JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES
KINGDOM OF THAILAND

THE DETAILED DESIGN STUDY ON THE BANG PAKONG DIVERSION DAM PROJECT

DETAILED DESIGN REPORT

MAIN REPORT

NOVEMBER 1993

SANYU CONSULTANTS INC.

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PREFACE

In response to a request from the Government of Kingdom of Thailand, the Government of Japan decided to conduct a detailed design study on the Bang Pakong Diversion Dam Project and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Dr. Jun'ichi Kitamura, Sanyu Consultants Inc., 3 times between October, 1992 and November, 1993.

The team held discussions with the officials concerned of the Government of Kingdom of Thailand, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

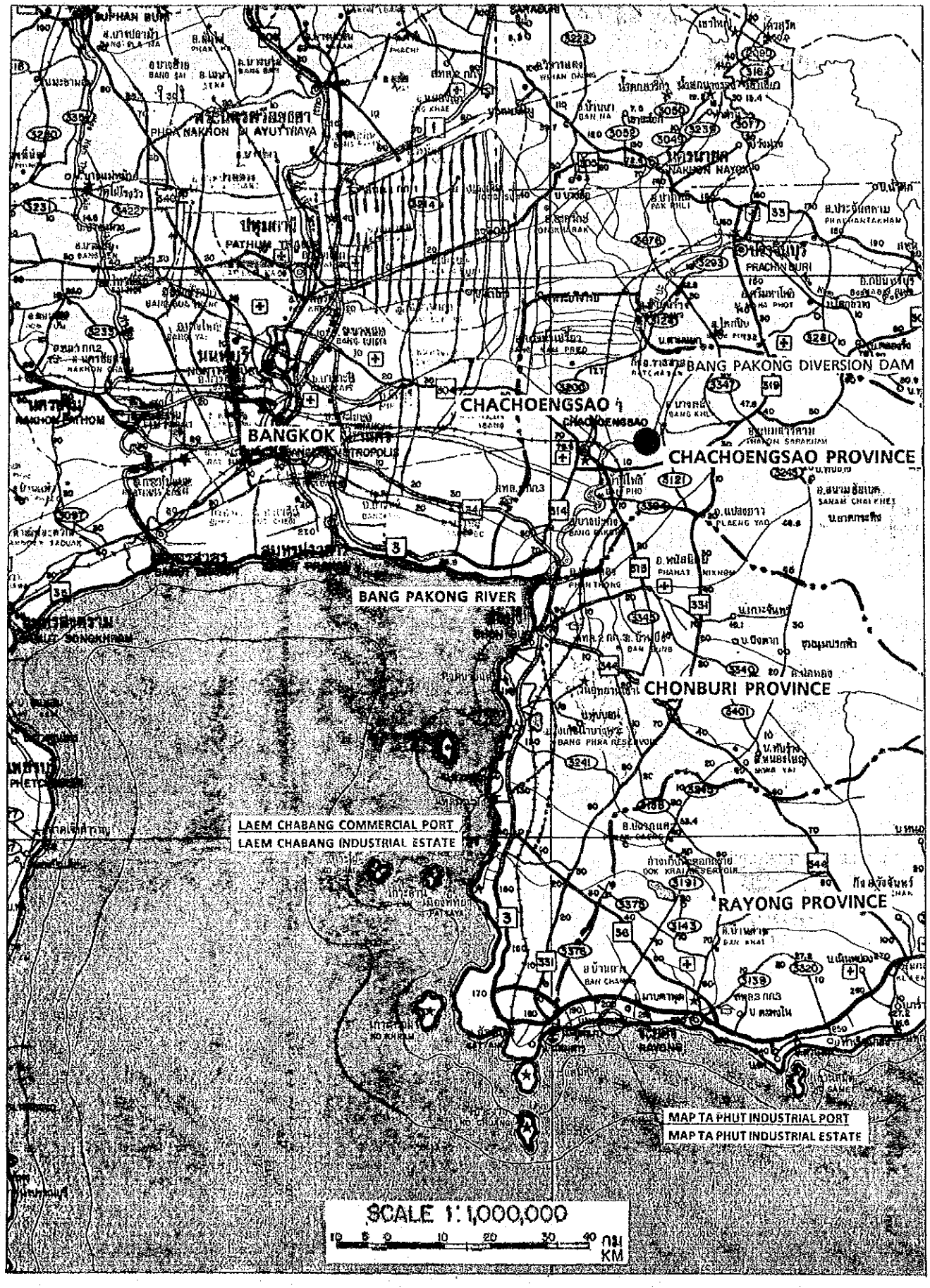
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

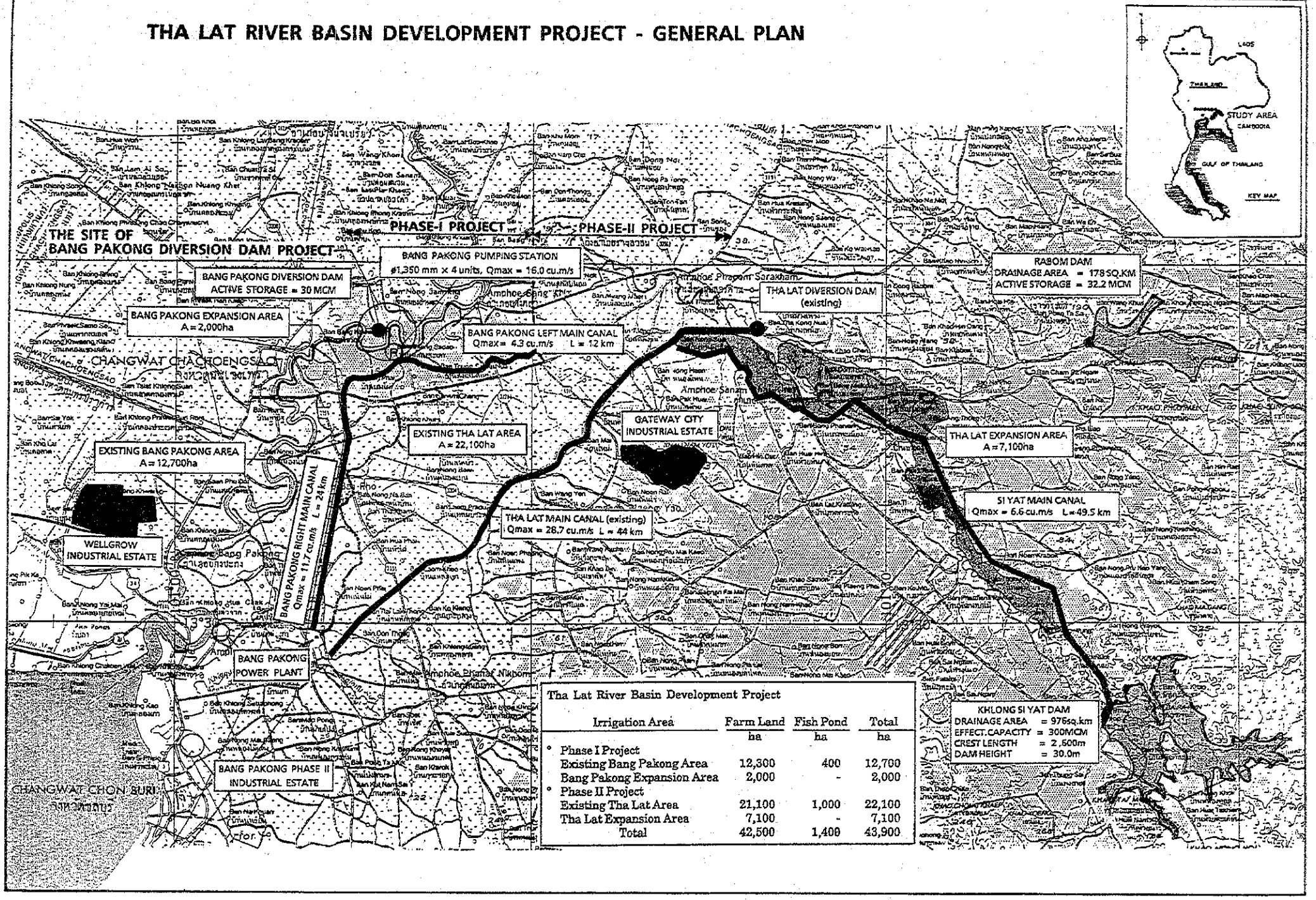
Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

