow weir without gate and the flow capacity of 125 m^3/s at H.W.L. The type of vertical tower is adopted for intake of the dam and the jet flow gate (D=1,000 mm) is prepared for outlet of the dam for the vested right water for irrigation.

2.4 Construction Schedule

The total work period required for the execution of the project is about 5 years from end of 1981 to 1986.

The construction schedule of each sector including the detailed design phase is given as below:

Sector		Construction Schedule
1. Nong Pla Lai Sub-project		
Nong Pla Lai Dam	:	JAN. 1983 - NOV. 1986
Water Transmission System		
Dok Krai - Mab Ta Pud	:	NOV. 1981 - AUG. 1984
Mab Ta Pud - Sattahip	:	MAY 1983 - DEC. 1985
Dok Krai - Laem Chabang	:	JAN. 1983 - NOV. 1986
Irrigation and Drainage System	:	JAN. 1983 - DEC. 1986
2. Ban Bung Sub-project		
Ban Bung Dam	:	JAN. 1983 - JUL. 1986

2.5 Project Benefit

The annual benefit of Nong Pla Lai Sub-project in full operation stage is estimated at US$ 21 million in case of Laem Chabang being included into the project area and also in case of Laem Chabang being excluded.

As for Ban Bung Sub-project, the annual benefit in full operation stage is estimated at US$ 2 million.

The abovestated benefits are classified by sector as below:

(unit: million US$)

Purpose	Annual Benefit
1. Nong Pla Lai Sub-project	
1.1 Municipal - Industrial	17.36
1.2 Irrigation	3.44
1.3 Flood Control	0.27
2. Ban Bung Sub-project	
2.1 Municipal - Industrial	2.04
2.2 Flood Control	0.01

2.6 Project Cost

The total project cost is estimated at US$ 242 million composed of US$ 218 million for Nong Pla Lai Sub-project and US$ 24 million for Ban Bung Sub-project in case that Laem Chabang area is added as one of the water demand areas in the Project.

If Laem Chabang area is excluded from the Project area, the abovestated cost may decrease to US$ 199 million in total and US$ 175 million in Nong Pla Lai Sub-project due to the elimination of the construction for the water transmission between Mab Ta Pud and Laem Chabang.

The project cost is on the contract basis by using 1981 price and classified by work item given as follows:

(Unit: million US$)

Work Item	Foreign Currency	Local Currency	Total
1. Nong Pla Lai Sub-project			
1.1 Nong Pla Lai Dam	29.85	36.70	66.55
1.2 Water Transmission System	88.37 (63.73)	47.01 (29.07)	135.38 (92.80)
1.3 Irrigation System	7.01	9.04	16.05
2. Ban Bung Sub-project (Ban Bung Dam)	12.47	11.12	23.59
Total	137.70 (113.06)	103.87 (85.93)	241.57 (198.99)

Note: The cost in parentheses is in case of elimination of Laem Chabang area from the Project area.

2.7 Economic Evaluation

Evaluation of the project was made by means of calculating Internal Rate of Return on the basis of the estimated benefit and economic cost.

The Internal Rate of Return for Nong Pla Lai Sub-project is calculated at 10.5% in case of including Laem Chabang area and 11.2% in case of excluding Laem Chabang area.

With regard to Ban Bung Sub-project, the Internal Rate of Return is calculated at 8.2%.

The above rates show economic viability of the project.

The Internal Rate of Return has been further calculated for each sector as below:

Sector	IRR (%)
1. Nong Pla Lai Sub-project	
1.1 Municipal - Industrial	10.4 (11.3)
1.2 Irrigation	12.1 (12.1)
1.3 Flood Control	3.5 (3.5)

Sector	IRR (%)
2. Ban Bung Sub-project	
2.1 Municipal - Industrial	8.3 (8.3)
2.2 Flood Control	2.9 (2.9)

Note: The IRR in a parenthesis is case of Laem Chabang area being excluded from the project areas.

2.8 Financial Evaluation

Financial evaluation for the project was made by means of calculating Internal Rate of Return (IRR) on the basis of the discount cash flow.

The IRR for Nong Pla Lai Sub-project is calculated at 4.9% in case of Laem Chabang area being included into the project and 5.9% in case of Laem Chabang being excluded.

With regard to Ban Bung Sub-project, the IRR is estimated at 1.8%.

FEATURES OF THE PROJECT

1. Nong Pla Lai Sub-project

1.1 Dam and Reservoir

Reservoir

Catchment area	426 km^2
Reservoir area at H.W.L.	23 km^2

Reservoir stage

High water level (H.W.L.)	EL. 47.0 m
Normal water level (N.W.L.)	EL. 45.0 m
Low water level (L.W.L.)	EL. 33.3 m

Reservoir storage

Gross	200,700,000 m^3
Surcharge	43,500,000 m^3
Irrigation, industrial & municipal	144,400,000 m^3
Sediment	12,800,000 m^3

Dam

Dam

Dam Type	Earth fill type with cut-off trench	
Crest elevation		EL. 49.0 m
Max. dam height		31.0 m
Crest length		4,000.0 m
Slope gradients	Upstream slope	1:3.0
	Downstream slope	1:2.5
Embankment volume		3,200,000 m^3

Spillway

Type	Side overflow weir with emergency gate
Capacity	700 m^3/s at H.W.L.
Gate (Emergency gate)	Roller gate 5.0m x 5.0m x 1 No.

Intake & Outlet

Intake	Vertical Tower	
Outlet for irrigation water		
Regulating valve	Jet flow gate	ϕ 1,500 mm x 1 set
Discharge capacity		14 m^3/s at L.W.L

House Evacuation and Land Acquisition

House Evacuation	200 houses
Land Acquisition	3,100 ha
Road Relocation	17.3 km

1.2 Water Transmission System

Water Transmission for Mab Ta Pud, Satttahip and Laem Chabang Areas

Supply to Mab Ta Pud

Pumping Station at Dok Krai Reservoir

Type of pumping station	Concrete caisson
Type of pump	Vertical shaft volute type
Design discharge	3.63 m^3/sec (43.56/min/unit)
Number of pumps	6 (1 for stand-by)
Total pump head	107 m
Motor output	5,250 kw

Pipeline

Design discharge	2.62 m^3/sec
Total length	27.6 km
Steel pipe	1,350 mm in diameter, 11.9 mm thick

Head tank

Location	6.0 km south of Dok Krai pumping station
Volume	3,000 m^3 x 2 units

Receiving facility

Location	West of Ban Chan Luk Ya along Route-3
Receiving well	780 m^3
Receiving basin	21,000 m^3

Supply to Sattahip from Mab Ta Pud

Booster pumping station at Mab Ta Pud

Type of pump	Horizontal shaft volute type
Design discharge	1.09 m^3/sec (32.7 m^3/min/unit)
Number of pumps	3 (1 for stand-by)
Total pump head	11 m
Motor output	150 kW

Pipeline

Design discharge	1.09 m^3/sec
Total Length	21.9 km
Steel pipe	ϕ 1,000 mm 8.7 mm thick

Receiving well

Location	Approx. 5km east of Amphoe Sattahip
Volume	350 m^3

Supply to Laem Chabang

Booster Pumping Station

Location	7.5 km southwest of Dok Krai pumping station
Type of pump	Horizontal shaft volute type
Design discharge	1.01 m^3/sec (30.3 m^3/min/unit)
Number of pumps	3 (1 for stand-by)
Total pump head	45 m
Motor output	600 kw

Pipeline

Total length	53.0 km
Steel pipe	ϕ 900, t 7.9 mm, L 24.5 km ϕ 1,000, t 8.7 mm, L 13.0 km ϕ 1,200, t 11.1 mm, L 6.5 km
Tunnel Section	ϕ 1,500 mm, L 9.0 km

Head tank for booster pumping station

Location	6.0 km northwest of booster pumping station
Volume	2,000 m^3

Receiving well

Location	South of Bang Thung Suk La along Route 3
Volume	300 m^3

1.3 Irrigation and Drainage System

Irrigation

Irrigation area	3,650 ha
Cropping intensity	100% in wet season and 80% in dry season
Cropping pattern	Paddy in wet season and paddy/groundnuts in dry season

Expected crop yield	Wet paddy	4.0 ton/ha
	Dry paddy	4.5 ton/ha
	Groundnuts	1.9 ton/ha
Irrigation water	69.4 MCM/year	
Diversion weir	Ban Nong Bau	
Irrigation canal		
Main length	46.2 km concrete lined	
Latral length	20 km ditto	

Drainage

Drainage area	
Inside the project area	21.3 km^2
Outside the project area	14.9 km^2
Design drainage discharge	20.4 m^3/sec
Drainage length	6.5 km

2. Ban Bung Sub-project

Reservoir

Catchment area	53 km^2
Reservoir area at H.W.L	4 km^2
Reservoir stage	
High water level (H.W.L)	EL. 84.3 m
Normal water level (N.W.L)	EL. 82.1 m
Low water level (L.W.L)	EL. 76.1 m
Reservoir storage	
Gross	21,900,000 m^3
Surcharge	7,800,000 m^3
Irrigation, industrial & municipal	12,500,000 m^3
Sediment	1,600,000 m^3

Dam

Dam

Dam Type	Earth fill type with cut-off trench	
Crest elevation		EL. 86.3 m
Max. dam height		21.5 m
Crest length		2,800.0 m
Slope gradients	Upstream slope	1:3.0
	Downstream slope	1:2.5
Embankment volume		1,400,000 m^3

Spillway

Type	Overflow weir without gate
Capacity	125 m^3/s at H.W.L

Intake & Outlet

Intake	Type: Vertical Tower
Outlet for irrigation water	
Regulating valve	Jet flow gate ϕ 1,000 mm x 1 unit
Discharge capacity	5 m^3/s at L.W.L

House Evacuation and Land Acquisition

House Evacuation	40 houses
Land Acquisition	270 ha

APPENDIX Nong Pla Lai Sub-project
(SUPPLY AREAS: RAYONG AND SATTAHIP)

Supply to Mab Ta Pud

Pumping Station at Dok Krai Reservoir

Type of pumping station	Concrete caisson
Type of pump	Vertical shaft volute type
Design discharge	2.62 m^3/sec (31.4 m^3/min/unit)
Number of pumps	6 (1 for stand-by)
Total pump head	90 m
Motor output	3,000 kw

Pipeline

Total length	27.6 km
Steel pipe	ϕ 1,350 mm, t 11.9 mm

Head tank

Location	6.0 km south of Dok Krai pumping station
Volume	2 unit x 3,000 m^3

Receiving Facility

Location	West of Ban Chan Luk Ya along Route-3
Receiving well	780 m^3
Receiving basin	21,000 m^3

Supply to Sattahip from Mab Ta Pud

Booster pumping station at Mab Ta Pud

Type of pump	Horizontal shaft volute type
Design discharge	1.09 m^3/sec (32.7 m^3/min/unit)
Number of pumps	3 (1 for stand-by)
Total pump head	11 m
Motor output	150 kW

Pipeline

Design discharge	1.09 m^3/sec
Total length	21.9 km
Steel pipe	ϕ 1,000 mm t 8.7 mm

Receiving well

Location	Approx. 5 km east of Amphoe Sattahip
Volume	350 m^3

Supply to Rayong

Weir

Location	Up stream of Ban Khai diversion weir on Rayong River
Flood gate	2 gates x 20 m x 2.5 m
Regulating gate	10 m x 3.0 m

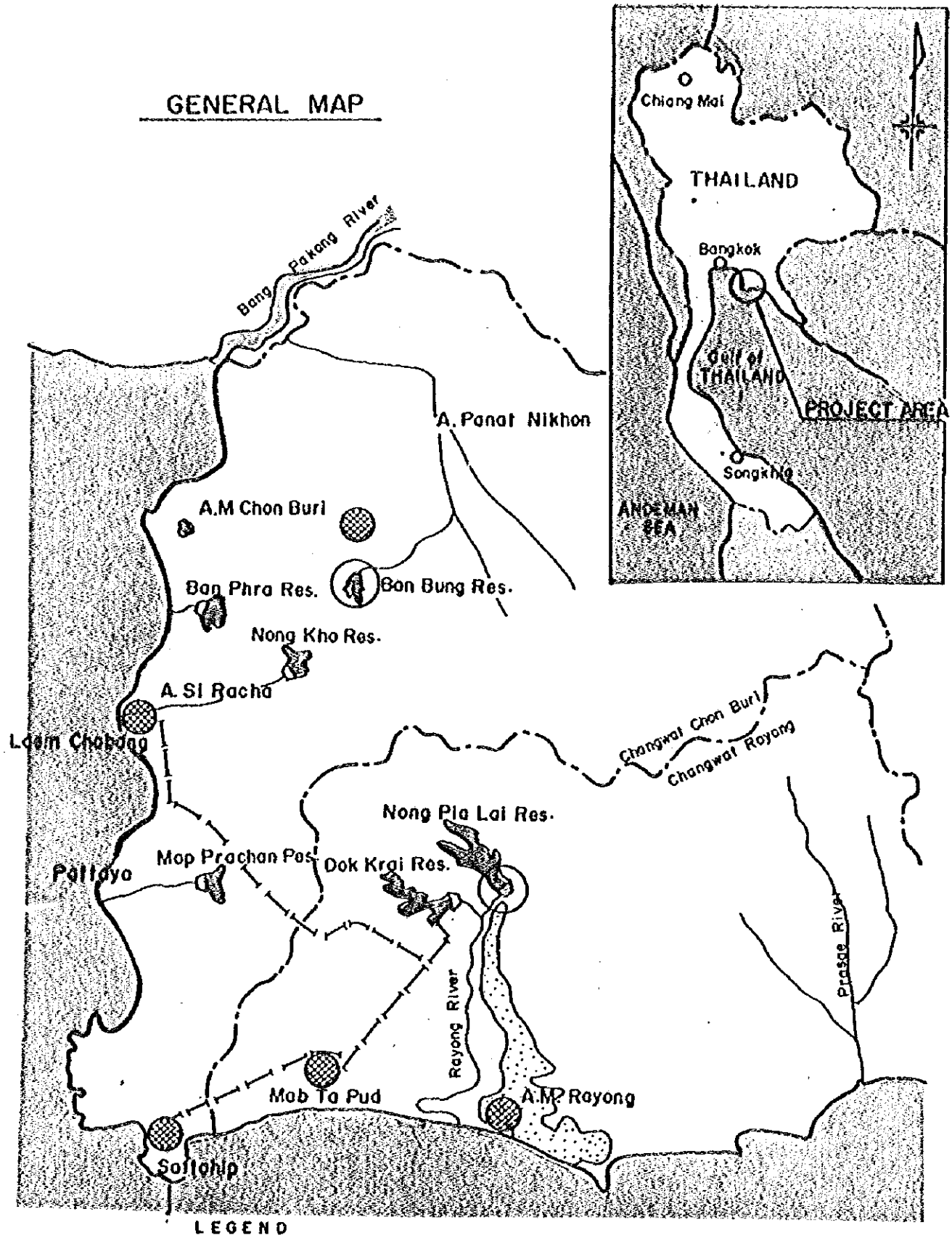
Intake and Transmission Facilities

Design discharge	1.01 m^3/sec
Pipe length	1.0 km
Concrete pipe	ϕ 1,500 mm

Receiving Facility

Location	Ban Khai
Receiving well	300 m^3

GENERAL MAP


Chiang Mai
THAILAND
Bangkok
Gulf of THAILAND
PROJECT AREA
Songkhla
ANDAMAN SEA
Bang Pakong River
A. Panat Nikhon
A.M Chon Buri
Ban Phra Res.
Bon Bung Res.
Nong Kho Res.
A. Si Racha
Laem Chabang
Changwat Chon Buri
Changwat Rayong
Nong Pla Lai Res.
Mop Prachan Res.
Dok Krai Res.
Pattaya
Rayong River
Prasae River
Mab Ta Pud
A.M. Rayong
Sattahip
LEGEND
Existing Dam
Proposed Dam
Center of Water Demand
Proposed Water Pipeline
Proposed Irrigation Area
5 0 10 20 30 km

