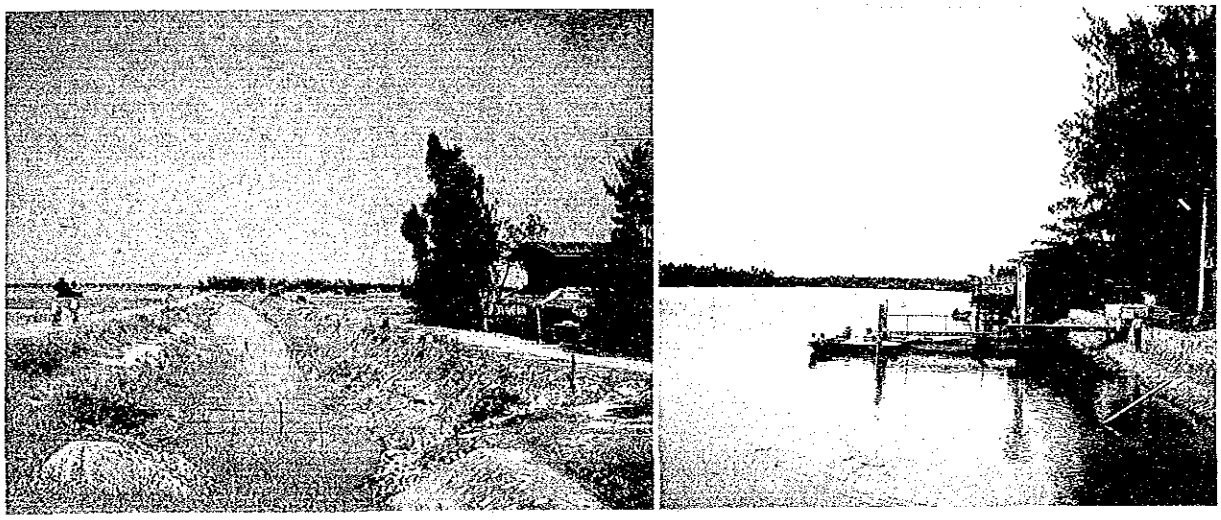
KINGDOM OF THAILAND
ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES

THE FEASIBILITY STUDY ON THE AGRICULTURAL WATER DEVELOPMENT PROJECT OF BANG PAKONG RIVER BASIN

Executive Summary



OCTOBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

KINGDOM OF THAILAND

ROYAL IRRIGATION DEPARTMENT

MINISTRY OF AGRICULTURE AND COOPERATIVES

THE FEASIBILITY STUDY
ON
THE AGRICULTURAL WATER DEVELOPMENT PROJECT
OF
BANG PAKONG RIVER BASIN

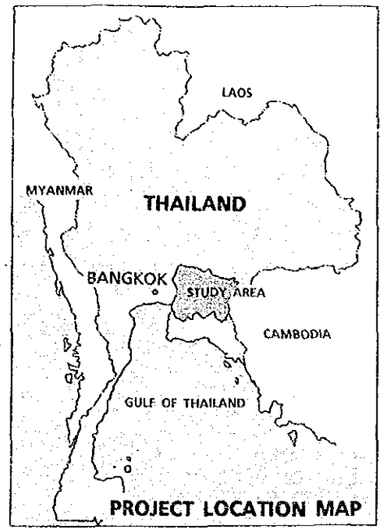
EXECUTIVE SUMMARY

OCTOBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

OVERALL BASIN STUDY

GENERAL LOCATION MAP



Maenum Nakhon Nayok Sub-Basin C.A=1,933sq.km

Maenum Hanuman Sub-Basin C.A=2,130sq.km

Upper Bang Pakong Sub-Basin C.A=2,757sq.km

Middle Phra Prong Sub-Basin C.A= 970sq.km

Upper Phra Prong Sub-Basin C.A=1,628sq.km

Lower Bang Pakong Sub-Basin C.A=3,106sq.km

Khlong Tha Lat Sub-Basin C.A=2,493sq.km

Khlong Phra Sathung Sub-Basin C.A=2,643sq.km

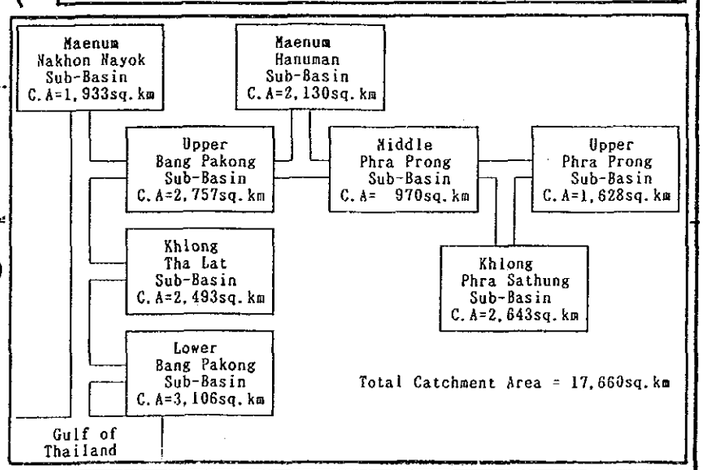
Khlong Bon Na Dam
Khlong Tha Dan Dam
Huai Sai Yai Dam
Lam Phraya Than Dam
Khlong Nong Koeo Dam
Huai Sai Noi Dam
Huai Somong Dam
U. Khlong Phra Prong Dam
Khlong Phra Prong Dam
Khlong Phra Sathung Dam
Rabom Dam
Khlong Luang Dam
Khlong Si Yat Dam
Bang Pakong Diversion Dam
Bang Pakong Left Bank Irrig.P.
Tha Dan Irrig. P.
Prachantakham Irrig. P.
Tha Hoe I.P.
Bang Phluang I.P.
Pra Ong Chaiyanuchit I.P.
Phan Thong I.P.
Phan Thong E-I.P.
Ban Bung I.P.

EXISTING IRRIGATION PROJECT

AREA NEWLY DEVELOPED

PROPOSED DAM/RESERVOIR

Sub-Basin	Irrigation Area (ha)	Water Requirement in MCM		
		Crop	Effect. Rain	Diversion
Upper Phra prong	62,400	377.830	211.933	310.179
Khlong Phra Sathung	43,000	261.950	146.077	216.740
Middle Phra Prong	25,000	159.574	94.342	118.959
Maenum Hanuman	39,600	230.404	128.192	191.662
Upper Bang Pakong	87,900	1,485.396	732.863	1,350.028
Maenum Nakhon Nayok	207,400	766.108	423.962	575.036
Khlong Tha Lat	8,700	54.923	19.995	64.567
Lower Bang Pakong	104,000	742.186	306.755	779.703
Whole River Basin	578,000	4,078.369	2,064.116	3,606.873



Total Catchment Area = 17,660sq.km

OVERALL BASIN STUDY

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

A. INTRODUCTION

A. 1. Study Objectives

The study objectives are to formulate comprehensive water resources development programs in the Bang Pakong River Basin and to put priorities on the project to implement them in order in which dam reservoirs are constructed upstream of the river and its tributaries, a diversion dam is built on the river just upstream of Chachoengsao City and the existing irrigation facilities for the irrigation projects are radically modified and the like; so as to stabilize water supply for paddy and dry cropping especially in a dry season to prevent saline water from intruding into the area, and to supply industries and inhabitants with water.

A. 2. Scope of Works

The study comprises two parts; one is "OVERALL BASIN STUDY" to cover the entire Bang Pakong River Basin and the other is "FEASIBILITY STUDY ON THE KHLONG THA LAT RIVER BASIN DEVELOPMENT PROJECT". Requested by the Thai Government at the commencement of the study in September 1989, the scope of works for the study was accordingly revised in November 1989 so as to involve the above two parts in parallel.

A. 3. Work Schedule of the Study

The Progress Report (I) was prepared and submitted in December 1989 to the Thai Government to summarize major findings obtained from the field surveys and investigations conducted as the Phase I Field Survey of the Study. The Phase I Home Office Work was uninterruptedly made in order to conclude the Phase I Study, and the Interim Report was issued at the end of March 1990 based on which this material was prepared. The Interim Report deals fully with formation of the basic plan of water resources development for irrigation and other purposes as the Overall Basin Study, and also proposes beneficial areas, water balance and dimensions of major project facilities as the component of the Feasibility Study. The Phase II Study was just commenced in May 1990 comprising about 50 days of the field investigation and 45 days of home office works, and was completed submitting the Final Reports for both OVERALL BASIN STUDY and FEASIBILITY STUDY by the end of October, 1990.

B. OVERALL BASIN STUDY

B.1. Present Conditions of The Basin

B. 1. 1. Location and Topography

Being situated in the east-central part of Thailand, the Bang Pakong River Basin has a catchment of 17,660 sq.km which covers about 3.4 percent of the total national land area. The basin occupies major portions of the Changwats Chonburi, Chachoengsao, Prachinburi and Nakhon Nayok.

Four major physiographic features are distributed in the basin. They are the northern mountain range on the south flank of the Khorat Plateau, the deeply dissected hills and low mountains in the south, the flood and terracial terrain among tributaries, and the extensive alluvial plain in the west.

B. 1. 2. Climate

Two pronounced seasons, wet and dry, dominate over the basin. The southern monsoon during May through October carries tropical air from the Gulf of Thailand and the Andaman Sea providing most of annual rainfall over the area. The northwest monsoon, during November through March, generally brings dry air and high temperature. Mean annual rainfall ranges between 900 mm and 2,400 mm in the recent 20 years, with considerable differences from place to place generally increasing in proportion to the latitude from the south to the north. Monthly temperatures vary from 26 to 30°C with insignificant difference in time and space.

B. 1. 3. Social and Economic Situation (Population and GPP)

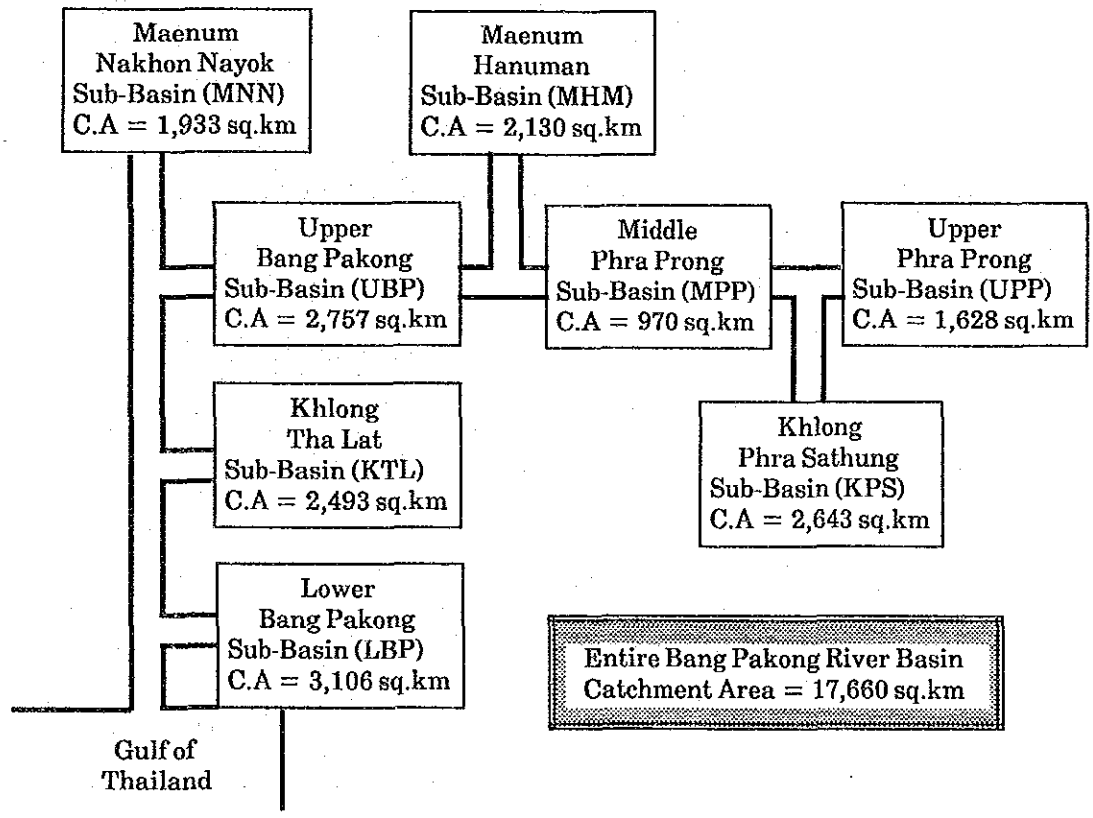
Item	Whole Kingdom	Eastern Region	Major Changwats in the Basin			
			Chonburi	Chachoe -ngsao	Nakhon Nayok	Prachin -buri
Gross Provincial Product						
- Agriculture	198,284	17,738	3,532	3,466	727	2,868
- Other Sectors	1,035,746	82,759	44,155	12,651	1,912	5,597
- Total	1,234,030	100,497	47,687	16,097	2,639	8,465
Population (1,000 person)	53,605	3,232	790	511	203	773
per Capita GPP (Bahts)	23,021	31,094	60,368	31,501	12,999	10,951

Note: GPP is given in million bahts.

B. 1. 4. River System and Sub-Basin Zoning

The two primary tributaries of the Bang Pakong river are the Nakhon Nayok and Prachin rivers which join near the western boundary of the basin. The Prachin river originates near Kabinburi where the Hanuman and Phra Prong rivers join. Approximately 57% of the Bang Pakong basin area drains into the Prachin river, 11% into the Nakhon Nayok river and the remainder of the basin drains into the Bang Pakong river downstream of the two major tributaries. The basin was divided into 8 sub-basins and in total 54 irrigation blocks as shown below:

Sub-Basin Zoning



B. 1. 5. Hydrology

Rainfall, river runoff and runoff coefficient analyzed in terms of an annual average in the recent 20 years are as follows:

Sub-basin	Catchment (sq.km)	Rainfall (mm)	Runoff (MCM)	Runoff Coefficient (%)
UPP	1,628	1,762	690	24
KPS	2,643	1,580	880	21
MPP	970	1,925	560	30
MHM	2,130	1,926	1,430	35
UBP	2,757	1,641	1,480	33
MNN	1,933	1,729	1,540	40
KTL	2,493	1,343	700	21
LBP	3,106	1,240	650	17
Whole Basin	17,660	1,590	7,930.0	27.5

B. 1. 6. Land Use

Existing land use by sub-basin is summarized as follows:

(Unit: ha)

Sub-Basin	Project Area	Agricultural Land					Other Land
		Paddy	Upland	Orchard	Vege.	Total	
Lower Bang Pakong	310,600	102,680	144,110	17,830	8,370	272,990	37,610
Khlong Tha Lat	249,300	3,990	61,050	700	160	65,900	183,400
Upper Bang Pakong	275,700	167,380	37,130	41,880	8,560	254,950	20,750
Mae Num Nakhon Nayok	193,300	81,680	2,550	12,110	3,380	99,720	93,580
Middle Phra Prong	97,000	19,520	21,820	-	-	41,340	55,650
Mae Num Hanuman	213,000	24,520	24,550	15,470	80	64,620	148,380
Khlong Phra Sathung	264,300	29,960	69,970	8,170	2,050	110,150	154,150
Upper Phra Prong	162.800	46,560	29,880	5,840	1,810	84,090	78,710
Whole River Basin	1,766,000	476,290	391,060	102,000	24,410	993,760	772,240

Note: Orchard includes tree crops such as para-rubber, eucalyptus, bamboo and other fruit crops.

B. 1. 7. Major Crops

Planted areas by major crops in the main four Changwat are extracted from agricultural statistics as follows:

(Unit: ha)

Crops	Chonburi	Chachoengsao	Prachinburi	Nakhon Nayok	Total
Paddy	47,900	78,800	226,700	78,900	432,300
Cassava	26,200	67,400	139,200	-	232,800
Sugarcane	29,800	7,000	-	-	36,800
Legumes	600	2,200	13,000	-	15,800
Maize	-	2,200	104,700	200	107,100
Mango	3,000	7,500	4,500	1,200	16,200

B. 1. 8. Crop Production

Crop production in the major four Changwats as an average in the past three years are as below:

Crop	Area (ha)		Production (ton)
	Planted	Harvested	
Paddy	432,300	432,300	914,700
Cassava	232,800	232,800	2,750,600
Maize	107,100	107,100	358,800
Sugarcane	36,800	36,800	1,519,600
Legumes	15,800	15,800	18,700
Mango	16,200	12,800	70,700

B. 2. Basic Strategy for Basin Development

B. 2. 1. Problems and Constraints Involved

Favored moderately with an annual rainfall of about 1,600 mm, paddy cultivation is dominant in the basin during wet season. Mainly for lack of interior drainage facilities combined with absolutely limited outflow capacities of rivers and tributaries, however, the existing paddy areas are often suffered from floodings and inundations. Another serious problem during wet season in the same area is frequent shortages of supplemental irrigation water. Under existing climatic condition, wet paddy consumes about 550 mm of water for evapotranspiration on the field, of which 300 mm only are covered by effective rains, meaning that supplemental irrigation of about 250 mm per growing period are still required. However, it has not been achieved for lack of irrigation facilities, limited river runoff and saline water intrusion. In dry season, on the contrary, the area is almost left fallow from of lack of water.

Acid sulfate soils of some 204,800 ha widely distribute in the major four Changwats. Marl application is recommended to improve soil acidity, however, land use on these soil may be quite limited. Development of the potential acid sulfate soils in the limited tidal area may cause the other problem, since these soils will be acid when they are drained or ridged.

Cassava is a profitable crop and is an easy crop to grow, requiring no particular technical knowledge, extensive labour and no irrigation. It also grow in a poor soil. However, based on the agreement signed between Thailand and EEC, exports must decrease. This will lead to limiting production of cassava, and in turn crop diversification plan should be examined. Crop conversion plan from cassava to other upland crops may be feasible only when countermeasures to grow valid alternative crops are given, and it is certain that irrigation development is the only basic solution to cope with this problem.

Land rights still represent a main problem in the basin because the boundary of national forest reserve covers a rather large area. In the encroached forest areas, land allocation projects are being operated by the Royal Forest Department (RFD) and the Agricultural Land Reform Office (ALRO). RFD issues a land use permit called "STK Certificate" for illegal settlers in the national forest reserve. ALRO also issues a land use permit (Sor Por Kor 401). A change in this type of document to Nor Sor 3 or Nor Sor 4 will have a significant economic impact to the local farmers. On the other hand, it may facilitate the transfer of ownership leading to the loss of land by poor farmers and eventually more encroachment of forest land.

The Study area involves 3,100 sq.km of National Park areas at Khao Yai, Thap Larn and Pang Sida. Wildlife reserve of 108 sq.km in Khao Ang Ru

Nai and 4,500 sq.km of national reserve spread over the area would to some extent restrict the Project formulation.

B. 2. 2. Basic Development Strategy

The land resources development depends on water supply and flood exclusion. In the lower reaches of the river basin forming wide flat paddy field zone, such cropping patterns as double paddy farming and wet season paddy plus dry season dry farmings are to be introduced by securing water by dam construction. The middle and upper reaches of the river basin, on the other hand, are expected to be developed urgently from a security viewpoint, since the eastern border of the basin is located near the Cambodian boundary.

In the economy of Thailand, the progress of the industry has been quite remarkable. The whole reaches of Bang Pakong river situated between Chonburi and Bangkok have suddenly been highlighted as the areas suitable for industrial estates. For industrial, municipal and domestic water supplies, the tasks are to secure water source, to extend and strengthen conveying, distributing and purifying facilities.