LOCATION MAP



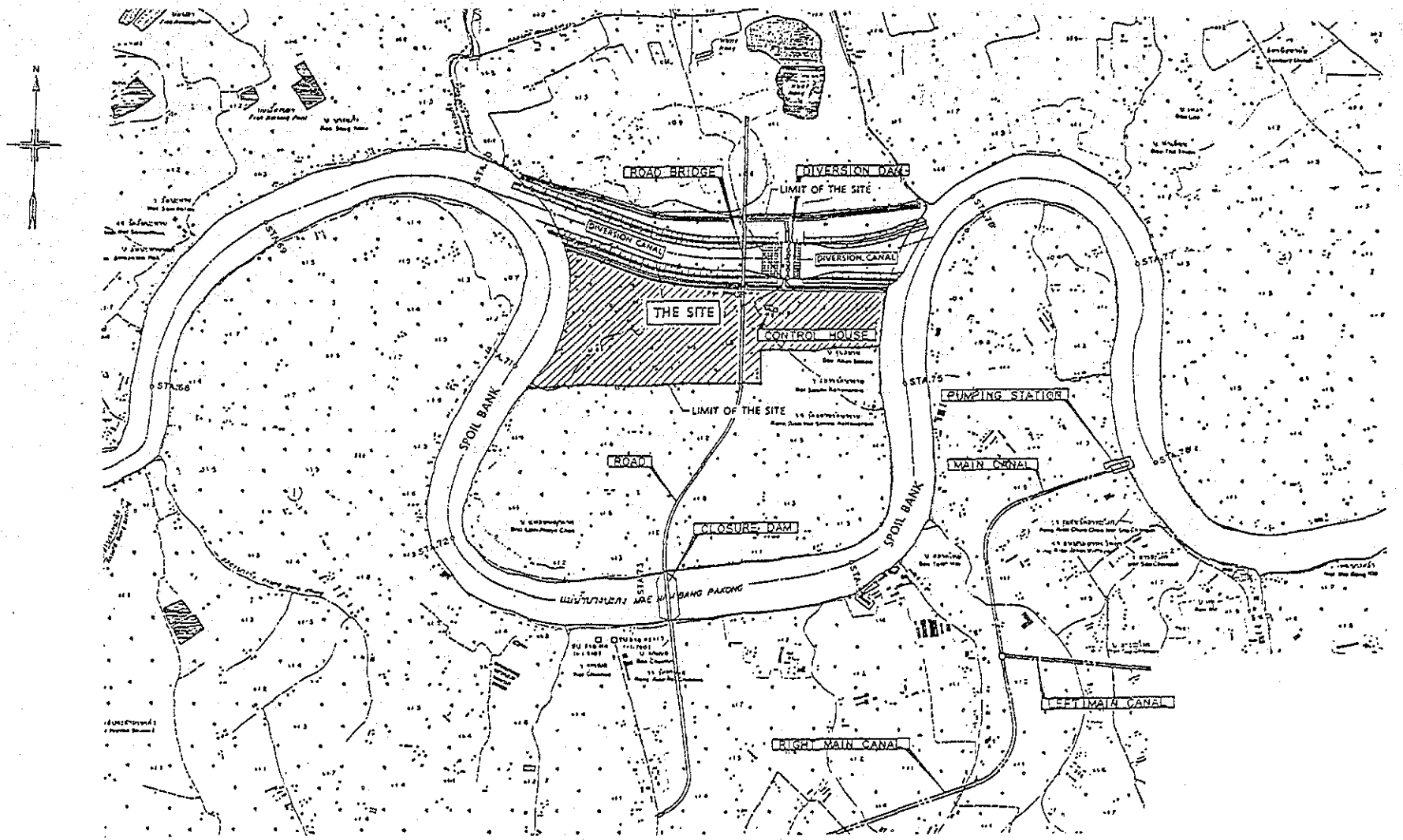
THA LAT RIVER BASIN DEVELOPMENT PROJECT - GENERAL PLAN

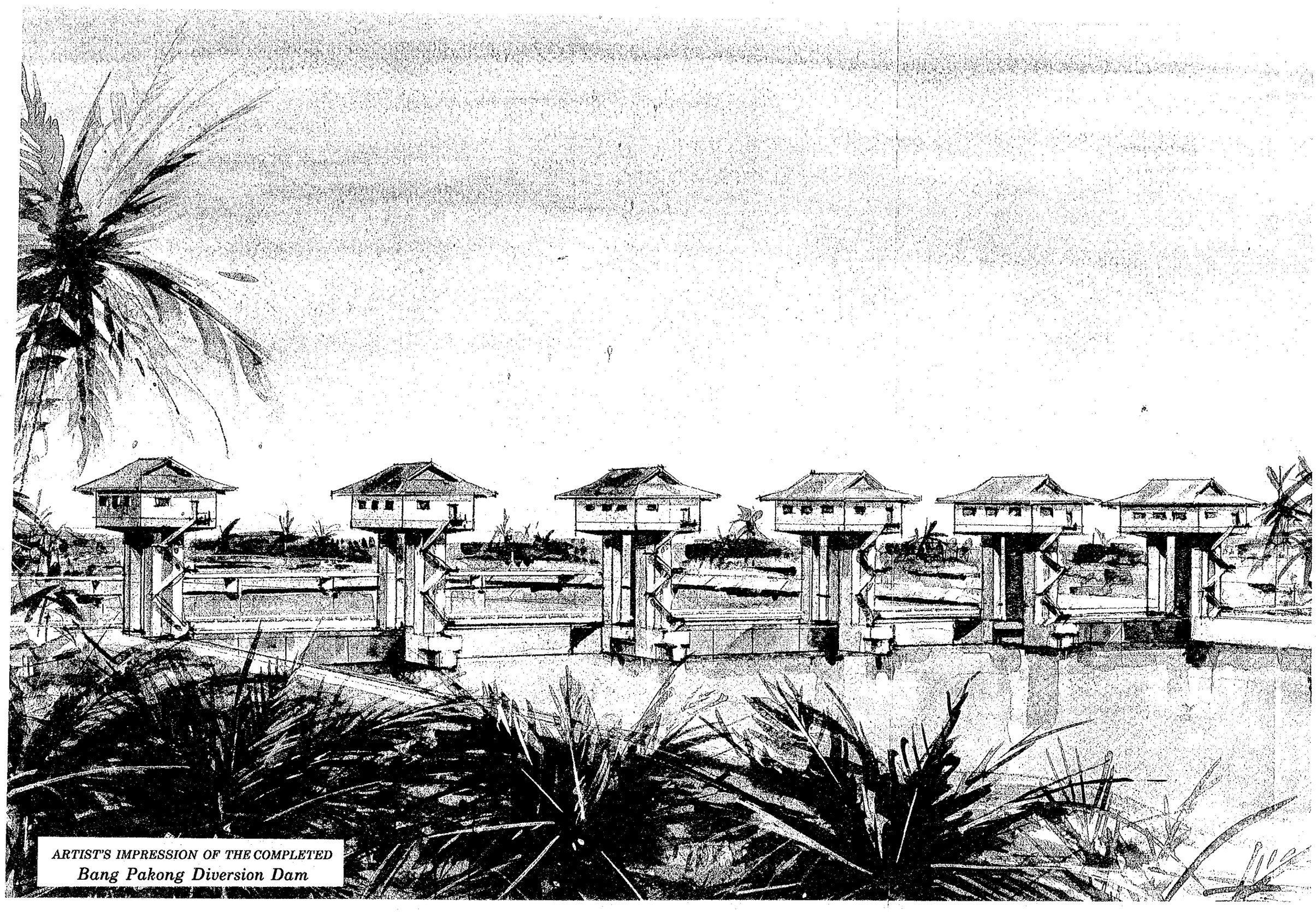


Tha Lat River Basin Development Project

Irrigation Area	Farm Land	Fish Pond	Total
	ha	ha	ha
° Phase I Project			
Existing Bang Pakong Area	12,300	400	12,700
Bang Pakong Expansion Area	2,000	-	2,000
° Phase II Project			
Existing Tha Lat Area	21,100	1,000	22,100
Tha Lat Expansion Area	7,100	-	7,100
Total	42,500	1,400	43,900

BANG PAKONG DIVERSION DAM PROJECT - GENERAL PLAN





ARTIST'S IMPRESSION OF THE COMPLETED
Bang Pakong Diversion Dam

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ABBREVIATIONS AND ACRONYMS USED

THAI GOVERNMENT

DOH	:	Department of Highway, MOC
DTEC	:	Department of Technical and Economic Cooperative
HD	:	Harbor Department, MOC
LDD	:	Livestock Development Department, MOAC
MD	:	Meteorological Department, MOC
MOAC	:	Ministry of Agriculture and Cooperatives
MOC	:	Ministry of Communications
MOI	:	Ministry of Industry
MOSTE	:	Ministry of Science, Technology and Environment
NEB	:	National Environment Board
NESDB	:	Office of National Economic and Social Development Board, Office of the Prime Minister
OEPP	:	Office of Environmental Policy and Planning
ONEB	:	Office of National Environment Board
PEA	:	Provincial Electricity Authority, Ministry of Interior
PWA	:	Provincial Waterworks Authority, Ministry of Interior
RID	:	Royal Irrigation Department, MOAC
RTSD	:	Royal Thai Survey Department
TOT	:	Telephone Organization of Thailand

GENERAL

B	:	Baht
BM	:	Bench Mark
EIRR	:	Economic Internal Rate of Return
EL	:	Elevation above Mean Sea Level
JICA	:	Japan International Cooperation Agency
M.	:	Million
W. L	:	Water Level
cu.m, m^3	:	Cubic meters
MCM	:	Million cubic meters
kw	:	Kilowatt
kwH	:	Kilowatt hour
l	:	Liter
ha	:	Hectare
m	:	Meter
kg	:	Kilograms
km	:	Kilometer
sq.km, km^2	:	Square kilometers
sq.m, m^2	:	Square meters
ton	:	Metric ton

p. a.	:	per annum
Yr.	:	Year
hr	:	Hour
min	:	Minute
sec	:	Second
°C	:	Degree Centigrade
HP	:	Horsepower
PS	:	French Horsepower
ppt	:	part per thousand
P. C.	:	Prestressed Concrete
R. C.	:	Reinforced Concrete
ITV	:	Industrial television system

GLOSSARY

Changwat	:	Province
Ampoe	:	District
Tambon	:	Sub-District
Muban	:	Village
Mae Nam	:	A large river
Sungai	:	A medium-sized river
Khlong	:	A tributary of the large river

THAI FISCAL YEAR

October 1 to September 30, next year

THAI WATER YEAR

April 1 to March 31, next year

PART - I. INTRODUCTION

CHAPTER 1. BACKGROUND OF THE STUDY

Bang Pakong river is one of Thailand's larger rivers with a drainage area of 17,660 sq.km and an average annual runoff of 7,900 MCM. It flows down through Chachoengsao Province situated north of the Eastern Seaboard Development Area and adjoining the eastern margin of the Bangkok Metropolitan Area.

In Chonburi and Rayon Provinces in the Eastern Seaboard Development Area, and in the Bangkok Metropolitan Area, there is nowhere that further development of water resources could be carried out on a large scale. In the proximity of these two areas regarded as the industrial and economic centers of Thailand, the Bang Pakong river passing through Chachoengsao Province is the only river leaving undeveloped water resources in the drainage area and allowing future development of water resources on a large scale.

The Bang Pakong river, however, is a tidal river, and sea water usually comes 120 km up the estuary in the dry season with small river runoff. Therefore, the construction of a diversion dam to prevent sea water intrusion will be essential for efficient utilization of the river water.

Paddy cultivation is made in the wet season, but the farmers frequently suffer from drought resulting in a low income level. There is no cultivation in the dry season because few storage dams have been built.