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GLOSSARY OF TERMS AND ABBREVIATIONS

1) Local Terms of Administrative Areas

Thai	English
Changwat:	Province
Muang (Amphoe Muang, A.M):	City
Amphoe (A.):	Township
King Amphoe (K.A):	Sub-Township
Tambon:	Town
Muban (Bang):	Village
Tesaban:	Municipality
Su Khapiban:	Sub-Municipality

2) Natural Features

Khlong: Canal

3) Administrative Organization

RID: Royal Irrigation Department

NESDB: National Economic and Social Development Board

DTEC: Department of Technical & Economic Coopration

IEAT: Industrial Estate Authority of Thailand

ACFT: Agricultural Cooperatives Federation of Thailand

MAC: Ministry of Agriculture and Cooperatives

MOI: Ministry of Industry

OPM: Office of Prime Minister

PWWA: Provincial Water Works Authority

NEA: National Energy Authority

PTT: Petroleum Authority of Thailand

CAT: Communication Authority of Thailand

SRT: State Railways of Thailand

4) Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer

5) Area

m^2 = square meter
ha = hectare = 10^4 m^2
km^2 = square kilometer = 10^6 m^2
rai = 0.16 ha

6) Volume

l = liter = 1,000 cm^3
m^3 = cubic meters
MCM = million cubic meters = 1,000,000 m^3

7) Weight

mg = milligram
g = gram
kg = kilogram
t = ton = 1,000 kg
qwt = quintal = 100 kg

8) Time

s (sec) = second
h (hr) = hour
d = day
yr = year

9) Currency

฿ = Baht
US$ = United States Dollar
US¢ = United States Cent

10) Electric Measures

kV = kilovolt
kW = kilowatt
MW = megawatt = 1,000 kW
kWh = kilowatt-hour
MWh = megawatt-hour = 1,000 kWh
kVA = kilovolt-ampere
Hz = hertz

11) Other Measures

% = percent
ppm = parts per million
rpm = revolutions per minute
HP = Horsepower
°C = Degrees centigrade
10^3 = Thousand
10^6 = Million
10^9 = Billion

12) Derived Measures based on the Same Symbols

m^3/s, m^3/sec = cubic meter per second

t/ha, ton/ha = ton per hectare

m^3/km^2 = cubic meter per square kilometer

mm/day = millimeter per day

l/day = liter per day

MCM/year = million cubic meter per year

m^3/yr = cubic meter per year

m^3/hr = cubic meter per hour

m^3/min = cubic meter per minute

l/sec = liter per second

l/sec/m = liter per second per meter

m/yr = meter per year

US$/ha = US Dollar per hectare

฿/ton = Baht per ton

kg/m^3 = kilogramme per cubic meters

$m^3/km^2/year$ = cubic meters per square kilometer per year

$m^3/s/km^2$ or $m^3/s/ha$ = cubic meters per second per square kilometer or hectare

$฿/m^3$ = Baht per cubic meters

13) Other Abbreviations

EL. = Elevation
W.L. = Water level
L.W.L. = Low water level
N.W.L. = Normal water level
H.W.L. = High water level
M.S.L. = Mean sea level
P.S. = Power station
S.S. = Substation
T/L = Transmission line
D/L = Distribution line
NNW = North-northwest
SSE = South-southeast
GDP = Gross domestic product
WHO = World Health Organization (UN)

CHAPTER I - INTRODUCTION

1.1 BACKGROUND OF THE PROJECT

The recent industrial development in Thailand owes much to the Social and Economic Development Plans under the First to Fourth Stages inclusive, of the country.

With development potential enough to attract attention of all the parties concerned, the East Coast Area has been highlighted in recent years. Development plan of various scope has been formulated by the Government and, furthermore, some part of the plan such as the natural gas separation plant has entered its commencement stage and is scheduled to be completed within 1983 /1 according to the Final Report of the Study on Eastern Seaboard Basic Industry Development and Deep Sea Port Development approved by the Cabinet in April 1981.

In order to materialize the development plan, the exploitation of water resources and their allocation to each industrial sector and community is given a vital role. However, the water resources development plan in the East Coast has been rather delayed in comparison to its infrastructural plan, in spite of the effort made by the Government and agencies concerned, because of the difficulties being encountered in developing the limited water resources due to the natural conditions and physical surroundings of the East Coast Area.

1.2 OUTLINE OF THE STUDY

1.2.1 Objectives of the Study

The objective of the study is to verify the feasibility of the water resources development project at Nong Pla Lai in Changwat Rayong and at Ban Bung in Changwat Chon Buri.

1.2.2 Study Area

The area subject to this feasibility study includes industrial development centers in Changwats Chon Buri and Rayong where demand for water will increase rapidly with implementation of industrial development plans. Agricultural area which is expected to benefit from the development of irrigation system of the project is also included.

1.2.3 Scope of the Study

The scope of the study for the water resources development includes the following items:

/1: The Government changed the schedule to April 1984.

- To collect and review the relevant existing data and information required for the study,

- To select and delineate the Project Area on the basis of the review of data and information, and reconnaissance survey,

- To carry out field surveys in the Project Area required for the study,

- To study the formulation of multi-purpose water resources development plans,

- To prepare a preliminary design for the dam, water transmission system, irrigation facilities and other related structures including their implementation schedule and cost estimation,

- To prepare an economic evaluation based on the estimation of costs and benefits of the Project,

- To study the effect of flood control and environmental impacts by the Project, and

- To study the organization and management for the Project.

1.3 OUTSTANDING ISSUE

Under the mutual agreement by and between RID and JICA Survey Team, the water demand in Laem Chabang area would be covered by the water which could be developed through construction of Nong Pla Lai Dam and, accordingly, Nong Pla Lai Sub-Project has been formulated in this Main Report with the aim of supplying municipal-industrial water (to Rayong, Sattahip and Laem Chabang areas) and agricultural water towards Nong Pla Lai Irrigation area.

In the course of the study, however, it becomes clear that the water transmission system extending to Laem Chabang area should cost very heavily and also that Laem Chabang area's demand could be met by alternative sources available in its vicinity. Such findings may suggest us to exclude Laem Chabang area from the water supply target of Nong Pla Lai Sub-Project.

Thereupon, Nong Pla Lai Sub-Project excluding Laem Chabang area from its supply area has also been formulated as an alternative plan and presented in APPENDIX I for reference.

CHAPTER II - PRESENT CONDITION OF THE PROJECT AREA

2.1 NATURAL CONDITION

2.1.1 Location

The Project area is located in two Changwats of Chon Buri and Rayong on the coast of the Gulf of Thailand in the eastern region of Thailand which consists of seven Changwats, viz: Nakhon Nayok, Prachin Buri, Chachoengsao, Chon Buri, Rayong, Chantha Buri and Trad.

This area is bordering on the Gulf of Thailand in the west and the south, to Chachoengsao in the north, and Chantha Buri in the east.

The two Changwats lie from the north latitude 12°30' to 13°30' and from east longitude 100°45' to 101°45', and the distance from Bangkok to Amphoe Muang (A.M.) Chon Buri and A.M. Rayong is about 70 km and 200 km, repectively.

2.1.2 Topography

Topography of the area is characterized by the extensive coastal flatlands which seldom exceed 100 m above the sea level and are pierced through by several small and medium rivers flowing in westerly or southerly directions all draining into the Gulf of Thailand. These coastal lowlands are occasionally interrupted by ridges reaching 300-800 m above M.S.L., which run in NNW to SSE directions in the east of A.M. Rayong. Except at Pattaya, Sattahip and their vicinity, these coastal flatlands are extending deeply into the interior.

2.1.3 Geology and Soil

The geological formation of Changwat Chon Buri and Rayong area is of Paleozoic sedimentary rocks, metamorphic rocks and granite which were forced up in Paleozoic and Mesozoic Eras. On the plains, these bed rocks are being covered by the Quaternary alluvium. Sedimentary rocks, predominantly shale, phyllite, silica and limestone, are spreading along the eastern coast in a broad belt, while metamorphic rocks made of schist, gneiss etc. are running in NW-SE direction in the east of the area. Granite is widely spreading centering at mountain massifs in the central part of the area.

The Quaternary alluvium composed of gravels, sands, clay, etc. is found in the coastal plains centering at Changwat Rayong.

Bedrocks are in the advanced stages of weathering, being covered by sedimentary soils, with a few outcrops. In the granite mountains, however, unweathered masses of rocks are scattering around in whitish color. The Paleozoic

limestone which is spreading on the coast sometimes steeply rises to mountain massifs surrounded by precipices, and they are partly utilized as quarries.

The soils in the Changwat Chon Buri and Rayong area are mainly consisting of sandy soils which were decomposed from the parent rocks such as granite and sandrock. Soil of paddyfields is alluvium of a considerable depth, consisting of loam, clay and clay-loam in its upper layer, but as it goes deeper, they change more and more to sandy soil. The surface soil contains a considerable amount of humus.

The upland soils consist of sandy soils containing insufficient humus and are liable to erosion. They have peculiar nature to hardening themselves in dry condition. The coastal area is made up of either sandy loam or sand with poor humus and are also liable to erosion.

2.1.4 Climate

Changwat Chon Buri and Rayong area belongs to the tropical monsoon area and its climate may be broadly divided into the rainy season from May to October and the dry season from November to April.

The rainfall in the area is comparatively less than the mean rainfall in Thailand as a whole, that is, between 1,300 and 1,500 mm per annum, as shown in Fig. 2-1. Monthly mean rainfall distribution is shown in Fig. 2-2.

According to the rainfall record kept at Ban Khai station in the middle reaches of the Rayong River in Changwat Rayong, during the last 20 years, the annual maximum was 1,863 mm in 1974 and the minimum, 700 mm in 1965. Though not quite prominent on the records, Rayong experienced the rare drought years continuing from 1978 to the first half of 1981.

Mean relative humidity (1951-1975) remains above 70% all through the year and it rises above 80% in two months of September and October. The annual mean evaporation ranges from 1,100 to 1,300 mm, as measured by pan evaporimeter as shown in Fig. 2-3.

Wind blows from NNW direction from October to January, and south to SSW direction during February and September, with the mean velocity of 5 to 10 km/hr.

Mean temperature (1951-1975) is 26°C at the minimum (December-January) and 30°C at the maximum (April), with small difference throughout the year.

2.1.5 Hydrology

The annual run-off ratio obtainable from the main hydrological stations in the two Changwats of Chon Buri and Rayong is 0.20-0.30. The majority of loss is due to evaporation and this makes the assurance of water resources more difficult.

The specific discharges of principal flood events in Thailand are shown in Fig. 2-4. The specific discharge assumed from the 100 km^2 basin will be 3.5 $m^3/s/km^2$, and that from the 500 km^2 basin, 1.5 $m^3/s/km^2$. This is primarily due to the flat terrain plus inundation caused by poor discharge capacity of the river channels in the area.

On the other hand, the river discharge during the dry season assumed from the available data is 0.01 to 0.005 $m^3/s/km^2$.

2.1.6 River

Rayong River

Rayong River where the proposed Nong Pla Lai Dam is located, is one of the largest rivers in the East Coast area and joins the Khlong Yai (left tributary) and the Dok Krai (right tributary) and has a length of 85 km and catchment area of 1,800 km^2, in total.

The river, during its southward journey to the Gulf of Thailand, is joined by other tributaries including Khlong Tap Ma which flows into Rayong River in the northern suburbs of A.M. Rayong. The river channel is generally left in natural condition as it has not received any improvement work except for some section; the limited flow capacity has been causing inundation of the adjoining areas (refer to Fig. 2-5). Longitudinal profile is as shown in Fig. 2-6.

In its downstream after crossing the Highway No. 3, the river starts meandering to a remarkable extent. This, coupled by estuary closure, makes the flow capacity very small. To cope with such condition, three floodways having a combined flow capacity of 130 m^3/s were constructed about 20 years ago.

Dok Krai Dam is located at 10 km upstream of Khlong Dok Krai's confluence with Rayong River. The proposed Nong Pla Lai Dam will be located at 7 km upstream of the Nong Pla Lai's confluence with the Dok Krai. The Nong Pla Lai's catchment area is 426 km^2.

Ban Bung River

Ban Bung River is a secondary tributary of the Bang Pa Kong River. In the upper reaches of the river, the existing Ban Bung Dam is located and is proposed to be expanded for water resources development.

Ban Bung River originates in Mt. Kaho Khieo with an elevation of 660 m and flows to north direction. After crossing the Highway No. 3133, the river joins the Huai Khlong Yai, a primary tributary of Bang Pa Kong River. The river length and catchment area of Ban Bung River at the confluence with the Khlong Yai are 17 km and 97 km^2, respectively (refer to Fig. 2-7). As the river channel is left in natural condition, the flow capacity of the channel is limited especially at the crossing point with Highway No. 3133. Longitudinal profile is as shown in Fig. 2-8.

2.2 ECONOMIC AND SOCIAL CONDITIONS

2.2.1 Population and Land-use

Population and Labor Force

The total registered population in Changwats Chon Buri and Rayong as of December 1980 was 1,083,323. Changwatwise as well as Amphoewise population increase during the five years from 1976 to 1980 are shown in Table 2-1. The average population increase rate in the two Changwats combined has been 2.07%, somewhat lower than 2.2% which is the national target during current 4th Five Year Plan Period (1977-1981). The population density per km^2 in 1976 in the two Changwats averaged at 95, a little more than that of the national average of 84, and 72 in the eastern region of Thailand.

According to the estimate of the Ministry of Interior, the labor force and the employed labor population represent 46% and 16% respectively of the total population (15-59 years). This means that the ratio of the employed labor out of the total labor force is 34.8% only which is very low. Accordingly, job seekers are flowing into Metropolitan Bangkok Area and to meet this demand for working opportunity, new industries ought to be introduced into this area.

A conspicuous inflow of the immigrants will be a necessary phenomenon accompanying the implementation of the envisaged industrial and port development projects.

Economic Situation

1) Changwat Chon Buri

From the economic point of view, Changwat Chon Buri is the most active Changwat among the seven Changwats in the eastern region, judging from its per capita provincial production value which is 1.2 times as large as the national mean value of ฿ 7,826 and 1.8 times the Regional mean value (Refer to Table 2-2). Though lacking in reliable data concerning the recent-most economic situations, the economic prosperity of Changwat Chon Buri is believed to be maintained by its industrial structure which consists of much higher ratios of the

secondary and tertiary industries compared to that of primary industry. The economic growth rate attained by Chon Buri during 1972-1976 averaged at 4.6% per annum which far exceeds the average national economic growth rate of 3.6% during 1970-1975. Changwat Chon Buri is thus playing an important role in Thai economy as a whole.