The project areas with higher priority must be developed in order, so as to utilize water resources effectively in the whole Bang Pakong river basin, and to plan a balanced development of the areas. Firstly, multi-purpose dams are constructed to supply water stably for agriculture, industry, municipal and domestic purposes, and fishery. Concurrently, a diversion dam is built on the main Bang Pakong river just upstream of Chachoengsao City to prevent saline water from intruding in dry season, and to supply water multi-purposely by storing fresh water in the river course upstream of the diversion dam.

B. 3. Water Resources Development Plan

B. 3. 1. Methodology

The following methods were employed to establish a multipurpose water resources development plan for irrigated agriculture and other water supply schemes to be unavoidably involved, such as domestic, industrial and fishery water supply, in the Bang Pakong river basin;

Water Resources Development:

- Topographic maps, hydro-meteorological data as well as information obtainable from existing reports and statistics were fully used to support field investigations. One to several technically possible damsites were selected and the most suitable damsites and development scales were determined through comparative study in sub-basins.

- Gravity irrigation method was employed in principle.

Water Requirement/Demand:

- Irrigation beneficial areas were mainly selected from such existing farmland that can be irrigated by the proposed storages by gravity.

- Existing status of crops and cropping scales, the Thai Government's policy on agricultural production, balance of supply and demand, guideline of the agricultural extension offices, profitability of crops, farming technique, etc. were fully considered in order to determine crops and cropping scales to be introduced by the project.

- Irrigation water demands by crop were computed based on crop water requirements, percolation, effective rainfall and efficiencies with a 10 day time step.

- Water supply demands for domestic and industrial purposes were estimated for the target year 2000, on the basis of development plans prepared by the Ministry of Industry and the Provincial Waterworks Authority.

- Compensatory water supply during dry season for the existing shrimp culture after construction of the proposed Bang Pakong diversion dam was estimated at the amount just to make the river water (33.5 ppt) thin to an allowable maximum level of salinity suitable for shrimp raising (30 ppt).

- The discharge of 0.1 cu.m/sec/100 sq.km was considered as the river maintenance water.

Sub-Basin Zoning:

- The entire Bang Pakong river basin was divided into 8 sub-basins and 54 irrigation blocks in consideration of topography, river skeleton and distribution of beneficial farmlands.

Water Balance:

- Technically suitable and economically feasible damsites were selected through water balance simulation studies for possible alternative development plans in due consideration of well balanced scheme of phased development.

- The development plan envisages to ensure stable water sources upstream river basin and, at the same time, to prevent saline water intrusion and to regulate water released and also natural runoff in the river channel system, by means of constructing a diversion dam across the Bang Pakong river near Chachoengsao city. In this connection, the effective fresh water storage of the proposed diversion dam has been estimated at about 30 MCM.

Priority Order:

- The top priority sub-project was selected through an overall study of evaluation including economic feasibility, technical possibility, inhabitant's needs, urgency for development and others.

B. 3. 2. Proposed Land Use

(Unit: ha)

Proposed:	Irrigated					
Present	Paddy	Upland	Orchard	Sub-Total	Not Irrigated	Total
Paddy	339,600	1,200	8,000	348,800	127,490	476,290
Upland	-	41,900	700	42,600	372,870	415,470
Orchard	-	-	14,200	14,200	87,800	102,000
Other Land	-	-	1,300	1,300	-	1,300
Total	339,600	43,100	24,200	406,900	588,160	995,060

B. 3. 3. Proposed Cropping Plan

(Unit: ha)

Crops	Paddy Field		Upland Field		Orchard	Total
	Wet	Dry	Wet	Dry		
Paddy	339,600	38,200	-	-	-	377,800
Soybean	-	65,000	-	5,000	-	70,000
Mungbean	-	20,000	-	5,000	-	25,000
Groundnuts	-	20,000	-	5,000	-	25,000
Maize	-	-	16,400	-	-	16,400
Vegetables	-	1,300	26,700	26,700	-	54,700
Mango	-	-	-	-	24,200	24,200
Total	339,600	144,500	43,100	41,700	24,200	593,100

B. 3. 4. Target Yield of Crops

Target yields of major crops are estimated as follows:

Crops	Target Yield (kg/ha)	Crops	Target Yield (kg/ha)
Wet Paddy	4,000	Groundnuts	1,875
Dry Paddy	4,500	Mungbean	1,125
Soybean	1,875	Mango	13,800

B. 3. 5. Available Water Resources

As the fundamental condition to be considered in the water balance simulation, alternative studies on possible live storage capacities expected from the selected 22 damsites were made as given in Table -1. The following summarizes four alternative plans of dam sizing:

(1) Maximum Plan : Dam sizes equivalent to the maximum dam inflows in the past 20 years or technically/topographically allowable maximum sizes are considered.

(2) Standard Plan : Standard capacities corresponding to the mean inflows during the past 20 years are given.

(3) Reduced Plan : A plan situated intermediate between the "standard" and "minimum" plan.

(4) Minimum Plan : Minimum capacities only to irrigate the existing scale of paddy during wet season as well as upland field and others in dry season are considered.

TABLE-1. POSSIBLE STORAGE CAPACITY AND WATER COST (BHRTS/CU.M)

Dam No.	Maximum Size Plan	Standard Size Plan	Reduced Size Plan	Minimum Size Plan	Remarks
1*	3.96 (169)	4.48 (134)	5.51 (97)	6.35 (74)	Lower Bang Pakong
2*	4.14 (136)	5.01 (98)	6.27 (66)	9.73 (35)	Sub-Basin
3*	3.39 (498)	3.72 (410)	3.97 (345)	4.41 (278)	Ta Lat Sub-Basin
4*	2.47 (382)	2.84 (293)	3.72 (205)	4.54 (140)	
5	1.28 (275)	1.54 (199)	1.93 (137)	2.52 (88)	
6*	2.92 (368)	3.50 (240)	4.48 (146)	6.30 (78)	
7*	2.63 (903)	2.90 (718)	3.30 (553)	3.88 (413)	Phra Sathung
8*	2.14 (534)	2.56 (391)	3.34 (255)	5.63 (130)	Sub-Basin
9	3.23 (249)	3.71 (186)	5.13 (104)	9.40 (44)	
10*	2.68 (402)	3.61 (232)	5.44 (120)	12.75 (40)	Upper Phra Prong
11	1.55 (136)	1.94 (93)	2.32 (67)	3.02 (46)	Sub-Basin
12	2.25 (341)	2.35 (286)	2.49 (236)	2.70 (188)	Maenum Hanuman
13	0.81 (113)	1.12 (72)	1.72 (41)	3.30 (19)	Sub-Basin
14	2.54 (36)	2.90 (29)	3.36 (23)	4.18 (17)	
15	1.53 (130)	1.89 (89)	2.70 (52)	4.69 (25)	
16	8.31 (42)	8.94 (33)	9.63 (26)	10.91 (19)	
17	5.91 (42)	6.69 (29)	7.86 (19)	10.28 (11)	
18/9	4.44 (320)	4.59 (278)	4.83 (236)	5.21 (196)	
20	9.11 (154)	9.20 (134)	9.30 (116)	9.40 (100)	Upper Bang Pakong
21	0.54 (254)	0.63 (184)	0.75 (134)	0.93 (94)	Nakhon Nayok
22	7.24 (130)	7.68 (100)	8.24 (73)	9.12 (51)	Sub-Basin

Note: (1) Water Cost = $\frac{\text{Construction Cost + Acquisition Cost}}{\text{Live Storage Volume}}$

(2) Parenthesis denotes live storage volume in MCM.
(3) Blanket method was considered for dams *-signed.

B. 3. 6. Alternative Irrigation Plans

Combining field findings in various sectors concerned, 4 cases of alternative irrigation plans in total were established. Basic concept employed in establishing these irrigation plans are briefly explained as follows:

Irrigation Plan-1 : In addition to full irrigation of the existing wet season paddy, the feasible maximum scale of upland crops, vegetables and fruit crops is introduced. Within the allowable limit of water resources, the maximum scale of dry season paddy is also considered. This plan would correspond with the maximum sizing plan of water resources development.

Irrigation Plan-2 : In the irrigation plan-1, the cropping rate on the existing paddy field was taken at about 150% as a target. This plan would correspond to the standard sizing plan of water resources development.

Irrigation Plan-3 : The second cropping on the existing paddy field is limited to the feasible maximum scale of upland crops. No dry paddy cultivation is expected. This plan would correspond with the reduced plan of water resources development.

Irrigation Plan-4 : Only existing scale of wet season paddy and upland crops is considered. This plan would correspond to the minimum plan of water resources development.

On the basis of crop water requirements and water demands for other sectors than irrigation, computations were made to simulate the proposed situation of water balance in irrigation blocks, and then computed results were summarized in sub-river basins as well as in the entire Bang Pakong river basin. Irrigable area by each irrigation plan is as follows:

Irrigable Area by Alternative Development Plan

Irrigation Plan	Wet Season		Dry Season				Net Irr. Area
	Paddy	Vege.	Paddy	Upland C	Vege.	Orchard	
Alt. Plan-1	339,600	28,000	67,200	120,000	28,000	24,200	406,800
Alt. Plan-2	339,600	28,000	38,200	120,000	28,000	24,200	406,800
Alt. Plan-3	339,600	28,000	-	120,000	28,000	24,200	406,800
Alt. Plan-4	339,600	28,000	-	15,000	28,000	24,200	406,800

Note: Net irrigation area = 339,600 + 28,000 + 15,000 + 24,200 = 406,800 ha.
Unit is ha.

B. 3. 7. Water Demand

B. 3. 7. 1. Irrigation Water Demand

Irrigation diversion requirement varies from time to time and from place to place depending upon the availability of effective rain. By way of an example, irrigation water demands were extracted from the specific case of water balance study (Alternative Development Plan-2), as follows:

Irrigation Diversion Requirement (Alternative Development Plan-2)

Sub-Basin	Irrigation Area (ha)	Water Requirement (MCM)		
		Crop	Effect. Rain	Diversion
Upper Phra Prong	62,400	377.830	211.933	310.179
Khlong Phra Sathung	43,000	261.950	146.077	216.740
Middle Phra Prong	25,000	159.574	94.342	118.959
Maenum Hanuman	39,600	230.404	128.192	191.662
Upper Bang Pakong	87,900	1,485.396	732.863	1,350.028
Maenum Nakhon Nayok	207,400	766.108	423.962	575.036
Khlong Tha Lat	8,700	54.923	19.995	64.567
Lower Bang Pakong	104,000	742.186	306.755	779.703
Total	578,000	4,078.369	2,064.116	3,606.873

B. 3. 7. 2. Domestic Water Supply

The targets of served population ratio in the year of 2000 in urban and rural areas were set up around 75 to 95% and 60% respectively. Water demand projection of 12 existing large-scale facilities under PWA was based primarily on the figure recommended by the authority. Average water consumptions in rural areas as well as sanitary districts, on the other hand, were assumed to be

TABLE-2 WATER DEMAND AND WATER BALANCE

Sub-River Basin	Mean Annual Runoff (MCM)	Water Demand (MCM)					Required Dam Capacity (MCM)			
		Irrigation	Domestic	Industry	Fishery	Total	Average	1/5 Drought	1/10 Drought	Maximum
Lower Bang Pakong (LBP)	647.6	779.7	52.9	148.2	14.5	995.3	433.5	490.5	526.4	588.1
Khlong Tha Lat (KTL)	700.5	64.6	8.1	3.9	-	76.6	36.9	52.1	65.3	51.2
Upper Bang Pakong (UBP)	1,481.4	1,350.0	17.9	28.2	-	1,396.1	625.9	707.7	767.2	906.7
Maenum Nakhon Nayok (MNN)	1,543.9	575.0	12.7	22.5	-	610.2	174.2	222.4	265.9	332.6
Middle Phra Prong (MPP)	559.7	119.0	2.4	2.3	-	123.7	42.9	52.2	58.3	65.4
Maenum Hanuman (MHM)	1,430.8	191.7	5.1	6.4	-	203.2	83.5	99.7	108.8	119.9
Khlong Phra Sathung (KPS)	877.2	216.7	6.7	1.7	-	225.2	96.3	108.9	116.6	129.0
Upper Phra Prong (UPP)	690.5	310.2	10.3	2.1	-	322.6	152.3	174.0	185.6	190.6
Entire River Basin	7,931.4	3,606.9	116.1	215.3	14.5	3,952.8	1,645.6	1,844.6	2,094.1	2,227.9

Note: (1) Data period is from 1968 to 1987.
(2) Irrigation demand is gross requirements after consideration of efective rains.
(3) Irrigation beneficiaries are selected from the areas situated downstream of proposed damsites where waters are conveyed by gravity.
(4) Available water resources are evaluated by sub-basin as follows:
- Lower Bang Pakong : No.1 damsite (119MCM)
- Khlong Tha Lat : No.4 damsite (300MCM)
- Khlong Phra Sathung: No.8 damsite (470MCM)
- Upper Phra Prong : No.10 and 11 damsites (160+86MCM)
- Maenum Hanuman : No.12,15,18 and 19 damsites (290+98+322MCM)
- Upper Bang Pakong : No.20 damsite (133MCM)
- Maenum Nakhon Nayok: No.21 and 22 damsites (188+98MCM)
Total 12 damsites (2,264 MCM)

about 150 liter/capita/day in gross with a service ratio of 60%. Population projection in rural area was made by assessing movement of population during 5 years from 1984 to 1988. As the rate of total losses due to conveyance, leakage and operation, 25% and 40% were used respectively for urban and rural areas, on the premise of system improvement. Water demands so estimated is summarized in Table-2.

B. 3. 7. 3. Industrial Water Supply

The scale and extent of industrial complex development in major local areas are assumed to be 200 to 400 ha (1,250 to 2,500 rai) based on the number of existing factories and the present status of infrastructure development. As the maximum unit water demand for 12 m^3/day/rai was obtained for the light industry, on the basis of the results of surveys and discussions made with IEAT, NESDB and private sectors. Total water demand in the target year 2000 so estimated is 232.86 MCM/year.

B. 3. 8. Cropping, Irrigation and Paddy Double Cropping Relations

Various parameters showing the rate of total cropping area, the rate of irrigation area and the rate of cropping on the paddy field obtained for each alternative development plan are as follows:

Alternative Plan	Net Beneficial Area (ha)	Cropping Ratio	Irrigation Ratio	Cropping Ratio on Paddy Field
Irrigation Plan-1	406,800	153%	149%	51%
Irrigation Plan-2	406,800	146%	142%	43%(*)
Irrigation Plan-3	406,800	136%	132%	31%
Irrigation Plan-4	406,800	111%	107%	0%

Note: The (*) value would be 50% if Nakhon Nayok sub-basin is excluded.

B. 3. 9. Required Dam Capacity

In total, 22 damsites were preliminarily selected and investigated. Water shortages obtained in terms of the required capacities of the proposed storage reservoirs were then compared with the available runoff at the proposed damsites. Figure-1 to 4 will explain such relations. Required capacities were thus allocated to each of possible damsite.

Require Dam Storage by Alternative Development Plan

(Unit: MCM)

Dam No.	Alt. Plan-1	Alt. Plan-2	Alt. Plan-3	Alt. Plan-4
1	172	119	119	79
4	370	300	300	-
5	-	-	-	81
Rabom	(40)	(40)	(40)	(40)
9	565	470	238	157
10	160	160	122	122
11	105	86	86	-
12	350	290	290	193
15	150	98	45	-
18 + 19	327	322	204	204
20	152	133	133	99
21	230	188	90	90
22	126	98	71	71
Total	2,747	2,304*	1,788	1,136

Note: (1) Rabom dam is under construction.
(2) 2,304 MCM (*) includes losses due to evaporation and seepage, corresponding to 10% of the required capacity.

B. 3. 10. Optimum Irrigation Development Plan

B. 3. 10. 1. Net Production Value

Net production values expected from implementation of alternative irrigation development plans were estimated as follows:

(Unit : million baht)

Sub-Basin	Alt. Plan-1	Alt. Plan-2	Alt. Plan-3	Alt. Plan-4
Lower Bang Pakong	648	624	547	501
Tha Lat	103	100	95	92
Upper Bang Pakong	1,365	1,300	1,194	382
Nakhon Nayok	160	137	62	62
Middle Phra Prong	96	85	85	59
Maenum Hanuman	254	240	240	198
Phra Sathung	254	239	239	205
Upper Phra Prong	412	390	390	338
Total	3,292	3,115	2,853	1,837

B. 3. 10. 2. Construction Cost (Agriculture Sector)

The project investment cost inclusive of the construction costs for storage dams, proposed Bang Pakong diversion dam, main and lateral irrigation facilities and on-farm facilities were estimated. The construction cost for storage dam was allocated between agricultural and other sectors in proportion to the amount of water to be released from the dam for use in each sector. Total investment cost to be shared by the agricultural sector was then accumulated as below:

(Unit: MCM & %)

Sector	Alt. Plan-1	Alt. Plan-2	Alt. Plan-3	Alt. Plan-4
Irrigation	4,066 (92%)	3,607 (92%)	2,997 (91%)	2,412 (87%)
Industrial Supply	215 (5%)	215 (5%)	215 (6%)	215 (8%)
Water Supply	116 (3%)	116 (6%)	116 (3%)	116 (4%)
Fishery	14 (0%)	14 (0%)	14 (0%)	14 (1%)
Total	4,412	3,953	3,343	2,758

Note: Irrigation and fishery are counted as agricultural sector.

CONSTRUCTION COST (AGRICULTURAL SECTOR) BY ALTERNATIVE PLAN

(Unit: Million Baht)

Construction Cost	Alt. Plan-1	Alt. Plan-2	Alt. Plan-3	Alt. Plan-4
Dam Construction	9,957	8,902	7,839	6,212
- do - (Agri. Sector)	92% = 9,160	92% = 8,190	91% = 7,133	88% = 5,466
Diversion Dam	595	595	595	595
Main Facilities	12,302	12,302	12,302	12,302
On-farm Facilities	4,037	4,037	4,037	4,037
Total	26,094	25,124	24,067	22,400

Note: (1) The Rabom dam is at present under construction.
(2) The proposed Khlong Luang dam is assigned as the No.1 dam.
(3) Some 1,500 million bahts of construction cost of the Bang Pakong diversion dam is allocated fifty fifty between agriculture and other sectors. The cost for agriculture sector is then allocated between both banks of the Bang Pakong river, as;
1,500 × 50% × 384.6 MCM/484.6 MCM = 595 million bahts (Left bank) and 1,500 × 50% - 595 = 155 million bahts (Right bank)

B. 3. 10. 3. Optimum Plan of Irrigation Development

The net production values expected from the project were compared with the investment costs to be allocated to agricultural sector, in order to produce the B/C ratio to be achieved from implementation of each alternative plan of irrigation development.