In the lowest area of the Bang Pakong river basin, very favourably located 40 - 50 km both from the Bangkok Metropolitan Area and from the commercial port of Laem Chabang, and well-treated as the second area of investment promotion, factory and industrial estate construction is flourishing. The total estate area has already surpassed the areas of Map Ta Phut Industrial Estate and Laem Chabang Industrial Estate which are typical industrial estates in the Eastern Seaboard Development Area. However, the necessary domestic and industrial water is supplied under very unstable conditions from the terminal irrigation canals. Considering the present agriculture in the basin and the domestic and industrial water supply conditions for the factories and industrial estates constructed in and around the

lowest area of the Bang Pakong river basin, the water resources development project in the Bang Pakong river basin, which aims to introduce irrigated agriculture in order to raise the farmers' income and to secure the domestic and industrial waters, is very urgent and indispensable. It is to be promoted as a top priority national development project.

In 1988 the Thai Government requested the Japanese Government to prepare a master plan for an agricultural water utilization development project for the Bang Pakong river basin and to conduct a feasibility study of the area selected for such a project. The Government of Japan agreed to the study which was carried out by JICA from 1989 to 1990. The final report was presented to the Thai Government in October 1990.

According to this report, the development plan for the overall river basin is to secure a total of 3,950 MCM of water, including 3,610 MCM of irrigation water for 410 thousand ha, 320 MCM of domestic and industrial water and 20 MCM of water for fisheries. In order to ensure the water to be developed, construction of 12 storage dams with active storage capacities of 2,260 MCM in total, effective use of the existing Rabom dam with an active storage capacity of 40 MCM and construction of the Bang Pakong diversion dam are proposed. The project on which the feasibility study was carried out is the Tha Lat river basin development project aiming at strengthening water utilization for 42,500 ha of agricultural land in the lower area of the Bang Pakong river basin and securing domestic and industrial water, both of which are in high demand.

The project area of the Tha Lat River Basin Development Project is classified into two sub-areas, one area to be supplied water from the Khlong Si Yat dam and the other area to be supplied water from the Bang Pakong diversion dam, according to the difference of main water sources.

At the time of project implementation, construction works are divided into Phase I and II according to urgency. The area to be supplied water from the Bang Pakong diversion dam will be developed first as the Phase I project and subsequently the area to be supplied water from Khlong Si Yat dam will be developed as the Phase II project.

The project facilities required for satisfying the Phase I project are as follows:

TABLE 1-1 PHASE I PROJECT FACILITIES

Facilities	Facilities Scale	Project Executing Body
① Bang Pakong Diversion Dam	166 m in length	RID
② Appurtenant Facilities		RID
(a) Diversion Canal	approx. 2,200 m in length	
(b) Closure Dam	approx. 280 m in crest length	
(c) Road	approx. 2,700 m in length	
(d) Road Bridge	approx. 227 m in length	
(e) O/M Building	approx. 60 ha building site	
③ Irrigation Facilities		RID
(a) Pumping Station	240 cu.m/min × 4 units	
(b) Irrigation Canal	36 km in length	
(c) Drainage Canal	30 km in length	
④ Purification Plants and Distribution Facilities for Domestic and Industrial Water	Annual water supply amount: 66.5 MCM (net)	PWA

Of the facilities to be constructed by RID, the Government of Thailand requested the Government of Japan to prepare a detailed design study for ① Bang Pakong diversion dam, ② Appurtenant facilities and Pumping station listed in ③ Irrigation facilities in June 1991, JICA is due to carry out this study.

The Government of Thailand entrusted the implementation of an Environmental Impact Assessment of the project area to a third party, Kasetsart University. They started in July 1991 and submitted the draft report on the environmental impact assessment of the Bang Pakong Diversion Dam Project in March 1992.

After receiving the report, the Government of Japan dispatched a preparatory study team for the detailed design of the Bang Pakong Diversion Dam Project in April 1992. The study team confirmed the Thai government's conclusions drawn from the contents and results of the environmental impact assessment conducted by Kasetsart University, and discussed the JICA detailed design study implementation with the government. The scope of work (S/W) for the detailed design study was then agreed upon and signed by RID and JICA Thai Office in July 1992. According to the S/W, JICA organized and dispatched a study team to the Kingdom of Thailand to commence the detailed design study in October 1992.

CHAPTER 2. OBJECTIVES OF THE STUDY

The objectives of the study are to carry out a detailed design on the Bang Pakong diversion dam and pumping station as shown in the study reports on the Agricultural Water Development Project of Bang Pakong River Basin, for which a study of the Project was made between September 1989 and October 1990 by the JICA Study Team.

The study on the Bang Pakong Diversion Dam Project is composed of Phase I study and Phase II study, and is to be completed in two years. The objectives of the study are to prepare the basic design reports and prequalification document for the Phase I study, and detailed design reports and bidding documents for the Phase II study.

In addition, the technology transfer from the JICA study team to its Thai counterparts will be made during the course of the study.

CHAPTER 3. REPORTS

The Phase I study is to be included in the following volumes;

(1) Basic Design Report - Main Report
(2) Basic Design Report - Drawings
(3) Basic Design Report - Appendix
(4) Prequalification Documents
(5) Evaluation Criteria for Prequalification Documents

The Phase II study is to be included in the following volumes;

(1) Detailed Design Report - Main Report
(2) Detailed Design Report - Appendix
(3) Bidding Documents Volume I : Instructions to Bidders

A. Invitation to Bid
B. Instructions to Bidders
C. Supplementary Instructions to Bidders
D. Form of Bid

E. Annexes to Form of Bid
F. Form of Bid Security

(4) Bidding Documents Volume II : Conditions of Contract

G. Form of Contract
H. Conditions of Contract
I. Supplementary Conditions of Contract
J. Form of Performance Security
K. Form of Advance Payment Security
L. Form of Retention Money Security

(5) Bidding Documents Volume III : Specifications (Part-1 Main Works)
(6) Bidding Documents Volume IV : Contract Drawings (Part-1 Main Works)
(7) Bidding Documents Volume V : Bill of Quantities (Part-1 Main Works)

The bidding documents volume III Specifications (Part-2 Building Works), volume IV Contract Drawings (Part-2 Building Works) and volume V Bill of Quantities (Part-2 Building Works), which are to be required for O/M building construction, will be provided by RID.

CHAPTER 4. ORGANIZATION OF THE STUDY

JICA organized the study team to carry out the detailed design study and RID organized the advisory committee and the working group to facilitate the smooth conduct of the study.

(1) JICA Study Team

1)	Dr. Jun'ichi KITAMURA	Team Leader
2)	Mr. Satoshi SHOJI	Hydrological & Hydraulic Analysis (1)
3)	Mr. Noriaki TAKEDA	Hydrological & Hydraulic Analysis (2)
4)	Mr. Kazuyoshi OHSAWA	Geology and Soil Mechanics
5)	Mr. Takeshi MATSUNAMI	Environmental Considerations (1)
6)	Mrs. Vipa PUNPRAW	Environmental Considerations (2)

	7)	Mr. Hiroshi MORIYAMA	Design (1) / Co-Team Leader (Diversion Dam & Closure Dam)
●	8)	Mr. Kiyonori HAYASHI	Design (2) (Diversion Dam & Diversion Canal)
	9)	Mr. Fumihiko KOMADA	Design (3) (Road & Road Bridge)
●	10)	Mr. Futoshi KUROMI	Design (4) (Assistant of Design (3) & (5))
	11)	Mr. Eiji ADACHI	DESIGN (5) (Pumping Station)
●	12)	Mr. Harumitsu NISHITANI	Mechanical & Electrical Facilities Design (1)
	13)	Mr. Hideo KOIZUMI	Mechanical & Electrical Facilities Design (2)
	14)	Mr. Masao SENJU	Building Design (1)
	15)	Mr. Alongkorn TRACHOO	Building Design (2)
	16)	Mr. Tsunesuke HIWATASHI	Control System Design
	17)	Mr. Etsuji TANAKA	Construction Planning
●	18)	Mr. Takashi KATSU	Construction Cost Estimation
	19)	Mr. Satoshi USUKI	Bidding Documents
	20)	Mr. Kazuo OHTSUBO	Specifications (1)
	21)	Mr. Jiro KAWAI	Specifications (2)
	22)	Miss Sachie OIKAWA	Coordination

●: Home Office Work only.

(2) RID Advisory Committee

Name	Section
Chairman	
1) Mr. Chamroon Chindasanguan	Deputy Director General for Engineering
Committee	
2) Mr. Sawet Yasaravana	Director of design Division
3) Mr. Narong Sopak	Director of Topographical Survey Division
4) Mr. Chaiwat Prechawit	Director of Geotechnical Division
5) Mr. Prasert Milintangul	Director of Hydrology Division
Committee and Secretary	
2) Mr. Sanan Sirion	Director of Bang Pakong River Basin Development Project Office

(3) RID Working Group

Name	Section
Chairman	
1) Mr. Montri Onvimol	Bang Pakong River Basin development Project Office
Staff	
2) Mr. Vorapote Nandhanapote	Hydrology Division
3) Mr. Wichit Udomrattanasiri	Design Division
4) Mr. Rang Champanoi	Topographical Survey Division
5) Mr. Rungroj Chumthong	Geotechnical Division
6) Mr. Suwit Thanopanuwat	Project Planning Division
7) Mr. Phitak Paksanond	Foreign Finance Project Administration Division
8) Mr. manop Boonyaprasit	Bang Pakong River Basin development Project Office
Staff and Secretary	
9) Mrs. Neowarat Damrongsak	Bang Pakong River Basin Development Project Office

PART - II. THA LAT RIVER BASIN DEVELOPMENT PHASE I PROJECT

CHAPTER 1. OUTLINE OF THE PROJECT

1.1 Objectives of the Project

Tha Lat River Basin Development Project aims at water supply for irrigation, domestic use, industrial use and fish culture, and is to be developed in two phases of implementation, Phase I project and Phase II project, as shown in Table 1-1.