Sectionwise shares of contribution to the 1978's GDP were 24.436% from the primary industry (agriculture), 45.71% from the secondary industry and 29.83% from the tertiary industry. The main agricultural products are cassava, sugarcane and pineapple. Among the prominent manufacturing industries, there are refining of petroleum and sugar, processing of cassava and foodstuff, alcohol etc. Total number of the registered manufacturers was 11,521 enterprises as in 1979.

The most important service industry in Chon Buri is tourism centering at Pattaya, the internationally reputed resort spot, which attracted in 1978 fiscal year a total of 0.7 million visitors (600,000 foreigners and 100,000 Thais), and hotel accommodation there has been expanded to about 3,800 rooms by 1980 fiscal year.

Table 2-3 shows the past performance (1972-76) and future projection (1977-81) of gross production in Changwat Chon Buri which was prepared by the Ministry of Interior. According to these data, the sectoral share is 20.9% for primary, 38.0% for secondary and 41.1% for tertiary in 1976 which represent a different share distribution to that in 1978 mentioned above, probably due to the different criteria for industrial classification. However, it can be said that the growth rate of agricultural sector is slightly above that of population and the future progress of the Changwat has to depend largely on the secondary and tertiary sectors.

2) Changwat Rayong

Changwat Rayong, on the other hand, is specialized in the primary industry consisting of agriculture, forestry and fishery. Among its main agricultural crops are sugarcane, cassava, fruits, rubber etc., which are locally processed to earn added value by such industries as tapioca processing, raw sugar milling, rubber smoking, lumber processing, marine industries which are being operated by some 800 enterprises, majority of which are small-scaled or petty even.

Changwat Rayong's economic structure is going to experience a radical change in the near future, however, as is witnessed by the emergence of a petro-chemical plant by private capital and the

Natural Gas Separating Plant of Petroleum Authority of Thailand in Amphoe Muang Rayong, together with the planned construction of a number of large-scale gas-related plants.

Outline of Land-Use Pattern

Changwats Chon Buri and Rayong have an area of 7,814 km^2, 36% of which is occupied by four forest districts of (1) mountain belt running from North to South inbetween the National Highways No. 3 and No. 331; (2) northern part of Ban Map Chalud (in Rayong) on the Highway No. 3; (3) the area stretching out inbetween Provincial Highways No. 3133 and No. 3138, and (4) the area bordering Changwat Chantha Buri.

Paddy field is spreading in the basin of Phan Thong River and in the middle and lower reaches of Rayong River, as well as in the limited area in the downstream of the Prasae River as shown in Fig. 2-9.

Coastal area is mainly utilized for cultivation of coconut, cassava, pineapple, fruit orchard and township.

In the hilly area in the northern and central parts are spreading plantations of sugarcane, cassava and pineapple, while the eastern hilly area is occupied by fruit orchards and rubber plantations.

Shrimp culture project taking advantage of the brackish water in the estuaries of Rayong River and Prasae River, which have been left unutilized so far, is said to be under consideration.

2.2.2 Infrastructure

Road

Construction of the main road network in this area was almost completed by 1981, attaining the target set under the 4th Five Year Plan. Upon completion of the trunk road network, the remaining job on hand will be improvement and construction of the feeder-roads. The road under construction is six routes and 180 km long in total.

Airport and Harbour

U-Tapao airport in Rayong is currently under the control of Thai Navy but it is reported that the Government is seriously considering its utilization in a full-fledged manner for civil aviation purposes in the near future.

Chuck Samet harbour at Sattahip which was originally built as a naval port was transferred in 1979, through revision of the relevant law, under the control of the Port Authority of Thailand (PAT) to be operated as a commercial port. Since December 1979 till April 1981, cargoes meant for

both foreign and domestic trades amounting to approx. 1,150,000 tons have been handled by Sattahip port. The port is equipped with 3 berths of 10 meter-deep wharf (total quay wall length = 540 m) and 2 berths of 8 meter-deep wharf (total quay wall length = 360 m). PAT's operational policy says that while Bangkok port will be specialized in handling break bulk cargoes, Sattahip will take up the duty centering at container-cargoes and bulk-cargoes.

Electricity and Communications

Electricity Generating Authority of Thailand (EGAT)'s power station for the Southeastern Region is located at Bang Pakong which lies in the northern neighbourhood of Changwat Chon Buri. Changwat Chon Buri and Rayong area is supplied with electric power from the Bang Pakong station by two high-tension transmission lines. The one is 230 kV line which is connected to Ao Phai station, and the other is 115 kV line which is linked to the substations at Chon Buri, Si Racha, Ao Phai, Bang Lamung, Sattahip I & II, Rayong, and Klaeng. Distribution of electric power from these substations to the end-users is the responsibility of Provincial Electricity Authority (PEA). At present, power demand in the area as a whole is around 58 MW., which is being shared between the domestic and the industrial uses by 62 and 37%, respectively.

Fifteen telephone exchanges with 12,400 circuits in total are being operated and maintained by Telephone Organization of Thailand (TOT) in this area. While the national average of the distribution ratio of the telephone remains at 0.83/100 heads, this area shows 1.15/100, but an expansion of telephone services will become essential in view of industrial development in the near future.

Water Supply

Distribution of potable water to the sanitary districts and municipalities is undertaken by the local authorities and Provincial Water Works Authority (PWWA). The consumption of the potable water in this area is shown in Table 2-4.

PWWA is drawing water from RID's dams and reservoirs (refer to Table 2-5); the local authorities are depending on such sources as the natural rivers, ponds and groundwater.

While municipal water distribution facilities can meet an annual demand up to 22.2 MCM/year (refer to Table 2-4), the estimated actual consumption remains at 15.8 million m^3 /1 or 71.2% of the existing capacity. This is due to the absolute shortage of source-water which obliges the authorities concerned to limit daily supply of water within 4-5 hours during dry season.

/1: Because of the absence of Rayong's consumption figure in 1980, data on the past peak consumption in 1978 was used instead.

The local people, both the beneficiaries and non-beneficiaries of the public water supply works, are habituated to collect rainwater in the porcelain pots or steel tanks, and those living in the area available to groundwater have their own shallow wells. The factories with spacious compounds are usually equipped with reservoirs to collect rainwater for their own consupmtion.

The big consumers like the hotels at Pattaya are purchasing lorry-borne water at 20 ฿/m^3, in addition to tapping of groundwater by their own efforts. As far as Pattaya is concerned, however, as Map Prachan Reservoir commenced supplying water to Na Klua purification pond on the final stage, no serious water shortage is expected to arise in the foreseeable future in Pattaya.

Changwat Office of Chon Buri conducted with its 12 municipal offices the 10-item survey related to the people's needs for improved administrative services in 1980; as a result, the answers collected from the 12 survey units almost unanimously pointed out the water supply as the biggest administrative issue. Though lacking in the similar survey results in case of Changwat Rayong the conditions actually prevailing there are supposed to be the same.

The assurance of the water resources is the most serious problem requiring utmost attention of all the concerned in planning and implementation of the development projects in this area.

2.2.3 Agriculture

General

The Project area extending over two Changwats of Rayong and Chon Buri is categorized into the Agro-Economic Zone 15. /1 Its main crops consist of cassava and sugarcane plus marine fisheries.

1) Cultivation Area

Cultivation area in Changwats Chon Buri and Rayong comprises paddy field of 959 km^2 (12.3% of whole area of two Changwats), upland field of 2,102 km^2 (26.9%) and orchard area of 1,297 km^2 (16.6%).

Compared with the national scale for occupation of paddy field which is 23.3.% of cultivation area, (upland field: 7.4% and orchard: 3.1%), the occupation ratio of paddy field in the project area is lower than those of upland field and orchard.

/1: One of 19 national divisions designated by the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

2) Farming Practice

Backwardness in farm mechanization is apparent with registered number of tractors by 1980 for Changwats Chon Buri and Rayong totalling 450 and 200. Water buffaloes are generally used for tilling and land breaking. Big tractors are owned exclusively by big land owners or sales agents and operated for charges. Power tillers have come into use gradually and number 6,000 approx., which is still small.

As for transport of farm products, paddy is carried by water buffaloes and small tractors. Sugarcane and cassava is transported by large trucks.

Power threshers are mostly unused as water buffaloes or hand threshing take their place. Since processing of unhulled rice is done by hand, dust and other impurities are often mixed. Milling is done by village mills.

3) Irrigation Facilities

There are four dams supplying irrigation water in Changwats Chon Buri and Rayong as shown in Table 2-5. Regarding Dok Krai Dam, it was constructed with irrigation system in 1975 to fulfill irrigation water requirement of Ban Khai irrigation project area of 8,000 ha along the middle reaches of Rayong River. At present, however, the benefitted area is limited only to 1,600 ha of paddy field due to the delay of farm land consolidation.

Irrigation facilities such as water management machinery are still very limited in number, with small scale water pumps for supplementary irrigation counted in the two Changwats as 16,000.

4) Farm Production and Yield

The summary of principal farm production for Changwat Chon Buri and Rayong area as follows.

	Rice	Sugarcane	Cassava
Chon Buri	99,294 t (0.7%)	3,218,539 t (15.7%)	1,014,949 t (6.7%)
Rayong	55,268 (0.4%)	2,301,092 (11.2%)	1,621,838 (10.8%)
National Total	15,206,212 (100%)	20,560,523 (100%)	15,048,317 (100%)

(Source: Agricultural Statistics of Thailand, Crop Year 1978/79)

The last five year average yeild of crops in two Changwats is paddy 1.7 t/ha; sugarcane 48.1 t/ha; and cassava 14.31 t/ha.

5) Processing and Marketing

The farmers sell unhulled rice directly to the mills and the agricultural cooperatives are not involved. Sugarcane is sold directly to processing factories and cassava to traders for drying process. The agricultural cooperatives act as lender of capital required and not as seller of farm supplies. Agricultural extension is carried out by outlets in rural districts. Due to limited number of attendant and lack of mobility, the service is not yet extensive.

Vicinity of Project Site

The agriculture activity in the vicinities of Nong Pla Lai and Ban Bung areas are expected to benefit from the Project. The present condition in respective areas are as follows.

1) Nong Pla Lai Area

This particular area is made up of flatland and gentle slope spreading on the left bank of Rayong River and it is extending over two Amphoes of Bang Kai and Mian. This 8,360 ha-wide genuine rural zone has a land-use pattern which is: 3,840 ha of paddy field, 3,090 ha of orchard, 1,010 ha of settlement area, and 420 ha of forest, roads and others. Though rice stands as the principal crop, its cultivation is confined during wet seasons only as there are no irrigation facilities. Paddy fields are irregularly shaped and almost entirely lacking in farm roads.

The harvested area varied from year to year, depending on annual availability of rainfall; for the last 3 years the harvested paddy field remained 62% on an average. Productivity per unit acreage is as low as 1,442 kg/ha in Amphoe Muang Rayong.

2) Ban Bung Area

This area, spreading in the downstream of Ban Bung Reservoir is made up of gentle slope and flatland extending over 2,320 ha, consisting of 490 ha of paddy field, 1,710 ha of upland field, and 120 ha of forest, roads, canals, etc. Cassava and sugarcane are two principal crops. Because of the absence of irrigation facilities, both rice and sugarcane are liable to drought damage and their production is, therefore, unstable.

2.2.4 Flood and Drought Damage

Flood

Because of poor discharge capacity, Rayong River causes flooding even in case of a moderate flood discharge. Relatively big flood occurs once in every two years and extends over some 160 km^2 from Ban Khai to the suburbs of A.M. Rayong. The flooding is also caused by the closure of the river mouth which helps further lowering the discharge capacity of the canals and diversion channels.

The hearing on the spot revealed that the major flood had occurred in 1974 and 1976, causing stagnation of flood water for several weeks in the middle reaches and over a couple of months in the lower reaches.

Ban Bung River's conditions are almost the same as those of the Rayong River and approx. 5 km^2 area which is blocked by a road in its downstream is habitually flooded once a year.

The reduction of yield and damage to the assets due to such habitual flooding is assumed to be considerable though lacking reliable data and record.

Drought

According to the data pertaining to the last several years available in the two Amphoes of Muang Rayong and Ban Khai in Changwat Rayong, 7.6% of the paddy field in these two Amphoes combined has been left unharvested due to water shortage even during wet season. The present acreage under paddy cultivation is confined to the locality which is guaranteed with minimum necessary water supply. The cultivation area, therefore, would be enlarged corresponding to the increased supply of irrigation water, if made available.

Shortage of water for non-agricultural purposes such as for drinking, cooking, bathing and washing is also seriously felt in this district, and the water supply during dry season depends on distribution by tank-lorries which collect meager water on the bottom of the rivers.

For three years from 1978 to 1980, an extremely severe drought occurred in this area, giving severe damage to agricultural production and serious hardships to the inhabitants' daily living.

2.3 EXISTING RESERVOIRS

In Changwats Chon Buri and Rayong, there are five existing reservoirs given respective aims and purposes. Their particulars are shown in Table 2-5.

Ban Bung Reservoir (Changwat Chon Buri)

This dam was completed in 1958, with the primary purpose of supplying industrial water to the Government sugar factory, the irrigation water to the sugarcane fields, and the municipal water to municipal facilities located in the downstream of the reservoir. Because its storage capacity is limited, a new dam is being proposed in its downstream for which the present survey is being conducted.

Bang Phra Reservoir (Changwat Chon Buri)

This was built in 1974 for expanding the storage capacity of the older one which had been completed on its immediate upstream, and is meant for supplying industrial water and municipal water being required in and around Chon Buri as well as flood-control.

Map Prachan Reservoir (Changwat Chon Buri)

This dam was originally built for the purpose of assuring supply of municipal water mainly to meet the felt demand in Pattaya, and was completed by the end of 1979. Its purification plant was completed in 1981 and water distribution facilities are being constructed at present.

Dok Krai Reservoir (Changwat Rayong)

This dam was completed in 1975 for the purpose of supplying irrigation water to Bang Khai agricultural project in its downstream on the one hand, and flood-control on the other. A considerable spill discharge is being witnessed with this dam and the surplus volume can be used as an urgent supply of municipal-industrial water.

Nong Kho Reservoir (Changwat Chon Buri)

This is still under construction and is expected to be completed in 1983. Upon completion, it will supply both municipal water and industrial water to the cities of Chon Buri, Si Racha and their suburbs, apart from irrigation water to its downstream farms.

CHAPTER III - COMPREHENSIVE WATER RESOURCES DEVELOPMENT

To supply a sufficient industrial and municipal water to meet the future water demand in Changwats Chon Buri and Rayong in the east coast area, it is required to conduct a comprehensive study including the estimation of the future water demand and the potentiality of water resources development, and the stepwise water resources development scheme is to be proposed and determined in accordance with the incremental demand of water.

3.1 BASIC CONCEPT

Basic concepts for the study to attain and justify the above substance are as follows:

1) Target year for the water resources development is to be established for the water demand of the year 2000.

2) Countermeasure for the water resources development is to be considered by dams.