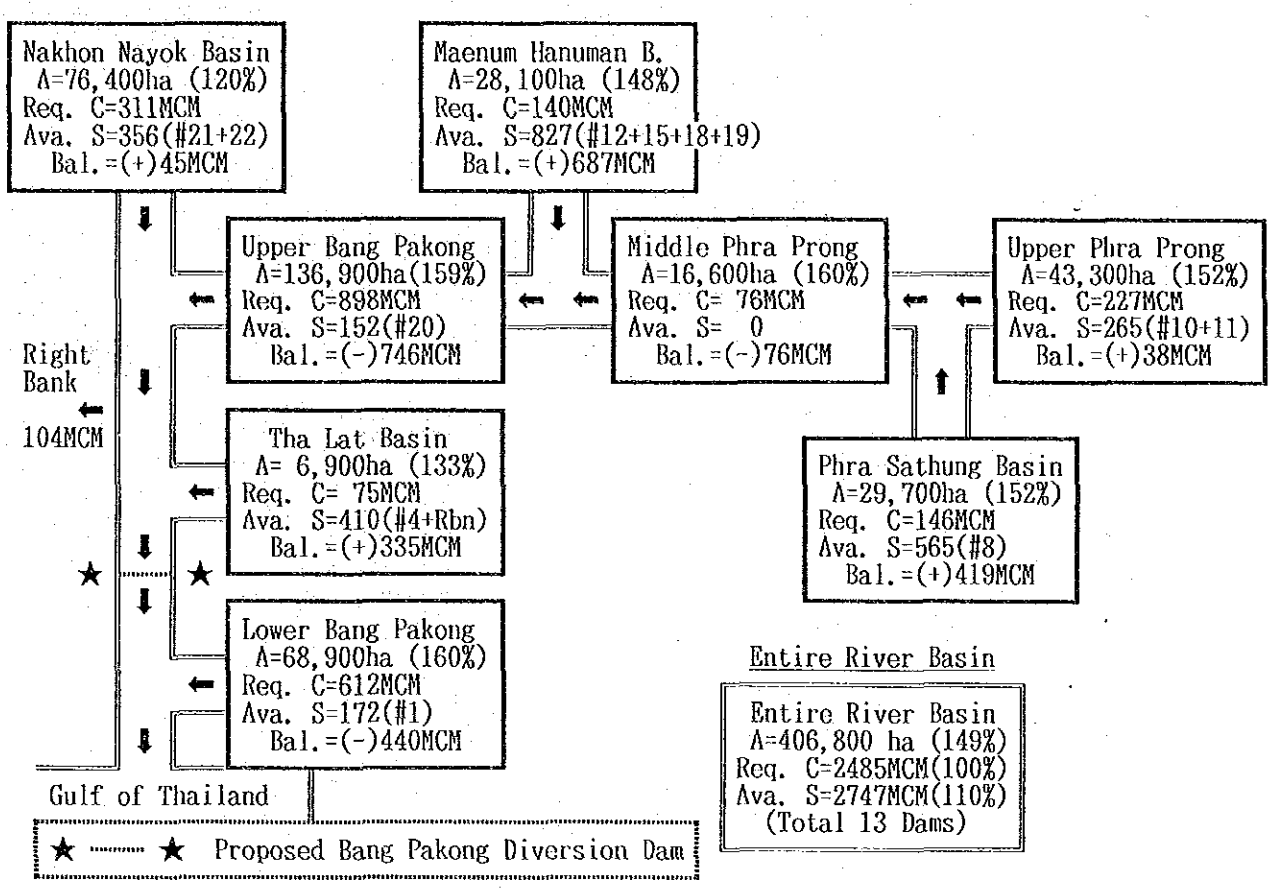
Item	Alt. Plan-1	Alt. Plan-2	Alt. Plan-3	Alt. Plan-4
Benefit				
- Benefit (1)	3,292	3,115	2,852	1,837
- O/M Cost (2)	302	301	300	299
- ((1) - (2))/0.12	24,917	23,450	21,267	12,817
Cost				
- Financial Cost	26,094	25,124	24,067	22,400
- Economic (0.9)	23,484	22,611	21,660	20,160
B/CRatio	1.06	1.04	0.98	0.64

Note: Discount rate was taken at 12% and project life was considered to be 60 years on an average.

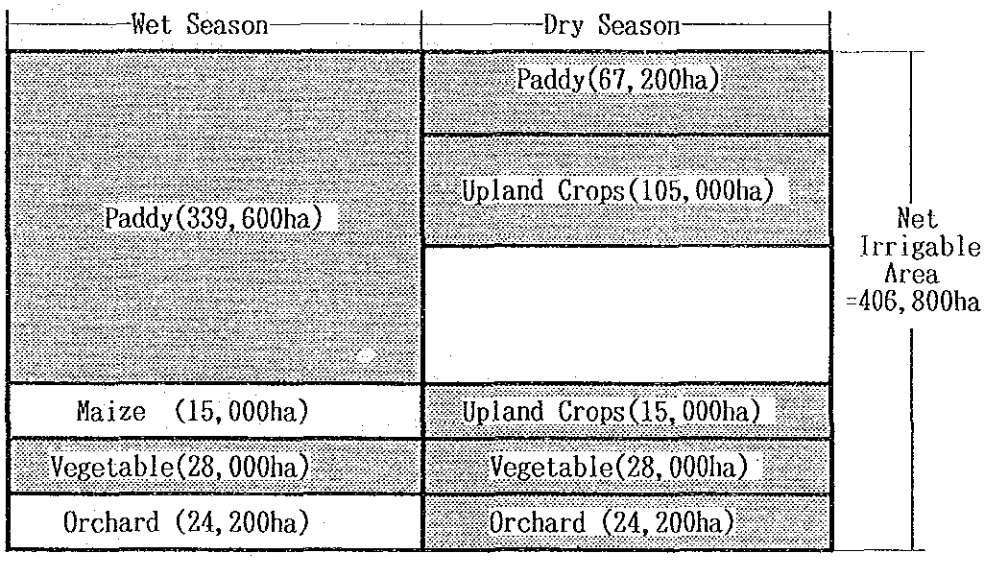
No significant difference has been realized from the above, excluding the alternative irrigation plan-4. However, the alternative plan-2 was selected on the optimum plan in consideration of the followings:

- Scale of dam and reservoir mostly corresponds with the average annual runoff from the catchment, and therefore, the plan-2 is considered to be appropriate and reasonable.
- Usable runoff from the dam catchment for irrigation and the other purposes will be maximized if the alternative development plan-1 is selected, however, more shortage of water than once in 10 year level will be resulted from the dam operation.
- Excluding the Nakhon Nayok sub-basin where availability of water resources is quite limited with isolated topographic situation, about 150% of cropping rate on paddy field is expected as a whole, meaning that farmers could plant crops on their paddy field every two years during dry season.

FIGURE - 1. OVERALL BASIN DEVELOPMENT PLAN (ALTERNATIVE PLAN-1)

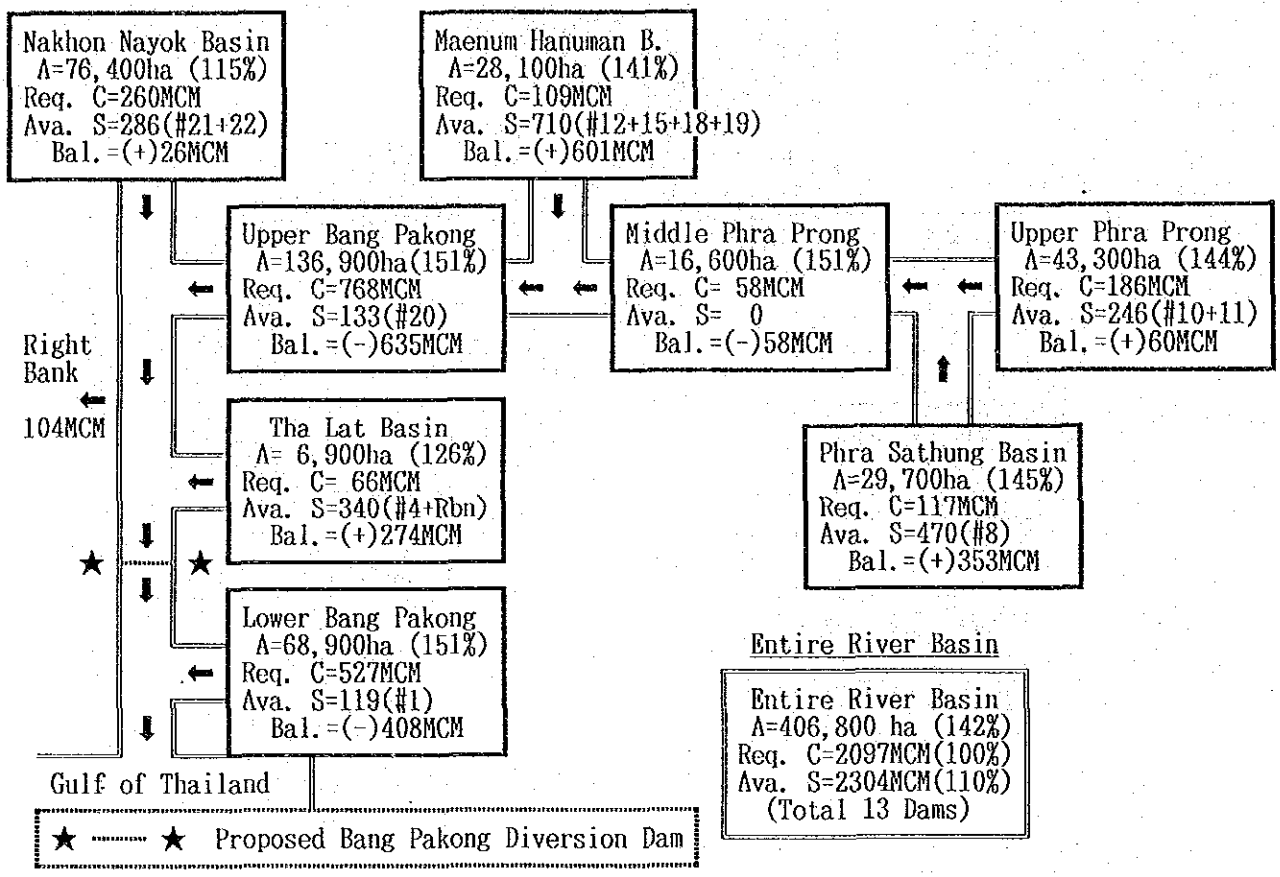


CROPPING AND IRRIGATION PLAN (ALTERNATIVE PLAN-1)

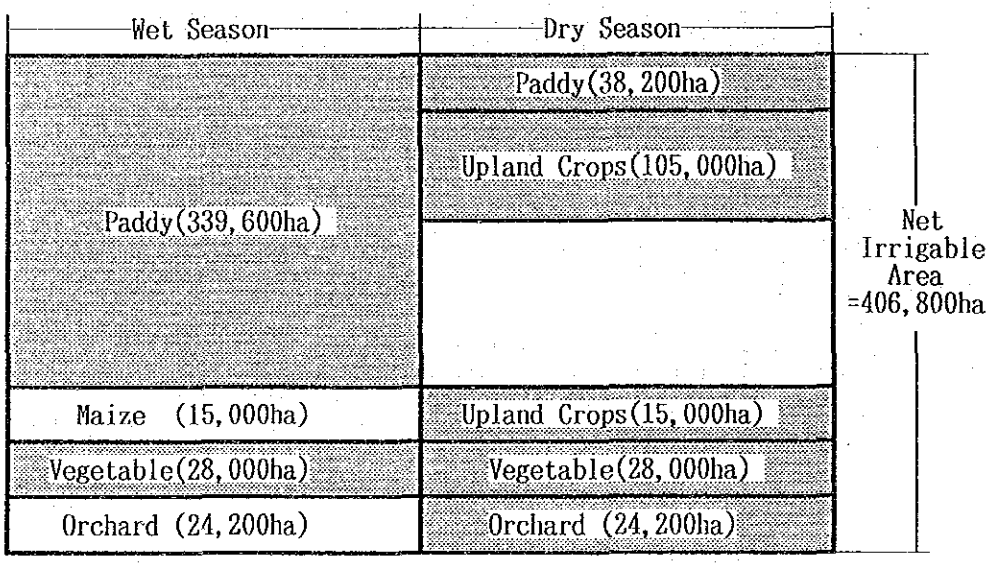


Notes : 1) Req.C stands for water shortage analyzed in terms of the required live storage of reservoirs.
2) Ava.S stands for available storage capacity at the proposed damsites.
3) Effective live storage of freshwater at the proposed Bang Pakong diversion dam is estimated at 30 MCM and is treated as the available channel storage in the water balance simulation study.

FIGURE - 2. OVERALL BASIN DEVELOPMENT PLAN (ALTERNATIVE PLAN-2)

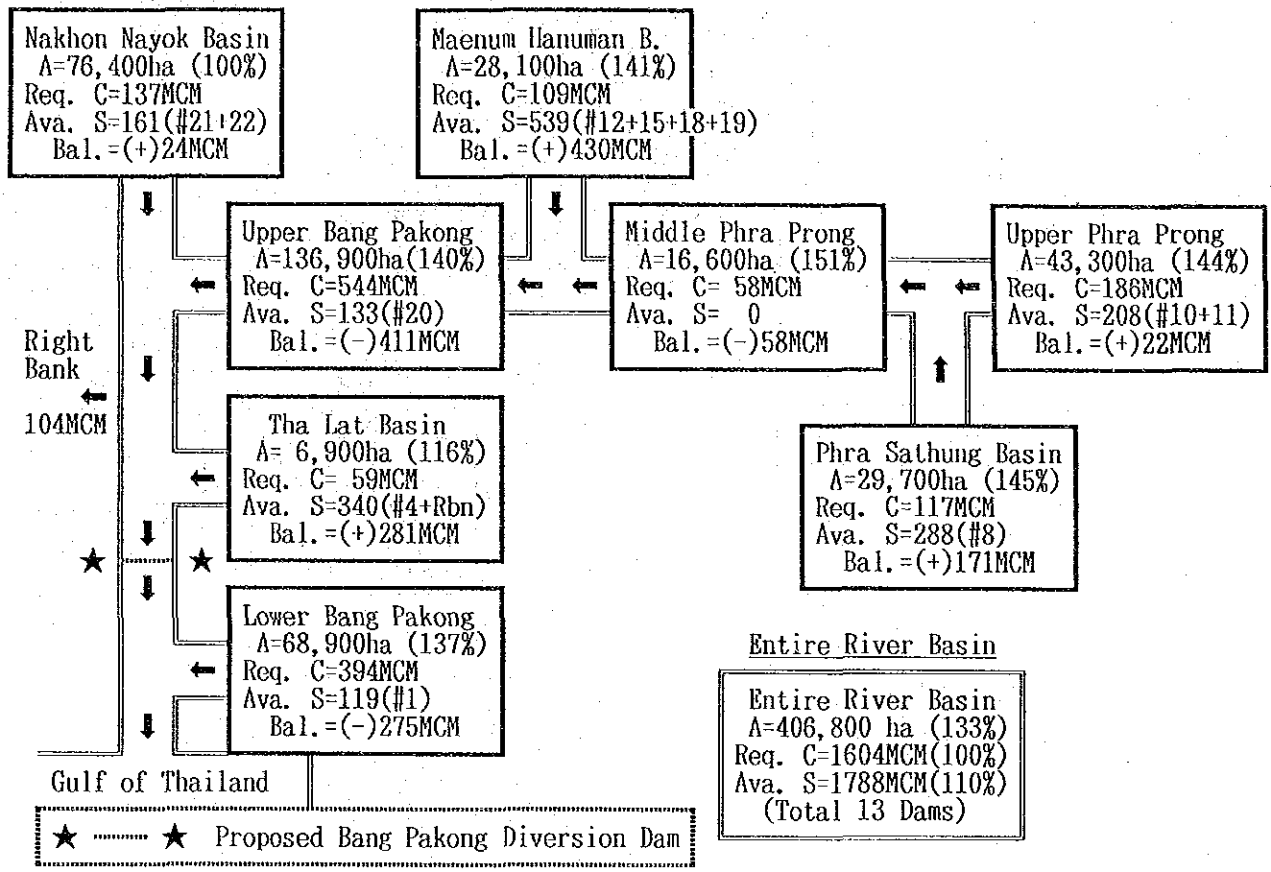


CROPPING AND IRRIGATION PLAN (ALTERNATIVE PLAN-2)

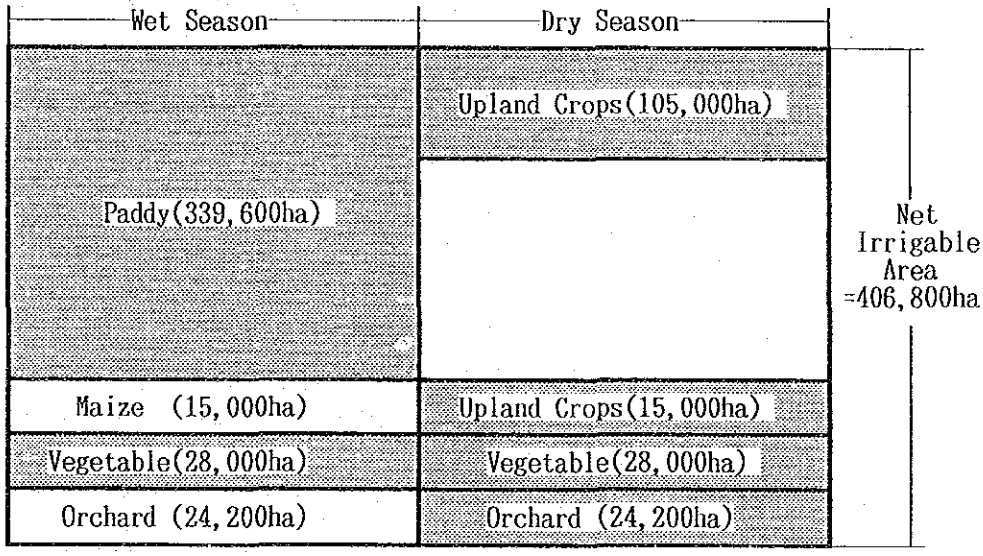


Notes : 1) Req.C stands for water shortage analyzed in terms of the required live storage of reservoirs.
2) Ava.S stands for available storage capacity at the proposed damsites.
3) Effective live storage of freshwater at the proposed Bang Pakong diversion dam is estimated at 30 MCM and is treated as the available channel storage in the water balance simulation study.