TABLE 1-1 OBJECTIVES OF THA LAT RIVER BASIN DEVELOPMENT PROJECT

Objectives	Phase I	Phase I + II
(1) Irrigation		
a) Irrigation Service Area		
Existing Bang Pakong Area	12,300 ha	12,300 ha
Bang Pakong Expansion Area	2,000 ha	2,000 ha
Existing Tha Lat Area	-	21,100 ha
Tha Lat Expansion Area	-	7,100 ha
Total	14,300 ha	42,500 ha
b) Cropping Intensity	150 %	150 %
(2) Domestic Water Supply : annual demand	18.9 MCM	32.3 MCM
(3) Industrial Water Supply : annual demand	69.7 MCM	89.7 MCM
(4) Fish Culture Water Supply		
a) freshwater fish culture	400 ha	1,400 ha
b) Shrimp culture	980 ha	980 ha
(5) Compensatory Water Supply for Agriculture in Bang Pakong Right Bank Area during dry season	-	104.4 MCM
(6) Surplus Water : annual amount	60 MCM	90 MCM

1.2 Project Facilities and Allocation of Construction Works

The project facilities of the Tha Lat River Basin Development Project are shown in Table 1-2. In the project facilities of Phase I project, the Bang Pakong diversion dam, the appurtenant facilities and irrigation facilities will be constructed under the control of RID and the facilities for domestic and industrial water supplies will be constructed under the control of PWA. All of the project facilities of Phase II project will be constructed under the control of RID.

The construction works of the project facilities to be constructed under the control of RID in the Tha Lat River Basin Development Project are divided into four construction works as shown in Table 1-3.

TABLE 1-2 PROJECT FACILITIES OF THA LAT RIVER BASIN DEVELOPMENT PROJECT

1. Phase I Project

1) Dam and Diversion Dam (Executing Body : RID)
   a) Rabom Dam (Existing) ..... Storage Dam, Active Storage 32.2 MCM
   b) Bang Pakong Diversion Dam & Its Appurtenant Facilities
   - Bang Pakong Diversion Dam ..... Active Storage 30 MCM, 30 m × 5 spans
   - Diversion Canal ..... about 2.2 km in length
   - Closure Dam ..... about 280 m in crest length
   - Road & Road Bridge ..... about 2.7 km in road length, about 227 m in road bridge length
   - O/M Buildings ..... about 60 ha in building lot

2) Irrigation Facilities (Executing Body : RID)
   a) Pumping Station ..... Pump Discharge 16 m^3/sec (960 m^3/min) ϕ1,350 mm × 4 units
   b) Main Irrigation Canal ..... 36 km in length
   c) Drainage Canal ..... 30 km in length

3) Facilities for Domestic and Industrial Water Supplies (Executing Body : PWA)
   - Net Amount of Annual Water Supply . 66.5 MCM (8,860 MCM × 0.75)

2. Phase II Project

1) Dam and Diversion Dam (Executing Body : RID)
   a) Khlong Si Yat Dam ..... Storage Dam, Active Storage 300 MCM
   b) Tha Lat Diversion Dam ..... Improvement of Existing Diversion Dam

2) Irrigation Facilities (Executing Body : RID)
   - Main Irrigation Canal ..... Improvement : 44 km
     New Construction : 50 km

Note : This table does not show farm facilities.

TABLE 1-3 ALLOCATION OF CONSTRUCTION WORKS OF RID's PROJECT FACILITIES

Construction Works	Details of Works
Phase I Project	
① Bang Pakong Diversion Dam Project	Construction of Bang Pakong Diversion Dam, its Appurtenant Facilities and Pumping Station
② Phase I Irrigation and Drainage Canals Project	Construction of Irrigation and Drainage Canals in Existing Bang Pakong Area and Bang Pakong Expansion Area
Phase II Project	
③ Khlong Si Yat Dam Project	Construction of Khlong Si Yat Dam
④ Phase II Irrigation Canal Project	Improvement of Existing Tha Lat Diversion Dam, Improvement and Construction of Irrigation Canals in Existing Tha Lat Area and Tha Lat Expansion Area

CHAPTER 2. PRESENT CONDITIONS OF THE PROJECT AREA

2.1 Location

As shown in Figure 2-1, the Tha Lat River Basin Development Phase I project has an irrigation service area of 14,300 ha situated on the left bank of the lower area of the Bang Pakong river basin and a service area of domestic and industrial water supplies situated along main roads Nos. 304, 314 and 34.

The project area exists mainly in Chacheongsao province with a part of the project area belonging to Chonburi province. Chacheongsao province is located in the north part of the Eastern Seaboard Development Area and adjoins the eastern margin of the Bangkok Metropolitan Area. The project area has an elevation of 0.8 meters to 1.5 meters on a flat alluvial plain.

2.2 Climate

The climate over the lower area of the Bang Pakong river basin is tropical and monsoonal. Two distinct seasons, the dry season with a northeast monsoon from November to April and the wet season with a southwest monsoon from May to October, are recognized in the area.

Annual rainfall during the past twenty years has ranged widely from a minimum of 880 mm in 1979 to a maximum of 1,660 mm in 1983, with 1,240 mm on an average. The peak of the wet season generally falls in September.

Temperature shows slight seasonal variation between a minimum of 26.2 °C in December and a maximum of 29.8°C in April, while the minimum relative humidity is recorded in December at 68% and the maximum in October at 81%.

Major climate features observed at the Chacheongsao station are summarized as shown in Figure 2-2.