3) The municipal-industrial areas to be supplied with the newly developed water are the four development centers of Rayong Area, Sattahip Area, Laem Chabang Area and Ban Bung Area in Changwats Rayong and Chon Buri.

4) The agricultural development areas to be taken into consideration are limited to the areas in downstream side of the proposed dam, Nong Pla Lai Irrigation Area (3,650 ha) and Thap Ma Irrigation Area (6,400 ha), the required irrigation water is to be supplied by using the proposed reservoir volume.

5) Stepwise water resources development scheme is to be proposed to cope with the incremental water demand, and the demand of required water is to be secured up to the year 2000.

3.2 FUTURE WATER DEMAND

The future water demand is to be estimated from the population, living standard, industrial production activities and irrigation requirement. The purpose of this estimate for water demand is to study the structural difference in demand caused by the Government's guideline for regional development.

3.2.1 Methodology and Terms for Demand Estimate

Municipal Water

Macro-scale estimate based on the future population estimate has been adopted and conducted until the target year 2000 by using the following formula:

$$MWD = [(Pn \times Up \times Wp) + IP] \times PCC \times 365 \text{ days} \times RC$$

here,

MWD = Municipal water annual demand
Pn = Population
Up = Urban population ratio
Wp = Water pervasion
PCC = Per capita consumption
IP = Induced population
RC = Raw water converter (1.1)

Factors in the above formula are as mentioned below:

1) Population (Pn)

According to the 1976 - 1980 statistics in Changwats Chon Buri and Rayong, the average population growth rate is 2.14% and 2.00% respectively, and the total population is estimated at about 1,300 thousands in 1990 and at about 1,500 thousands in 2000 in Changwats Chon Buri and Rayong (refer to Table 3-1).

2) Urban Population Ratio (Up), Water Pervasion (Wp) and Per Capita Consumption (PCC)

Parameters of Up, Wp and PCC in the above equation are shown below:

Year	Area	Up (%)	Wp (%)	PCC /1 (t)
1980	Chon Buri	30.0	45.3	0.345
	Rayong	9.9	58.6	0.220
1990	Chon Buri	35.0	60.0	0.350
	Rayong	30.0	70.0	0.300
2000	Chon Buri	45.0	75.0	0.350
	Rayong	40.0	80.0	0.350

3) Induced population

Tables 3-2 and 3-3 show the projection of the induced population and labor force by areas in the year 1990 and 2000 respectively.

The induced population consists only of manpower for port and industry sectors where skilled labor is required.

The induced population of port and industry sector are 20 and 80% of the total employed work force. The service sector related to the above two sectors is assumed to rely on local manpower and thus excluded from induced population. Also, the induced population

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/1: Per capita consumption is estimated from the data of actual consumption compiled by PWWA.

is assumed to settle in planned residential areas where Up is 100%. Further, the intra-regional movement of local work force due to port or industry to be developed has not been accounted for induced population.

Industrial Water

The estimate for water demands of industrial and port use in the project area has been based on the figures released in the Final Report of the Committee /1 , except Laem Chabang and Rayong Areas.

Among the figures thus released, the one for soda ash industry in Sattahip is different from what has been published in its feasibility report by JICA. The larger figure of feasibility report has been adopted here for the planning on safer side.

In Laem Chabang and Rayong Areas where no estimate is released, the water demand is estimated by multiplying the area of development by unit water requirement in ton/ha.

The area of development in Rayong industrial complex is estimated in the Final Report as 96 to 160 ha which has no account for aspects of potential as sub-sectoral industries of proposed primary industry and possible airport oriented industry around U-Tapao. With full account of such development potentials, the estimate of required land development would be 320 ha. The Laem Chabang industrial complex of IEAT has an area of 448 ha. Water requirement for these two industrial complexes will be calculated from an average water requirement per unit area of five representative industrial parks of Thailand, which is 90 ton/ha.

Irrigation Water

The diversion water requirement will be estimated by the following procedure. Crop consumptive use is the depth of water to meet the water loss through evapo-transpiration; it is estimated from the climatic data and crop growing stage for each crop. The percolation is also taken into account for the paddy cropping. The water needed for land preparation is considered.

1) Proposed Irrigation Area

Of the newly proposed irrigable area, Nong Pla Lai Irrigation Area, to be supplied from Nong Pla Lai Dam which is to be completed in 1986, is 3,650 ha, and after completion of Khlong Yai and Thap Ma Dams, Thap Ma Irrigation Area of 6,400 ha, can also become irrigable. The all area is to be utilized in wet season for paddy and 80% in dry season for paddy and groundnut.

/1: Basic Industries Development Committee, Secretariat Office, Thailand.

2) Crop Consumptive Use

Crop consumptive use is the depth of water consumed through evapo-transpiration; evapo-transpiration was estimated by Penman Formula on the basis of the meteorological data from Chon Buri Station.

3) Cropping Pattern

Cropping pattern was investigated based on the traditional produce, efficiency of products in commercial value, effective use of limited irrigation water and labor force allocation, and determined as below (refer to Fig. 3-1).

Item	Wet Season	Dry Season
Periods	Jul. - Nov.	Jan. - May
Crops	Paddy	Paddy & Groundnuts
Crop Intensity	100%	80%

4) Percolation

Percolation was actually surveyed and found to be 3mm/day.

5) Water Required for Land Preparation

Water required for land preparation is 200 mm for paddy field and 60 mm for upland field.

6) Effective Rainfall

The effective rainfall for crop cultivation is estimated by monthly rainfall and is put in the following ratio:

Monthly rainfall (mm)	Ratio
0 - 10	0
10 - 100	0.80
100 - 200	0.70
200 - 250	0.60
250 - 300	0.55
300 up	0.50

7) Coefficient of Water Loss

The coefficients of water loss in the irrigation system represented by irrigation efficiency are as follows:

Canal Efficiency	90%
Field Efficiency	70%

3.2.2 Estimated Future Water Demand

The estimated future water demand by aforementioned four target areas, Rayong, Sattahip, Laem Chabang and Ban Bung Area, are obtained as below mentioned:

Rayong Area

	1990	1995	2000
Industrial	23.1 MCM/year	23.1 MCM/year	27.9 MCM/year
Industry-related municipal	8.5	8.5	15.5
Other municipal	4.4	6.8	12.6
Irrigation	69.4	128.1	194.7

Sattahip Area

	1990	1995	2000
Industrial	13.7 MCM/year	14.3 MCM/year	17.2 MCM/year
Industry-related municipal	0.8	0.9	1.5
Other municipal	3.1	4.2	5.3

Laem Chabang Area

	1990	1995	2000
Industrial	6.6 MCM/year	12.0 MCM/year	16.8 MCM/year
Industry-related municipal	3.4	6.0	7.0
Other municipal	2.9	4.2	5.5

Ban Bung Area

Municipal water demand is based on the population projection without taking into consideration the induced population by the industrial and urban developments. As for industrial water demand, it is assumed that the current consumption of 1.8 MCM will increase by 10% per annum.

	1990	1995	2000
Industrial	2.9 MCM/year	3.8 MCM/year	4.8 MCM/year
Municipal	2.5	3.2	4.2

Breakdown of the above estimation results are as shown in Tables 3-4, 3-5, 3-6, 3-7, 3-8, and Fig.3-2.

3.3 WATER RESOURECES DEVELOPMENT

3.3.1 Measure of Water Resources Development

Water resources development is usually achieved by tapping of surface flow, development of groundwater and desalinization of sea water. The optimum choice will be made after evaluation of each alternative as an optimum measure for its performance in available volume, water quality (chemical, bacteriological and sediment), environmental impacts and overall economy.

As a result of the evaluation mentioned below the construction of dam/reservoir is chosen as an optimum measure for the water resources development in the Project area.

Desalinization of sea water, although technically possible, would be very difficult to apply for the present water resources development which is far larger than the capacity of operational plants seen in Hong Kong or Saudi Arabia. Economically, this alternative would be out of question with its present cost of development at US$1.5/$m^3$, which is many times as much as that of surface flow exploitation.

The observation of ground water table in the vicinity has revealed that extensive exploitation would be difficult as it should bring about such foreseeable impacts as saline water intrusion and land subsidence due to over-tapping of groundwater, and consequently it would result at the decline of the ground water table and difficulty in the utilization of big amount of water as the resources.

As for the direct pumping from the streams in the project area, tapping of large volume water cannot be expected, because the year-round discharge of the rivers varies greatly from rainy season to dry season. The only development of surface flow by construction of dam/reservoir seems to be feasible since water supply can be made to meet the future demand throughout the year.

3.3.2 Proposed Dam Development

Dam development program for the east coast area has already been prepared by RID. It includes, as main dams, Nong Pla Lai, Khlong Yai, Thap Ma, Khlong Luang and Prasae Dams and expansion of Ban Bung Dam (refer to Fig. 3-3). Among above dams, Nong Pla Lai, Thap Ma, Khlong Yai and Ban Bung Dams are nominated to be studied for their high development potentiality and vicinity to the demand area.

Dam	Catchment Area	Storage Capacity
Nong Pla Lai	426 km^2	144.4 MCM
Thap Ma	154	35.0
Khlong Yai	223	45.0
Ban Bung	53	8.0/1

/1: Proposed Capacity (10 MCM) - Existing Capacity (2MCM) = Increased Capacity (8 MCM)

Features of the above selected four dams are as follows:

Nong Pla Lai Dam

With a largest catchment area in the project area, Nong Pla Lai Dam is located in the upstream of Rayong River, the stream that flows down the center of A.M. Rayong. The developed water can be conveyed to A.M. Rayong, a principal development center in the east coast, to Mab Ta Pud with proposed industrial complex, and to Sattahip and Laem Chabang where industrial complex and deep sea port development is planned. The water can also be supplied for municipal and industrial use and for irrigation purpose to the newly developed tract in the middle reaches.

The flooding water in Rayong River could be lessened by flood control function of the dam, which would protect the property assets in the river basin.

Khlong Yai Dam

The proposed dam is located in the upstream tributary of Rayong River, and supply approximately the water to the same area mentioned in the above Nong Pla Lai Dam.

The flood damage in the mid-low reaches of the river may also be mitigated by the dam.

Thap Ma Dam

The dam is proposed in a tributary of Rayong River, that meets the main course in its middle reaches. Developed water can be supplied for municipal-industrial use in A.M. Rayong and its vicinity as well as for irrigation.

Ban Bung Dam

The proposed dam is located in Ban Bung River, the secondary tributary of Ban Pakon River. The existing Ban Bung Dam will be expanded to 10 MCM from 2 MCM. This developed volume of water is meant to ease the acute shortage of municipal-industrial supply to A.M. Ban Bung Area. The latent demand and future demand to be induced by regional development will also be met.

3.4 STEPWISE DEVELOPMENT

3.4.1 Dam Construction Priority

For the priority ranking of the proposed dams in the Project area, phasing of water supply for municipal, industrial and irrigation demand was carried out, and water resources development was studied based on the below mentioned aspects:

1) To ensure the development capacity of the reservoirs to make the water supply meet the increased future demand in the target areas.

2) To develop the water resources stepwise in accordance with the development efficiency.

3) To give the priority of dam construction taking the urgency of water demand in the respective area into consideration.

The most urgent demand is to supply the industrial water to the Mab Ta Pud Development Center by 1984, and Nong Pla Lai Dams which is expected to cope with the future demand with its big reservoir capacity, cannot successfully supply the required amount of water on time, because its construction period requires rather long.

The existing Dok Krai Dam, which was constructed in 1975, is for the irrigation purpose to supply the water to Ban Khai Area, and it has still leeway reservoir capacity beside the actual irrigation requirement on the ground that water is not taken to the whole irrigation area due to the insufficient secondary and tertialy irrigation canals.

Therefore, Dok Krai Dam can be utilized to meet the urgent municipal and industrial water demand by construction of appropriate water supply system until the year 1984. Nong Pla Lai Dam is for the demand until 1995, and Thap Ma and Khlong Yai Dams both with rather small reservoir capacity are for the long range demand until the target year 2000.

With regard to Ban Bung Area, the only expansion of Ban Bung Dam can meet the required municipal and industrial water demand until the target year 2000.

3.4.2 Phasing of Water Supply

Detailed stepwise water resources development scheme for water supply is as follows:

Year*	Description	Water Supply
1984	Completion of water transmission system from Dok Krai Dam to Hab Ta Pud; Urgent industrial water demand until 1986 can be ensured to Hab Ta Pud.	• Municipal - MCM/Year • Industrial 19.1 • Industry-related municipal 3.7 • Irrigation - Total 22.8
1986	Completion of Nong Pla Lai Dam; Municipal and industrial water demand until the year 1995 can be supplied to Rayong, Sattahip, and Laem Chabang areas, Cropping intensity also becomes 100% in wet season and 80% in dry season for Nong Pla Lai Irrigataion Area (3,650 ha). Vested right of water for Ban Khai Irrigation can be ensured.	• Municipal 15.2 MCM/Year • Industrial 49.4 • Industry-related municipal 15.4 • Irrigation 69.4 Total 149.4
1986	Completion of Ban Bung Dam; Municipal and industrial water demand until the year 2000 can be supplied to the Ban Bung Area. Existing vested right of water also can be ensured.	• Municipal 4.2 MCM/Year • Industrial 4.8 • Industry-related municipal - • Irrigation - Total 9.0
1995	Completion of Khlong Yai Dam; Municipal and industrial water demand until the year 2000 can be supplied to Rayong, Sattahip and Laem Chabang Area /1. Irrigation water also can be newly supplied to Thap Ha Irrigation Area (3,000 ha).	• Municipal 22.1 MCM/Year • Industrial 57.1 • Industry-related municipal 23.0 • Irrigation 128.1 Total 230.3
1998	Completion of Thap Ha Dam; Increased irrigation water also can be newly supplied to Thap Ha Irrigation Area (3,400 ha) until the year 2000.	• Municipal 22.1 MCM/Year • Industrial 57.1 • Industry-related municipal 23.0 • Irrigation 194.7 Total 296.9

NOTE * : Completion year

/1: Maximum supply water through Laem Chabang transmission system is at 22.2 MCM/year, and the water demand of Laem Chabang Area in the year 2000 is at 29.3 MCM/year. This 7.1 MCM/year of shortage is expected to be replenished by water resources development in the vicinity.

3.4.3 Water Balance

The balance calculated from estimated water demand and supply is tabulated in Table 3-9 and Fig.3-4. It is apparent from the table that 17.3 MCM/year of shortage would occur in 1985 for the total area of Rayong, Sattahip and Laem Chabang. It would be difficult to expedite the completion of Nong Pla Lai and Ban Bung Dams because they require long construction periods. The delay, on the other hand, of the operation at start of these two dams would cause shortage of industrial and municipal water in 1986 by about 26.5 MCM/year (Refer to Fig.3-4).

After the year 1987 until the target year 2000, required water demand can be satisfactorily supplied.

CHAPTER IV - PROJECT FORMULATION

4.1 GENERAL

Priority-ranking among the sub-projects of which are comprised in the Water Resources Development Project envisaged in the east coast area of Thailand has been determined in Chapter III; the two sub-projects of Nong Pla Lai and Ban Bung have thus been taken up for project formulation in this chapter.