FIGURE - 3. OVERALL BASIN DEVELOPMENT PLAN (ALTERNATIVE PLAN-3)

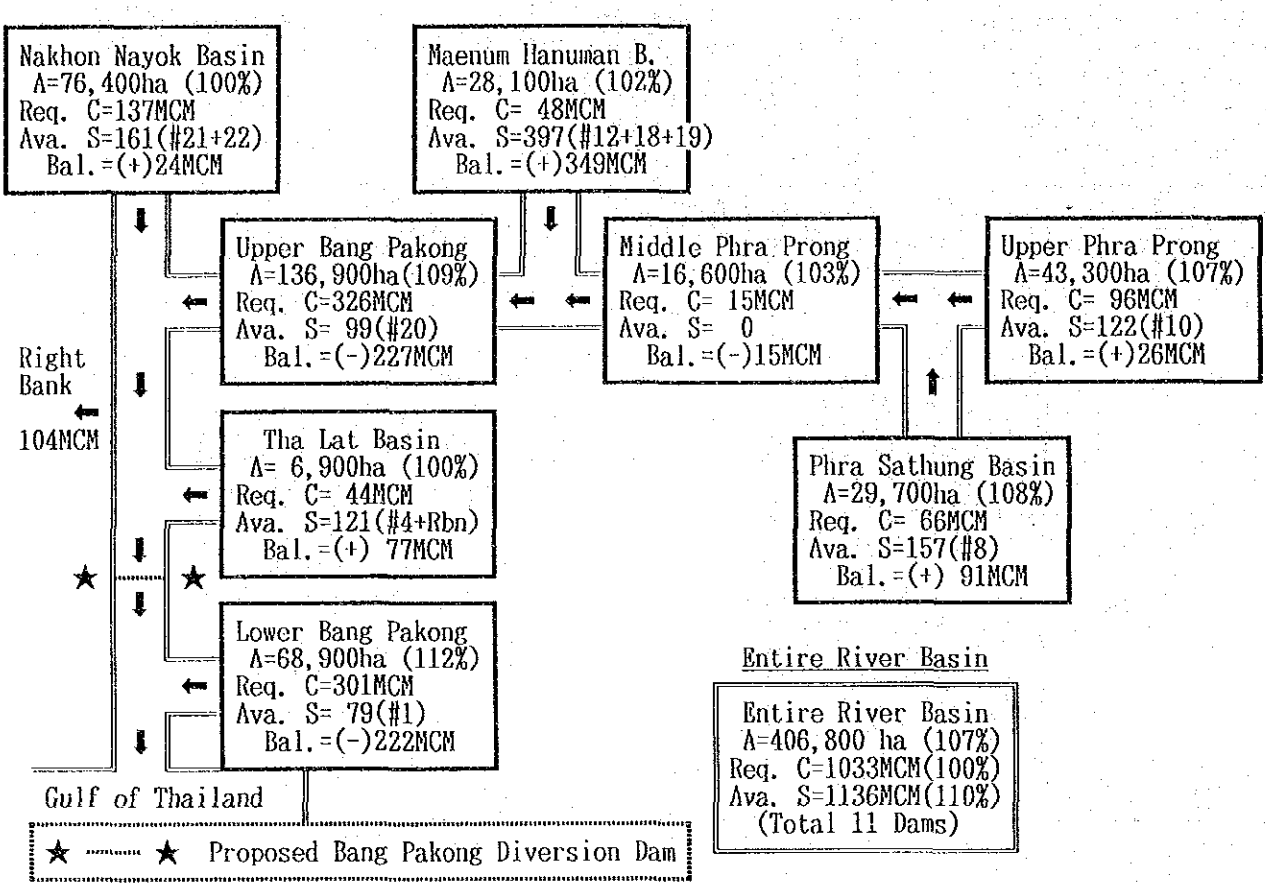


CROPPING AND IRRIGATION PLAN (ALTERNATIVE PLAN-3)

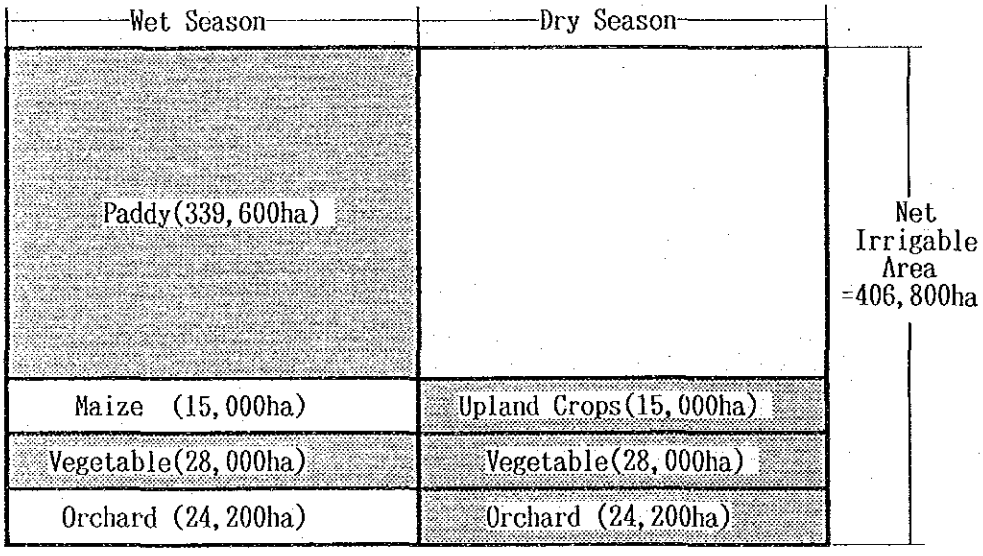


Notes : 1) Req.C stands for water shortage analyzed in terms of the required live storage of reservoirs.
2) Ava.S stands for available storage capacity at the proposed damsites.
3) Effective live storage of freshwater at the proposed Bang Pakong diversion dam is estimated at 30 MCM and is treated as the available channel storage in the water balance simulation study.

FIGURE - 4. OVERALL BASIN DEVELOPMENT PLAN (ALTERNATIVE PLAN-4)



CROPPING AND IRRIGATION PLAN (ALTERNATIVE PLAN-4)



Notes : 1) Req.C stands for water shortage analyzed in terms of the required live storage of reservoirs.
2) Ava.S stands for available storage capacity at the proposed damsites.
3) Effective live storage of freshwater at the proposed Bang Pakong diversion dam is estimated at 30 MCM and is treated as the available channel storage in the water balance simulation study.

B. 4. Project Implementation Plan

B. 4. 1. Selection of Priority Project

Based on the optimum basin development plan (alternative irrigation development plan-2), the highest priority sub-project was selected and proposed for implementation. As the guideline to select the highest priority sub-project, the followings were fully investigated:

National Economic Feasibility

- The cost-benefit ratios were calculated and compared in order to evaluate the investment efficiency to be expected from the development of each sub-basin.

Technical and Engineering Feasibility

- Availability of water resources at the proposed damsites was extracted from hydrological study, and they were compared each other in order to evaluate potentiality of water resources development.
- Relative difficulty of dam construction from technical and engineering point of view, especially in view of reliability of dam foundation, quality and quantity of embankment material and workability, was evaluated and compared.
- Relative difficulty of land acquisition and compensation in and around the dam/reservoir area was evaluated and compared.

Social Feasibility

- Needs and request of inhabitants as well as urgency for consolidation of irrigation facilities, domestic water supply facilities, road, electricity and industrial water supply facilities were evaluated.

Farm Economic Feasibility

- As index, the net incremental annual benefit per unit area to be expected by implementation of irrigated agricultural development was evaluated and compared.

The above items were then combined to make an overall evaluation as shown in Table-3. The following figures summarize the overall evaluation.

Sub-Basin	Total Point	Priority Order
Lower Bang Pakong	7.2	3
Tha Lat	8.7	1
Upper Bang Pakong	7.8	2
Nakhon Nayok	5.0	8
Middle Phra Prong	6.0	6
Maenum Hanuman	6.4	5
Khlong Phra Sathung	5.9	7
Upper Phra Prong	7.2	3

Eventually the areas irrigable with the water to be stored in the Rabom dam under construction and Si Yat dan to be built on the tributaries of Tha Lat river, have been established in the sub-river basins of Khlong Tha Lat (KTL) and Lower Bang Pakong (LBP).

TABLE-3. INTEGRATED EVALUATION OF PRIORITY SUB-PROJECT

View	Evaluation	Lower Bang Pakong	Tha Lat	Upper Bang Pakong	Nakhon Nayok	Middle Phra Prong	Maenum Hanuman	Phra Sathung	Upper Phra Prong
National Economic	Benefit - Cost Ratio	1.02	1.22	1.37	0.23	0.80	0.66	1.02	1.83
	Evaluation (Max=10)	5.6	6.7	7.5	1.3	4.4	3.6	5.6	10.0
	Evaluation x 0.2	1.1	1.3	1.5	0.3	0.8	0.7	1.1	2.0
Technical & Engineering	Availability of Water	1	2	1	2	3	3	3	2
	Difficulty of Construction	2	2	2	0.5	1	1	1	1.5
	Difficulty of Acquisition	1	1	2	2.5	2.3	2.3	1	2
	Sub-Total	4	5	5	5	6.3	6.3	5	5.5
	Evaluation (Max=10)	6.3	7.9	7.9	7.9	10.0	10.0	7.9	8.7
	Evaluation x 0.3	1.9	2.4	2.4	2.4	3.0	3.0	2.4	2.6
Social	Inhabitant's Needs	2	3	3	2	2	2	1	1
	Urgency of Industry	3	3	2	2	1	1	1	1
	Urgency of Water Supply	3	3	2	2	1	1	1	1
	Sub-Total	8	9	7	6	4	4	3	3
	Evaluation (Max=10)	8.9	10.0	7.8	6.7	4.4	4.4	3.3	3.3
	Evaluation x 0.3	2.7	3.0	2.3	2.0	1.3	1.3	1.0	1.0
Farm Economic	per Ha. Benefit	9.0	11.8	9.4	1.8	5.1	8.2	8.0	9.2
	Evaluation (Max=10)	7.7	10.0	8.0	1.5	4.4	7.0	6.8	7.8
	Evaluation x 0.2	1.5	2.0	1.6	0.3	0.9	1.4	1.4	1.6
OVERALL EVALUATION (TOTAL POINT)		7.2	8.7	7.8	5.0	6.0	6.4	5.9	7.2
PRIORITY ORDER		3	1	2	8	6	5	7	3

B. 4. 2. Project Implementation Plan

B. 4. 2. 1. Project Investment Cost

Item	Amount	Unit Cost
1. Irrigation Component	(million Baht)	(Baht/ha)
1.1. Direct Cost		
- Construction Cost		
Storage Dam	8,098	
Diversion Dam	595	
Main Irrigation Canal	12,302	
Sub-Total	20,995	
- Administration/Others	8,125	
Total	29,120	71,600
1.2. Indirect Cost		
- Construction Cost (On-farm)	4,037	
- Administration/Others	1,193	
Total	5,230	12,900
Grand Total	34,350	84,500
2. Water Supply/Industry Component		
- Construction Cost		
Storage Dam	794	
Diversion Dam	750	
Conveyance System (*)	1,000	
Sub-Total	2,544	
- Administration/Others	616	
Total	3,160	
Grand Total (1. + 2.)	37,510	

Note: Conveyance systems consist of facilities for Bang Pakong and Plaeng Yao industrial estates.

B. 4. 2. 2. Project Implementation Schedule

In due consideration of well-balanced regional development as well as high efficiency of the project investment, staged development is considered to be recommendable. The scheme was proposed to be of three stages. The following table summarizes the staged development scheme proposed by the study.

	First Stage	Second Stage	Third Stage	Total
1. Irrigation Component				
1.1. Irrigation Area (ha)	37,900 (LBP)	30,300 (LBP)	136,900 (UBP)	
	8,500 (KTL)	29,700 (KPS)	43,300 (UPP)	
		16,600 (MPP)	28,100 (MHM)	
			76,400 (MNN)	
Sub-Total	46,400	76,600	284,700	406,800
1.2. Investment Cost (million baht)				
- Direct Cost	3,930	6,170	19,020	29,120
- Indirect Cost	600	850	3,780	5,230
Sub-Total	4,530	7,020	22,800	34,350
(baht/ha)	97,600	850	80,100	84,400
2. Water Supply/Industry Component				
2. 1. Investment Cost (million baht)				
- Raw Water Supply	2,280	210	670	3,160
Sub-Total	2,280	210	670	3,160
Total Investment	6,810	7,230	23,470	37,510

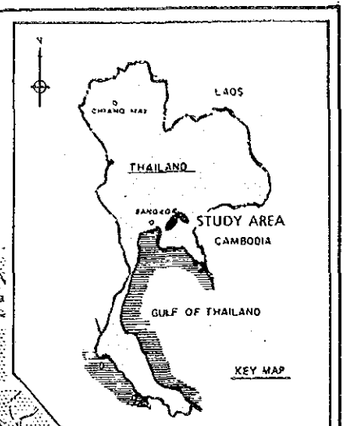
B. 4. 3. Environmental Assessment

A preliminary study of environmental assessment was made on the basis of the tentative project dimension as well as of the NEB guideline.

FEASIBILITY STUDY

THA LAT RIVER BASIN DEVELOPMENT PROJECT

SCALE 1 ; 250,000



BANG PAKONG PUMPING STATION
C = 17.64cu.m/s M = 390KW

BANG PAKONG DIVERSION DAM
EFFECT. CAPACITY 30MCM

BANG PAKONG EXPANSION AREA
A = 2,000ha

BANG PAKONG LEFT MAIN CANAL
L = 12km INITIAL C = 4.50cu.m/s

THA LAT DIVERSION WEIR
(existing)

RABOM DAM
DRAINAGE AREA = 175sq.km
EFFECT. CAPACILTY = 36.5MCM

EXISTING THA LAT AREA
A = 22,100ha

PLAENG YAO
INDUSTRIAL ESTATE

THA LAT EXPANSION AREA
A = 7,100ha

EXISTING BANG PAKONG AREA
A = 12,700ha

BANG PAKONG RIGHT MAIN CANAL
L = 24km INITIAL C = 12.89cu.m/s

THA LAT MAIN CANAL (existing)
L = 44km INITIAL C = 22.1cu.m/s

SI YAT MAIN CANAL
L = 49.5km INITIAL C = 7.10cu.m/s

BANG PAKONG
INDUSTRIAL ESTATE

KHLONG SI YAT DAM
DRAINAGE AREA = 976sq.km
EFFECT.CAPACITY = 300MCM
CREST LENGTH = 2,600m
HEIGHT = 30.0m

CHANGWAT CHACHOENGSAO
จังหวัดฉะเชิงเทรา

CHANGWAT CHON BURI
จังหวัดชลบุรี

Amphoe Bang Khla
Amphoe Phanom Sarakham
King Amphoe Ratchasan
Amphoe Sanam Chai Khet
Amphoe Bang Pakong
Amphoe Phan Thong
Amphoe Phrae Nikhom

THA LAT RIVER BASIN DEVELOPMENT PROJECT

IRRIGABLE AREA	
Tha Lat Expansion Area	7,100 ha
Existing Tha Lat Area	22,100
Existing Bang Pakong Area	12,700
Bang Pakong Expansion Area	2,000
Total	43,900 ha

FEASIBILITY STUDY

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

A. MAKING DEVELOPMENT PLAN

A. 1. Definition of the Project

In the overall basin study for the agricultural water resources development project of Bang Pakong river basin, the river basin development plan was established, and the priorities to be developed were given to respective sub-basin projects. Consequently, as the project area with top priority, the Tha Lat river basin project area consisting of two sub-basins, that is, Lower Bang Pakong and Khlong Tha Lat, was selected. In these two sub-basins, the Feasibility Study area of 60,600 ha was finally fixed.

So as to supply the above-mentioned area stably with irrigation water as well as the staple cities along the river with drinking water, the industrial estates near the river with industrial water and the fish ponds and the shrimp culture with fresh water to control the salinity for the latter; such water resources development as Si Yat dam to be constructed, Rabom dam under construction by RID and Bang Pakong diversion dam to be built, new construction and rehabilitation of main irrigation and drainage canals and consolidation of facilities on farm level are major works of the Project.

A. 2. Integrated Agriculture Development Plan

A. 2. 1. Land Use Plan

The present land use in the Feasibility Study area is categorized as shown below.

Present Land Use (ha)

Paddy field	Dry field	Orchard	Bush land	Fish pond	Sub-total	Other land	Total
34,710	2,780	4,060	2,000	1,400	44,950	15,650	60,600

The land use plan is shown below as compared with the present land use.

Land Use Plan (ha)

Land Use	Present	Planned	Balance
Paddy Field	34,710	34,400	(-) 310
Dry Field	2,780	940	(-) 1,840
Orchard	4,060	7,160	3,100
Bush Land	2,000	450	(-) 1,550
Other Land	250	850	600
Total	43,800	43,800	0

A. 2. 2. Project Crop Selection and Cropping Pattern

Depending on the careful study, Paddy, Maize, Soybean, Groundnuts, Mungbean, Mango and Vegetables are recommended as adaptable crops in the Project area. Basically, double cropping pattern is adopted and the following five categories are proposed.

Field Character	Wet Season	Dry Season
- Paddy field:	1) Paddy	Paddy
	2) Paddy	Legume, Maize, Vegetables(cropping rate is about 50%)
- Upland field:	3) Maize	Legume
	4) Vegetables	Vegetables
- Orchard:	5) Mango	Mango

A. 2. 3. Cropping Areas by Crops

The cropping areas by crops are summarized below. Incidentally, maize is not irrigated only in wet season.

Cropping Areas by Crops (ha)

Crops	Wet Season	Dry Season	Total
Paddy	34,400	6,880	41,280
Maize	700	460	1,160
Soybean	-	3,350	3,350
Groundnuts	-	2,930	2,930
Mungbean	-	3,160	3,160
Vegetables	240	4,350	4,590
Mango	7,160	(7,160)	7,160
Total	42,500	21,130	63,630

The crop intensity will be 149%. (101.5% at present)

A. 2. 4. Project Crop Production

Project Crop Production

Crops	Harvested Areas	Yield	Production
	(ha)	(kg/ha)	(t)
Paddy in Wet Season	34,400	4,000	137,600
Paddy in Dry Season	6,880	4,500	30,960
Maize in Wet Season	700	2,100	1,470
Maize in Dry Season	460	2,500	1,150
Soybean	3,350	1,500	5,023
Groundnuts	2,930	1,500	4,395
Mungbean	3,160	1,100	3,476
Vegetables	4,590	14,300	65,626
Mango	7,160	13,800	98,808
Total	63,630		348,508

Note: It takes 10 years or more to attain the above target production excepting mango in proposed Bang Pakong Expansion Area.

A. 3. Water Resources Development Plan

A. 3. 1. Irrigable Area

The irrigable area of the Tha Lat river basin development project is divided into four areas.

1) Existing Tha Lat Area

This area consists mainly of paddy fields of 21,100 ha and fish ponds of 1,000 ha irrigated by gravity, with a weir, main and lateral canals.

The second cropping for 48% of paddy fields with irrigation water is planned to be introduced.

2) Existing Bang Pakong Left Bank Area

This area is so called a water conservation area of 12,300 ha and fish pond of 400 ha without exclusive irrigation facilities, consisting of paddy fields of 9,900 ha, dry fields of 190 ha and orchard of 2,210 ha.

The second cropping with irrigation water for 64% of paddy fields is planned to be introduced.