FIGURE 2-1 THA LAT RIVER BASIN DEVELOPMENT PHASE I PROJECT - GENERAL PLAN

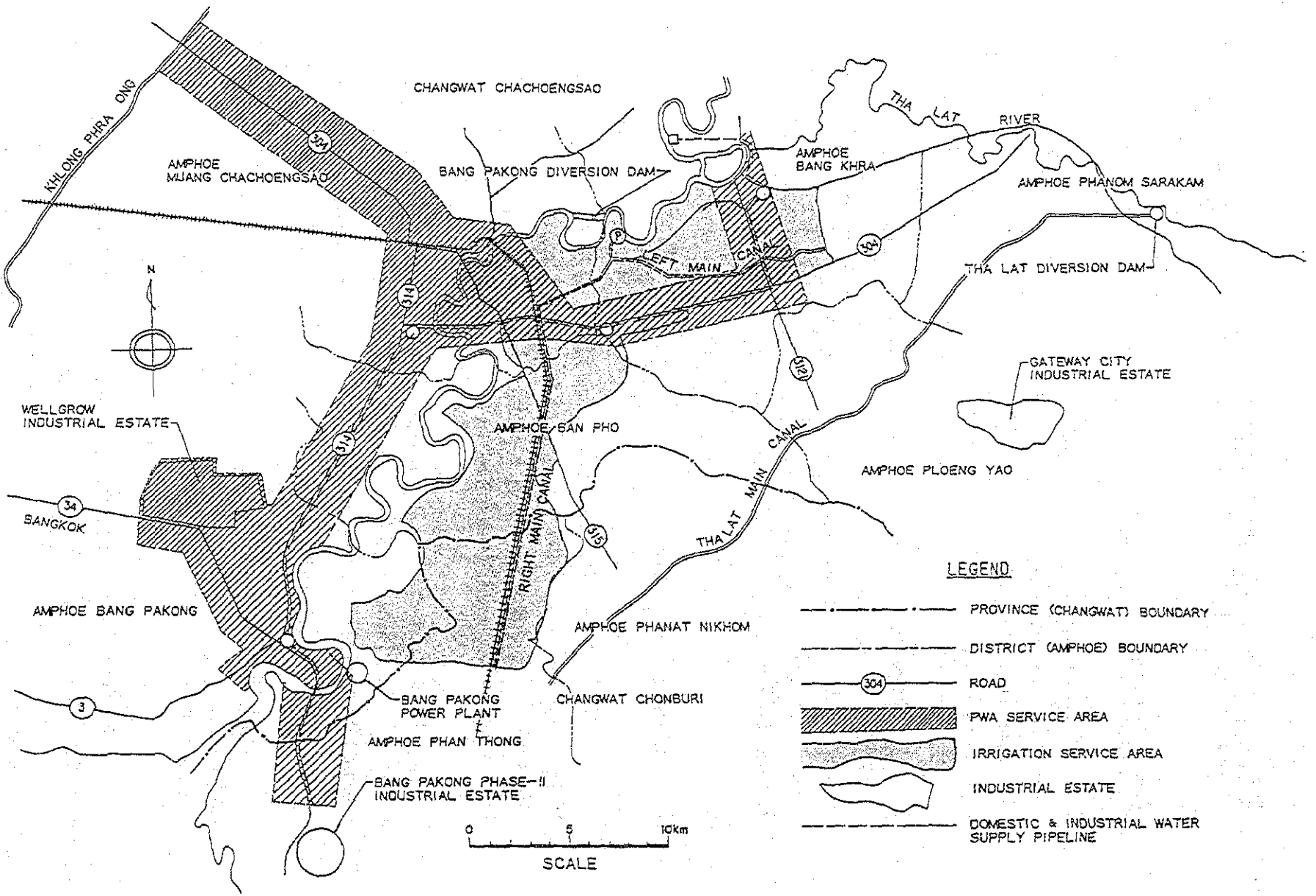


FIGURE 2-2 CLIMATIC CHARACTERISTICS AT CHACHOENGSAO

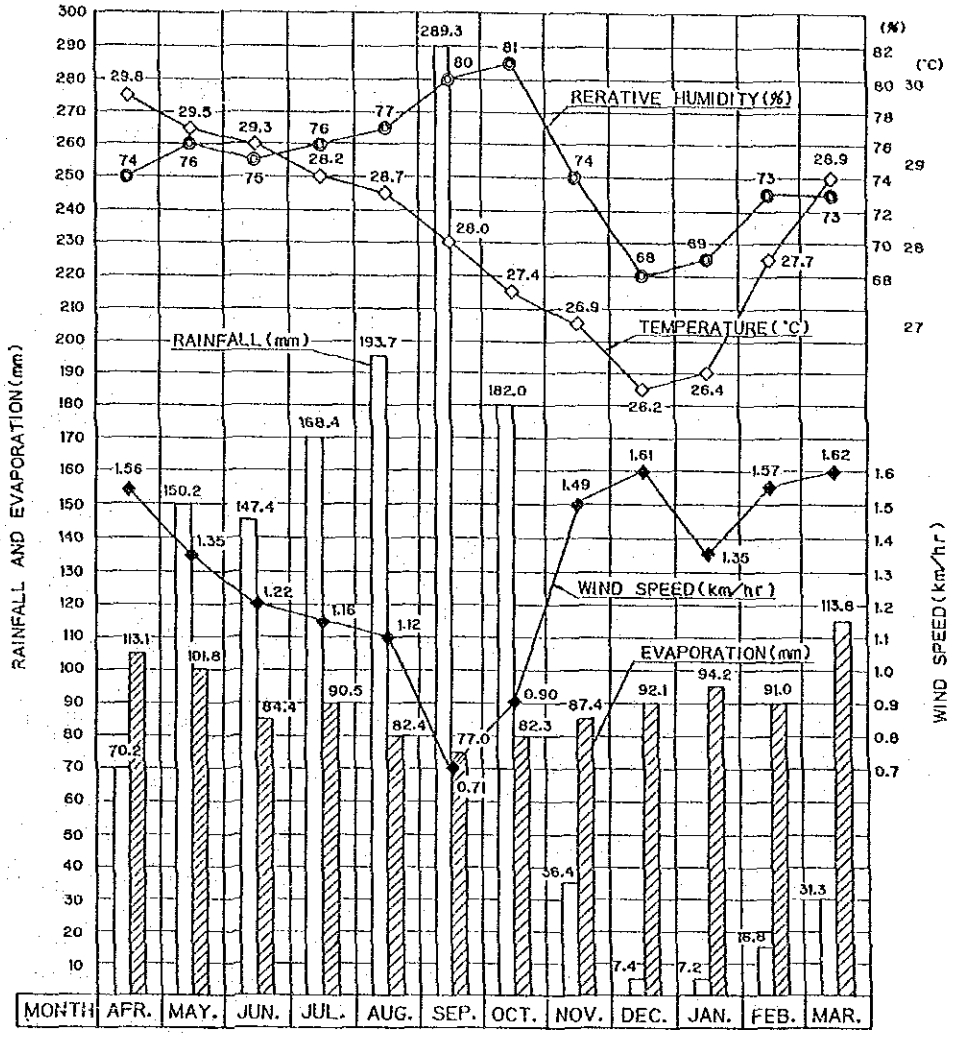
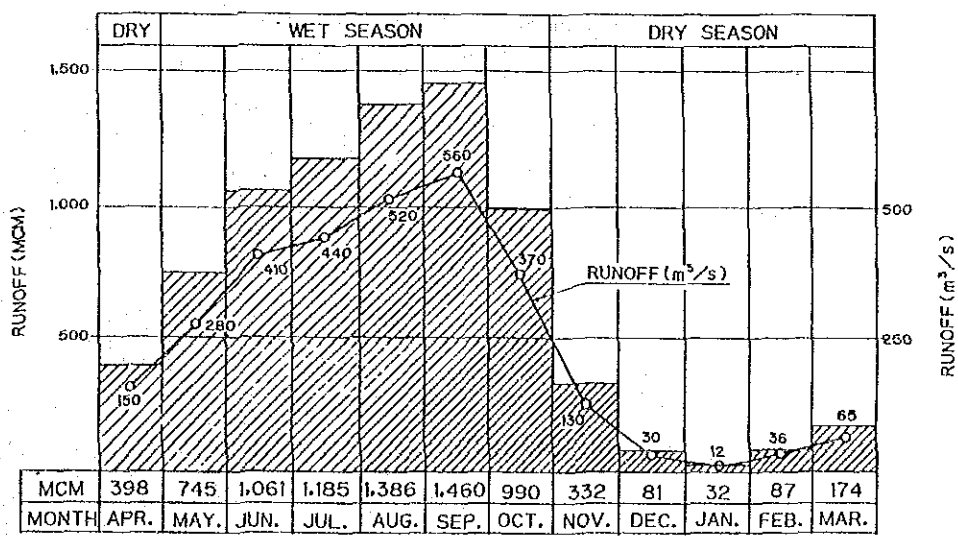


FIGURE 2-3 AVERAGE MONTHLY RUNOFF OF BANG PAKONG RIVER



2.3 Water Resources

The major water resource of the Tha Lat River Basin Development Phase I project is the Bang Pakong river with a drainage area of 17,660 km^2 and an average annual runoff of 7,900 MCM. As shown in Figure 2-3, the average monthly runoff varies from a maximum of 1,460 MCM (560 m^3/sec) in September to a minimum of 32 MCM (12 m^3/sec) in January.

2.4 Social and Economic Situation

The relative values of the Gross Provincial Product of Chacheongsao and Chonburi provinces are as follows;

TABLE 2-1 SOCIAL AND ECONOMIC SITUATION

Item	Whole Thailand	Chacheongsao	Chonburi
Gross Provincial Product (GPP)			
- Agriculture (million Baht)	198,300	3,470	3,530
- Other Sectors (million Baht)	1,035,700	12,650	44,160
- Total (million Baht)	1,234,000	16,120	47,690
Population (1,000 people)	53,600	510	760
per Capita GPP (Bahts)	23,000	31,500	60,400

Present land use in the irrigation service area of 14,300 ha includes 10,000 ha of paddy field, 4,060 ha of orchard land and 240 ha of upland, and the cropping intensity is 100 percent.

CHAPTER 3. DEVELOPMENT PLAN

3. 1 Agricultural Development Plan

1) Proposed Land Use

Proposed cropping plan and estimated yield are as follows;

TABLE 3-1 PROPOSED CROPPING PLAN AND ESTIMATED YIELD

Crops	Wet Season	Dry Season	Total	Yield
	(ha)	(ha)	(ha)	(ton)
Paddy	9,900	1,980	11,880	48,150
Soybean	-	280	280	420
Groundnuts	-	920	920	1,380
Mungbean	-	1,780	1,780	1,958
Vegetables	240	2,140	2,380	34,034
Mango	4,160	(4,160)	4,160	57,408
Total	14,300	7,100	21,400	143,710

Note : The cropping intensity is 150 percent.

2) Irrigation Water Demand

The amount of irrigation water required for the cultivation of 14,300 ha of land in the wet season and of 7,100 ha in the dry season was computed for the twenty years from 1968 to 1987, and the results are summarized in the following table.

TABLE 3-2 IRRIGATION WATER DEMAND (MCM)

Season	Maximum	Minimum	Average
Wet Season	84.0 (1979)	40.8 (1983)	58.6
Dry Season	100.4 (1986)	79.1 (1987)	91.6
Annual	182.1 (1979)	130.0 (1983)	150.5

3) Fish Culture Water Demand

Fish culture water requirements include 980 ha of fresh water for brackish water shrimp culture and 400 ha of fresh water fish ponds. The amount of water required is estimated as follows.

TABLE 3-3 FISH CULTURE WATER DEMAND (MCM)

Season	Maximum	Minimum	Average
Wet Season	4.7 (1979)	40.1 (1983)	4.4
Dry Season	12.3 (1986)	10.5 (1987)	12.1
Annual	17.1 (1979)	14.9 (1987)	16.5

3.2 Domestic and Industrial Development Plan

Domestic and industrial water demands in the year 2005 are estimated by PWA as shown below.

- Domestic Water Demand : annual demand 18.9 MCM
- Industrial Water Demand : annual demand 69.7 MCM

3.3 Water Resources Development Plan

1) Overall Water Demand

Overall water demand including surplus water of 60 MCM/year are as follows;

TABLE 3-4 OVERALL WATER DEMAND (MCM)

Season	Maximum	Minimum	Average
Wet Season	166.6 (1979)	122.8 (1983)	140.9
Dry Season	190.4 (1986)	141.6 (1987)	180.5
Annual	355.1 (1979)	289.4 (1987)	321.4

2) Water Balance Computation

The results of water balance computation for the twenty years from 1968 to 1987 are shown in Figure 3-1. As shown below, water shortages occur three years in every twenty years.

TABLE 3-5 YEARS OF WATER SHORTAGE

Year of Water Shortage	Amount of Water Shortage
1978	18.0 MCM
1979	38.7 MCM
1983	11.8 MCM

FIGURE 3-1 WATER BALANCE COMPUTATION (AFTER COMPLETION OF PHASE I PROJECT, SURPLUS WATER : 60 MCM)