Nong Pla Lai Sub-Project

Nong Pla Lai Sub-Project is to be divided into the two stages as follows:

1) First Stage

Establishment of a water transmission system which aims at an urgent supply of municipal-industrial water to Mab Ta Pud industrial complex which will be made up of several industrial enterprises including a natural gas plant, through utilization of the surplus volume available from the existing Dok Krai Reservoir, during the course of time beginning in 1984 and lasting until the completion of Nong Pla Lai Dam/Reservoir.

2) Second Stage

Supply of water, upon completion of Nong Pla Lai Dam/Reservoir, to cope with municipal and industrial demands for it in such areas as Rayong (including Mab Ta Pud), Sattahip and Laem Chabang, as well as supply of irrigation water towards 3,650 ha Nong Pla Lai Irrigation Area which will be newly developed in the meanwhile. The design year of water supply by means of the above-said Dam/Reservoir is 1995.

The scope of works defined for this Sub-Project includes the Nong Pla Lai Dam/Reservoir, the water transmission system to provide the municipal-industrial water to the above-mentioned areas, and the irrigation drainage system meant for Nong Pla Lai Irrigation Area.

Ban Bung Sub-Project

Ban Bung Sub-Project has a sole purpose of supplying municipal-industrial water, through construction of a dam, to Ban Bung Area which has been suffering from the chronic shortage in which drinking water is hardy obtainable. The design year of water supply by this Dam/Reservoir is 2000.

As the topographic limitations hamper construction of a large-scale reservoir, supply of any additional irrigation water is not being considered.

4.2 NONG PLA LAI SUB-PROJECT

4.2.1 Water Supply Plan

First Stage

Dok Krai Dam was completed in 1975 for the purpose of supplying irrigation water to Bang Khai agricultural project in its downstream on the one hand, and flood-control on the other. A considerable spill discharge is being witnessed with this dam and the surplus volume can be used as an urgent supply of municipal-industrial water to Mab Ta Pud.

This supply meets the municipal-industrial water demand, 22.8MCM/year, which will rise in 1986 (Fig.4-1).

Such urgent supply will be made possible through equipment of new water transmission system.

Second Stage

In 1995, which has been decided as the design year for the Second Stage, the demand for municipal-industrial water in the beneficiary areas such as Sattahip, Laem Chabang and Rayong including Mab Ta Pud, is 80.0 MCM/year.

In addition, it is required to meet a demand of 91.3 MCM/year in Ban Khai Irrigation Area to satisfy the vested water rights there, and to supply irrigation water towards 3,650ha of Nong Pla Lai Irrigation Area which is to be newly developed, by the constuction of new reservoir and the discharge from the residual basin.

To meet such demands, the following water distribution plan, based on new development plan of a large scale reservoir, Nong Pla Lai Reservoir, and alteration of the original purpose of Dok Krai Reservoir, has been adopted.

1) Dok Krai Reservoir

   This Reservoir will meet 80 MCM/year of municipal-industrial water of Rayong (including Mab Ta Pud), Sattahip and Laem Chabang (Fig.4-2).

2) Nong Pla Lai Reservoir

   Nong Pla Lai Reservior which will have a water utilization storage capacity of 144.4 MCM shall meet the demand of 69.4 MCM/year for Nong Pla Lai Irrigation Area, and also the vested water right for Ban Khai Irrigation Area (refer to Fig. 4-3).

The irrigation water of 69.4 MCM/year in Nong Pla Lai Irrigation Area will assure cropping intensity of 100% in wet season and 80% in dry season.

Such confinement of purposes, the supply of municipal-industrial water from Dok Krai Reservoir and that of irrigation water from Nong Pla Lai Reservoir, are believed practicable through effective utilization of the intake facilities which will be provided at Dok Krai Reservoir in the first stage, and to facilitate for its smooth operation and maintenance.

Volume of water supply in 1995 is shown in Fig. 4-4.

4.2.2 Nong Pla Lai Dam and Reservoir

Scale of the reservoir is determined by considering the volume of the required water utilization storage and surcharge, estimated sediment deposit, plus social problems.

The crest elevation and the high water level of the reservoir is determined at EL. 49 and EL. 47.0 m, at which the volume of the reservoir will accommodate the combined capacities of the water utilization storage of 144.4 MCM, the surcharge of 43.5 MCM, and the sediment of 12.8 MCM. Fig. 4-5 shows storage capacity curve.

The reservoir impounding area is now covered by cassava field, and the houses which need to be evacuated are 200. When the high water level exceeds EL. 47m, the area to be submerged will expand to Plunk Daeng resulting in a notable increase of submergable houses.

The main features of Nong Pla Lai Reservoir are as follows:

Catchment area	426	km^2
Reservoir area at H.W.L.	23.0	km^2
Reservoir stage		
High water level (H.W.L.)	EL. 47.0	m
Normal water level (N.W.L.)	EL. 45.0	m
Low water level (L.W.L.)	EL. 33.3	m
Reservoir storage		
Gross	200,700,000	m^3
Surcharge	43,500,000	m^3
Water utilization	144,400,000	m^3
Sediment	12,800,000	m^3

4.2.3 Water Transmission System

Water Demand

The specific demand for municipal-industrial water in the beneficiary areas is estimated as follows:

Unit: MCM/Year

Year	Rayong municipality	Mab Ta Pud	Sattahip	Laem Chabang
1986	4.8	22.8	14.9	6.6
1995	8.4	30.0	19.4	22.2
2000	22.2	33.8	24.0	29.3

Location of Intake of Water Transmission System

As for the decision of the location of the intake, there are two alternatives namely, direct intake at Dok Krai Reservoir itself, and the intake from the lower reaches of Rayong River into which the discharge from Dok Krai Dam flows.

The final decision is that the intake shall take place directly from Dok Krai Reservoir itself towards Mab Ta Pud, Sattahip and Laem Chabang, and from Rayong River at existing Ban Khai weir towards Rayong municipality due to the results of the following studies.

As to the intake for Mab Ta Pud, an alternative plan of intaking the water at Ban Bong Saphan which is located proximate to Mab Ta Pud was studied but eventually rejected on the ground that it would result at a greater water loss at almost the same cost compared with the plan based on the direct intake form Dok Krai Reservoir.

The above intake method for Rayong municipality was adopted owing to its economical advantage brought about by proposed use of present intake facilities.

Water Transmission Method

Pipeline system is adopted for municipal-industrial water supply to Mab Ta Pud, Sattahip and Laem Chabang, because open channel is topographically handicapped to convey water to the said demand areas.

As far as water supply to Rayong municipality is concerned, the water channel existing in the vicinity of Rayong municipality was decided as an optimal means of water supply judging from the topographic conditions ruling there.

Route of Pipeline and Facilities

Two routes of pipeline, Dok Krai Dam - Mab Ta Pud - Sattahip Route and Dok Krai Dam - Laem Chabang Route, have been finalized, based on the result of the careful comparative study.

The features of the proposed routes and required facilities are as follows:

1) Dok Krai Dam - Mab Ta Pud - Sattahip Route

   Pumped-up water at Dok Krai Reservoir is transmitted to the receiving well (of the purification plant) at Ban Chak Luk Ya, by pipeline through head tanks on the midway along routes 3191 and 3. Water will be supplied from there to the industrial complex and new town of Mab Ta Pud.

   From Mab Ta Pud, water will be supplied through a booster pumping station to the receiving well at Sattahip, by pipeline along Route 3.

2) Dok Krai Dam - Laem Chabang Route

   Pumped-up water at Dok Krai Reservoir is transmitted to the head tank along Route 3191, and from there branched off to reach the receiving well near Ban Thung Suk La along Route 3, by pipeline and a tunnel. As the pipeline is crossing a mountain, a booster pumping station is required on the midway.

Main valves, air valves, drain valves and emergency valves are to be equipped at the appropriate places for all the pipelines.

Design Discharge of Pipeline Systems

Design demand volume along Dok Krai Dam - Mab Ta Pud -Sattahip Route has been set up in line with the demand expected in the target year, that is 2000. On the other hand, the pipeline route from Dok Krai Dam to Laem Chabang has been designed to meet the expected demand in 1995. This decision has been arrived at from the consideration that the construction cost of Dok Krai Dam - Laem Chabang Route is far higher than the other route because of longer distance and that water supply to Laem Chabang may be possible from the other source, too.

Design discharges of the pipeline system have been identified by multiplying water demand volumes by the load factor of 1.3 and the loss ratio of 1.1, as follows:

Route	Design Discharge	Demand Volume
Dok Krai - Mab Ta Pud	2.62 m^3/sec	57.8 MCM/year
Mab Ta Pud - Sattahip	1.09	24.0
Dok Krai - Laem Chabang	1.01	22.2

General map of water transmission system is shown in Fig.4-6.

4.2.4 Irrigation and Drainage System

Irrigation System

Irrigation water towards Nong Pla Lai Irrigation Area is planned to be diverted at Ban Nong Bau diversion weir which will be constructed at the downstream of the confluencing point of Nong Pla Lai River with Khlong Yai. The main irrigation canal is aligned along the hillside on the left bank of Rayong River.

The irrigation area is planned to be divided into 25 irrigation blocks, in due consideration of the topographic conditions. Each irrigation block is commanded by one turnout on the main canal.

In the small irrigation blocks bordering the main irrigation canal, irrigation water will be diverted into the on-farm irrigation ditches from the turnout on the main canal. In the larger irrigation blocks and the blocks off the main irrigation canal, however, lateral canals will be provided so that irrigation water can be diverted into the on-farm irrigation ditches through the lateral canals.

The unit water requirement for determining the canal design capacity is decided at 2.68 l/sec/ha, which is the maximum diversion water requirement occuring on the last day of the land preparation for wet season paddy cropping.

The irrigation canal system is shown in Fig.4-7.

The commanded area and the design discharge of each turnout is listed in Table 4-1.

Drainage System

Drainage problems in most of the Project Area can be solved through construction of the on-farm drainage canal which serve to drain out excess water into the adjacent tributaries of Rayong River. However, in the low-lying area which involves such irrigation blocks especially as numbers B-17, B-18, B-19, B-20 and B-21 (see Fig. 4-7) where a stream originating at a hill standing outside the Project Area does run into and eventually bifurcates into the paddy field, main drainage canal would have to be constructed to drain excess rain water and to keep a suitable depth in the paddy field.

The proposed drainage area is 21.3 km^2 inside the Project Area and 14.9 km^2 outside it.

The unit drainage capacity to design the drainage canal would be 4.1 l/sec/ha inside the Project Area and 7.9 l/sec/ha outside it. This value has been arrived at from the 10-year probable daily rainfall of 135 mm and the allowable inundation depth of 200 mm.

4.2.5 Flood Control Effect

Rayong River inundates its basin even in case of small-scale flood, due to the poor flow capacity of the river channel. Relatively larger flooding occurs every other year. The inundated area between the river mounth and Ban Khai used to be around 160 km^2.

The flood control of this project is to be effected only by surcharge storage of a dam in consideration of the land use pattern which is characterized by universal paddy cultivation and the extent of inundation in the project area.

Peak of the flooding can be lowered by storage in Nong Pla Lai Reservoir. Consequently, the inundation area in its downstream will be diminished. The annual average damage without Nong Pla Lai Reservoir and with it is estimated at ฿ 62.2 million and 56.0 million, respectively. Therefore, the expected annual diminution of flood damage would amount to ฿ 6.2 million.

4.3 BAN BUNG SUB-PROJECT

4.3.1 Water Supply Plan

From the topographic limitations, new Ban Bung Dam will have to be built at an immediate downstream of the existing Ban Bung Dam which will have been submerged under the new Reservoir.

So far, 0.8 MCM/year of irrigation water demand and 2.3 MCM/year of municipal-industrial water demand for Ban Bung area has been satisfied by the existing Ban Bung Reservoir.

Since the demand for municipal-industrial water in Ban Bung Area will reach 9.0 MCM/year in the target year, that is, 2000, 9.8 MCM/year which is the sum-total of the said municipal-industrial water for Ban Bung Area and 0.8 MCM/year to satisfy the vested irrigation water rights shall be assured from the new Ban Bung Reservoir which shall have 12.5 MCM water utilization storage capacity to justify itself (refer to Fig. 4-8).

4.3.2 Ban Bung Dam and Reservoir

Scale of the reservoir has been determined on the basis of the required volume of water utilization and the surcharge, plus the estimated sediment deposit.

The crest elevation and the high water level of the reservoir is determined at EL. 86.3 and EL. 84.3 m at which the volume of the reservoir will accommodate the combined capacities of water utilization storage of 12.5 MCM, surcharge of 7.8 MCM and sediment of 1.6 MCM. Fig.4-9 shows storage capacity curve.

The maximum height of the dam is 21.5 meters; the bed-rock of the dam-site is made up of the weathered granite which has a sufficient bearing strength and permeability for this size of a dam.

The reservoir inpounding area is now covered by cassava field, and the houses which need to be evacuated are 40.

The main features of Ban Bung Reservoir are as follows:

Catchment area	53 km^2
Reservoir area at H.W.L.	4 km^2
Reservoir stage	
High water level	EL. 84.3 m
Normal water level	EL. 82.1 m
Low water level	EL. 76.1 m
Reservoir Storage	
Gross	21,900,000 m^3
Surcharge	7,800,000 m^3
Water utilization	12,500,000 m^3
Sediment	1,600,000 m^3

4.3.3 Flood Control Effect

The limited flow capacity of Ban Bung River has been causing inundation of its riparian areas even in case of minor flood.

The flood control of this project is to be effected only by surcharge storage of a dam in consideration of the land use pattern which is characterized by universal paddy cultivation and the extent of inundation in the project area.

Peak of the flooding can be lowered by storage in Ban Bung Reservoir. Consequently, the inundation area in its downstream will be diminished. The annual average damage without new Ban Bung Reservoir and with it is estimated at ฿13.70 million and 13.38 million, respectively. Therefore, the expected annual diminution of flood damage would amount to ฿ 0.32 million.

CHAPTER V - PRELIMINARY DESIGN

Based on the formulation which has been studied in Chapter IV, preliminary design has been done. The design discussed for Nong Pla Lai Sub-Project includes Nong Pla Lai Dam, municipal-industrial water transmission system from Dok Krai Dam to Mab Ta Pud, Sattahip and Laem Chabang areas, as well as irrigation and drainage system for newly developed Nong Pla Lai Irrigation Area. The design discussed for Ban Bung Sub-Project includes Ban Bung Dam.

5.1 NONG PLA LAI SUB-PROJECT

5.1.1 Dam and Reservoir

Geology

The geology of the dam site and the reservoir is granite based with alluvium deposit over the valley area. This alluvium strata is classified into two layers as either old or young. The young strata is observed along the river bed and it overlays the old one. The old strata is also found at the right bank of the dam site.

The bed-rock consists of coarse biotite-granite which has been reduced into either residual soil or decomposed granite depending on degree of weathering. As to the presence of fresh bed-rock basement, no report has been made.

The residual soil is distributed to the depth in the range of 3 to 6 meters, with deposit thicker on the right bank than on the left. The feature of the soil is that of clayey sand with N-value not greater than 20. Decomposed granite is also dominated by clayey sand with N-value greater than 50 owing to high density.