3) Tha Lat Expansion Area

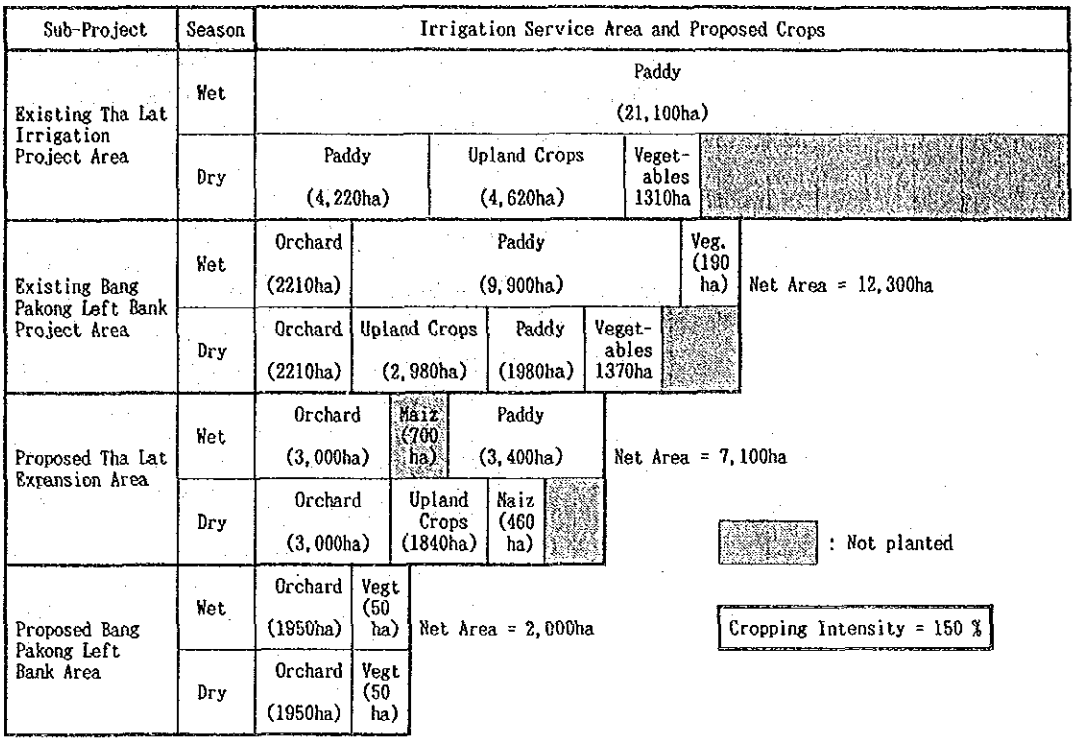
This area is situated downstream of Si Yat dam to be constructed and upstream of the Existing Tha Lat Area. The farm land of 7,100 ha will be developed and irrigated by this project plan.

4) Bang Pakong Expansion Area

This area is situated in the orchard belt zone between Existing Bang Pakong Left Bank Area and the Bang Pakong river. The orchard and the dry fields with vegetables will be fully irrigated through the year by this project plan.

A. 3. 2. Irrigation Plan

The irrigation plan is shown in the following figure.



A. 3. 3. Irrigation Water Demand

The yearly irrigation demands by irrigation service areas for 20 years from 1968 till 1987 are summarized in the following table.

Irrigation Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
Existing Tha Lat	wet	175.2 (1979)	80.0 (1983)	119.3
	dry	115.6 (1968)	79.0 (1975)	106.8
	annual	287.4 (1979)	180.3 (1983)	226.1
Existing & Proposed Expansion of Bang Pakong	wet	81.5 (1979)	39.4 (1983)	57.2
	dry	196.8 (1968)	178.2 (1973)	186.3
	annual	274.1 (1979)	224.2 (1983)	243.5
Tha Lat Expansion	wet	27.2 (1979)	12.8 (1983)	18.7
	dry	58.9 (1968)	46.6 (1984)	52.0
	annual	84.1 (1979)	59.9 (1969)	70.7
Whole Service Area	wet	283.9 (1979)	132.2 (1983)	195.3
	dry	371.3 (1968)	322.3 (1973)	345.0
	annual	645.6 (1979)	465.5 (1983)	540.3

A. 3. 4. Fisheries Water Demand

As the fisheries water, fresh water supplies for brackish water shrimp culture of 1,350 ha and fresh water fish ponds of 1,400 ha will be needed. The required water amount is estimated as follows.

Fishery Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
Existing Tha Lat	wet	3.2 (1979)	2.6 (1983)	3.0
	dry	3.7 (1971)	3.4 (1983)	3.0
	annual	6.9 (1979)	6.0 (1983)	6.4
Existing & Proposed Expansion of Bang Pakong	wet	2.0 (1979)	1.6 (1983)	1.8
	dry	11.2 (1968)	11.0 (1983)	11.0
	annual	13.1 (1979)	12.6 (1983)	12.8
Tha Lat Expansion	annual			
Whole Service Area	wet	5.2 (1979)	4.2 (1983)	4.8
	dry	14.8 (1979)	14.4 (1973)	14.3
	annual	20.0 (1979)	18.7 (1983)	19.1

A. 3. 5. Industrial and Domestic Water Demand

Industrial and Domestic Water Demand

Irrigation Service Area	Amphoe	Water Source	Water Demand		
			Industry	Domestic	Total
			(MCM/yr)	(MCM/yr)	(MCM/yr)
Tha Lat, Existing	Phnom Sarakan	Existing Tha Lat Weir	9.798	3.810	13.609
	Plaeng Yao		36.304	1.519	37.822
	Sub-total		46,103	5.329	51.432
Bang Pakong, Existing	Ban Pho	Bang Pakong Diversion Dam	9.350	1.760	11.109
	Bang Pakong		61.950	4.596	66.546
	Sub-total		71.300	6.356	77.656
Tha Lat, Expansion	Sanamchai Ket	Rabom Dam & Si Yat Dam	1.480	7.416	8.896
	Sub-total		1.480	7.416	8.896
Bang Pakong, Expansion	Bang Khra	Bang Pakong Diversion Dam	19.217	2.849	22.066
	Chachoengsao		22.653	10.735	33.388
	Sub-total		41.870	13.584	55.454
Total			160.753	32.685	193.438

A. 3. 6. Total Water Demand

The total water demand including irrigation, fisheries, Domestic and industrial water supplies is thus summed as follows:

Overall Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
Existing Tha Lat	Wet	205.7 (1970)	109.9 (1983)	149.6
	Dry	146.3 (1968)	127.5 (1975)	136.8
	Annual	348.6 (1979)	240.6 (1983)	286.4
Existing & Proposed Expansion of Bang Pakong	Wet	166.6 (1979)	124.1 (1983)	142.2
	Dry	291.4 (1968)	272.1 (1973)	278.9
	Annual	453.3 (1979)	402.9 (1983)	421.1
Tha Lat Expansion	Wet	31.8 (1979)	17.4 (1983)	23.3
	Dry	63.5 (1968)	51.2 (1984)	56.6
	Annual	93.4 (1979)	69.2 (1969)	79.9
Whole Service Area	Wet	404.0 (1979)	251.4 (1983)	315.0
	Dry	501.2 (1968)	451.3 (1973)	472.3
	Annual	895.2 (1979)	713.8 (1983)	787.3

A. 3. 7. Water Balance

The following two cases of water balance study were undertaken.

Case-1: Proposed final condition after completion of Rabom dam, Bang Pakong diversion dam and Si Yat dam.

Case-2: Transitional condition after completion of Rabom dam and Bang Pakong diversion dam only, but before completion of Si Yat dam.

The following assumptions were employed in water balance studies: that is,

Live storages of

(1) Rabom dam : 40 MCM
(2) Si Yat dam : 300 MCM
(3) Bang Pakong diversion dam: 30 MCM of fresh water between the upper water level of (+) 1.0 m and the lower water level of (-) 1.0 m under the control.

The water allocation manner will be shown as follows :

Water Allocation

Water Source		Water Users
Bang Pakong diversion dam	Irrigation:	Existing and proposed expansion of Bang Pakong plus compensatory supply to the Right Bank area
	Industry, Drinking and others.	
Existing		
Tha Lat Weir	Irrigation:	Existing Tha Lat area
	Industry, Drinking and others.	
Rabom and		
Si Yat dam	Irrigation:	Proposed Tha Lat Expansion.

As a result of water balance study in 20 years, on condition that the Bang Pakong diversion dam is so operated as to keep the upper limit of controlled water level of (+) 1.0 m as far as Rabom and/or Si Yat dams have storage capacties in reserve, the water shortage in each irrigation area and the minimum water storage amount of each dam were summarized below:

Summary of Water Balance Computation (CASE-1)

	Shortage in Irrigation Area			Minimum Storage (MCM)	
Year	Area (1)	Area (2)	Area (3)	Diversion Dam	Upstream Dam
1968	0.000	0.000	0.000	30.000	75.739
1969	0.000	0.000	0.000	30.000	64.370
1970	0.000	0.000	0.000	30.000	110.482
1971	0.000	0.000	0.000	30.000	61.979
1972	0.000	0.000	0.000	30.000	17.245
1973	0.000	0.000	0.000	30.000	1.000
1974	0.000	6.716	4.553	30.000	1.000
1975	0.000	6.863	2.180	30.000	4.000
1976	0.000	0.000	0.000	30.000	83.084
1977	0.000	0.000	0.000	30.000	79.217
1978	0.000	0.000	0.000	30.000	25.918
1979	0.000	0.000	0.000	30.000	9.048
1980	0.000	0.000	0.000	30.000	0.000
1981	0.000	0.000	0.000	30.000	112.364
1982	0.000	0.000	0.000	30.000	76.541
1983	0.000	0.000	0.000	30.000	19.527
1984	0.000	0.000	0.000	30.000	82.670
1985	0.000	0.000	0.000	30.000	60.999
1986	0.000	0.000	0.000	30.000	57.578
1987	0.000	0.000	0.000	30.000	38.471

Note : Area (1) = Existing and proposed expansion of Bang Pakong
(2) = Existing Tha Lat
(3) = Proposed Tha Lat expansion

FIGURE - 1. ALTERNATIVE CASE STUDIES OF WATER BALANCE

(Case-1 : Bang Pakong Diversion Dam + Si Yat Dam + Rabom Dam)

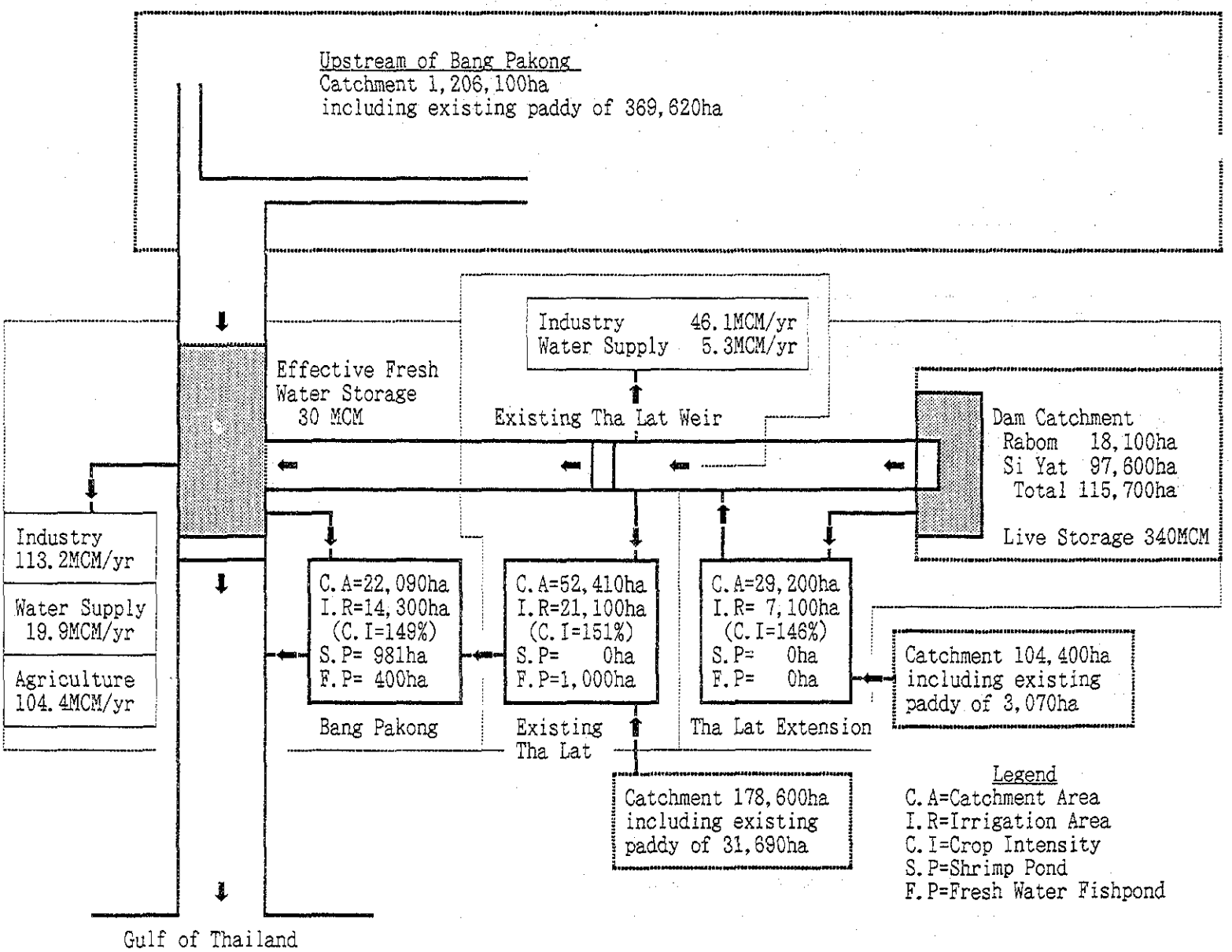
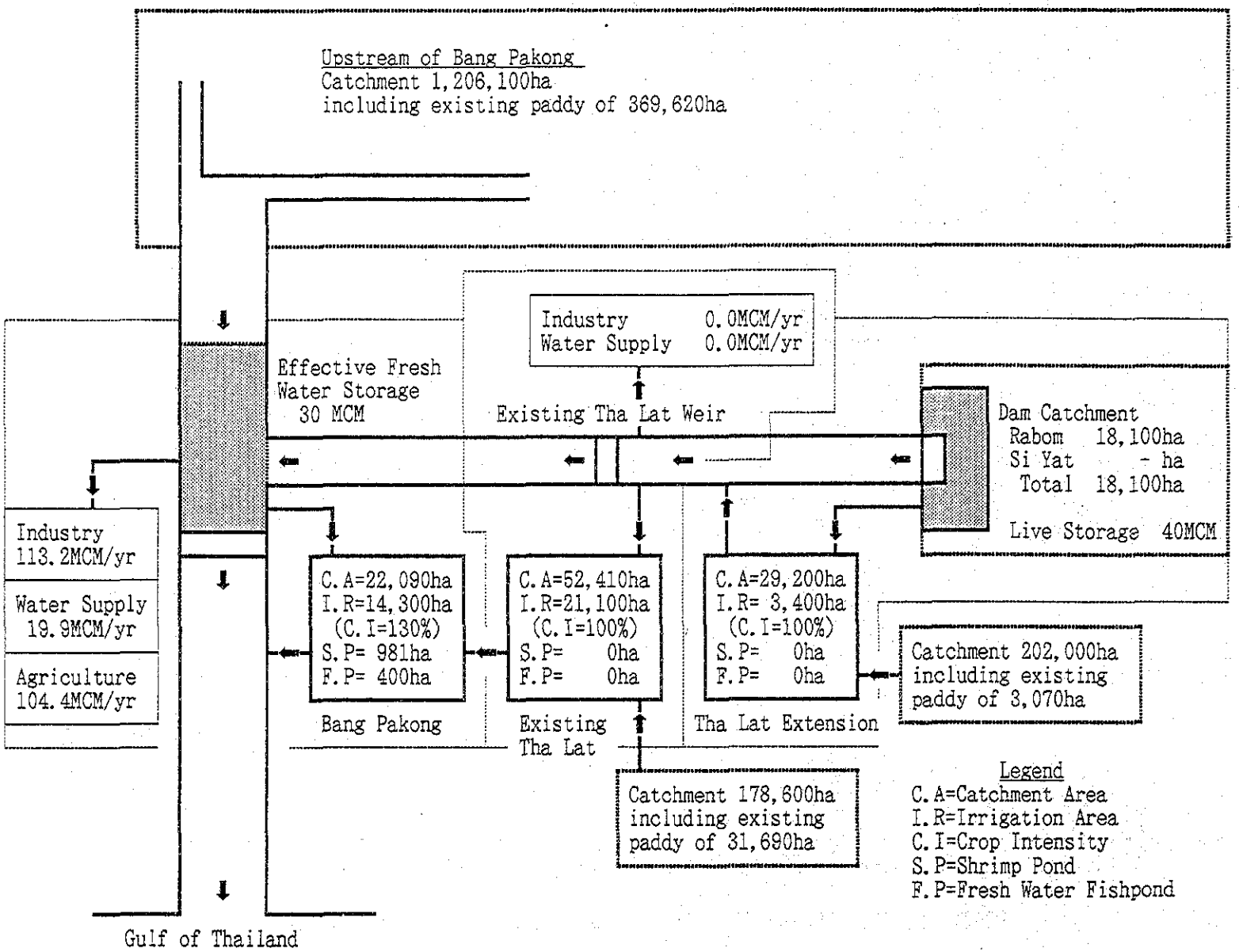


FIGURE - 2. ALTERNATIVE CASE STUDIES OF WATER BALANCE

(Case-2 : Bang Pakong Diversion Dam + Rabom Dam)



B. PROJECT FACILITIES

B. 1. Khlong Si Yat Dam

B. 1. 1. General Concept

The Khlong Si Yat dam is composed of a main dam, saddle dam, intake facilities and a floodway.

The main dam is constructed on the Si Yat river about 40 km upstream of the conjunction of the Rabom river.

An earthfill dam of homogeneous type with impermeable blanket is adopted for Khlong Si Yat dam.

The dam construction cost is estimated as 1,060 million baht and the construction period will be for four years.

TABLE - 1. KHLONG SI YAT RESERVOIR AND DAM FEATURES

Reservoir		
Average annual rainfall	1,343	mm
Drainage area	976	sq.km
Maximum annual runoff	487	MCM
Minimum annual runoff	182	MCM
Average annual runoff	286	MCM
Maximum water level	65.4	m
Normal water level	63.1	m
Minimum operating level	51.5	m
Reservoir area (at normal water level)	45.5	sq.km
Active storage	300	MCM
Dead storage	25	MCM
Gross storage	325	MCM
Dam		
Type	Homogeneous earthfill dam	
Crest length	Main dam 2,600	m
	Saddle dam 620	m
Maximum height	Main dam 30	m
	Saddle dam 12.5	m
Crest elevation	67.5	m
Embankment volume	approx. 3,600,000	cu.m

Spillway

Type	Side channel spillway	
Crest length	150	m
Crest elevation	63.1	m
Spillway capacity	1,030	cu.m/s
Inflow design flood (1,000 year frequency flood)	2,037	cu.m/s

Outlet Works

Type Concrete-encased pressure pipe conduit

Function

- to release stored water into Si Yat Main Canal (Qmax = 7.81 cu.m/s)
- to release stored water into Khlong Si Yat for supplemental water supply to the downstream areas excluding Tha Lat Expansion Area. (Qmax = 34.17 cu.m/s)

B. 1. 2. Site Selection

A comparative study has been made carefully for two alternative damsites No.1 and No.2 sites. The result is shown as follows:

Dams		Si Yat Dam (No.1)	Si Yat Dam (No.2)
Active Storage	(MCM)	396	300
Embankment Volume	(cu.m)	8,200	3,740
Active Storage / Embankment Volume		48.3	80.2
Rough Estimate of Construction Cost			
Embankment	('000 Baht)	820,000	374,000
Spillway	(〃)	266,000	206,000
Compensation	(〃)	293,000	221,000
Total		1,379,000	801,000
Water Cost	(Baht/cu.m)	3.48	2.67
Acquisition Area	(ha)	9,760	7,370

As shown above, No.2 site is advantageous because of its lower water cost and less expenses for acquisition of land to be submerged. Eventually, No.2 site was selected in agreement with RID in May 1990.

B. 1. 3. Site Topography, Geology and Fill Materials

1) Topography

The topographic feature of the proposed damsite is characterized with the prevalence of gentle but discernible low hills and widely extended flood plain.

The Si Yat river about 20 m in width flows down through alluvial plain to the northwest by west and is united at the damsite from the left bank by a tributary.

The alluvial flood plain has a width of 300 m on the left bank and 800 m on the right bank, and elevations of 45 to 48 m. The river-bed has an elevation of 39.7 m.