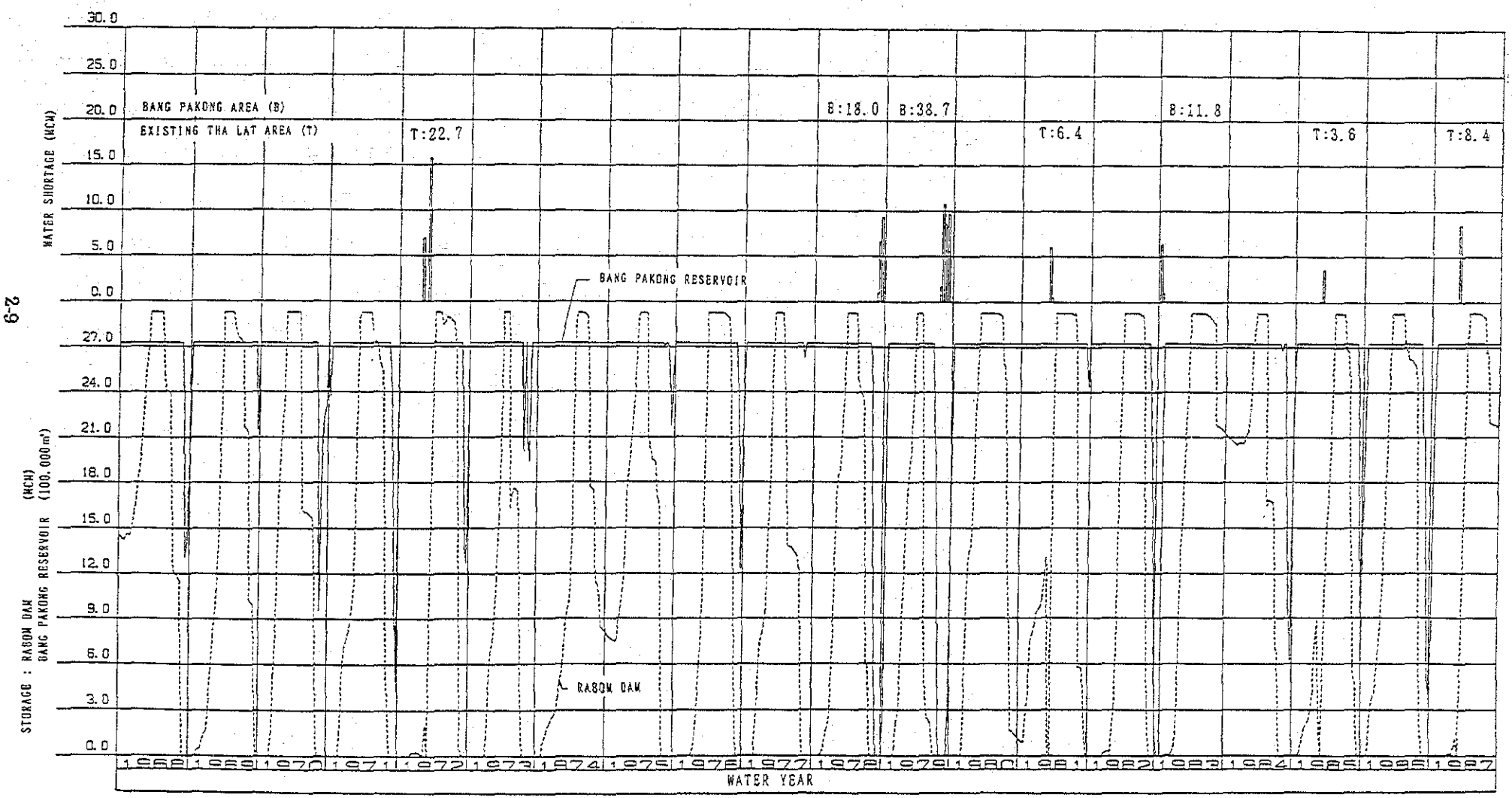


FIGURE 3-2 WATER BALANCE COMPUTATION (AFTER COMPLETION OF PHASE I PROJECT, SURPLUS WATER : 20 MCM)

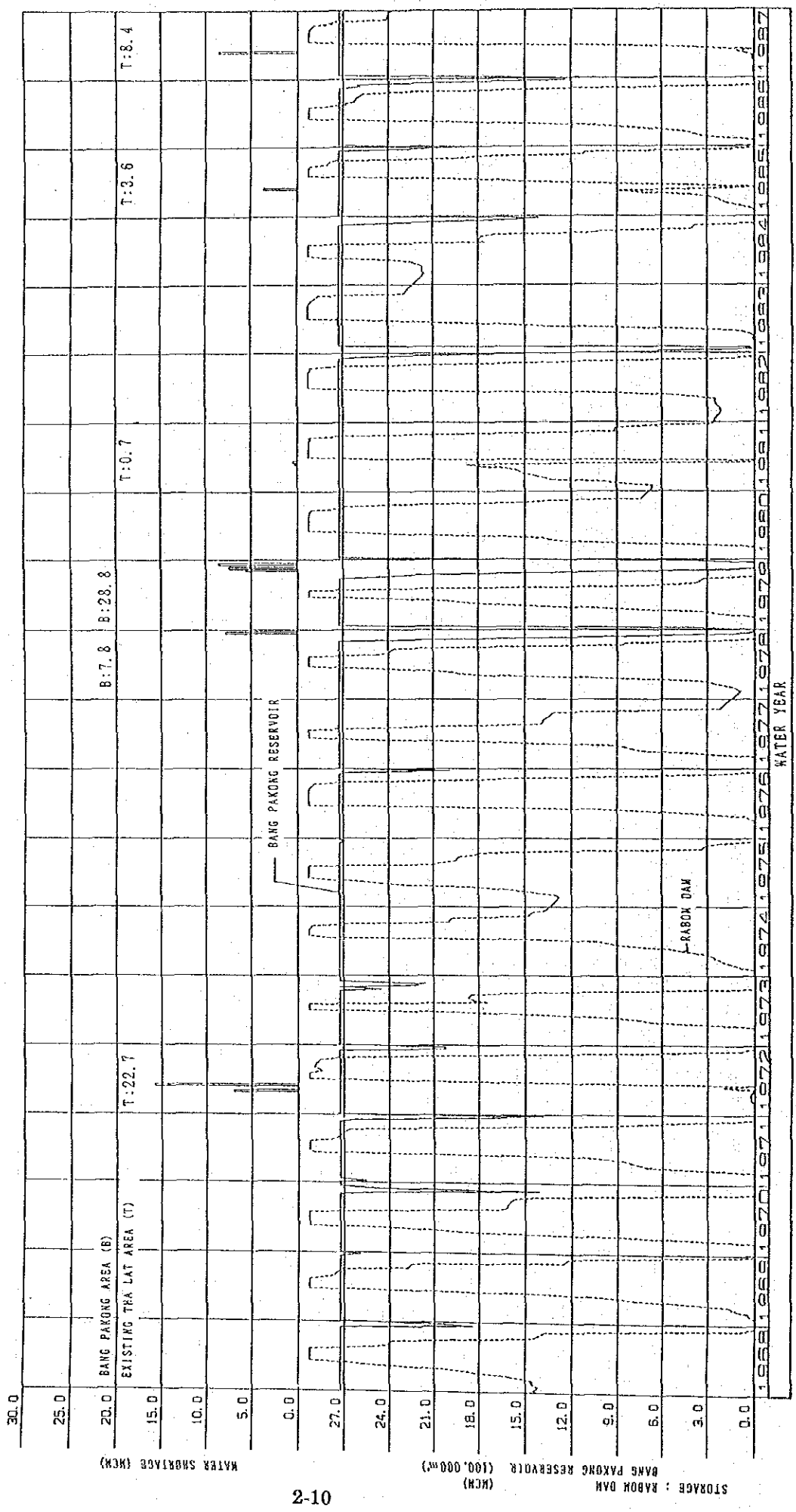
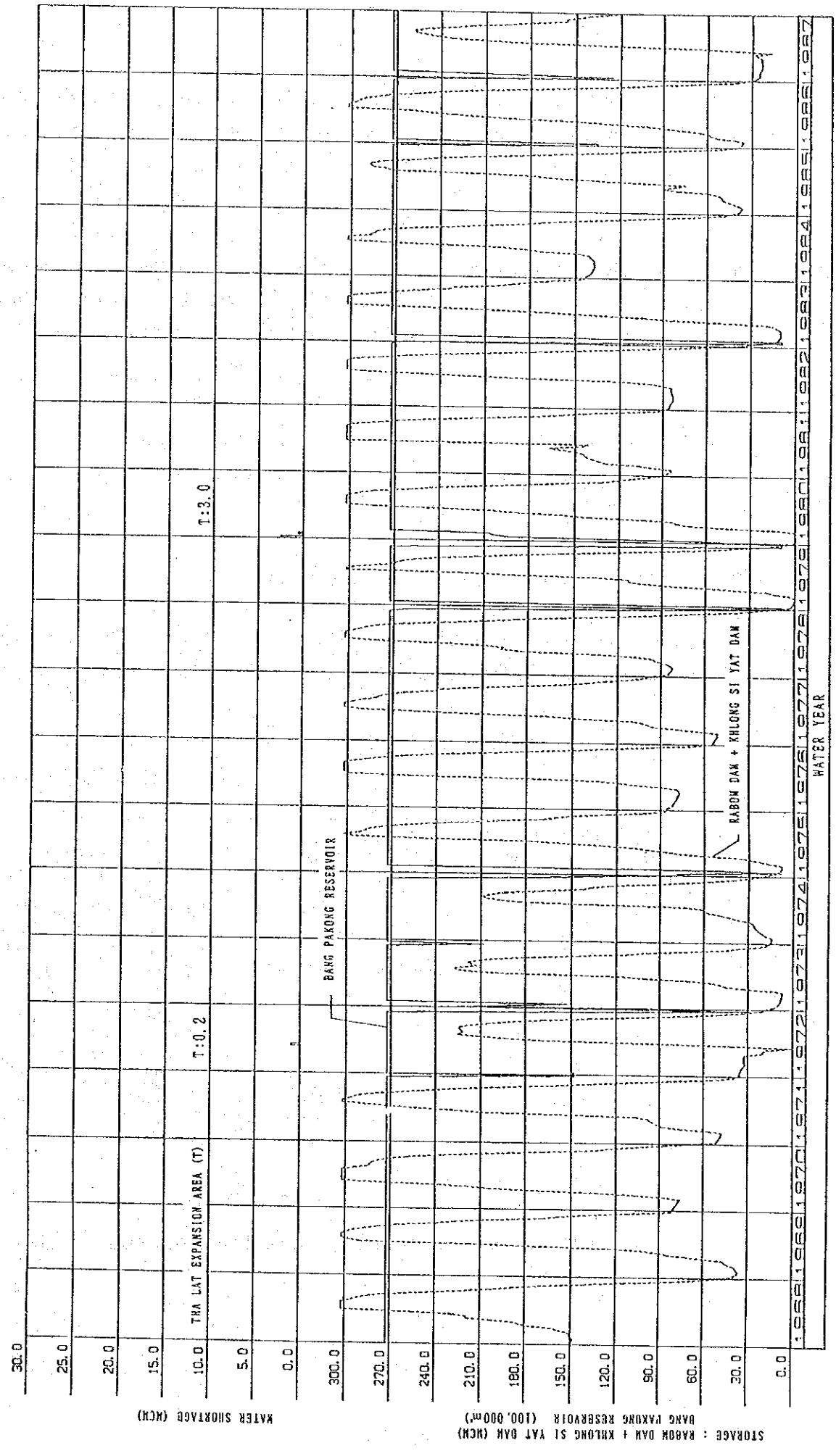


FIGURE 3-3 WATER BALANCE COMPUTATION (AFTER COMPLETION OF PHASE I & II PROJECTS, SURPLUS WATER : 90 MCM)



If there had been a surplus of only 20 MCM of water, water shortages would have occurred in only two years out of the twenty years because the water shortage of 1983 could not have occurred, as shown in Figure 3-2.

After the Khlong Si Yat dam has been completed in Phase II project, water shortages will not occur in the project area of Phase I project, and surplus water will increase from 60 MCM to 90 MCM. The results of water balance computation after completion of the Phase II project are shown in Figure 3-3.

3.4 Project Justification

1) Economic Analysis

a) Project Cost

The disbursement schedule for the project cost of the Tha Lat River Basin Development Phase I Project is estimated as shown in Table 3-6.