Alluvium distribution in the valley area comprises either clayey sand or silty sand with old stratum having the deposit thickness as much as 15 meters and the young stratum 6 meters. Both strata have wide range of N-value which are found to be between 1 and 20 for the young and between 2 and 50 or over for the old one.

Of the bed-rock the residual soil strata is moderately impervious, and decomposed granite strata, moderately impervious to impervious. Alluvium is permeable to moderately permeable. The ground water level is found to be 1 to 1.5 meters below surface at river beds and 3 to 6 meters on hills.

The borrow pits are proposed in both up-and down-streams of the dam site on both left and right banks. The materials found in these pits are of clayey sand with enough quantity to be used for the construction of the embankment.

Concrete aggregates and rip-rap materials will be obtained in a large quantity at a quarry located 12 km north of Sattahip. Another source of these materials in the vicinity of the dam site could be found in the highlands of granite rock located 8 km to the east or 20 km to the north-east.

Geological map of Nong Pla Lai Dam axis is shown in Fig. 5-1.

Dam

Earth-fill dam is chosen for this dam site, judging from its geology and the availability of construction materials therein.

The proposed dam will be set on the impervious strata with the cut-off trench of the bottom width of 6.0 m to 8.0 m along the dam axis to prevent excessive leakage through foundation.

The principal features of the proposed dam will be as follows:

Dam Type	Earth-fill type with cut-off trench	
Crest elevation	EL.	49.0 m
Max. dam height		31.0 m
Crest length		4,000.0 m
Slope gradients	Upstream slope	1:3.0
	Downstream slope	1:2.5
Embankment volume		3.2 MCM

Embankment volume includes 0.7 MCM for main coffer dam and coffer dams.

The slopes of the dam body to both up and downstreams will be protected from erosion by providing rip-rap and sodding.

In order to protect the municipality of Pluck Daeng from submersion caused by the proposed impounding reservoir, low dyke will have to be constructed.

General plan, longitudinal profile, and standard cross section of Nong Pla Lai Dam are shown in Figs. 5-2, 5-3 and 5-4.

Spillway

The design flood for spillway, 700 m^3/s at EL. 47 m (H.W.L.), has been determined from the dam design flood inflow of 1,050 m^3/s, which is 1.2 times of 200-year probability flood, in consideration of regulation effectiveness of the reservoir. Inflow and outflow hydrograph of the design flood for spillway is shown in Fig. 5-5.

From the viewpoint of the dam site topography, the spillway is located at the left abutment of the dam.

The spillway comprises a side overflow weir without a control gate, a chute way and an energy dissipator of hydraulic jump type. The width of the weir for the spillway design flood is 120 m.

The spillway has been aligned to minimize the total length. The total length of the spillway including overflow weir, water conveyance portion and channel will be 1,000 m.

A roller gate of 5.0 m wide and 5.0 m high is provided for the energency draw-down of water level of reservoir.

Plan, longitudinal and details of spillway of Nong Pla Lai Dam are shown in Figs. 5-6, 5-7 and 5-8.

Intake and Outlet Facilities

The intake and outlet facilities will serve to tap irrigation water for Ban Khai Irrigation Area and for newly developed Nong Pla Lai Irrigation Area and energency draw-down of the storage level of the reservoir.

Intake is of vertical tower type and the diversion conduit will be utilized as a part of outlet facility by narrowing its diameter with concrete after completion of the dam construciton.

The irrigation water requirement is estimated at 10.0 m^3/s in max., but the facilities are designed to discharge 14 m^3/s at the low water level so that the water stage can be safely drawn down even in case of energency.

The discharge volume will be controlled by a valve (jet flow gate ϕ 1,500 mm) at the outlet. Another gate (slide ϕ 1,500 mm) will be provided just upstream of the jet flow gate for its maintenance.

The discharged water will be dissipated in the stilling basin and conveyed to the existing river through a channel of 510 m long.

Fig. 5-9 shows the intake and outlet facilities.

Diversion Facilities

The streamflow of the two rivers, namely Khlong Ra Woeng (left side river) and Khlong Pong Nam Bit (right side river) will have to be diverted during the construction works of the dam to ensure smooth and safe execution of such works.

Main diversion facilities are connection channel of two rivers, diversion conduit, upstream coffer dam, main coffer dam, downstream coffer dam and downstream channel.

The streamflow of Khlong Pong Nam Bit will be firstly diverted through an open channel into Khlong Ra Woeng and then conveyed into a diversion conduit beneath the dam embankment together with the streamflow of Khlong Ra Woeng.

The facilities are designed to be safe against the estimated flood of 10-year probability.

Hydro-power Facility

To meet the pressure of demand for electricity expected in the future, a branch valve for penstock will be placed at the end of irrigation water outlet conduit so as to enable hydro-power generation (see Fig. 5-9).

Land Acquisition and Road Relocation

A land of 24.6 km^2 at EL.48.0 m, 1 m above H.W.L., most of which is presently under cassava production shall be acquired and 200 houses shall be evacuated for the implementation of dam construction.

When other areas such as dam site, borrow pit and right of way for road to be relocated are added to the above area, the total land acquisition will be 31 km^2.

The relocated roads will be on the right bank of the reservoir with the total length of 17.3 km. Approximately 10 bridges need to be constructed on the relocated roads.

The existing and relocated roads and 10 bridges to be constructed are shown in Fig. 5-10.

5.1.2 Water Transmission System

The water transmission system is provided to supply municipal-industrial water to Mab Ta Pud, Sattahip, and Laem Chabang from Dok Krai Reservoir.

This system mainly consists of intake pumping station, pipelines, booster pumping station, head tanks, air chambers, and receiving well. Design of purification and distribution facilities are out of the scope of this project.

Plans and longitudinal profiles of water supply routes from Dok Krai Dam to Mab Ta Pud, from Mab Ta Pud to Sattahip and from Dok Krai Dam to Laem Chabang, are shown in Figs. 5-11, 5-12 and 5-13, respectively.

Intake Pumping Station

Intake tower/pumping station will be installed within the reservoir featuring vertical shaft volute pumps in caison.

The features of intake pupmping station are as follows:

Number of pump	6 units (incl. 1 stand-by)
Capacity	43.56 m^3/min/unit
Total pump head	107 m
Motor output	5,250 kw

Location map of the pumping station, profile of pumping station and transmission pipe and general plan of pumping station are shown in Figs. 5-14, 5-15 and 5-16, respectively.

Pipeline

Conveyance of municipal-industrial water is all done by pipelines except where construction of a tunnel through mountain is planned along the Laem Chabang Route.

The length, diameter and wall thickness of pipeline for respective routes are as shown below:

Dok Krai Dam - Mab Ta Pud Route

Length:	27.6 km
Diameter:	1,350 mm
Wall thickness:	11.9 mm

Mab Ta Pud - Sattahip Route

Length:	21.9 km
Diameter:	1,000 mm
Wall thickness:	8.7 mm

Dok Krai Dam - Laem Chabang Route

Length: 53.0 km (including a tunnel)

Diameter	Length	Wall thickness
900 mm	24.5 km	7.9 mm
1,000 mm	13.0 km	8.7 mm
1,200 mm	6.5 km	11.1 mm

A tunnel of 9.0 km in length on the midway.

Owing to various conditions of terrain along Laem Chabang Route, three types of cross-section are employed to minimize the construction cost.

Steel was selected as the material for pipeline after comparative study among steel, ductile iron and reinforced concrete.

Booster Pump

1) Mab Ta Pud - Sattahip Route

Number of pumps	3 units (incl. 1 stand-by)
Capacity	32.7 m^3/min/unit
Total pump head	11 m
Motor output	150 kw

2) Dok Krai Dam - Laem Chabang Route

Number of pump	3 units (incl. 1 stand-by)
Capacity	30.3 m^3/min/unit
Total pump head	45.0 m
Motor output	600 kw

Air Chamber

As the head of pumps to be installed at Dok Krai Reservoir and Laem Chabang Route is considerably high, it is required to make clear the effects caused by the impact of water hammer and to study the necessary measures. Based on such investigation, construction of air chambers with total capacity of 120 m^3, consisting of three air chambers 40 m^3 each, is proposed (refer to Fig. 5-17).

Head Tank

The volume of water to be stored in the head tank is determined by a water level control switch operating the pump and by filling water in pipeline in case of power suspension.

Taking into consideration the convenience of maintenance as well as the capacity required for the minimum idle time, construction of three tanks consisting of two 3,000 m^3 each for Mab Ta Pud and Sattahip (refer to Fig. 5-18) and one 2,000 m^3 for Laem Chabang, is decided.

Receiving Well

The capacity of the receiving wells mentioned below is determined taking their 5-minute volume.

Mab Ta Pud	780 m^3
Sattahip	350 m^3
Laem Chabang	300 m^3

The general plan of receiving well is shown in Fig. 5-19.

5.1.3 Irrigation and Drainage System

Irrigation System

The work items included in the irrigation system are diversion weir at Rayong River, main canal, lateral canals and related facilities. Land consolidation is not included.

The main irrigation canal which is aligned along the hillside on the left bank of Rayong River has the total length of 46.2 km.

The maximum design velocity is controlled below 1.5 m/sec in order to secure the stable flow.

Main canal has an average gradient of 1/5,000 in general (1/3,000 in the downstream portion). It has an trapezoidal cross section, as shown in Fig. 5-20. Bottom width and freeboard in a main canal are fixed by discharge, as below:

Discharge (m^3/sec)	Bottom width (m)	Freeboard (m)
0 - 2.0	1.60	0.30
2.0 - 4.0	2.00	0.30
4.0 - 6.0	2.40	0.40
6.0 up	2.80	0.40

It is lined with a concrete thickness of 7 cm. Operation and maintenance service road of 5.0 m wide will be constructed along the canals.

Twelve lateral canals with a total length of 20 km are planned. They will be also trapezoidal and lined with concrete thickness of 5 cm. The free board of 0.15 m is taken for the lateral canals. Operation and maintenance road of 3.0 m wide will be constructed along the canals.

Drainage System

An earth canal is recommended for the drainage canal from the economic viewpoint. The alignment of the main drainage canal is so selected as to run through the lowest portion of the area.

The drainage canal has a length of 6.5 km and trapezoidal cross section with an average slope of 1/700 - 1/1,000 as shown Fig. 5-20.

The embankment slope of the main drainage canal is 1:1.5.

The operation and maintenance road with the 3.0 m wide is to be constructed.

5.2 BAN BUNG SUB-PROJECT

In Ban Bung Sub-Project, the design of dam and its related facilities is included in the scope of works.

Geology

The geology dominating the damsite and reservoir is granite based with superficial strata covered by alluvial deposit of mountain debris. Alluvium has deposited in the river bed and in the present reservoir.

The basement consists of coarse biotite-granite which has been reduced into either residual soil, decomposed granite or fresh rock depending on degree of weathering. Fresh rock is observed only in bore holes taken at the river bed.

The residual soil is so distributed that the deposit is thicker on the right bank than on the left ranging from 4 to 8 meters. The feature of the soil is that of clayey sand with N-value between 10 and 50.

Alluvial deposit carried over from surrounding highlands is mostly semi-compact fine grain sand and covers the residual soil deposited underneath. The layer is 1 to 3 meters thick and thicker at slopes.

Alluvium distribution in the valley comprises mainly of the clayey sand which is up to 7 meters thick. N-value is below 10 characterized by loose layer.

In addition to the above, small hill of slate may be observed which interfers with the granite.

Of the bed-rock in the dam site area, residual soil, decomposed granite and fresh rock are moderately impervious to impervious in permeability while the alluvium is permeable to semi-permeable.

Underground water level at the river bank is 1.0 meter below surface and at left and right side abutments, 2 to 3 meters below. The borrow pits are scheduled in both up and down streams of left and right abutment location. The material to be taken from the borrow pits is mainly clayey sand which is found in ample supply. As for the core material, a small hill of laterized surface layer located 2 km down-stream of dam site would be a good source.

Aggregates and rip-rap materials may be acquired in a large volume at a quarry of limestone 7.5 km south of Chon Buri. Another source is found in a hill of granite rock adjacent to the right bank of the dam site.

Geological map of Ban Bung Dam axis is shown in Fig. 5-21.

Dam

Earth-fill dam is chosen for this dam site, judging from its geology and the availability of construciton materials therein.

The proposed dam will be set on the impervious strata with the botton width of 6.0 m along the dam axis to prevent excessive leakage through foundation.

The principal features of the proposed dam will be as follows:

Dam Type	Earth-fill type with cut-off trench	
Crest elevation	EL.	86.3 m
Max. dam height		21.5 m
Crest length		2,800.0 m
Slope gradients	Upstream slope	1:3.0
	Downstream slope	1:2.5
Embankment volume		1.4 MCM

The slopes of the dam-body to both up and downstreams will be protected from erosion by providing rip-rap and sodding.

General plan, longitudinal profile, and standard cross section are shown in Figs. 5-22, 5-23 and 5-24.

Spillway

The design flood for spillway, 125 m^3/s at EL. 84.3 m (H.W.L.), has been determined from the dam design flood of 245 m^3/s, which is 1.2 times of 200-years probability flood, in consideration of regulation effectiveness of the reservoir.

Inflow and outflow hydrograph of the design flood for spillway is shown in Fig. 5-25.

The spillway comprises a center overflow weir without a control gate, a chute way and an energy dissipator of hydraulic jump type. The width of the weir for the spillway design flood is 20 m.

From the viewpoint of the dam site topography, the right bank of the river is the only place suitable for the location of the spillway.

The spillway has been aligned to minimize the total length. The total extent of the spillway including overflow weir, water conveyance portion and channel will be 250 m.

Plan and details of the spillway are shown in Figs. 5-26 and 5-27.

Intake and Outlet Facilities

The intake and outlet together with diversion conduit will serve to tap irrigation water for vested right and emergency drawdown of storage level of the reservoir.

Intake is of vertical tower type and the diversion conduit will be utilized as a part of outlet facility by narrowing its diameter with concrete after completion of the dam construction.

The maximum outflow volume is decided based on the capacity for emergency discharge of 7.0 m^3/s at normal water level and 5.0 m^3/s at low water level.

The discharge volume will be controlled by a valve (jet flow gate ϕ 1,000 mm) at the outlet. Another gate (slide gate ϕ 1,000 mm) will be provided just upstream of the jet flow gate for its maintenance.

The discharged water will be dissipated in the stilling basin and conveyed to the existing river.

Figs. 5-26 and 5-28 show the intake and outlet facilities.

Diversion Facilities

A diversion conduit will be built for smooth and safe execution of the construciton works of the dam together with appurtenant structures such as open channel and coffer dam.

The proposed diversion conduit is on the right side of the river. This location is the only one to be recommended as the site in view of the topography and geology.

The facilities are designed to be safe against the discharge released from the existing reservoir when 10 year probability flood occurs.

Land Acquisition and Road Relocation

A land of 2.7 km^2, at EL.85.3 m, 1 m above H.W.L., most of which is presently under cassava production, shall be acquired and 40 houses shall be evacuated for implemetation of the dam construction.

The relocated roads will be on the right bank of the reservoir with the total length of 3.7 km.

The existing and relocated roads are shown in Fig. 5-29.