The undulated hill is distributed on the left bank where two discernible heights of flat terrains are traceable.

The flat terrains with an altitude of 50 to 54 m and 60 to 80 m are of terrace origin and the latter develops extensively 8 km in width. The undulated hill shifts into 200 m in height of mountainous terrain in the eastern divide.

The alluvial flood plain shifts into the mountainous terrain through the transitional detritus zone in the right abutment where the highest peak attains 158 m.

2) Site Geology

The formation is composed mainly of silty gravels and is characterized by the presence of rock fragments. The rock fragments and silty gravel on the left bank grade into clay in the riverbed and, sand and silty gravel on the right bank.

The mountainous terrain, which forms the right abutment of the main dam and also the left abutment of the saddle dam, is mainly underlain by sandstone and siltstone of Tanaosi Group of the Carboniferous in the basement. Although no outcrops of the rocks are found in the area, rock fragments of fresh siltstone are found on the mountain slope on the right abutment.

The permeability of the beds were determined by the Open-End Test in respective drilling holes. The figure shows that the layer of more than 10^{-2} cm/sec permeability is distributed in the flood plain on the right bank and in the lower terrace deposits, and thickness of these layers are 2 to 6 and 7 m respectively. Another layers underlaying at the damsite indicate less permeability of 10^{-3} cm/sec in any place.

B. 1. 4. Preliminary Design

1) Reservoir Plan

- Effective storage capacity: 300 MCM

  (nearly the same amount as annual mean run-off)

- Dead water capacity : 25 MCM

  (250 cu.m/sq.km/year × 976 sq.km × 100 year)

- Gross storage capacity : 325 MCM

- Normal water level : 63.1 m in elevation

- Minimum operating level : 51.5 m in elevation

- Reservoir area : 4.5 sq.km on normal water level

2) Dam

The earthfill dam of a homogeneous type is proposed for Khlong Si Yat dam by the following reasons:

Topography

The topographic feature of the proposed site is characterized with the prevalence of gentle but discernible low hill and widely extended flood plain.

The dam is approximately 2,600 m long at the dam crest, 67.5 m in elevation, with a maximum height of approximately 23 m above the river-bed.

An earthfill dam is recommendable due to the location in low dam height, from an economic point of view.

Foundation Condition

The foundation at almost all the parts of the proposed damsite consists of fine-grained materials such as silt, clay, silty clay, etc. These foundation layers must be good for the support of earthfill dam, but are not suitable for concrete gravity dam nor rockfill dam.

The seepage control through the permeable layer is to spread an artificial earth blanket upstream of the earth embankment of the dam.

Application of the grouting for the seepage control is not realistical, because the layers are composed largely of unconsolidated fine materials.

3) Fill Materials

The borrow-pit site for earth materials is located about 1 km upstream of the damsite. The site is underlain by impermeable fill materials with which people could be satisfied in terms of quantity and quality. More than 70% of the earth materials which can be taken from the borrow-pit are classified into CL.

The proposed quarry of rock materials for coarse aggregate and riprap is located in Khao Ba Ra Run 3 km far from the damsite. It is underlain by solid granite which has enough quality for the coarse aggregate and riprap.

4) Spillway

In consideration of the project scale and the site conditions, a 1,000 year frequency flood with a peak flood discharge of 2,037 cu.m/sec should be adopted as the design flood discharge flowing into the reservoir according to the criteria for storage dams of the Project Planning Division, RID.

As the proposed damsite has a large reservoir area of 45.5 sq.km on the normal water level of 63.1 m, the surcharge storage will be relatively large. Accordingly, the spillway capacity can be reduced and determined to be 1,030 cu.m/sec judging from flooding routing.

Rock foundation is only found on the mountainous terrain which forms the right abutment of the main dam and also the left abutment of the saddle dam. The location of the spillway is selected on the left abutment of the saddle dam in consideration of topographic feature, foundation conditions and the location of the outlet works. By taking the topography and foundation conditions of the site into account, the side channel spillway is recommended.

5) Outlet Works

Main functions required for the outlet works are as follows:

- To release stored water into the Si Yat Main Canal (Qmax = 7.81 cu.m/sec)
- To release stored water into the Si Yat river for supplemental water supply to the downstream areas excluding Tha Lat Expansion Area. (Qmax = 34.17 cu.m/sec)

The outlet works will be classified structurally into two types, one is tunnel type and the other is cut-and-cover conduit type. As a tunnel is not contact directly with the dam embankment, it may be safer than a cut-and-

cover conduit. However, the latter is recommended, because it is more economical as compared with the former.

B. 1. 5. Construction Plan and Schedule

1) Work Volume

The work volume by each working item for Khlong Si Yat dam is shown in the following table.

Item of Works	Work Volume
Fill of Impervious Zone	3,200,000 m^3
Fill of Filter Zone and Riprap	390,000 m^3
Excavation, Dams	700,000 m^3
〃 ,Spillway	2,000,000 m^3
〃 , Outlet Works	250,000 m^3
Concrete	41,000 m^3

2) Working Schedule

The working schedule of dam construction is made based on the volumes of earth works and concrete works.

Tentative working schedule for Khlong Si Yat dam is summarized as follwos;

Working Item	Year			
	1st	2nd	3rd	4th
1. Temporary Work				
2. Main Dam Excavation				
3. Main Dam Embankment				
4. Spillway Excavation				
5. Spillway Concreting				
6. Outlet Works				
7. Road Works				

B. 2. Bang Pakong Diversion Dam

B. 2. 1. Site Selection

Fifteen possible diversion damsites were selected on the meandering part of the Bang Pakong river from the river mouth confluence point of Tha Lat river.

As the results of comprehensive study on the site selection, the site No.2, where situate at just upstream of Chachoengsao city.

B. 2. 2. Preliminary Design

The design sectional area of the proposed diversion damsite is recommended as 1,500 sq.m which is the average section of 10 km between 5 km upstream and 5 km downstream of the site.

Design Hydraulic Condition

1) Water Level at the Site

- Case-1: Upstream level = 1.30 + 0.50 = 1.80 m
  Downstream level = - 1.50 m
- Case-2: Upstream level = - 1.50 m
  Downstream level = 1.30 + 0.50 = 1.80 m

2) Bottom Elevation and Water Depth at the Site

- Bottom elevation : - 9.0 m
- Water depth : Max. 1.3 - (-) 9.0 = 10.3 m
  Min. (-) 1.5 - (-) 9.0 = 7.5 m

Gate Type

The double shell type roller gate with normal system is recommendable for the regulating gate.

The single shell type roller gate is recommendable for the main gate.

Regulating Gate Dimension

Specification	Upper Leaf	Lower Leaf
- Top of the leaf	(+) 1.80 m the same as design high water level of upstream side	(-) 1.50 m the same as design low water level of downstream side
- Bottom of the leaf	(-) 1.90 m 0.40 m lower than design low water level	(-) 9.00 m proposed sill level of the diversion dam
- height of the gate	3.70 m	7.50 m

No fishway and no navigation lock will be set up judging from environmental, social and economic studies. (cf. F.2 (7) and (9))

Diversion Channel

The bottom width of the channel is decided to meet the flow width of the diversion dam and the side slope is assumed as 1 : 5, considering the stability of side slope. As a result, the water flow area will be estimated at 2,240 sq.m.

The left bank upstream of the diversion dam is designed as straight line and the right bank is considered with smooth curve as the transition to make steady water flow.

The opening of transition will be 20 degree from the hydrological viewpoint and the radius of the curve shall be more than five times of the channel width of about 800 m.

Closure Dam

The side slope of 1 : 5 is applied for the closure dam section to stabilize the river flow. The top elevation of the dam will be (+) 3.0 m in elevation which is estimated as the flood level in 1983 of (+) 2.03 m plus 0.5 m of wave height and 0.5 m of free board.

Connecting Road

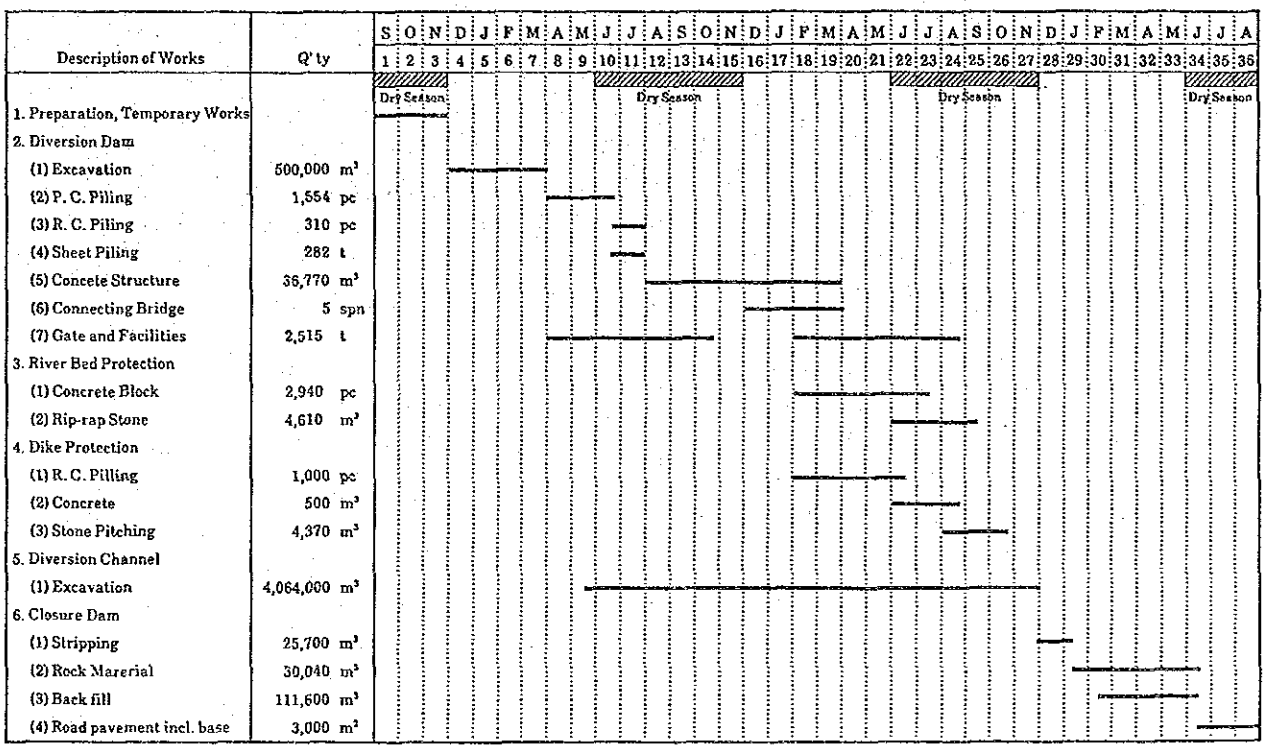
The bridge is installed on the diversion dam body for the purpose of gate operation and connecting right and left bank transportations.

The connecting road will be provided using the bridge and the closure dam. It will be used as the trunk road instead of navigation.

B. 2. 3. Construction Plan

Tentative construction schedule for the diversion dam is illustrated in Figure - 3.

FIGURE - 3. TENTATIVE CONSTRUCTION SCHEDULE FOR BANG PAKONG DIVERSION DAM



B. 3. Irrigation and Drainage Facilities

B. 3. 1. General Concept

The project area is composed of three major irrigation systems; namely Si Yat Irrigation System for the Tha Lat Expansion area, Tha Lat Irrigation System for the Tha Lat Existing area and Bang Pakong Irrigation System for Bang Pakong Left Bank Irrigation area and the Bang Pakong Expansion area.

1) Tha Lat Irrigation System

The Tha Lat Irrigation System was constructed in 1953. The intake of the main canal for the Project is located on the left bank 60 m upstream of the Tha Lat weir. And the main canal runs southwest in parallel with the Bang Pakong river. There regulating gates are installed 3.0 km from the intake and the discharge of main canal is controlled by these gates. According to the rehabilitation plan prepared in 1986 by RID, the design intake water level is EL. 5.50 m. The canal slope is so flat as 1/50,000 from the intake to the regulating gates and 1/14,000 from the regulating gates to the terminal.

Total length of the main canal is 44 km. Initially it was designed as concrete canal, it, however, was replaced by the earth canal during construction for lack of the budget for the Project. The maximum capacity of this canal is 15.90 cu.m/sec and the flow velocity is considerably slow ranging from 0.3 to 0.5 m/sec. The canal section has been reduced by scouring and silting. According to the Project plan, the canal capacity will be up-graded to 22.1 cu.m/sec so that the canal section and related structures are improved to meet the plan.

More than 10 laterals have been constructed by farmers except 6 regular laterals which were initially installed by RID. Earth canal is applied for laterals and only structures were made of concrete. The laterals are aligned at right angles to the main canal. The water level in the laterals are assumed somewhat lower than the ground elevation of the service area.

2) Bang Pakong Irrigation System

A polder dike is constructed surrounding the project area and regulating gates are provided at the outlet of natural creeks to take fresh water when the water level of the river is higher than that of the service area and to save the water to be released during low water level of the river. Those gates also function to prevent the saline water intrusion into the irrigation service area during dry season. Some of them were, however, damaged and not functioning.

Natural creeks are connected each other forming canal networks. The stored water in these creeks is supplied to the service area, however, it is not enough to irrigate the area in dry season.

Farmers use their own small pumps to supply the irrigation water to their paddy fields due to the insufficient water level. Accordingly, those creeks are used for dual purposes of irrigation and drainage. The flow direction in the creeks is not constant so that check structures are not applicable.

The polder dike shall be improved at the insufficient part and used as the operation road. There re-gulating gates which are installed at the outlet of creeks along the polder dike shall also be rehabilitated or improved. Several regulating gates are required upstream of the proposed diversion damsite to control the intake water and downstream to prevent saline water from intruding into the orchard area located outside of the polder dike. Although these creeks have a role to drain out excess water, the combined check gates shall be considered to make operation easier. There exist considerable extent of chicken and pig cultivation in the orchard area. The problem is the polluted water drained from those livestock yards. Drainage canals for those polluted water shall therefore be separated from irrigation canals.

About 37 km of main canal shall be installed to improve the irrigation network to maximize the effect of construction of the diversion dam. Irrigation water will be diverted to existing creeks through the main canal and head gates. The canal will be lined by thin concrete to reduce land acquisition, operation and maintenance costs.

3) Si Yat Irrigation System

The Si Yat Irrigation System is newly developed with service areas of about 5,400 ha on the right bank and about 1,700 ha on the left bank of the Si yat river which is a tributary of the That Lat river. A gravity irrigation method is recommended. Since the elevation of right bank area is considerably high and the area is located near the proposed dam, the direct intake method will be provided for the area. As an alternative plan for the left bank area, it was considered to discharge required volume of water directly into the Si Yat river and take it from the diversion weir to be newly installed at 10 km upstream of the Existing Tha Lat Diversion Weir. This method, however, is not recommendable because a high diversion weir is required to take water from the Si Yat river. Accordingly the water is conveyed crossing the That Lat river at Wat Bang Phaniyang by a siphon extending the right bank main canal.

The main and lateral canals are constructed by the Project and the on-farm facilities will be consolidated by the beneficiaries.

B. 3. 2. Irrigation and Drainage Scheme

The existing irrigation system are to be efficiently utilized with additional construction as well as rehabilitation of main and lateral canals and their appurtenant structures, and with consolidation of on-farm facilities, except for the Tha Lat Expansion area where new system of irrigation and drainage are constructed separately.

Water duties for irrigation canals and ditches are summarized as follows:

Water Duties for Irrigation Canals and Ditches

(Unit: liter/sec/ha)

Service Area	Main and Lateral Canal	Ditch
Existing Tha Lat Area	1.0	1.21
Tha Lat Expansion	1.1	1.21
Existing & Proposed Bang Pakong	1.2	1.21

The Project aims to set up the design intensity of storm rainfall as the 3-day consecutive rainfall of a 5-year return period, and 150 mm was obtained from the measurements. The design modulus was then determined so as to drain the probable 3-day consecutive rainfall on the irrigated field in 3 days. Losses due to evaporation and percolation were disregarded for safety reason. The design modulus of 5.79 liter/sec/ha is, however, based on a Point rainfall. The resulted design modulus is accordingly applicable for the area of on-farm level not exceeding 2,000 rai (320 ha). Reduction factors to apply the design modulus for drainage areas larger than 2,000 rai are quoted from the RID's previous study as follows:

Reduction Factors for Drainage Areas Larger Than 2,000 Rai

Drainage Area in Rai	Reduction Factor
less than 2,000	1.00
2,000~ 5,000	0.95
5,000~ 10,000	0.90
10,000~ 20,000	0.86
20,000~ 50,000	0.76
50,000~ 100,000	0.72
100,000~ 200,000	0.68
200,000~ 500,000	0.64
500、000~ 1,000,000	0.60
> 1,000,000	0.58

B. 3. 3. Tha Lat Irrigation System

1) Tha Lat Weir

The crest level of the weir shall be heightened 1 m to raise the capacity of te main canal and to increase the effect of gravity irrigation system for the service area. In order to drain flood water safely without reduction of the width of existing weir and to maintain normal water surface, a flap type gate will be effective. A rubber gate is, therefore, recommended in consideration of the above functions, and from viewpoints of operation and maintenance as well as its reasonable construction cost.

2) Main Canal

The canal section between the intake and regulating gate has not enough capacity due to silting so that is shall be excavated to the proper size. Generally as the canal size is inadequate downstream of the regulating gates due to silting, it shall be expanded to maintain proper canal section. Rock excavation will be required for some part of canal located downstream.

Furthermore for the purpose of enforcing canal capacity from the existing 15.9 cu.m/sec to the proposed 22.1 cu.m/sec to meet the improvement plan, the main canal will be lined with concrete taking the limited land property and reduction of operation and maintenance cots into consideration.

Since the free board is also insufficient at some parts of the main canal especially at the downstream portion, additional filling will be needed and both the banks will be used as trunk roads. Check gates are required immediately downstream of head gates or the tail of the canal to maintain the necessary water level. Some culverts and siphons crossing roads or natural creeks have not enough capacity in its section especially downstream of the main canal and, therefore, they shall be improved to the proper section.

3) Lateral Canal

Lateral canal were designed with a lining section initially, however, the lining was not implemented due to the budget shortage. Accordingly the canal section which has been reduced by silting shall be expanded to a proper capacity. Both the banks shall be improved with required sizes and they will be used for operation and maintenance and agricultural purposes.

New construction of check gates at the proper stations, repairing of the protection up and downstream of the structures, improvement of the structures having insufficient capacity, etc. shall be required in order to maintain the sufficient irrigation water level. Several laterals are also requested to be improved for the proper irrigation distribution system in the area.

4) Farm Turn-out

The farm turn-out will be improved into a constant head type turn-out with one gate. They are principally installed at the same stations of existing turn-outs, however, additional installation will be required so that a turn-out will cover about 50 ha of irrigation service area.

5) Drainage Canal

Usually natural streams and creeks are used for main or lateral drainage canals. Farm drains shall be constructed by the beneficiaries and maintenance cost of natural creeks is included in the O & M costs.

B. 3. 4. Bang Pakong Irrigation System

1) Pump Station

Since the control water level upstream of the proposed Bang Pakong diversion dam varies from (+) 1.30 m to (-) 1.50 m, a low head pumping station with the maximum capacity of 17.64 cu.m/sec shall be installed to lift the water from the diversion dam to the main canal.