TABLE 3-6 DISBURSEMENT SCHEDULE OF PROJECT COST

(Unit: million Bahts)

Year	Financial Cost			Economic Cost
	RID's Facilities (Diversion Dam & Irrigation Facilities)	PWA's Facilities (Facilities for Domestic & Industrial Water Supplies)	Total	(90% of Financial Cost)
1992	179 1)	157	336	302.4
1993	219	471	690	621.0
1994	536	785	1,321	1,188.9
1995	1,213	942	2,155	1,939.5
1996	1,488	785	2,273	2,045.7
1997	994	-	994	894.6
1998	254	-	254	228.6
Total	4,883	3,140	8,023	7,220.7

Note : 1) The project cost of 120 million Bahts for Rabom dam construction is included.

b) Operation and Maintenance Costs

The annual operation and maintenance costs are shown in Table 3-7.

TABLE 3-7 ANNUAL OPERATION AND MAINTENANCE COST

(Unit: million Bahts)

Facility	Financial Cost	Economic Cost
RID's Facilities	17.0	15.3
PWA's Facilities	94.2 [1]	84.8
Total	111.2	100.1

Note : 1) The annual operation and maintenance costs for PWA's facilities is estimated to be 3% of the project cost.

c) Replacement Cost

The irrigation pumps to be set up by RID and the purification plant, etc. to be installed by PWA are planned to be replaced once every twenty years. The replacement cost is shown in Table 3-8.

TABLE 3-8 REPLACEMENT COST

(Unit: million Bahts)

Facility	Financial Cost	Economic Cost
RID's Facilities (Pumps)	170.0	153.0
PWA's Facilities (Purification Plants, etc.)	628.2 [1]	565.2
Total	798.0	718.2

Note : 1) The replacement cost for the PWA's facilities is planned to be 20% of the project cost

d) Incremental Benefit

The incremental benefit for the Phase I project is shown in Table 3-9.

TABLE 3-9 INCREMENTAL BENEFIT

(Unit: million Bahts)

Agricultural sector (Agriculture : 440.6 + Fisheries : 5.3)	= 445.9
Domestic & industrial water supplies sector	
- Domestic & industrial water supply by PWA	
66.5 MCM × 10 Baht/cu.m	= 665.0
- Future demand for domestic & industrial water	
60.0 MCM × 0.75 × 3 Baht/cu.m	= 135.0
Total	1,245.9

e) Economic Internal Rate of Return

An analysis of the economic internal rate of return of the Phase I project amounts to 10.5%. The results of the sensibility analyses are shown below.

Case -1:	In the case of surplus water of 20 MCM ..	10.2%
Case -2:	10% increase in the project cost	9.7%
Case -3:	10% decrease in the project benefit	9.5%

2) Project Evaluation

The Tha Lat River Basin Development Phase I project can be evaluated as follows;

a) The Phase I project is of great importance and urgency to Thailand, and is useful for the national economy judging from the feasible and viable value of 10.5% in the economic internal rate of return.

b) In the irrigation service area, the farming population amounts to about 30 thousand in 5,700 farming households, the net farm income per household, the off-farm income per household and the total income per household are estimated as 26,800 Baht, 59,000 Baht and 85,800 Baht respectively, at present. By implementing the Phase I project, the net farm income per household is expected to reach 81,600 Baht corresponding to three times the existing income resulting in stabilization of the farmers' lives and a rise in their standard of living.

c) By implementing the Phase I project, domestic water supply for about 250 thousand persons will be possible, contributing to an improvement of the sanitary conditions and the living environment of the inhabitants in the project area.

d) The domestic and industrial water supply to the factories and industrial estates in the project area situated in the northern part of the Eastern Seaboard Development Area, has been unstable. Since a stable water supply is possible and will stabilize factory operation with the implementation of the Phase I project, new factories will be attracted to the industrial estates under construction and employment opportunities will be created.

e) By implementing the Phase I project, it will be possible to provide a surplus of 60 MCM of domestic and industrial water once the planned capacities of irrigation water, fisheries water and domestic and industrial water, have been confirmed. The project area is favorably located near the Bangkok Metropolitan Area and Laem Chabang commercial port, and the infrastructure of roads, electricity, communication, railways, etc., has been consolidated. Therefore, if a stable domestic and industrial water supply is available, it will be much easier to attract factories to the area. By constructing light industrial factories of the labour-intensive type in the project area and creating new employment opportunities, the concentration of economic activity and new population in the Bangkok Metropolitan Area will be curbed.

PART - III. BANG PAKONG DIVERSION DAM PROJECT

CHAPTER 1. FEATURES OF THE PROJECT FACILITIES

The project facilities of the Bang Pakong Diversion Dam project are shown in Table 1-1 and Figure 1-1, in which the detailed design of the O/M buildings is prepared by RID and the other facilities are designed in detail by the JICA study team.

The Bang Pakong diversion dam is constructed at a site about 71 km upstream from the Bang Pakong river estuary, and the construction sites of other project facilities are situated within 3 km of the diversion dam.

TABLE 1-1 FEATURES OF THE PROJECT FACILITIES

1) Facilities to be designed by JICA study team

① Bang Pakong Diversion Dam

Design Flood	:	1,600 m^3/sec
Length of Diversion Dam	:	166 m
Tide Protection Gates		
- Regulating Gate	:	Double Leaf Wheel Type Gate, 30 m span × 2 sets, Height of Upper Gate 3. 1 m Height of Lower Gate 6.9 m
- Flood Gate	:	Single Leaf Wheel Type Gate, 30 m span × 3 sets, Height of Gate 10 m
Pier	:	Height 26.5 m, Length 19.0 m, Thickness 4 m
O/M Bridge	:	Width 6.6 m, Prestressed Concrete Box Girder Bridge span length 33.95 m × 5 spans
Foundation Works	:	Steel Pipe Pile Foundation
Concrete Volume	:	approx. 39,000 m^3

② Diversion Canal

Bottom Width	:	105 m
Slope of Bank	:	1 : 5.0
Excavation Depth	:	approx. 11 m
Length of Canal	:	approx. 2. 2 km (including the section of the Bang Pakong diversion dam)
Excavation Volume	:	approx. 3,500,000 m^3 (including an excavation for Bang Pakong diversion dam)

③ Closure Dam

Crest Length	:	approx. 280 m
Dam Height	:	15.9 m (not including height of camber)
Width of Dam Crest	:	12.0 m
Slope of Embankment	:	1 : 5.5
Embankment Volume	:	approx. 310,000 m^3 (rock material 70,000 m^3, coarse-grained soil material 240,000 m^3)

④ Road

Road Width	:	Total Width 9~ 28 m, Width of Asphalt Pavement 6 ~ 19 m
Road Length	:	approx. 2. 7 km

⑤ Road Bridge

Bridge Class	:	First Class
Width of Bridge	:	13.0 m
Type of Bridge	:	Prestressed Concrete Box Girder Bridge
Length of Bridge	:	span length 28.3 m × 8 spans

⑥ Pumping Station

Pump Discharge	:	16 m^3/sec (960 m^3/min)
Actual Pump Head	:	5. 4 m
Pump	:	Vertical Shaft Type Mixed Flow Pump, ø1,350 mm × 4 units
Prime Mover	:	Electric Motor 350 kw × 3 units Diesel Engine 500 PS × 1 unit
Pump House	:	R.C. made, Total Floor Area approx. 500 m^2
Concrete Volume	:	approx. 3,500 m^3

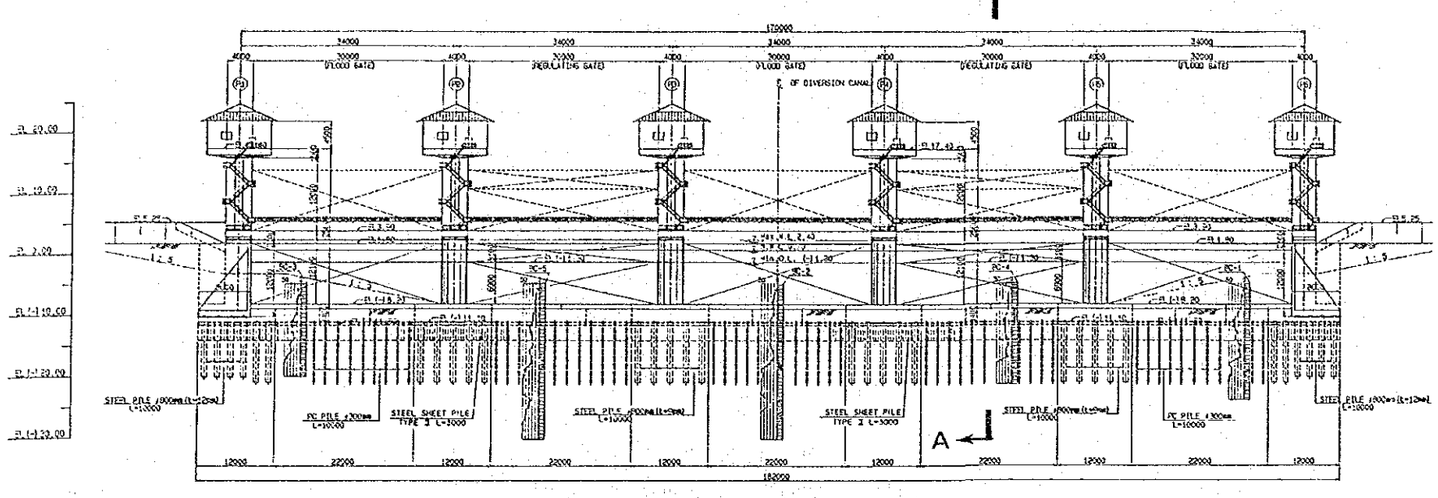
⑦ Control System & Electrical Facilities

Control System	:	Remote Control System for Tide Protection Gates & Pumps, ITV Monitoring System, Two River Water Level Gauging Stations, etc.
Electrical Facilities	:	Incoming Electrical Works, Substations, Distribution Lines, etc.