CHAPTER - VI CONSTRUCTION PLAN AND COST

6.1 CONSTRUCTION PLAN

The construction plan is to be formulated taking availability of construction materials on the site, weather conditions, topographic and geologic conditions, etc. into consideration.

Wherever practically possible, mechanical execution of work is to be adhered to major items of the work.

6.1.1 Nong Pla Lai Sub-Project

Nong Pla Lai Dam

1) Construction Materials

a. Embankment Materials

Earth required for the construction of the dam is estimated at 3.20 MCM in total consisting of: core & shell: 2.83 MCM, filter: 0.12 MCM and rip-rap: 0.25 MCM.

The results of boring survey and field reconnaissance show that major construction materials, such as core & shell are found in abundance in the vicinity of the dam site, and no problem is expected in obtaining such materials. In this plan, the borrow pit is located at left and right bank abutments down-stream of the proposed dam site. A considerable volume of earth from the excavation of the dam foundation and spillway will be used for embankment materials after temporary storage during excavation.

For the filter material (drain material), sand obtained from the upper layer of the borrow pit is expected to be used. Prior to securing the earth for core and shell, this will be temporarily stored in the stockyard and then embanked in compliance with the required work schedule. Rip-rap material of rock is to be supplied from the local source.

b. Concrete Materials

The total amount required of concrete for spillway, intake, etc. is estimated at about 48,000 m^3. Coarse aggregate and fine aggregate are to be supplied from the local source.

Cement (12,000 tons) and reinforcement (3,000 tons) are to be supplied in a foreign currency portion.

2) Construction Equipments

Construction equipment to be used in the construction work consist of motor scraper, (Capacity: heaped 16 m^3) bulldozer (Capacity: 21 and 32 tons), wheel loader (Capacity: 3.3 m^3), Crawler loader (Capacity: 3.2 m^3), heavy dump truck (Capacity: 20 tons), etc. These construction equipment are prepared by the contractor.

3) Metal Plants

Metal plants consist of gates and valves for flood and of intake and outlet facilities, whose costs are covered by a foreign currency portion.

4) Construction Facilities

Such facilities as office, living quarters, storage house, motor pool, repair shop, form assembly, reinforcement fabrication, concrete batchig, water supply, power supply, temporary stockyard for aggregate and rip-rap materials, etc., and construction road of 6 km are required for the smooth execution of the construction work.

A part of the office will remain even after completion of construction of the dam and will be used permanently as a part of the administration office building.

5) Land Acquisition and Reloation

The existing road, about 17.3 km in length, will be relocated and about 200 houses will be evacuated. The area of 31.0 km^2 which include the impounding area of reservoir, dam site, borrow area and relocated road will be acquired for implementation of the dam construction.

6) Implementation Schedule

The implementation schedule of the dam is shown in Fig. 6-1.

Commencement of the detailed design works is scheduled in 1983, preparatory works in 1984, excavation in 1984, earth works in 1984, and completion is scheduled in 1986. The period of the said entire work is 48 months in total.

Water Transmission System

1) Construction Materials

a. Concrete and steel

An approximate quantity required of concrete, reinforcement and steel pipe is as shown below:

Route	Concrete	Reinforcement	Steel Pipe
	m^3	ton	ton
Dok Krai-Mab Ta Pud /1	4,500	500	9,500
Mab Ta Pud-Sattahip	500	100	4,700
Dok Krai-Laem Chabang	20,000	800	9,300
Total	25,000	1,400	23,500

The steel pipe of STPY 41 will be used and manufacture of the steel pipe is assumed to be done in Thailand.

b. Other materials

Machinery and equipment such as pumps, gates, valves, etc. are to be imported.

The number of pumps will be 6 units and each of them will have the capacity of 43.56 m^3/sec. equipped with 1,050 kW motor.

2) Construction Equipments

Construction equipment to be used in the construction works consist of backhoe (Capacity: 0.6m^3), heavy dump truck (Capacity: 11 tons), crawler crane (Capacity: 30 tons), etc. These construction equipments are prepared by the contractor.

3) Land Acquisition

The area of 40 ha in total will be acquired for the construction of head tank, receiving well and pipeline.

4) Implementation Schedule

The implementation schedule of the water transmission system is shown in Fig. 6-1.

The water transmission system is composed of three routes; Dok Krai-Mab Ta Pud, Mab Ta Pud-Sattahip, and Dok Krai-Laem Chabang. As for the route of Dok Krai-Mab Ta Pud, its detailed design works are scheduled to be started in 1981 and all construction works are scheduled to be completed in 1984, intending for the surplus water of Dok Krai Dam to be conveyed to the demand center in Mab Ta Pud.

/1; Including intake facilities.

As for other two routes, namely, Mab Ta Pud-Sattahip, and Dok Krai-Laem Chabang, their detailed design works are scheduled to be started in 1983 and construction works are scheduled to be completed in 1986, intending that Dok Krai Dam will supply water to Sattahip area via Mab Ta Pud through the expansion of pipeline system of Dok Krai-Mab Ta Pud and to Laem Chabang area through the pipeline system of Dok Krai-Laem Chabang.

Irrigation and Drainage System

1) Construction Materials and Equipments

The embankment materials of the main and lateral canals are to be provided by side borrow method and compacted by type-rollers after excavated, conveyed, then spreaded by bulldozers.

The excavation of the main canal is done by scrapers and trimming by graders. Besides, backhoes and mannual labor are used for the excavation works of lateral canals and drainage channels.

2) Implementation Schedule

The implementation schedule of irrigation and drainage system is shown in Fig. 6-1.

Commencement of the detailed design works is scheduled in 1983 intending that all construction works are completed in 1986 in order to supply water to the new irrigable area of 3,650 ha by Nong Pla Lai Dam. The period of the entire works is 48 months.

6.1.2 Ban Bung Sub-Project

Ban Bung Dam

1) Construction Materials

a. Embankment Materials

The total embankment volume is 1,400,000 m^3. The results of boring survey and field reconnaissance show that embankment materials are available in the vicinity of the dam site and no problem is anticipated in securing such materials both quality-wise and quantity-wise.

The quality of earth excavated for dam and spillway foundation may safely be assumed same as the one of the borrow area earth, therefore a part of the said excavated earth may be used for the dam body material after temporary storage.

For the filter material, sand obtained from the upper layer of the borrow area may be used. This will be temporarily stored in the stockyard before obtaining

the earth for the dam body material and then embarked in compliance with the required work schedule.

Rip-rap materials of rock are to be supplied from the local source.

b. Concrete Materials

Concrete for the construction of the Project is estimated at about 12,000 m^3.

Such concrete materials as aggregate (sand, gravel) and forms are supplied locally. The cement and reinforcement are to be supplied in a foreign currency portion.

2) Construction Equipment

Major equipment to be used in the construction of the Project consist of motor scraper (Capacity: heaped 16 m^3), bulldozer (Capacity: 21 & 32 t), wheel loader (Capacity: 3.2 m^3), crawler loader (Capacity: 3.3 m^3), power shovel & backhoe (Capacity: 2.0 m^3), heavy dump truck, etc.

The equipment mentioned above are prepared by the contractor.

3) Metal Plants

Gates and valves to be used for the intake and outlet are all supplied in a foreign currency portion.

4) Construction Facilities

Such facilities as office, living quarters, storage house, motor pool, repair shop, form assembly, reinforcement fabrication, concrete batchig, water supply, power supply, temporary stockyard for rip-rap materials and aggregates and etc., and construction handling road are required for the smooth execution of the construction work.

A part of the office will remain even after completion of construction of the dam and will be used permanently as a part of the administration office building.

5) Load Acquisition and Relocation

The existing road, about 3.7 km, will be relocated along the right bank of the dam and about 40 houses will be evacuated. The impounding area of the reservoir covering 2.7 km^2 will be acquired also for implementation of the dam construction.

6) Implementation

The construction schedule of the dam is shown in Fig. 6-2.

Commencement of the detailed design works is scheduled in 1983, preparatory works in 1984, earth works in 1984/1985, and completion is scheduled in 1986. The period of the said entire works is 43 months.

6.2 CONSTRUCTION COST

The estimated construction cost of Nong Pla Lai Sub-Project and Ban Bung Sub-Project is as follows:

Unit: Million US$

	F.C.	L.C.	Total
1. Nong Pla Lai Sub-Project			
Nong Pla Lai Dam	29.85	36.70	66.55
Water transmission	88.37	47.01	135.38
Irrigation & Drainage System	7.01	9.04	16.05
Sub-Total	125.23	92.75	217.98
2. Ban Bung Sub-Proejct			
Ban Bung Dam	12.47	11.12	23.59
Grand Total	137.70	103.87	241.57

The breakdown of the above estimated cost is shown in Tables 6-1 to 6-2.

The above mentioned costs include costs of main works, land acquisition and compensation, engineering services, contingency and interest to be paid during the construction.

Price escalation rate of 7% and 12% are adopted for foreign and local currency portions, respectively. 15% of physical contingencies is adopted for cost estimation of the work items excluding water transmission, in which 10% is considered.

The cost of construction equipment and metal material is estimated at CIF price plus duty and tax. Reinforcement bar, fuel and oil and cement are included in the foreign currency portion. Duty and imposts and miscellaneous local expenses are included in the local currency portion.

Interest during the construction period is only considered in the foreign currency portion. Interest rate is fixed at 3%.

All US$, Baht and Yen conversions are made on a US$1 = ฿23 = ¥230 basis.

CHAPTER VII - OPERATION AND MAINTENANCE

7.1 REQUIRED WORKS AND ORGANIZATION

The operation and maintenance for the project facilities aside from pipeline system will be undertaken by Royal Irrigaiton Department (RID) which is also to be the executing agency for the project construction works. As for the pipe line system, the agency for the operation and maintenance has not been established.

The personnel required for the operation and maintenance of Dok Krai Dam, Nong Pla Lai Dam, pipeline system, irrigation system and Ban Bung Dam is shown in Table 7-1 and its required works are described in the following chapter.

7.1.1 Nong Pla Lai Sub-Project

Before Completion of Nong Pla Lai Dam

1) Dok Krai Dam

The main works required for operation and maintenance of the Dam are as follows:

- Daily patrol and inspection of dam and reservoir
- Discharge operation for water demand
- Hydrology data collection and filing

2) Pipeline System

The main works required for operation and maintenance are as follows:

- Daily patrol and inspection of pipeline system
- Overall management of principal facilities
- Administration for water distribution

After Completion of Nong Pla Lai Dam

1) Dok Krai Dam

Dok Krai Dam will serve mainly for industrial and municipal demand at Rayong, Sattahip and Laem Chabang areas after completion of Nong Pla Lai Dam.

The main works of operation and maintenance are the same as before completion of Nong Pla Lai Dam. However, the personnel required will be added due to the increased supply areas.

2) Nong Pla Lai Dam

The main works of operation and maintenance are the same as those of Dok Krai Dam.

3) Irrigation System

The main works for operation and maintenance are as follows:

- Daily patrol an inspection of intake and irrigation canal
- Gate operation as for required intake volume
- Hydrology data collection and filing

4) Pipeline System

After completion of Nong Pla Lai Dam, Dok Krai Dam will supply water to Sattahip areas via Mab Ta Pud through the expansion of pipeline system mentioned foregoing and to Laem Chabang through pipeline system.

The works for operation and maintenance are the same as shown in "Before Completion of the Nong Pla Lai Dam Construction".

7.1.2 Ban Bung Sub-Project

After the completion of an expansion of Ban Bung Dam, storage capacity will increase 5 times as much as before.

The main works required for operation and maintenance are the same as those of Dok Krai Dam.

7.2 OPERATION AND MAINTENANCE COST

The annual required cost of operation and maintenance for dam and irrigation system is estimated at 0.48 million US$. As for the pipeline system, the annual cost of operation and maintenance is estimated at 1.41 million US$ which mainly counts for the electric energy consumed as the pumping power.

CHAPTER VIII - PROJECT EVALUATION

8.1 ECONOMIC EVALUATION

8.1.1 Economic Cost Estimation

Based on the preliminary designs, the economic construction cost was estimated in such a manner that all taxes, insurance cost, and compensation have been deducted. Estimation of costs required for equipment and engineering services, which are to be procured by international competitive bidding, is based on the international price levels. As to the labor cost, 70% of unskilled labor cost and 100% of skilled labor cost of the financial estimation has been adopted. Financial price has been adopted for the engineering service. Physical contingency of 10% and 15% has been considered for the water transmission system and other sectors, respectivelt. No price contingency is included. All economic prices shown are in February, 1981 fixed price.

Nong Pla Lai Sub-Project

For pipeline, three routes of Dok Krai - Mab Ta Pud, Mab Ta Pud - Sattahip, and Dok Krai - Laem Chabang are adopted as base case. The economic costs of Nong Pla Lai Sub-Project are shown below:

1) Construction Cost

The total economic construction cost is estimated to be 140.36 million US$, which can be classified by work item as follows:

Work Item	Cost (million US$)
Nong Pla Lai Dam	35.58
Water Transmission System	92.79
Irrigation and Drainage System	8.40
Land Consolidation	3.59
Total	140.36

Annual disbursement of the cost is presented in Tables 8-1 and 8-2 by work item.

2) Cost Allocation of Dam Construction Cost

The dam construction cost has been allocated by means of "Separable Cost - Remaining Benefit Method", as shown below:

Sector	Cost (million US$)
Flood Control	4.91
Industrial and Municipal Water	21.35
Irrigation	9.32
Total	35.58

3) Cost Estimate by Sector

Based on the above allocation of the dam construction cost, the total project economic cost can be further classified by each sector as follows:

Sector	Cost (million US$)
Flood Control	4.91
Water Transmission System	114.14
Irrigation	21.31
Total	140.36

4) Operation and Maintenance Cost

Operation and maintenance cost of Nong Pla Lai Dam and irrigation system is estimated to be 0.18 and 0.08 million US$ per year, respectively.

For pipelines (Dok Krai - Mab Ta Pud - Sattahip, Dok Krai - Laem Chabang), operation and maintenance cost is estimated to be 1.41 million US$ at full operation. This cost mainly consists of electricity cost of motors for pumping up the water.

Ban Bung Sub-Project

1) Construction Cost

The economic cost of Ban Bung Sub-Project which consists of only Ban Bung Dam is estimated at 14.23 million US$, whose annual disbursement is given in Table 8-1.

2) Allocation of Dam Construction Cost

In the same method as the Nong Pla Lai dam, the construction cost of Ban Bung dam can be allocated as follows:

Sector	Cost (million US$)
Flood Control	0.28
Industrial and Municipal Water	13.95
Total	14.23

3) Operation and Maintenance Cost

Operation and maintenance cost of Ban Bung Dam is estimated to be 0.10 million US$ per year.

8.1.2 Benefit Estimation

Value of Municipal and Industrial Water

Economic value has to be assigned to municipal and industrial water developed by the project to estimate the project benefit, although it is quite difficult to quantify the value in monetary terms.

In this study, the unit water value is assumed to be 5.0 ฿/m^3 for Nong Pla Lai Sub-Project and 7.0 ฿/m^3 for Ban Bung Dam Sub-Project in due consideration of willingness to pay as studied in the Supporting Report as well as the unit cost estimated under the condition that the cost covers all the capital cost including an interest of 9% per annum/1 and OM cost.