The design condition of pump is as follows:

Design discharge	:	Q = 17.64 cu.m/sec
Lowest suction water level	:	(-) 1.5 m
Discharge water level	:	(+) 3.7 m

Judging from the monthly water requirement, the type and dimensions of the pump are recommended as follows:

Type	:	Vertical diagonal flow pump
Unit	:	4 units
Size	:	1,500 mm
Discharge capacity	:	26.4 cu.m/min
Total head	:	6.10 m
Motor capacity	:	390 kw

2) Main Canal

At the point 700 m downstream of the discharge basin of pumping station, the intake canal is diverted to the Left main canal and the Right main canal. The capacity of Right main canal is 12.89 cu.m/sec with the canal size deducted according to the irrigation requirement. The canal length is as follows:

Canal Name	Capacity	Length
	(cu.m/sec)	(km)
Intake Canal	17.64	0.7
Left Main Canal	4.75	12.0
Right Main Canal	12.89	24.0

The canal section is designed as trapezoidal shape having a side slope of 1 : 1.5. And it is lined with the concrete to reduce the land acquisition cost and seepage.

3) Check gate and Head Gate

Head gates are installed at the proper stations to deliver water to the service area through existing creeks. In order to supply proper amount of water to the service area, several check gates are arrange along the main canal.

4) Drainage System

To prevent polluted water from intruding into the proposed diversion dam, a drainage canal along the Bang Pakong river is provided. Regulating gates will be provided at the outlet of existing creeks upstream of the dam to control outflow of polluted water and inflow of irrigation water. So the gates work as intakes during the high water level of the dam.

On the other hand, several natural creeks are to be expanded to maintain enough capacity to release excess water. Furthermore, some regulating gates with insufficient capacity shall be rehabilitated and improved.

B. 3. 5. Si Yat Irrigation System

1) Main Canal

About 50 km of main canal will be installed for the irrigation of Tha Lat Expansion area.

Because the long canal is provided in order to take water directly from the dam and to convey water to the left bank, a concrete lined canal is recommended to save water from leakage. In order to minimize the water to be released from the dam, the drained excess water from the catchment area will be received by the drain inlet structure or waste culvert. Adequate numbers of

spillways and waste ways are also provided for the convenience of operation and maintenance works.

The canal slope is decided to maintain allowable velocity to avoid scouring and silting. Drop structures are provided to waste excess water head where the steep topography is predominant.

The check gate shall be provided at the immediately downstream of lateral head gates and at proper stations to maintain enough water level and to use water effectively. Both or either bank shall be used for the operation road and farm road.

2) Lateral Canal

Lateral canal are constructed for the head gate of lateral to deliver the water to the lateral canal.

Farm ditches, farm inlets, farm drains, etc. will be arranged according to the standard stated in the Tha Lat Irrigation System.

C. PROJECT IMPLEMENTATION PROGRAMME

C. 1. Project Management and Implementation

C. 1. 1. Project Leading and Executing Agencies

The project components consist of water supplies for irrigation, industry, drinking, fisheries and Bang Pakong power station.

Project Implementation Organization

- Ministry of Agriculture and Cooperatives (MOAC)	Royal Irrigation Department (RID) Department of Agricultural Extension (DOAE) Department of Agriculture (DOA) Department of Fisheries (DOF) Royal Forestry Department (RFD)
- Ministry of Industry (MIND)	Industrial Estate Authority (IEAT)
- Ministry of Interior (MOI)	Provincial Waterwork Authority (PWA)
- Prime Minister's Office	Electric Generation Authority of Energy (EGAT)
- Local Administration	

C. 1. 2. Coordination Committee

As the decisive organization at the national stage, the coordinating committee to be presided by MOAC with the members of above-stated 4 ministries, the National Economics and Social Development Board (NESDB) and the Governor of Chachoengsao Province, will be recommended.

Under the coordinating committee, the conference at the secretarial stage with the members of RID, IEAT, PWA, DOF, RFD and EGAT should be set up.

The items to be put for deliberation will be water resources development policy, water distribution management, project budget, project cost, allocation, etc.

The system of the executing organization is composed of such sections as administration, land procurement, audit, cooperation, engineering, project control, and construction.

C. 1. 3. Establishment of Water Management Organization

The Water resources development in this project aims at storing the river run-off with storage dams and a diversion dam and utilizing it effectively for the purposes of irrigation and others. This basin has large potentiality to be developed, but phased development must be applied according to the objectives and the priorities in the fields of water utilization. As the project area with top priority to be developed in the Bang Pakong river basin, the Tha Lat river basin project area was selected. The Bang Pakong diversion dam has the following functions:

- To prevent saline water from intruding into the upstream area in a dry season.
- To store river run-off for the transition periods from dry to wet season and vice versa.
- To control the water to be released from the storage dams to be constructed upstream of the diversion dam.
- To contribute toward the regional development by constructing the bridge and the road connecting both the banks of the Bang Pakong river.

According to the regulations for the operations of Si Yat dam and Rabom dam, the water level on the upstream side of the Bang Pakong diversion dam should be kept (+) 1.0 m in elevation to the utmost.

The storage of water in the river course functioning as a reservoir for the water users in many fields will reach the point about 50 km upstream of the diversion dam.

The water Management Board (WMB) on the provincial level should be established in order to distribute the water resources effectively and harmoniously.

C. 2. Project Implementation Programme

C. 2. 1. Implementation Programme

The implementation programme should be prepared by taking into account phased water demand tendency as well as urgency of water supply policy, effectiveness of investment and quick development of the project. The project implementation programme are divided into two phases.

1) Beneficiaries

Phase-1 -	Irrigation :	Existing Bang Pakong area	(12,700 ha)
		Bang Pakong Expansion area	(2,000 ha)
	<-Industry>:	Bang Pakong Industrial Estate	(10,000rai=1,600 ha)
Phase-2 -	Irrigation :	Existing Tha Lat area	(22,100 ha)
		Tha Lat Expansion area	(7,100 ha)
	<-Industry>:	Plaeng Yao Industrial Estate	(10,000rai=1,600ha)

2) Major Facilities

Phase-1

- Common facilities: Bang Pakong diversion dam
- Irrigation facilities: Rehabilitation/construction of main and lateral canals as well as related structures.
  Construction of as pump station.
  Dredging of drainage canals.
  Rehabilitation of regulating gates.

<-Industrial> facilities: Construction of a pump station, pipelines and a regulating reservoir.

Phase-2

- Common facilities: Khlong Si Yat dam
- Irrigation facilities: Rehabilitation/construction of main and lateral canals as well as related structures.
  Dredging of drainage canals.

<-Industrial> facilities: Construction of a pump station, pipelines and a regulating reservoir.

This project area is located between Bangkok Metropolitan and Eastern Seaboard area as their hinter land.

The government of Thailand decided recently to accerelate water resources development as well as infrastructural development in the said region.

C. 2. 2. Optimum Construction Schedule

The project implementation schedule is shown in the following figure.

C. 3. Operation and Maintenance

Three irrigation systems are set up for the development project. The proposed organizations for operation and maintenance of respective systems are illustrated.

Each system has four sections in charge of administration, water control service, engineering service and mechanical engineering. Irrigation system is divided into several area managing sections which are composed of some managing units. The area managing section will be responsible for the service area of 5,000 ha to 7,000 ha more or less. The zone managing unit responsible for the area of around 1,000 ha more or less.

Each area managing section is controlled by water master under the management of the system manager. Each zone managing unit is controlled by a zone man with the assistance of several water tender and canal tenders.

In the water management plan of the Tha Lat river basin, how control the water level upstream of the proposed Bang Pakong diversion dam is proposed in the main report.

That is, the control water level upstream of the diversion dam are basically as follows:

- Highest control water level : (+) 1.0 m MSL
- Lowest control water level : (-) 1.0 m MSL
- Control water level for transition period : (+) 1.0 m MSL
- Control water level for wet season : Full opening of the gates

FIGURE - 4. PROJECT IMPLEMENTATION SCHEDULE (1/2) PHASE I PROJECT

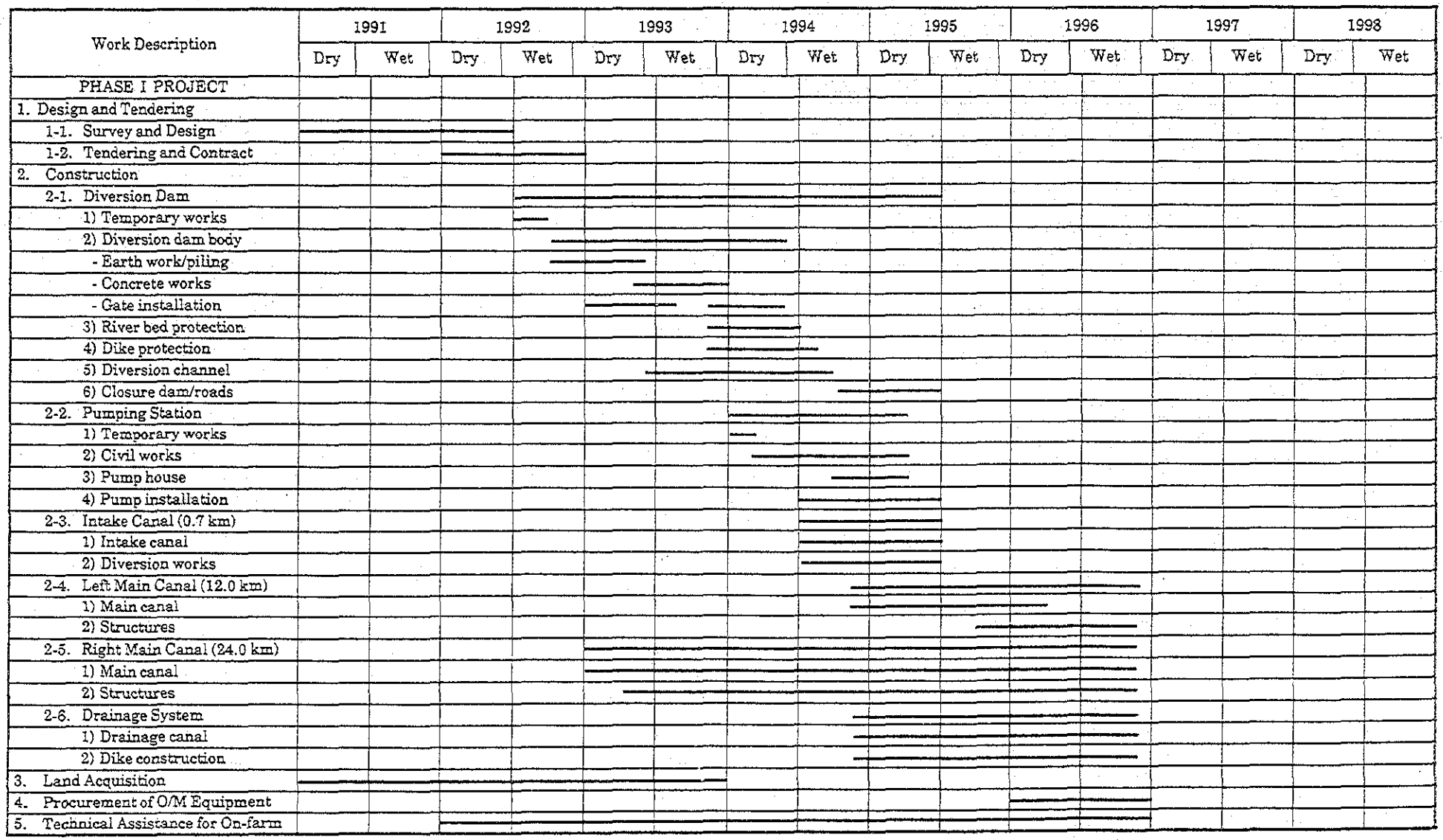
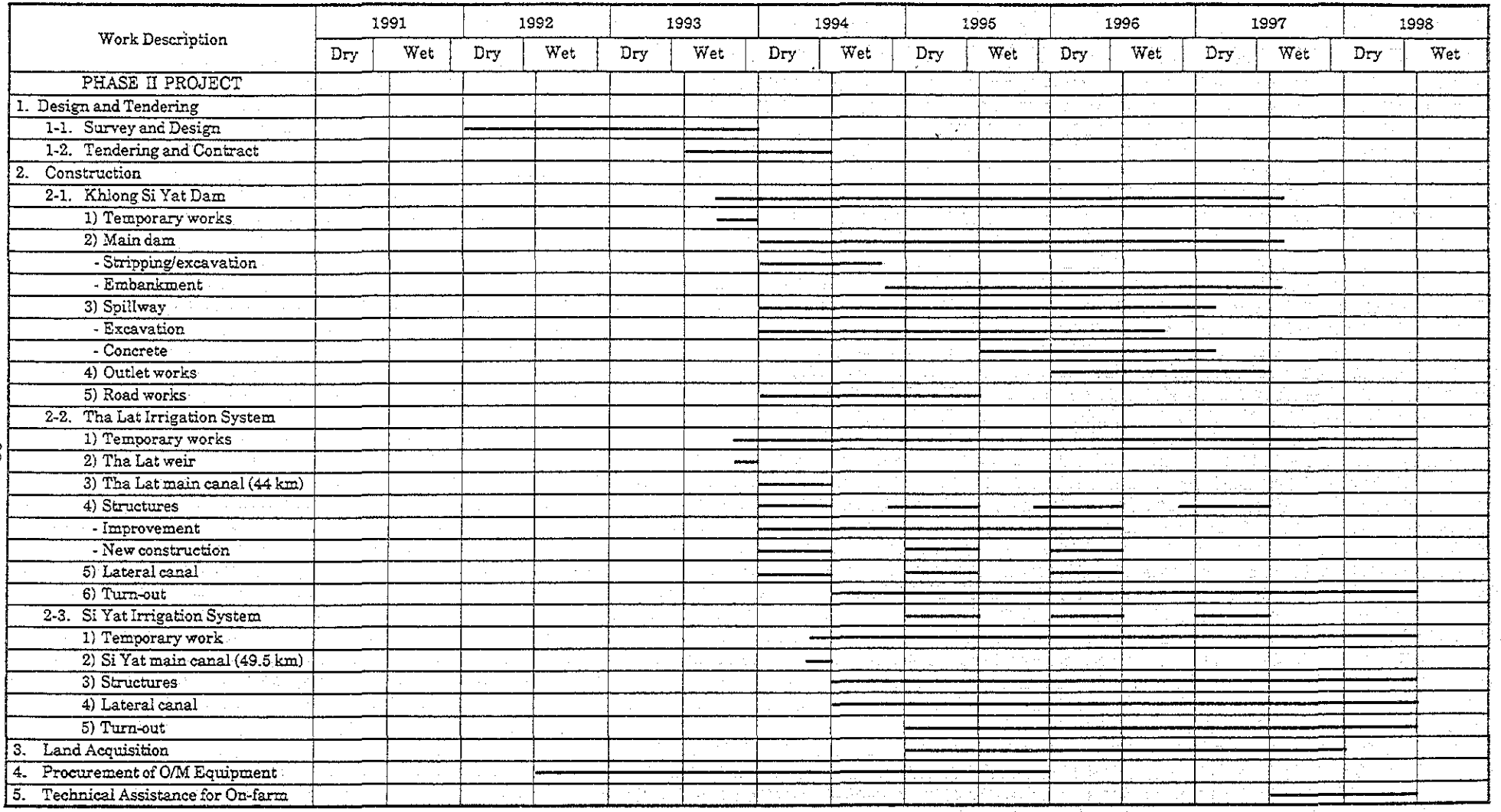


FIGURE - 5. PROJECT IMPLEMENTATION SCHEDULE (2/2) PHASE II PROJECT



D. COST ESTIMATE

D. 1. Project Cost

Project costs which consist of direct and indirect project cost are summarized in the Table - 2 and Table - 3.

TABLE - 2. SUMMARY OF PROJECT COST

- Unit : Million baht

Work Description	Phase I Project	Phase II Project	Total
A. Direct Project Cost			
1. Preparatory Work	20	26	46
2. Construction Cost	2,160	1,943	4,103
3. Land Acquisition / Resettlement	375	680	1,055
4. O & M Equipment	11	11	22
5. Survey and Investigation	24	15	39
6. Administration Cost	106	130	236
7. Engineering Service	216	194	410
8. Physical Contingency	291	299	590
Total (1 - 8)	3,203	3,298	6,501
9. Price Escalation	474	803	1,277
Total (1 - 9)	3,677	4,101	7,778
B. Indirect Project Cost			
1. Construction Cost	220	452	672
2. Engineering Cost	26	54	80
3. Physical Contingency	25	50	75
Total (1 - 3)	271	556	827
4. Price Escalation	51	147	198
Total (1 - 4)	322	703	1,025
Grand Total (A+B)	3,999	4,804	8,803
Foreign Currency	(2,215)	(1,980)	(4,195)
Local Currency	(1,784)	(2,824)	(4,608)

TABLE - 3. PROJECT COST

- Unit : 1,000 Baht -

Cost Item	Phase I Project			Phase II Project			Total		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
A. Direct Project Cost									
1. Preparatory Work	5,045	14,955	20,000	6,440	19,560	26,000	11,485	34,515	46,000
2. Construction Cost									
2.1 Storage Dam	-	-	-	562,000	498,000	1,060,000	562,000	498,000	1,060,000
2.2 Diversion Dam	1,200,000	470,000	1,670,000	-	-	-	1,200,000	470,000	1,670,000
2.3 Pumping Station	103,004	39,996	143,000	-	-	-	103,004	39,996	143,000
2.4 Irrigation System	118,318	142,682	261,000	431,450	45,550	883,000	549,768	594,232	1,144,000
2.5 Drainage System	44,738	41,262	86,000	-	-	-	44,738	41,262	86,000
Sub - Total	1,466,060	693,940	2,160,000	993,450	949,550	1,943,000	2,459,510	1,643,490	4,103,000
3. Land Acquisition/Resettlement and Compensation	-	375,000	375,000	-	680,000	680,000	-	1,055,000	1,055,000
4. O & M Equipment	8,802	2,198	11,000	9,040	2,260	11,300	17,842	4,458	22,300
5. Survey and Investigation	11,362	12,438	23,800	7,862	6,738	14,600	19,224	19,176	38,400
6. Administration	-	106,000	106,000	-	130,000	130,000	-	236,000	236,000
7. Engineering Service	146,600	69,400	216,000	135,800	58,200	194,000	282,400	127,600	410,000
Total (1 - 7)	1,637,869	1,273,931	2,911,800	1,152,592	1,846,308	2,998,900	2,790,461	3,120,239	5,910,700
8. Physical Contingency	164,131	127,069	291,200	115,408	183,692	299,100	279,539	310,761	590,300
Total (1 - 8)	1,802,000	1,401,000	3,203,000	1,268,000	2,030,000	3,298,000	3,070,000	3,431,000	6,501,000
9. Price escalation	216,000	258,000	474,000	280,000	523,000	803,000	496,000	781,000	1,277,000
Total (1 - 9)	2,018,000	1,659,000	3,677,000	1,548,000	2,553,000	410,000	3,566,000	4,212,000	7,778,000
B. Indirect Project Cost									
1. On-Farm Facilities	138,285	81,715	220,000	285,175	166,825	452,000	423,460	248,540	672,000
2. Engineering Cost	16,340	9,660	26,000	34,070	19,930	54,000	50,410	29,590	80,000
Total (1 - 2)	154,625	91,375	246,000	319,245	186,755	506,000	473,870	278,130	752,000
3. Physical Contingency	15,375	9,625	25,000	31,755	18,245	50,000	47,130	27,870	75,000
Total (1 - 3)	170,000	101,000	271,000	351,000	205,000	556,000	521,000	306,000	827,000
4. Price Escalation	27,000	24,000	51,000	81,000	66,000	147,000	108,000	90,000	198,000
Total (1 - 4)	197,000	125,000	322,000	432,000	271,000	703,000	629,000	396,000	1,025,000
Grand Total (A + B)	2,215,000	1,784,000	3,999,000	1,980,000	2,824,000	4,804,000	4,195,000	4,608,000	8,803,000

D. 2. Disbursement Schedule

The disbursement schedule for the direct and the indirect projects is made based on the project implementation programme.