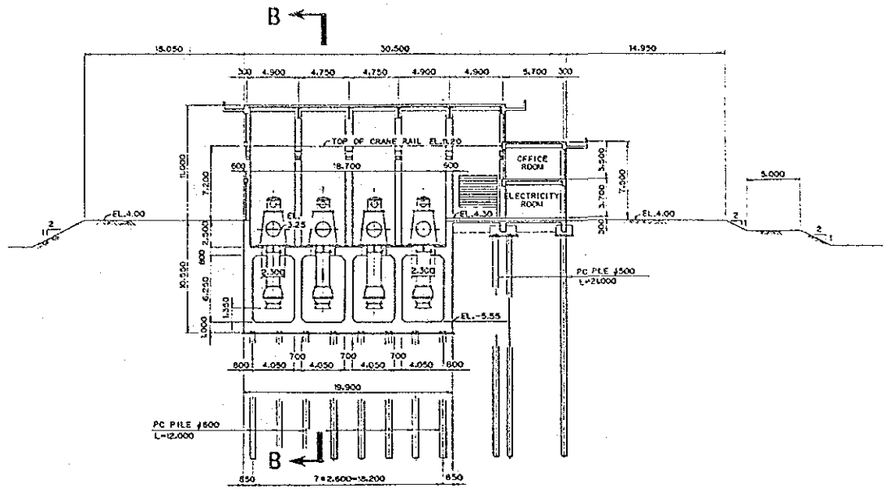
2) Facilities to be designed by RID

⑧ O/M Building	:	Area of Building Lot approx. 60 ha, Control House, Training Center Building, Residential Houses, etc.

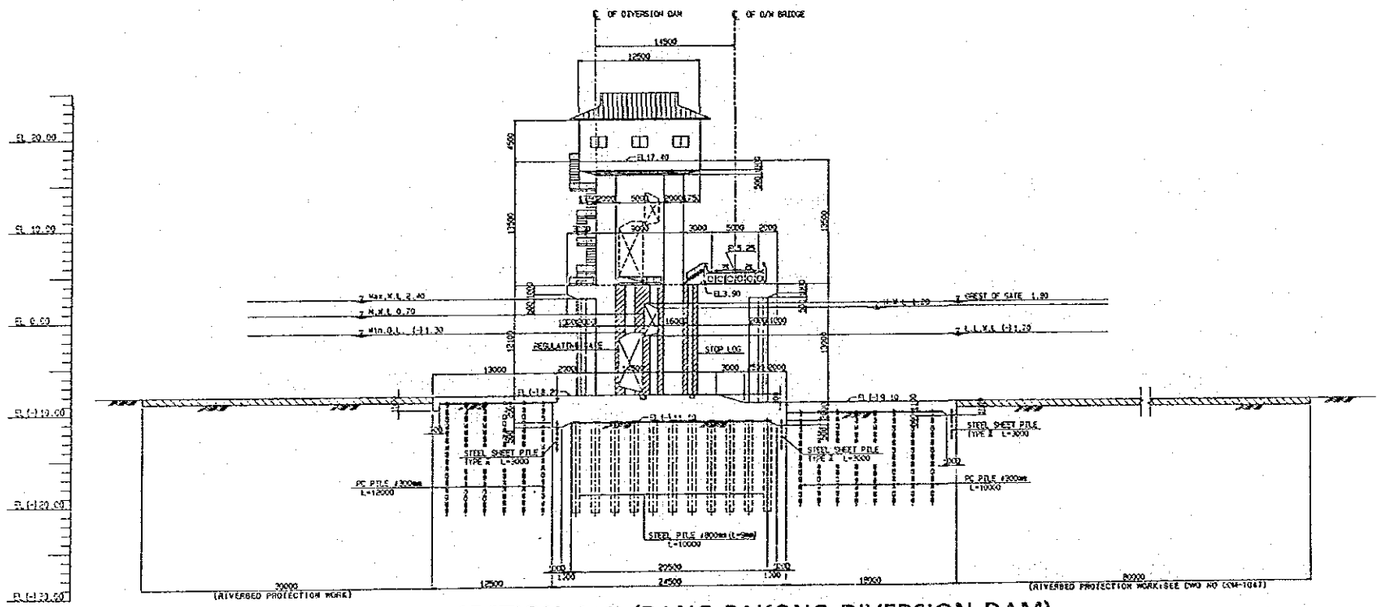
FIGURE 1-1 FEATURES OF THE PROJECT FACILITIES



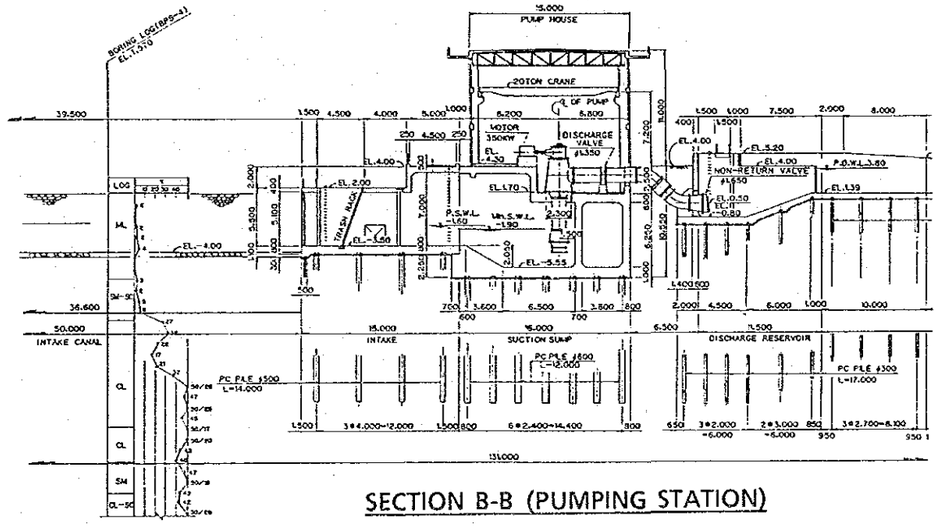
ELEVATION OF BANG PAKONG DIVERSION DAM



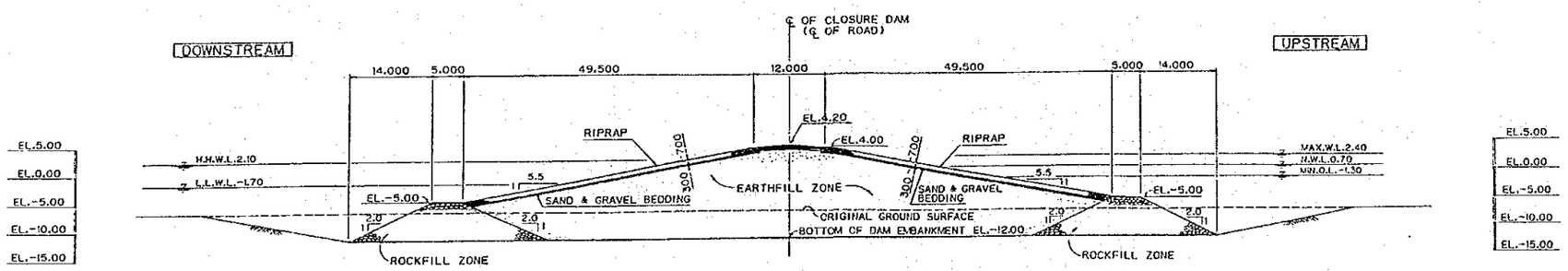
ELEVATION OF PUMPING STATION



SECTION A-A (BANG PAKONG DIVERSION DAM)



SECTION B-B (PUMPING STATION)



MAXIMUM SECTION OF CLOSURE DAM

CHAPTER 2. TOPOGRAPHY AND GEOLOGY

2. 1 Topography

The Bang Pakong diversion damsite is located about 71 km upstream from the estuary, 0.8 to 1.3 m in ground elevation and with flat topography. The cropping area is composed mostly of mango, banana, and coconut, orchards. There are paddy fields, however, north of the diversion canal, and shrimp ponds interspersed through the area. The Bang Pakong river meanders from east to west near the diversion damsite 230 m in mean width, and about 11 m in depth. The meandering line of the river has about 2.7 km in mean wave length and about 1.2 km in mean amplitude.

2. 2 Geology

The construction sites of the diversion dam, pumping station and related facilities are located on an alluvial plain formed by the conveying and accumulating actions of the Bang Pakong river. The alluvial layer in this area is composed of flood plain deposit mainly with such fine particles as silt, clay, etc., with intercalation of the fine to coarse sand layers in some parts, and the upper layer reaching at a depth of about 8 m from the ground surface is a typical soft ground. The geological features at each facility obtained through the bore-hole drillings are shown in Figure 2 -1(a) to 2 - 1 (d).

1) Sites of Diversion Dam and Diversion Canal

According to the results of the boring investigation, the typical stratigraphy around the diversion dam site can be classified into the following 4 layers, and it is found that each layer is distributed more or less in a horizontal structure.

1st layer: Brown clay layer (corresponding to topsoil layer)
(1 to 2 m in thickness)

2nd layer: Blackish gray - brown clay and silt layer
(17 to 19 m in thickness)

3rd layer: Yellowish brown fine - coarse sand layer
(1 to 2 m in thickness)

4th layer: Yellowish brown - reddish brown silty clay and fine sand layer
(more than 10 m in thickness)

The geological features of each layer are as follows;

1st layer : The 1st layer consists of somewhat compacted silty clay corresponding to the topsoil and indicates 2 to 4 in the N-values.

2nd layer: The clay and silt layer belonging to the 2nd layer consists of very fine particles and is classified as CL and ML under the Unified Soil Classification System.

The upper half of the layer shows less than 4 in the N-value (mostly 0 to 1) making for an extremely soft layer (compressive strength ranging between 0.3 to 1.1 kgf/cm^2). The depth of this soft layer from ground surface reaches 7.0 to 8.5 m at the diversion damsite and 8.0 to 10.5 m along the diversion canal.

The lower half of the layer indicates 10 to 30 in the N-value and 1.2 to 4.8 kgf/cm^2 in compressive strength, and is of a somewhat compacted nature in comparison to the upper half of the layer. The N-values of this layer are widely distributed with a considerable variation in depth and location. Since 10 to 15 in the N-value are found here and there in the lower half of the layer even at a depth of more than 16 m below the ground surface, it is impossible to regard it as a stable bearing layer.

3rd layer : The fine and coarse sand layer belonging to the 3rd layer is classified as SC to SM and distributed almost horizontally in the whole area with good continuation, indicting 24 to 50 in the N-value partly well compacted. Therefore, it can be recognized as a sufficient bearing layer in some parts.