Nong Pla Lai Sub-Project

1) Municipal and Industrial Water

The direct benefit is calculated by multiplying the unit value with the water consumption volume.

Table 8-3 shows the annual water supply and benefit based on the water consumption volume by each year that has been already studied in 3.2.2 Estimated Future Water Demand.

The benefit for industrial and municipal water will be estimated to be 17.36 million US$/year in full operation stage in 1995 and thereafter.

2) Irrigation Benefit

The water developed by the proposed Nong Pla Lai Dam would be put to use for increment of paddy and groundnuts production. After the completion of the project, paddy production in a wet season will be much more assured than the present, and it will become possible to newly produce paddy and groundnuts in a dry season in areas of 975 ha and 1,945 ha, respectively.

Irrigation benefit is defined as an increase of net production value under the with- and without-the-project conditions. The net production value without the project would remain at approximately 41.32 million ฿ (1.80 million US$). On the other hand, the net projection value with the project will reach 120.36 million ฿ in a year (5.23 million US$), as detailed in Tables 8-4 to 8-6.

Note /1 This rate is generally applied to the loan of international banking facilities such as IBRD and ADB.

The benefit in the year 1993 (at the time the benefit comes up to full value) turns to be 79.04million ฿ (3.44 million US$). Assuming that the volume of water supply is 69.4 MCM, the benefit will be 1.14 ฿/m^3 (0.05 US$/$m^3$).

3) Flood Control

The economic benefit by the flood control is as stated before, 6.2 milion ฿ (0.27 million US$) on the annual average.

Ban Bung Sub-Project

1) Industrial and Municipal Water

The direct benefit will be estimated by multiplying the water value with volume of supplied water.

Table 8-7 shows the annual water supply and benefit.

The benefit for industrial and municipal water will be 2.04 million US$/year after 2000.

2) Flood Control

The economic benefit by the flood control is 0.32 million ฿ (0.01 million US$) on the annual average.

Indirect Benefit

1) Promotion of Industrial Development

Major industrial projects such as gas separation & petrochemical plant, soda ash plant, chemical fertilizer plant, sponge iron plant, industrial estate, deep sea port, etc. are planned to be implemented in the East Coast area in the future. This project will supply essential industrial water to these industrial projects, and will promote industrial development in this area.

2) Improvement of Living Standard

The population subject to new supply of municipal water by two sub-projects would total 250,000 to 300,000 persons, with expected per capita consumption of 320 l/day by 1993.

The present per capita water consumption of 220 l/day, therefore, would be enhanced by 100 l/day which is a substantial amount resultant to the improvement of living in the future.

Furthermore, the pervasion of waterworks being very limited in Ban Bung area, the supply is so unstable that the houses receiving the service have to have their own rain catcher and/or tank.

In the drought period of 1979-80, water tank lorries carried water to inhabitants almost daily. In the severest condition of drought days, the people themselves would go over to the water purification plant to dare unauthorized tapping. Stabilizing water supply to such area would undoubtedly bring about the betterment of the inhabitants' well-being.

3) Land Enhancement by Flood Control

The mitigation of flood in the area will bring about more effective use of land in the future.

8.1.3 Economic Evaluation

Evaluation of the project was made by means of calculating Internal Rate of Return on the basis of the estimated benefit and economic cost.

Nong Pla Lai Sub-Project

The Internal Rate of Return (IRR) of the Nong Pla Lai Sub-Project is calculated at 10.5%.

Internal Rate of Return has been further calculated for each sector based on cost estimate by sector which results in the following percentages.

Sector	IRR (%)
Industrial and Municipal Water	10.4
Irrigation	12.1
Flood Control	3.5
The Project	10.5

Ban Bung Sub-Project

From the economic cost and benefit calculated previously, the relation between cost and benefit of the industrial & municipal water supply at dam site and flood control are studied. The IRR of each sector is as follows:

Sector	IRR (%)
Industrial and Municipal Water	8.3
Flood Control	2.9
The Project	8.2

8.1.4 Sensitivity Analysis

Sensitivity analysis to identify the IRR's change in response to the changes of factors such as construction cost and delay of water demand has been done. Changing factors of each case and the results of IRR calculation are shown in Tables 8-8 and 8-9.

Nong Pla Lai Sub-Project

1) Construction Cost

In response to 10% and 20% increase of construction cost, IRR would decrease to 9.5% and 8.7%, respectively.

2) Delay of Water Demand by 10 Years

In case that the occurrence of water demand is assumed to be delayed by 10 years from the year 1995, benefit would decrease according to the delay. Consequently, IRR would be 8.6%, which is 1.9% less than the base case. Careful planning is therefore necessary to avoid providing a possible over-capacity beyond the actual water demand in this case.

Ban Bung Sub-Project

1) Construction Cost

In response to 10% and 20% increase of construction cost, IRR would decrease to 7.6% and 7.0%, respectively.

2) Delay of Water Demand by 10 Years

In case that the occurrence of water demand is assumed to be delayed by 10 years from the year 2000, benefit would decrease according to the delay. Consequently, IRR would be 7.0%, which is 1.2% less than the base case.

8.2 FINANCIAL EVALUATION

8.2.1 Financial Background of the Project

In Thailand, Royal Irrigation Department is in charge of the constructin of dam and irrigation system financed by national budget, but as a matter of custom, the collection of water tariff from farmers or land-owners for the irrigation water supply service is not carried out. The collection of water tariff is opposed by the National Assembly for the reason that the farmers do still not have the solvency, and present situation seems unlikely to be changed in the near future. Therefore, financial analysis for the development of irrigation water system is impossible.

On the other hand, the collection of water tariff for industrial and municipal water is put into practice. Therefore, the financial analysis of the pipeline and dam can afford to be discussed.

8.2.2 Financial Projections

For the financial analysis of industrail and municipal water supply system, financial projections are set up as follows.

Nong Pla Lai Sub-Project

1) Total Capital Requirement

According to the cost allocation, the construction cost of the dam for industrial and municipal water supply claims 60% of the construction cost of Nong Pla Lai Dam. The construction cost of the pipeline includes the routes of Dok Krai - Mab Ta Pud - Sattahip, and Dok krai - Laem Chabang. The total capital requirement will be 175.31 million US$, with 60.6% (106.27 million US$) of foreign portion and 39.4% (69.04 million US$) of local portion, as summarized below.

	Foreign Currency	Local Currency	Total
Dam (for ind.) (mil. US$)	17.91	22.02	39.93
Pipeline (mil. US$)	88.37	47.01	135.38
Total (mil. US$)	106.28	69.03	175.31

The annual disbursement of the total financial project cost is presented in Table 8-10.

2) Water Tariff

The water tariff is set up at 3.5 B/m^3 (0.152 US$/$m^3$) for both industrial and municipal water.

This tariff has been determined through the considerations of capital cost recovery and the houshold income, as studied in details in the Supporting Report.

3) Depreciation and Operation and Maintenance Cost

37 years will be adopted as an average depreciation period of dam and pipeline. Operation and maintenance cost is estimated as US$ 0.0180×10^6 and 0.410×10^6 for dam and pipeline respectively.

4) Loan Condition of Foreign Capital

The loan condition of foreign capital is assumed as below.

Interest rate	3%
Term of repayment	30 years
Grace period	10 years

Note; The conditions above are of the case of OECF.

Ban Bung Sub-Project

1) Total Capital Requirement

The construction cost of Ban Bung Dam is allocated by 98% to the sector of industrial and municipal water supply. The total capital requirement for this sector is estimated at 23.12 million US$, which is composed of 12.22 million US$ of foreign currency (52.8%) and 10.9 million US$ of local currency (47.2%). The annual disbursement of the total financial project cost is presented in Table 8-10.

2) Water Tariff

The water tariff is set up, same as Nong Pla Lai Sub-Project, at 3.5 ฿/m^3 (0.152 US$/$m^3$) for both industrial and municipal water. This tariff has been determined through the considerations of capital cost recovery and the houshold income, as studied in details in the Supporting Report.

3) Depreciation and Operation and Maintenance Cost

37 years will be adopted as an average depreciation period of dam and pipeline. Operation and maintenance cost is 100,000 US$/year at the time of full operation (after 2000).

4) Loan Condition of Foreign Capital

The loan condition of foreign capital is assumed to be same as Nong Pla Lai Sub-Project.

8.2.3 Financial Analysis

Nong Pla Lai Sub-Project

1) Income statement

Table 8-11 shows the income statement based on the financial conditions set up in 8.2.2. The revenue will accrue from 1984 when water supply is to be started. From 1987 both interest and depreciation

will start to be counted so that the profit will show a sharp decrease but thereafter it will gradually continue to increase. As the repayment of foreign currency will end by 2023, from 2024 annual profit will constantly be 7.21 million US$.

2) IRR Calculation

The calculation of Internal Rate of Return based on the Cash Flow (refer to Table 8-12) would be shown below.

IRR = 4.9%

Ban Bung Sub-Project

1) Income statement

Table 8-13 shows the income statement based on the financial conditions set up in 8.2.2. The revenue will accrue from 1987 when water supply is to be started. From 1990 both interest and depreciation will start to be counted so that the profit will show a sharp decrease but thereafter it will gradually continue to increase. As the repayment of foreign currency will end by 2017, from 2018 annual profit will constantly be 0.25 million US$.

2) IRR Calculation

The financial IRR of Ban Bung Sub-Project is calculated to be 1.8% (see Table 8-14).

8.2.4 Sensitivity Analysis

In the sensitivity analysis, it has been studied how a change in each single factor, namely water tariff, construction cost and water demand will affect IRR. Tariff factor is especially affective to IRR.

Sensitivity analyses for Nong Pla Lai and Ban Bung Sub-Projects are summarized in Tables 8-15 and 8-16.

8.3 ENVIRONMENTAL IMPACT EVALUATION

The National Environmental Board (NEB) responsible for supervising evaluation of new and previous projects for their possible threat to environment has come up with "The Manual of NEB Guidelines for Preparation of Environmental Impact Evaluation". The manual contains study items and their descriptions for evaluation of varied projects. Under "Dam and Reservoir" the study items contain four resources and values, which are subdivided for detailed investigation.

According to this guideline, the overall evaluation of the project including dams in two river sytems may be concluded as follows.

8.3.1 Physical Resources

Surface Water Hydrology

Basic calculation for water supply development has been conducted with previous discharge data. The annual runoff coefficient of the project area ranged between f=0.2 to 0.3. This relatively small figure of run-off is due to evaporation. The dam/reservoir has been planned as consecutive storage dam in which the reservoir becomes full almost in every other year.

Geology/Seismology

The geology of the proposed site for dam and reservoir is occupied by granite as base rock and alluvium spreads over the flood plain. Decomposed granite characterizes the damsite, and the geology is well secured for its bearing power and permeability as foundation for the proposed dam of 20 to 30 m high. The geology of the foundation for the pipeline to be laid out along the provincial highway R3191 also has not shown any problem. On the account of seismology, horizontal earthquake coefficient of 0.05 has been considered only for dams.

Soils

The soil has sandy characteristics with granite and sandstone as its base rock. Paddy field is covered by thick alluvium deposit with surface soil composed of loam, clay and clay loam. Dry field is covered by sandy soil with low humus content. In the agricultural development plan due consideration has to be given to the water and soil quality so as not to invite reduction in soil richness caused by continuous operation of irrigation.

Sedimentation/Erosion

The geology of the river basin comprises decomposed granite and sandstone with alluvium deposited in flood plain. Surface and bank erosion is the cause of rather heavy suspended sediment in water. However, no land collapse can

be observed in the basin. On the account of sedimentation in the reservoir, the samples of previous dams have been referred to and no serious impact is considered to deter orderly operation of dam.

Surface Water Quality

The water stored in reservoir is released through pipeline system and/or Rayong River which is presently not found to have any source of the contamination and as for the water contamination during coveyance from reservoir to demand centers, there may never exist any serious matter for the time being.

The water quality mentioned below concerns the water stored in reservoir.

The present water quality for proposed reservoir was analysed by JICA survey team based on the test of heavy metals and mineral constituents (refer to Tables 8-17 and 18). The RID has also carried out a series of water quality survey for Dok Krai Irrigation Project, approximately once a month since 1979 (refer to Table 8-19).

The above analysed data have been compared with standard of each water use for suitability, as below.

1) Municipal Water

World Health Organization (WHO) published the standard of the potable water quality (refer to Tables 8-20 to 8-22). When the survey results conducted by JICA survey team are compared with WHO standard, the content of TDS, Fe, Mn, Mg + Na, Cn and As surveyed in the project area have lower figures than WHO standard. The year-round survey results prepared by RID also show that Fe and Mg + Na content in the projec area are within the allowable limit. Judging from the aforesaid survey results compared with WHO standard, the water quality for proposed reservoir is assessed to be applicable to municipal water.

2) Irrigation Water

Items comparable with standard for irrigation supply water such as pH, Ec, Mn and As, indicated in Tables 8-17 and 8-18, and items pH and Ec from year-round survey data on Table 8-19, show that each value is far below the allowable limit, and thus is acceptable for irrigation.

3) Industrial Water

The main use of industrial water may be categorized into raw material, water cooling, product processing and product washing. The data acquired in the survey (Tables 8-18 and 8-19) show that all ingredients contained in the water surveyed in the project area are assessed never to pose any serious problems for the said use of industrial water.

As stated above, the survey results and year-round survey results show that water quality is acceptable for municipal, industrial and irrigation water.

The present condition of water quality of the reservoirs and the rivers is found to be clean enough for water supply, though there is no sewage treatment system in the catchment areas which is categorized as rural area. But the future development of municipalities and industries in the areas might possibly cause water contamination though not in near future.

8.3.2 Ecological Resources

Fisheries

As for freshwater fish, no commercial fishery of large scale exists in the project area. The fluctuation of year-round river discharge may be eased by reservoir and so any hindrance to growing fishes is not anticipated. A newly created reservoir may bring about recreational fishing.

As for salt water fish, fishing activity is very brisk around coast of Rayong city with concentration of fishing villages. Conspicuous urbanization induced by the project may invite pollution of sea water and call attention for protection of sea water fishes.

Fauna and Flora

No rare species to be protected exist in the project area. Although some fauna and flora might be submerged, the impact would be slight.

8.3.3 Human Use Values

Water Supply

Newly developed volume of 116 MCM/year approx. will be supplied to Rayong, Sattahip and Laem Chabang areas for municipal and much required industrial requirement.

The water will also irrigate the newly developed tract of 3,650 ha in the middle reaches of Rayong River.

Flood Control

The diminished flood discharge by the regulation of Nong Pla Lai and Ban Bung dams will contribute to mitigating flood damage and securing well-being of inhabitants. Further river improvement works are necessary to cope with the limited flow capacity of streams at present.

8.3.4 Quality of Life Values

Socio-Economy

Since the project area is located in a very significant place for development of Thailand as a whole, the water resources development project will have great influence on socio-economy of the nation.

Resettlement and Compensation

The properties that would inevitably be resettled by construction of dam, reservoir and pipe line will be compensated either by payment of equal value money or alternative land lots equipped with infrastructures. The compensation matter is to be discussed further for the best available means.

Construction

Any foreseeable impacts by construction have to be studied well in line with the construction schedule. The implementation is to be carried out in the way that would minimize the adverse effect to environment.