The summary of the disbursement schedule is shown in Table - 4.

TABLE - 4 SUMMARY OF DISBURSEMENT SCHEDULE

- Unit : Million Baht -

Project Year	Phase I Project			Phase II Project			Total			
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	(%)
A. Direct Project Cost										
1991	56.3	157.0	213.3	-	-	-	56.3	157.0	213.3	2.7
1992	195.3	251.5	446.8	51.2	455.6	506.8	246.5	707.1	953.6	12.3
1993	702.0	481.0	1,183.0	113.5	371.3	484.8	815.5	852.3	1,667.8	21.4
1994	635.6	399.2	1,034.8	213.9	288.8	502.7	849.5	688.0	1,537.5	19.8
1995	326.4	250.1	576.5	357.5	479.4	836.9	683.9	729.5	1,413.4	18.2
1996	102.6	120.1	222.7	485.2	593.5	1,078.7	587.8	713.6	1,301.4	16.7
1997	-	-	-	277.8	303.4	581.2	277.8	303.4	581.2	7.5
1998	-	-	-	48.9	60.8	109.7	48.9	60.8	109.7	1.4
Total	2,018.2	1,658.9	3,677.1	1,548.0	2,552.8	4,100.8	3,566.2	4,211.7	7,777.9	100.0
B. Indirect Projet Cost										
1991	2.7	1.6	4.3	-	-	-	2.7	1.6	4.3	0.4
1992	29.8	18.6	48.4	5.5	3.5	9.0	35.3	22.1	57.4	5.6
1993	31.4	19.7	51.1	39.8	25.1	64.9	71.2	44.8	116.0	11.3
1994	33.3	20.8	54.1	78.1	49.1	127.2	111.4	69.9	181.3	17.7
1995	35.0	21.9	56.9	82.1	51.8	133.9	117.1	73.7	190.8	18.6
1996	64.8	42.4	107.2	86.1	54.3	140.4	150.9	96.7	247.6	24.2
1997	-	-	-	89.8	56.8	146.6	89.8	56.8	146.6	14.3
1998	-	-	-	50.6	30.4	81.0	50.6	30.4	81.0	7.9
Total	197.0	125.0	322.0	432.0	271.0	703.0	629.0	396.0	1,025.0	100.0
Grand Total	2,215.2	1,783.9	3,999.1	1,980.0	2,823.8	4,803.8	4,195.2	4,607.7	8,802.9	

E. PROJECT JUSTIFICATION

E. 1. General Concept

The project justification is made through the study of project feasibility from economic, financial and socio-economic aspects.

The economic feasibility is studied by calculating the economic internal rate of return (EIRR). Sensitivity analysis is made in order to elucidate the economic viability of the project against the change in prices, delay in implementation, cost overrun and yield.

Financial analysis is made by typical farm budget analysis and cost recovery including joint cost allocation.

The social effects and economic impacts from the implementation of the Project are treated in intangible benefit study and environmental impact evaluation.

E. 2. Identification of Project Benefit

E. 2. 1. Tangible Benefit

Economic incremental net production values are shown in the following tables.

INCREMENTAL BENEFITS FROM ALL SECTORS

Unit : Million Baht

Project Year	Agricultural Water (Overrall)	Industrial and Domestic Water	Total
1995	- 3.1	-	- 3.1
1996	162.3	59.4	221.7
1997	244.5	74.8	319.3
1998	587.6	128.3	715.9
1999	639.6	153.7	793.3
2000	677.5	190.1	867.6
2001	675.3	200.0	875.3
2002	683.0	203.9	886.9
2003	690.0	203.9	893.9
2004	709.9	203.9	913.8
2005	747.4	203.9	951.3
2006	804.2	203.9	1,008.1
2007	862.2	203.9	1,066.1
2008	904.1	203.9	1,108.0
2009	930.1	203.9	1,134.0
2010	930.1	203.9	1,134.0

E. 2. 2. Intangible Benefit

In addition to the tangible benefit for agriculture and fishery, various intangible benefits and socio-economic impacts are expected from implementation of the project comprised by agricultural sector, industrial water supply sector and drinking water supply sector. The major intangible benefits are shown as follows:

1) Creation of new job opportunities
2) Improvement of local transportation
3) Improvement of sanitary condition
4) Improvement of water front environment

E. 3. Economic Analysis Cost

E. 3. 1. Capital Cost

The project cost consists of the direct project cost and the indirect project cost.

All these costs are estimated on a financial basis as shown in Table - 3.

In order to estimate the economic cost for agricultural sector, financial cost for Si Yat storage dam and Bang Pakong diversion dam are previously allocated by 63% of agricultural water sector and 37% of industrial and drinking water sectors.

The financial costs are converted into the economic costs by applying the conversion factor as cost component (CCF).

E. 3. 2. Annual Operation and Maintenance Cost

The financial cost does not include the depreciation cost of O & M equipment. This financial cost is converted into economic cost using conversion factor of 0.9.

(million baht)

Phase	Financial	Economic
Phase-1	17.0	15.3
Phase-2	21.8	19.7
Overall	38.8	35.0

E. 3. 3. Replacement Cost

Pumps proposed in Phase-1 project and Resettlement plan of Phase-2 are replaced by interval of 20 years.

(million baht)

Phase	Financial	Economic
Phase-1	170	153
Phase-2	0.08	0.07

E. 3. 4. Economic Internal Rate of Return

The economic internal rate of return for the agricultural sector is calculated on the basis of the flows of economic benefits and costs mentioned above. EIRR by phase is calculated as follows:

	Agricultural Sector	All Sector
Phase-1	14.0%	12.2%
Phase -2	9.7%	
Overall	11.7%	
Phase-1 (tentative)	13.6 %	

E. 3. 5. Sensitivity Analysis

Sensitivity analysis is the effective measures of testing for the riskiness of the project. Analysis are made for the following cases:

Case-1: 10% increase in project cost due to unforeseen geological and topographical conditions and unexpected increase of material costs.

Case-2: 10% decrease in project benefit due to unexpected decrease in prices of commodities and in crop yield.

Case-3: Two years overrun of full-development period of project benefit.

Case-4: Two years overrun of construction period.

The EIRR of four cases are estimated as follows:

	EIRR (%)		
Case	Overall	Phase-1	Phase-2
Original	11.7	14.0	9.7
Case-1	10.8	13.0	9.0
Case-2	10.7	12.9	8.9
Case-3	11.1	13.3	9.4
Case-4	10.8	12.7	9.2

E. 4. Farm Budget Analysis

The farm budget analysis are studied in order to evaluated the Project from the financial aspect of the beneficialis. Typical farms are represented by three farms with cropped acreage averaged by the sub-project area, that is, Existing Bang Pakong area, Existing Tha Lat area and Tha Lat Expansion area.

Net farm income with and without the project are estimated as shown in the Table - 5.

E. 5. Project Justification

Economic internal rate of return (EIRR) for all sectors was estimated at 12.2 percent.

It was reported that the latest prime rate of loan interest is 15 percent at the minimum and the deposit loan rate is 12.5 to 13 percent. When the marginal productivity of capital is considered to be approximately the deposit loan rate, the economy of all sector projects is rightly justifiable. The cost benefit ratio for the agricultural sector will be considered nearly justifiable from the national economic point of view.

TABLE - 5. FARM BUDGET ANALYSIS

Item	Unit	Existing Bang Pakong Average Farm		Existing Tha Lat Average Farm		Tha Lat Expansion Average Farm		
		WO/P	W/P	WO/P	W/P	WO/P	W/P	W/P
Cultivated Land	rai	18	18	17	17	30.0	34.6	34.6
	ha	2.9	2.9	2.7	2.7	4.8	5.5	5.5
A. Gross Farm Income	Baht						(2001 yr)	(2003 yr)
Crop		34,679	145,799	18,049	70,041	35,909	126,607	249,293
Livestock		1,840	1,840	3,970	3,970	3,940	3,940	3,940
Total		36,519	147,639	22,019	74,011	39,849	130,547	253,233
B. Production Cost	Baht							
Crop		14,992	65,218	7,349	39,576	18,171	63,340	93,610
Livestock		874	874	2,603	2,603	725	725	725
Total		15,866	66,092	9,952	42,179	18,896	64,065	94,335
C. Net Farm Income	Baht	20,653	81,547	12,067	31,832	20,953	66,482	158,898
D. Incremental NFI	〃		60,894		19,765		45,529	137,945
E. Payable Cost of	〃		24,360		7,806		18,212	55,178
which : Repayment	〃		10,254		7,525		17,640	21,208
O & M Cost (Water Charge)	〃		302		281		572	572
F. Full Repayment Cost		3,536 × 2.9	= 10,254	3,856 × 2.7	= 10,411		3,856 × 5.5	= 21,208

Note : 1. WO/P ... without project, W/P ... with project
2. Average size of farm by sub-project area is estimated basing on the Socio-Economic Data in 1987, NSO. Difference of WO/P and W/P in Tha Lat Expansion Area is orchard area reclaimed.
3. Gross farm income for Tha Lat Expansion Area are shown by two case in 2001 and 2003 because of maturity period of new mango.
4. Family labor cost is excluded.
5. Payable cost is estimated as follows. Increment net farm income × 0.4 (marginal saving propensity)
6. Repayment cost is estimated for on-farm work cost to be born by beneficiaries. Beneficiaries would borrow the BAAC's long term loans with simple interest of 11% and installment years of 20.
7. Operation and maintenance cost is assumed that beneficiaries bear a part of total O & M cost under condition of ratio of on-farm work costs to total project costs.
8. Full repayment cost is estimated on all on-farm work cost.

F. ENVIRONMENTAL IMPACT EVALUATION

F. 1. Introduction

The detailed Environmental Impact Statement (EIS) is required if the main features of the proposed project exceed the following guideline:

- Effective storage : 100 MCM
- Reservoir area : 15 sq.km
- Irrigation area : 80,000 rai (12,800 ha)

The proposed Tha Lat river basin development project has been divided into two phases in view of the project implementation, and the both phases are larger than the above guideline in scale and therefore the detailed EIS will be required.

Main Feature of Tha Lat River Basin Development Project

	Phase-1	Phase-2	Overall Development
Effective Storage (MCM)	30	300	330
Reservoir Area (sq.km)	10	45.5	55.5
Irrigation Area (ha)	14,700	30,240	43,540

The environmental study comprises manifold items of environmental impact evaluations. They are primarily classified into the following four categories:

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

Preliminary studies were only carried out at the current stage of the study for the purpose of pointing out the present environmental problems and constraints and the anticipated alternation in environmental resources, either positive or negative, probably be caused by the project implementation.

F. 2. Preliminary Environmental Impact Study for Phase-1 Project

Since there are manifold items of environmental evaluation, some of the important items to be stated in this summary report, will be introduced as follows:

1) Surface Water Hydrology

At the operation phase of the Bang Pakong diversion dam, there will be no impact on flow discharges and patterns during wet season, because the gates will be fully opened to release flow naturally. On the contrary, during dry season, the river flow will much decrease due to water diversion for various water supply purposes. Occurrence of flash flood may not induce back water upstream if an appropriate rule of the gate operation is introduced accompanied with establishment of the basin monitoring systems.

Downstream of the diversion site, the water will become more saline than that at present, because small amount of fresh water will only be released in dry season. The water of high salinity of more than 25 ppt will effect growth rate of shrimp. Provision of fresh water to dilute water salinity within the suitable limit should be taken into consideration.

2) Surface Water Quality

The discussion on water contamination in the river, will conclude preliminarily that the values of pesticides, and DO, BOD and coliform bacteria were rather beyond the standard level of NEB.

The measures for controlling the concentration within the allowable limit should be implemented as early as possible. The possible measures at this moment may be as follows:

- Campaign to farmers to use less toxic pesticides
- To advise the farmers to plant rice with a variety of high resistant to pest and diseases
- Serious intention to be paid on controlling measures of effluent water from swine farm and industries
- To release retained water at the location below water surface
- Continuous monitoring of water quality after completion of the diversion

In this connection, the proposed Project envisages to consolidate drainage facilities to drain effluent water from swine farm and industries downstream of the diversion dam.

3) Soil Erosion

Nipa palms are observed along the banks of the river and its tributaries. After the project implementation, the nipa palms growing may be impeded in some cases, by salinity change, resulting in some impact on possible

soil erosion on river banks after a long white. It is very important to monitor the growing situation carefully.

4) Groundwater

The water level of the diversion dam is planned to be controlled within the range between (+) 1.5 m and (-) 1.5 m. The level below zero is, however, to be avoided whenever possible, since it would cause adverse flow of groundwater and in turn leakage of saline water would be resulted.

5) Sedimentation

The riverbed upstream of the diversion dam, will be elevated because of back sand at the edge of the reservoir during dry season. It is planned however, that the gates are fully opened in wet season during which the sediments are easily flashed down through the river channel into the sea. Therefore, environmental impact by change of transportation mechanism of sediment is considered very little.

6) Aquatic Ecology

Retention of fresh water in the river will induce significant changes in aquatic eco-system. Study of existing ecological characteristics is considered to be important so that the ecological changes can be anticipated and mitigated as much as possible.

This river is still abundance of aquatic animals but have a trend of decreasing due to human activities.

The economic type of zooplankton are still abundant. The fry of these planktons appear for different period due to their spawning season. Shrimp fry was found all the year but commonly observed to migrate upstream in March. Fish fry normally appear the upper river section for growth in fresh or brackish water in May and August.

The aquatic ecology as mentioned above will change when the diversion dam has been implemented. Ecology of Bang Pakong river is very complicate and requires a little more time for study in order to minimize the impact change.

7) Fisheries

As high as 106 species of fishes and aquatic animals including fresh water, brackish water and marine species were observed with economic species, respectively, carp; sea-loach and giant prawn; squid, globefish and sea-bass. These aquatic animals distribute and migrate up and down the river according

to the changing pattern of salinity. The total catch of fishes and other aquatic animals in the river by the fishermen was estimated at 230 ton/year.

The construction of diversion dam will effect migratory of fry and adult of fishes and some aquatic animals. In the Bang Pakong river, the spawning season of fishes is around April to July, and the fish fry migrate upstream to growth during May to August. The operation of the diversion as well as engineering facilities design should be taken into consideration.

In this regard, the proposed Project aims to release the minimum flow discharge at the diversion dam through a year even during a critical dry period. This minimum discharge will spill over the regulating gates with the water depth of 10 to 20 cm, through which fishes can proceed over the gates upstream and downstream.

The fishway construction will cost too high to afford facility to fishes and aquatic animals only in a dry season.

The shrimp growers downstream of the diversion dam will be fully supplied with fresh water by the Project, resulting in a great improvement of the present growing condition of shrimp.

An area of about 1,000 ha of fresh water fish ponds located nearby the terminal areas of the Existing Tha Lat and the proposed Bang Pakong irrigation main canals are also supplied with adequate volume of water by the Project, improving existing one cycle of fish culture per year into two cycles.

8) Nipa Palm

Presently, the nipa is considered as one of economic tree crops among villagers located close to the river channels. The growing situation will therefore be monitored carefully after the project implementation.

9) Navigation

The transportation of goods by boats are rarely observed there. If the road linking both the river banks by way of the diversion dam is proposed, a ferry will not be necessary and the transportation to the other bank be improved very much. The transportation along the river, however, will be interfered by the diversion dam. Landing places for passenger boats at the site will therefore unavoidably be needed to transfer the boats. The construction cost for navigation lock is too expensive to offer convenience to the villagers.

F. 3. Preliminary Environmental Impact Study for Phase-2 Project

Since there are lots of environmental evaluation, some of the important items only to be stated in this report, will be introduced as follows:

1) Surface Water Quality

The quality of the Si Yat river is still within the range adaptable to domestic and irrigation waters.

A thermocline will be easily formed in the Si Yat reservoir judging from the calculation using reservoir area, inflow discharge and storage capacity. Once it is formed, the water quality will become worse owing to reduction of DO.

G. CONCLUSIONS AND RECOMMENDATION

G. 1. Conclusion

As a result of the overall basin study for the agricultural water resources development project of Bang Pakong river basin, the Tha Lat river basin project was selected as the one with top priority from several sub-basin development projects.

Continuously the feasibility study on the project has been made carefully. The project has multi-purposes for water resources development, that is, for irrigation, industry, drinking, and fisheries, and two sub-phased implementation schedules.

As stated above, it has been found that the project is accorded high priority and great urgency to be developed with water supply for attaining quick benefits to the project area and accelerating regional development.

It is, therefore, concluded that after its prudent findings, the Project is technically feasible and economically viable.

G. 2. Recommendation

1) In the time of the implementation of the Tha Lat river basin development project with storage dam and diversion dam constructions, not only the technical and economic examinations, but also social or environmental considerations must inevitably be needed according to the result of the environmental impact study to be carried out by the third party.

2) The facilities plan and their cost estimate made in this feasibility study must be reexamined at the detailed design stage to enhance their precision.

3) The organization of the project implementation and their operation and maintenance must be strongly functioned, because of multipurpose water resources development schemes and multi-phased implementation programs.

4) Especially, the control of the water to be released from the dams and the diversion dam after construction will be quite important. It must be unifiedly controlled by the technical officials of the government.

5) The water management board on a provincial level should be organized to coordinate the water distribution plan based on the water demand request from respective sectors for effective utilization of water resources.

6) The project implementation schedule must be phased in conformity to water demand tendency, urgency of water supply policy, effectiveness of investment, etc.

7) The resettlement areas for Khlong Si Yat dam and Bang Pakong diversion dam must be finally determined after the more detailed investigation and study.

8) Based on the understanding of the basic concept in which irrigation and drainage must be separated each other, the irrigation and drainage plans must be implemented. Besides, RID should educate and cooperate farmers to be benefited to implement construction works and proper operation/maintenance of the terminal irrigation and drainage facilities in order to execute quick yielding of the proposed crop productions.

9) So as to bring the cultivation technic of diversification crops and transportation system on a higher level, administratively and financially assisting countermeasures for such agricultural supporting services as agricultural extension, farmers' organization, credit, circulating system, etc. will be required.

10) The diversion dam works to be implemented near the existing communities require the treatment of plenty of dredged soil. Acquisition of the land to fill up the soil and how to use the filled land must be seriously examined.

11) Since the construction of conducting facilities for industrial and domestic water supplies is concurred with the construction of the diversion dam and irrigation facilities, scrupulous coordination will be necessary for implementing the project harmoniously and economically.

12) The topographic survey and geological investigation must be carried out for further detailed design, land acquisition and construction works.

- Topographic surveys for storage and diversion damsites and main irrigation/drainage facilities.

- Geological investigations for storage and diversion dams and major facilities related.

13) Since the arrears of the planned construction schedule influence upon the economy of the investment, the construction works on time will be inevitably needed.